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Arsenic Removal from Drinking Water by Point of Entry/Point of Use Adsorptive Media U.S. EPA Demonstration Project at Oregon Institute of Technology at Klamath Falls, OR Final Performance Evaluation Report

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed during and the results obtained from the arsenic removal treatment technology demonstration project at Oregon Institute of Technology (OIT) at Klamath Falls, OR. The objectives of the project were to evaluate: (1) the effectiveness of three point of entry (POE) adsorptive media (AM) systems, all manufactured by Kinetico, and two types of point of use (POU) AM units, one manufactured by Kinetico and the other by AdEdge, in removing arsenic to meet the maximum contaminant level (MCL) of 10 µg/L, (2) the reliability of these POE/POU treatment systems/units for use at small water facilities (3) the required system operation and maintenance (O&M) and operator skill levels, and (4) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and residuals generated by the treatment process. The types of data collected included system operation, water quality, process residuals, and capital and O&M cost.

The three POE systems included one 30-gal/min (gpm) system installed in Purvine Hall, one 60-gpm system installed in the Residence Hall, and one 60-gpm system installed in the College Union. The 30-gpm system had two parallel treatment trains, each consisting of two 18-in × 65-in fiber reinforced plastic (FRP) vessels configured in series. Each vessel contained 5 ft^3 of ArsenX^{np} (without underbedding), an iron-modified/resin-based media manufactured by Purolite. Each 60-gpm system consisted of two 36-in × 72-in FRP vessels configured in series. The Residence Hall system contained 20 ft^3/vessel of ARM 200 media (without underbedding), an iron oxide/hydroxide media developed by Engelhard Corporation. Because of an unexpected short run length, the lead vessel was first rebedded with ARM 300 (a newer version of ARM 200 media) and then rebedded, along with the lag vessel, with E33-S. E33-S is an iron-based media developed by Lanxess, formerly Bayer AG. The College Union system contained 16 and 19.5 ft^3 of Adsorbsia™ GTO™ (a titanium dioxide-based media) in the lead and lag vessels, respectively. About 4 and 0.5 ft^3 of Adsorbsia™ GTO™ media were washed from each vessel during initial system backwash, resulting in a large quantity of milky white effluent to be discharged to the sewer.

At the design flowrates of 30 and 60 gpm, the POE systems had a design hydraulic loading rate of 8.5 gpm/ft^3 and a design empty bed contact time (EBCT) of 2.5 min/vessel. Because the systems were operated on demand, actual flowrates were based on user consumption and could vary significantly from (but mostly lower than) the respective design flowrates. As such, actual hydraulic rates could be much lower than the design value of 8.5 gpm/ft^3 and actual EBCTs much longer than the design value of 2.5 min.

Source water at OIT was supplied by two wells, i.e., Wells No. 1 and No. 4, with Well No. 1 as the primary well. After being chlorinated with a gas chlorine addition system, chlorinated water was stored in a 250,000-gal aboveground storage tank before being distributed to the campus. At each building, water pressure was reduced to 50 to 76 lb/in^2 (psi) by a pressure reducing valve before water was allowed to flow into the adsorption system. The inlet water contained 24.7 to 35.8 µg/L of total arsenic, existing predominately as soluble As(V). Iron and manganese concentrations were low, typically less than method detection limits (MDLs) at 25 and 0.3 µg/L, respectively. pH values ranged from 7.3 to 8.5 and averaged 8.0. The only competing anion in the inlet water was silica with concentrations ranging from 27.8 to 31.5 mg/L (as SiO_2).

The performance evaluation studies for the ArsenX^{np} and ARM 200 systems began on December 12, 2005. Because of the issues with media backwashing, the Adsorbsia™ GTO™ system required rebedding after initial media loading. Based on its pilot test results, Dow Chemical performed media backwashing in February 2006. The performance evaluation study for the Adsorbsia™ GTO™ system did not begin until February 17, 2006. The ArsenX^{np} system operated for a total of 1,353 days without media changeout. The ARM 200 system operated for 406 days. Because of early arsenic breakthrough,

the lead vessel was rebedded with ARM 300 media on January 24, 2007, and then with E33-S media, together with the lag vessel, on October 3, 2007. The Adsorbsia™ GTO™ system operated for a total of 1,286 days without media changeout.

Under on-demand conditions with varying system flowrates and water usage, E33-S media performed the best, achieving approximately 50,000 bed volumes (BV) before reaching 10 µg/L arsenic in vessel effluent. Adsorbsia™ GTO™ media was the next best performer, achieving 33,500 BV. ARM 200, ARM 300, and ArsenX^{np} media had a rather common media life spanning from 13,940 to 16,200 BV.

Little or no pressure rise was observed across the adsorption vessels during the performance evaluation studies, therefore, the POE systems did not require backwash. However, one backwash was performed for all three systems on May 16 or 17, 2006. Backwash wastewater and solids samples were collected and analyzed for pH, total dissolved solids (TDS), total suspended solids (TSS), and/or metal contents.

Results of the distribution system water sampling indicated that arsenic concentrations decreased significantly from an average of 29.2 µg/L before system startup to an average of 0.8 and 0.6 µg/L in Purvine Hall and the College Union, respectively, after system startup. Distribution system water samples in the Residence Hall essentially mirrored ARM 200 system effluent. Post-baseline lead concentrations ranged from <0.1 to 1.6 µg/L, which were below the action level of 15 µg/L. Post-baseline copper concentrations ranged from 39.7 to 448 µg/L, which were below the action level of 1,300 µg/L.

Eight Kinetico POU units were installed either under a sink or inside a drinking water fountain in eight different buildings on campus, but only three were monitored for their performance. Each POU unit used a single cartridge to house 600 mL of ARM 200 media for arsenic removal. A shut-off assembly and an indicator on the outside of the filter head were used to measure and show the relative remaining cartridge capacity, based on a maximum capacity of 500 gal. When 500 gal of water was processed, the shut-off assembly was completely closed, preventing any more water from passing through the cartridge. About 11 months into the performance evaluation study, OIT began to install 40 AdEdge E33-S POU units and replace the eight Kinetico units with AdEdge units.

Total arsenic concentrations were consistently reduced to below 1.0 µg/L by two Kinetico ARM 200 POU units after treating up to 740 gal of water. The third ARM 200 unit removed arsenic to <2.1 µg/L after treating 500 gal of water; its effluent concentration rose steadily to 6.0 µg/L after treating 1,000 gal of water. Arsenic was consistently removed to the MDL by three AdEdge E33-S POU units after treating 500 gal of water. The E33-S unit could treat up to 3,000 gal of water.

The normalized capital cost was $1,862/gpm ($1.29/gpd) for the ArsenX^{np} system, $992/gpm ($0.69/gpd) for the ARM 200 system, and $1,221/gpm ($0.85/gpd) for the Adsorbsia™ GTO™ system. Based on the actual annual water use rate, the unit capital cost was $10.77/1,000 gal for the ArsenX^{np} system, $0.93/1,000 gal for the ARM 200 system, and $4.14/1,000 gal for the Adsorbsia™ GTO™ system. The operation and maintenance (O&M) cost included the cost for replacing media and the cost of labor to operate the system. Media replacement is the major cost for an adsorptive media system. Using vendor provided quotes, a series of cost curves was constructed for all media tested (excluding ARM 300) in terms of media cost per 1,000 gal of water treated as a function of the projected media run length to the 10 µg/L arsenic breakthrough.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
bgs	below ground surface
BV	bed volume
C/F	coagulation/filtration process
CRF	capital recovery factor
DBP	disinfection byproducts
DHS	Department of Human Services
DO	dissolved oxygen
DWP	Drinking Water Program
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
Fe	iron
FRP	fiber reinforced plastic
gpd	gallons per day
gpm	gallons per minute
HIX	hybrid ion exchanger
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IOC	inorganic compounds
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elecktron, Inc.
Mn	manganese
NPT	National Pipe Thread
NTU	nephelometric turbidity unit
O&M	operation and maintenance
OIT	Oregon Institute of Technology

ABBREVIATIONS AND ACRONYMS (Continued)

ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&ID	piping and instrumentation diagram
psi	pounds per square inch
PO_4	orthophosphate
POE	Point of Entry
POU	Point of Use
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RO	reverse osmosis
RPD	relative percent difference
RSSCT	rapid small scale column test
SDWA	Safe Drinking Water Act
SiO_2	silica
SMCL	secondary maximum contaminant level
SOC	synthetic organic compound
STS	Severn Trent Services
TCLP	toxicity characteristic leaching procedure
TDH	total dynamic head
TDS	total dissolved solids
TSS	total suspended solids
VOC	volatile organic compound
WET	Waste Extraction Test

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1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the 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 (As) 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 required 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 for reducing compliance cost. 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, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement published in the *Federal Register* requested water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 of the 115 candidate sites to host the demonstration studies.

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 recommended to EPA the technologies they determined to be 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 project. 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.

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites, and the water system at Oregon Institute of Technology (OIT) in Klamath Falls, OR was one of those selected.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic-removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving two to eight proposals. In April 2004, EPA convened another technical panel to review the proposals and provide recommendations to EPA; the number of proposals per site ranged from none (for two sites) to four. At the sites receiving at least one proposal, the final selection of the treatment technology was made through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. Three point of entry (POE) adsorptive media (AM) systems and eight point of use (POU) AM units, all manufactured by Kinetico, were selected in October 2004 for demonstration at the OIT facility. The three POE systems separately contained ArsenX^{np}, ARM 200, and Adsorbsia™ GTO™ media manufactured by Purolite, Engelhard Corporation, and Dow Chemical, respectively. About 11 months into the study, OIT

began to install 40 additional AdEdge POU AM units and replace the eight Kinetico units with AdEdge units.

As of January 2010, 39 of the 40 systems were operational and the performance evaluation of all 39 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Round 1 and Round 2 demonstration host sites include 25 AM systems (the OIT site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, 17 POU units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site), and one system modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including As, iron [Fe], and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital costs 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.

1.3 Project Objectives

The overall objective of the arsenic demonstration program is to conduct full-scale arsenic treatment 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 costs of the technologies.

This report summarizes the performance of the POE AM systems and POU AM units at OIT in Klamath Falls, OR, from December 12, 2005, through December 16, 2009. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

Table 1-1. Summary of Arsenic Removal Demonstration Sites

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Northeast/Ohio							
Wales, ME	Springbrook Mobile Home Park	AM (A/I Complex)	ATS	14	38[a]	<25	8.6
Bow, NH	White Rock Water Company	AM (G2)	ADI	70[b]	39	<25	7.7
Goffstown, NH	Orchard Highlands Subdivision	AM (E33-S)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33-S)	AdEdge	100	36[a]	46	8.2
Dummerston, VT	Charette Mobile Home Park	AM (A/I Complex)	ATS	22	30	<25	7.9
Felton, DE	Town of Felton	C/F (Macrolite)	Kinetico	375	30[a]	48	8.2
Stevensville, MD	Queen Anne's County	AM (E33-S)	STS	300	19[a]	270[c]	7.3
Houghton, NY[d]	Town of Caneadea	C/F (Macrolite)	Kinetico	550	27[a]	1,806[c]	7.6
Buckeye Lake, OH	Buckeye Lake Head Start Building	AM (ARM 200)	Kinetico	10	15[a]	1,312[c]	7.6
Springfield, OH	Chateau Estates Mobile Home Park	AM (E33-S)	AdEdge	250[e]	25[a]	1,615[c]	7.3
Great Lakes/Interior Plains							
Brown City, MI	City of Brown City	AM (E33-S)	STS	640	14[a]	127[c]	7.3
Pentwater, MI	Village of Pentwater	C/F (Macrolite)	Kinetico	400	13[a]	466[c]	6.9
Sandusky, MI	City of Sandusky	C/F (Aeralater)	Siemens	340[e]	16[a]	1,387[c]	6.9
Delavan, WI	Vintage on the Ponds	C/F (Macrolite)	Kinetico	40	20[a]	1,499[c]	7.5
Greenville, WI	Town of Greenville	C/F (Macrolite)	Kinetico	375	17	7827[c]	7.3
Climax, MN	City of Climax	C/F (Macrolite)	Kinetico	140	39[a]	546[c]	7.4
Sabin, MN	City of Sabin	C/F (Macrolite)	Kinetico	250	34	1,470[c]	7.3
Sauk Centre, MN	Big Sauk Lake Mobile Home Park	C/F (Macrolite)	Kinetico	20	25[a]	3,078[c]	7.1
Stewart, MN	City of Stewart	C/F&AM (E33-S)	AdEdge	250	42[a]	1,344[c]	7.7
Lidgerwood, ND	City of Lidgerwood	Process Modification	Kinetico	250	146[a]	1,325[c]	7.2
Midwest/Southwest							
Arnaudville, LA	United Water Systems	C/F (Macrolite)	Kinetico	770[e]	35[a]	2,068[c]	7.0
Alvin, TX	Oak Manor Municipal Utility District	AM (E33-S)	STS	150	19[a]	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33-S)	AdEdge	40	56[a]	<25	8.0
Wellman, TX	City of Wellman	AM (E33-S)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33-S)	STS	320	23[a]	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33-S)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33-S)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33-S)	AdEdge	90[b]	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33-S)	AdEdge	50	32	<25	8.2
Valley Vista, AZ	Arizona Water Company	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8

Table 1-1. Summary of Arsenic Removal Demonstration Sites (Continued)

Demonstration Location	Site Name	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
					As (µg/L)	Fe (µg/L)	pH (S.U.)
Far West							
Three Forks, MT	City of Three Forks	C/F (Macrolite)	Kinetico	250	64	<25	7.5
Fruitland, ID	City of Fruitland	IX (A300E)	Kinetico	250	44	<25	7.4
Homedale, ID	Sunset Ranch Development	POU RO[f]	Kinetico	75 gpd	52	134	7.5
Okanogan, WA	City of Okanogan	C/F (Electromedia-I)	Filtronics	750	18	69[c]	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbsia™ GTO™/ARM 200/ArsenX^{np}) and POU AM (ARM 200)[g]	Kinetico	60/60/30	33	<25	7.9
Vale, OR	City of Vale	IX (Arsenex II)	Kinetico	525	17	<25	7.5
Reno, NV	South Truckee Meadows General Improvement District	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4
Susanville, CA	Richmond School District	AM (A/I Complex)	ATS	12	37[a]	125	7.5
Lake Isabella, CA	Upper Bodfish Well CH2-A	AM (HIX)	VEETech	50	35	125	7.5
Tehachapi, CA	Golden Hills Community Service District	AM (Isolux)	MEI	150	15	<25	6.9

AM = adsorptive media process; C/F = coagulation/filtration; HIX = hybrid ion exchanger; IX = ion exchange process; RO = reverse osmosis
ATS = Aquatic Treatment Systems; MEI = Magnesium Elektron, Inc.; STS = Severn Trent Services
(a) Arsenic existing mostly as As(III).
(b) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.
(c) Iron existing mostly as Fe(II).
(d) Withdrew from program in 2007. Selected originally to replace Village of Lyman, NE site, which withdrew from program in June 2006.
(e) Facilities upgraded systems in Springfield, OH from 150 to 250 gpm, Sandusky, MI from 210 to 340 gpm, and Arnaudville, LA from 385 to 770 gpm.
(f) Including nine residential units.
(g) Including eight under-the-sink units.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected from operation of the Kinetico POE/POU treatment systems/units at Klamath Falls, OR from December 12, 2005 through August 26, 2009, the following summary and conclusions are provided relating to the overall objectives of the treatment technology demonstration study.

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

- Under on-demand conditions with varying water flowrates and use rates, E33-S and Adsorbsia™ GTO™ media achieved a run length of 50,000 and 33,500 bed volumes (BV), respectively, before reaching 10 µg/L arsenic breakthrough. ARM 200, ARM 300, and ArsenX^{np} media had shorter media life spanning from 13,940 to 16,200 BV.
- The ARM 200 POU units consistently removed arsenic to <6.0 µg/L after treating up to 1,000 gal of water. The E33-S POU units could treat up to 3,000 gal of water with arsenic concentrations below the MCL.
- The initial backwash after media loading required up to 115 BV of backwash water for Adsorbsia™ GTO™ media while ARM 200 and ArsenX^{np} media required only a few BV of backwash water.
- Media backwashing during prolonged system operation (up to 3 to 4 years) did not appear to be necessary.
- Arsenic concentrations in the distribution system (downstream from the treatment systems) appeared to mirror those in system effluent. Post-baseline lead and copper levels were significantly below the respective action levels.

Required system O&M and operator skill levels:

- Under normal operation, the daily demand on the operator was typically 30 min to visually inspect the system and record operational parameters for each of the three POE systems.
- Daily operation of the system did not require additional skills beyond those necessary to operate the existing water supply equipment. OIT is classified by the State of Oregon as an "S" class water treatment system and the operator has a matching certificate.

Characteristics of residuals produced by the technology:

- Residuals produced by the operation of the treatment system included backwash wastewater and spent media.
- The POE systems were backwashed only once during close to four years of system operation. A total of 1,540-gal backwash wastewater was produced from the backwash event, which contained up to 91.6 g of solids.

Capital and O&M cost of the technology:

- Using the system's rated capacity, the normalized cost was $1,862/gal/min (gpm) (or $1.29/gal/day [gpd]) for the Purvine Hall system, $992/gpm (or $0.69/gpd) for the Residence Hall system, and $1,221/gpm (or $0.85/gpd) for the College Union system.
- Media replacement is a major cost for operating an AM system. Among the four media with vendors' quotes, the unit media cost is $300/ft^3 for E33-S, $468/ft^3 for ARM 200, $595/ft^3 for ArsenX^{np}, and $678/ft^{3}for Adsorbsia™ GTO™.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Table 3-1 summarizes pre-demonstration activities and completion dates. Following the pre-demonstration activities, the performance evaluation study of the POE/POU treatment systems/units began on December 12, 2005 (evaluation of the Adsorbsia™ GTO™ system did not begin until February 17, 2006), and ended on December 16, 2009. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall performance of the systems/units was evaluated based on their abilities to consistently remove arsenic to below the MCL of 10 μg/L. This was monitored through the collection of water samples across treatment trains, as described in a study plan (Battelle, 2006). The reliability of the systems/units was evaluated by tracking unscheduled system downtime and the frequency and extent of repair and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

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

Activity	Date
Introductory Meeting Held	October 27, 2004
Project Planning Meeting Held	January 19, 2005
Final Letter of Understanding Issued	March 8, 2005
Request for Quotation Issued to Vendor	June 15, 2005
Vendor Quotation Received by Battelle	August 5, 2005
Purchase Order Completed and Signed	August 30, 2005
Engineering Plans Submitted to Oregon DHS DWP	October 13, 2005
System Delivered to OIT	October 28, 2005
Permit Issued by Oregon DHS DWP	October 31, 2005
System Installation Completed	December 4, 2005
ARM 200 and ArsenX^{np} System Shakedown Completed	December 10, 2005
ARM 200 and ArsenX^{np} System Performance Evaluation Begun	December 12, 2005
Adsorbsia™ GTO™ System Rebedded	January 5, 2006
Final Study Plan Issued	January 9, 2006
Adsorbsia™ GTO™ System Shakedown Completed	February 17, 2006
Adsorbsia™ GTO™ System Performance Evaluation Begun	February 17, 2006
Performance Evaluation Completed	December 16, 2009

DHS DWP = Department of Human Services Drinking Water Program

O&M and operator skill requirements were assessed through quantitative data and qualitative considerations, including the need for pre- and/or post-treatment, level of system automation, extent of preventative maintenance activities, frequency of chemical and/or media handling and inventory, and general knowledge needed for relevant chemical processes and related health and safety practices. Staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

The quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash wastewater produced during each backwash cycle. Backwash wastewater was sampled and analyzed for chemical characteristics.

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 task required tracking the capital cost for equipment,

Table 3-2. General Types of Data

Evaluation Objective	Data Collection
Performance	-Ability to consistently meet 10 μg/L of arsenic MCL 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 preventative 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, engineering, and installation -O&M cost for media replacement, chemical use, electricity consumption, and labor

site engineering, and installation, as well as the O&M cost for media replacement and disposal, chemical supplies, electricity usage, and labor.

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 the vendor and Battelle. On a regular basis, the operator recorded POE system operational data such as pressure, flowrate, and throughput readings (see Appendix A) on a System Operation Log Sheet, checked the position of all manual valves, and conducted visual inspections to ensure normal operation of the systems/units. If any problem occurred, the operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded relevant information, including the problems encountered, course of actions taken, materials and supplies used, and associated cost and labor incurred on the Repair and Maintenance Log Sheet. On a regular basis, the plant operator measured onsite temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on an Onsite Water Quality Parameters Log Sheet. Backwash data also were recorded on a Backwash Log Sheet.

The capital cost for the POE/POU arsenic removal systems/units consisted of the expenditure for equipment, site engineering, and system installation. The O&M cost consisted of the cost for media replacement and labor. There were no electrical components associated with the POE systems. Labor hours for various activities such as the routine system O&M, system troubleshooting and repair, and demonstration-related work, were tracked using an Operator Labor Hour Record. The routine system O&M included activities such as completing field logs, ordering supplies, performing system inspections, and others as recommended by the vendor. The labor for demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for cost analysis.

3.3 Sample Collection Procedures and Schedules

Three POE systems and eight POU units were initially installed for the demonstration study. One each POE system was installed at the Purvine Hall, the Residence Hall, and the College Union. The Purvine Hall houses a number of classrooms, laboratories, offices, and the Oregon Renewable Energy Center. The Residence Hall provides domitory facilities for 250 students. The College Union houses a bookstore, post office, campus dining, and offices for admissions, financial aid, information, and student affairs.

All three POE systems were monitored for their performance. Samples were collected at the wellhead, across the treatment plant, during adsorption vessel backwash, and from the distribution system. Among the eight POU units installed, only three located in the University Advancement building, Snell Hall, and the Facility Service building were monitored for their performance. Performance of these units was monitored by tracking arsenic concentrations in unit effluent. Table 3-3 shows sampling schedules and analytes measured during each sampling event.

Figures 3-1 to 3-4 present flow diagrams of the treatment systems, along with the analytes and schedules for each sampling location. 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, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial site visit on October 27, 2004, one set of source water samples was collected from Well No. 1 and speciated using an arsenic speciation kit (Section 3.4.1). The samples were analyzed for detailed water quality analyses with analytes listed in Table 3-3. The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation.

3.3.2 Treatment Plant Water. Samples were initially collected from the POE systems biweekly on an eight-week cycle and from the POU units monthly. Over the course of the study, the sampling frequency decreased to monthly, bimonthly, and quarterly for the POE systems and to quarterly for the POU units.

- **Purvine Hall (Figure 3-1).** The system performance evaluation began on January 11, 2006. Speciation samples were collected during the first sampling event at the inlet (IN) and combined effluent (TT) locations. Afterwards, samples were collected bi-weekly for two eight-week cycles with speciation and other analytes analyzed at IN and TT at the beginning of the cycle and total arsenic analyzed at IN and after Vessels B1, A1, B2, and A2 (TB1, TA1, TB2, TA2) for the next three bi-weekly sampling events (note that Vessels B1 and B2 were at the lead position). Starting on May 9, 2006, samples were collected bi-weekly for six four-week cycles with a speciation event at IN and TT at the beginning of the cycle and total arsenic at IN, TB1, TA1, TB2, and TA2 during the other sampling event in each four-week cycle. Samples were collected bi-monthly from January 10, 2007, through May 2, 2007, at the five locations for total arsenic. On August 1, 2007, samples were collected quarterly until August 26, 2009.
- **Residence Hall (Figure 3-2).** The first samples were collected on January 11, 2006, at IN and after Vessels B and A (TB and TA) (note that Vessel B was at the lead position). Afterwards, samples were collected bi-weekly at all three locations for two eight-week cycles with speciation at the beginning of the cycle and total arsenic during the remaining three bi-weekly samplings events. Starting on May 9, 2006, samples were collected bi-weekly for six four-week cycles with a speciation event at the beginning of the cycle and total arsenic during

Table 3-3. Sampling Schedule and Analytes

Sample Type	Adsorptive Media System				Sample Locations[a]	# of Samples	Sampling Frequency	Analytes	Sampling date
	Type	Design Flowrate (gpm)	Media	Location					
Source Water	NA	NA	NA	NA	At Wellhead	1	Once (during introductory meeting)	Onsite: pH, temperature, DO, and ORP Offsite: Arsenic speciation Fe (total and soluble), Mn (total and soluble), V (total and soluble), U (total and soluble), Na, Ca, Mg, Cl, F, NO_2, NO_3, NH_3, SO_4, SiO_2, PO_4, turbidity, alkalinity, TDS, and TOC	10/27/04
Treatment Plant Water	POE	30	ArsenX^{np}	PV	IN, TB1, TA1, TB2, TA2	5	Bi-weekly until 04/26/07; Monthly until 10/11/06; Quarterly thereafter	Onsite: pH, temperature, DO, ORP, and Cl_2 (free and total) Off-site: As (total)	See Appendix B
		60	ARM 200/ ARM 300/ E33-S	RH	IN, TB, TA	3	Bi-weekly until 04/26/07; Monthly until 06/01/07; Quarterly from 12/18/07		See Appendix B
		60	Adsorbsia™ GTO™	CU	IN, TA, TB	3	Bi-weekly until 04/26/07; Monthly until 10/11/06; Bi-monthly until 05/02/07; Quarterly thereafter		See Appendix B
	POE	30	ArsenX^{np}	PV	IN, TT	2	Bi-monthly until 05/09/06; Monthly until 09/27/06	Onsite: pH, temperature, DO, ORP, and Cl_2 (free and total) Offsite: As speciation, Fe (total and soluble), Mn (total and soluble), Ca, Mg, Ti[a], F, NO_3, SO_4, SiO_2, turbidity and alkalinity	See Appendix B
		60	ARM 200	RH	IN, TB, TA	3	Bi-monthly until 05/09/06; Monthly until 09/27/06		See Appendix B
		60	Adsorbsia™ GTO™	CU	IN, TA, TB	3	Bi-monthly until 05/09/06 Monthly until 09/27/06		See Appendix B

Table 3-3. Sampling Schedule and Analytes (Continued)

Sample Type	Adsorptive Media System				Sample Locations[a]	# of Samples	Sampling Frequency	Analytes	Sampling date
	Type	Design Flowrate (gpm)	Media	Location					
Treatment Plant Water (Con't)	POU	0.75	ARM 200/ E33-S[c]	UA	AF1	1	Monthly until 06/06/07; Quarterly thereafter	Offsite: As (total)	See Appendix B
				SH/CH[b]	AF2	1			
				FS	AF3	1			
Distri-bution System Water	POE	30	ArsenX^{np}	PV	One LCR location in PV (DS3)	1	Monthly	As (total), Fe (total), Mn (total), Cu, Pb, pH, and alkalinity	See Table 4-24
		60	ARM 200/ ARM 300	RH	One LCR location in RH (DS1)	1			
		60	Adsorbsia™ GTO™	CU	One LCR location in CU (DS2)	1			
Backwash Water	POE	30	ArsenX^{np}	PV	Discharge point	4	Once	pH, TDS, TSS, As (total and soluble), Fe (total and soluble), Mn (total and soluble)	See Table 4-22
		60	ARM 200	RH	Discharge point	2			
		60	Adsorbsia™ GTO™	CU	Discharge point	2			
Backwash Solids	POE	30	ArsenX^{np}	PV	Wastewater container	4	Once	Total As, Ba, Ca, Fe, Mg, Mn, P, Si	See Table 4-23
		60	ARM 200	RH	Wastewater container	1			
		60	Adsorbsia™ GTO™	CU	Wastewater container	2			

IN = at inlet; TA = after Vessel A; TA1 = after Vessel A1; TB = after Vessel B; TB1 = after Vessel B1; TT = after effluent combined
AF1 = after POU unit 1; AF2 = after POU unit 2; AF3 = after POU unit 3
CH = Cornett Hall; CU = College Union; FS = Facility Services; PV = Purvine Hall; RH = Residence Hall; SH = Snell Hall; UA = University Advancement

(a) Ti analysis for Adsorbsia™ GTO™ system in CU only.
(b) On 02/13/08, AF2 was changed from Snell Hall to Cornett Hall.
(c) On 11/15/07, 05/25/08, and 08/15/08, kinetic POUs were replaced with AdEdge POU units loaded with E33-S at University Advancement, Cornett Hall, and Facility Services, respectively.

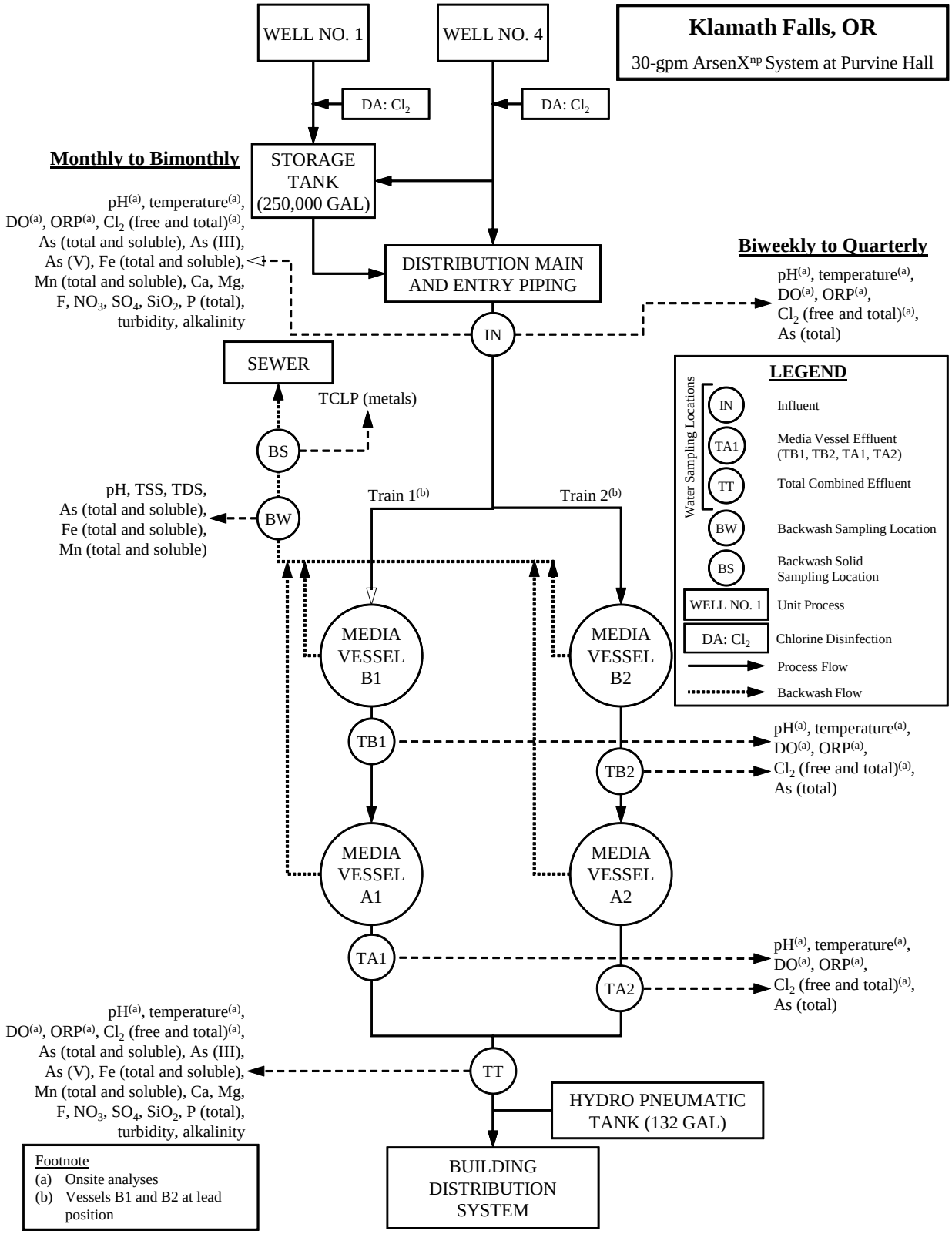

Figure 3-1. Process Flow Diagram and Sampling Locations for ArsenX^{np} System

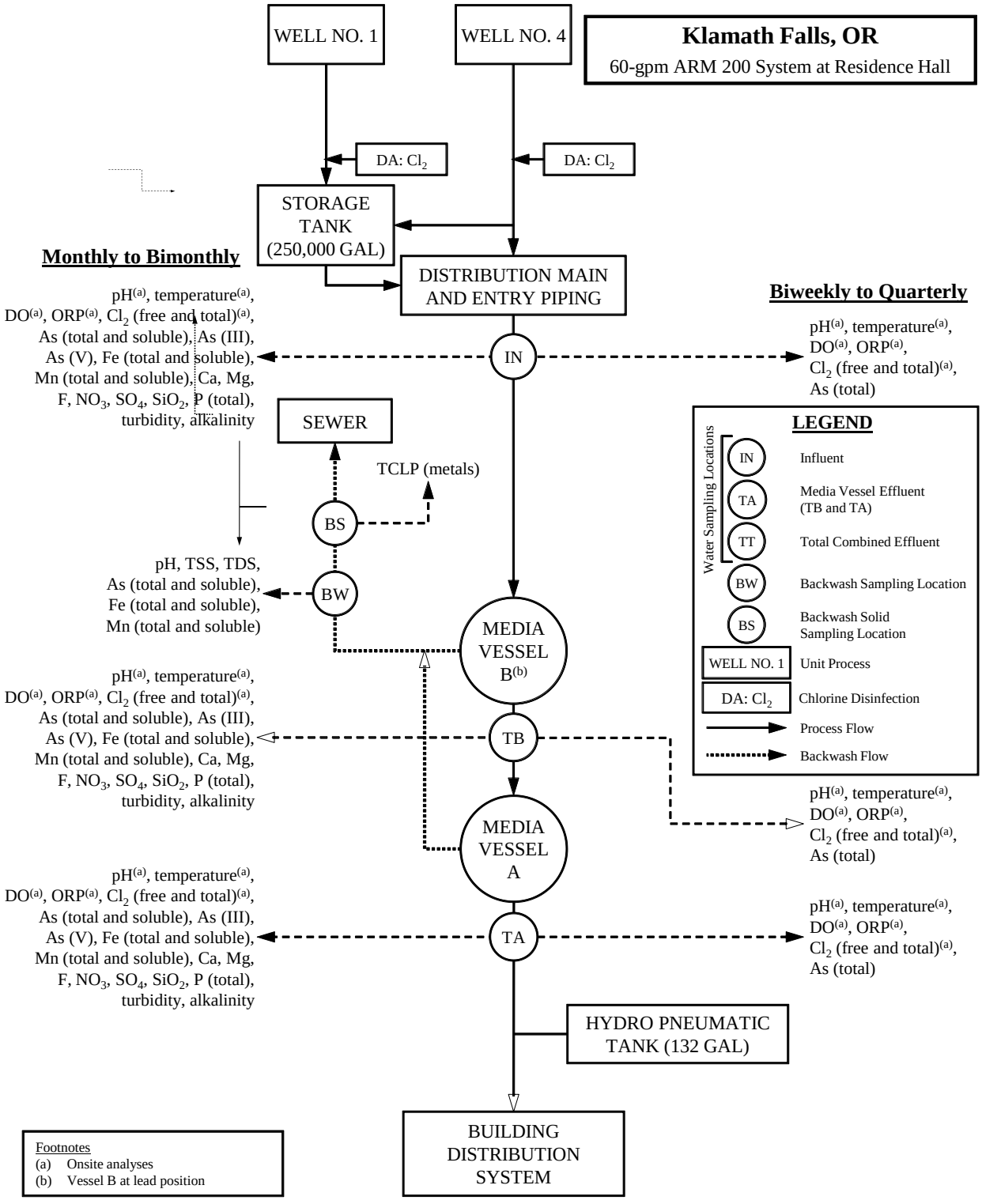

Figure 3-2. Process Flow Diagram and Sampling Locations for ARM 200 System

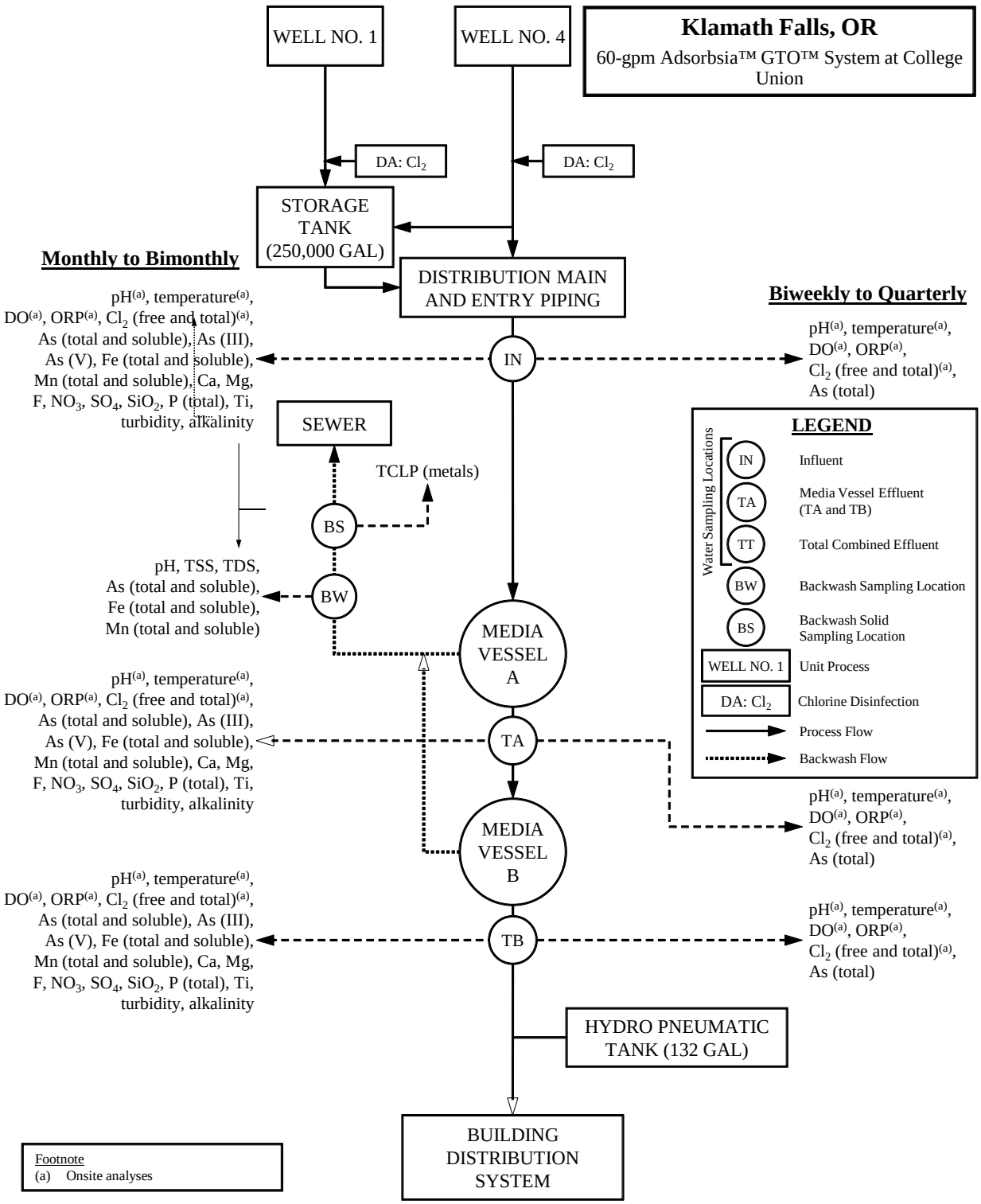

Figure 3-3. Process Flow Diagram and Sampling Locations for Adsorbsia™ GTO™ System

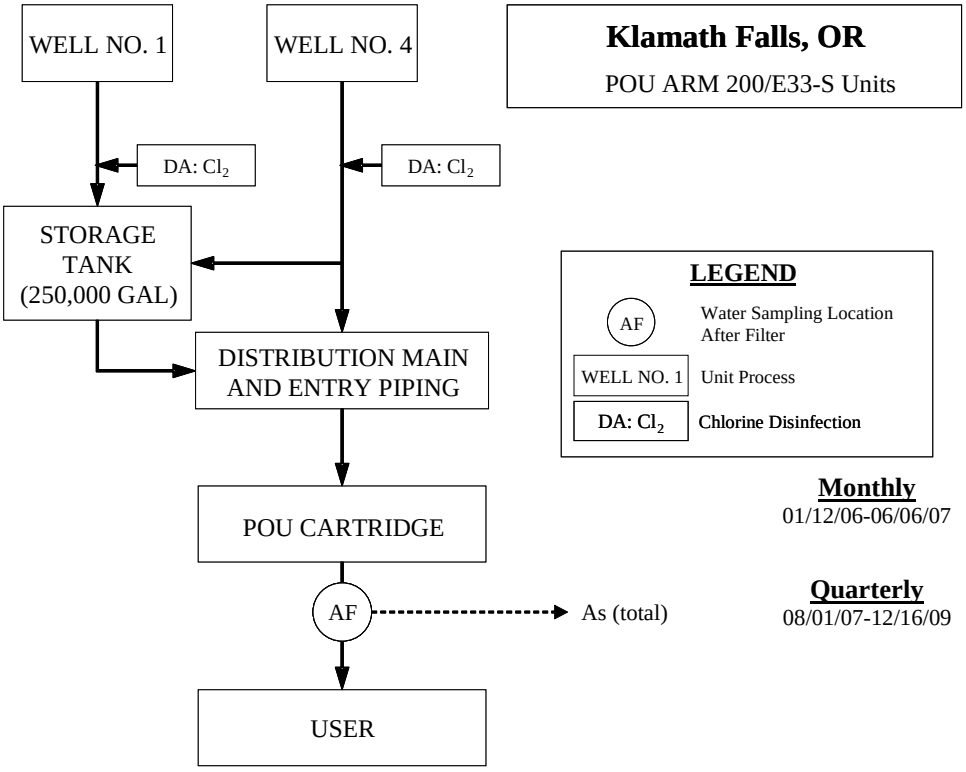

Figure 3-4. Process Flow Diagram and Sampling Locations for POU Units

the other sampling events. On November 16, 2006, the sampling frequency was reduced to bi-monthly for total arsenic only leading up to rebedding with ARM 300 media on January 24, 2007. Following rebedding, samples were collected monthly until June 1, 2007. On July 11, 2007, the system was placed in bypass until rebedding with E33-S on October 3, 2007. The system was sampled quarterly between December 18, 2007, and August 26, 2009.

- **College Union (Figure 3-3)**. On March 1, 2006, samples were collected at IN, TA, and TB for total arsenic (note that Vessel A was in the lead position). After the first sampling event, samples were collected bi-weekly on an eight-week cycle with speciation performed at all locations at the beginning of the cycle and total arsenic during the remaining three bi-weekly sampling events. Starting on May 9, 2006, samples were collected bi-weekly for six four-week cycles with speciation performed at all locations at the beginning of the cycle and total arsenic during the other sampling events. Samples were collected bi-monthly from January 1, 2007 through May 5, 2007. On August 1, 2007, samples were collected quarterly until August 26, 2009.

For all sampling events, pH, temperature, DO, and ORP were measured onsite using a VWR SymPhony handheld meter. Free chlorine residuals also were measured onsite using a Hach handheld colorimeter. DO and ORP were not measured from February 13, 2008, through August 26, 2009.

Three of the eight POU units located in the University Advancement building (POU 1), Snell Hall (POU 2), and the Facility Services building (POU 3) were designated for monthly sampling from January 12, 2006, through June 6, 2006 and quarterly from August 1, 2007, through December 16, 2009. On

February 13, 2008, the POU unit at Snell Hall was moved to Cornett Hall. Samples were collected after cartridge filters for total arsenic analyses. Total flow measurements for the three POU units were recorded through Kent meters. On November 15, 2007, May 25, 2008, and August 15, 2008, the three Kinetico POU units were replaced with AdEdge POU units loaded with E33-S.

3.3.3 Backwash Wastewater and Solids. During the performance evaluation study, the three POE systems were backwashed once on May 16 or 17, 2006. One backwash wastewater sample was collected from each adsorption vessel. The procedure involved diverting a portion of backwash wastewater from the backwash discharge line to a 32-gal plastic container over the duration of the backwash for each vessel. After the content in the container had been thoroughly mixed, a composite sample was collected and/or filtered onsite with 0.45-µm disc filters. Analytes for the backwash wastewater samples are listed in Table 3-3.

The content in the 32-gal plastic container was allowed to settle and the supernatant was carefully siphoned using a piece of plastic tubing to avoid agitation of settled solids in the container. The remaining solids/water mixture was then transferred to a 1-gal plastic jar. After solids in the jar were settled and the supernatant was carefully decanted, one aliquot of the solids/water mixture was air dried before being acid-digested and analyzed for the metals listed in Table 3-3.

3.3.4 Distribution System Water. Water samples were collected from the distribution system to determine the impact of the three POE arsenic treatment systems on its water chemistry, specifically, the arsenic, lead and copper levels. Prior to system startup, four monthly baseline distribution water samples were collected from three locations within the distribution system from July to September 2005. Following system startup, distribution system sampling continued on a monthly basis at the same three locations from January 25, 2006 to April 4, 2007. Analytes for the distribution system sampling are presented in Table 3-3.

The three distribution system sampling locations were at Purvine Hall, the Residence Hall, and the College Union. These three locations were part of OIT's historic sampling network for the Lead and Copper Rule (LCR). The system operator collected the first draw distribution system samples following an instruction sheet developed by Battelle in accordance with the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The operator 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. All samples were collected from a cold water faucet that had not been used for at least 6 hr to ensure that stagnant water was sampled. The samples were analyzed for the analytes listed in Table 3-3. Arsenic speciation was not performed for the distribution system water samples.

3.3.5 Residual Solids. Three ARM 200 spent media samples were collected from the lead vessel (Tank B) during media changeout at the Residence Hall on January 24, 2007. Spent media was sampled from the top (i.e., 0 to 4 in into the bed), middle (i.e., 22 to 26 in), and bottom (i.e., 35 to 39 in) of the media bed using a 6.5-horsepower (hp) wet/dry shop vac that had been thoroughly cleaned and disinfected before sampling. The media collected from each target layer was transferred from the shop vac to a clean 5-gal bucket and mixed carefully with a small garden spade. A composite sample from each layer was collected into a wide-mouth, 1-gal plastic container and sent to Battelle for analysis. Metal analyses were conducted on air dried and acid digested samples (see analytes in Table 3-3) and toxicity characteristic leaching procedure (TCLP) tests were conducted on unprocessed samples following the protocol described in the QAPP (Battelle, 2004).

3.4 Sampling Logistics

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

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate soluble arsenic species, i.e., As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories in accordance with the procedures detailed in Appendix A of the QAPP (Battelle, 2004).

3.4.2 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 affixed with a pre-printed, colored-coded, waterproof label consisting of the 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 the demonstration site, the sampling date, a two-letter code for a specific sampling location, and a one-letter code for designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. The labeled bottles for each sampling location were placed in separate zip loc bags (each corresponding to a specific sample location) and packed in the cooler. When needed, the sample cooler also included bottles for the distribution system sampling.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, and bubble wrap, were placed in each cooler. The chain-of-custody forms and air bills were complete except for the operator's signature and the sample dates and times. After preparation, the sample cooler was sent to the site via FedEx for the following week's sampling event.

3.4.3 Sample Shipping and Handling. After sample collection, samples for offsite analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian checked sample IDs against the chain-of-custody forms and verified that all samples indicated on the forms were included and intact. The Battelle Study Lead addressed discrepancies noted by the sample custodian with the plant operator. The shipment and receipt of all coolers by Battelle were recorded on a cooler tracking log.

Samples for metal analyses were stored and analyzed at Battelle's Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) laboratory. Samples for other water quality analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, OH and Belmont Labs in Englewood, 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 disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time, and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the QAPP (Battelle, 2004) were followed by Battelle's ICP-MS laboratory, AAL, and Belmont Labs. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), 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 upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a handheld field 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 probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Site Description

4.1.1 Pre-existing Facility. The OIT-Klamath Falls campus (Figure 4-1) is located just east of the Cascade Mountains in southern Oregon. The non-transient, non-community water system supplies water to a population of 3,315 via 15 connections to individual buildings. The average daily use for the year of 2003 to 2004 was 167,000 gpd and the peak daily use was 350,000 gpd. A large quantity of water was used for outdoor irrigation and landscaping due to the dry climate. Only 20,000 to 60,000 gpd was used by facilities such as dormitories, classrooms, laboratories, and offices for drinking, sanitary, and teaching/research purposes.

Source water is groundwater supplied by two wells, Wells No. 1 and No. 4, located on the east side of the campus. Well No. 1 is the primary supply well and Well No. 4 is a backup well. Figure 4-2 shows the Well No. 1 pump house. Well No. 1 was drilled to a depth of 1,205 ft below ground surface (bgs) with a screen interval from 455 ft to 1,205 ft bgs. The well casings are 8-in in diameter from the surface to 685 ft bgs and 6-in in diameter from 685 ft to 1,205 ft bgs. Well No. 1 is equipped with a 60-hp closed line shaft turbine pump rated for 300 gpm at a total dynamic head (TDH) of 600 ft of water or 260 lb/in^2 (psi). Well No. 4 has a total depth of 1,224 ft with a screen interval from 300 ft to 1,221 ft bgs. The well casings are 12-in in diameter from the surface to 732 ft bgs, 10-in in diameter from 732 ft to 1,037 ft bgs, and 8-in in diameter from 1,037 ft to 1,224 ft bgs. It is equipped with a 75-hp submersible pump rated for 250 gpm at a TDH of 530 ft of water or 230 psi. The static water level was measured at 449 ft bgs in Well No. 1 and 315 ft bgs in Well No. 4. Well No. 1 typically operates approximately 2.5 hr/day in winter and 12 hr/day in summer to meet the water demand.

Figure 4-1. View of OIT Campus

Figure 4-2. Well No. 1 Pump House at OIT

The existing water treatment includes wellhead chlorination using chlorine gas to maintain a free chlorine residual level of 0.25 to 0.35 mg/L (as Cl_2). Figures 4-3 and 4-4 show an existing chlorine gas storage unit and a chlorine addition system for Well No. 1. The chlorinated water is stored in a 250,000-gal aboveground storage tank located near the pump house (Figure 4-5) before being distributed to the campus.

Figure 4-3. Well No. 1 Chlorine Gas Storage Unit at OIT

Figure 4-4. Close-up View of Well No. 1 Chlorine Addition System at OIT

Figure 4-5. 250,000-gal Aboveground Storage Tank at OIT

4.1.2 Distribution System. The distribution system at OIT supplies water to 13 buildings on the campus. Chlorinated water from the Well No. 1 pump house flows to the 250,000 gal storage tank before entering the distribution system. Chlorinated water from the Well No. 4 pump house feeds directly into the distribution system with excess water going to the storage tank. The distribution piping consists of 10-in asbestos cement, 8-in polyvinyl chloride (PVC), and 6-in ductile iron piping. The size and material of the plumbing as well as the system pressure at each building inlet are presented in Table 4-1. Once entering a building, the system pressure is reduced to 50 to 76 psi by a pressure reducing valve. Figure 4-6 shows a photograph of a pressure reducing valve at one building inlet.

Figure 4-6. Pressure Reducing Valve at a Building Entry Point

The routine distribution system sampling at OIT included coliform (once a month), lead and copper (once every three years), and asbestos (once every nine years). In December 2004, OIT conducted lead and copper sampling at 20 locations. The 90th percentile results were below the respective action levels of 15 and 1,300 µg/L. As part of the EPA demonstration study, one location each in Purvine Hall, the Residence Hall, and the College Union was selected for monthly distribution sampling before and after installation of the POE treatment systems. These locations are part of OIT's historic LCR sampling network. In addition, OIT conducted routine sampling at the distribution system entry points of Well No. 1 and Well No. 4 for arsenic, inorganic chemicals (IOC), nitrate, nitrite, volatile organic compounds (VOCs), synthetic organic compounds (SOCs), and disinfection byproducts (DBP) from yearly to once every nine years as directed by the Oregon DHS DWP.

4.1.3 Source Water Quality. Source water samples were collected from Well No. 1 on October 27, 2004, and analyzed for the analytes shown in Table 3-3. The analytical results are presented in Table 4-2 and compared to the data (for both Wells No. 1 and No. 4) provided by OIT to EPA for the demonstration site selection and the data independently collected by Kinetico. Based on the data presented in Table 4-2, water quality of the two wells was similar.

Table 4-1. Source Water Quality Data for OIT Site

Parameter	Unit	Facility Data		Kinetico	Battelle
		Well No. 4[a]	Well No. 1		Well No. 1
Sampling Date		NA	07/30/01	10/28/03	10/27/04
pH	–	7.6	7.6	8.0	7.9
Temperature	°C	NA	NA	NA	23.0
DO	mg/L	NA	NA	NA	4.2
ORP	mV	NA	NA	NA	82.0
Total Alkalinity (as aCO_3)	mg/L	NA	NA	112	107
Hardness (as $CaCO_3$)	mg/L	NA	NA	80	81.0
Turbidity	NTU	NA	NA	NA	0.6
TDS	mg/L	NA	NA	NA	200
TOC	mg/L	NA	NA	NA	<0.7
Nitrate (as N)	mg/L	NA	0.8, 0.7[b]	NA	0.6
Nitrite (as N)	mg/L	NA	<0.01[b]	NA	<0.01
Ammonia (as N)	mg/L	NA	NA	NA	<0.05
Chloride	mg/L	NA	NA	3.9	2.6
Fluoride	mg/L	NA	0.1	0.2	<0.1
Sulfate	mg/L	23.0	22.7	22.0	21.0
Silica (as SiO_2)	mg/L	NA	NA	34.2	30.3
Orthophosphate (as PO_4)	mg/L	NA	NA	<0.5	<0.06
As (total)	µg/L	29.0–35.0	29.0, 27.0[c]	36.0	32.8
As (soluble)	µg/L	NA	NA	NA	33.0
As (particulate)	µg/L	NA	NA	NA	<0.1
As(III)	µg/L	NA	NA	NA	0.5
As (V)	µg/L	NA	NA	NA	32.5
Fe (total)	µg/L	ND	NA	<30	<25
Fe (soluble)	µg/L	NA	NA	NA	<25
Mn (total)	µg/L	ND	NA	<0.01	0.2
Mn (soluble)	µg/L	NA	NA	NA	<0.1
U (total)	µg/L	NA	NA	NA	0.3
U (soluble)	µg/L	NA	NA	NA	0.2
V (total)	µg/L	NA	NA	NA	35.0
V (soluble)	µg/L	NA	NA	NA	35.8
Na	mg/L	23.0	22.9	25.0	31.9
Ca	mg/L	NA	NA	23.0	20.8
Mg	mg/L	NA	NA	5.8	7.0

(a) Provided by the facility to EPA for site selection.
(b) Sample taken on July 21, 2004.
(c) Sample taken on September 9, 2004.
DO = dissolved oxygen; NA= not available; ND = not determined; ORP = oxidation-reduction potential; TDS = total dissolved solids; TOC = total organic carbon

Arsenic. Total arsenic concentrations in source water (from both wells) ranged from 27.0 to 36.0 µg/L. Based on the October 27, 2004, speciation results, out of 32.8 µg/L of total arsenic, 32.5 µg/L existed as As(V). Although pre-chlorination was not required, the existing wellhead chlorination system continued to be used to disinfect water throughout the study period.

Iron and Manganese. Iron and manganese concentrations in source water were low, typically less than their MDLs of 25 and 0.1 µg/L, respectively. In general, AM technologies are best suited to water with

low iron levels (i.e., less than 300 μg/L, which is the secondary maximum contaminant level [SMCL] for iron).

pH. The pH of raw water ranged from 7.6 to 8.0. Typically, the target pH range for the use of AM for arsenic removal is between 5.5 to 8.5. A pH value of 7.6 to 8.0 is within this range; therefore, pH adjustment was not included for the arsenic treatment system.

Competing Anions. Arsenic adsorption could be influenced by the presence of competing anions such as silica and phosphate. Analysis of source water indicated silica levels at 30.3 to 34.2 mg/L (as SiO_2) and orthophosphate levels below 0.5 mg/L (as PO_4). Concentrations of these anions were monitored on a regular basis during the system performance evaluation.

Other Water Quality Parameters. Nitrate was measured between 0.6 and 0.8 mg/L (as N). Nitrite, ammonia, and fluoride were either below or close to their respective detection limits.

Table 4-3 presents historical treated water quality data from July 2001 through August 2005 obtained from the Oregon DHS DWP. These treated water quality data were similar to the source water quality data presented in Table 4-2. Total arsenic concentrations of the treated water ranged from 27 to 38 μg/L. No arsenic speciation data were available.

Table 4-3. Treated Water Quality Data for OIT Site

Parameter	Unit	Oregon DHS Treated Water Data
	Date	07/30/01–08/08/05
Nitrate	mg/L (as N)	0.45–0.76
Sulfate	mg/L	21.9–22.7
As(total)	μg/L	27–38
Na	mg/L	22.9–29.0

4.2 Treatment Process Description

4.2.1 POE/POU Approaches. Kinetico originally proposed a centralized treatment system at the wellhead. This approach was replaced with one using three smaller POE systems during the January 19, 2005, project planning meeting attended by OIT, Kinetico, EPA, and the Oregon DHS DWP. The POE approach was selected because (1) a POE system can be placed in an existing maintenance room in each building, thus eliminating the need for a new treatment building to house a wellhead treatment system and (2) a POE system only treats the water entering the building, not the water for irrigation and landscaping, thus reducing the amount of water treated and the associated operational cost. Water usage and flowrate information was not available during the system sizing and design phase of the project due to the lack of water meters in any of the buildings. Weber Elliot Engineers and Kinetico provided flow estimates based on fixture counts in each building. Table 4-3 summarizes these estimates.

To more accurately estimate flowrates, a portable ultrasonic flow meter (Greyline Instruments, Inc.) was used for 24-hr real-time flow measurements in two buildings: the Residence Hall from March 28 to 29, 2005 (Figure 4-7) and Purvine Hall from April 4 to 5, 2005 (Figure 4-8). Flow measurements were made by strapping the ultrasonic flow meter onto the entry piping in each building. The measurements indicated that the total water usage at the Residence Hall was 14,456 gal with flowrates ranging from 0 to 156 gpm and averaging 19.4 gpm. The total water usage at Purvine Hall was 2,073 gal with flowrates ranging from 0 to 62 gpm and averaging 8.4 gpm. Although these one-time measurements might not be

Table 4-3. POE Locations and Estimated Flowrates at OIT

No.	Building Name	Pipe Size and Material	Pressure after Pressure Reducing Valves (psi)	Peak Demand Based on Fixture Count (gpm)		Design Flowrate Based on Flow Measurement (gpm)[(b)]
				Weber Elliot Engineers[(a)]	Kinetico	
1	Residence hall	4-in cast iron	65	NA	NA	60
2	University Advancement	NA	NA	NA	NA	1 POU
3a	College Union South	3- in PVC	72	NA	NA	60
3b	College Union North	4-in iron	76	NA	NA	
4a	Snell Hall	1.5-in copper	62	36	33–63	1 POU
4b	Owens Hall	2-in copper	65	59	58–83	1 POU
4c	Semon Hall	2-in copper	75	80	95–120	N/A
4d	Boivin Hall	3-in steel	60	72	70–95	N/A
5a	Physical Education (PE)	2.5-in copper	68	110	100–125	1 POU
5b	Learning Resource Center	3-in copper	70	NA	NA	1 POU
6	Purvine Hall	3-in copper	60	57	60–85	30
7a	Cornett Hall South	1-in/3-in copper	65	85	73–97	N/A
7b	Cornett Hall North	2-in copper	NA			
8	Facility Services	2.5-in copper	50	33	35–60	1 POU
9	Stadium	NA	NA	41	46–48	1 POU
Total (based on total fixture counts)				310	270	NA

(a) From uniform plumbing code demand curves.
(b) Each POE system equipped with a 132-gal hydro tank.
N/A = not applicable/not available; POE = point of entry; POU = point of use; PVC = polyvinyl chloride

representative of the year-long use, they appeared to be more accurate than the estimates based on building fixture counts provided by Weber Elliot Engineers and Kinetico. A decision was then made by EPA to install three POE AM systems and eight POU AM units for this demonstration study. The size and location of the POE systems are listed as follows:

- A 30-gpm ArsenX^{np} system in Purvine Hall
- A 60-gpm ARM 200 system in the Residence Hall
- A 60-gpm Adsorbsia™ GTO™ system in the College Union

Due to early arsenic breakthrough, ARM 200 media was changed out on two occasions with ARM 300 and E33-S. The eight Kinetico POU units were replaced with AdEdge POU units loaded with E33-S; another 40 AdEdge POU units also were installed in various campus buildings.

4.2.2 Adsorptive Media. The three POE systems initially employed one of three adsorptive media: (1) ArsenX^{np}, an iron-modified/resin-based media manufactured by Purolite; (2) ARM 200 (Ultrasorb-F as branded by Kinetico), an iron-based media manufactured by Engelhard Corporation; and (3) Adsorbsia™ GTO™, a titanium dioxide-based media manufactured by Dow Chemical. The system loaded with ARM 200 was rebedded with ARM 300, an iron-based media also manufactured by Engelhard Corporation, and then E33-S, an iron-based media manufactured by Lanxess (formerly Bayer AG). The eight POU units used ARM 200 media initially, but were replaced with AdEdge POU units loaded with E33-S. All adsorptive media are listed by NSF International (NSF) under Standard 61 for use in drinking water, and their physical and chemical properties are summarized in Table 4-4. More detailed descriptions of the media are provided below.

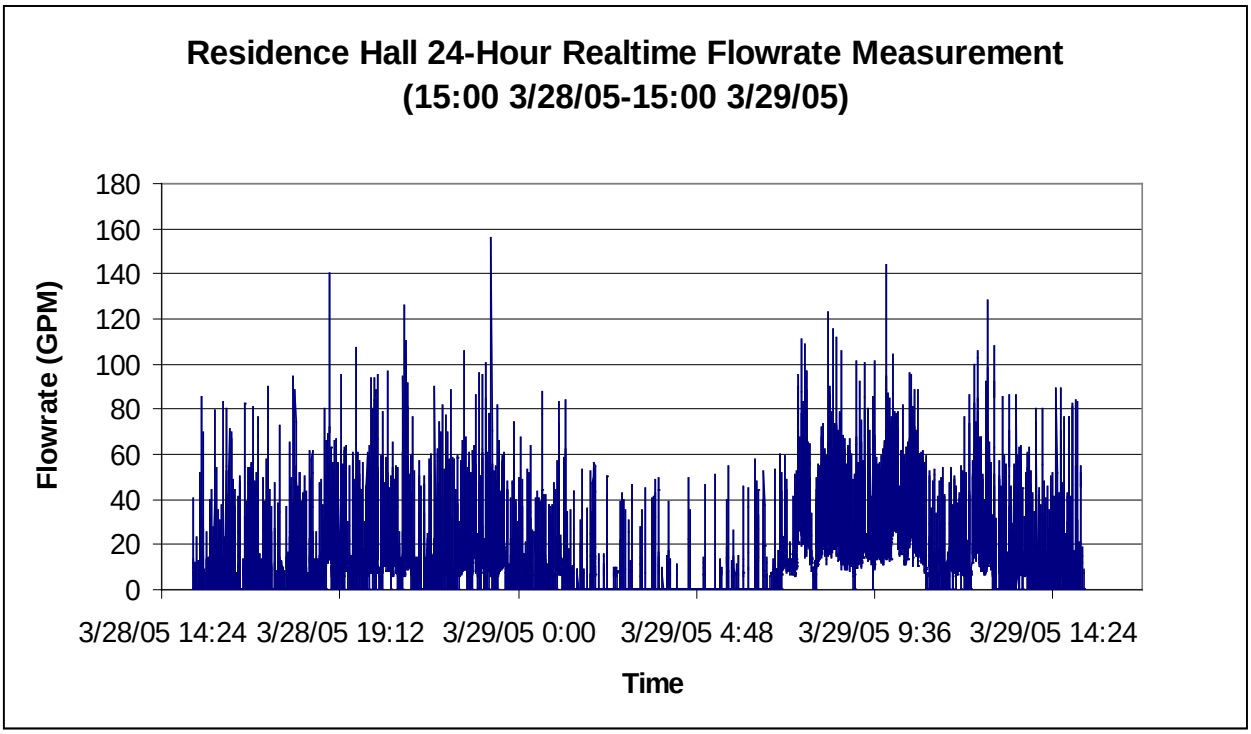

Figure 4-7. Twenty-Four-Hour Real-Time Flowrate Measurements at Residence Hall

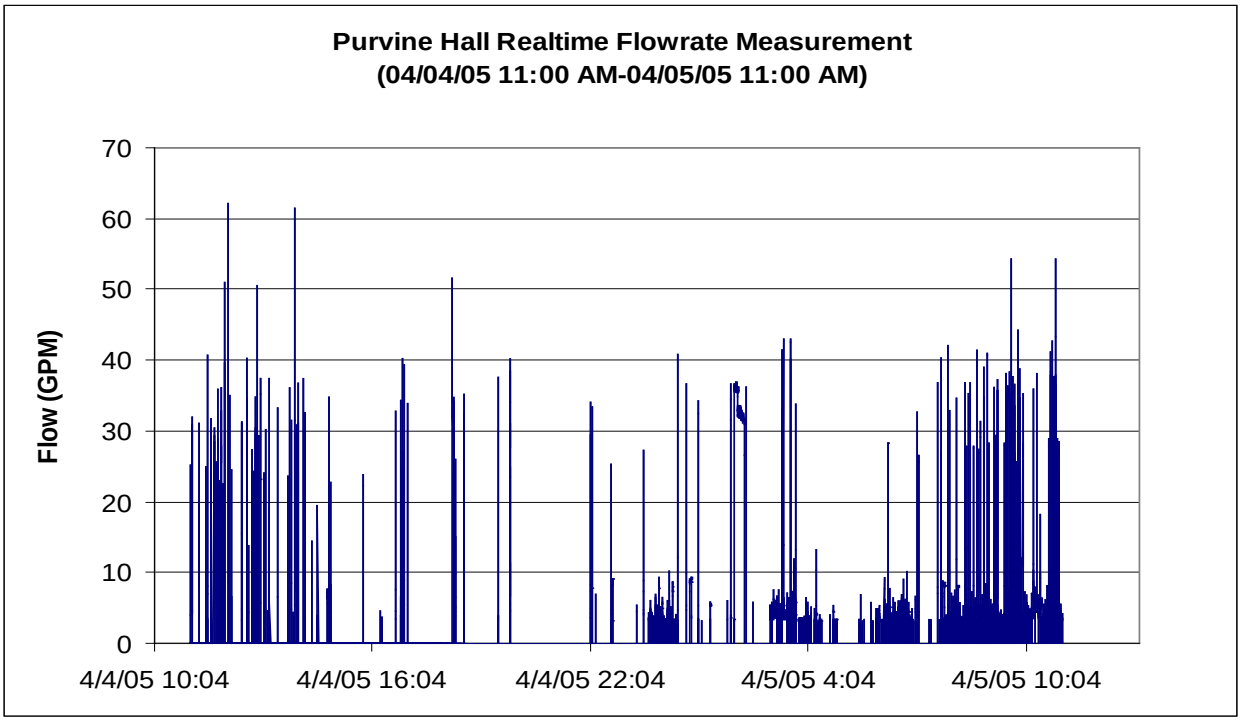

Figure 4-8. Twenty-Four-Hour Real-Time Flowrate Measurements at Purvine Hall

Table 4-4. Adsorptive Media Properties

Property	ArsenX^{np} [(a)]	Adsorbsia™ GTO™ [(b)]	ARM 200 [(c)]	ARM300 [(c)]	E33-S [(d)]
Physical Property					
Color	Brown	White	Brown	Brown	Amber
Matrix	Macro-porous polystyrene/ divinylbenzene	Nano-crystalline Titanium oxide	Iron oxide/ hydroxide	Iron oxide/ hydroxide	Iron oxide composite
Physical Form	Uniform spherical Beads	Dry granules	Dry granules	Dry granules	Dry granules/ pellets
Color	Reddish Brown	White	Dark Brown	Dark Brown	Amber
Bulk Density (g/cm^3)	0.79–0.84	0.8	0.72–0.80	0.56	0.47/0.56
Bulk Density (lb/ft^3)	49–52	50	45-50	35-40	28/35
BET Surface Area (m^2/g)	NA	200–300	225	NA	120–200
Pore Volume (mL/g)	NA	0.20–0.25	NA	NA	NA
Moisture Content (% by wt.)	55–60	<15	8	NA	<15
Particle Size (U.S. standard mesh)	16 × 50	10 × 60	12 × 40	12 × 50	10 × 35
Attrition (%)	NA	NA	<1	NA	0.3
Crystal Size (Å)	NA	NA	NA	NA	70
Crystal Phase	NA	NA	NA	NA	A–FeOOH
Chemical Property					
Active Ingredient	Hydrous iron oxide	Titanium dioxide	Iron oxide/ hydroxide	Iron oxide/ hydroxide	Iron oxide composite
Constituents					
Titanium Dioxide (%)	NA	89.0–99.0	NA	NA	0.11
Binder (%)	NA	1.0–10.0	NA	NA	NA
Metal Oxide (%)	35–65	0.01–1.0	NA	NA	91.97
pH Range	4–9	4–9	5–6	NA	NA

(a) Provided by SolmeteX.
(b) Provided by Dow Chemical.
(c) Provided by Engelhard.
(d) Provided by Bayer AG.
BET = Brunauer, Emmett, and Teller; NA = not available

ArsenX^{np}. ArsenX^{np} media was developed by SolmeteX, Inc. and manufactured and distributed by Purolite, Inc. under an exclusive license from Lehigh University. It has a base structure of macro-porous polystyrene/divinylbenzene impregnated with nanoparticles containing hydrous iron oxide functional groups. The media adsorbs both As(V) and As(III), with a higher capacity for As(V). It also removes other contaminants, such as vanadium, molybdenum, chromium, and uranium. The media has good mechanical strength and attrition resistance and does not generate fines during long-term vessel operation. The media can handle water with a pH range from 4 to 9. ArsenX^{np} media can be regenerated multiple times with a dilute caustic NaOH/NaCl solution. However, media regeneration and reuse were not planned for the OIT site.

ARM 200 and ARM 300 Media. Developed by Engelhard Corporation, ARM 200 media is a granular iron oxide/hydroxide media designed to remove dissolved arsenic from drinking water supplies via adsorption onto its surface. Kinetico marketed the media as Ultrasorb-F. ARM 200 adsorbs both As(V) and As(III) in a pH range from 5 to 9. The media is less effective for As(III) and at the upper

end of the pH range. ARM 300 media is similar to ARM 200, but has a lighter bulk density (i.e., 35 to 40 vs. 45 to 50 lb/ft^3) and somewhat broader size distribution (12 × 50 vs. 12 × 40 U.S. standard mesh).

Adsorbsia™ GTO™ Media. Adsorbsia™ GTO™ is a white, free-flowing granular titanium oxide-based media manufactured by Dow Chemical. The media is capable of adsorbing both As(V) and As(III), with a higher capacity for As(V). It adsorbs arsenic at a pH range of 6.5 to 8.5, but the adsorption is less effective at the upper end of the range. According to the vender, the media's capacity for arsenic may be independent of anion ions such as sulfate, phosphate, and vanadium. However, the presence of silica can reduce arsenic removal. Source water at OIT contained 30.3 to 34.2 mg/L of silica (as SiO_2); its impact on arsenic adsorption was closely monitored. Adsorbsia™ GTO™ cannot be regenerated.

E33-S. Bayoxide E33-S media (branded as AD-33 by AdEdge), is an iron-based AM developed by Lanxess (formerly Bayer AG) for the removal of arsenic from drinking water supplies. The media is available in both granular and pelletized forms and delivered in a dry, crystalline form. The pelletized media is 25% denser than its granular counterpart (i.e., 35 vs. 28 lb/ft^3).

4.2.3 Treatment Process Description

4.2.3.1 Key Process Steps/System Components. The major process steps and system components of the water system at OIT are discussed as follows:

- **Intake.** Raw water was supplied by two wells, with Well No. 1 being the primary well and Well No. 4 being the backup well. Based on the water meter at the Well No. 1 pump head, the total water consumption during the first year of performance evaluation study was approximately 55,085,000 gal, compared to the 8,184,000 gal of water treated by the three POE systems combined. The majority of water consumption on campus was for irrigation.
- **Prechlorination**. The pre-existing wellhead chlorination system was used to disinfect water. Gas chlorine was used to maintain a target free chlorine residual level of 0.35 to 0.4 mg/L (as Cl_2). Chlorine gas cylinders (150 lb) were kept in a room partitioned from the rest of the Well 1 pump house. The chlorine gas feed rate was regulated at 2.4 lb/day using a panel-mounted V100 chlorinator (Wallace & Tiernan). A dual-cylinder scale was used to monitor the chlorine gas consumption. Chlorine gas was injected to a side stream where an injector was used to create a venturi effect to mix chlorine gas with carrier water. Chlorinated water then was blended with source water prior to entering a 250,000-gal aboveground storage tank.
- **Water storage**. Chlorinated water was temporarily stored in the existing 250,000-gal aboveground storage tank located on a hill near the Well No. 1 pump house before being distributed to the campus.
- **Distribution main and entry piping**. The distribution main delivered water by gravity from the storage tank to the 13 buildings on campus. Upon entering a building, the system pressure was reduced to between 50 to 76 psi using pressure reducing valves (see Table 4-1). The inlet piping to Purvine Hall, the Residence Hall, and the College Union consisted of 3-in copper, 4-in copper, and 3-in copper, respectively, which was plumbed separately to the 30- gpm ArsenX^{np}, 60 gpm ARM 200, and 60-gpm Adsorbsia™ GTO™ systems. Figure 4-9 shows the inlet and exit piping to and from the 30-gpm ArsenX^{np} system at Purvine Hall.

Figure 4-9. Inlet and Exit Piping to ArsenX^{np} System in Purvine Hall

- **POE/POU adsorptive media systems**. The POE treatment systems and POU units are discussed in detail in Sections 4.2.3.2 and 4.2.3.3, respectively.
- **Hydropneumatic tank**. A 132-gal hydropneumatic tank (Amtrol Model WX-450-C) was installed downstream of each POE treatment system to meet demand and provide water for backwashing. The 24-in × 86⅝-in tank had a steel shell coated with blue enamel paint on top of red oxide primer and an inner bladder constructed of heavy duty butyl rubber. The tank was pre-charged at the factory with air at 25 psi, a pressure lower than the inlet piping pressure (i.e., the pressure after the respective pressure reducing valve).
- **Building distribution system.** The effluent piping from each POE system and hydropneumatic tank was tied into the exit piping to provide treated water to the distribution system inside each building.

4.2.3.2 POE Treatment Systems. All three POE arsenic removal systems are fixed-bed adsorption systems, each consisting of one or two parallel treatment trains. Each treatment train consisted of two adsorption vessels configured in series.

For series operation, the media in the lead vessel is removed and disposed of when it completely exhausts its capacity or when the effluent from the lag vessel reaches 10 µg/L of arsenic. Upon rebedding, the lead vessel is switched to the lag position and the lag vessel is switched to the lead position. In general, the series operation better utilizes the media capacity when compared to parallel operation because the lead vessel may be allowed to exhaust completely prior to changeout.

When comparing the performance of the lead vessel (series operation) with that of two smaller in-parallel vessels of a similarly-sized system (parallel operation), the number of BV treated by the system is calculated based on the media volume in the lead vessel for the series operation and in both vessels for the parallel operation. The calculation does not use the media volume in the lead and lag vessels because this approach considers the two vessels as one large vessel, which has twice as much media than the in-parallel system. The media volume in the lead vessel is equal to the sum of the media volume in each of the two vessels in parallel; the flow through the lead vessel is equal to the sum of the flow through each of the two vessels in parallel; and the empty bed contact time (EBCT) in the lead vessel is the same as the EBCT in each of the two vessels in parallel. BV following the lag vessel were calculated based on the combined media volume in both the lead and lag vessels.

ArsenX^{np} System. The ArsenX^{np} system installed in Purvine Hall had two parallel treatment trains, each consisting of two pressure vessels configured in series. The process equipment included four 18-in × 65-in vessels and associated piping/valves, sample ports, and pressure and flow instrumentation. Rated at 150 psi working pressure, the pressure vessels featured a fiber reinforced plastic (FRP) outer shell and polyethylene inner shell. Each vessel had a 6-in top and bottom flange opening and was equipped with a diffuser-style upper distributor and a hub and lateral-style lower distributor.

The system performance was monitored by inlet and outlet pressure, pressure differential across each vessel, treated water flowrate and volume through each train, and wastewater flowrate and volume during backwash. The flowrate was monitored through an inline vertical rotameter with a polysulphone tube housing. The volume of treated water or backwash wastewater was measured using an Amco Bronze water meter (Model C-700-1.5). The system also featured schedule 80 PVC solvent bonded plumbing, valves, and sampling ports. The wall-mounted, pre-plumed plumbing was 1½-in in diameter, which inter-connected various system components. The piping size at the tie-in point to the water inlet, outlet, and sewer were 3, 3, and 1½-in, respectively. Figure 4-10 shows the wall-mounted plumbing and pressure and flow instrumentation.

The treatment system was an on-demand system and the flowrate and volume of water treated were based on user consumption. Each treatment train was equipped with a 15-gpm flow-limiting device to prevent overrun. Thus, actual flowrates through each treatment train could range from 0 to 15 gpm based on demand. The system was manually operated and there was no electrical connection associated with the system. All flow meters and pressure gauges were mechanical and all valves were manual.

Table 4-5 presents the system's design specifications. Each tank was filled with 5 ft^3 of ArsenX^{np} media without underbedding support. At the design flowrate of 30 gpm, it yielded a hydraulic loading rate of 8.5 gpm/ft^2 and an EBCT of 2.5 min/vessel. However, actual hydraulic loading rates and EBCTs could vary significantly because this was an on-demand system. The working capacity as projected by the vendor was 52,750 BV, which is equivalent to 3,945,700 gal of water treated (1 BV = 5 ft^3 = 37.4 gal/train or 74.8 gal for both trains). Based on a daily use rate of 2,000 gal from the 24-hr real-time flow measurement performed on April 4 and 5, 2005 (see section 4.1), arsenic breakthrough at 10 µg/L

Figure 4-10. Wall-mounted Plumbing and Pressure and Flow Instrumentation for ArsenX^{np} System in Purvine Hall

following the lead vessels would occur after 65 months of system operation. During the system performance evaluation study, the vessels were not rebedded as arsenic concentrations from the lag vessels were <1.0 µg/L.

Media backwash was an entirely manual process, involving physically opening and closing 2-in ball valves. The vendor recommended that the treatment system be backwashed on a regular basis to remove particulate accumulating in the media beds. Backwash can be initiated when the differential pressure (Δp) of any tank is 10 psi greater than that of a clean bed, after processing 10,000 BV of water, or after 60 days of operation. Each train in parallel can be backwashed independently or together. A manual valve on the treated water line of each train (HV-7 for Train 1 and HV-20 for Train 2) was closed to isolate the train for backwash; the other train continued to treat water and meet the demand along with the hydropneumatic tank. Further, only one vessel in a train was backwashed at a time while the other vessel in that train continued to treat water. The recommended backwash flowrate was 12 gpm, equivalent to a hydraulic loading rate of 6.8 gpm/ft^2. The backwash flowrate was monitored through the rotameter on the wastewater outlet and adjusted using the metering valve on the wastewater discharge line. The flowrate should be reduced if full-sized media granules were observed to escape the vessels. At a recommended

Table 4-5. Design of 30-gpm ArsenX^{np} Adsorptive Media System

Parameter	Value	Remarks
Adsorption Vessels		
Vessel Size (in)	18 D × 65 H	–
Cross-Sectional Area (ft^2/vessel)	1.8	–
No. of Vessels	4	–
Configuration	2 parallel trains, each with 2 vessels in series	Vessel B1 and B2 in lead position; Vessel A1 and A2 in lag position
Media Type	ArsenX^{np}	–
Media Volume (ft^3/vessel)	5	10 ft^3 in both lead vessels; 20 ft^3 total
Media Bed Depth (in)	34	–
Service Mode		
Design Flowrate (gpm)	30	15 gpm per train
Hydraulic Loading Rate (gpm/ft^2)	8.5	Based on 15-gpm flowrate per lead/lag train
EBCT (min/vessel)	2.5	Based on 15-gpm flowrate per lead/lag train; 5 min EBCT per train
Estimated Working Capacity (BV)	52,750	To 10 µg/L Arsenic Breakthrough from Lead Vessel
Estimated throughput to 10 µg/L Arsenic Breakthrough Following Lead Vessel (gal)	3,945,700	1 BV = 5 ft^3/train = 37.4 gal/train or 74.8 gal for both trains
Average Use Rate (gal/day)	2,000	Based on 24-hr real time flowrate measurement at Purvine Hall during 04/04/05–04/05/05
Estimated Media Life (month)	65	Estimated frequency of media change-out in lead vessels based on average use rate
Backwash Mode		
Backwash Frequency	Every 60 days	Backwash conducted only once during system performance evaluation
Backwash Duration (min/vessel)	12	–
Backwash Flowrate (gpm)	12	–
Hydraulic Loading Rate (gpm/ft^2)	6.8	–
Wastewater Production (gal)	576	–

backwash duration of 12 min for each vessel, approximately 144 gal of backwash wastewater would be produced during each vessel backwash. A total of 576 gal of wastewater would be discharged to the sanitary sewer during each backwash event. During the system performance evaluation, the vessels were backwashed once.

ARM 200 System. The ARM 200 system installed in the Residence Hall consisted of two 36-in × 72-in vessels configured in series. Each vessel had a 6-in top and a 6-in bottom flange opening and was equipped with a diffuser-style upper distributor and a hub and lateral-style lower distributor. The pressure vessels were constructed of FRP and rated at 150 psi working pressure. The vessels were bolted to the concrete floor. The piping size was 2-in within the system, 4-in at the system inlet and outlet tie-ins, and 2-in at the tie-in to the sewer. Similar to the ArsenX^{np} system, flowrates were monitored through inline vertical rotameters and volumes of treated water and backwash wastewater were measured using Amco Bronze water meters (Model C-700-2). Figure 4-11 presents a photograph of the ARM 200 system.

Figure 4-11. ARM 200 System in Residence Hall

Table 4-6 presents key design features of the system. At the start of the study, each vessel was loaded with 20 ft^3 of ARM 200 media with no underbedding media support. The system was operated on-demand with a minimum combined EBCT of 2.5 min and a maximum hydraulic loading rate of 8.5 gpm/ft^2, both based on a design flowrate of 60 gpm. Switching of the lead and lag vessel positions was controlled by a series of 2-in PVC ball valves.

The working capacity estimated by the vendor was 62,600 BV (or approximately 9,365,000 gal of water [1 BV = 20 ft^3 = 149.6 gal in lead vessel]). Based on a daily use rate of 15,000 gal (from the 24-hr real time flow measurement performed prior to the demonstration study [see section 4.2]), arsenic breakthrough at 10 µg/L following the lead vessel would occur after approximately 21 months of system operation.

Due to unexpectedly rapid arsenic breakthrough from the adsorption vessels, ARM 200 media in the lead vessel was rebedded with ARM 300 and the newly rebedded lead vessel was placed in the lag position. Both the lead and lag vessel were rebedded with E33-S media due to a short run length again. The short run length observed is discussed in detail in Section 4.5.2.2.

Manual backwash was recommended by the vendor to remove particulate using water in the hydropneumatic tank. The backwash triggers were the same as those used by the ArsenX^{np} system. Only one vessel was backwashed at a time while the other vessel continued to treat water used for backwash. The recommended backwash flowrate was 50 gpm (or 7.0 gpm/ft^2) and the recommended backwash duration was 12 min for each vessel. Therefore, approximately 600 gal of backwash wastewater would be

Table 4-6. Design of 60-gpm ARM200 and Adsorbsia™ GTO™ Adsorptive Media Systems

Parameter	Value	Remarks
Adsorption Vessels		
Vessel Size (in)	36 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	7.1	–
No. of Vessels	2	–
Configuration	in series	Vessel B in lead position for ARM 200 system; Vessel A in lead position for Adsorbsia™ GTO™ system
ARM 200 Adsorptive Media		
Media Quantity (lb)	1,800–2,000	Data source: Engelhard
Media Volume (ft^3/vessel)	20	40 ft^3 total
Media Bed Depth (in)	34	–
Adsorbsia™ GTO™ Adsorptive Media		
Media Quantity (lb)	1,760	Data source: Dow Chemicals
Media Volume (ft^3/vessel)	20	40 ft^3 total
Media Bed Depth (in)	34	–
Service Mode		
Design Flowrate (gpm)	60	–
Hydraulic Loading Rate (gpm/ft^2)	8.5	Based on design flowrate of 60 gpm
EBCT (min)	2.5	Based on 60 gpm design flowrate; 5 min total EBCT for both vessels
Estimated Working Capacity (BV)	62,600 (ARM 200) 60,150 (Adsorbsia™ GTO™)	To 10 µg/L arsenic breakthrough following lead vessel
Throughput to 10 µg/L Arsenic Breakthrough Following Lead Vessel (gal)	9,364,960 (ARM 200) 8,998,440 (Adsorbsia™ GTO™)	1 BV = 20 ft^3 = 149.6 gal in lead vessel
Average Use Rate (gal/day)	15,000	Based on 24-hr real time flowrate measurement at Residence Hall on 03/28/05 and 03/29/05
Estimated Media Life (months)	21 (ARM 200) 20 (Adsorbsia™ GTO™)	Estimated frequency of media changeout in lead vessel based on average use rate
Backwash Mode		
Backwash Frequency	Every 60 days of operation	–
Backwash Flowrate (gpm)	50	–
Backwash Duration (min/vessel)	12	–
Hydraulic Loading Rate (gpm/ft^2)	7.0	–
Wastewater Production (gallons)	1,200	–

produced during backwash of each vessel. A total of 1,200 gal of wastewater would be produced from backwashing both vessels.

Adsorbsia™ GTO™ System. The 60-gpm system at the College Union was designed and built in the same fashion as the system in the Residence Hall. The only difference was that it was used to evaluate a different type of media (i.e., Adsorbsia™ GTO™). Based on the vendor-estimated working capacity and a daily use rate of 15,000 gal, the media would last for 20 months, after treating approximately 8,998,400 gal of water (1 BV = 20 ft^3 = 149.6 gal in the lead vessel). The system was backwashed in a similar

Figure 4-12. Adsorbsia™ GTO™ System in College Union

manner as the 60-gpm ARM 200 system at the Residence Hall. Table 4-6 summarizes the system design specifications. Figure 4-12 presents a photograph of the system.

4.2.3.3 POU Units. Each Kinetico POU unit used a single cartridge to house 600 mL of ARM 200 media for arsenic removal. The cartridge housing had exterior dimensions of 70 mm × 320 mm and ¼-in female National Pipe Thread (NPT) threads for direct connections to an incoming cold water line and an exit line. Treated water was delivered from the exit line to a separately installed faucet. The POU units were installed either under a sink or inside a drinking water fountain as shown in Figure 4-13.

As untreated water flowed into the feed water inlet, it was allowed to past a turbine, which was connected to a gear to gradually close a measured shut-off assembly. An indicator on the outside of the filter head showed the relative remaining cartridge capacity, based on a maximum capacity of 500 gal. When 500 gal of water was processed, the measured shut-off assembly was completely closed, preventing any more water from passing through the cartridge. Eight POU systems were installed in eight buildings on campus as summarized in Table 4-7.

Figure 4-13. POU Systems Installed Under a Sink (top) and Inside a Drinking Water Fountain (bottom)

Table 4-7. Kinetico POU System Locations (2006-2008)

Building Name	Location
University Advancement	Sink in the break room
Snell Hall	Drinking Fountain
Owens Hall	Drinking Fountain
Learning Resource Center	Drinking Fountain
Physical Education	Drinking Fountain
Facility Services	Drinking Fountain
Cornett South	Drinking Fountain
Stadium	Drinking Fountain

About 11 months into the performance evaluation study, OIT began to replace the Kinetico ARM 200 POU units with AdEdge E33-S POU units. On November 15, 2007, May 25, 2008, and August 15, 2008, AdEdge POU units were installed at the University Advancement, Cornett Hall, and the Facility Services building, respectively. Overall, OIT replaced the eight Kinetico units with AdEdge units and installed 40 additional units.

The AdEdge POU units were comprised of a polypropylene housing. They had a ⅜-in inlet and a ¼-in outlet. The approximate flowrate with a system inlet pressure of 60 psi was 1 gpm. The working pressure ranged from 20 to 125 psi. The unit had a height of 13 in and a diameter of 6.75 in. Figure 4-14 shows the AdEdge housing and filter cartridge. Table 4-8 summarizes design specifications of the Kinetico and AdEdge POU units.

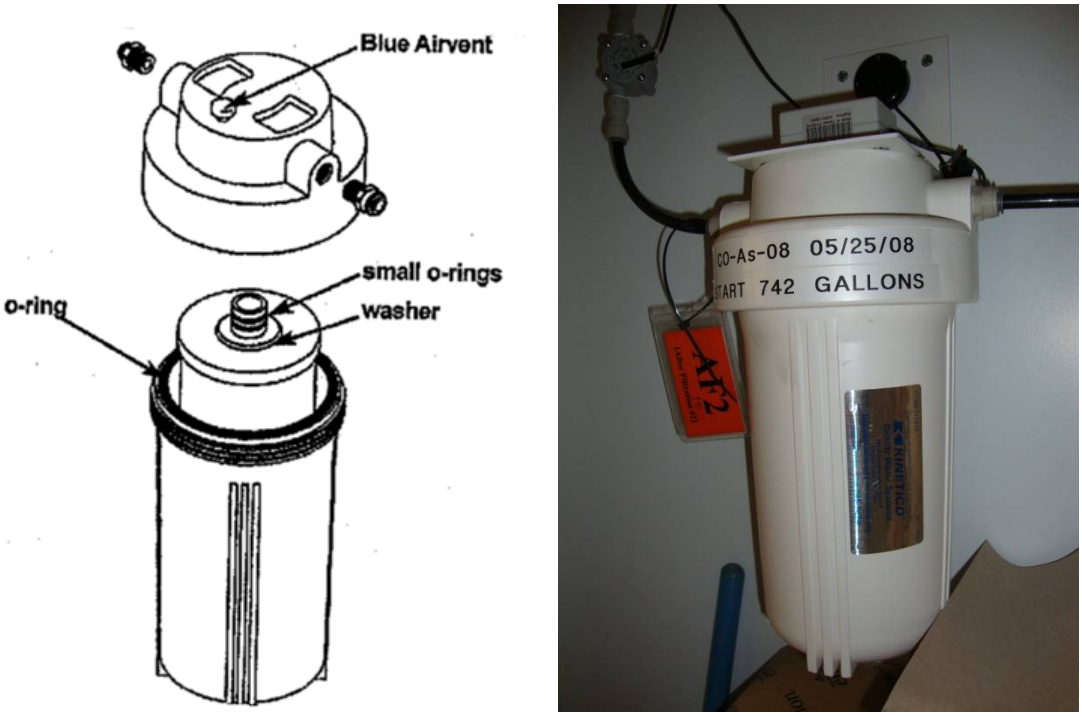

Figure 4-14. AdEdge POU Housing and Cartridge

Table 4-8. Design Specifications of Kinetico and AdEdge POU Units

Parameter	Kinetico Unit	AdEdge Unit
Housing Material	Polypropylene	Polypropylene
Cartridge Dimensions (mm)	54 × 265 (Slightly tapered)	–
Housing Dimensions	–	–
Height (mm)	425	330
Width (mm)	150	–
Diameter (mm)	100	171
Unit Weight (lb)	11	4
Media Type	ARM 200	E33-S
Media Volume (mL)	600	–
Inlet Connection	¼-in Female NPT	⅜ in
Outlet Connection	¼-in Female NPT	¼ in
Particulate Retention (µm)	5.0	0.5
Water Pressure (psi)	20–120	30–125
Flowrate (gpm)	0.7–1.0	1.0 @ 60 psi
Treatment Capacity (gal)	490	–

4.3 Treatment System Installation

This section provides a summary of system installation, startup, and shakedown activities and the associated prerequisites including permitting and building preparation.

4.3.1 System Permitting. Engineering plans for the system permit application were prepared by Weber Elliott Engineers, a Kinetico subcontractor (also serving as the engineer for OIT) located in Eugene, OR. The plans included diagrams and specifications of the three POE systems and eight POU units, as well as drawings detailing the connections of the new systems/units to the tie-ins in each building. The engineering package was certified by a Professional Engineer registered in the State of Oregon and submitted to Oregon DHS for review and approval on October 13, 2005. The permit was issued by Oregon DHS on October 31, 2005, and was received by Battelle on November 1, 2005.

4.3.2 Building Construction. The three POE systems were placed into the existing mechanical or storage room of each building. Necessary arrangements were made to accommodate the treatment systems and pipe/conduit supports were hung from the ceiling and/or attached to the walls. Plumbing was modified to provide connections from the new treatment systems to the building distribution entry points and sewer system. In particular, the two connections (i.e., south and north) to the campus water distribution network in the College Union were combined for a single inlet tie-in to the Adsorbsia™ GTO™ system in that building.

4.3.3 System Installation, Startup, and Shakedown. The treatment systems arrived at OIT on October 28, 2005. Quality Water Systems, a local subcontractor to Kinetico, performed off-loading and installation of the systems. The installation activities, which lasted about one week, included placing the POE systems and 132-gal hydropneumatic tanks in each of the three buildings and connecting system piping at the tie-in points.

Upon completion of system installation, JDB Consulting, a subcontractor to Kinetico, traveled to the site on December 5 through 10, 2005, to perform system inspections, hydraulic testing, and media loading. Before media loading, empty vessels were hydraulically tested to check pressure loss at normal flowrates and observe the flow patterns for uniformity. The media were then loaded separately through the 6-in

flange openings on top of the vessels. No underbedding media support was used for any of the vessels. Figure 4-15 shows loading of media into one of the vessels in the Residence Hall. After media loading, the vessels were backwashed one at a time to remove media fines. For the 30-gpm ArsenX^{np} system in the Purvine Hall and the 60-gpm ARM 200 system in the Residence Hall, backwash wastewater ran clear within a few BV. The Adsorbsia™ GTO™ media in the College Union, however, would not run clear.

Figure 4-15. Media Loading into an Adsorption Vessel

Freeboard measurements for the ArsenX^{np} and ARM 200 systems were taken after media backwash and the results are summarized in Table 4-9. Freeboards were measured from the top of the flange to the top of the media beds. For the ArsenX^{np} system, 31.0 to 33.3 in freeboards were measured; these freeboard measurements resulted in a bed depth of 36.7 to 39.0 in. (Note that bed depths were measured by subtracting the freeboard from the distance from the bottom of the tank to the top of the flange [i.e., 70 in].) Measurements for the bed depth appeared to be inflated when compared with the design value of 34 in (see Table 4-5). This was caused by the displacement of media by the lower distributor at the bottom of each vessel. The ARM 200 system had a bed depth of 48.5 to 50.0 in, compared to the design value of 34 in (see Table 4-6). The higher actual bed depth values were caused, again, by the displacement of media by the laterals at the bottom of each vessel. Note that both ArsenX^{np} and ARM 200 media were loaded directly into the adsorption vessels without the use of any underbedding support. Because of issues related to backwashing of Adsorbsia™ GTO™ media, the freeboard measurements and resulting bed depths obtained during the initial media loading were not considered valid.

After the freeboard measurements, the vendor inspected the systems for leaks, tested individual vessels and treatment trains for balanced flows, and sanitized the systems with a strong NaOCl solution to a minimum chlorine residual of 40 mg/L (as Cl_2). By late afternoon on December 10, 2005, the three POE systems were put online for a test run over the weekend. On the following Monday, “milky” water was found in the Adsorbsia™ GTO™ system effluent and the system was immediately taken offline. The

Table 4-9. Freeboard Measurements and Media Bed Depths for ArsenX^{np} and ARM 200 Systems

Location	Media Loading Date	Media Volume ft^3	Media Type	Media Vessels	Freeboard at Initial Loading[(a)] (in)	Under-bedding Depth (in)	Bed Depth (in)	Freeboard at Removal (in)
Purvine Hall[(b)]	12/20/05	5.0	ArsenX^{np}	TB1 (Lead)	31.5	None	38.5[(d)]	-
		5.0		TA1(Lag)	31.3	None	38.7[(d)]	-
		5.0		TB2 (Lead)	31.0	None	39.0[(d)]	-
		5.0		TA2 (Lag)	33.3	None	36.7[(d)]	-
Residence Hall[(c)]	12/20/05	20.0	ARM 200	B (Lead)	26.0	None	50.0[(d)]	25.8
		20.0		A (Lag)	27.5	None	48.5[(d)]	NA
	01/24/07	20.0	ARM 300	B (Lag)	27.0	None	49.0[(d)]	NA
	10/03/07	20.0	E33-S	A (Lead)	NA	None	NA	NA
		20.0		B (Lag)	NA	None	NA	NA

(a) Freeboard measured from surface of media bed to top of flange.
(b) For 30 gpm system, tank height was 65 in; distance from bottom of tank to top of flange was 70 in.
(c) For 60 gpm system, tank height was 72 in; distance from bottom of tank to top of flange was 76 in.
(d) Calculated bed depth appeared inflated due to displacement of media by lateral at bottom of tank.
NA = not available

other two POE systems continued to be online and the performance evaluation of these systems officially began on December 12, 2005.

After discussing the milky white effluent issue with the media manufacturer, Dow Chemical, Kinetico informed Battelle that Dow Chemical's decision was to rebed the vessels (thinking that the media could have come from "a bad batch"). Dow Chemical also requested that a garnet underbedding support be provided in the vessels before rebedding (thinking that the media could have leaked through the bottom laterals).

According to Kinetico, an underbedding support should have particle sizes between 8 and 50 mesh and a density over 75 lb/ft^3. The underbedding support also should be installed to a depth about 1 to 2 in above the bottom laterals. On January 5, 2006, Dow Chemical visited OIT to rebed the vessels at the College Union. Prior to rebedding, the previously installed Adsorbsia™ GTO™ media was vacuumed out of the two vessels and sent to a local landfill for disposal. The acceptance of the waste was based on Dow Chemical's TCLP and California Waste Extraction Test (WET) test results using challenge water. Figure 4-16 shows the Adsorbsia™ GTO™ media after being removed from the adsorption vessels.

Before media loading, 30 × 40 mesh garnet was installed to provide media support in both vessels. Following media loading, the lead vessel (Vessel A) was backwashed at 30 gpm for 4 hr and 8.8 gpm for 2 hr for a total of 55 BV (see Table 4-10). The bed expansion at 30 gpm was roughly 25%. Approximately 3.5 ft^3 of media (or 17% of the total bed volume) was lost even though the bed expansion was much less than the 66% projected expansion before any media was lost. Non-uniform flow was suggested by Dow Chemical as a possible cause for the media loss. The lag vessel (Vessel B) was backwashed the next day at 20 gpm for 1.5 hr before it was terminated due to concerns over high pressure drop (twice the projected value) across Vessel A in the service mode (Vessel A was in the service mode when Vessel B was being backwashed). The backwash wastewater appeared turbid from both vessels. The system remained offline.

Figure 4-16. Adsorbsia™ GTO™ Taken Out of Adsorption Vessels

Table 4-10. Adsorbsia™ GTO™ Media Backwash During Rebedding

Date	Tank A			Tank B		
	Flowrate (gpm)	Throughput (BV)	Media Loss (ft^3)	Flowrate (gpm)	Throughput (BV)	Media Loss (ft^3)
01/05/06	30/8.8	48/7	3.5	20	12	-
02/17/06	55–60	60	0.5	55–62	96	0.5
Sum	-	115	4.0	-	108	0.5

Two Battelle staff members traveled to Klamath Falls, OR to conduct system inspections and provide operator training on data and sample collection on January 10 and 11, 2006. During the visit, Battelle collected effluent samples from the newly rebedded Adsorbsia™ GTO™ system at four different service flowrates, i.e., 5, 30, 45, and 60 gpm. As shown in Figure 4-17, the effluent samples became cloudier as system flowrates increased incrementally from 30 to 60 gpm. Turbidity measurements also increased correspondingly from 3 nephelometric turbidity unit (NTU) (at 45 gpm) to 64 NTU (at 60 gpm) (see Table 4-11). Δp readings across both vessels increased significantly from 5 to 6 psi (at 45 gpm) to 8 to 11 psi (at 60 gpm), indicating that the media was not sufficiently cleaned of fines during the backwash attempts on January 5 and 6, 2006. Backwashing the lead vessel was attempted using treated water from the lag vessel at approximately 20 gpm. However, after about 1 min into the backwash, the backwash effluent water turned milky and bulk media were seen entering the bottom of the backwash flowmeter (Figure 4-18). The backwash attempt was terminated immediately.

Figure 4-17. Effluent Samples from Rebedded Adsorbsia™ GTO™ System at Different Service Flowrates

Table 4-11. Effluent Turbidity and Δp Readings from Rebedded Adsorbsia™ GTO™ System

Flowrate	Turbidity	Δp Reading (psi)	
(gpm)	(NTU)	Vessel A	Vessel B
5	0	0	0
30	0	1	1
45	3	5	6
60	64	8	11

On February 17, 2006, Dow Chemical returned to the site to perform media backwash again. The visit followed a media backwash pilot-scale study conducted at its Midland facilities in Michigan. The lead vessel (Vessel A) was backwashed at 55 to 60 gpm (or 7.7 to 8.5 gpm/ft^2) for 2.5 hr for a total of 60 BV (see Table 4-10). To achieve the target backwash flowrate of 60 gpm, the flowrate was slowly increased over a few minutes. At this flowrate, bed expansions would range between 30 to 35%. The backwash effluent showed signs of clearing, but maintained a cloudy appearance over the course of the backwash. Following backwash, the lead vessel was put into the downflow service mode (to drain) at 60 gpm and the effluent was visibly clear with the turbidity measured at <1 NTU after 10 min. Due to the various episodes happening to Vessel A, approximately 4 ft^3 of the media was lost from the vessel.

The lag vessel (Vessel B) was then backwashed at 55 to 62 gpm (7.7 to 8.7 gpm/ft^2) for 4 hr for a total of 96 BV. A turbidity of <1 NTU was measured from the effluent after the lag vessel was put into service

Figure 4-18. Bulk Media Entering Flow Meter (right) During Backwash Attempt

(to drain) at 60 gpm for 10 min. The amount of media lost from the vessel was 0.5 ft^3, or 1 in of the media bed. The pressure loss across the two vessels was 8 psi at a service flowrate of 60 gpm.

The system was then placed in the lead/lag position (inlet to Vessel A, to Vessel B, and then to the distribution system) on February 17, 2006, and the performance evaluation study on the Adsorbsia™ GTO™ system officially began on the same day.

4.4 System Operation

4.4.1 Service Operation. Operational parameters of the treatment systems were tabulated and are attached as Appendix A. Key parameters are summarized in Table 4-12, and discussed in detail below.

4.4.1.1 ArsenX^{np} System. The performance evaluation study on the ArsenX^{np} system in Purvine Hall began on December 12, 2005, and ended on August 26, 2009. The system operated for a total of 1,353 days, treating 1,814,428 gal (or 24,254 BV) of water (1 BV = 5 ft^3/train = 37.4 gal/train or 74.8 gal for both trains; see arsenic breakthrough behavior in Section 4.5.2.1). Significantly imbalanced flow between the two parallel trains was observed, with 878,214 gal treated by Train 1 and 936,214 gal treated by Train 2. More detailed discussions about this imbalanced flow are provided in Section 4.4.5.

During the first year of system operation, the average daily demand was 2,077 gal, very close to the 2,073 gal use rate measured during the 24-hr real-time flow measurement on April 4 and 5, 2005. The daily demand dropped to 1,542 gal after 2 years of system operation. The average daily demand through the entire study period was 1,341 gal. The higher daily demand during the first year of system operation was due to a higher setting on a trap primer, a solenoid valve that discharged treated water to the drain to prevent sewer gas from entering the building.

Table 4-12. Operational Parameters of Treatment Systems

Parameter	Values				
	Purvine Hall System	Residence Hall System			College Union System
Media Evaluated	ArsenX^{np}	ARM 200	ARM 300	E33-S	Adsorbsia™ GTO™
Operating Period	12/12/05–08/26/09	12/12/05–01/22/07[(a)]	01/24/07–07/09/07	10/03/07–08/26/09	02/17/06–08/26/09
Total Operating time (hr)	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]
Total Operating Days (day)	1,353	406	166	693	1,286
Throughput (gal)	Train 1: 878,214 Train 2: 936,214 Combined: 1,814,428	6,698,103	5,325,660	12,170,210	5,889,749
Average Daily Demand (gpd)	1,341	16,498	32,082	17,562	4,580
Range (Average) of Flowrates (gpm)	1.0–27 (7.0)	1.0–60 (20.0)	14–58 (35.3)	1.0–60 (18.8)	1–34 (6.7)
Range (Average) of Hydraulic Loading Rates (gpm/ft^2)	0.3–7.5 (1.9)	0.1–8.5 (2.8)	2.0–8.2 (5.0)	0.1–8.5 (2.6)	0.1–4.8 (0.9)
Range (Average) of EBCT (min)	2.8–74.8 (10.7)	2.5–150 (7.5)	2.6–10.7 (4.2)	2.5–150 (8.0)	3.5–120 (17.9)
Range (Average) of System Inlet Pressure (psi)	45–67 (57.0)	50–62 (58.5)	40–62 (53.6)	50–62 (57.8)	55–64 (60.8)
Range (Average) of System Outlet Pressure (psi)	40–65 (57.4)	30–62 (54.9)	28–61 (45.4)	32–62 (52.6)	28-64 (59.7)
Range (Average) of Δp Readings Across System (psi)	0–11	0–20	0–20	0–18	0–32
Range (Average) of Δp Readings Across Each Vessel (psi)	0	0	0	0	0

(a) System went on being rebedded twice with ARM 300 and E33-S media.
(b) System on-demand; operating time not tracked.

Instantaneous on-demand flowrates to each of the parallel trains ranged from 0.5 to 15 gpm with combined flowrates ranging from 1 to 27 gpm and averaging 7 gpm. At these flowrates, hydraulic loading rates ranged from 0.3 to 7.5 gpm/ft^2 and averaged 1.9 gpm/ft^2, compared to the design value of 8.5 gpm/ft^2. Based on the flowrates to the individual trains and system, EBCTs in each vessel varied from 2.8 to 74.8 min (or 10.7 min on average).

Inlet pressure readings for Trains 1 and 2 ranged from 45 to 67 psi with both averaging 57.0 psi. Outlet pressure readings for Trains 1 and 2 ranged from 40 to 65 psi with both averaging 57.4 psi. The Δp across each adsorption vessel remained at 0 psi throughout the performance evaluation study.

4.4.1.2 ARM 200/ARM 300/E33-S System. The evaluation of ARM 200 media in the Residence Hall began on December 12, 2005. In 406 days, the system treated 6,698,103 gal (or 44,767 BV) of water. (Bed volumes were calculated based on 20 ft^3 of media in the lead vessel; see Section 4.5.2.2 for arsenic breakthrough.) The average daily demand was 16,498 gal, compared to the 14,456 gpd measured during the 24-hr real-time flow measurement on March 28 and 29, 2005. Due to the on-demand system configuration, the flowrates through the ARM 200 system ranged from 1 to 60 gpm and averaged 20.0

gpm. Based on the flow to the system, EBCTs varied from 2.5 to 150 min (7.5 gpm [on average]); hydraulic loading rates varied from 0.1 to 8.5 gpm/ft^2 (2.8 gpm/ft^2 [on average]).

Inlet pressure readings for the system ranged from 50 to 62 psi and averaged 58.5 psi; outlet pressure readings ranged from 30 to 62 psi and averaged 54.9 psi. The average Δp across the system was 3.6 psi. Pressure drops across each ARM 200 vessel were negligible.

The lead vessel (Vessel B) was rebedded with ARM 300 media on January 24, 2007, due to early arsenic breakthrough from the lead and lag vessels (see Section 4.5.2.2). Upon rebedding, the vessel containing ARM 300 was placed in the lag position and the vessel containing partially exhausted ARM 200 media in the lead position. The ARM 200/ARM 300 test lasted from January 24, 2007, through July 9, 2007, with the system treating 5,325,660 gal of water (or 35,595 BV). (Bed volumes, again, were calculated based on 20 ft^3 of media in the lead vessel; see discussions of arsenic breakthrough in Section 4.5.2.2) The average daily demand was 32,082 gal, which was about twice the amount experienced previously during the ARM 200 test run. A pipe break at the Residence Hall apparently contributed to the higher water demand experienced during the ARM 200/ARM 300 test.

As expected, flowrates measured during the ARM 200/ARM 300 test run were higher than the ARM 200 test run, ranging from 14 to 58 gpm and averaging 35.3 gpm. Correspondingly, EBCTs were shorter (ranging from 2.6 to 10.7 min and averaging 4.2 min) and hydraulic loading rates were higher (ranging from 2.0 to 8.2 gpm/ft^2 and averaging 5.0 gpm/ft^2). Inlet and outlet pressure readings for the system averaged 53.6 and 45.4 psi, respectively. The resulting pressure drop across the system was 8.2 psi (on average), which is higher than that observed previously for the ARM 200 system. Pressure losses across the vessels remained to be negligible, most likely due to errors associated with the pressure gauges.

On July 11, 2007, the system was placed in bypass as the system effluent had exceeded the arsenic MCL in May 2007. On October 3, 2007, the lead and lag vessels were rebedded with E33-S media. The E33-S test ran began on October 3, 2007, and ended on August 26, 2009. In 693 days, the system treated approximately 12,170,210 gal of water (or 81,341 BV). The average daily demand was 17,562 gal, close to that observed during the ARM 200 test run.

Operational parameters, including flowrates, EBCTs, hydraulic loading rates, system inlet/outlet pressure and system differential pressure, measured during the E33-S test run were very close to those measured during the ARM 200 test run.

4.4.1.3 Adsorbsia™ GTO™ System. Due to the difficulties encountered during the initial media backwash, the Adsorbsia™ GTO™ system wasn't placed online until February 17, 2006. During the 1,286 days of system performance evaluation, the system treated 5,889,749 gal of water. This total throughput corresponded to 49,212 BV based on 16 ft^3 of media in the lead vessel (the lag vessel had 19.5 ft^3 of media [see Table 4-12].) The average daily demand was 4,580 gal. The average daily demand appeared to increase over time, with 3,776 gal treated, for example, during the first six months of system operation and 5,162 gal treated during the last year of system operation.

The instantaneous flowrates ranged from 1 to 34 gpm and averaged 6.7 gpm. Because of the low flowrates, EBCTs were long (ranging from 3.5 to 120 min and averaging 17.9 min) and hydraulic loading rates were low (ranging from 0.1 to 4.8 gpm/ft^2 and averaging 0.9 gpm/ft^2). Inlet and outlet pressure readings averaged 60.8 and 59.7 psi, respectively, resulting in only 1.1 psi pressure loss across the system. Pressure drops across the vessels were 0 psi throughout the study.

4.4.2 Media Loading and Removal. After the initial media loading, only the ARM 200 system was rebedded with its lead vessel replaced with ARM 300 media and then placed in the lag position. The

ARM 200/ARM 300 system was then rebedded with E33-S media. Rebedding of the lead vessel with ARM 300 media was performed by Kinetico's local subcontractor, Quality Water System. Before the removal of spent media, the freeboard was measured as 25.8 in from the top of the flange to the media surface, which was close to the freeboard (26 in) measured during initial media loading in December 2005. Spent media samples were collected at the top, middle, and bottom sections of the media bed at depths of 0 to 4, 22 to 26, and 35 to 39 in., respectively. The vessel was rinsed and any remaining media removed from the bottom of the vessel. The vessel was then half filled with water before virgin media was poured through a large funnel from the top of the tank. After the vessel was completely filled with water and the media was soaked for 1 hr, the vessel was backwashed with 1,440-gal of treated water from Vessel A. After backwashing, freeboard measurements were taken, and the newly-rebedded Vessel B was placed in the lag position. The freeboard was 27 in after ARM 300 media loading. On October 3, 2007, the ARM 200/ARM 300 media in the lead and lag vessels were rebedded with E33-S. The same local subcontractor rebedded the vessels following the procedure used during the first media changeout.

4.4.3 Backwash Operation. Kinetico recommended that the three POE systems be backwashed on a regular basis to remove particulates and media fines accumulating in the media beds. Backwash could be initiated when the pressure differential of any tank was 10 psi greater than that of a clean tank, after processing 10,000 BV of water, or after 60 days of operation. Due to negligible pressure drops across adsorption vessels, the three POE systems were backwashed only once on May 16 or 17, 2006. Table 4-13 summarizes backwash flowrates and durations and amounts of wastewater produced during backwash of each of the POE systems. Backwash flowrates for the two 60-gpm systems ranged 8 to 40 gpm (or 1.1 to 5.7 gpm/ft^2), which were significantly lower than the design value of 50 gpm (7.0 gpm/ft^2). The operator used lower backwash flowrates to avoid losing any media during backwash. When backwashing Adsorbsia™ GTO™ media at 40 gpm, backwash wastewater looked slightly milky. After 4 min into backwash, the operator reduced the flowrate from 40 to 8 gpm.

Table 4-13. Summary of Backwash Flowrate and Duration

Vessel	Flowrate (gpm)	Hydraulic Loading (gpm/ft^2)	Duration (min)	Wastewater Produced at Different Flowrate (gal)	Wastewater Produced from Each Vessel (gal)
ArsenX^{np} System					
TB1 (lead)	12	6.8	12	144	144
TA1 (lag)	12	6.8	12	144	144
TB2 (lead)	12	6.8	12	144	144
TA2 (lag)	12	6.8	12	144	144
ARM 200 System					
TB (lead)	20	2.8	1	20	350
	30	4.2	11	330	
TA (lag)	20	2.8	3	60	136
	10	1.4	2	20	
	8	1.1	7	56	
Adsorbsia™ GTO™ System					
TA (lead)	40	5.7	4	160	240
	8	1.1	10	80	
TB (lag)	40	5.7	4	160	240
	8	1.1	10	80	

4.4.4 Residual Management. Residuals produced by the operation included backwash water and spent media. There was only one backwash event for each of the three POE systems during the system performance evaluation. Approximately 1,540 gal of wastewater was generated, with 580, 480, and 480 gal from the ArsenX^{np}, ARM 200, and Adsorbsia™ GTO™ systems, respectively. The backwash wastewater was discharged to the city sanitary sewer.

On January 24, 2007, approximately 20 ft^3 of spent ARM 200 media in the lead vessel at the Residence Hall was rebedded with ARM 300. The spent media passed TCLP tests (Section 4.5.8), and was disposed of by Waste Management, Inc. On October 3, 2007, spent ARM 200 and ARM 300 in the lead and lag vessels were rebedded with E33-S. The spent media was stored at OIT. In December 2009, the operator sent an ARM 300 spent media sample to Battelle for TCLP analysis by Belmont Labs. The spent ARM 300 media passed the TCLP test.

4.4.5 System/Operation Reliability and Simplicity. During the system performance evaluation, there were no major operational issues except for a few minor leaks, imbalanced flow from the parallel treatment trains, and a malfunctioned totalizer. Water-dripping leaks were noticed at several union/valve thread connections of the 30-gpm ArsenX^{np} system at Purvine Hall right after the system startup and were repaired on February 28, 2006.

Imbalanced flow was observed between the two treatment trains of the ArsenX^{np} system, with each train treating 878,214 and 936,214 gal of water. Before the flow restriction valve on each train was adjusted on February 1, 2006, approximately 40% and 60% of the flow passed through Trains 1 and 2, respectively. Following the adjustment, the flows through both trains were close with an average of 47.3% and 52.7% passing through Trains 1 and train 2, respectively.

A totalizer malfunction occurred on the Adsorbsia™ GTO™ system at the College Union on May 18, 2006. The flow totalizer (Kent positive displacement meter) installed on the treated water side of the 60-gpm system failed to register any flow when the water flowrate was at or below 10 gpm. Clogging of the meter with particles was thought to be the problem. The system was restarted in an attempt to flush away any particles that might have been present; however, the problem persisted until the vendor replaced the malfunctioned totalizer on July 18, 2006. During the period of totalizer malfunction, the average daily flow rate calculated based on the meter reading was 2,108 gal, compared to 4,580 gal prior to the totalizer malfunctioning. Because the number of consumers and their daily activities remained essentially unchanged during these two periods, the 54% decrease in average daily usage was likely caused by the malfunctioning totalizer. The average daily water usage of 4,580 gal also was supported by additional data collected after replacement of the totalizer. As such, the treated water throughput during the period from May 18 to July 18, 2005, was adjusted based on an average daily water usage of 4,580 gal.

The system O&M and operator skill requirements are discussed below in relation 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.

4.4.5.1 Pre- and Post-Treatment Requirements. There was no pre- or post-treatment required for the systems. The pre-existing centralized chlorination system at the wellhead continued to be used for disinfection purposes.

4.4.5.2 System Automation. The POE systems were designed for complete manual operation. There was no electrical connection associated with the system; all flow meters and pressure gauges were mechanical and all valves were manual. Pressure was the driving force for water flowing through the treatment systems. During system backwash, manual valves had to be physically opened and closed to change flow paths and adjust flowrates.

4.4.5.3 Operator Skill Requirements. Under normal operating conditions, the daily demand on the operator was about 30 min for visual inspection of the system and recording of operational parameters such as pressure, volume, and flowrate on field log sheets. The O&M of the POE systems required minimal additional operator skills beyond those required for small system operators, such as a solid work ethic, basic mathematical skills, ability to understand chemical properties, familiarity 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 systems were of complete manual operation, the operator was required to understand system piping and be able to follow the valve chart to operate the system under service and backwash modes after receiving proper training by the vendor.

All Oregon public water systems, both community and non-transient non-community water systems, must be under the supervision of a certified operator. The Oregon DHS Drinking Water Program classifies water distribution systems and treatment plants into two types according to their complexity or size and establishes minimum standards for personnel responsible for operating these systems. Systems with 149 and fewer connections, either using groundwater as their only source or purchasing all their water from another public water system without adding any additional treatment, require an "S" certification; those with 150 or more connections require certification at "Levels 1 to 4" for treatment and/or distribution. The operators of systems with "S" certification are required to attend a small water system training course once every three years and submit a new Small Water System Operator Application with proof of training attendance. The OIT Water System is classified as an “S” system and the plant operator attends a training course once every three years to be qualified as a small water system operator.

4.4.5.4 Preventive Maintenance Activities. Preventive maintenance tasks recommended by the vendor included daily to monthly visual inspection of the piping, valves, tanks, flow meters, pressure gauges, and other system components. Chlorine residual across the treatment train also was checked on a regular basis using a Hach colorimeter, even though the addition of chlorine was only for disinfection purposes, and not required by the systems.

4.4.5.5 Chemical Handling and Inventory Requirements. No chemicals were required for the system operation.

4.5 System Performance

Performance of the three POE systems was evaluated based on analyses of water samples collected across the treatment trains, from the media backwash, and from the distribution system. The three POU units were evaluated by collecting effluent water samples for arsenic analysis. The performance evaluation studies began on December 12, 2005, for the ArsenX^{np} system in Purvine Hall and the ARM 200 system in the Residence Hall, and on February 17, 2006, for the Adsorbsia™ GTO™ system at the College Union. The evaluations for all three POE systems were completed on August 26, 2009.

For the ArsenX^{np} system in Purvine Hall, water samples were collected at six locations: IN, TB1, TA1, TB2, TA2, and TT (with Vessels TB1 and TB2 at the lead position). Sampling was conducted on 36 occasions (including three duplicate sampling events) with field speciation performed at IN and TT for eight of the 36 occasions.

Sampling in the Residence Hall was conducted on 28 occasions (including three duplicate sampling events) during the ARM 200 test from January 11, 2006, through January 10, 2007, with field speciation performed for eight of the 28 occasions. On January 24, 2007, ARM 200 media in the lead vessel (Vessel B) was replaced with ARM 300 and the newly-rebedded vessel was placed in the lag position. Sampling was conducted on five occasions for the ARM 200/ARM 300 test from February 7, 2007, through June 1,

2007, with no field speciation performed during the test. On July 11, 2007, the system was placed in bypass until media rebedding. On October 3, 2007, ARM 200 and ARM 300 media in the lead (Vessel A) and lag vessels (Vessel B) were replaced with E33-S. Sampling was conducted on eight occasions from December 18, 2007, through August 26, 2009, with no field speciation performed. Water samples were collected at IN, TB, and TA for all sampling events.

The late system startup for the Adsorbsia™ GTO™ system at the College Union did not limit the number of sampling events during the system performance evaluation study. Sampling was conducted on 32 occasions (including three duplicate sampling events) from March 1, 2006, through August 26, 2009, with field speciation performed on seven of the 32 occasions. Water samples were collected at the wellhead and following Vessels A and B at IN, TA, and TB for all sampling events.

Tables 4-14 through 4-16 summarize arsenic, iron, manganese, and/or titanium analytical results for the ArsenX^{np}, ARM 200/ARM 300/E33-S, and Adsorbsia™ GTO™ systems, respectively. Tables 4-17 through 4-19 summarize other water quality parameter results for the three systems. Appendix B contains a complete set of analytical results collected during the system performance evaluation. The results of the water samples collected are discussed below.

Table 4-14. Summary of Arsenic, Iron, and Manganese Analytical Results at Purvine Hall

Parameter	Sample Location[(a)]	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	µg/L	36	25.2	35.5	29.8	2.3
	TB1	µg/L	28	0.1	21.6	5.7	7.1
	TA1	µg/L	28	0.1	1.4	0.4	0.3
	TB2	µg/L	28	0.1	30.6	6.0	9.2
	TA2	µg/L	28	0.1	0.8	0.4	0.2
	TT	µg/L	8	0.1	1.9	0.6	0.5
As (soluble)	IN	µg/L	8	27.6	33.9	30.5	2.0
	TT	µg/L	8	0.1	1.9	0.6	0.5
As (particulate)	IN	µg/L	8	0.1	1.7	0.8	0.6
	TT	µg/L	8	0.5	0.5	0.5	0.0
As(III)	IN	µg/L	8	0.1	0.6	0.3	0.2
	TT	µg/L	8	0.1	0.5	0.3	0.2
As(V)	IN	µg/L	8	27.4	33.6	30.2	2.0
	TT	µg/L	8	0.5	1.6	0.6	0.4
Fe (total)	IN	µg/L	8	<25	<25	<25	0.0
	TT	µg/L	8	<25	28	<25	0.0
Fe (soluble)	IN	µg/L	8	<25	<25	<25	0.0
	TT	µg/L	8	<25	<25	<25	0.0
Mn (total)	IN	µg/L	8	0.1	0.6	0.4	0.2
	TT	µg/L	8	0.1	0.5	0.5	0.1
Mn (soluble)	IN	µg/L	8	0.2	0.5	0.5	0.1
	TT	µg/L	8	0.2	0.5	0.5	0.1

(a) Vessels B1 and B2 in lead position; Vessels A1 and A2 in lag position.
One-half of detection limit used for samples with concentrations less than detection limit for calculations.
Outliers excluded from average if all other values are less than the detection limit.

Table 4-15. Summary of Arsenic, Iron, and Manganese Analytical Results at Residence Hall

Parameters	Sample Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
As (total)	IN	µg/L	28	25.7	33.2	29.6	1.8
			5	*25.4*	*32.5*	*29.4*	*3.1*
			8	**24.7**	**32.8**	**29.1**	**2.6**
	TA[b]	µg/L	28	<0.1	19.5	2.8	5.4
	TA[a]		*5*	*22.2*	*27.8*	*25.3*	*2.3*
	TA[a]		**8**	**1.1**	**19.2**	**12.5**	**6.4**
	TB[a]	µg/L	28	0.2	30.3	10.5	9.0
	TB[b]		*5*	*0.4*	*17.7*	*9.1*	*7.6*
	TB[b]		**8**	**<0.1**	**3.1**	**1.3**	**1.2**
As (soluble)	IN	µg/L	8	26.6	30.6	29.1	1.3
	TA[b]	µg/L	8	0.1	1.8	0.5	0.6
	TB[a]	µg/L	8	0.2	18.7	9.9	5.4
As (particulate)	IN	µg/L	8	<0.1	2.1	0.7	0.8
	TA[b]	µg/L	8	<0.1	0.8	0.1	0.3
	TB[a]	µg/L	8	<0.1	0.6	0.2	0.2
As(III)	IN	µg/L	8	0.1	0.6	0.2	0.1
	TA[b]	µg/L	8	<0.1	0.4	0.2	0.1
	TB[a]	µg/L	8	<0.1	0.5	0.2	0.1
As(V)	IN	µg/L	8	26.3	30.5	28.9	1.3
	TA[b]	µg/L	8	<0.1	1.8	0.4	0.6
	TB[a]	µg/L	8	<0.1	18.5	9.7	5.4
Fe (total)	IN	µg/L	8	<25	<25	<25	0.0
	TA[b]	µg/L	8	<25	45	<25	11.3
	TB[a]	µg/L	8	<25	<25	<25	0.0
Fe (soluble)	IN	µg/L	8	<25	<25	<25	0.0
	TA[b]	µg/L	8	<25	<25	<25	0.0
	TB[a]	µg/L	8	<25	<25	<25	0.0
Mn (total)	IN	µg/L	8	<0.1	0.6	0.2	0.2
	TA[b]	µg/L	8	<0.1	1.0	0.3	0.4
	TB[a]	µg/L	8	<0.1	0.6	0.1	0.2
Mn (soluble)	IN	µg/L	8	<0.1	0.3	0.1	0.1
	TA[b]	µg/L	8	<0.1	1.1	0.2	0.4
	TB[a]	µg/L	8	<0.1	<0.1	<0.1	0.0

(a) Vessel in lead position.
(b) Vessel in lag position.
Regular font for results of ARM 200 test run; italic font for results of ARM 200/ARM 300 test run; bold font for results of E33-S test run.
One-half of detection limit used for samples with concentrations less than detection limit for calculations; duplicate samples included in calculations.
Outliers excluded from average if all other values are less than the detection limit.

4.5.1 Inlet Water to POE Systems. Inlet water data were extracted from Tables 4-14 to 4-19 and summarized in Table 4-20. The historic source water data (before chlorination) also were reproduced from Table 4-3 for comparison. As expected, results of inlet water sampling in each of the three buildings were similar, as all three buildings received their inlet (chlorinated) water from the same storage tank.

Table 4-16. Summary of Arsenic, Iron, Manganese, and Titanium Analytical Results at College Union

Parameter	Sample Location[(a)]	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	μg/L	32	25.1	35.8	29.9	2.4
	TA	μg/L	32	0.2	24.3	3.7	7.1
	TB	μg/L	32	0.1	1.5	0.3	0.3
As (soluble)	IN	μg/L	7	27.4	35.7	30.7	3.0
	TA	μg/L	7	0.2	0.5	0.4	0.1
	TB	μg/L	7	0.1	0.5	0.2	0.2
As (particulate)	IN	μg/L	7	0.2	1.6	0.7	0.5
	TA	μg/L	7	0.5	0.5	0.5	0.0
	TB	μg/L	7	0.5	0.5	0.5	0.0
As(III)	IN	μg/L	7	0.1	0.5	0.2	0.1
	TA	μg/L	7	0.1	0.5	0.3	0.2
	TB	μg/L	7	0.1	0.5	0.3	0.2
As(V)	IN	μg/L	7	27.2	35.6	30.5	3.0
	TA	μg/L	7	0.2	0.5	0.4	0.1
	TB	μg/L	7	0.5	0.5	0.5	0.0
Fe (total)	IN	μg/L	7	<25	<25	<25	0.0
	TA	μg/L	7	<25	<25	<25	0.0
	TB	μg/L	7	<25	<25	<25	0.0
Fe (soluble)	IN	μg/L	7	<25	<25	<25	0.0
	TA	μg/L	7	<25	<25	<25	0.0
	TB	μg/L	7	<25	<25	<25	0.0
Mn (total)	IN	μg/L	7	0.1	0.5	0.4	0.2
	TA	μg/L	7	0.5	0.5	0.5	0.0
	TB	μg/L	7	0.1	0.5	0.4	0.1
Mn (soluble)	IN	μg/L	7	0.1	0.5	0.4	0.1
	TA	μg/L	7	0.1	0.5	0.4	0.1
	TB	μg/L	7	0.2	0.5	0.5	0.1
Ti (total)	IN	μg/L	7	1.7	9.7	3.1	2.9
	TA	μg/L	7	1.6	10.2	3.3	3.0
	TB	μg/L	7	1.8	10.6	3.3	3.2

(a) Vessel A in lead position; Vessel B in lag position.
Outliers excluded from average if all other values are less than the detection limit.

Total arsenic concentrations in inlet water (with samples collected from all three buildings) ranged from 24.7 to 35.8 μg/L and averaged 29.7 μg/L. Soluble As(V) was the predominating species, ranging from 26.3 to 35.6 μg/L and averaging 29.8 μg/L. Soluble As(III) and particulate arsenic concentrations were low, averaging 0.2 and 0.7 μg/L, respectively. The concentrations of arsenic species in inlet water sampled during the system performance evaluation were consistent with those of the historical source water sampling. Because the inlet water was chlorinated (with 0.3 mg/L of free chlorine [as Cl_2], on average), it was highly oxidizing, as reflected by high ORP readings (498 mV [on average]) and high DO levels (3.4 mg/L [on average]).

Similar to the historic results, iron and manganese concentrations in inlet water were low, typically less than the MDLs at 25 and 0.3 μg/L, respectively. pH values of the inlet water ranged from 7.3 to 8.5 and averaged 8.0, which is at the higher end of the commonly recommended range of 5.5 to 8.5 for arsenic removal by adsorptive media. Media run lengths at pH 8.0 most likely would be shorter than the runs at

Table 4-17. Summary of Other Water Quality Parameter Results at Purvine Hall

Parameter	Sample Location[a]	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	8	112	122	116	3.6
	TT	mg/L	8	101	123	113	6.5
Fluoride	IN	mg/L	8	<0.1	<0.1	<0.1	0.0
	TT	mg/L	8	<0.1	0.2	<0.1	0.1
Sulfate	IN	mg/L	8	21.0	35.0	23.9	4.9
	TT	mg/L	8	20.0	30.0	23.0	3.6
Nitrate (as N)	IN	mg/L	8	0.5	1.0	0.7	0.1
	TT	mg/L	8	<0.05	0.9	0.6	0.3
Total P (as P)	IN	μg/L	7	<10	12	<10	2.7
	TT	μg/L	7	<10	<10	<10	0.0
Silica (as SiO_2)	IN	mg/L	8	27.9	31.2	29.9	1.4
	TT	mg/L	8	11.4	31.5	26.9	6.6
Turbidity	IN	NTU	8	0.1	0.6	0.4	0.2
	TT	NTU	8	0.1	0.9	0.5	0.3
pH	IN	S.U.	32	7.3	8.4	8.0	0.2
	TB1	S.U.	24	7.3	8.4	8.1	0.2
	TA1	S.U.	24	7.0	8.4	8.0	0.3
	TB2	S.U.	24	7.4	8.4	8.0	0.2
	TA2	S.U.	24	7.2	8.3	8.0	0.2
	TT	S.U.	8	6.9	8.4	7.9	0.4
Temperature	IN	°C	32	12.8	26.3	19.3	4.5
	TB1	°C	24	12.9	25.2	19.0	4.2
	TA1	°C	24	13.0	24.8	19.4	4.0
	TB2	°C	24	12.1	24.5	18.9	4.4
	TA2	°C	24	12.2	24.5	19.0	4.3
	TT	°C	8	12.8	23.1	19.9	4.4
DO	IN	mg/L	24	2.4	5.1	3.7	0.7
	TB1	mg/L	17	2.9	5.0	3.4	0.5
	TA1	mg/L	17	2.3	4.5	3.4	0.6
	TB2	mg/L	17	3.0	6.6	3.6	0.9
	TA2	mg/L	17	3.0	4.6	3.5	0.5
	TT	mg/L	7	2.7	3.5	3.1	0.4
ORP	IN	mV	25	319	586	488	76.8
	TB1	mV	17	255	488	409	73.3
	TA1	mV	17	264	491	430	59.8
	TB2	mV	17	253	483	419	58.1
	TA2	mV	17	257	484	420	58.3
	TT	mV	8	264	568	400	93.0
Free Chlorine (as Cl_2)	IN	mg/L	32	0.2	0.4	0.3	0.1
	TB1	mg/L	24	0.0	0.2	0.0	0.0
	TA1	mg/L	24	0.0	0.2	0.0	0.0
	TB2	mg/L	24	0.0	0.1	0.0	0.0
	TA2	mg/L	24	0.0	0.1	0.0	0.0
	TT	mg/L	8	0.0	0.1	0.0	0.0
Hardness (as $CaCO_3$)	IN	mg/L	8	72.3	107	82.8	10.7
	TT	mg/L	8	74.2	106	84.2	9.6
Ca Hardness (as $CaCO_3$)	IN	mg/L	8	53.9	79.1	61.5	7.9
	TT	mg/L	8	53.7	78.5	61.4	7.6
Mg Hardness (as $CaCO_3$)	IN	mg/L	8	16.5	27.6	21.3	3.6
	TT	mg/L	8	20.4	27.4	22.9	2.3

(a) Vessels B1 and B2 in lead position; Vessels A1 and A2 in lag position.
One-half of detection limit used for samples with concentrations less than detection limit for calculations; duplicate samples included in calculations.

Table 4-18. Summary of Other Water Quality Parameter Results at Residence Hall

Parameter	Sample Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	8	110	123	116	5.1
	TA[b]	mg/L	8	106	122	115	5.2
	TB[a]	mg/L	8	110	125	117	4.6
Fluoride	IN	mg/L	8	<0.1	<0.1	<0.1	0.0
	TA[b]	mg/L	8	<0.1	<0.1	<0.1	0.0
	TB[a]	mg/L	8	<0.1	<0.1	<0.1	0.0
Sulfate	IN	mg/L	8	21.0	26.0	22.5	1.7
	TA[b]	mg/L	8	21.0	26.0	22.2	1.6
	TB[a]	mg/L	8	21.0	24.0	21.8	1.0
Nitrate (as N)	IN	mg/L	8	0.5	0.9	0.7	0.1
	TA[b]	mg/L	8	0.5	0.9	0.7	0.1
	TB[a]	mg/L	8	0.5	0.9	0.7	0.1
Phosphorus (as P)	IN	μg/L	7	<10	<10	<10	0.0
	TA[b]	μg/L	7	<10	<10	<10	0.0
	TB[a]	μg/L	7	<10	<10	<10	0.0
Silica (as SiO_2)	IN	mg/L	8	28.5	31.2	30.1	0.9
	TA[b]	mg/L	8	2.2	31.7	25.7	9.6
	TB[a]	mg/L	8	18.6	31.6	28.2	4.0
Turbidity	IN	NTU	8	0.1	1.1	0.4	0.3
	TA[b]	NTU	8	0.1	0.7	0.3	0.2
	TB[a]	NTU	8	0.1	0.5	0.2	0.2
pH	IN	S.U.	24	7.3	8.3	7.9	0.2
			5	*7.9*	*8.0*	*8.0*	*0.1*
			8	**8.0**	**8.3**	**8.2**	**0.1**
	TA[b]	S.U.	24	6.9	8.5	8.0	0.3
	TA[a]		*5*	*7.9*	*8.1*	*8.0*	*0.1*
	TA[a]		**8**	**8.0**	**8.3**	**8.2**	**0.1**
	TB[a]	S.U.	24	7.1	8.5	8.0	0.3
	TB[b]		*5*	*7.9*	*8.0*	*8.0*	*0.1*
	TB[b]		**8**	**8.0**	**8.8**	**8.2**	**0.3**
Temperature	IN	°C	24	13.2	24.3	19.6	3.3
			5	*18.5*	*22.4*	*20.5*	*1.9*
			8	**16.1**	**24.2**	**20.8**	**3.0**
	TA[b]	°C	24	13.5	24.3	19.7	3.3
	TA[a]		*5*	*18.5*	*23.1*	*20.7*	*2.1*
	TA[a]		**8**	**15.9**	**24.5**	**20.8**	**3.1**
	TB[a]	°C	24	13.6	24.1	19.7	3.3
	TB[b]		*5*	*18.4*	*23.1*	*20.6*	*2.1*
	TB[b]		**8**	**15.9**	**24.6**	**20.8**	**3.1**
DO	IN	mg/L	22	2.3	4.9	3.2	0.6
			5	*3.2*	*5.2*	*4.3*	*0.9*
			1	**3.7**	**3.7**	**3.7**	**0.0**
	TA[b]	mg/L	22	2.2	4.3	3.0	0.6
	TA[a]		*5*	*2.8*	*4.2*	*3.6*	*0.7*
	TA[a]		**1**	**3.1**	**3.1**	**3.1**	**0.0**
	TB[a]	mg/L	22	2.5	5.1	3.1	0.7
	TB[b]		*5*	*3.0*	*4.2*	*3.8*	*0.5*
	TB[b]		**1**	**4.7**	**4.7**	**4.7**	**0.0**

Table 4-18. Summary of Other Water Quality Parameter Results at Residence Hall (Continued)

Parameter	Sample Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
ORP	IN	mV	24	276	570	494	71.2
			5	*503*	*564*	*529*	*22.1*
			1	**562**	**562**	**562**	**0.0**
	TA[b]	mV	24	326	600	522	63.9
	TA[a]		*5*	*555*	*579*	*570*	*9.1*
	TA[a]		**1**	**596**	**596**	**596**	**0.0**
	TB[a]	mV	24	405	609	542	50.5
	TB[b]		*5*	*574*	*613*	*586*	*15.5*
	TB[b]		**1**	**546**	**546**	**546**	**0.0**
Free Chlorine (as Cl_2)	IN	mg/L	24	0.2	0.4	0.3	0.0
			5	*0.3*	*0.4*	*0.3*	*0.0*
			8	**0.4**	**0.4**	**0.4**	**0.0**
	TA[b]	mg/L	24	0.1	0.3	0.2	0.1
	TA[a]		*5*	*0.3*	*0.3*	*0.3*	*0.0*
	TA[a]		**8**	**0.4**	**0.4**	**0.4**	**0.0**
	TB[a]	mg/L	24	0.1	0.3	0.3	0.1
	TB[b]		*5*	*0.2*	*0.3*	*0.3*	*0.0*
	TB[b]		**8**	**0.3**	**0.4**	**0.4**	**0.1**
Total Hardness (as $CaCO_3$)	IN	mg/L	8	77.6	93.8	84.3	5.9
	TA[b]	mg/L	8	76.2	91.6	82.9	5.1
	TB[a]	mg/L	8	78.5	103	85.2	8.0
Ca Hardness (as $CaCO_3$)	IN	mg/L	8	54.7	66.9	60.7	4.5
	TA[b]	mg/L	8	54.9	65.5	60.0	3.6
	TB[a]	mg/L	8	55.1	75.8	61.7	6.6
Mg Hardness (as $CaCO_3$)	IN	mg/L	8	21.2	26.9	23.5	1.7
	TA[b]	mg/L	8	21.0	26.0	22.9	1.8
	TB[a]	mg/L	8	21.5	26.9	23.5	1.7

(a) Vessel in lead position.
(b) Vessel in lag position.
Regular font for results of ARM 200 test run.
Italic font for results of ARM 200/ARM 300 test run.
Bold font for results of E33-S test run.
One-half of detection limit used for samples with concentrations less than detection limit for calculations.

lower pH values. Lowering pH values prior to adsorption can prolong the adsorption runs, but often is avoided by small system operators because of the need to handle acids and bases. When benefits of lowering pH values are out-weighed by concerns over the handling of acids and bases, pH adjustments are not performed.

Competing anions such as silica and phosphorus were measured in source water during the initial site visit and in inlet water during the performance evaluation study. Analysis of inlet water showed silica levels at 27.8 to 31.5 mg/L (as SiO_2), compared to 30.3 to 34.2 mg/L (as SiO_2) in source water during the initial site visit. Silica adsorption by the five adsorptive media tested is discussed in detail in Section 4.5.2. Total phosphorus in inlet water was below its MDL of 10 µg/L, consistent with the measurements of orthophosphate levels measured (below the MDL of 0.06 mg/L [as PO_4]) during the initial site visit.

Other analytes measured were either low or close to or below their respective MDLs. Their effects on arsenic removal by the media evaluated were expected to be minimal.

Table 4-19. Summary of Other Water Quality Parameter Results at College Union

Parameter	Sample Location[a]	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	7	110	127	118	6.4
	TA	mg/L	7	104	122	116	6.6
	TB	mg/L	7	103	122	114	8.0
Fluoride	IN	mg/L	7	<0.1	<0.1	<0.1	0.0
	TA	mg/L	7	<0.1	<0.1	<0.1	0.0
	TB	mg/L	7	<0.1	0.7	0.1	0.2
Sulfate	IN	mg/L	7	21.0	28.0	22.5	2.5
	TA	mg/L	7	21.0	26.0	22.1	1.8
	TB	mg/L	7	<1.0	26.0	19.4	8.6
Nitrate (as N)	IN	mg/L	7	0.5	0.9	0.7	0.1
	TA	mg/L	7	0.6	0.9	0.7	0.1
	TB	mg/L	7	0.6	1.0	0.7	0.1
Phosphorus (as P)	IN	μg/L	7	<10	<10	<10	0.0
	TA	μg/L	7	<10	<10	<10	0.0
	TB	μg/L	7	<10	<10	<10	0.0
Silica (as SiO_2)	IN	mg/L	7	27.8	31.5	29.9	1.4
	TA	mg/L	7	28.2	32.3	29.9	1.6
	TB	mg/L	7	27.3	31.7	29.8	1.7
Turbidity	IN	NTU	7	0.1	1.5	0.6	0.5
	TA	NTU	7	0.2	0.5	0.3	0.1
	TB	NTU	7	0.1	0.7	0.3	0.2
pH	IN	S.U.	29	7.8	8.5	8.0	0.2
	TA	S.U.	29	7.2	8.6	8.0	0.2
	TB	S.U.	29	7.4	8.6	8.0	0.2
Temperature	IN	°C	29	12.1	25.1	20.1	4.2
	TA	°C	29	11.9	25.3	20.1	4.2
	TB	°C	29	11.9	25.4	20.1	4.3
ORP	IN	mV	22	315	575	505	59.6
	TA	mV	22	474	600	554	33.6
	TB	mV	22	460	611	563	36.3
DO	IN	mg/L	20	2.5	5.4	3.3	0.7
	TA	mg/L	20	2.7	3.9	3.1	0.4
	TB	mg/L	20	2.4	7.1	3.3	1.0
Free Chlorine (as Cl_2)	IN	mg/L	29	0.3	0.4	0.3	0.1
	TA	mg/L	29	0.2	0.4	0.3	0.1
	TB	mg/L	28	0.1	0.4	0.3	0.1
Total Hardness (as $CaCO_3$)	IN	mg/L	7	67.0	106	83.8	11.5
	TA	mg/L	7	63.9	107	83.5	12.6
	TB	mg/L	7	68.6	103	83.0	10.9
Ca Hardness (as $CaCO_3$)	IN	mg/L	7	54.8	78.2	62.9	7.5
	TA	mg/L	7	46.8	80.0	61.2	9.7
	TB	mg/L	7	50.1	75.9	60.8	8.4
Mg Hardness (as $CaCO_3$)	IN	mg/L	7	12.2	27.3	20.9	5.3
	TA	mg/L	7	17.1	27.0	22.3	3.1
	TB	mg/L	7	18.5	27.0	22.3	2.8

(a) Vessel A in lead position and Vessel B in lag position.

Table 4-20. Comparison of Water Quality Between Building Inlet and Historic Results

Parameter	Unit	Building	Sample Count	Concentration Range (Average)		
				At Each Building	Across Three Buildings	Historic Data[a]
pH	S.U.	Purvine Hall	32	7.3–8.4 (8.0)	7.3–8.5 (8.0)	7.6–8.0
		Residence Hall	37	7.3–8.3 (8.0)		
		College Union	29	7.4–8.5 (8.0)		
DO	mg/L	Purvine Hall	24	2.4–5.1 (3.7)	2.3–5.4 (3.4)	4.2
		Residence Hall	28	2.3–5.2 (3.4)		
		College Union	20	2.5–5.4 (3.3)		
ORP	mV	Purvine Hall	25	319–586 (488)	276–586 (498)	82
		Residence Hall	30	276–570 (502)		
		College Union	22	315–575 (505)		
Total Alkalinity (as $CaCO_3$)	mg/L	Purvine Hall	8	112–122 (116)	110–127 (117)	107–112
		Residence Hall	8	110–123 (116)		
		College Union	7	110–127 (118)		
Total Hardness (as $CaCO_3$)	mg/L	Purvine Hall	8	72.3–107 (82.8)	67.0–107 (83.6)	80–81
		Residence Hall	8	77.6–93.8 (84.3)		
		College Union	7	67.0–106 (83.8)		
Turbidity	NTU	Purvine Hall	8	0.1–0.6 (0.4)	0.1–1.5 (0.5)	0.6
		Residence Hall	8	0.1–1.1 (0.4)		
		College Union	7	0.1–1.5 (0.6)		
Nitrate (as N)	mg/L	Purvine Hall	8	0.5–1.0 (0.7)	0.5–1.0 (0.7)	0.6–0.8
		Residence Hall	8	0.5–0.9 (0.7)		
		College Union	7	0.5–0.9 (0.7)		
Fluoride	mg/L	Purvine Hall	8	<0.1–<0.1 (<0.1)	<0.1–<0.1 (<0.1)	<0.1–0.2
		Residence Hall	8	<0.1–<0.1 (<0.1)		
		College Union	7	<0.1–<0.1 (<0.1)		
Sulfate	mg/L	Purvine Hall	8	21.0–35.0 (23.9)	21.0–35.0 (23.0)	21.0–23.0
		Residence Hall	8	21.0–26.0 (22.5)		
		College Union	7	21.0–28.0 (22.5)		
Silica (as SiO_2)	mg/L	Purvine Hall	8	27.9–31.2 (29.9)	27.8–31.5 (30.0)	30.3–34.2
		Residence Hall	8	28.5–31.2 (30.1)		
		College Union	7	27.8–31.5 (29.9)		
Phosphorus (as P)	µg/L	Purvine Hall	7	<10–12.0 (<10)	<10–12.0 (<10)	<60[c]
		Residence Hall	7	<10–<10 (<10)		
		College Union	7	<10–<10 (<10)		
As (total)	µg/L	Purvine Hall	36	25.2–35.5 (29.8)	24.7–35.8 (29.7)	29.0–36.0
		Residence Hall	41[b]	24.7–33.2 (29.4)		
		College Union	32	25.1–35.8 (29.9)		
As (soluble)	µg/L	Purvine Hall	8	27.6–33.9 (30.5)	26.6–35.7 (30.1)	33.0
		Residence Hall	8	26.6–30.6 (29.1)		
		College Union	7	27.4–35.7 (30.7)		
As (particulate)	µg/L	Purvine Hall	8	0.1–1.7 (0.8)	<0.1–2.1 (0.7)	<0.1
		Residence Hall	8	<0.1–2.1 (0.7)		
		College Union	7	0.2–1.6 (0.7)		
As(III)	µg/L	Purvine Hall	8	0.1–0.6 (0.3)	0.1–0.6 (0.2)	0.5
		Residence Hall	8	0.1–0.6 (0.2)		
		College Union	7	0.1–0.5 (0.2)		
As(V)	µg/L	Purvine Hall	8	27.4–33.6 (30.2)	26.3–35.6 (29.8)	32.5
		Residence Hall	8	26.3–30.5 (28.9)		
		College Union	7	27.2–35.6 (30.5)		

Table 4-20. Comparison of Water Quality Between Building Inlet and Historic Results (Continued)

Parameter	Unit	Building	Sample Count	Concentration Range (Average)		
				At Each Building	Across Three Buildings	Historic Data[(a)]
Fe (total)	µg/L	Purvine Hall	8	<25–<25 (<25)	<25–<25 (<25)	<25
		Residence Hall	8	<25–<25 (<25)		
		College Union	8	<25–<25 (<25)		
Fe (soluble)	µg/L	Purvine Hall	8	<25–<25 (<25)	<25–<25 (<25)	<25
		Residence Hall	8	<25–<25 (<25)		
		College Union	7	<25–<25 (<25)		
Mn (total)	µg/L	Purvine Hall	8	0.1–0.6 (0.4)	<0.1–0.6 (0.3)	<0.1–0.2
		Residence Hall	8	<0.1–0.6 (0.2)		
		College Union	7	0.1–0.5 (0.4)		
Mn (soluble)	µg/L	Purvine Hall	8	0.2–0.5 (0.5)	<0.1–0.5 (0.3)	<0.1
		Residence Hall	8	<0.1–0.3 (0.1)		
		College Union	7	0.1–0.5 (0.4)		
Ti (total)	µg/L	Purvine Hall	NA	NA	NA	NA
		Residence Hall	NA	NA		
		College Union	7	1.7–9.7 (3.1)		

(a) See Table 4-2 (data reflect results before chlorination).
(b) Including all three tests.
(c) Concentration of orthophosphate (as PO_4).

4.5.2 Treated Water Following Media Adsorption

4.5.2.1 ArsenX^{np}. Figure 4-19 presents arsenic breakthrough curves at TB1, TA1, TB2, TA2, and TT. Arsenic breakthrough at 10 µg/L following the lead vessels (TB1 and TB2) occurred after treating approximately 594,440 and 609,700 gal of water (or 15,900 and 16,300 BV), respectively. (BV was calculated based on 5 ft^3 of media in a lead vessel.) These run lengths represented only approximately 30% of the 52,750-BV run length estimated by the vendor. By the end of the performance evaluation study, arsenic levels following the two lead vessels were approaching those in inlet water. At this time, the system had treated 1,814,428 gal (or 24,254 BV [1 BV = 10 ft^3 of media in both lead vessels]) of water. The run-length differences observed between the two trains were caused by the imbalanced flow experienced during the initial stage of system operation (see Section 4.4.5).

At the end of the performance evaluation study, arsenic concentrations following the lag vessels (TA1 and TA2) were 0.4 µg/L. Since then, the system continued to treat and provide drinking water to taps in Purvine Hall.

Figure 4-20 presents silica breakthrough curves from the treatment system. Silica broke through from the treatment system soon after system startup. Complete silica breakthrough occurred at approximately 5,000 BV (1 BV = 10 ft^3 of media in both lead vessels). Silica adsorption has been observed at a number of arsenic demonstration sites using AM; a review of silica adsorption at these sites was documented in a system performance evaluation report authored by Chen et al. (2010).

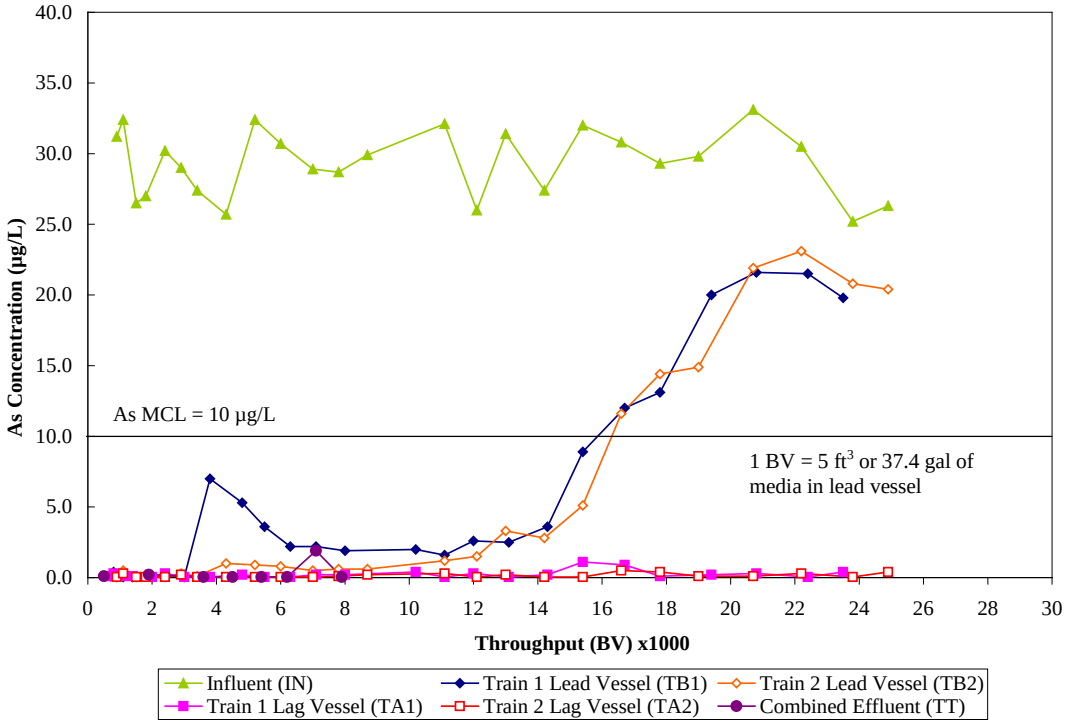

Figure 4-19. Total Arsenic Breakthrough from ArsenX^{np} Media

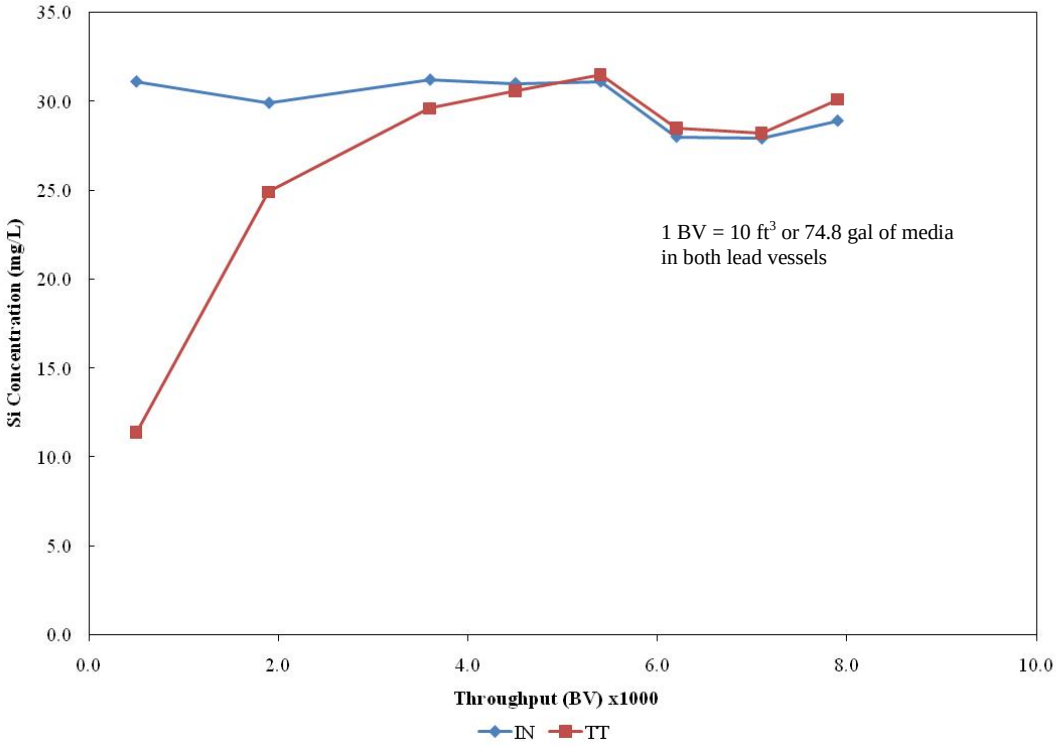

Figure 4-20. Silica Breakthrough from ArsenX^{np} Media

4.5.2.2 ARM 200/ARM 300/E33-S Media. Figure 4-21 presents breakthrough curves following the lead and lag vessels. Total arsenic concentrations exceeded 10 µg/L after the lead vessel (TB) containing ARM 200 had treated 2,085,000 gal (or 13,940 BV) of water. (BV was calculated based on 20 ft^3 of media in the lead vessel.) The BV was only 22% of the vendor-estimated run length of 62,600 BV. Since then, total arsenic concentrations following the lead vessel fluctuated between 9.9 and 12.6 µg/L before spiking to 17.6, 28.5, and 30.3 µg/L at 27,800, 36,200, and 39,400 BV, respectively. By the end of the ARM 200 test, total arsenic concentrations following the lead vessel had reached the inlet water level of approximately 30 µg/L. At this time, the lead vessel had treated approximately 6,698,000 gal of water (or 44,770 BV [1 BV = 20 ft^3 = 149.6 gal]).

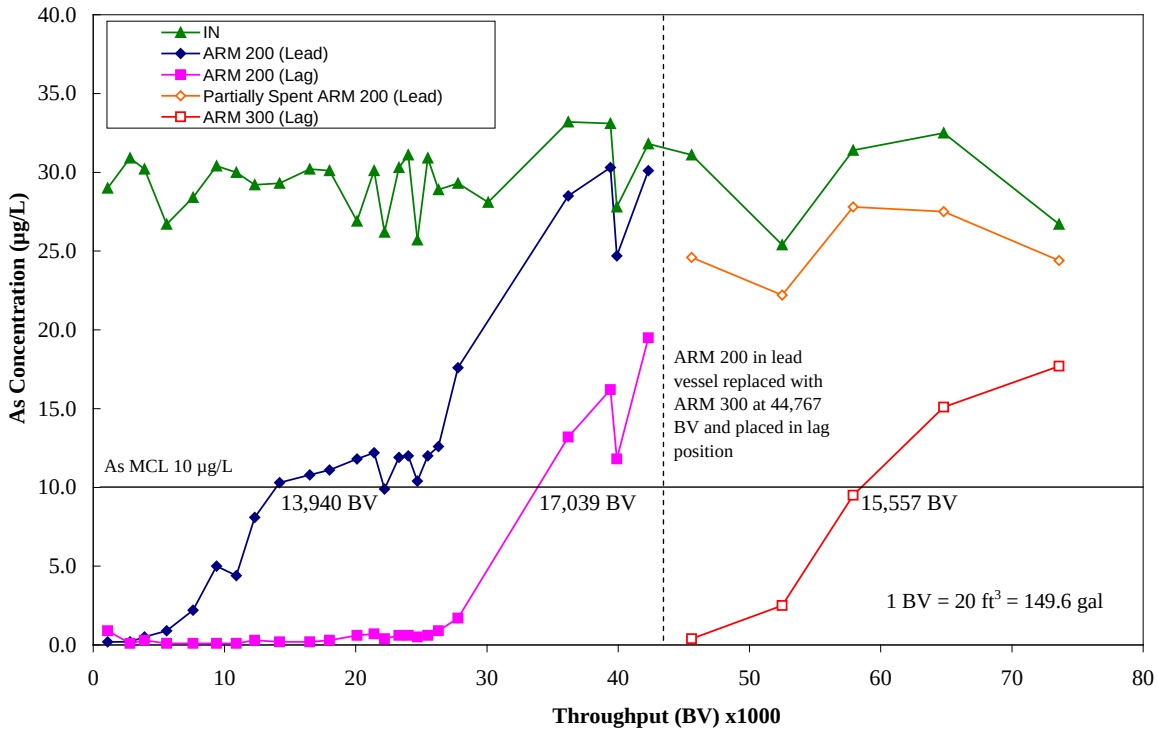

Figure 4-21. Total Arsenic Breakthrough from ARM 200 and/or ARM 300 Media

Breakthrough of total arsenic at 10 µg/L following the lag vessel (TA) containing ARM 200 media occurred at 34,078 BV (1 BV = 20 ft^3 of media in one vessel). Considering the lead and lag vessels as one large vessel, breakthrough at 10 µg/L in system effluent would occur at 17,039 BV (1 BV = 40 ft^3 of media in both vessels). The difference between the two-vessel and one-vessel run lengths (17,039 vs. 13,940 BV) likely was caused by twice as long EBCT for the lead/lag system. By the end of the ARM 200 test, the total arsenic concentration in the system effluent had reached 19.5 µg/L.

Because of the unexpected early arsenic breakthrough, the system was taken offline and the lead vessel was rebedded with ARM 300 when the lag vessel had an arsenic effluent concentration of 19.5 µg/L. After vessel switching (with partially spent ARM 200 in the lead position and virgin ARM 300 in the lag position), the system was put online on January 24, 2007. The lead vessel containing partially spent ARM 200 (TA) continued to remove arsenic but the percentage removal was diminishing from about 21%

at 3,200 BV (since rebedding and vessel switching) to <9% at 31,300 BV (1 BV = 20 ft^3 = 149.6 gal). Total arsenic concentrations from the lag vessel (TB) reached 9.5 µg/L on April 4, 2007 after treating 2,327,650 gal (or 15,557 BV) of water. This run length was very close to that (13,940 BV) for ARM 200.

Because of the short run lengths experienced with both ARM 200 and ARM 300 media, the system was put in the standby mode on July 11, 2007, pending results of a series of rapid small-scale column tests (RSSCTs) funded under another EPA task order. The RSSCTs evaluated the run lengths of five different adsorptive media (i.e., $ArsenX^{np}$, ARM 200, GFH [a granular ferric hydroxide media developed by GEH Wasserchemie Gmbh and marketed by Siemens], Metsorb [a titanium dioxide-based media developed by HydroGlobe], and E33-S) using 100 × 140 U.S. standard mesh media fractions packed separately in 1.1-cm × 30.5-cm glass columns. The results indicated that E33-S was able to achieve a useful run length of approximately 40,000 BV, while the rest would achieve only 12,000 to 20,000 BV. As such, E33-S was used to rebed both lead and lag vessels on October 3, 2007, and the system was put back online immediately for additional testing.

E33-S media treated approximately 7,480,000 gal (or 50,000 BV [1 BV = 20 ft^3 = 149.6 gal]) of water before effluent concentrations from the lead vessel exceeded the 10-µg/L MCL (see Figure 4-22). This run length was 20% longer than the RSSCT-projected run length and much longer than those achieved by ARM 200 (13,940 BV), ARM 300 (16,200 BV [with 8.6 to 20.1% of arsenic already removed by ARM 200 media]), and $ArsenX^{np}$ (16,000 BV). During the last sampling event on August 26, 2009, the arsenic concentration following the lag vessel was 3.1 µg/L. By now, the system had treated 12,170,210 gal of water (equivalent to 40,670 BV based on 40 ft^3 of media in both vessels).

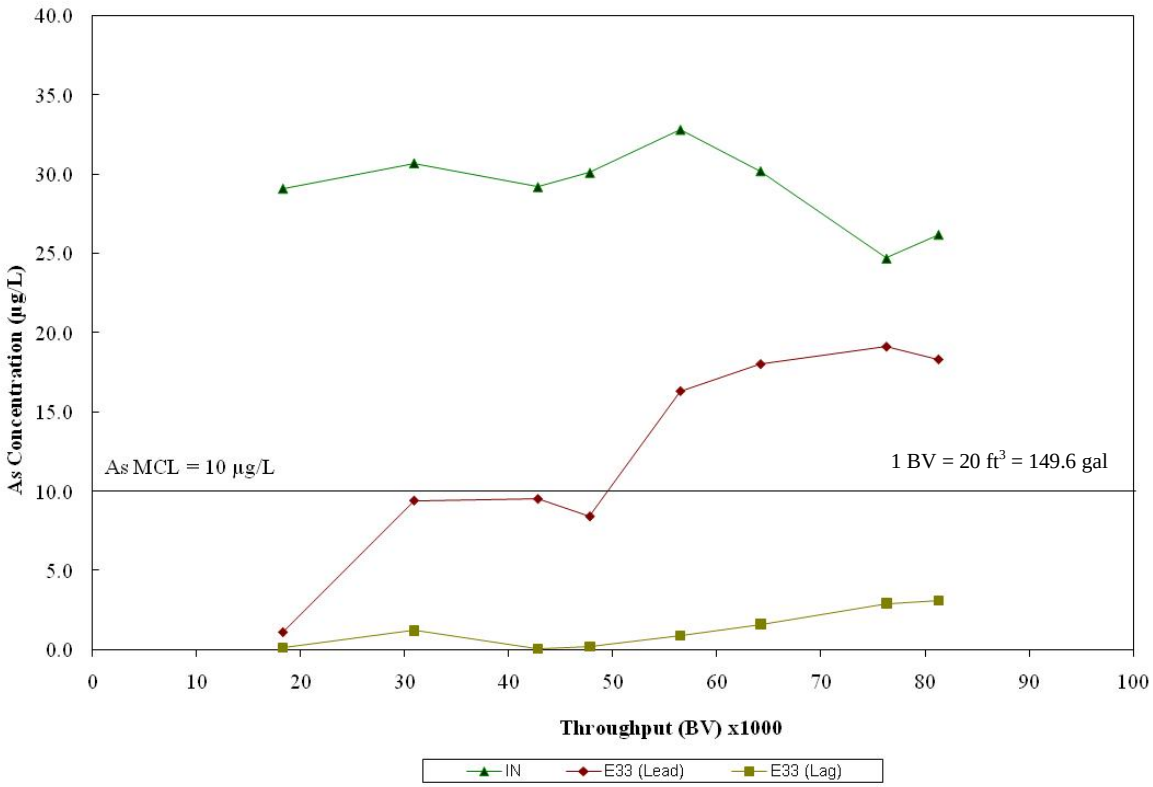

Figure 4-22. Arsenic Breakthrough from E33-S Media

Removal of silica (as SiO_2) by ARM 200 was observed during the initial stage of the ARM 200 adsorption run. Because only two samples were collected during the first three months of system operation and because silica concentrations had already reached inlet levels during the second sampling event (at approximately 9,400 BV), precise silica breakthrough behavior may not be determined using the available data (see Figure 4-23).

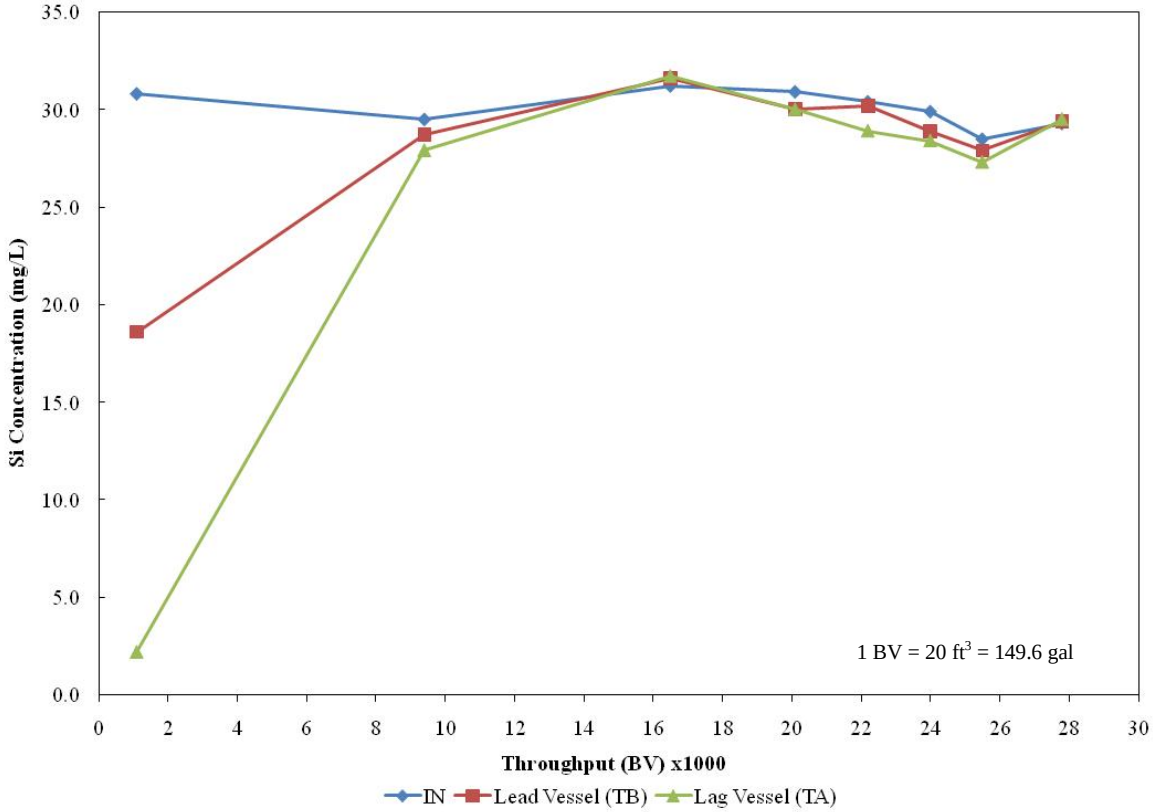

Figure 4-23. Silica Breakthrough from ARM 200 Media

4.5.2.3 Adsorbsia™ GTO™. Figure 4-24 shows total arsenic breakthrough from Adsorbsia™ GTO™ media. Total arsenic concentrations following the lead vessel (TA) remained below 1.1 µg/L after the system had treated 2,571,229 gal of water (or 21,484 BV based on 16 ft^3 of media in the lead vessel). Since then, total arsenic concentrations rose sharply to 10 µg/L after treating an additional 12,000 BV of water. Afterwards, total arsenic concentrations continued to increase to 24.3 µg/L in 7,200 BV. During the last sampling event of the system performance evaluation study, the arsenic concentration following the lead vessel was 21.1 µg/L, which was within 22% to the inlet level; the arsenic concentration following the lag vessel (TB) was 0.6 µg/L. At this time, the system had treated 5,889,749 gal of water (equivalent to 21,872 BV based on 36 ft^3 of media). The vendor-estimated media life was 60,150 BV, which was about 80% higher than the run length achieved by the lead vessel.

Silica did not seem to compete with arsenic for adsorption sites, as evidenced by the same level of silica in the treated water.

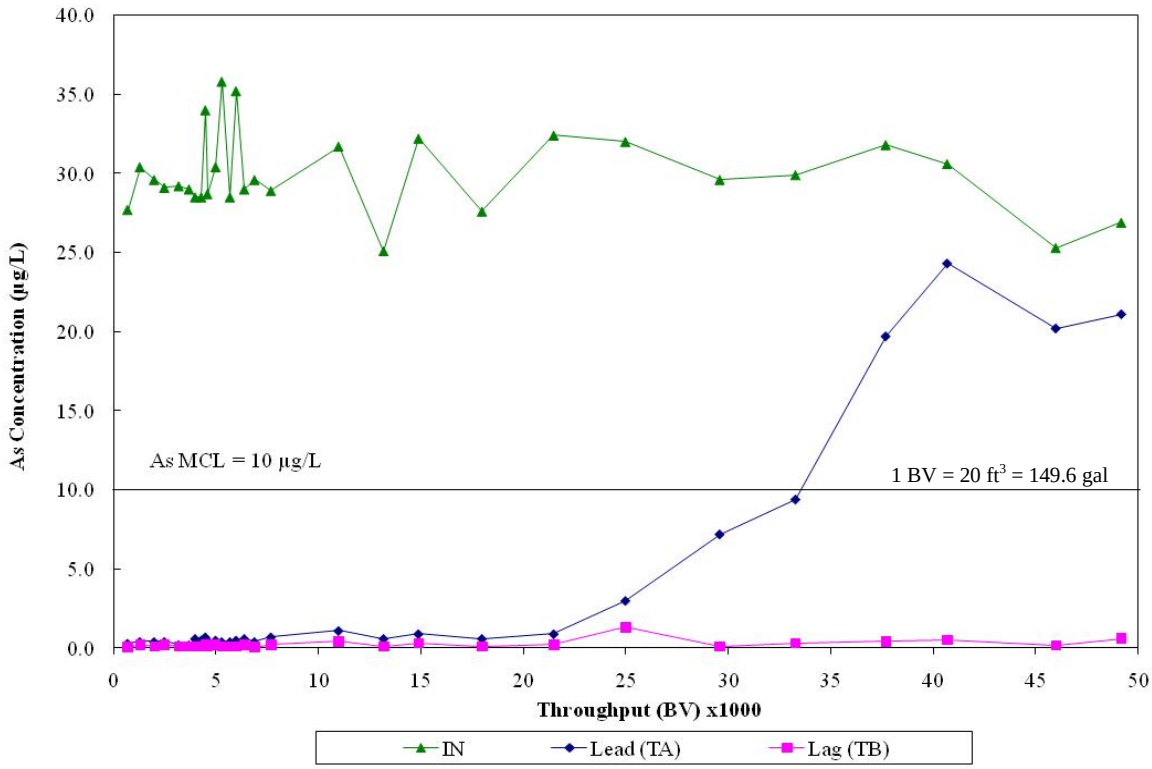

Figure 4-24. Total Arsenic Breakthrough from Adsorbsia™ GTO™ Media

4.5.2.4 POE System Performance Comparison. Table 4-21 summarizes the run length data of the three POE systems. Among the media evaluated, E33-S performed the best, achieving approximately 50,000 BV. Adsorbsia™ GTO™ was the next best performer, achieving 33,500 BV. ARM 200, ARM 300, and ArsenX^{np} had a media life of around 16,000 BV.

Table 4-21. Summary of Media Run Lengths

	Purvine Hall	Residence Hall			College Union
Run Length[(a)]	**ArsenX^{np}**	**ARM 200**	**ARM 300**	**E33-S**	**Adsorbsia™ GTO™**
POE Systems	16,000	13,940	16,200[(b)]	50,000	33,500
RSSCT	15,000	14,000	NA	40,000	NA

(a) To 10 µg/L arsenic breakthrough.
(b) Before contacting ARM 300, 8.6 to 20.9% of arsenic in inlet water already removed by partially spent ARM 200 media.

The full-scale system data seemed to match the RSSCT data rather well, with projected run lengths within 6.3%, 0.4%, and 20% of the actual run lengths for ArsenX^{np}, ARM 200, and E33-S, respectively.

4.5.2.5 POU Units. Figures 4-25 and 4-26 show total arsenic concentrations following three POU units loaded with ARM 200 media and three POU units loaded with E33-S, respectively. Total arsenic was consistently removed to less than 1.0 µg/L from ARM 200 Units 1 and 2 after treating approximately 400 and 740 gal of water, respectively. ARM 200 Unit 3 effectively removed arsenic to <2.1 µg/L after treating 500 gal, but the effluent arsenic concentrations rose steadily to 6.0 after treating approximately 1,000 gal. Arsenic was consistently removed to the MDL level by the three E33-S POU units after treating approximately 500 gal. A follow-on study that allowed inlet water to flow through an E33-S POU unit at about 1 gpm showed the concentration reduction to <10 µg/L by the unit during the first 3,000 gal of throughput (Figure 4-27).

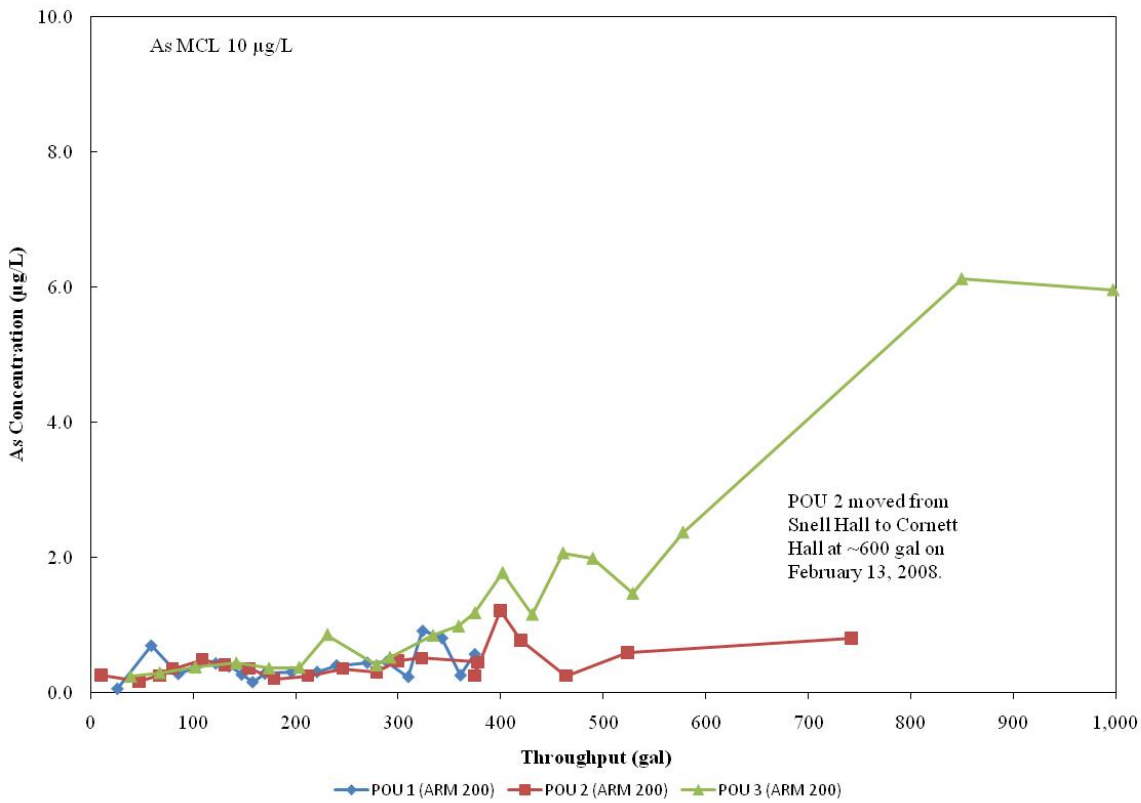

Figure 4-25. Arsenic Breakthrough Curves for Three ARM 200 POU Units

4.5.6 Backwash Wastewater Sampling. Table 4-22 summarizes analytical results of the backwash wastewater sampling during backwash of the three POE systems on May 16 or 17, 2006. The unfiltered samples were analyzed for pH, TDS, TSS, and total arsenic, iron, and manganese. Filtered samples using 0.45-µm disc filters were analyzed for soluble arsenic, iron, and manganese. Backwash solid results are presented in Table 4-23.

4.5.6.1 ArsenX^{np} System. The lead vessels (TB1 and TB2) were backwashed using treated water from the lag vessels (TA1 and TA2) in the same train. Similarly, the lag vessels (TA1 and TA2) were backwashed using treated water from the lead vessels (TB1 and TB2) in the same train. The treated water from the lag and lead vessels contained, at the time, no more than 0.1 µg/L of total arsenic. Wastewater collected from the two lead vessels contained 15.2 and 14.3 µg/L of total arsenic, respectively, existing primarily in the soluble form (this is contrary to what would be expected). Wastewater collected from the two lag vessels contained only 0.2 µg/L of total arsenic, similar to the level in the treated water. Solids in

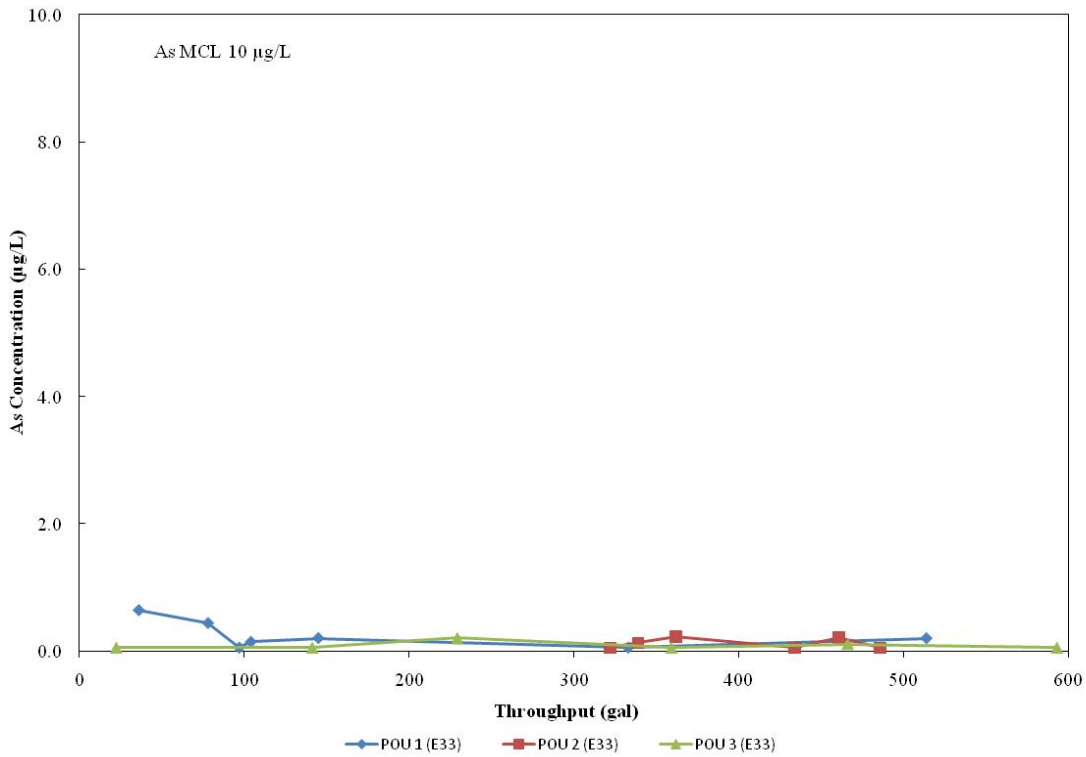

Figure 4-26. Arsenic Breakthrough Curves for Three AdEdge E33-S POU Units

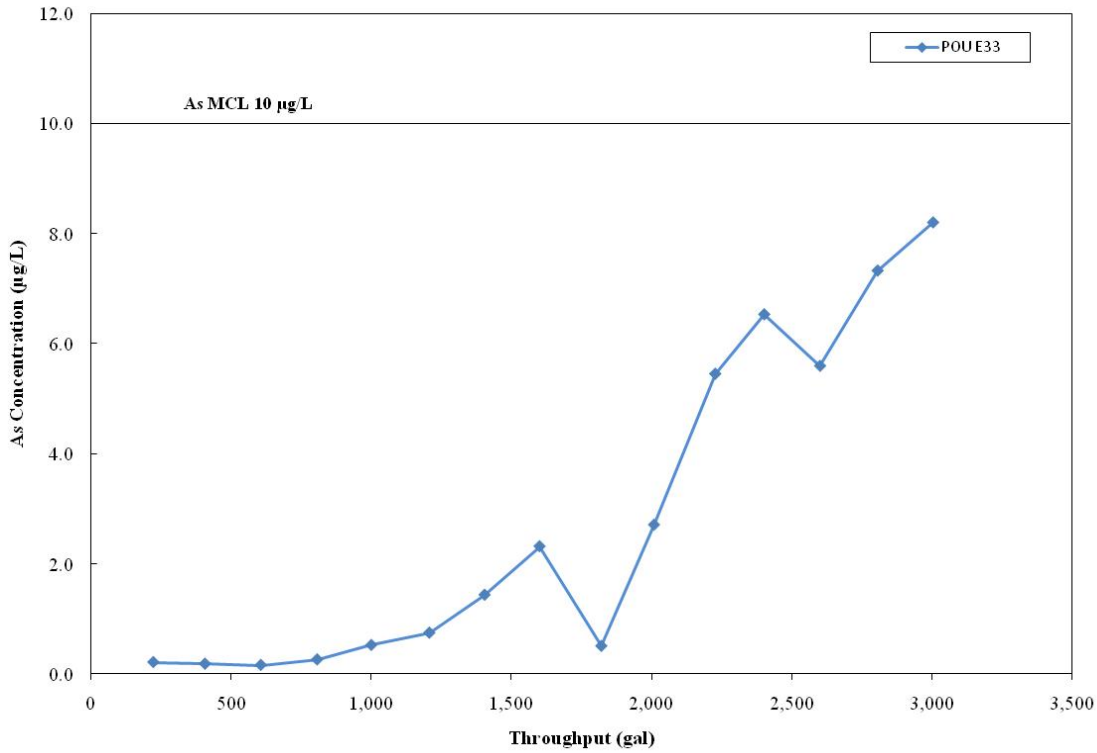

Figure 4-27. Results of AdEdge E33-S POU Unit Run Length Study

Table 4-22. Backwash Sampling Results

Sampling Location	pH	TDS	TSS	As (total)	As (soluble)	As (particulate)	Fe (total)	Fe (soluble)	Mn (total)	Mn (soluble)
	S.U.	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
ArsenX^{np} System in Purvine Hall										
TB1 (Lead/Train 1)	7.9	174	48	15.2	12.5	2.7	2,758	<25	19.1	<0.1
TA1 (Lag/Train 1)	7.8	188	18	0.2	0.1	0.1	1,867	<25	3.9	0.3
TB2 (Lead/Train 2)	7.9	164	4	14.3	13.7	0.7	389	<25	3.6	<0.1
TA2 (Lag/Train 2)	7.9	172	60	0.2	0.1	0.1	2,499	<25	5.1	0.2
ARM 200 System in Residence Hall										
TB (Lead)	7.9	188	6	19.0	18.2	0.8	1,280	<25	19.4	<0.1
TA (Lag)	8.0	180	34	13.9	10.4	3.5	3,637	<25	29.0	0.2
Adsorbsia™ GTO™ System in College Union										
TA (Lead)	7.8	184	120	10.9	12.3	<0.1	421	<25	7.3	<0.1
TB (Lag)	7.9	162	62	1.3	1.9	<0.1	137	<25	3.1	<0.1

TDS = Total Dissolved Solids
TSS = Total Suspended Solids

the backwash wastewater, as reflected by TSS at 4 to 60 mg/L, most likely were media fines measured as particulate iron (at 389 to 2,758 µg/L). The unusually low TSS value (4 mg/L) measured at TB2 might have been the result of sampling errors caused by insufficient mixing of the solids/water mixtures in the backwash water collection containers immediately before sampling. Based on an average TSS level of 42 mg/L (excluding the 4 mg/L outlier) and the quantity of backwash wastewater produced (144 gal/vessel), approximately 91.6 g of solids was discharged during the backwash event. The discharged solids contained negligible amount of arsenic (due to the low particulate arsenic concentrations in the wastewater) and 5.2 g of iron (5.6% by weight), which does not reconcile well with the 91.6-g TSS measured in the wastewater sample or the 18.7% iron measured in the backwash solids (see Table 4-25). The solids analysis showed low arsenic and manganese loadings at 0.04% and 0.11%, respectively.

4.5.6.2 ARM 200 System. Backwash was performed using treated water from the other vessel in the treatment system. At the time of backwash, the treated water from the lead and lag vessels contained no more than 11.1 and 0.3 µg/L of arsenic, respectively. However, the backwash water from the lead and lag vessels contained 19.0 and 13.9 µg/L of arsenic, respectively. Again, the majority of arsenic in the wastewater existed as soluble arsenic. As expected, more arsenic was found from the lead than the lag vessel, due the higher arsenic loading in the lead vessel (even though the treated water from the lag vessel used for backwashing the lead vessel contained less arsenic). The TSS levels were 6 and 34 mg/L for the lead and lag vessels, respectively. The low TSS value found for the lead vessel might be the result of sampling errors as discussed above. Based on the TSS levels (6 and 34 mg/L) and the quantity of backwash water produced (350 and 136 gal), approximately 25.4 g of solids was discharged during the backwash event. The discharged solids contained 3.6 g of iron (or 14.1% by weight) but negligible amounts of arsenic and manganese. Similar to the ArsenX^{np} solid results, the individual elemental results do not reconcile well with the TSS results or backwash solids results (i.e., 41% iron, 0.3% manganese, and 0.04% arsenic).

4.5.6.3 Adsorbsia™ GTO™ System. Similar to the ARM 200 system in the Residence Hall, backwash of the Adsorbsia™ GTO™ system was performed using treated water from the other vessel in

Table 4-23. Backwash Solids Results

Sample ID	Mg µg/g	Si µg/g	P µg/g	Ca µg/g	Mn µg/g	Fe µg/g	As µg/g	Ba µg/g	Ti µg/g
ArsenX^{np} System in Purvine Hall									
BW1-A (TA1)	1,350	541	348	5,384	939	184,546	7.8	11.6	NA
BW1-B (TA1)	1,331	<250	362	5,489	976	187,074	8.9	12.4	NA
BW1-C (TA1)	1,307	284	332	5,761	954	186,709	8.3	12.2	NA
Average	1,329	412	347	5,545	956	186,110	8.3	12.0	NA
BW2-A (TB1)	462	<250	640	2,065	1,271	196,535	923	16.4	NA
BW2-B (TB1)	458	293	625	2,100	1,276	195,133	942	17.1	NA
BW2-C (TB1)	469	<250	639	2,148	1,281	196,798	947	16.7	NA
Average	463	293	634	2,104	1,276	196,155	937	16.7	NA
BW3-A (TA2)	956	473	343	4,362	1,068	200,127	26.7	12.7	NA
BW3-B (TA2)	928	<250	354	4,298	1,065	190,703	19.9	13.6	NA
BW3-C (TA2)	933	419	358	4,360	1,018	196,192	18.8	12.7	NA
Average	939	446	352	4,340	1,051	195,674	21.8	13.0	NA
BW4-A (TB2)	1,746	429	519	11,608	994	177,617	784	15.5	NA
BW4-B (TB2)	1,716	441	515	11,369	950	171,429	763	14.9	NA
BW4-C (TB2)	1,783	<250	543	11,925	1,001	171,784	790	18.5	NA
Average	1,748	435	526	11,634	982	173,610	779	16.3	NA
ARM 200 System in Residence Hall									
BW1-A (TA)	4,953	846	328	24,469	3,008	424,855	434	8.1	NA
BW1-B (TA)	5,046	938	353	25,360	2,966	398,674	434	8.6	NA
BW1-C (TA)	4,786	1,074	374	25,280	3,005	408,767	421	7.7	NA
Average	4,929	953	352	25,036	2,993	410,765	430	8.1	NA
Adsorbsia™ GTO™ System in College Union									
BW1-A (TA)	3,177	441	106	20,867	40.5	1,294	2.0	19.4	211,113
BW1-B (TA)	3,221	534	98.7	21,530	38.9	1,418	0.6	20.0	189,643
BW1-C (TA)	3,157	324	72.3	21,352	42.0	1,251	<0.5	20.1	NA
Average	3,185	433	92.3	21,249	40.5	1,321	1.0	19.8	200,388
BW2-A (TB)	4,920	849	158	28,276	62.4	1,735	<0.5	13.2	340,379
BW2-B (TB)	4,868	886	154	28,197	59.9	1,753	<0.5	13.6	343,268
BW2-C (TB)	4,781	917	155	27,810	62.7	1,746	<0.5	13.2	NA
Average	4,856	884	156	28,094	61.7	1,745	<0.5	13.3	341,824

the treatment system. At the time of backwash, the treated water from the lead and lag vessels contained no more than 0.6 and 0.1 µg/L of arsenic, respectively. Backwash water analytical data indicated more arsenic from the lead vessel (i.e., 10.9 vs. 1.3 µg/L) due to more arsenic loading. The majority of the total arsenic in the backwash water was in the soluble form. Based on the TSS levels (120 and 62 mg/L) and the quantity of backwash water produced (240 gal/vessel), approximately 165g of solids was discharged during the backwash event. Because titanium was not analyzed, its amount in backwash wastewater could not be estimated. However, based on the amounts measured in backwash solids, over 34% of the solids could be present as titanium.

4.5.7 Distribution System Water Sampling. Prior to the installation/operation of the three POE treatment system, first draw baseline distribution system water samples were collected at three locations on July 13, August 4, August 24, and September 14, 2005. Following the installation of the treatment system, distribution water sampling continued on a monthly basis until April 4, 2007. Table 4-24 summaries results of the distribution system sampling.

Table 4-24. Distribution System Sampling Results

		DS1								DS2								DS3							
	Address	**Purvine Hall**								**College Union**								**Residence Hall**							
	Sample Type	**LCR**								**LCR**								**LCR**							
	Flushed / 1st Draw	**1st Draw**								**1st Draw**								**1st Draw**							
No. of Sampling Events	**Sampling Date**	**Stagnation Time (hr)**	**pH (S.U.)**	**Alkalinity (mg/L as $CaCO_3$)**	**As (µg/L)**	**Fe (µg/L)**	**Mn (µg/L)**	**Pb (µg/L)**	**Cu (µg/L)**	**Stagnation Time (hr)**	**pH (S.U.) (mg/L as $CaCO_3$)**	**Alkalinity**	**As (µg/L)**	**Fe (µg/L)**	**Mn (µg/L)**	**Pb (µg/L)**	**Cu (µg/L)**	**Stagnation Time (hrs)**	**pH (S.U.)**	**Alkalinity (mg/L as $CaCO_3$)**	**As (µg/L)**	**Fe (µg/L)**	**Mn (µg/L)**	**Pb (µg/L)**	**Cu (µg/L)**
BL1	07/13/05	14.8	7.6	110	27.0	<25	<0.1	0.4	98	15.1	7.7	110	36.0	<25	0.3	0.6	224	15.2	7.3	110	28.1	<25	<0.1	0.3	91
BL2	08/04/05	17.0	7.5	110	26.6	<25	<0.1	1.4	94	16.4	7.6	128	26.3	<25	0.2	0.5	138	16.3	7.6	110	26.3	<25	<0.1	0.7	88
BL3	08/24/05	15.7	7.8	110	35.4	<25	1.2	0.4	63	16.0	7.8	114	33.0	<25	0.6	0.4	81	13.9	7.8	110	32.1	<25	0.2	0.6	72
BL4	09/14/05	15.3	7.7	110	25.6	<25	<0.1	0.8	101	15.7	7.7	106	28.3	<25	0.2	0.6	208	16.0	7.7	114	26.0	<25	<0.1	0.4	95
1	01/25/06	10.3	7.7	119	1.7	<25	1.0	0.2	155	NS	NS	NS	NS	NS	NS	NS	NS	9.8	7.7	114	1.2	<25	2.3	0.2	177
2	03/02/06	10.2	7.9	112	1.5	<25	0.4	0.1	40	15.8	7.5	104	0.8	<25	<0.1	0.1	97	16.0	7.9	112	0.9	<25	<0.1	<0.1	87
3	03/30/06	15.1	7.9	112	1.4	<25	1.1	1.5	160	16.3	7.7	108	1.3	<25	0.8	1.3	448	16.1	8.0	112	0.6	<25	0.4	0.4	117
4	04/26/06	14.9	7.9	112	0.7	<25	0.4	0.9	106	15.1	7.8	112	0.5	<25	<0.1	0.4	223	15.6	8.0	112	0.8	<25	<0.1	0.3	110
5	05/25/06	15.0	7.7	112	0.7	<25	0.5	0.1	53	15.0	7.7	108	0.2	<25	<0.1	0.1	41	15.2	7.8	112	0.5	<25	<0.1	<0.1	44
6	06/21/06	14.9	7.9	112	0.6	<25	0.4	0.1	100	15.0	7.8	112	0.2	<25	<0.1	0.1	98	15.6	7.8	112	0.6	<25	<0.1	0.3	87
7	08/17/06	19.6	7.7	111	0.5	<25	0.5	1.3	137	19.8	7.9	117	1.4	<25	0.4	1.6	119	19.8	7.9	113	1.5	<25	<0.1	0.9	115
8	08/31/06	NA	7.9	124	0.8	<25	0.6	1.4	167	7.8	7.9	120	0.7	<25	0.2	1.2	121	7.6	7.8	118	1.0	<25	0.4	0.7	109
9	09/13/06	15.3	7.8	137	0.6	<25	0.4	1.3	171	15.5	7.9	123	1.0	<25	0.2	1.4	199	18.0	7.8	123	1.4	<25	<0.1	1.0	110
10	10/11/06	15.3	7.8	124	0.6	<25	<0.1	0.5	106	15.3	7.8	120	0.3	<25	<0.1	0.3	165	16.6	7.8	129	3.5	<25	<0.1	0.3	103
11	11/16/06	15.3	7.6	135	0.7	<25	0.3	0.1	89	15.3	7.7	124	0.4	<25	<0.1	0.1	135	15.5	7.8	133	9.9	<25	<0.1	0.2	90
12	12/13/06	15.0	7.7	115	<0.1	<25	0.4	<0.1	44	14.1	7.8	119	<0.1	<25	<0.1	<0.1	72	15.3	7.8	126	12.7	<25	<0.1	<0.1	49
13	01/10/07	16.0	8.0	124	0.8	<25	0.3	0.5	94	15.3	8.1	123	0.4	<25	<0.1	0.6	129	15.3	8.0	124	17.0	<25	<0.1	0.4	85
14	02/07/07	14.8	8.1	121	0.7	<25	0.3	0.5	73	14.8	8.1	123	0.4	<25	<0.1	0.5	101	14.6	8.0	123	1.3	<25	<0.1	1.0	99
15	03/08/07	15.0	8.0	124	0.6	<25	<0.1	0.4	126	15.7	8.1	124	3.6	<25	<0.1	0.7	92	15.1	8.0	124	0.7	<25	<0.1	0.5	86
16	04/04/07	15.4	8.0	124	7.3	<25	<0.1	1.0	77	15.6	8.0	117	0.5	<25	<0.1	0.5	126	15.3	8.1	117	0.6	<25	0.2	0.4	76

BL = baseline sampling; NA = not available

Lead action level = 15 µg/L; copper action level = 1.3 mg/L

The most noticeable change in the distribution water samples after system startup was decreases in arsenic concentration at all three locations. Baseline arsenic concentrations for all three locations ranged from 25.6 to 36.0 µg/L and averaged 29.2 µg/L. After system startup, arsenic concentrations ranged from <0.1 to 1.7 µg/L and averaged 0.8 µg/L (excluding one outlier at 7.3 µg/L on April 4, 2007) in Purvine Hall and ranged from <0.1 to 1.4 µg/L and averaged 0.6 µg/L (excluding one outlier at 3.6 µg/L on March 8, 2007) in the College Union. Distribution system water samples in the Residence Hall essentially mirrored ARM 200 system effluent (although arsenic concentrations in the distribution system water samples taken during the first several months of system operation were, in general, higher than those in the system efflent, suggesting resuspension, solublization, and/or desorption of arsenic-laden particles/scales in the distribution system). Arsenic concentrations exceeded the 10 µg/L MCL on December 13, 2006 and January 10, 2007, before the lead vessel was rebedded with ARM 300 on January 24, 2007.

Post-baseline lead concentrations ranged from <0.1 to 1.6 µg/L, with none of the samples exceeding the action level of 15 µg/L. Post-baseline copper concentrations ranged from 39.7 to 448 µg/L across all sampling locations, with no sample exceeding the 1,300 µg/L action level. The arsenic treatment systems do not seem to affect lead or copper concentrations in the distribution system.

Measured pH values ranged from 7.5 to 8.1 and averaged 7.9 at all three locations. Alkalinity levels ranged from 104 to 137 mg/L (as $CaCO_3$). The arsenic treatment systems do not seem to affect these water quality parameters in the distribution system.

4.5.8 Spent Media Sampling. Three ARM 200 spent media samples were collected from the top, middle, and bottom of the lead vessel in the Residence Hall during the media changeout on January 24, 2007. Tables 4-25 and 4-26 present metals and TCLP results, respectively. Arsenic, barium, and chromium were detected at concentrations slightly higher than their respective detection limit. The other TCLP metals were less than the respective MDLs. Because the media passed the TCLP test, it can be disposed of as non-hazardous waste.

The ICP-MS results of the spent media indicated that the media contained mostly iron at 569 mg (as Fe)/g of dry media or 56.9% by weight. The chemical formula that best represents the iron media was not available from the product literature. The spent media also contained trace levels of Al, Ca, Cu, Mg, Mn, P, and Si at 0.58, 11.8, 0.65, 1.0, 1.7, 0.54, and 0.42 mg/g, respectively. Some of these elements were detected in inlet water and apparently were removed by ARM 200 media. The spent media also removed some Al, Cu, Pb, and Zn from inlet water, as evidenced by the decreasing loadings from the top to the bottom of the media bed. It is not clear what mechanisms were involved in the removal of these cations.

The arsenic loading on the spent media based on the ICP-MS results was 0.83 mg/g (average across bed from Table 4-25). For comparison to the spent media results, the adsorptive capacity was calculated by dividing the arsenic mass removed by the amount of dry media in the lead vessel. The arsenic mass removed was estimated by multiplying the average throughput to the 10-µg/L breakthrough (15,490 BV, see Table 4-21) by the average arsenic level in inlet water (29.7 µg/L). The dry weight of the media, i.e., 874 lb, was calculated based on a wet weight of 950 lb (i.e., 20 ft^3 of media at 47.5 lb/ft^3) and a moisture content of 8% (Table 4-3). Using this approach, the arsenic loading for the spent media was 0.66 mg/g of dry media. The ICP-MS analysis appeared to over-recover by 26%.

4.6 System Cost

The system cost was evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. Capital cost for the treatment system included the expenditure for equipment, site engineering, and system installation, shakedown, and startup. O&M cost included the

Table 4-25. ARM 200 Media Metals Results

Metals	Unit	Sampling Location		
		Top	Middle	Bottom
Aluminum	µg/g	1,191 1,244	175 143	320 396
Arsenic	µg/g	854 926	825 837	779 726
Cadmium	µg/g	<0.5 <0.5	<0.5 <0.5	<0.5 <0.5
Calcium	µg/g	12,098 13,056	11,652 11,925	11322 10617
Copper	µg/g	1,806 1,871	71.6 73.6	45.3 41.6
Iron	µg/g	403,334 436,097	403,582 413,431	407,958 378,185
Lead	µg/g	11.9 12.8	5.9 6.4	3.8 3.5
Magnesium	µg/g	943 1,009	927 941	1231 1171
Manganese	µg/g	1,745 1,880	1,692 1,711	1702 1587
Nickel	µg/g	130 143	146 151	126 116
Phosphorus	µg/g	570 603	514 548	487 488
Silica	µg/g	463 498	423 472	382 293
Zinc	µg/g	724 765	196 208	133 123

Table 4-26. Spent Media TCLP Results

Analyte	As	Ba	Cd	Cr	Pb	Hg	Se	Ag
Concentration (mg/L)	0.18	0.84	< 0.010	0.012	< 0.050	< 0.0020	< 0.10	< 0.010

expenditure for media replacement and labor. The cost associated with the plumbing modification was not included in the capital cost because it was out of the scope of the demonstration project, and was funded separately by OIT.

4.6.1 Capital Cost. The total capital investment for the Kinetico POE systems and POU units was $198,958, which included $142,448 (71.6%) for equipment, $33,560 (16.9%) for site engineering, and $22,950 (11.5%) for installation. Table 4-27 presents cost breakdowns provided by the vendor. The equipment cost was broken down for major cost components such as adsorptive media, filter vessels, hydropneumatic tank, process valves and piping, labor, and shipping for each system.

The site engineering cost included the cost for preparing a process design report and required engineering plans, including a general arrangement drawing, piping and instrumentation diagram (P&ID), inter-connecting piping layouts, tank fill details, and other associated drawings. After being certified and stamped by an Oregon-registered professional engineer, the plans were submitted to Oregon DHS for permit review and approval.

Table 4-27. Capital Investment Cost for Kinetico POE/POU Treatment Systems

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
30-gpm ArsenX^{np} System in Purvine Hall			
Fiberglass Adsorption Tanks & Internals	2	$6,901	–
ArsenX^{np} Media	20 ft^3	$12,728	
132-gal Hydropneumatic Tank	1	$4,246	
Process Valve and Piping	1	$5,597	–
Additional Sample Taps/Totalizer/Meters	1	$7,465	–
Subtotal	–	*$36,937*	–
60-gpm ARM 200/ARM 300/E33-S System in Residence Hall			
Fiberglass Adsorption Tanks & Internals	2	$7,237	–
ARM 200 Media	40 ft^3	$20,002	
132-gal Hydropneumatic Tank	1	$4,246	
Process Valve and Piping	1	$3,543	–
Additional Sample Taps/Totalizer/Meters	1	$4,349	–
Subtotal	–	*$39,377*	–
60-gpm Adsorbsia™ GTO™ System in College Union			
Fiberglass Adsorption Tanks & Internals	2	$7,237	–
Adsorbsia Media	40 ft^3	$29,093	
132-gal Hydropneumatic Tank	1	$4,246	
Process Valve and Piping	1	$3,543	–
Additional Sample Taps/Totalizer/Meters	1	$4,349	–
Subtotal	–	*$48,468*	–
POU Units			
Kinetico POU Cartridges	8	$1,216	
AdEdge POU Cartridges	*48*	$9,120	Paid by OIT
Subtotal	–	*$10,336*	–
Shipping	–	$4,250	
Labor	–	$3,080	
Equipment Total	–	**$142,448**	**71.6%**
Engineering Cost			
Vendor Labor	–	$20,760	–
Vendor Travel	–	$2,150	
Subcontractor Labor		$3,000	
System Startup Vendor Labor		$5,500	
System Startup Vendor Travel		$2,150	
Site Engineering Total	–	**$33,560**	**16.9%**
Installation Cost[(a)]			
Vendor Labor	–	$3,300	–
Vendor Travel	–	$1,650	–
Subcontractor Labor	–	$18,000	–
Installation Total	–	**$22,950**	**11.5%**
Total Capital Investment	–	**$198,958**	**100%**

(a) Not including cost for installing 48 AdEdge POU units.

The installation cost included labor and materials for system unloading and anchoring, plumbing, mechanical connections, media loading, system startup and shakedown, and operator's training (see Section 4.3).

To calculate the normalized capital cost based on the design capacity of each POE system, the composite engineering cost and installation cost provided by the vendor were broken down proportionally for each system based on the ratio calculated from their equipment cost breakdown. The rearranged cost breakdowns for each POE system are summarized in Table 4-28.

Table 4-28. Rearranged Capital Investment Cost for Each Kinetico POE System

Location	POE System	Capital Cost			
		Equipment[(a)]	Engineering	Installation	Total
Purvine Hall	30-gpm ArsenX^{np}	$39,108	$9,941	$6,798	$55,847
Residence Hall	60-gpm ARM 200	$41,689	$10,587	$7,240	$59,516
College Union	60-gpm Adsorbsia™ GTO™	$51,314	$13,032	$8,912	$73,258
	Total	$132,111	$33,560	$22,950	$188,621

(a) Including shipping and labor cost.

4.6.1.1 ArsenX^{np} System. The capital cost of $55,847 was normalized to $1,862/gpm ($1.29/gpd) of design capacity using the system's rated capacity of 30 gpm (or 43,200 gpd). The capital cost also was converted to an annualized cost of $5,271/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-yr return period. Assuming that the system operated 24 hr/day, 7 day/wk, and 365 day/yr at the design flowrate of 30 gpm, the unit capital cost would be $0.33/1,000 gal. During the system performance evaluation, the system treated an average of 489,480 gal/yr (see Table 4-12); at this reduced rate of usage, the unit capital cost increased to $10.77/1,000 gal.

4.6.1.2 ARM 200 System. The capital cost of $59,516 was normalized to $992/gpm ($0.69/gpd) of design capacity using the system's rated capacity of 60 gpm (or 86,400 gpd). The capital cost also was converted to an annualized cost of $5,618/yr using a CRF of 0.09439 based on a 7% interest rate and a 20-yr return period. Assuming that the system operated 24 hr/day, 7 day/wk, and 365 day/yr at the design flowrate of 60 gpm, the unit capital cost would be $0.18/1,000 gal. The system was operated on demand, producing 6,698,103 gal of water in 406 days during the ARM 200 test (see Table 4-12). At this reduced rate of operation (i.e., 6,021,694 gal/yr), the unit capital cost increased to $0.93/1,000 gal.

4.6.1.3 Adsorbsia™ GTO™ System. The capital cost of $73,258 was normalized to $1,221/gpm ($0.85/gpd) of design capacity using the system's rated capacity of 60 gpm (or 86,400 gpd). The capital cost also was converted to an annualized cost of $6,915/yr using a CRF of 0.09439 based on a 7% interest rate and a 20-yr return period. Assuming that the system operated 24 hr/day, 7 day/wk, and 365 day/yr at the design flowrate of 60 gpm, the unit capital cost would be $0.22/1,000 gal. During the evaluation study, the system produced 5,889,749 gal of water in 1,286 days (or 1,671,663 gal/yr; see Table 4-12); at this reduced rate of usage, the unit capital cost increased to $4.14/1,000 gal.

4.6.2 Operation and Maintenance Cost. The O&M cost included the cost for replacing media and the cost of labor to operate the systems, as summarized in Table 4-29 for the three POE systems. Media replacement is a major cost for operating an adsorptive media system. According to vendor estimates, it would cost $11,900 to replace 20 ft^3 of ArsenX^{np}, $18,700 to replace 40 ft^3 of ARM 200, $12,000 to replace 40 ft^3 of E33-S, and $27,100 to replace 40 ft^3 of Adsorbsia™ GTO™. Therefore, the unit cost from the lowest to the highest would be $300/ft^3 for E33-S, $468/ft^3 for ARM 200, $595/ft^3 for ArsenX^{np}, and $678/ft^{3}for Adsorbsia™ GTO™. These estimates do not include the cost for labor, travel, freight, spent media analysis, and media disposal. These costs are expected to be similar regardless of the media type.

Table 4-29. Operation and Maintenance Cost for POE systems

POE Location	Purvine Hall	Residence Hall		College Union
Media Replacement Cost[(a)(b)]				
Media Type	ArsenX^{np}	ARM 200	E33-S	Adsorbsia™ GTO™
Media Volume (ft^3)	20	40	40	40
Media Cost ($)	$11,900	$18,700	$12,000	$27,100
Media Unit Cost ($/ft^3)	$595	$468	$300	$678
Normalized Media Cost ($/1,000 gal)	See Figure 4-36			
Labor Cost				
Average Weekly Labor (hr/wk)	2.5	2.5	2.5	2.5
Average Annual Labor (hr/yr)	130	130	130	130
Labor Rate ($/hr)	$21	$21	$21	$21
Annual Labor Cost ($/yr)	$2,730	$2,730	$2,730	$2,730
Annual Throughput (gal/yr)	489,480	6,021,694	6,410,130	1,671,662
Unit Labor Cost ($/1,000)	$5.58	$0.45	$0.43	$1.63

(a) Cost for labor, travel, freight, spent media analysis, and media disposal fee not included in quote, but expected to be similar regardless of media type.
(b) Media quote provided by Kinetio in August 2005 except for E33-S, which was provided by a local vendor.

Based on the actual cost incurred to replace 20 ft^3 of ARM 200 at the Residence Hall in February 2007, the media cost was $7,700 and the labor and travel cost for emptying one vessel, disposing spent media, and reloading the new media was $3,500. The labor cost could be less if a local vendor was hired for the job with the assistance of the operator. To help select the most cost-effective media, a cost curve was constructed for each media type in terms of media cost per 1,000 gal of water treated as a function of the projected media run length to the 10-µg/L arsenic breakthrough (Figure 4-28). For example, the average ARM 200 media run length at the Residence Hall was 13,490 BV (Table 4-21), so the media cost based on Figure 4-28 was approximately $4/1,000 gal. The actual media replacement cost incurred was $11,200, which translated to $5.55/1,000 gal.

Under normal conditions, routine labor activities to operate and maintain each POE system consumed 30 min per day on average, or 2.5 hr for a five-day week. Based on this time commitment and a labor rate of $21/hr, the annual labor cost was estimated to be $2,730 to operate each POE system. Depending on the annual water production of each POE system, the normalized labor cost was $5.58/1,000 gal for the Purvine Hall system and $1.63/1,000 gal for the College Union system. At Residence Hall, the estimated labor cost was similar for the ARM 200 and E33-S media runs, which was $0.45/1,000 gal and $0.43/1,000 gal, respectively.

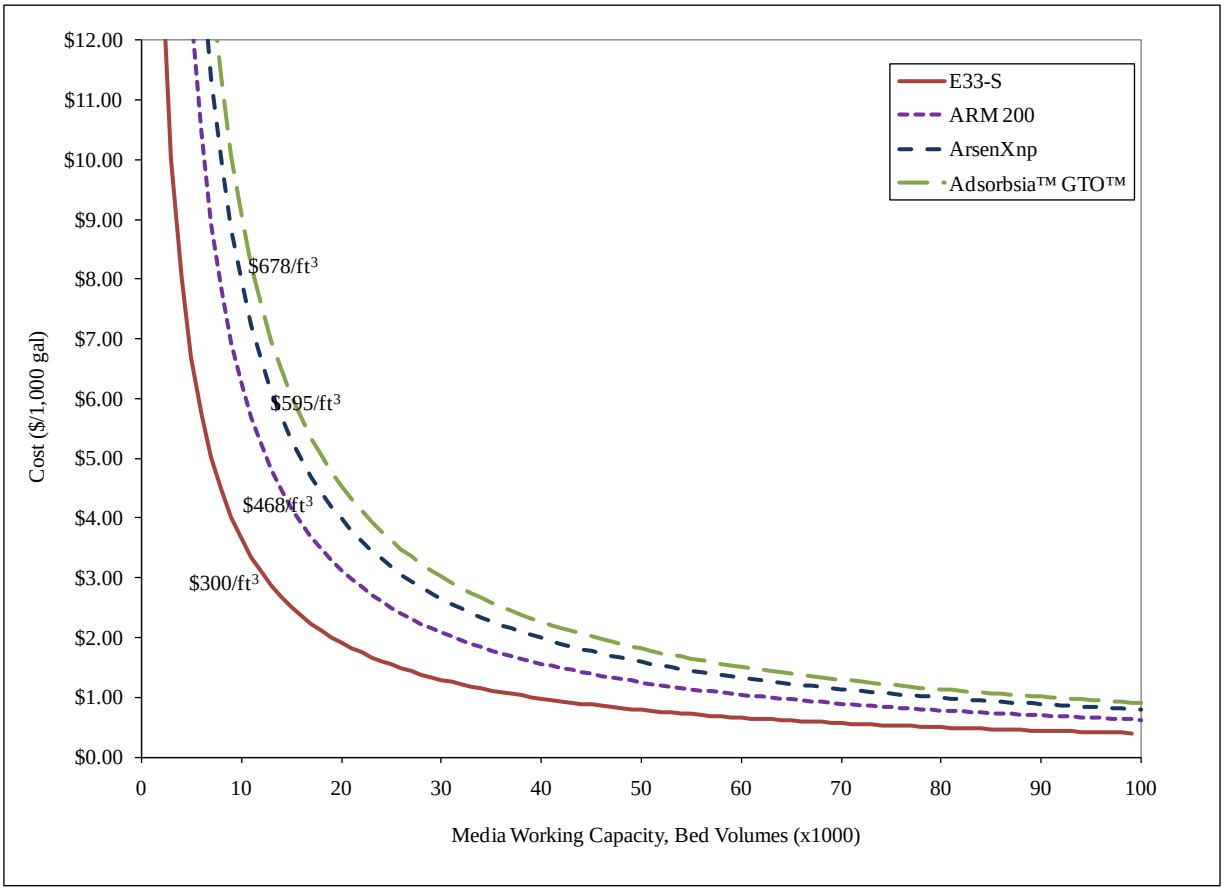

Figure 4-28. Media Replacement Cost Curves for POE System

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APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet

				Treatment System															
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
1	Mon	12/12/05	7:50	15 Test	3,521	NA	NA	NA	15 Test	3,691	NA	NA	NA	NA			30 Test	NA	NA
	Tue	12/13/05	8:00	2	4,026	505	505	14	2	4,276	585	585	16	80	80	2	4	1,090	15
	Wed	12/14/05	13:45	0	4,591	565	1,070	29	0	4,932	656	1,241	33	91	171	5	0	2,311	31
	Thu	12/15/05	11:30	0	5,029	438	1,508	40	0	5,550	618	1,859	50	180	351	9	0	3,367	45
	Fri	12/16/05	9:00	0	5,590	561	2,069	55	0	6,008	458	2,317	62	(103)	248	7	0	4,386	59
2	Mon	12/19/05	15:05	15 Test	7,039	1,449	3,518	94	15 Test	7,768	1,760	4,077	109	311	559	15	30 Test	7,595	102
	Tue	12/20/05	8:40	0	7,542	503	4,021	107	0	8,220	452	4,529	121	(51)	508	14	0	8,550	114
	Wed	12/21/05	8:10	0	7,906	364	4,385	117	0	9,018	798	5,327	142	434	942	25	0	9,712	130
	Thu	12/22/05	8:40	0	8,408	502	4,887	131	0	9,972	954	6,281	168	452	1,394	37	0	11,168	149
	Fri	12/23/05	8:15	0	8,834	426	5,313	142	0.5	10,820	848	7,129	191	422	1,816	49	1	12,442	166
3	Tue	12/27/05	8:55	0	10,389	1,555	6,868	184	0	13,113	2,293	9,422	252	738	2,554	68	0	16,290	218
	Wed	12/28/05	22:20	0	10,780	391	7,259	194	0	13,688	575	9,997	267	184	2,738	73	0	17,256	231
	Thu	12/29/05	22:15	0	11,566	786	8,045	215	0	14,744	1,056	11,053	295	270	3,008	80	0	19,098	255
4	Tue	01/03/06	10:00	0	16,085	4,519	12,564	336	0	20,693	5,949	17,002	455	1,430	4,438	119	0	29,566	395
	Wed	01/04/06	16:04	13.5 Test	16,543	458	13,022	348	4.5 Test	21,322	629	17,631	471	171	4,609	123	28 Test	30,653	410
	Thu	01/05/06	8:30	0	16,984	441	13,463	360	0	21,781	459	18,090	484	18	4,627	124	0	31,553	422
	Fri	01/06/06	15:00	0	17,382	398	13,861	371	0	22,480	699	18,789	502	301	4,928	132	0	32,650	436
5	Mon	01/09/06	9:10	0	18,785	1,403	15,264	408	0	24,485	2,005	20,794	556	602	5,530	148	0	36,058	482
	Tue	01/10/06	15:00	0	19,692	907	16,171	432	0	25,846	1,361	22,155	592	454	5,984	160	0	38,326	512
	Wed	01/11/06	13:40	1	20,573	881	17,052	456	1	26,925	1,079	23,234	621	198	6,182	165	2	40,286	539
	Thu	01/12/06	15:17	0	21,600	1,027	18,079	483	0	28,654	1,729	24,963	667	702	6,884	184	0	43,042	575
	Fri	01/13/06	8:35	0	22,050	450	18,529	495	0	29,072	418	25,381	679	(32)	6,852	183	0	43,910	587
6	Tue	01/17/06	11:50	0	24,218	2,168	20,697	553	0	32,342	3,270	28,651	766	1,102	7,954	213	0	49,348	660
	Wed	01/18/06	14:00	2	25,198	980	21,677	580	2	33,671	1,329	29,980	801	349	8,303	222	4	51,657	691
	Thu	01/19/06	12:15	0	25,802	604	22,281	596	0	34,472	801	30,781	823	197	8,500	227	0	53,062	709
	Fri	01/20/06	12:15	0	26,500	698	22,979	614	0	35,354	882	31,663	846	184	8,684	232	0	54,642	730
7	Mon	01/23/06	16:10	0	28,195	1,695	24,674	660	0	37,948	2,594	34,257	916	899	9,583	256	0	58,931	788
	Tue	01/24/06	9:07	13 Test	28,600	405	25,079	670	15 Test	38,720	772	35,029	936	367	9,950	266	27 Test	60,108	803
	Wed	01/25/06	10:30	0	29,492	892	25,971	694	0	39,980	1,260	36,289	970	368	10,318	276	0	62,260	832
	Thu	01/26/06	9:50	0	30,190	698	26,669	713	0	41,092	1,112	37,401	1,000	414	10,732	287	0	64,070	856
	Fri	01/27/06	8:15	0	30,854	664	27,333	731	0	42,081	989	38,390	1,026	325	11,057	296	0	65,723	879
8	Mon	01/30/06	10:40	0	32,545	1,691	29,024	776	0	44,564	2,483	40,873	1,093	792	11,849	317	0	69,897	934
	Tue	01/31/06	10:00	2	33,324	779	29,803	797	2	45,690	1,126	41,999	1,123	347	12,196	326	4	71,802	960
	Wed	02/01/06	8:05	5 Test	33,930	606	30,409	813	12 Test	46,630	940	42,939	1,148	334	12,530	335	17 Test	73,348	980
	Thu	02/02/06	7:42	4	35,135	1,205	31,614	845	3	48,100	1,470	44,409	1,187	265	12,795	342	7	76,023	1,016
	Fri	02/03/06	11:45	0.5	35,387	252	31,866	852	0.5	48,240	140	44,549	1,191	(112)	12,683	339	1	76,415	1,021

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System															
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
9	Mon	02/06/06	10:46	1	38,243	2,856	34,722	928	1	51,347	3,107	47,656	1,274	251	12,934	346	2	82,378	1,101
	Tue	02/07/06	8:19	0	39,183	940	35,662	953	0	52,370	1,023	48,679	1,301	83	13,017	348	0	84,341	1,127
	Wed	02/08/06	7:45	0	40,136	953	36,615	979	0	53,410	1,040	49,719	1,329	87	13,104	350	0	86,334	1,154
	Thu	02/09/06	8:09	0	41,075	939	37,554	1,004	0	54,432	1,022	50,741	1,357	83	13,187	353	0	88,295	1,180
	Fri	02/10/06	11:15	8.5 Test	42,050	975	38,529	1,030	8.5 Test	55,515	1,083	51,824	1,385	108	13,295	355	17 Test	90,353	1,208
10	Mon	02/13/06	9:24	0.5	43,835	1,785	40,314	1,078	0.5	57,361	1,846	53,670	1,435	61	13,356	357	1	93,984	1,256
	Tue	02/14/06	9:48	2.5	44,855	1,020	41,334	1,105	5.5	58,435	1,074	54,744	1,464	54	13,410	359	8	96,078	1,284
	Fri	02/17/06	8:19	4	47,512	2,657	43,991	1,176	4	61,222	2,787	57,531	1,538	130	13,540	362	8	101,522	1,357
11	Mon	02/20/06	8:30	1	49,402	1,890	45,881	1,227	1	63,175	1,953	59,484	1,590	63	13,603	364	2	105,365	1,408
	Tue	02/21/06	13:50	1	50,575	1,173	47,054	1,258	1	64,418	1,243	60,727	1,623	70	13,673	366	2	107,781	1,441
	Wed	02/22/06	8:57	8	51,220	645	47,699	1,275	8	65,100	682	61,409	1,642	37	13,710	367	16	109,108	1,458
	Thu	02/23/06	7:50	3	52,210	990	48,689	1,302	3	66,115	1,015	62,424	1,669	25	13,735	367	6	111,113	1,485
	Fri	02/24/06	8:00	4	53,025	815	49,504	1,323	2	66,958	843	63,267	1,691	28	13,763	368	6	112,771	1,507
12	Mon	02/27/06	8:50	1	55,030	2,005	51,509	1,377	1	69,012	2,054	65,321	1,746	49	13,812	369	2	116,830	1,562
	Tue	02/28/06	9:10	1	56,090	1,060	52,569	1,405	1	70,071	1,059	66,380	1,775	(1)	13,811	369	2	118,949	1,590
	Wed	03/01/06	10:20	9	57,001	911	53,480	1,430	9	71,150	1,079	67,459	1,803	168	13,979	374	18	120,939	1,617
	Thu	03/02/06	7:55	7	58,031	1,030	54,510	1,457	7	72,255	1,105	68,564	1,833	75	14,054	376	14	123,074	1,645
	Fri	03/03/06	11:15	1	59,051	1,020	55,530	1,485	1	73,352	1,097	69,661	1,862	77	14,131	378	2	125,191	1,673
13	Mon	03/06/06	8:50	2	60,971	1,920	57,450	1,536	2	75,560	2,208	71,869	1,921	288	14,419	385	4	129,319	1,729
	Tue	03/07/06	8:28	2	62,074	1,103	58,553	1,565	2	76,532	972	72,841	1,947	(131)	14,288	382	4	131,394	1,756
	Wed	03/08/06	9:05	2	62,934	860	59,413	1,588	2	77,460	928	73,769	1,972	68	14,356	384	4	133,182	1,780
	Thu	03/09/06	8:15	2	63,920	986	60,399	1,615	2	78,510	1,050	74,819	2,000	64	14,420	386	4	135,218	1,807
	Fri	03/10/06	10:14	1	64,805	885	61,284	1,638	1	79,455	945	75,764	2,026	60	14,480	387	2	137,048	1,832
14	Mon	03/13/06	9:00	1	66,800	1,995	63,279	1,692	1	81,561	2,106	77,870	2,082	111	14,591	390	2	141,149	1,887
	Tue	03/14/06	9:25	0	68,002	1,202	64,481	1,724	0	82,850	1,289	79,159	2,116	87	14,678	392	0	143,640	1,920
	Wed	03/15/06	8:13	0.5	68,808	806	65,287	1,745	1	83,709	859	80,018	2,139	53	14,731	394	2	145,305	1,942
	Thu	03/16/06	8:00	3	69,868	1,060	66,347	1,774	3	84,827	1,118	81,136	2,169	58	14,789	395	6	147,483	1,971
	Fri	03/17/06	9:00	1	70,812	944	67,291	1,799	1	85,842	1,015	82,151	2,196	71	14,860	397	2	149,442	1,998
15	Mon	03/20/06	9:10	0	72,812	2,000	69,291	1,852	0	87,942	2,100	84,251	2,252	100	14,960	400	0	153,542	2,052
	Tue	03/21/06	8:15	0	73,606	794	70,085	1,874	0	88,792	850	85,101	2,275	56	15,016	401	0	155,186	2,074
	Wed	03/22/06	9:40	2	74,364	758	70,843	1,894	2	89,600	808	85,909	2,297	50	15,066	403	4	156,752	2,095
	Thu	03/23/06	13:40	0	75,172	808	71,651	1,916	0	90,458	858	86,767	2,320	50	15,116	404	0	158,418	2,118
	Fri	03/24/06	8:35	0	75,670	498	72,149	1,929	0	90,968	510	87,277	2,333	12	15,128	404	0	159,426	2,131
16	Mon	03/27/06	8:33	0	77,140	1,470	73,619	1,968	0	92,502	1,534	88,811	2,374	64	15,192	406	0	162,430	2,171
	Tue	03/28/06	13:05	0	77,700	560	74,179	1,983	0	93,082	580	89,391	2,390	20	15,212	407	0	163,570	2,186
	Wed	03/29/06	12:15	0	78,252	552	74,731	1,998	0	93,654	572	89,963	2,405	20	15,232	407	0	164,694	2,201
	Thu	03/30/06	15:00	7.5	78,880	628	75,359	2,015	7.5	94,322	668	90,631	2,423	40	15,272	408	15	165,990	2,219
	Fri	03/31/06	9:05	7.5	79,390	510	75,869	2,028	7.5	94,848	526	91,157	2,437	16	15,288	409	15	167,026	2,233

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System																
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
17	Mon	04/03/06	9:40	2	81,812	2,422	78,291	2,093	2	97,360	2,512	93,669	2,504	90	15,378	411	4	171,960	2,299
	Tue	04/04/06	9:00	12	83,100	1,288	79,579	2,127	12	98,710	1,350	95,019	2,540	62	15,440	413	24	174,598	2,334
	Wed	04/05/06	8:10	9	84,040	940	80,519	2,153	9	99,685	975	95,994	2,566	35	15,475	414	18	176,513	2,359
	Thu	04/06/06	11:03	8.5	86,870	2,830	83,349	2,228	8.5	102,610	2,925	98,919	2,645	95	15,570	416	17	182,268	2,436
	Fri	04/07/06	8:10	7.5	87,671	801	84,150	2,250	7.5	103,430	820	99,739	2,666	19	15,589	417	15	183,889	2,458
18	Mon	04/10/06	8:15	11	91,000	3,329	87,479	2,339	11	106,909	3,479	103,218	2,759	150	15,739	421	22	190,697	2,549
	Tue	04/11/06	8:20	4	92,534	1,534	89,013	2,380	4	108,512	1,603	104,821	2,802	69	15,808	423	8	193,834	2,591
	Wed	04/12/06	9:22	8.5	94,565	2,031	91,044	2,434	8.5	110,631	2,119	106,940	2,859	88	15,896	425	17	197,984	2,646
	Thu	04/13/06	7:55	2	95,935	1,370	92,414	2,471	2	112,048	1,417	108,357	2,897	47	15,943	426	4	200,771	2,684
	Fri	04/14/06	8:30	6.5	97,381	1,446	93,860	2,509	6.5	113,550	1,502	109,859	2,937	56	15,999	428	13	203,719	2,723
19	Mon	04/17/06	8:45	9.5	100,565	3,184	97,044	2,594	9.5	116,865	3,315	113,174	3,026	131	16,130	431	19	210,218	2,810
	Tue	04/18/06	8:10	3	102,290	1,725	98,769	2,641	3	118,920	2,055	115,229	3,081	330	16,460	440	6	213,998	2,861
	Wed	04/19/06	8:30	5	103,985	1,695	100,464	2,686	5	120,355	1,435	116,664	3,119	(260)	16,200	433	10	217,128	2,902
	Thu	04/20/06	8:10	3	105,400	1,415	101,879	2,724	3	121,860	1,505	118,169	3,159	90	16,290	436	6	220,048	2,941
	Fri	04/21/06	13:52	9	107,670	2,270	104,149	2,784	9	124,182	2,322	120,491	3,221	52	16,342	437	18	224,640	3,003
20	Mon	04/24/06	9:10	5	110,386	2,716	106,865	2,857	5	126,986	2,804	123,295	3,296	88	16,430	439	10	230,160	3,077
	Tue	04/25/06	8:30	4	111,800	1,414	108,279	2,895	4	128,433	1,447	124,742	3,335	33	16,463	440	8	233,021	3,115
	Wed	04/26/06	11:35	8.5	113,770	1,970	110,249	2,947	8.5	130,465	2,032	126,774	3,389	62	16,525	442	17	237,023	3,168
	Thu	04/27/06	14:17	1	115,810	2,040	112,289	3,002	1	132,570	2,105	128,879	3,446	65	16,590	444	2	241,168	3,224
	Fri	04/28/06	8:20	1	117,990	2,180	114,469	3,060	1	134,747	2,177	131,056	3,504	(3)	16,587	443	2	245,525	3,282
21	Mon	05/01/06	9:00	4	119,770	1,780	116,249	3,108	4	136,660	1,913	132,969	3,555	133	16,720	447	8	249,218	3,331
	Tue	05/02/06	8:15	10.5	121,728	1,958	118,207	3,160	10.5	138,005	1,345	134,314	3,591	(613)	16,107	431	21	252,521	3,375
	Wed	05/03/06	10:15	0	123,728	2,000	120,207	3,214	0	140,705	2,700	137,014	3,663	700	16,807	449	0	257,221	3,438
	Thu	05/04/06	10:00	2	124,824	1,096	121,303	3,243	2	141,390	685	137,699	3,681	(411)	16,396	438	4	259,002	3,462
	Fri	05/05/06	8:35	4	125,380	556	121,859	3,258	4	142,385	995	138,694	3,708	439	16,835	450	8	260,553	3,483
22	Mon	05/08/06	8:26	4	128,738	3,358	125,217	3,348	4	145,877	3,492	142,186	3,801	134	16,969	454	8	267,403	3,574
	Tue	05/09/06	9:03	11.5	130,802	2,064	127,281	3,403	11.5	148,005	2,128	144,314	3,858	64	17,033	455	23	271,595	3,630
	Wed	05/10/06	15:21	2	133,330	2,528	129,809	3,470	2	150,580	2,575	146,889	3,927	47	17,080	457	4	276,698	3,699
	Thu	05/11/06	7:23	0	133,400	70	129,879	3,472	0	150,650	70	146,959	3,929	0	17,080	457	0	276,838	3,701
	Fri	05/12/06	7:45	0	134,625	1,225	131,104	3,505	0	151,980	1,330	148,289	3,964	105	17,185	459	0	279,393	3,735
23	Mon	05/15/06	8:40	4	138,420	3,795	134,899	3,606	4	155,832	3,852	152,141	4,067	57	17,242	461	8	287,040	3,837
	Tue	05/16/06	9:00	7	140,108	1,688	136,587	3,652	7	157,585	1,753	153,894	4,114	65	17,307	463	14	290,481	3,883
	Wed	05/17/06	14:15	2	141,500	1,392	137,979	3,689	2	159,190	1,605	155,499	4,157	213	17,520	468	4	293,478	3,923
	Thu	05/18/06	15:30	1	142,445	945	138,924	3,714	1	160,078	888	156,387	4,181	(57)	17,463	467	2	295,311	3,947
	Fri	05/19/06	14:35	0	143,412	967	139,891	3,740	0	161,065	987	157,374	4,207	20	17,483	467	0	297,265	3,974
24	Mon	05/22/06	10:55	0	145,210	1,798	141,689	3,788	0	162,800	1,735	159,109	4,254	(63)	17,420	466	0	300,798	4,021
	Tue	05/23/06	10:00	0	146,310	1,100	142,789	3,817	0	164,018	1,218	160,327	4,286	118	17,538	469	0	303,116	4,052
	Wed	05/24/06	9:30	0	147,130	820	143,609	3,839	0	165,190	1,172	161,499	4,318	352	17,890	478	0	305,108	4,078
	Thu	05/25/06	13:50	0	148,750	1,620	145,229	3,883	0	166,030	840	162,339	4,340	(780)	17,110	457	0	307,568	4,111
	Fri	05/26/06	9:18	1	148,970	220	145,449	3,888	1	166,790	760	163,099	4,360	540	17,650	472	2	308,548	4,124

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System															
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
25	Tue	05/30/06	8:00	8	152,065	3,095	148,544	3,971	8	169,890	3,100	166,199	4,443	5	17,655	472	16	314,743	4,207
	Wed	05/31/06	8:40	6	153,605	1,540	150,084	4,012	6	171,554	1,664	167,863	4,488	124	17,779	475	12	317,947	4,250
	Thu	06/01/06	4:05	0	155,600	1,995	152,079	4,066	0	173,580	2,026	169,889	4,542	31	17,810	476	0	321,968	4,304
	Fri	06/02/06	7:30	2	156,370	770	152,849	4,086	2	174,365	785	170,674	4,563	15	17,825	477	4	323,523	4,325
26	Mon	06/05/06	2:42	7.5	160,450	4,080	156,929	4,195	7.5	178,535	4,170	174,844	4,674	90	17,915	479	15	331,773	4,435
	Tue	06/06/06	7:15	0	161,720	1,270	158,199	4,229	0	179,922	1,387	176,231	4,711	117	18,032	482	0	334,430	4,470
	Wed	06/07/06	8:14	12	162,970	1,250	159,449	4,263	12	181,100	1,178	177,409	4,743	(72)	17,960	480	24	336,858	4,503
	Thu	06/08/06	2:15	0	164,935	1,965	161,414	4,315	0	183,089	1,989	179,398	4,796	24	17,984	481	0	340,812	4,556
	Fri	06/09/06	10:24	2	166,143	1,208	162,622	4,348	2	184,300	1,211	180,609	4,828	3	17,987	481	4	343,231	4,588
27	Mon	06/12/06	8:53	4.4	169,633	3,490	166,112	4,441	4	187,829	3,529	184,138	4,923	39	18,026	482	8	350,250	4,682
	Tue	06/13/06	8:10	4	170,875	1,242	167,354	4,474	4	189,888	2,059	186,197	4,978	817	18,843	504	8	353,551	4,726
	Wed	06/14/06	8:16	0	172,280	1,405	168,759	4,512	0	190,600	712	186,909	4,997	(693)	18,150	485	0	355,668	4,754
	Thu	06/15/06	8:28	4.4	173,300	1,020	169,779	4,539	4.4	191,715	1,115	188,024	5,027	95	18,245	488	9	357,803	4,783
	Fri	06/16/06	8:35	4	174,400	1,100	170,879	4,568	4	192,900	1,185	189,209	5,058	85	18,330	490	8	360,088	4,813
28	Mon	06/19/06	10:30	1	177,630	3,230	174,109	4,655	1	196,409	3,509	192,718	5,152	279	18,609	498	2	366,827	4,903
	Tue	06/20/06	8:20	4	178,595	965	175,074	4,680	4	197,235	826	193,544	5,174	(139)	18,470	494	8	368,618	4,927
	Wed	06/21/06	8:00	7	181,345	2,750	177,824	4,754	7	199,355	2,120	195,664	5,231	(630)	17,840	477	14	373,488	4,992
	Thu	06/22/06	7:55	3	181,422	77	177,901	4,756	3	200,032	677	196,341	5,249	600	18,440	493	6	374,242	5,003
	Fri	06/23/06	8:10	4	181,500	78	177,979	4,758	4	200,610	578	196,919	5,265	500	18,940	506	8	374,898	5,011
29	Mon	06/26/06	11:00	2	185,730	4,230	182,209	4,871	2	205,201	4,591	201,510	5,387	361	19,301	516	4	383,719	5,129
	Tue	06/27/06	11:50	1	186,800	1,070	183,279	4,900	1	206,365	1,164	202,674	5,418	94	19,395	519	2	385,953	5,159
	Wed	06/28/06	9:30	9.5	187,870	1,070	184,349	4,928	9.5	207,520	1,155	203,829	5,449	85	19,480	521	19	388,178	5,189
	Thu	06/29/06	8:35	4	188,912	1,042	185,391	4,956	4	208,652	1,132	204,961	5,480	90	19,570	523	8	390,352	5,218
	Fri	06/30/06	9:32	0	190,200	1,288	186,679	4,991	0	210,046	1,394	206,355	5,517	106	19,676	526	0	393,034	5,254
30	Mon	07/03/06	14:04	1	193,040	2,840	189,519	5,067	1	213,130	3,084	209,439	5,599	244	19,920	533	2	398,958	5,333
	Wed	07/05/06	10:48	0	195,100	2,060	191,579	5,122	0	215,370	2,240	211,679	5,659	180	20,100	537	0	403,258	5,390
	Thu	07/06/06	8:24	4	195,950	850	192,429	5,144	4	216,290	920	212,599	5,684	70	20,170	539	8	405,028	5,414
	Fri	07/07/06	8:11	4	197,180	1,230	193,659	5,177	4	217,625	1,335	213,934	5,719	105	20,275	542	8	407,593	5,448
31	Mon	07/10/06	7:20	0	200,275	3,095	196,754	5,260	1	220,000	2,375	216,309	5,783	(720)	19,555	523	1	413,063	5,521
	Tue	07/11/06	7:25	2	201,390	1,115	197,869	5,290	2	222,180	2,180	218,489	5,841	1,065	20,620	551	4	416,358	5,566
	Wed	07/12/06	8:30	5	202,612	1,222	199,091	5,323	5	223,522	1,342	219,831	5,877	120	20,740	554	10	418,922	5,600
	Thu	07/13/06	7:45	0	203,685	1,073	200,164	5,351	0	224,680	1,158	220,989	5,908	85	20,825	557	0	421,153	5,630
32	Tue	07/19/06	14:10	1	209,980	6,295	206,459	5,520	1	231,820	7,140	228,129	6,099	845	21,670	579	2	434,588	5,809
	Wed	07/20/06	10:35	2	210,756	776	207,235	5,540	2	232,345	525	228,654	6,113	(251)	21,419	573	4	435,889	5,827
	Thu	07/21/06	10:00	1	211,620	864	208,099	5,563	1	233,280	935	229,589	6,138	71	21,490	575	2	437,688	5,851
	Fri	07/22/06	8:00	4	212,700	1,080	209,179	5,592	4	234,550	1,270	230,859	6,172	190	21,680	580	8	440,038	5,882

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System																
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
33	Mon	07/24/06	9:20	4	215,770	3,070	212,249	5,674	4	237,800	3,250	234,109	6,259	180	21,860	584	8	446,358	5,967
	Tue	07/25/06	15:00	2	217,070	1,300	213,549	5,709	2	239,205	1,405	235,514	6,296	105	21,965	587	4	449,063	6,003
	Wed	07/26/06	15:10	0	218,160	1,090	214,639	5,738	0	240,375	1,170	236,684	6,328	80	22,045	589	0	451,323	6,033
	Thu	07/27/06	15:00	0	219,350	1,190	215,829	5,770	0	241,660	1,285	237,969	6,362	95	22,140	592	0	453,798	6,066
	Fri	07/28/06	8:00	0	220,218	868	216,697	5,793	0	242,620	960	238,929	6,388	92	22,232	594	0	455,626	6,090
34	Mon	07/31/06	8:00	1	223,109	2,891	219,588	5,871	1	245,760	3,140	242,069	6,472	249	22,481	601	2	461,657	6,171
	Tue	08/01/06	7:30	1	224,530	1,421	221,009	5,909	1	247,020	1,260	243,329	6,505	(161)	22,320	597	2	464,338	6,207
	Wed	08/02/06	8:05	2	225,640	1,110	222,119	5,938	2	248,580	1,560	244,889	6,547	450	22,770	609	4	467,008	6,243
	Thu	08/03/06	14:30	0	227,410	1,770	223,889	5,986	0	250,420	1,840	246,729	6,596	70	22,840	611	0	470,618	6,291
	Fri	08/04/06	8:30	4	228,400	990	224,879	6,012	4	251,500	1,080	247,809	6,625	90	22,930	613	8	472,688	6,319
35	Mon	08/07/06	10:34	0	231,430	3,030	227,909	6,093	0	254,800	3,300	251,109	6,713	270	23,200	620	0	479,018	6,403
	Tue	08/08/06	7:45	0	232,125	695	228,604	6,112	0	255,548	748	251,857	6,733	53	23,253	622	0	480,461	6,422
	Wed	08/09/06	14:05	0	233,010	885	229,489	6,135	0	256,300	752	252,609	6,753	(133)	23,120	618	0	482,098	6,444
	Thu	08/10/06	16:55	0	234,525	1,515	231,004	6,176	0	258,135	1,835	254,444	6,802	320	23,440	627	0	485,448	6,489
	Fri	08/11/06	10:00	0	235,270	745	231,749	6,196	0	259,025	890	255,334	6,826	145	23,585	631	0	487,083	6,511
36	Tue	08/15/06	8:35	4	239,500	4,230	235,979	6,309	4	263,555	4,530	259,864	6,947	300	23,885	639	8	495,843	6,628
	Wed	08/16/06	10:00	6	240,655	1,155	237,134	6,340	6	264,820	1,265	261,129	6,981	110	23,995	641	12	498,263	6,660
	Thu	08/17/06	8:30	3	241,540	885	238,019	6,363	3	265,920	1,100	262,229	7,011	215	24,210	647	6	500,248	6,687
	Fri	08/18/06	8:15	0	242,739	1,199	239,218	6,395	0	267,080	1,160	263,389	7,042	(39)	24,171	646	0	502,607	6,718
37	Fri	08/25/06	15:55	0	250,210	7,471	246,689	6,595	0	275,170	8,090	271,479	7,258	619	24,790	663	0	518,168	6,926
38	Mon	08/28/06	7:55	0	252,740	2,530	249,219	6,663	0	277,915	2,745	274,224	7,331	215	25,005	668	0	523,443	6,997
	Tue	08/29/06	7:50	0	253,730	990	250,209	6,689	0	278,985	1,070	275,294	7,360	80	25,085	671	0	525,503	7,025
	Wed	08/30/06	12:20	0	254,937	1,207	251,416	6,721	0	280,290	1,305	276,599	7,395	98	25,183	673	0	528,015	7,058
	Thu	08/31/06	8::55	4	255,710	773	252,189	6,742	4	281,120	830	277,429	7,417	57	25,240	675	8	529,618	7,080
	Fri	09/01/06	7:50	2	256,730	1,020	253,209	6,769	2	282,225	1,105	278,534	7,446	85	25,325	677	4	531,743	7,108
39	Tue	09/05/06	7:55	0	260,760	4,030	257,239	6,877	0	286,585	4,360	282,894	7,563	330	25,655	686	0	540,133	7,220
	Fri	09/08/06	14:50	0	264,505	3,745	260,984	6,977	0	290,630	4,045	286,939	7,671	300	25,955	694	0	547,923	7,324
40	Mon	09/11/06	9:42	4	267,340	2,835	263,819	7,053	4	293,700	3,070	290,009	7,753	235	26,190	700	8	553,828	7,403
	Tue	09/12/06	10:04	0	268,310	970	264,789	7,079	0	294,750	1,050	291,059	7,781	80	26,270	702	0	555,848	7,430
	Wed	09/13/06	11:51	7.5	269,575	1,265	266,054	7,113	7.5	296,100	1,350	292,409	7,817	85	26,355	705	15	558,463	7,465
	Thu	09/14/06	11:00	0	270,555	980	267,034	7,139	0	297,165	1,065	293,474	7,846	85	26,440	707	0	560,508	7,492
	Fri	09/15/06	15:00	0	271,560	1,005	268,039	7,166	0	298,250	1,085	294,559	7,875	80	26,520	709	0	562,598	7,520
41	Mon	09/18/06	8:05	0	274,580	3,020	271,059	7,247	0	301,650	3,400	297,959	7,966	380	26,900	719	0	569,018	7,606
	Tue	09/19/06	7:35	0	275,630	1,050	272,109	7,275	0	302,660	1,010	298,969	7,993	(40)	26,860	718	0	571,078	7,634
	Wed	09/20/06	9:00	3	276,760	1,130	273,239	7,305	3	303,870	1,210	300,179	8,025	80	26,940	720	6	573,418	7,665
	Thu	09/21/06	7:55	0	277,750	990	274,229	7,331	0	304,900	1,030	301,209	8,053	40	26,980	721	0	575,438	7,692
	Fri	09/22/06	8:15	0	278,770	1,020	275,249	7,359	0	305,600	700	301,909	8,071	(320)	26,660	713	0	577,158	7,715

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System																
				Train 1					Train 2					Train2-Train1			Combined			
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
42	Mon	09/25/06	8:30	3	281,760	2,990	278,239	7,439	3	309,250	3,650	305,559	8,169	660	27,320	730	6	583,798	7,804
	Tue	09/26/06	8:15	1	283,200	1,440	279,679	7,477	1	310,790	1,540	307,099	8,210	100	27,420	733	2	586,778	7,844
	Wed	09/27/06	11:00	9	285,100	1,900	281,579	7,528	9	312,840	2,050	309,149	8,265	150	27,570	737	18	590,728	7,896
	Fri	09/29/06	9:00	6	287,760	2,660	284,239	7,599	6	315,720	2,880	312,029	8,342	220	27,790	743	12	596,268	7,970
43	Mon	10/02/06	8:30	0	290,270	2,510	286,749	7,666	0	318,432	2,712	314,741	8,414	202	27,992	748	0	601,490	8,040
	Tue	10/03/06	8:22	0	291,602	1,332	288,081	7,702	0	319,865	1,433	316,174	8,453	101	28,093	751	0	604,255	8,077
	Wed	10/04/06	8:25	0	292,871	1,269	289,350	7,736	0	321,222	1,357	317,531	8,489	88	28,181	753	0	606,881	8,112
	Thu	10/05/06	9:48	6	294,862	1,991	291,341	7,789	6	323,365	2,143	319,674	8,546	152	28,333	757	12	611,015	8,168
	Fri	10/06/06	9:00	0	295,739	877	292,218	7,812	0	324,308	943	320,617	8,572	66	28,399	759	0	612,835	8,192
44	Tue	10/10/06	10:05	2	299,990	4,251	296,469	7,926	2	328,870	4,562	325,179	8,693	311	28,710	768	4	621,648	8,310
	Wed	10/11/06	11:20	0	301,680	1,690	298,159	7,971	0	330,475	1,605	326,784	8,736	(85)	28,625	765	0	624,943	8,354
	Thu	10/12/06	15:35	1	303,000	1,320	299,479	8,006	1	332,100	1,625	328,409	8,780	305	28,930	773	2	627,888	8,393
	Fri	10/13/06	14:55	2	304,310	1,310	300,789	8,041	2	333,490	1,390	329,799	8,817	80	29,010	776	4	630,588	8,429
45	Wed	10/18/06	15:15	0	309,880	5,570	306,359	8,190	0	337,370	3,880	333,679	8,921	(1,690)	27,320	730	0	640,038	8,556
46	Wed	10/25/06	11:45	3	317,500	7,620	313,979	8,394	3	347,475	10,105	343,784	9,191	2,485	29,805	797	6	657,763	8,792
	Thu	10/26/06	9:55	1	318,610	1,110	315,089	8,424	1	348,650	1,175	344,959	9,222	65	29,870	799	2	660,048	8,823
	Fri	10/27/06	11:45	2	319,980	1,370	316,459	8,460	2	350,100	1,450	346,409	9,261	80	29,950	801	4	662,868	8,861
47	Mon	10/30/06	10:10	2	323,900	3,920	320,379	8,565	2	354,330	4,230	350,639	9,374	310	30,260	809	4	671,018	8,970
	Wed	11/01/06	11:30	0	326,300	2,400	322,779	8,629	0	356,840	2,510	353,149	9,441	110	30,370	812	0	675,928	9,035
48	Mon	11/05/06	7:30	0	330,772	4,472	327,251	8,749	0	361,640	4,800	357,949	9,570	328	30,698	821	0	685,200	9,159
	Thu	11/07/06	9:40	0	334,920	4,148	331,399	8,860	0	366,030	4,390	362,339	9,687	242	30,940	827	0	693,738	9,273
49	Tue	11/14/06	10:00	0	339,774	4,854	336,253	8,990	0	NA	NA	NA	NA	NA	NA	NA	0	NA	NA
	Wed	11/15/06	9:10	0	341,085	1,311	337,564	9,025	0	372,610	NA	368,919	9,863	NA	31,355	838	0	706,483	9,444
	Fri	11/17/06	11:35	0	344,750	3,665	341,229	9,123	0	376,470	3,860	372,779	9,966	195	31,550	843	0	714,008	9,544
50	Mon	11/20/06	8:30	4	347,320	2,570	343,799	9,191	4	379,220	2,750	375,529	10,040	180	31,730	848	8	719,328	9,615
	Wed	11/22/06	11:10	0	350,040	2,720	346,519	9,264	0	382,090	2,870	378,399	10,116	150	31,880	852	0	724,918	9,690
51	Mon	11/27/06	8:00	0	354,370	4,330	350,849	9,380	0	386,781	4,691	383,090	10,242	361	32,241	862	0	733,939	9,811
	Wed	11/29/06	14:25	0	357,090	2,720	353,569	9,452	0	389,625	2,844	385,934	10,318	124	32,365	865	0	739,503	9,885
	Fri	12/01/06	15:33	12	361,710	4,620	358,189	9,576	12	394,520	4,895	390,829	10,449	275	32,640	873	24	749,018	10,012
52	Mon	12/04/06	8:30	4	363,820	2,110	360,299	9,632	4	396,780	2,260	393,089	10,509	150	32,790	877	8	753,388	10,071
	Wed	12/06/06	7:50	2	365,570	1,750	362,049	9,679	2	398,620	1,840	394,929	10,558	90	32,880	879	4	756,978	10,119
53	Mon	12/11/06	14:10	0	368,850	3,280	365,329	9,767	0	402,100	3,480	398,409	10,651	200	33,080	884	0	763,738	10,209
	Wed	12/13/06	10:45	0	369,950	1,100	366,429	9,796	0	403,270	1,170	399,579	10,683	70	33,150	886	0	766,008	10,239
	Fri	12/15/06	11:10	3	371,280	1,330	367,759	9,832	3	404,800	1,530	401,109	10,723	200	33,350	892	6	768,868	10,278
54	Tue	12/19/06	15:10	0	373,370	2,090	369,849	9,888	0	406,940	2,140	403,249	10,781	50	33,400	893	0	773,098	10,334
55	Tue	01/02/07	9:20	0	380,410	7,040	376,889	10,076	0	414,500	7,560	410,809	10,983	520	33,920	907	0	787,698	10,529
	Fri	01/05/07	8:45	0	382,130	1,720	378,609	10,122	0	416,320	1,820	412,629	11,031	100	34,020	910	0	791,238	10,577
56	Tue	01/09/07	13:30	0	383,970	1,840	380,449	10,171	0	418,280	1,960	414,589	11,084	120	34,140	913	0	795,038	10,627
	Wed	01/10/07	10:22	0	384,700	730	381,179	10,191	0	418,730	450	415,039	11,096	(280)	33,860	905	0	796,218	10,643
	Fri	01/12/07	8:55	3	385,730	1,030	382,209	10,218	3	420,120	1,390	416,429	11,133	360	34,220	915	6	798,638	10,676

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System															
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
57	Tue	01/16/07	15:30	0	387,530	1,800	384,009	10,266	0	422,010	1,890	418,319	11,184	90	34,310	917	0	802,328	10,725
	Thu	01/18/07	14:02	0	388,910	1,380	385,389	10,303	0	423,430	1,420	419,739	11,221	40	34,350	918	0	805,128	10,762
	Fri	01/19/07	14:35	0	389,680	770	386,159	10,324	0	424,240	810	420,549	11,243	40	34,390	919	0	806,708	10,783
58	Mon	01/22/06	8:15	0	392,380	2,700	388,859	10,396	0	427,090	2,850	423,399	11,319	150	34,540	923	0	812,258	10,858
59	Mon	01/29/07	8:30	0	396,540	4,160	393,019	10,507	0	431,380	4,290	427,689	11,434	130	34,670	927	0	820,708	10,971
	Fri	02/02/07	8:30	0	400,070	3,530	396,549	10,601	0	435,000	3,620	431,309	11,531	90	34,760	929	0	827,858	11,066
60	Mon	02/05/07	8:00	2	401,080	1,010	397,559	10,628	2	436,060	1,060	432,369	11,559	50	34,810	931	4	829,928	11,094
	Wed	02/07/07	10:25	0	402,900	1,820	399,379	10,677	0	437,930	1,870	434,239	11,609	50	34,860	932	0	833,618	11,143
	Fri	02/09/07	10:43	0	404,500	1,600	400,979	10,720	0	439,570	1,640	435,879	11,653	40	34,900	933	0	836,858	11,186
61	Mon	02/12/07	8:35	0	405,630	1,130	402,109	10,750	0	440,760	1,190	437,069	11,685	60	34,960	935	0	839,178	11,217
	Wed	02/14/07	8:50	2	407,260	1,630	403,739	10,794	2	442,430	1,670	438,739	11,729	40	35,000	936	4	842,478	11,262
	Fri	02/16/07	11:55	1	409,210	1,950	405,689	10,846	1	444,460	2,030	440,769	11,784	80	35,080	938	2	846,458	11,315
62	Mon	02/19/07	8:50	0	410,420	1,210	406,899	10,878	0	445,730	1,270	442,039	11,818	60	35,140	939	0	848,938	11,348
	Wed	02/21/07	10:20	0	411,870	1,450	408,349	10,917	0	447,240	1,510	443,549	11,858	60	35,200	941	0	851,898	11,387
	Fri	02/23/07	15:30	0	413,380	1,510	409,859	10,957	0	448,840	1,600	445,149	11,901	90	35,290	943	0	855,008	11,429
63	Mon	02/26/07	14:52	1	414,780	1,400	411,259	10,995	1	450,300	1,460	446,609	11,940	60	35,350	945	2	857,868	11,467
	Wed	02/28/07	16:05	0	416,620	1,840	413,099	11,044	0	452,050	1,750	448,359	11,987	(90)	35,260	943	0	861,458	11,515
64	Mon	03/05/07	8:00	0	418,790	2,170	415,269	11,102	0	454,580	2,530	450,889	12,054	360	35,620	952	0	866,158	11,578
	Wed	03/07/07	11:07	2	420,300	1,510	416,779	11,142	2	456,180	1,600	452,489	12,097	90	35,710	955	4	869,268	11,620
	Fri	03/09/07	9:25	2	421,630	1,330	418,109	11,178	2	457,580	1,400	453,889	12,134	70	35,780	957	4	871,998	11,656
65	Mon	03/12/07	9:10	2	423,270	1,640	419,749	11,222	2	459,330	1,750	455,639	12,181	110	35,890	959	4	875,388	11,701
	Wed	03/14/07	7:45	0	425,000	1,730	421,479	11,268	0	461,180	1,850	457,489	12,231	120	36,010	963	0	878,968	11,749
	Fri	03/16/07	9:00	0	427,220	2,220	423,699	11,327	0	463,530	2,350	459,839	12,294	130	36,140	966	0	883,538	11,810
66	Mon	03/19/07	11:55	1	428,290	1,070	424,769	11,356	1	464,660	1,130	460,969	12,324	60	36,200	968	2	885,738	11,840
	Thu	03/22/07	9:05	0	430,030	1,740	426,509	11,402	0	466,400	1,740	462,709	12,370	-	36,200	968	0	889,218	11,886
67	Tue	03/27/07	8:25	0	431,790	1,760	428,269	11,450	0	468,360	1,960	464,669	12,423	200	36,400	973	0	892,938	11,936
	Thu	03/29/07	9:10	0	432,680	890	429,159	11,473	0	469,100	740	465,409	12,442	(150)	36,250	969	0	894,568	11,958
68	Mon	04/02/07	10:05	0	433,930	1,250	430,409	11,507	0	470,640	1,540	466,949	12,484	290	36,540	977	0	897,358	11,995
	Wed	04/04/07	11:40	2	435,360	1,430	431,839	11,545	2	472,160	1,520	468,469	12,524	90	36,630	979	4	900,308	12,035
	Fri	04/06/07	11:10	1	436,600	1,240	433,079	11,578	1	473,480	1,320	469,789	12,560	80	36,710	981	2	902,868	12,069
69	Mon	04/09/07	8:40	0	437,670	1,070	434,149	11,607	0	474,620	1,140	470,929	12,590	70	36,780	983	0	905,078	12,098
	Wed	04/11/07	15:00	0	439,665	1,995	436,144	11,660	0	476,735	2,115	473,044	12,647	120	36,900	986	0	909,188	12,153
	Fri	04/13/07	8:50	0	440,700	1,035	437,179	11,688	0	477,838	1,103	474,147	12,676	68	36,968	988	0	911,326	12,182
70	Mon	04/16/07	8:00	4	441,950	1,250	438,429	11,721	4	479,180	1,342	475,489	12,712	92	37,060	991	9	913,918	12,217
	Fri	04/20/07	8:00	0	445,041	3,091	441,520	11,804	0	482,435	3,255	478,744	12,799	164	37,224	995	0	920,264	12,301
71	Mon	04/23/07	14:30	0	446,500	1,459	442,979	11,843	0	483,890	1,455	480,199	12,838	(4)	37,220	995	0	923,178	12,340
	Wed	04/25/07	7:35	0	447,425	925	443,904	11,868	0	484,980	1,090	481,289	12,867	165	37,385	999	0	925,193	12,367
72	Mon	04/30/07	11:10	0	450,285	2,860	446,764	11,944	0	487,990	3,010	484,299	12,947	150	37,535	1,003	0	931,063	12,446
	Wed	05/02/07	11:55	1	452,010	1,725	448,489	11,990	1	489,810	1,820	486,119	12,996	95	37,630	1,006	2	934,608	12,493
73	Mon	05/07/07	8:10	0	454,600	2,590	451,079	12,059	0	492,550	2,740	488,859	13,069	150	37,780	1,010	0	939,938	12,564
	Wed	05/09/07	15:34	0	456,580	1,980	453,059	12,112	0	494,660	2,110	490,969	13,126	130	37,910	1,014	0	944,028	12,619
	Fri	05/11/07	8:15	0	457,450	870	453,929	12,136	0	495,580	920	491,889	13,150	50	37,960	1,015	0	945,818	12,643

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System																
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
74	Mon	05/14/07	15:20	0	458,960	1,510	455,439	12,176	0	497,170	1,590	493,479	13,193	80	38,040	1,017	0	948,918	12,684
	Thu	05/17/07	10:10	0	460,710	1,750	457,189	12,223	0	499,030	1,860	495,339	13,243	110	38,150	1,020	0	952,528	12,733
	Fri	05/18/07	15:15	0	461,630	920	458,109	12,247	0	500,000	970	496,309	13,269	50	38,200	1,021	0	954,418	12,758
75	Mon	05/21/07	14:15	0	463,130	1,500	459,609	12,287	0	501,600	1,600	497,909	13,311	100	38,300	1,024	0	957,518	12,799
	Wed	05/23/07	15:35	0	464,710	1,580	461,189	12,330	0	503,240	1,640	499,549	13,355	60	38,360	1,026	0	960,738	12,842
76	Tue	05/29/07	7:52	0	467,010	2,300	463,489	12,391	0	505,680	2,440	501,989	13,420	140	38,500	1,029	0	965,478	12,906
	Wed	05/30/07	14:50	0	468,060	1,050	464,539	12,419	0	506,790	1,110	503,099	13,450	60	38,560	1,031	0	967,638	12,935
	Fri	06/01/07	13:35	0	469,300	1,240	465,779	12,452	0	508,110	1,320	504,419	13,485	80	38,640	1,033	0	970,198	12,969
77	Mon	06/04/07	10:40	2	470,400	1,100	466,879	12,482	2	509,290	1,180	505,599	13,517	80	38,720	1,035	4	972,478	12,999
	Wed	06/06/07	9:55	0	471,795	1,395	468,274	12,519	0	510,630	1,340	506,939	13,553	(55)	38,665	1,034	0	975,213	13,036
	Thu	06/07/07	NA	4	472,480	685	468,959	12,537	4	511,440	810	507,749	13,574	125	38,790	1,037	8	976,708	13,056
78	Tue	06/12/07	10:45	0	475,170	2,690	471,649	12,609	0	514,370	2,930	510,679	13,653	240	39,030	1,043	0	982,328	13,131
	Fri	06/15/07	15:20	0	476,680	1,510	473,159	12,650	0	515,940	1,570	512,249	13,695	60	39,090	1,045	0	985,408	13,172
79	Mon	06/18/07	NA	0	477,652	972	474,131	12,676	0	516,990	1,050	513,299	13,723	78	39,168	1,047	0	987,430	13,199
80	Wed	06/27/07	9:55	0	480,790	3,138	477,269	12,759	0	520,365	3,375	516,674	13,813	237	39,405	1,053	0	993,943	13,286
	Fri	06/29/07	13:10	0	481,740	950	478,219	12,785	0	521,370	1,005	517,679	13,840	55	39,460	1,055	0	995,898	13,312
81	Mon	07/02/07	11:09	1	482,800	1,060	479,279	12,813	1	522,600	1,230	518,909	13,873	170	39,630	1,059	2	998,188	13,343
	Fri	07/06/07	8:00	0	484,150	1,350	480,629	12,849	0	523,965	1,365	520,274	13,909	15	39,645	1,060	0	1,000,903	13,379
82	Mon	07/09/07	3:05	0	485,200	1,050	481,679	12,877	0	525,170	1,205	521,479	13,941	155	39,800	1,064	0	1,003,158	13,409
	Wed	07/11/07	2:15	0	486,250	1,050	482,729	12,905	0	526,191	1,021	522,500	13,969	(29)	39,771	1,063	0	1,005,229	13,437
83	Mon	07/16/07	10:30	0	488,180	1,930	484,659	12,957	0	528,270	2,079	524,579	14,024	149	39,920	1,067	0	1,009,238	13,491
	Wed	07/18/07	12:10	0	489,300	1,120	485,779	12,987	0	529,440	1,170	525,749	14,056	50	39,970	1,069	0	1,011,528	13,521
84	Mon	07/23/07	8:00	0	491,080	1,780	487,559	13,035	0	531,320	1,880	527,629	14,106	100	40,070	1,071	0	1,015,188	13,570
	Wed	07/25/07	7:50	0	491,760	680	488,239	13,053	0	532,050	730	528,359	14,125	50	40,120	1,073	0	1,016,598	13,589
	Fri	07/27/07	8:30	0	492,525	765	489,004	13,073	0	532,849	799	529,158	14,147	34	40,154	1,073	0	1,018,162	13,610
85	Mon	07/30/07	8:30	0	493,420	895	489,899	13,097	0	533,840	991	530,149	14,173	96	40,250	1,076	0	1,020,048	13,635
	Wed	08/01/07	9:10	0	494,600	1,180	491,079	13,129	0	534,880	1,040	531,189	14,201	(140)	40,110	1,072	0	1,022,268	13,665
86	Mon	08/06/07	9:30	1	496,070	1,470	492,549	13,168	1	536,660	1,780	532,969	14,249	310	40,420	1,081	2	1,025,518	13,708
	Wed	08/08/07	8:15	0	496,820	750	493,299	13,188	0	537,450	790	533,759	14,270	40	40,460	1,082	0	1,027,058	13,729
87	Mon	08/13/07	3:20	0	498,520	1,700	494,999	13,233	0	539,270	1,820	535,579	14,318	120	40,580	1,085	0	1,030,578	13,776
	Wed	08/15/07	8:51	0	499,200	680	495,679	13,252	0	540,000	730	536,309	14,338	50	40,630	1,086	0	1,031,988	13,795
	Fri	08/17/07	11:00	0	499,990	790	496,469	13,273	0	540,831	831	537,140	14,360	41	40,671	1,087	0	1,033,609	13,816
88	Tue	08/21/07	11:45	0	501,280	1,290	497,759	13,307	0	542,220	1,389	538,529	14,397	99	40,770	1,090	0	1,036,288	13,852
	Fri	08/24/07	11:35	0	502,490	1,210	498,969	13,340	0	543,300	1,080	539,609	14,426	(130)	40,640	1,086	0	1,038,578	13,883
89	Mon	08/26/07	8:15	0	503,150	660	499,629	13,357	0	544,230	930	540,539	14,451	270	40,910	1,094	0	1,040,168	13,904
	Wed	08/28/07	8:20	0	503,850	700	500,329	13,376	0	544,970	740	541,279	14,471	40	40,950	1,095	0	1,041,608	13,923
90	Mon	09/04/07	8:30	0	505,900	2,050	502,379	13,431	0	547,170	2,200	543,479	14,530	150	41,100	1,099	0	1,045,858	13,980
91	Tue	09/11/07	8:04	0	508,300	2,400	504,779	13,495	0	549,735	2,565	546,044	14,598	165	41,265	1,103	0	1,050,823	14,047
92	Mon	09/17/07	12:00	0	510,200	1,900	506,679	13,546	0	551,770	2,035	548,079	14,653	135	41,400	1,107	0	1,054,758	14,099
94	Mon	10/01/07	3:22	0	517,020	6,820	513,499	13,728	0	558,950	7,180	555,259	14,845	360	41,760	1,116	0	1,068,758	14,286
	Wed	10/03/07	11:15	0	518,200	1,180	514,679	13,760	0	560,140	1,190	556,449	14,876	10	41,770	1,117	0	1,071,128	14,318
	Fri	10/05/07	16:00	0	519,780	1,580	516,259	13,802	0	561,670	1,530	557,979	14,917	(50)	41,720	1,115	0	1,074,238	14,360

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System															
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
95	Tue	10/16/07	8:15	0	525,530	5,750	522,009	13,956	0	567,540	5,870	563,849	15,074	120	41,840	1,119	0	1,085,858	14,515
	Fri	10/19/07	11:35	0	527,630	2,100	524,109	14,012	0	569,630	2,090	565,939	15,130	(10)	41,830	1,118	0	1,090,048	14,571
96	Wed	10/24/07	9:39	0	530,230	2,600	526,709	14,081	0	572,330	2,700	568,639	15,202	100	41,930	1,121	0	1,095,348	14,642
97	Mon	10/29/07	9:00	1	532,770	2,540	529,249	14,149	1	574,910	2,580	571,219	15,271	40	41,970	1,122	2	1,100,468	14,710
	Wed	10/31/07	8:35	0	534,200	1,430	530,679	14,187	0	576,340	1,430	572,649	15,309	-	41,970	1,122	0	1,103,328	14,748
	Fri	11/02/07	8:35	0	535,000	800	531,479	14,209	0	577,610	1,270	573,919	15,343	470	42,440	1,135	0	1,105,398	14,776
98	Tue	11/05/07	8:30	0	536,670	1,670	533,149	14,253	0	578,910	1,300	575,219	15,378	(370)	42,070	1,125	0	1,108,368	14,816
	Fri	11/07/07	10:50	0	538,110	1,440	534,589	14,292	0	580,420	1,510	576,729	15,419	70	42,140	1,127	0	1,111,318	14,855
99	Tue	11/20/07	15:15	1	544,850	6,740	541,329	14,472	1	587,570	7,150	583,879	15,610	410	42,550	1,138	2	1,125,208	15,041
100	Mon	12/03/07	11:55	0	550,640	5,790	547,119	14,627	0	593,550	5,980	589,859	15,770	190	42,740	1,143	0	1,136,978	15,198
101	Wed	12/12/07	8:21	0	554,240	3,600	550,719	14,723	0	597,260	3,710	593,569	15,869	110	42,850	1,146	0	1,144,288	15,296
102	Tue	12/18/07	11:40	0	556,150	1,910	552,629	14,774	0	599,270	2,010	595,579	15,922	100	42,950	1,148	0	1,148,208	15,348
103	Wed	12/26/07	11:58	0	558,600	2,450	555,079	14,840	0	601,845	2,575	598,154	15,991	125	43,075	1,152	0	1,153,233	15,415
104	Wed	01/09/08	9:00	0	563,170	4,570	559,649	14,962	0	606,700	4,855	603,009	16,121	285	43,360	1,159	0	1,162,658	15,541
105	Fri	02/01/08	11:46	0	575,460	12,290	571,939	15,290	0	619,420	12,720	615,729	16,461	430	43,790	1,171	0	1,187,668	15,876
106	Wed	02/13/08	9:16	8	581,170	5,710	577,649	15,443	8	625,340	5,920	621,649	16,619	210	44,000	1,176	16	1,199,298	16,031
107	Tue	02/26/08	18:00	0	588,520	32,370	584,999	15,640	0	632,990	33,720	629,299	16,824	1,350	44,300	1,184	0	1,214,298	16,232
	Fri	02/29/08	3:45	0	590,500	1,980	586,979	15,693	0	634,930	1,940	631,239	16,876	(40)	44,260	1,183	0	1,218,218	16,284
108	Thu	03/06/08	15:05	1	596,600	6,100	593,079	15,856	NA	634,935	5	631,244	16,876	(6,095)	38,165	1,020	1	1,224,323	16,366
	Fri	03/07/08	16:00	NA	597,960	1,360	594,439	15,892	NA	634,935	-	631,244	16,876	(1,360)	36,805	984	NA	1,225,683	16,384
109	Mon	03/10/08	8:20	NA	597,960	-	594,439	15,892	2	636,640	1,705	632,949	16,922	1,705	38,510	1,030	2	1,227,388	16,407
110	Mon	03/17/08	15:15	0	597,960	-	594,439	15,892	0	644,620	7,980	640,929	17,135	7,980	46,490	1,243	0	1,235,368	16,513
111	Tue	03/25/08	9:24	0	603,620	5,660	600,099	16,043	0	644,620	-	640,929	17,135	(5,660)	40,830	1,092	0	1,241,028	16,589
	Fri	03/28/08	7:33	0	603,620	-	600,099	16,043	0	646,450	1,830	642,759	17,184	1,830	42,660	1,140	0	1,242,858	16,614
113	Wed	04/09/08	7:33	0	609,730	6,110	606,209	16,207	0	652,810	6,360	649,119	17,354	250	42,910	1,147	0	1,255,328	16,780
115	Tue	04/22/08	8:34	0	616,650	6,920	613,129	16,392	0	660,000	7,190	656,309	17,546	270	43,180	1,154	0	1,269,438	16,969
116	Wed	04/30/08	10:30	2	620,260	3,610	616,739	16,488	2	663,720	3,720	660,029	17,645	110	43,290	1,157	4	1,276,768	17,067
	Thu	05/01/08	15:40	0	621,030	770	617,509	16,509	0	664,520	800	660,829	17,667	30	43,320	1,158	0	1,278,338	17,088
118	Tue	05/13/08	8:16	0	626,880	5,850	623,359	16,665	0	670,500	5,980	666,809	17,827	130	43,450	1,162	0	1,290,168	17,246
120	Thu	05/29/08	8:34	0	634,870	7,990	631,349	16,879	0	678,960	8,460	675,269	18,053	470	43,920	1,174	0	1,306,618	17,466
121	Mon	06/02/08	9:40	0	636,600	1,730	633,079	16,925	0	680,770	1,810	677,079	18,101	80	44,000	1,176	0	1,310,158	17,513
123	Thu	06/19/08	8:00	0	644,280	7,680	640,759	17,130	0	688,820	8,050	685,129	18,317	370	44,370	1,186	0	1,325,888	17,723
124	Tue	06/24/08	NA	0	646,180	1,900	642,659	17,181	0	690,860	2,040	687,169	18,371	140	44,510	1,190	0	1,329,828	17,776
125	Thu	07/03/08	15:10	0	649,240	3,060	645,719	17,263	0	694,110	3,250	690,419	18,458	190	44,700	1,195	0	1,336,138	17,860
127	Fri	07/18/08	14:00	0	656,100	6,860	652,579	17,446	0	701,220	7,110	697,529	18,648	250	44,950	1,202	0	1,350,108	18,047
129	Mon	07/28/08	8:00	0	660,060	3,960	656,539	17,552	0	705,480	4,260	701,789	18,762	300	45,250	1,210	0	1,358,328	18,157
132	Wed	08/20/08	14:00	0	669,400	9,340	665,879	17,802	0	715,500	10,020	711,809	19,030	680	45,930	1,228	0	1,377,688	18,416
138	Fri	10/03/08	9:45	0	686,770	17,370	683,249	18,266	0	733,580	18,080	729,889	19,513	710	46,640	1,247	0	1,413,138	18,890

Table A-1. EPA Arsenic Demonstration Project at Purvine Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Treatment System																
				Train 1					Train 2					Train2-Train1			Combined		
Week No.	Day of Week	Date	Time	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Flow Rate	Totalizer	Daily Water Treated	Cum. Throughput	Bed Volume	Daily Water Treated	Cum. Throughput	Bed Volume	Total Flow	Cum. Throughput	Bed Volume
				gpm	gal	gal	gal	#BV	gpm	gal	gal	gal	#BV	gal	gal	#BV	gpm	gal	#BV
140	Mon	10/13/08	14:01	0	692,415	5,645	688,894	18,417	0	739,490	5,910	735,799	19,671	265	46,905	1,254	0	1,424,693	19,044
144	Mon	11/10/08	15:35	0	722,960	30,545	719,439	19,234	0	772,300	32,810	768,609	20,548	2,265	49,170	1,315	0	1,488,048	19,891
145	Wed	11/19/08	13:50	0	729,530	6,570	726,009	19,409	0	779,380	7,080	775,689	20,738	510	49,680	1,328	0	1,501,698	20,073
147	Mon	12/01/08	11:03	1	734,490	4,960	730,969	19,542	1	787,550	8,170	783,859	20,956	3,210	52,890	1,414	2	1,514,828	20,249
148	Tue	12/09/08	15:30	0	738,380	3,890	734,859	19,646	0	788,670	1,120	784,979	20,986	(2,770)	50,120	1,340	0	1,519,838	20,316
149	Thu	12/18/08	7:59	0	744,340	5,960	740,819	19,805	0	795,020	6,350	791,329	21,156	390	50,510	1,350	0	1,532,148	20,481
151	Sun	12/28/08	15:30	0	748,150	3,810	744,629	19,907	0	799,120	4,100	795,429	21,265	290	50,800	1,358	0	1,540,058	20,586
	Wed	12/31/08	14:55	0	748,900	750	745,379	19,927	0	799,920	800	796,229	21,287	50	50,850	1,359	0	1,541,608	20,607
152	Mon	01/05/09	9:57	0	750,840	1,940	747,319	19,979	0	802,010	2,090	798,319	21,343	150	51,000	1,363	0	1,545,638	20,661
153	Tue	01/13/09	11:08	0	756,400	5,560	752,879	20,128	0	807,830	5,820	804,139	21,498	260	51,260	1,370	0	1,557,018	20,813
154	Fri	01/23/09	13:05	0	762,610	6,210	759,089	20,294	0	814,345	6,515	810,654	21,672	305	51,565	1,379	0	1,569,743	20,983
156	Mon	02/02/09	8:10	0	775,240	12,630	771,719	20,631	0	828,582	14,237	824,891	22,053	1,607	53,172	1,422	0	1,596,610	21,342
157	Wed	02/11/09	8:52	0	781,830	6,590	778,309	20,808	0	834,740	6,158	831,049	22,218	(432)	52,740	1,410	0	1,609,358	21,513
158	Mon	02/16/09	15:10	0	784,960	3,130	781,439	20,891	0	837,900	3,160	834,209	22,302	30	52,770	1,411	0	1,615,648	21,597
159	Thu	02/26/09	14:30	0	791,310	6,350	787,789	21,061	0	844,570	6,670	840,879	22,480	320	53,090	1,419	0	1,628,668	21,771
160	Mon	03/02/09	8:20	0	793,080	1,770	789,559	21,108	0	846,450	1,880	842,759	22,531	110	53,200	1,422	0	1,632,318	21,820
161	Mon	03/09/09	9:48	0	797,330	4,250	793,809	21,222	0	850,870	4,420	847,179	22,649	170	53,370	1,427	0	1,640,988	21,935
163	Wed	03/25/09	11:46	0	805,150	7,820	801,629	21,431	0	859,140	8,270	855,449	22,870	450	53,820	1,439	0	1,657,078	22,150
165	Tue	04/06/09	9:22	1	811,360	6,210	807,839	21,597	0	865,590	6,450	861,899	23,042	240	54,060	1,445	1	1,669,738	22,320
166	Wed	04/15/09	8:15	0	815,900	4,540	812,379	21,718	0	870,440	4,850	866,749	23,172	310	54,370	1,454	0	1,679,128	22,445
169	Mon	05/04/09	12:10	0	827,240	11,340	823,719	22,022	0	882,880	12,440	879,189	23,505	1,100	55,470	1,483	0	1,702,908	22,763
172	Wed	05/27/09	9:30	2	840,180	12,940	836,659	22,368	2	895,730	12,850	892,039	23,848	(90)	55,380	1,481	4	1,728,698	23,108
173	Mon	06/01/09	11:35	2	842,880	2,700	839,359	22,440	2	898,600	2,870	894,909	23,925	170	55,550	1,485	4	1,734,268	23,182
179	Fri	07/17/09	8:22	1	862,360	19,480	858,839	22,961	1	919,110	20,510	915,419	24,473	1,030	56,580	1,513	2	1,774,258	23,717
184	Mon	08/17/09	8:30	0	878,540	16,180	875,019	23,393	0	936,520	17,410	932,829	24,939	1,230	57,810	1,546	0	1,807,848	24,166
185	Wed	08/26/09	11:10	0	881,735	3,195	878,214	23,479	0	NA	NA	936,214	NA	NA	NA	NA	0	NA	NA

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[(a)] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
1	Mon	12/12/05	7:50	B	A	NM	12,600	NA	NA	NA	62	62	0	0	0
	Tue	12/13/05	8:20	B	A	NM	17,215	4,615	4,615	31	62	62	0	0	0
	Wed	12/14/05	13:45	B	A	NM	22,230	5,015	9,630	64	62	62	0	0	0
	Thu	12/15/05	11:30	B	A	NM	26,278	4,048	13,678	91	62	62	0	0	0
	Fri	12/16/05	9:00	B	A	NM	30,012	3,734	17,412	116	65	65	0	0	0
2	Mon	12/19/05	14:30	B	A	2	40,502	10,490	27,902	186	58	NA	NA	0	0
	Tue	12/20/05	8:23	B	A	2	43,780	3,278	31,180	208	58	NA	NA	0	0
	Wed	12/21/05	8:32	B	A	2	48,414	4,634	35,814	239	58	NA	NA	0	0
	Thu	12/22/05	8:15	B	A	2	53,151	4,737	40,551	271	58	NA	NA	0	0
	Fri	12/23/05	7:50	B	A	2	56,871	3,720	44,271	296	58	NA	NA	0	0
3	Tue	12/27/05	8:20	B	A	2	67,821	10,950	55,221	369	60	NA	NA	0	0
	Wed	12/28/05	8:30	B	A	2	72,152	4,331	59,552	398	59	NA	NA	0	0
	Thu	12/29/05	9:23	B	A	2	76,142	3,990	63,542	425	60	NA	NA	0	0
4	Tue	01/03/06	6:45	B	A	2	91,952	15,810	79,352	530	61	64	-3	0	0
	Wed	01/04/06	16:40	B	A	2	97,840	5,888	85,240	570	61	64	-3	0	0
	Thu	01/05/06	9:20	B	A	2	99,312	1,472	86,712	580	61	64	-3	0	0
	Fri	01/06/06	15:30	B	A	2	105,535	6,223	92,935	621	61	64	-3	0	0
5	Mon	01/09/06	8:05	B	A	40	133,780	28,245	121,180	810	58	58	0	0	0
	Tue	01/10/06	15:20	B	A	18	157,530	23,750	144,930	969	60	61	-1	0	0
	Wed	01/11/06	9:47	B	A	8	172,392	14,862	159,792	1,068	61	62	-1	0	0
	Thu	01/12/06	14:43	B	A	19	195,920	23,528	183,320	1,225	59	58	1	0	0
	Fri	01/13/06	7:40	B	A	44	208,715	12,795	196,115	1,311	56	57	-1	0	0
6	Tue	01/17/06	11:30	B	A	33	288,550	79,835	275,950	1,844	58	56	2	0	0
	Wed	01/18/06	13:35	B	A	20	311,410	22,860	298,810	1,997	60	62	-2	0	0
	Thu	01/19/06	9:30	B	A	26.5	330,351	18,941	317,751	2,124	60	61	-1	0	0
	Fri	01/20/06	10:24	B	A	23	351,550	21,199	338,950	2,265	60	60	0	0	0
7	Mon	01/23/06	16:30	B	A	26	417,758	66,208	405,158	2,708	58	55	3	0	0
	Tue	01/24/06	8:25	B	A	29	429,880	12,122	417,280	2,789	55	51	4	0	0
	Wed	01/25/06	7:30	B	A	23	450,555	20,675	437,955	2,927	60	60	0	0	0
	Thu	01/26/06	10:40	B	A	15	474,440	23,885	461,840	3,087	60	60	0	0	0
	Fri	01/27/06	9:01	B	A	27.5	494,580	20,140	481,980	3,221	60	60	0	0	0
8	Mon	01/30/06	11:07	B	A	7.5	553,555	58,975	540,955	3,616	61	62	-1	0	0
	Tue	01/31/06	10:20	B	A	32.5	571,915	18,360	559,315	3,738	59	60	-1	0	0
	Wed	02/01/06	8:35	B	A	37.5	592,250	20,335	579,650	3,874	57	52	5	0	0
	Thu	02/02/06	10:30	B	A	27	614,280	22,030	601,680	4,021	57	51	6	0	0
	Fri	02/03/06	11:20	B	A	6.5	636,405	22,125	623,805	4,169	62	61	1	0	0
9	Mon	02/06/06	13:30	B	A	18.5	695,035	58,630	682,435	4,561	60	60	0	0	0
	Tue	02/07/06	8:45	B	A	34	709,660	14,625	697,060	4,659	58	44	14	0	0
	Wed	02/08/06	8:15	B	A	24	727,225	17,565	714,625	4,776	58	55	3	0	0
	Thu	02/09/06	8:25	B	A	27.5	749,750	22,525	737,150	4,927	58	56	2	0	0
	Fri	02/10/06	11:30	B	A	7	776,820	27,070	764,220	5,108	60	58	2	0	0
10	Mon	02/13/06	8:40	B	A	27	831,640	54,820	819,040	5,474	58	50	8	0	0
	Tue	02/14/06	10:25	B	A	36	852,936	21,296	840,336	5,616	55	43	12	0	0
	Wed	02/15/06	NM	NM	NM	NM	NM	NA	NA	NA	NM	NM	NA	0	0
	Thu	02/16/06	NM	NM	NM	NM	NM	NA	NA	NA	NM	NM	NA	0	0
	Fri	02/17/06	8:35	B	A	33	916,000	63,064	903,400	6,038	58	55	3	0	0
11	Mon	02/20/06	8:07	B	A	40	971,850	55,850	959,250	6,411	55	45	10	0	0
	Tue	02/21/06	14:52	B	A	16	1,000,422	28,572	987,822	6,602	58	58	0	0	0
	Wed	02/22/06	8:43	B	A	35	1,001,650	1,228	989,050	6,610	55	43	12	0	0
	Thu	02/23/06	8:29	B	A	35	1,033,620	31,970	1,021,020	6,824	58	55	3	0	0
	Fri	02/24/06	7:50	B	A	32.5	1,053,980	20,360	1,041,380	6,960	56	50	6	0	0
12	Mon	02/27/06	9:00	B	A	11.5	1,111,775	57,795	1,099,175	7,346	60	58	2	0	0
	Tue	02/28/06	11:15	B	A	25	1,134,870	23,095	1,122,270	7,501	60	55	5	0	0
	Wed	03/01/06	11:42	B	A	20	1,156,580	21,710	1,143,980	7,646	58	57	1	0	0
	Thu	03/02/06	7:45	B	A	16	1,172,037	15,457	1,159,437	7,749	60	60	0	0	0
	Fri	03/03/06	7:53	B	A	19	1,193,930	21,893	1,181,330	7,896	55	45	10	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[(a)] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
13	Mon	03/06/06	8:10	B	A	41.5	1,251,520	57,590	1,238,920	8,280	54	40	14	0	0
	Tue	03/07/06	8:02	B	A	28.5	1,271,665	20,145	1,259,065	8,415	58	52	6	0	0
	Wed	03/08/06	8:57	B	A	11.5	1,295,728	24,063	1,283,128	8,576	60	61	-1	0	0
	Thu	03/09/06	8:43	B	A	30	1,315,705	19,977	1,303,105	8,709	58	57	1	0	0
	Fri	03/10/06	10:32	B	A	23	1,341,000	25,295	1,328,400	8,878	58	57	1	0	0
14	Mon	03/13/06	8:50	B	A	42.5	1,398,950	57,950	1,386,350	9,266	55	50	5	0	0
	Tue	03/14/06	11:13	B	A	30	1,422,650	23,700	1,410,050	9,424	55	50	5	0	0
	Wed	03/15/06	7:45	B	A	32	1,439,200	16,550	1,426,600	9,535	58	53	5	0	0
	Thu	03/16/06	7:50	B	A	16	1,459,310	20,110	1,446,710	9,669	60	59	1	0	0
	Fri	03/17/06	8:00	B	A	36	1,483,530	24,220	1,470,930	9,831	58	48	10	0	0
15	Mon	03/20/06	8:10	B	A	27	1,541,235	57,705	1,528,635	10,217	56	50	6	0	0
	Tue	03/21/06	8:02	B	A	21	1,564,375	23,140	1,551,775	10,371	59	57	2	0	0
	Wed	03/22/06	8:57	B	A	29	1,585,740	21,365	1,573,140	10,514	59	56	3	0	0
	Thu	03/23/06	8:43	B	A	24	1,606,560	20,820	1,593,960	10,653	59	58	1	0	0
	Fri	03/24/06	10:32	B	A	9	1,619,912	13,352	1,607,312	10,743	60	60	0	0	0
16	Mon	03/27/06	8:25	B	A	3	1,636,650	16,738	1,624,050	10,854	61	61	0	0	0
	Tue	03/28/06	14:00	B	A	2	1,643,545	6,895	1,630,945	10,901	60	61	-1	0	0
	Wed	03/29/06	9:55	B	A	2	1,647,346	3,801	1,634,746	10,926	61	61	0	0	0
	Thu	03/30/06	7:58	B	A	2	1,651,345	3,999	1,638,745	10,953	60	60	0	0	0
	Fri	03/31/06	8:10	B	A	5	1,656,105	4,760	1,643,505	10,985	60	60	0	0	0
17	Mon	04/03/06	9:00	B	A	17.5	1,683,720	27,615	1,671,120	11,169	60	59	1	0	0
	Tue	04/04/06	8:45	B	A	35	1,700,440	16,720	1,687,840	11,281	55	48	7	0	0
	Wed	04/05/06	7:45	B	A	27	1,719,900	19,460	1,707,300	11,411	59	57	2	0	0
	Thu	04/06/06	10:51	B	A	30	1,742,390	22,490	1,729,790	11,561	55	52	3	0	0
	Fri	04/07/06	7:42	B	A	21	1,758,191	15,801	1,745,591	11,667	61	59	2	0	0
18	Mon	04/10/06	7:47	B	A	38	1,812,690	54,499	1,800,090	12,031	55	40	15	0	0
	Tue	04/11/06	7:45	B	A	16.5	1,813,632	942	1,801,032	12,037	59	58	1	0	0
	Wed	04/12/06	10:26	B	A	31	1,857,315	43,683	1,844,715	12,329	59	58	1	0	0
	Thu	04/13/06	7:45	B	A	17	1,872,480	15,165	1,859,880	12,431	61	60	1	0	0
	Fri	04/14/06	8:00	B	A	34	1,895,000	22,520	1,882,400	12,581	56	50	6	0	0
19	Mon	04/17/06	8:00	B	A	40	1,945,150	50,150	1,932,550	12,916	54	43	11	0	0
	Tue	04/18/06	9:10	B	A	26	1,965,915	20,765	1,953,315	13,055	58	54	4	0	0
	Wed	04/19/06	8:55	B	A	20	1,987,550	21,635	1,974,950	13,200	56	52	4	0	0
	Thu	04/20/06	7:45	B	A	25	2,005,600	18,050	1,993,000	13,320	60	59	1	0	0
	Fri	04/21/06	13:43	B	A	19	2,039,935	34,335	2,027,335	13,550	55	48	7	0	0
20	Mon	04/24/06	8:42	B	A	38	2,097,485	57,550	2,084,885	13,935	58	49	9	0	0
	Tue	04/25/06	8:24	B	A	23	2,116,550	19,065	2,103,950	14,062	58	50	8	0	0
	Wed	04/26/06	9:12	B	A	35	2,141,010	24,460	2,128,410	14,225	58	56	2	0	0
	Thu	04/27/06	7:54	B	A	19	2,158,860	17,850	2,146,260	14,345	59	57	2	0	0
	Fri	04/28/06	7:43	B	A	8	2,182,490	23,630	2,169,890	14,503	57	52	5	0	0
21	Mon	05/01/06	8:45	B	A	28	2,242,424	59,934	2,229,824	14,903	59	56	3	0	0
	Tue	05/02/06	7:50	B	A	23	2,261,210	18,786	2,248,610	15,029	58	55	3	0	0
	Wed	05/03/06	13:35	B	A	10	2,291,775	30,565	2,279,175	15,233	60	59	1	0	0
	Thu	05/04/06	8:36	B	A	20	2,307,180	15,405	2,294,580	15,336	60	58	2	0	0
	Fri	05/05/06	3:10	B	A	45	2,331,700	24,520	2,319,100	15,500	57	42	15	0	0
22	Mon	05/08/06	8:54	B	A	35	2,387,958	56,258	2,375,358	15,876	58	44	14	0	0
	Tue	05/09/06	11:34	B	A	10	2,436,220	48,262	2,423,620	16,199	60	60	0	0	0
	Wed	05/10/06	15:15	B	A	15	2,437,333	1,113	2,424,733	16,206	60	58	2	0	0
	Thu	05/11/06	8:30	B	A	20	2,453,200	15,867	2,440,600	16,312	58	52	6	0	0
	Fri	05/12/06	8:55	B	A	30	2,474,080	20,880	2,461,480	16,452	59	48	11	0	0
23	Mon	05/15/06	8:00	B	A	28	2,525,170	51,090	2,512,570	16,793	58	52	6	0	0
	Tue	05/16/06	7:55	B	A	30	2,545,130	19,960	2,532,530	16,926	56	48	8	0	0
	Wed	05/17/06	13:15	B	A	10	2,573,540	28,410	2,560,940	17,116	61	60	1	0	0
	Thu	05/18/06	13:50	B	A	15	2,596,940	23,400	2,584,340	17,273	60	60	0	0	0
	Fri	05/19/06	15:00	B	A	12	2,620,505	23,565	2,607,905	17,430	56	57	-1	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[(a)] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
24	Mon	05/22/06	10:30	B	A	25	2,677,370	56,865	2,664,770	17,810	60	58	2	0	0
	Tue	05/23/06	9:35	B	A	35	2,697,030	19,660	2,684,430	17,942	55	45	10	0	0
	Wed	05/24/06	15:35	B	A	10	2,712,512	15,482	2,699,912	18,045	60	60	0	0	0
	Thu	05/25/06	14:45	B	A	35	2,746,800	34,288	2,734,200	18,274	60	60	0	0	0
	Fri	05/26/06	9:46	B	A	30	2,763,572	16,772	2,750,972	18,386	56	48	8	0	0
25	Tue	05/30/06	7:50	B	A	25	2,819,750	56,178	2,807,150	18,762	60	58	2	0	0
	Wed	05/31/06	8:50	B	A	23	2,842,095	22,345	2,829,495	18,911	58	55	3	0	0
	Thu	06/01/06	8:00	B	A	25	2,860,850	18,755	2,848,250	19,037	54	43	11	0	0
	Fri	06/02/06	8:40	B	A	40	2,884,740	23,890	2,872,140	19,196	55	42	13	0	0
26	Mon	06/05/06	2:55	B	A	12	2,953,470	68,730	2,940,870	19,656	59	59	0	0	0
	Tue	06/06/06	7:30	B	A	12	2,971,333	17,863	2,958,733	19,775	60	59	1	0	0
	Wed	06/07/06	15:25	B	A	10	2,998,555	27,222	2,985,955	19,957	60	59	1	0	0
	Thu	06/08/06	11:20	B	A	20	3,015,360	16,805	3,002,760	20,069	60	58	2	0	0
	Fri	06/09/06	10:13	B	A	28	3,038,155	22,795	3,025,555	20,222	60	58	2	0	0
27	Mon	06/12/06	13:29	B	A	24	3,100,190	62,035	3,087,590	20,636	58	54	4	0	0
	Tue	06/13/06	7:45	B	A	18	3,115,225	15,035	3,102,625	20,737	58	57	1	0	0
	Wed	06/14/06	8:59	B	A	38	3,136,860	21,635	3,124,260	20,881	55	45	10	0	0
	Thu	06/15/06	7:55	B	A	20	3,156,800	19,940	3,144,200	21,015	59	57	2	0	0
	Fri	06/16/06	8:15	B	A	10	3,174,310	17,510	3,161,710	21,132	60	60	0	0	0
28	Mon	06/19/06	8:45	B	A	10	3,207,800	33,490	3,195,200	21,355	61	61	0	0	0
	Tue	06/20/06	8:08	B	A	2	3,210,500	2,700	3,197,900	21,373	61	61	0	0	0
	Wed	06/21/06	10:46	B	A	10	3,219,350	8,850	3,206,750	21,433	59	59	0	0	0
	Thu	06/22/06	7:40	B	A	4	3,226,300	6,950	3,213,700	21,479	61	61	0	0	0
	Fri	06/23/06	7:45	B	A	2	3,235,100	8,800	3,222,500	21,538	60	60	0	0	0
29	Mon	06/26/06	11:15	B	A	2	3,260,110	25,010	3,247,510	21,705	61	61	0	0	0
	Tue	06/27/06	11:40	B	A	2	3,269,700	9,590	3,257,100	21,769	61	61	0	0	0
	Wed	06/28/06	8:50	B	A	2	3,276,850	7,150	3,264,250	21,817	61	61	0	0	0
	Thu	06/29/06	8:15	B	A	8	3,285,900	9,050	3,273,300	21,877	61	61	0	0	0
	Fri	06/30/06	9:20	B	A	2	3,295,800	9,900	3,283,200	21,944	61	61	0	0	0
30	Mon	07/03/06	8:30	B	A	5	3,328,412	32,612	3,315,812	22,162	60	60	0	0	0
	Wed	07/05/06	9:07	B	A	4	3,338,804	10,392	3,326,204	22,231	61	60	1	0	0
	Thu	07/06/06	7:50	B	A	45	3,379,600	40,796	3,367,000	22,504	58	40	18	0	0
	Fri	07/07/06	8:05	B	A	3	3,390,500	10,900	3,377,900	22,577	61	60	1	0	0
31	Mon	07/10/06	14:35	B	A	1	3,421,110	30,610	3,408,510	22,781	61	61	0	0	0
	Tue	07/11/06	8:00	B	A	4	3,428,850	7,740	3,416,250	22,833	62	62	0	0	0
	Wed	07/12/06	7:54	B	A	2	3,436,780	7,930	3,424,180	22,886	60	60	0	0	0
	Thu	07/13/06	8:20	B	A	5	3,445,500	8,720	3,432,900	22,944	60	60	0	0	0
32	Tue	07/18/06	5:30	B	A	10	3,492,353	46,853	3,479,753	23,257	60	60	0	0	0
	Wed	07/19/06	8:57	B	A	12	3,736	3,436	3,483,189	23,280	60	60	0	0	0
	Thu	07/20/06	10:00	B	A	10	9,255	5,519	3,488,708	23,317	60	60	0	0	0
	Fri	07/21/06	8:55	B	A	5	13,100	3,845	3,492,553	23,343	61	60	1	0	0
33	Mon	07/24/06	9:30	B	A	12	16,090	2,990	3,495,543	23,363	60	60	0	0	0
	Tue	07/25/06	7:30	B	A	0	20,533	4,443	3,499,986	23,393	60	60	0	0	0
	Wed	07/26/06	15:20	B	A	0	45,030	24,497	3,524,483	23,556	60	60	0	0	0
	Thu	07/27/06	10:30	B	A	2	52,947	7,917	3,532,400	23,609	60	60	0	0	0
	Fri	07/28/06	9:30	B	A	8	61,330	8,383	3,540,783	23,665	60	60	0	0	0
34	Mon	07/31/06	7:24	B	A	0	85,223	23,893	3,564,676	23,825	60	60	0	0	0
	Tue	08/01/06	7:45	B	A	2	91,520	6,297	3,570,973	23,867	58	58	0	0	0
	Wed	08/02/06	8:15	B	A	1	103,072	11,552	3,582,525	23,944	60	59	1	0	0
	Thu	08/03/06	8:30	B	A	2	115,905	12,833	3,595,358	24,030	60	60	0	0	0
	Fri	08/04/06	8:16	B	A	12	124,075	8,170	3,603,528	24,085	59	57	2	0	0
35	Mon	08/07/06	10:25	B	A	4	149,660	25,585	3,629,113	24,256	60	60	0	0	0
	Tue	08/08/06	7:52	B	A	2	155,715	6,055	3,635,168	24,296	60	59	1	0	0
	Wed	08/09/06	7:30	B	A	5	162,690	6,975	3,642,143	24,343	61	60	1	0	0
	Thu	08/10/06	10:11	B	A	12	176,980	14,290	3,656,433	24,438	60	59	1	0	0
	Fri	08/11/06	10:30	B	A	16	183,870	6,890	3,663,323	24,484	60	60	0	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[(a)] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
36	Tue	08/15/06	8:38	B	A	8	216,060	32,190	3,695,513	24,699	60	58	2	0	0
	Wed	08/16/06	10:00	B	A	5	223,190	7,130	3,702,643	24,747	58	57	1	0	0
	Thu	08/17/06	8:30	B	A	0	230,190	7,000	3,709,643	24,794	59	57	2	0	0
	Fri	08/18/06	8:15	B	A	10	239,410	9,220	3,718,863	24,855	58	56	2	0	0
37	Fri	08/25/06	13:50	B	A	4	274,845	35,435	3,754,298	25,092	61	60	1	0	0
38	Mon	08/28/06	7:50	B	A	4	314,920	40,075	3,794,373	25,360	60	58	2	0	0
	Tue	08/29/06	7:40	B	A	3	323,040	8,120	3,802,493	25,414	61	59	2	0	0
	Wed	08/30/06	10:45	B	A	5	331,973	8,933	3,811,426	25,474	61	59	2	0	0
	Thu	08/31/06	7:50	B	A	5	339,060	7,087	3,818,513	25,521	61	60	1	0	0
	Fri	09/01/06	7:35	B	A	4	346,790	7,730	3,826,243	25,573	61	60	1	0	0
39	Tue	09/05/06	7:45	B	A	8	375,750	28,960	3,855,203	25,767	61	59	2	0	0
	Wed	09/06/06	7:50	B	A	5	389,680	13,930	3,869,133	25,860	60	59	1	0	0
	Thu	09/07/06	7:50	B	A	4	393,790	4,110	3,873,243	25,887	61	60	1	0	0
	Fri	09/08/06	14:30	B	A	8	404,810	11,020	3,884,263	25,961	61	60	1	0	0
40	Mon	09/11/06	9:10	B	A	5	431,925	27,115	3,911,378	26,142	61	59	2	0	0
	Tue	09/12/06	9:52	B	A	10	442,800	10,875	3,922,253	26,215	60	58	2	0	0
	Wed	09/13/06	10:19	B	A	5	453,910	11,110	3,933,363	26,289	61	60	1	0	0
	Thu	09/14/06	10:30	B	A	8	464,380	10,470	3,943,833	26,359	60	58	2	0	0
	Fri	09/15/06	14:45	B	A	5	476,890	12,510	3,956,343	26,443	60	58	2	0	0
41	Mon	09/18/06	7:45	B	A	30	503,900	27,010	3,983,353	26,623	58	48	10	0	0
	Tue	09/19/06	7:50	B	A	15	519,840	15,940	3,999,293	26,730	59	58	1	0	0
	Wed	09/20/06	8:00	B	A	18	528,230	8,390	4,007,683	26,786	58	52	6	0	0
	Thu	09/21/06	7:45	B	A	19	542,180	13,950	4,021,633	26,879	59	57	2	0	0
	Fri	09/22/06	7:55	B	A	17	559,240	17,060	4,038,693	26,993	58	56	2	0	0
42	Mon	09/25/06	8:10	B	A	60	627,960	68,720	4,107,413	27,452	50	30	20	0	0
	Tue	09/26/06	8:05	B	A	50	650,450	22,490	4,129,903	27,603	52	38	14	0	0
	Wed	09/27/06	10:10	B	A	30	680,800	30,350	4,160,253	27,805	58	55	3	0	0
	Fri	09/29/06	8:55	B	A	20	729,800	49,000	4,209,253	28,133	58	48	10	0	0
43	Mon	10/02/06	8:05	B	A	42	801,060	71,260	4,280,513	28,609	54	40	14	0	0
	Tue	10/03/06	8:40	B	A	25	827,094	26,034	4,306,547	28,783	58	44	14	0	0
	Wed	10/04/06	8:04	B	A	54	852,950	25,856	4,332,403	28,956	50	35	15	0	0
	Thu	10/05/06	9:12	B	A	13	878,990	26,040	4,358,443	29,130	58	60	-2	0	0
	Fri	10/06/06	8:50	B	A	56	905,680	26,690	4,385,133	29,308	52	40	12	0	0
44	Tue	10/10/06	10:05	B	A	28	1,004,830	99,150	4,484,283	29,971	60	55	5	0	0
	Wed	10/11/06	11:20	B	A	25	1,030,280	25,450	4,509,733	30,141	58	52	6	0	0
	Thu	10/12/06	15:35	B	A	8	1,063,380	33,100	4,542,833	30,362	60	58	2	0	0
	Fri	10/13/06	14:55	B	A	15	1,090,720	27,340	4,570,173	30,545	59	57	2	0	0
45	Mon	10/16/06	9:00	B	A	30	1,153,080	62,360	4,632,533	30,962	56	50	6	0	0
	Wed	10/18/06	9:30	B	A	24	1,229,810	76,730	4,709,263	31,475	60	55	5	0	0
46	Wed	10/25/06	11:35	B	A	16	1,403,660	173,850	4,883,113	32,637	60	52	8	0	0
	Thu	10/26/06	9:20	B	A	22	1,425,370	21,710	4,904,823	32,782	58	56	2	0	0
	Fri	10/27/06	11:50	B	A	35	1,456,500	31,130	4,935,953	32,990	58	55	3	0	0
47	Mon	10/30/06	10:25	B	A	30	1,528,840	72,340	5,008,293	33,473	58	52	6	0	0
	Wed	11/01/06	10:35	B	A	28	1,581,460	52,620	5,060,913	33,825	56	49	7	0	0
	Fri	11/03/06	8:40	B	A	35	1,629,080	47,620	5,108,533	34,143	55	49	6	0	0
48	Mon	11/05/06	9:15	B	A	20	1,703,250	74,170	5,182,703	34,639	59	57	2	0	0
	Thu	11/08/06	9:15	B	A	15	1,786,200	82,950	5,265,653	35,194	60	57	3	0	0
49	Tue	11/14/06	8:45	B	A	30	1,890,410	104,210	5,369,863	35,890	59	44	15	0	0
	Wed	11/15/06	8:10	B	A	45	1,915,170	24,760	5,394,623	36,055	54	42	12	0	0
	Thu	11/16/06	8:45	B	A	35	1,940,920	25,750	5,420,373	36,228	55	45	10	0	0
	Fri	11/17/06	11:00	B	A	16	1,971,220	30,300	5,450,673	36,430	58	52	6	0	0
50	Mon	11/20/06	8:20	B	A	42	2,044,180	72,960	5,523,633	36,918	54	42	12	0	0
	Wed	11/22/06	9:45	B	A	30	2,096,110	51,930	5,575,563	37,265	54	44	10	0	0
51	Mon	11/27/06	7:30	B	A	45	2,163,610	67,500	5,643,063	37,716	58	50	8	0	0
	Wed	11/29/06	14:15	B	A	15	2,218,970	55,360	5,698,423	38,086	58	54	4	0	0
	Fri	12/01/06	15:45	B	A	18	2,272,210	53,240	5,751,663	38,442	60	57	3	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[a] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
52	Mon	12/04/06	8:10	B	A	14	2,339,410	67,200	5,818,863	38,891	58	52	6	0	0
	Wed	12/06/06	8:35	B	A	36	2,392,500	53,090	5,871,953	39,246	54	42	12	0	0
	Thu	12/07/06	8:50	B	A	24	2,420,070	27,570	5,899,523	39,430	58	54	4	0	0
53	Mon	12/11/06	10:50	B	A	5	2,470,000	49,930	5,949,453	39,764	61	58	3	0	0
	Wed	12/13/06	9:10	B	A	10	2,489,710	19,710	5,969,163	39,895	60	58	2	0	0
	Fri	12/15/06	10:35	B	A	5	2,509,740	20,030	5,989,193	40,029	60	59	1	0	0
54	Tue	12/19/06	14:45	B	A	15	2,546,690	36,950	6,026,143	40,276	61	59	2	0	0
55	Tue	01/02/07	9:05	B	A	5	2,671,220	124,530	6,150,673	41,109	60	58	2	0	0
	Fri	01/05/06	10:40	B	A	12	2,716,950	45,730	6,196,403	41,414	58	56	2	0	0
56	Tue	01/09/07	9:00	B	A	42	2,810,720	93,770	6,290,173	42,041	50	40	10	0	0
	Wed	01/10/07	12:00	B	A	25	2,848,530	37,810	6,327,983	42,294	55	50	5	0	0
	Fri	01/12/07	16:10	B	A	20	2,917,400	68,870	6,396,853	42,754	57	51	6	0	0
57	Tue	01/18/07	14:10	B	A	16	3,035,200	117,800	6,514,653	43,541	58	56	2	0	0
	Fri	01/19/07	14:30	B	A	32	3,135,420	100,220	6,614,873	44,211	62	58	4	0	0
58	Mon	01/22/07	8:10	B	A	40	3,218,650	83,230	6,698,103	44,767	52	42	10	0	0
59	Mon	01/29/07	8:37	B	A	45	3,455,900	237,250	165,000	1,103	51	41	10	0	0
	Thu	02/01/07	10:30	B	A	40	3,563,970	108,070	273,070	1,825	55	44	11	0	0
	Fri	02/02/07	9:50	B	A	34	3,598,590	34,620	307,690	2,056	62	61	1	0	0
60	Mon	02/05/07	7:50	B	A	42	3,695,300	96,710	404,400	2,703	51	41	10	0	0
	Wed	02/07/07	8:35	B	A	50	3,766,480	71,180	475,580	3,179	50	32	18	0	0
	Fri	02/09/07	8:40	B	A	40	3,835,800	69,320	544,900	3,642	50	40	10	0	0
61	Mon	02/12/07	7:57	B	A	40	3,934,570	98,770	643,670	4,302	52	42	10	0	0
	Wed	02/14/07	8:40	B	A	48	4,007,260	72,690	716,360	4,788	51	37	14	0	0
	Fri	02/16/07	11:45	B	A	30	4,082,900	75,640	792,000	5,293	57	45	12	0	0
62	Mon	02/19/07	8:40	B	A	40	4,176,000	93,100	885,100	5,916	52	43	9	0	0
	Wed	02/21/07	10:45	B	A	32	4,250,170	74,170	959,270	6,411	57	48	9	0	0
	Fri	02/23/07	15:15	B	A	38	4,327,330	77,160	1,036,430	6,927	52	42	10	0	0
63	Mon	02/26/07	14:42	B	A	14	4,428,300	100,970	1,137,400	7,602	57	56	1	0	0
	Wed	02/28/07	15:40	B	A	18	4,499,800	71,500	1,208,900	8,080	57	55	2	0	0
	Fri	03/02/07	15:20	B	A	22	4,570,490	70,690	1,279,590	8,552	58	52	6	0	0
64	Mon	03/05/07	7:50	B	A	45	4,657,010	86,520	1,366,110	9,131	52	42	10	0	0
	Wed	03/07/07	7:53	B	A	44	4,730,910	73,900	1,440,010	9,624	46	40	6	0	0
	Fri	03/09/07	9:15	B	A	45	4,809,550	78,640	1,518,650	10,150	54	42	12	0	0
65	Mon	03/12/07	9:10	B	A	52	4,913,670	104,120	1,622,770	10,846	50	30	20	0	0
	Wed	03/14/07	7:45	B	A	26	4,997,480	83,810	1,706,580	11,406	58	56	2	0	0
	Fri	03/16/07	NA	B	A	18	5,074,040	76,560	1,783,140	11,918	58	56	2	0	0
66	Mon	03/19/07	13:30	B	A	32	5,131,390	57,350	1,840,490	12,301	56	44	12	0	0
	Thu	03/22/07	8:52	B	A	28	5,283,800	152,410	1,992,900	13,320	54	44	10	0	0
	Fri	03/23/07	8:48	B	A	22	5,314,790	30,990	2,023,890	13,527	57	50	7	0	0
67	Tue	03/27/07	15:30	B	A	16	5,410,200	95,410	2,119,300	14,165	58	56	2	0	0
	Thu	03/29/07	8:44	B	A	15	5,448,100	37,900	2,157,200	14,418	58	56	2	0	0
68	Mon	04/02/07	9:37	B	A	38	5,549,600	101,500	2,258,700	15,096	54	46	8	0	0
	Wed	04/04/07	8:36	B	A	55	5,618,550	68,950	2,327,650	15,557	50	32	18	0	0
	Fri	04/06/07	10:15	B	A	34	5,697,990	79,440	2,407,090	16,088	52	42	10	0	0
69	Mon	04/09/07	8:40	B	A	44	5,797,250	99,260	2,506,350	16,751	52	38	14	0	0
	Wed	04/11/07	15:10	B	A	28	5,880,660	83,410	2,589,760	17,309	55	49	6	0	0
	Fri	04/13/07	8:40	B	A	46	5,943,900	63,240	2,653,000	17,732	45	43	2	0	0
70	Mon	04/16/07	7:50	B	A	48	6,046,250	102,350	2,755,350	18,416	51	38	13	0	0
	Fri	04/20/07	7:50	B	A	24	6,205,575	159,325	2,914,675	19,481	58	56	2	0	0
71	Mon	04/23/07	14:50	B	A	30	6,313,450	107,875	3,022,550	20,202	55	51	4	0	0
	Wed	04/25/07	7:45	B	A	48	6,374,700	61,250	3,083,800	20,611	46	40	6	0	0
	Fri	04/27/07	7:30	B	A	58	6,459,270	84,570	3,168,370	21,176	48	28	20	0	0
72	Mon	04/30/07	10:55	B	A	30	6,575,670	116,400	3,284,770	21,954	57	45	12	0	0
	Wed	05/02/07	8:10	B	A	52	6,658,770	83,100	3,367,870	22,509	45	32	13	0	0
73	Mon	05/07/07	7:50	B	A	45	6,839,780	181,010	3,548,880	23,719	52	39	13	0	0
	Wed	05/09/07	8:35	B	A	40	6,915,940	76,160	3,625,040	24,228	56	40	16	0	0
	Fri	05/11/07	8:08	B	A	52	6,989,870	73,930	3,698,970	24,722	50	32	18	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[a] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
52	Mon	12/04/06	8:10	B	A	14	2,339,410	67,200	5,818,863	38,891	58	52	6	0	0
	Wed	12/06/06	8:35	B	A	36	2,392,500	53,090	5,871,953	39,246	54	42	12	0	0
	Thu	12/07/06	8:50	B	A	24	2,420,070	27,570	5,899,523	39,430	58	54	4	0	0
53	Mon	12/11/06	10:50	B	A	5	2,470,000	49,930	5,949,453	39,764	61	58	3	0	0
	Wed	12/13/06	9:10	B	A	10	2,489,710	19,710	5,969,163	39,895	60	58	2	0	0
	Fri	12/15/06	10:35	B	A	5	2,509,740	20,030	5,989,193	40,029	60	59	1	0	0
54	Tue	12/19/06	14:45	B	A	15	2,546,690	36,950	6,026,143	40,276	61	59	2	0	0
55	Tue	01/02/07	9:05	B	A	5	2,671,220	124,530	6,150,673	41,109	60	58	2	0	0
	Fri	01/05/06	10:40	B	A	12	2,716,950	45,730	6,196,403	41,414	58	56	2	0	0
56	Tue	01/09/07	9:00	B	A	42	2,810,720	93,770	6,290,173	42,041	50	40	10	0	0
	Wed	01/10/07	12:00	B	A	25	2,848,530	37,810	6,327,983	42,294	55	50	5	0	0
	Fri	01/12/07	16:10	B	A	20	2,917,400	68,870	6,396,853	42,754	57	51	6	0	0
57	Tue	01/18/07	14:10	B	A	16	3,035,200	117,800	6,514,653	43,541	58	56	2	0	0
	Fri	01/19/07	14:30	B	A	32	3,135,420	100,220	6,614,873	44,211	62	58	4	0	0
58	Mon	01/22/07	8:10	B	A	40	3,218,650	83,230	6,698,103	44,767	52	42	10	0	0
59	Mon	01/29/07	8:37	B	A	45	3,455,900	237,250	165,000	1,103	51	41	10	0	0
	Thu	02/01/07	10:30	B	A	40	3,563,970	108,070	273,070	1,825	55	44	11	0	0
	Fri	02/02/07	9:50	B	A	34	3,598,590	34,620	307,690	2,056	62	61	1	0	0
60	Mon	02/05/07	7:50	B	A	42	3,695,300	96,710	404,400	2,703	51	41	10	0	0
	Wed	02/07/07	8:35	B	A	50	3,766,480	71,180	475,580	3,179	50	32	18	0	0
	Fri	02/09/07	8:40	B	A	40	3,835,800	69,320	544,900	3,642	50	40	10	0	0
61	Mon	02/12/07	7:57	B	A	40	3,934,570	98,770	643,670	4,302	52	42	10	0	0
	Wed	02/14/07	8:40	B	A	48	4,007,260	72,690	716,360	4,788	51	37	14	0	0
	Fri	02/16/07	11:45	B	A	30	4,082,900	75,640	792,000	5,293	57	45	12	0	0
62	Mon	02/19/07	8:40	B	A	40	4,176,000	93,100	885,100	5,916	52	43	9	0	0
	Wed	02/21/07	10:45	B	A	32	4,250,170	74,170	959,270	6,411	57	48	9	0	0
	Fri	02/23/07	15:15	B	A	38	4,327,330	77,160	1,036,430	6,927	52	42	10	0	0
63	Mon	02/26/07	14:42	B	A	14	4,428,300	100,970	1,137,400	7,602	57	56	1	0	0
	Wed	02/28/07	15:40	B	A	18	4,499,800	71,500	1,208,900	8,080	57	55	2	0	0
	Fri	03/02/07	15:20	B	A	22	4,570,490	70,690	1,279,590	8,552	58	52	6	0	0
64	Mon	03/05/07	7:50	B	A	45	4,657,010	86,520	1,366,110	9,131	52	42	10	0	0
	Wed	03/07/07	7:53	B	A	44	4,730,910	73,900	1,440,010	9,624	46	40	6	0	0
	Fri	03/09/07	9:15	B	A	45	4,809,550	78,640	1,518,650	10,150	54	42	12	0	0
65	Mon	03/12/07	9:10	B	A	52	4,913,670	104,120	1,622,770	10,846	50	30	20	0	0
	Wed	03/14/07	7:45	B	A	26	4,997,480	83,810	1,706,580	11,406	58	56	2	0	0
	Fri	03/16/07	NA	B	A	18	5,074,040	76,560	1,783,140	11,918	58	56	2	0	0
66	Mon	03/19/07	13:30	B	A	32	5,131,390	57,350	1,840,490	12,301	56	44	12	0	0
	Thu	03/22/07	8:52	B	A	28	5,283,800	152,410	1,992,900	13,320	54	44	10	0	0
	Fri	03/23/07	8:48	B	A	22	5,314,790	30,990	2,023,890	13,527	57	50	7	0	0
67	Tue	03/27/07	15:30	B	A	16	5,410,200	95,410	2,119,300	14,165	58	56	2	0	0
	Thu	03/29/07	8:44	B	A	15	5,448,100	37,900	2,157,200	14,418	58	56	2	0	0
68	Mon	04/02/07	9:37	B	A	38	5,549,600	101,500	2,258,700	15,096	54	46	8	0	0
	Wed	04/04/07	8:36	B	A	55	5,618,550	68,950	2,327,650	15,557	50	32	18	0	0
	Fri	04/06/07	10:15	B	A	34	5,697,990	79,440	2,407,090	16,088	52	42	10	0	0
69	Mon	04/09/07	8:40	B	A	44	5,797,250	99,260	2,506,350	16,751	52	38	14	0	0
	Wed	04/11/07	15:10	B	A	28	5,880,660	83,410	2,589,760	17,309	55	49	6	0	0
	Fri	04/13/07	8:40	B	A	46	5,943,900	63,240	2,653,000	17,732	45	43	2	0	0
70	Mon	04/16/07	7:50	B	A	48	6,046,250	102,350	2,755,350	18,416	51	38	13	0	0
	Fri	04/20/07	7:50	B	A	24	6,205,575	159,325	2,914,675	19,481	58	56	2	0	0
71	Mon	04/23/07	14:50	B	A	30	6,313,450	107,875	3,022,550	20,202	55	51	4	0	0
	Wed	04/25/07	7:45	B	A	48	6,374,700	61,250	3,083,800	20,611	46	40	6	0	0
	Fri	04/27/07	7:30	B	A	58	6,459,270	84,570	3,168,370	21,176	48	28	20	0	0
72	Mon	04/30/07	10:55	B	A	30	6,575,670	116,400	3,284,770	21,954	57	45	12	0	0
	Wed	05/02/07	8:10	B	A	52	6,658,770	83,100	3,367,870	22,509	45	32	13	0	0
73	Mon	05/07/07	7:50	B	A	45	6,839,780	181,010	3,548,880	23,719	52	39	13	0	0
	Wed	05/09/07	8:35	B	A	40	6,915,940	76,160	3,625,040	24,228	56	40	16	0	0
	Fri	05/11/07	8:08	B	A	52	6,989,870	73,930	3,698,970	24,722	50	32	18	0	0

Table A-2. EPA Arsenic Demonstration Project at Residence Hall, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate[a] gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
149	Tue	12/09/08	9:35	A	B	25	17,395,220	153,520	8,778,660	58,673	50	40	10	0	0
152	Mon	12/29/08	15:40	A	B	2	17,493,090	97,870	8,876,530	59,327	60	58	2	0	0
	Wed	12/31/08	14:19	A	B	3	17,498,100	5,010	8,881,540	59,361	61	60	1	0	0
153	Mon	01/05/09	9:48	A	B	18	17,530,910	32,810	8,914,350	59,580	61	60	1	0	0
154	Tue	01/13/09	10:30	A	B	24	17,674,080	143,170	9,057,520	60,537	58	52	6	0	0
155	Fri	01/23/09	14:05	A	B	12	17,855,710	181,630	9,239,150	61,751	58	54	4	0	0
157	Mon	02/02/09	7:50	A	B	25	18,042,670	186,960	9,426,110	63,000	58	50	8	0	0
158	Wed	02/11/09	11:17	A	B	2	18,222,810	180,140	9,606,250	64,204	61	61	0	0	0
159	Mon	02/16/09	15:45	A	B	1	18,317,950	95,140	9,701,390	64,840	60	60	0	0	0
160	Thu	02/26/09	15:13	A	B	18	18,508,910	190,960	9,892,350	66,116	58	55	3	0	0
161	Tue	03/03/09	7:50	A	B	30	18,597,680	88,770	9,981,120	66,710	58	48	10	0	0
162	Mon	03/09/09	9:50	A	B	30	18,714,520	116,840	10,097,960	67,491	58	42	16	0	0
164	Tue	03/24/09	7:50	A	B	1	18,960,140	245,620	10,343,580	69,132	61	60	1	0	0
166	Tue	04/06/09	8:41	A	B	28	19,102,750	142,610	10,486,190	70,085	54	43	11	0	0
170	Mon	05/04/09	11:50	A	B	10	19,617,160	514,410	11,000,600	73,524	59	58	1	0	0
173	Wed	05/27/09	10:59	A	B	18	20,032,450	415,290	11,415,890	76,299	56	54	2	0	0
173	Mon	06/01/09	15:35	A	B	12	20,134,390	101,940	11,517,830	76,981	57	52	5	0	0
179	Fri	07/17/09	8:00	A	B	12	20,488,780	354,390	11,872,220	79,349	60	58	2	0	0
184	Mon	08/17/09	8:50	A	B	3	20,728,850	240,070	12,112,290	80,954	61	60	1	0	0
185	Wed	08/26/09	9:35	A	B	4	20,786,770	57,920	12,170,210	81,341	61	60	1	0	0

Note: System contains two vessels in series, each containing 20 ft^3 of media.
Lead vessel (TB) rebedded with ARM 300 and put into lag position on January 24, 2007.
(a) From Week 5 through Week 20, flowrate readings recorded as a range; values recorded in table representing midpoint of the range.
NA = not available
NM = not measured

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
1	Fri	02/17/06	7:40	A	B	7.5	10,200	NA	NA	NA	60	60	0	0	0
2	Mon	02/20/06	8:20	A	B	11	30,570	20,370	20,370	170	61	61	0	0	0
	Tue	02/21/06	16:00	A	B	5	41,590	11,020	31,390	262	64	64	0	0	0
	Wed	02/22/06	8:14	A	B	14	45,310	3,720	35,110	293	62	62	0	0	0
	Thu	02/23/06	10:48	A	B	11.5	55,329	10,019	45,129	377	61	60	1	0	0
	Fri	02/24/06	8:05	A	B	6	61,274	5,945	51,074	427	61	62	-1	0	0
3	Mon	02/27/06	10:15	A	B	11.5	74,692	13,418	64,492	539	60	60	0	0	0
	Tue	02/28/06	21:55	A	B	12.5	81,532	6,840	71,332	596	60	60	0	0	0
	Wed	03/01/06	12:31	A	B	11	89,636	8,104	79,436	664	64	61	3	0	0
	Thu	03/02/06	10:30	A	B	15	95,085	5,449	84,885	709	60	54	6	0	0
	Fri	03/03/06	11:00	A	B	10	101,189	6,104	90,989	760	62	62	0	0	0
4	Mon	03/06/06	8:42	A	B	5	117,242	16,053	107,042	894	62	62	0	0	0
	Tue	03/07/06	20:11	A	B	5.5	123,468	6,226	113,268	946	60	61	-1	0	0
	Wed	03/08/06	21:35	A	B	8.5	131,900	8,432	121,700	1,017	62	62	0	0	0
	Thu	03/09/06	8:27	A	B	4	137,760	5,860	127,560	1,066	62	62	0	0	0
	Fri	03/10/06	10:45	A	B	23	144,580	6,820	134,380	1,123	60	55	5	0	0
5	Mon	03/13/06	8:40	A	B	4	159,962	15,382	149,762	1,251	60	60	0	0	0
	Tue	03/14/06	14:52	A	B	4	170,444	10,482	160,244	1,339	61	61	0	0	0
	Wed	03/15/06	7:55	A	B	2	173,880	3,436	163,680	1,367	62	62	0	0	0
	Thu	03/16/06	8:15	A	B	2	181,130	7,250	170,930	1,428	60	60	0	0	0
	Fri	03/17/06	8:15	A	B	1	187,705	6,575	177,505	1,483	62	61	1	0	0
6	Mon	03/20/06	8:18	A	B	3	203,586	15,881	193,386	1,616	60	61	-1	0	0
	Tue	03/21/06	7:58	A	B	3	210,208	6,622	200,008	1,671	61	62	-1	0	0
	Wed	03/22/06	8:58	A	B	3	217,711	7,503	207,511	1,734	61	62	-1	0	0
	Thu	03/23/06	8:48	A	B	3	228,687	10,976	218,487	1,825	61	60	1	0	0
	Fri	03/24/06	8:30	A	B	1	235,312	6,625	225,112	1,881	60	61	-1	0	0
7	Mon	03/27/06	8:45	A	B	2	240,539	5,227	230,339	1,924	60	60	0	0	0
	Tue	03/28/06	14:40	A	B	1	244,463	3,924	234,263	1,957	60	60	0	0	0
	Wed	03/29/06	11:10	A	B	1	246,135	1,672	235,935	1,971	62	62	0	0	0
	Thu	03/30/06	7:33	A	B	3	247,760	1,625	237,560	1,985	62	62	0	0	0
	Fri	03/31/06	8:25	A	B	3	249,940	2,180	239,740	2,003	64	64	0	0	0
8	Mon	04/03/06	9:15	A	B	7.5	256,280	6,340	246,080	2,056	60	60	0	0	0
	Tue	04/04/06	8:37	A	B	11	263,635	7,355	253,435	2,117	60	61	-1	0	0
	Wed	04/05/06	8:00	A	B	12	270,635	7,000	260,435	2,176	61	58	3	0	0
	Thu	04/06/06	10:43	A	B	17.5	282,230	11,595	272,030	2,273	60	60	0	0	0
	Fri	04/07/06	7:55	A	B	2	287,800	5,570	277,600	2,319	60	60	0	0	0
9	Mon	04/10/06	7:55	A	B	2	301,365	13,565	291,165	2,433	62	61	1	0	0
	Tue	04/11/06	8:05	A	B	2	307,675	6,310	297,475	2,485	62	61	1	0	0
	Wed	04/12/06	11:02	A	B	2	315,588	7,913	305,388	2,551	62	62	0	0	0
	Thu	04/13/06	8:15	A	B	4	321,528	5,940	311,328	2,601	61	62	-1	0	0
	Fri	04/14/06	8:20	A	B	3.5	327,380	5,852	317,180	2,650	62	61	1	0	0
10	Mon	04/17/06	7:55	A	B	10	340,990	13,610	330,790	2,764	60	60	0	0	0
	Tue	04/18/06	8:05	A	B	4	348,272	7,282	338,072	2,824	61	61	0	0	0
	Wed	04/19/06	11:02	A	B	8	355,320	7,048	345,120	2,883	61	62	-1	0	0
	Thu	04/20/06	8:15	A	B	3	359,150	3,830	348,950	2,915	61	62	-1	0	0
	Fri	04/21/06	8:20	A	B	26	367,750	8,600	357,550	2,987	62	50	12	0	0
11	Mon	04/24/06	8:55	A	B	1	380,595	12,845	370,395	3,094	61	60	1	0	0
	Tue	04/25/06	8:05	A	B	3	386,014	5,419	375,814	3,140	60	61	-1	0	0
	Wed	04/26/06	10:03	A	B	28	392,230	6,216	382,030	3,192	63	57	6	0	0
	Thu	04/27/06	7:35	A	B	2	397,880	5,650	387,680	3,239	63	63	0	0	0
	Fri	04/28/06	8:00	A	B	2	402,970	5,090	392,770	3,281	61	61	0	0	0
12	Mon	05/01/06	8:30	A	B	2	417,385	14,415	407,185	3,402	62	63	-1	0	0
	Tue	05/02/06	8:00	A	B	4	422,100	4,715	411,900	3,442	62	62	0	0	0
	Wed	05/03/06	13:15	A	B	4	430,018	7,918	419,818	3,508	61	61	0	0	0
	Thu	05/04/06	8:45	A	B	2	432,651	2,633	422,451	3,530	61	61	0	0	0
	Fri	05/05/06	8:00	A	B	4	436,522	3,871	426,322	3,562	61	61	0	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet(Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
13	Mon	05/08/06	8:43	A	B	2	445,242	8,720	435,042	3,635	62	62	0	0	0
	Tue	05/09/06	1:29	A	B	32	450,262	5,020	440,062	3,677	60	48	12	0	0
	Wed	05/10/06	15:00	A	B	2	454,444	4,182	444,244	3,712	59	59	0	0	0
	Thu	05/11/06	8:42	A	B	2	456,220	1,776	446,020	3,727	61	61	0	0	0
	Fri	05/12/06	8:05	A	B	2	459,565	3,345	449,365	3,755	61	61	0	0	0
14	Mon	05/15/06	8:20	A	B	2	468,132	8,567	457,932	3,826	62	62	0	0	0
	Tue	05/16/06	8:10	A	B	2	470,860	2,728	460,660	3,849	61	61	0	0	0
	Wed	05/17/06	10:40	A	B	0	473,066	2,206	462,866	3,868	61	61	0	0	0
	Thu	05/18/06	13:20	A	B	10	475,590	2,524	465,390	3,889	60	58	2	0	0
	Fri	05/19/06	15:40	A	B	0	477,452	1,862	467,252	3,904	58	58	0	0	0
15	Mon	05/22/06	8:10	A	B	0	481,444	3,992	471,244	3,938	60	60	0	0	0
	Tue	05/23/06	9:20	A	B	0	484,755	3,311	474,555	3,965	60	60	0	0	0
	Wed	05/24/06	11:01	A	B	20	490,100	5,345	479,900	4,010	60	58	2	0	0
	Thu	05/25/06	14:05	A	B	20	494,360	4,260	484,160	4,045	60	58	2	0	0
	Fri	05/26/06	9:27	A	B	20	496,865	2,505	486,665	4,066	60	60	0	0	0
16	Tue	05/30/06	8:10	A	B	18	504,712	7,847	494,512	4,132	60	58	2	0	0
	Wed	05/31/06	9:10	A	B	0	507,636	2,924	497,436	4,156	60	59	1	0	0
	Thu	06/01/06	7:30	A	B	0	510,512	2,876	500,312	4,180	62	57	5	0	0
	Fri	06/02/06	7:45	A	B	0	512,885	2,373	502,685	4,200	62	60	2	0	0
17	Mon	06/05/06	2:36	A	B	0	520,581	7,696	510,381	4,265	62	62	0	0	0
	Tue	06/06/06	7:40	A	B	0	522,705	2,124	512,505	4,282	59	58	1	0	0
	Wed	06/07/06	10:45	A	B	24	524,909	2,204	514,709	4,301	60	54	6	0	0
	Thu	06/08/06	13:55	A	B	20	528,330	3,421	518,130	4,329	61	55	6	0	0
	Fri	06/09/06	9:57	A	B	32	529,690	1,360	519,490	4,341	62	54	8	0	0
18	Mon	06/12/06	9:08	A	B	0	535,801	22,916	525,601	4,392	62	60	2	0	0
	Tue	06/13/06	8:15	A	B	0	538,887	3,086	528,687	4,418	62	60	2	0	0
	Wed	06/14/06	10:16	A	B	15	541,660	2,773	531,460	4,441	61	58	3	0	0
	Thu	06/15/06	8:15	A	B	0	543,975	2,315	533,775	4,460	61	60	1	0	0
	Fri	06/16/06	8:25	A	B	0	546,231	2,256	536,031	4,479	61	60	1	0	0
19	Mon	06/19/06	8:30	A	B	10	551,045	4,814	540,845	4,519	62	61	1	0	0
	Tue	06/20/06	8:00	A	B	0	552,128	1,083	541,928	4,528	61	61	0	0	0
	Wed	06/21/06	10:00	A	B	0	552,642	514	542,442	4,532	61	61	0	0	0
	Thu	06/22/06	7:46	A	B	0	553,035	393	542,835	4,536	62	62	0	0	0
	Fri	06/23/06	7:50	A	B	0	553,286	251	543,086	4,538	61	61	0	0	0
20	Mon	06/26/06	10:40	A	B	20	554,000	714	543,800	4,544	61	59	2	0	0
	Tue	06/27/06	11:10	A	B	0	554,234	234	544,034	4,546	62	55	7	0	0
	Wed	06/28/06	8:10	A	B	0	554,279	45	544,079	4,546	61	58	3	0	0
	Thu	06/29/06	8:00	A	B	0	554,325	46	544,125	4,546	62	61	1	0	0
	Fri	06/30/06	8:15	A	B	0	555,708	1,383	545,508	4,558	62	61	1	0	0
21	Mon	07/03/06	7:45	A	B	30	560,240	4,532	550,040	4,596	59	48	11	0	0
	Tue	07/04/06	NA	A	B	NA	NA	NA	NA	NA	NA	NA	NA	0	0
	Wed	07/05/06	1:05	A	B	22	566,560	6,320	556,360	4,649	62	52	10	0	0
	Thu	07/06/06	8:30	A	B	20	567,765	1,205	557,565	4,659	60	57	3	0	0
	Fri	07/07/06	7:30	A	B	2	569,870	2,105	559,670	4,676	62	62	0	0	0
22	Mon	07/10/06	7:20	A	B	2	580,874	11,004	570,674	4,768	61	61	0	0	0
	Tue	07/11/06	7:25	A	B	3	584,036	3,162	573,836	4,795	61	59	2	0	0
	Wed	07/12/06	8:30	A	B	18	588,109	4,073	577,909	4,829	60	55	5	0	0
	Thu	07/13/06	7:45	A	B	2	591,338	3,229	581,138	4,856	61	60	1	0	0
23	Tue	07/18/06	13:20	A	B	18	604,165	12,827	593,965	4,963	60	55	5	0	0
	Wed	07/19/06	11:45	A	B	0	2,621	2,970	596,935	4,988	62	61	1	0	0
	Thu	07/20/06	9:45	A	B	2	5,954	3,333	600,268	5,016	62	62	0	0	0
	Fri	07/21/06	8:20	A	B	12	9,941	3,987	604,255	5,049	62	61	1	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
24	Mon	07/24/06	0:00	A	B	8	17,750	7,809	612,064	5,114	62	61	1	0	0
	Tue	07/25/06	8:30	A	B	4	24,415	6,665	618,729	5,170	60	60	0	0	0
	Wed	07/26/06	14:05	A	B	2	24,970	555	619,284	5,174	61	61	0	0	0
	Thu	07/27/06	9:50	A	B	2	27,515	2,545	621,829	5,196	61	61	0	0	0
	Fri	07/28/06	9:45	A	B	1	30,294	2,779	624,608	5,219	61	61	0	0	0
25	Mon	07/31/06	8:10	A	B	12	35,840	5,546	630,154	5,265	60	58	2	0	0
	Tue	08/01/06	7:12	A	B	2	39,111	3,271	633,425	5,293	61	61	0	0	0
	Wed	08/02/06	8:35	A	B	2	43,295	4,184	637,609	5,328	61	60	1	0	0
	Thu	08/03/06	7:15	A	B	1	46,470	3,175	640,784	5,354	61	61	0	0	0
	Fri	08/04/06	7:20	A	B	1	50,531	4,061	644,845	5,388	62	62	0	0	0
26	Mon	08/07/06	7:30	A	B	1	57,432	6,901	651,746	5,446	62	61	1	0	0
	Tue	08/08/06	7:30	A	B	2	61,034	3,602	655,348	5,476	60	60	0	0	0
	Wed	08/09/06	7:20	A	B	2	64,578	3,544	658,892	5,505	62	61	1	0	0
	Thu	08/10/06	14:30	A	B	2	70,575	5,997	664,889	5,556	60	60	0	0	0
	Fri	08/11/06	13:00	A	B	2	72,685	2,110	666,999	5,573	62	61	1	0	0
27	Tue	08/15/06	7:35	A	B	0	82,555	9,870	676,869	5,656	62	61	1	0	0
	Wed	08/16/06	7:24	A	B	4	86,061	3,506	680,375	5,685	61	59	2	0	0
	Thu	08/17/06	7:45	A	B	2	89,138	3,077	683,452	5,711	61	60	1	0	0
	Fri	08/18/06	7:35	A	B	2	92,340	3,202	686,654	5,737	61	60	1	0	0
28	Fri	08/25/06	14:00	A	B	2	112,668	20,328	706,982	5,907	60	58	2	0	0
29	Mon	08/28/06	7:15	A	B	2	117,910	5,242	712,224	5,951	60	60	0	0	0
	Tue	08/29/06	7:30	A	B	1	121,220	3,310	715,534	5,979	60	60	0	0	0
	Wed	08/30/06	9:16	A	B	20	124,540	3,320	718,854	6,006	55	60	-5	0	0
	Thu	08/31/06	7:30	A	B	2	129,433	4,893	723,747	6,047	61	60	1	0	0
	Fri	09/01/06	7:25	A	B	2	132,250	2,817	726,564	6,071	62	61	1	0	0
30	Tue	09/05/06	7:35	A	B	1	140,512	8,262	734,826	6,140	60	60	0	0	0
	Wed	09/06/06	7:40	A	B	3	143,290	2,778	737,604	6,163	55	60	-5	0	0
	Thu	09/07/06	7:21	A	B	2	146,800	3,510	741,114	6,192	61	60	1	0	0
	Fri	09/08/06	14:20	A	B	2	150,790	3,990	745,104	6,226	62	61	1	0	0
31	Mon	09/11/06	10:00	A	B	4	157,468	6,678	751,782	6,282	61	59	2	0	0
	Tue	09/12/06	7:50	A	B	2	160,710	3,242	755,024	6,309	61	60	1	0	0
	Wed	09/13/06	8:50	A	B	3	165,230	4,520	759,544	6,346	60	60	0	0	0
	Thu	09/14/06	8:00	A	B	3	169,200	3,970	763,514	6,380	60	60	0	0	0
	Fri	09/15/06	8:00	A	B	2	173,490	4,290	767,804	6,415	61	60	1	0	0
32	Mon	09/18/06	7:30	A	B	4	179,610	6,120	773,924	6,467	61	60	1	0	0
	Tue	09/19/06	15:40	A	B	8	189,720	10,110	784,034	6,551	60	58	2	0	0
	Wed	09/20/06	7:30	A	B	2	193,080	3,360	787,394	6,579	60	59	1	0	0
	Thu	09/21/06	7:10	A	B	3	198,834	5,754	793,148	6,627	60	59	1	0	0
	Fri	09/22/06	6:25	A	B	3	204,730	5,896	799,044	6,677	60	59	1	0	0
33	Mon	09/25/06	7:40	A	B	3	218,525	13,795	812,839	6,792	60	48	12	0	0
	Tue	09/26/06	7:35	A	B	2	226,580	8,055	820,894	6,859	61	59	2	0	0
	Wed	09/27/06	8:40	A	B	6	234,750	8,170	829,064	6,927	60	60	0	0	0
	Thu	09/28/06	15:30	A	B	2	246,965	12,215	841,279	7,029	60	60	0	0	0
	Fri	09/29/06	9:20	A	B	3	252,290	5,325	846,604	7,074	61	60	1	0	0
34	Mon	10/02/06	7:45	A	B	16	265,800	13,510	860,114	7,187	60	58	2	0	0
	Tue	10/03/06	8:30	A	B	2	275,355	9,555	869,669	7,267	61	61	0	0	0
	Wed	10/04/06	9:40	A	B	14	284,090	8,735	878,404	7,340	60	58	2	0	0
	Thu	10/05/06	9:00	A	B	0	291,444	7,354	885,758	7,401	62	62	0	0	0
	Fri	10/06/06	8:30	A	B	8	298,582	7,138	892,896	7,461	60	58	2	0	0
35	Mon	10/09/06	7:30	A	B	25	311,200	12,618	905,514	7,566	60	54	6	0	0
	Tue	10/10/06	10:30	A	B	4	319,540	8,340	913,854	7,636	60	58	2	0	0
	Wed	10/11/06	8:47	A	B	3	326,880	7,340	921,194	7,697	61	59	2	0	0
	Thu	10/12/06	8:10	A	B	5	336,500	9,620	930,814	7,778	60	58	2	0	0
	Fri	10/13/06	15:30	A	B	2	347,970	11,470	942,284	7,873	61	60	1	0	0
36	Mon	10/16/06	8:05	A	B	2	356,480	8,510	950,794	7,944	60	60	0	0	0
	Wed	10/18/06	15:45	A	B	33	373,660	17,180	967,974	8,088	58	50	8	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
37	Wed	10/25/06	11:55	A	B	12	415,440	41,780	1,009,754	8,437	60	58	2	0	0
	Thu	10/26/06	9:40	A	B	25	421,870	6,430	1,016,184	8,491	59	54	5	0	0
	Fri	10/27/06	11:35	A	B	3	429,360	7,490	1,023,674	8,553	60	60	0	0	0
38	Mon	10/30/06	7:35	A	B	3	443,050	13,690	1,037,364	8,668	61	61	0	0	0
	Wed	11/01/06	9:50	A	B	2	459,460	16,410	1,053,774	8,805	61	61	0	0	0
	Fri	11/03/06	8:52	A	B	3	473,930	14,470	1,068,244	8,926	60	60	0	0	0
39	Mon	11/05/06	9:00	A	B	4	485,790	11,860	1,080,104	9,025	59	58	1	0	0
	Wed	11/07/06	9:30	A	B	12	501,020	15,230	1,095,334	9,152	60	58	2	0	0
	Thu	11/08/06	9:30	A	B	18	508,010	6,990	1,102,324	9,211	60	58	2	0	0
40	Tue	11/14/06	9:00	A	B	0	530,460	22,450	1,124,774	9,398	61	61	0	0	0
	Wed	11/15/06	8:30	A	B	4	550,910	20,450	1,145,224	9,569	60	57	3	0	0
	Fri	11/17/06	11:25	A	B	5	551,535	625	1,145,849	9,574	60	60	0	0	0
41	Mon	11/20/06	9:20	A	B	8	562,220	10,685	1,156,534	9,664	56	57	-1	0	0
	Wed	11/22/06	9:00	A	B	0	575,660	13,440	1,169,974	9,776	59	59	0	0	0
51	Mon	11/27/06	7:15	A	B	0	586,500	10,840	1,180,814	9,866	61	61	0	0	0
	Tue	11/28/06	8:30	A	B	2	593,100	6,600	1,187,414	9,922	61	60	1	0	0
	Wed	11/29/06	14:00	A	B	12	601,380	8,280	1,195,694	9,991	60	58	2	0	0
	Fri	12/01/06	14:15	A	B	1	614,000	12,620	1,208,314	10,096	60	60	0	0	0
52	Mon	12/04/06	8:00	A	B	2	622,790	8,790	1,217,104	10,170	60	60	0	0	0
	Tue	12/05/06	8:30	A	B	10	629,700	6,910	1,224,014	10,227	60	58	2	0	0
	Wed	12/06/06	8:10	A	B	4	635,140	5,440	1,229,454	10,273	60	60	0	0	0
53	Mon	12/11/06	7:35	A	B	1	652,410	17,270	1,246,724	10,417	63	62	1	0	0
	Wed	12/13/06	10:35	A	B	3	658,900	6,490	1,253,214	10,471	58	58	0	0	0
	Fri	12/15/06	9:50	A	B	2	665,000	6,100	1,259,314	10,522	62	61	1	0	0
54	Mon	12/18/06	10:10	A	B	1	669,650	4,650	1,263,964	10,561	62	62	0	0	0
	Tue	12/19/06	13:45	A	B	2	672,120	2,470	1,266,434	10,582	61	61	0	0	0
	Fri	12/22/06	NA	A	B	1	678,730	6,610	1,273,044	10,637	61	61	0	0	0
55	Tue	01/02/07	9:40	A	B	4	696,570	17,840	1,290,884	10,786	61	60	1	0	0
	Thu	01/04/07	12:10	A	B	3	701,470	4,900	1,295,784	10,827	62	60	2	0	0
	Fri	01/05/07	10:30	A	B	4	703,490	2,020	1,297,804	10,844	61	61	0	0	0
56	Tue	01/09/07	13:10	A	B	20	722,440	18,950	1,316,754	11,002	60	55	5	0	0
	Wed	01/10/07	11:12	A	B	18	728,030	5,590	1,322,344	11,049	61	58	3	0	0
	Fri	01/12/07	15:00	A	B	8	737,060	9,030	1,331,374	11,124	59	58	1	0	0
57	Tue	01/16/07	7:50	A	B	14	757,260	20,200	1,351,574	11,293	60	58	2	0	0
	Thu	01/18/07	14:05	A	B	3	766,700	9,440	1,361,014	11,372	61	60	1	0	0
	Fri	01/19/07	14:10	A	B	0	772,600	5,900	1,366,914	11,421	61	60	1	0	0
58	Mon	01/22/07	8:30	A	B	2	780,830	8,230	1,375,144	11,490	62	61	1	0	0
	Wed	01/24/07	7:50	A	B	11	793,610	12,780	1,387,924	11,597	59	58	1	0	0
59	Mon	01/29/07	8:15	A	B	3	819,400	25,790	1,413,714	11,812	62	61	1	0	0
	Wed	01/31/07	8:13	A	B	4	832,500	13,100	1,426,814	11,922	61	61	0	0	0
	Fri	02/02/07	9:20	A	B	1	845,590	13,090	1,439,904	12,031	60	60	0	0	0
60	Mon	02/05/07	8:20	A	B	3	854,990	9,400	1,449,304	12,110	61	60	1	0	0
	Wed	02/07/07	10:05	A	B	2	867,360	12,370	1,461,674	12,213	61	61	0	0	0
	Fri	02/09/07	8:30	A	B	1	879,230	11,870	1,473,544	12,312	61	61	0	0	0
61	Mon	02/12/07	8:08	A	B	10	886,930	7,700	1,481,244	12,377	60	60	0	0	0
	Wed	02/14/07	8:19	A	B	4	898,600	11,670	1,492,914	12,474	59	58	1	0	0
	Fri	02/16/07	11:30	A	B	3	910,010	11,410	1,504,324	12,570	60	61	-1	0	0
62	Mon	02/19/07	8:55	A	B	3	919,300	9,290	1,513,614	12,647	61	61	0	0	0
	Wed	02/21/07	10:35	A	B	2	931,120	11,820	1,525,434	12,746	61	61	0	0	0
	Fri	02/23/07	3:08	A	B	2	941,490	10,370	1,535,804	12,833	62	62	0	0	0
63	Mon	02/26/07	3:05	A	B	4	949,220	7,730	1,543,534	12,897	61	60	1	0	0
	Wed	02/28/07	4:23	A	B	2	958,010	8,790	1,552,324	12,971	61	61	0	0	0
	Thu	03/01/07	9:40	A	B	8	963,290	5,280	1,557,604	13,015	61	60	1	0	0
	Fri	03/02/07	2:45	A	B	2	970,000	6,710	1,564,314	13,071	60	60	0	0	0
64	Mon	03/05/07	9:45	A	B	2	975,280	5,280	1,569,594	13,115	63	62	1	0	0
	Wed	03/07/07	15:05	A	B	1	989,440	14,160	1,583,754	13,233	63	62	1	0	0
	Fri	03/09/07	8:35	A	B	2	996,930	7,490	1,591,244	13,296	63	62	1	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
65	Mon	03/12/07	8:32	A	B	15	1,006,410	9,480	1,600,724	13,375	61	61	0	0	0
	Wed	03/14/07	9:12	A	B	2	1,018,170	11,760	1,612,484	13,473	62	62	0	0	0
	Fri	03/16/07	9:00	A	B	4	1,030,200	12,030	1,624,514	13,574	60	61	-1	0	0
66	Mon	03/19/07	13:05	A	B	2	1,040,790	10,590	1,635,104	13,662	62	61	1	0	0
	Thu	03/22/07	7:55	A	B	2	1,054,560	13,770	1,648,874	13,777	60	59	1	0	0
67	Mon	03/26/07	11:55	A	B	1	1,060,770	6,210	1,655,084	13,829	62	62	0	0	0
	Thu	03/29/07	8:59	A	B	4	1,065,710	4,940	1,660,024	13,871	62	61	1	0	0
68	Mon	04/02/07	9:09	A	B	2	1,071,100	5,390	1,665,414	13,916	62	61	1	0	0
	Tue	04/03/07	8:15	A	B	2	1,076,200	5,100	1,670,514	13,958	62	61	1	0	0
	Wed	04/04/07	11:25	A	B	15	1,082,360	6,160	1,676,674	14,010	58	60	-2	0	0
	Fri	04/06/07	8:50	A	B	1	1,087,930	5,570	1,682,244	14,056	62	61	1	0	0
69	Mon	04/09/07	8:00	A	B	0	1,091,800	3,870	1,686,114	14,089	0	0	0	63	64
	Wed	04/11/07	9:15	A	B	2	1,103,610	11,810	1,697,924	14,187	0	0	0	64	63
	Fri	04/13/07	8:25	A	B	18	1,113,992	10,382	1,708,306	14,274	60	58	2	0	0
70	Mon	04/16/07	8:15	A	B	4	1,121,200	7,208	1,715,514	14,334	60	60	0	0	0
	Fri	04/20/07	8:15	A	B	10	1,144,980	23,780	1,739,294	14,533	60	60	0	0	0
71	Mon	04/23/07	5:14	A	B	20	1,154,420	9,440	1,748,734	14,612	61	58	3	0	0
	Wed	04/25/07	8:10	A	B	16	1,165,540	11,120	1,759,854	14,705	60	28	32	0	0
	Fri	04/27/07	7:40	A	B	0	1,174,990	9,450	1,769,304	14,784	60	61	-1	0	0
72	Mon	04/30/07	10:30	A	B	10	1,182,890	7,900	1,777,204	14,850	60	58	2	0	0
	Wed	05/02/07	11:02	A	B	12	1,189,925	7,035	1,784,239	14,908	60	58	2	0	0
73	Wed	05/09/07	15:10	A	B	2	1,221,380	31,455	1,815,694	15,171	60	60	0	0	0
	Fri	05/11/07	10:30	A	B	3	1,234,020	12,640	1,828,334	15,277	62	61	1	0	0
74	Mon	05/14/07	8:35	A	B	2	1,242,180	8,160	1,836,494	15,345	61	61	0	0	0
	Wed	05/16/07	11:10	A	B	30	1,256,550	14,370	1,850,864	15,465	61	54	7	0	0
	Thu	05/17/07	9:05	A	B	2	1,261,920	5,370	1,856,234	15,510	60	60	0	0	0
	Fri	05/18/07	14:45	A	B	15	1,272,240	10,320	1,866,554	15,596	60	58	2	0	0
75	Mon	05/21/07	13:54	A	B	18	1,283,870	11,630	1,878,184	15,693	60	58	2	0	0
	Wed	05/23/07	15:50	A	B	3	1,297,330	13,460	1,891,644	15,806	60	60	0	0	0
76	Tue	05/29/07	11:00	A	B	4	1,315,070	17,740	1,909,384	15,954	60	60	0	0	0
	Wed	05/30/07	10:35	A	B	4	1,321,270	6,200	1,915,584	16,006	60	60	0	0	0
	Fri	06/01/07	10:20	A	B	15	1,343,150	21,880	1,937,464	16,189	58	55	3	0	0
77	Mon	06/04/07	10:00	A	B	0	1,355,230	12,080	1,949,544	16,290	62	61	1	0	0
	Thu	06/07/07	10:24	A	B	8	1,375,630	20,400	1,969,944	16,460	60	59	1	0	0
78	Tue	06/12/07	9:42	A	B	20	1,398,720	23,090	1,993,034	16,653	60	58	2	0	0
	Fri	06/15/07	14:10	A	B	1	1,418,810	20,090	2,013,124	16,821	60	60	0	0	0
79	Mon	06/18/07	NA	A	B	8	1,430,320	11,510	2,024,634	16,917	60	60	0	0	0
80	Wed	06/27/07	8:40	A	B	4	1,456,265	25,945	2,050,579	17,134	62	61	1	0	0
	Fri	06/29/07	11:50	A	B	11	1,467,130	10,865	2,061,444	17,225	60	58	2	0	0
81	Mon	07/02/07	11:00	A	B	3	1,473,180	6,050	2,067,494	17,275	60	60	0	0	0
	Thu	07/05/07	8:15	A	B	1	1,479,420	6,240	2,073,734	17,327	60	60	0	0	0
	Fri	07/06/07	8:32	A	B	0	1,482,060	2,640	2,076,374	17,349	58	58	0	0	0
82	Mon	07/09/07	8:05	A	B	0	1,490,020	7,960	2,084,334	17,416	61	59	2	0	0
	Wed	07/09/07	2:00	A	B	5	1,498,470	8,450	2,092,784	17,486	62	60	2	0	0
83	Mon	07/16/07	9:40	A	B	0	1,509,992	11,522	2,104,306	17,583	62	60	2	0	0
	Wed	07/18/07	12:35	A	B	8	1,518,282	8,290	2,112,596	17,652	62	60	2	0	0
84	Mon	07/23/07	7:45	A	B	5	1,533,250	14,968	2,127,564	17,777	60	63	-3	0	0
	Thu	07/25/07	8:50	A	B	10	1,539,144	5,894	2,133,458	17,826	61	62	-1	0	0
	Fri	07/27/07	8:20	A	B	6	1,546,190	7,046	2,140,504	17,885	61	62	-1	0	0
85	Mon	07/30/07	8:30	A	B	28	1,552,230	6,040	2,146,544	17,936	60	50	10	0	0
	Wed	08/01/07	10:26	A	B	10	1,559,540	7,310	2,153,854	17,997	62	60	2	0	0
	Fri	08/03/07	10:19	A	B	4	1,567,270	7,730	2,161,584	18,061	63	61	2	0	0
86	Mon	08/06/07	9:05	A	B	2	1,572,320	5,050	2,166,634	18,104	60	60	0	0	0
	Wed	08/08/07	8:00	A	B	3	1,579,330	7,010	2,173,644	18,162	62	61	1	0	0
87	Mon	08/13/07	10:25	A	B	3	1,589,520	10,190	2,183,834	18,247	61	60	1	0	0
	Wed	08/15/07	8:10	A	B	2	1,596,835	7,315	2,191,149	18,308	61	62	-1	0	0
	Thu	08/16/07	9:50	A	B	3	1,599,910	3,075	2,194,224	18,334	62	61	1	0	0
	Fri	08/17/07	10:20	A	B	12	1,604,110	4,200	2,195,349	18,343	61	61	0	0	0
88	Tue	08/21/07	8:32	A	B	2	1,611,580	7,470	2,202,819	18,406	63	62	1	0	0
	Fri	08/24/07	10:25	A	B	0	1,620,880	9,300	2,212,119	18,484	62	61	1	0	0
89	Mon	08/26/07	8:05	A	B	0	1,623,640	2,760	2,214,879	18,507	63	62	1	0	0
	Wed	08/28/07	8:40	A	B	0	1,628,850	5,210	2,220,089	18,550	62	61	1	0	0
90	Tue	09/04/07	8:20	A	B	0	1,642,670	13,820	2,233,909	18,666	62	61	1	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
91	Mon	09/10/07	3:47	A	B	3	1,659,440	16,770	2,250,679	18,806	60	59	1	0	0
	Tue	09/11/07	10:05	A	B	3	1,661,640	2,200	2,252,879	18,824	60	59	1	0	0
	Wed	09/12/07	2:12	A	B	8	1,669,320	7,680	2,260,559	18,888	60	60	0	0	0
	Fri	09/14/07	1:20	A	B	3	1,684,165	14,845	2,275,404	19,012	59	58	1	0	0
92	Mon	10/01/07	3:10	A	B	4	1,768,490	84,325	2,359,729	19,717	62	61	1	0	0
	Wed	10/03/07	9:30	A	B	20	1,779,290	10,800	2,370,529	19,807	60	58	2	0	0
	Fri	10/05/07	8:10	A	B	0	1,790,410	11,120	2,381,649	19,900	63	62	1	0	0
93	Mon	10/15/07	11:00	A	B	0	1,842,310	51,900	2,433,549	20,334	62	61	1	0	0
	Wed	10/19/07	11:05	A	B	0	1,869,040	26,730	2,460,279	20,557	60	58	2	0	0
94	Tue	10/23/07	8:00	A	B	0	1,888,000	18,960	2,479,239	20,716	61	62	-1	0	0
	Wed	10/24/07	7:50	A	B	0	1,897,210	9,210	2,488,449	20,793	62	61	1	0	0
95	Mon	10/29/07	9:10	A	B	8	1,924,120	26,910	2,515,359	21,017	62	60	2	0	0
	Wed	10/31/07	7:50	A	B	3	1,937,350	13,230	2,528,589	21,128	62	61	1	0	0
	Fri	11/02/07	8:05	A	B	2	1,951,390	14,040	2,542,629	21,245	62	61	1	0	0
96	Mon	11/05/07	9:00	A	B	0	1,965,770	14,380	2,557,009	21,365	60	60	0	0	0
	Wed	11/07/07	9:25	A	B	0	1,979,990	14,220	2,571,229	21,484	61	59	2	0	0
97	Tue	11/20/07	14:40	A	B	5	2,049,990	70,000	2,641,229	22,069	61	60	1	0	0
98	Mon	12/03/07	11:50	A	B	4	2,104,410	54,420	2,695,649	22,524	62	61	1	0	0
99	Wed	12/12/07	8:00	A	B	1	2,142,140	37,730	2,733,379	22,839	62	62	0	0	0
100	Tue	12/18/07	11:50	A	B	18	2,158,650	16,510	2,749,889	22,977	60	55	5	0	0
101	Thu	12/20/07	8:45	A	B	4	2,164,830	6,180	2,756,069	23,029	62	62	0	0	0
102	Wed	12/26/07	11:55	A	B	2	2,172,280	7,450	2,763,519	23,091	63	64	-1	0	0
	Fri	12/28/07	8:45	A	B	1	2,174,690	2,410	2,765,929	23,111	62	63	-1	0	0
103	Wed	01/09/08	8:20	A	B	0	2,199,600	24,910	2,790,839	23,319	61	62	-1	0	0
104	Mon	01/28/08	3:00	A	B	0	2,305,180	105,580	2,896,419	24,201	61	60	1	0	0
	Tue	01/29/08	2:30	A	B	5	2,311,090	5,910	2,902,329	24,251	61	60	1	0	0
105	Fri	02/01/08	11:20	A	B	0	2,329,680	18,590	2,920,919	24,406	60	61	-1	0	0
106	Wed	02/13/08	10:30	A	B	0	2,399,440	69,760	2,990,679	24,989	63	62	1	0	0
107	Tue	02/26/08	10:30	A	B	2	2,467,020	67,580	3,058,259	25,554	60	60	0	0	0
	Fri	02/29/08	3:24	A	B	15	2,489,080	22,060	3,080,319	25,738	61	60	1	0	0
108	Tue	03/04/08	8:05	A	B	2	2,501,220	12,140	3,092,459	25,839	62	62	0	0	0
	Fri	03/07/08	11:15	A	B	5	2,521,840	20,620	3,113,079	26,012	61	61	0	0	0
109	Mon	03/10/08	8:40	A	B	5	2,529,990	8,150	3,121,229	26,080	61	61	0	0	0
110	Mon	03/17/08	15:45	A	B	5	2,570,900	40,910	3,162,139	26,422	62	61	1	0	0
111	Tue	03/24/08	10:30	A	B	1	2,596,820	25,920	3,188,059	26,638	61	62	-1	0	0
	Fri	03/28/08	7:00	A	B	3	2,607,620	10,800	3,198,859	26,728	61	61	0	0	0
113	Wed	04/09/08	14:00	A	B	2	2,671,240	63,620	3,262,479	27,260	62	61	1	0	0
114	Mon	04/14/08	10:25	A	B	12	2,706,906	35,666	3,298,145	27,558	61	59	2	0	0
115	Wed	04/22/08	8:50	A	B	10	2,782,350	75,444	3,373,589	28,188	61	60	1	0	0
116	Tue	04/29/08	10:00	A	B	4	2,831,180	48,830	3,422,419	28,596	61	60	1	0	0
	Thu	05/01/08	15:15	A	B	18	2,852,280	21,100	3,443,519	28,773	60	57	3	0	0
117	Thu	05/08/08	9:10	A	B	12	2,912,430	60,150	3,503,669	29,275	60	58	2	0	0
118	Tue	05/13/08	10:35	A	B	12	2,950,930	38,500	3,542,169	29,597	61	58	3	0	0
120	Thu	05/29/08	8:20	A	B	2	3,044,700	93,770	3,635,939	30,381	60	60	0	0	0
121	Mon	06/02/08	10:00	A	B	14	3,066,850	22,150	3,658,089	30,566	60	58	2	0	0
123	Thu	06/19/08	7:45	A	B	2	3,163,290	96,440	3,754,529	31,371	61	61	0	0	0
124	Tue	06/24/08	14:25	A	B	2	3,182,560	19,270	3,773,799	31,532	61	61	0	0	0
126	Mon	07/07/08	14:25	A	B	4	3,239,880	57,320	3,831,119	32,011	59	58	1	0	0
127	Fri	07/18/08	8:40	A	B	2	3,274,880	35,000	3,866,119	32,304	60	59	1	0	0
129	Mon	07/28/08	8:05	A	B	5	3,307,740	32,860	3,898,979	32,578	61	60	1	0	0
131	Thu	08/07/08	8:14	A	B	2	3,339,250	31,510	3,930,489	32,842	61	60	1	0	0
132	Fri	08/15/08	10:01	A	B	14	3,367,810	28,560	3,959,049	33,080	60	58	2	0	0
133	Wed	08/20/08	10:51	A	B	4	3,388,200	20,390	3,979,439	33,251	62	60	2	0	0
139	Fri	10/03/08	8:40	A	B	3	3,599,540	211,340	4,190,779	35,017	62	61	1	0	0
140	Fri	10/10/08	9:30	A	B	4	3,647,110	47,570	4,238,349	35,414	62	62	0	0	0
144	Mon	11/10/08	15:16	A	B	15	3,862,970	215,860	4,454,209	37,218	60	58	2	0	0
145	Wed	11/19/08	23:20	A	B	3	3,920,870	57,900	4,512,109	37,701	62	61	1	0	0
147	Mon	12/01/08	10:30	A	B	10	3,977,490	56,620	4,568,729	38,175	59	59	0	0	0
148	Tue	12/09/08	8:30	A	B	0	4,025,970	48,480	4,617,209	38,580	60	60	0	0	0
149	Thu	12/18/08	8:30	A	B	2	4,062,580	36,610	4,653,819	38,886	62	62	0	0	0
150	Mon	12/29/08	15:40	A	B	1	4,084,140	21,560	4,675,379	39,066	62	62	0	0	0
	Wed	12/31/08	9:01	A	B	1	4,087,530	3,390	4,678,769	39,094	63	62	1	0	0
151	Mon	01/05/09	9:38	A	B	4	4,097,980	10,450	4,689,219	39,181	63	62	1	0	0

Table A-3. EPA Arsenic Demonstration Project at College Union, Klamath Falls, OR - Daily System Operation Log Sheet (Cont.)

				Tank Position		Treatment System					System Pressure			Differential Pressure Across Vessel	
Week No.	Day of Week	Date	Time	Lead A/B	Lag A/B	Flowrate gpm	Totalizer gal	Daily Water Treated gal	Cum. Throughput gal	Bed Volume #BV	Inlet psig	Outlet psig	In-Out psig	DPI 1 psig	DPI 2 psig
152	Tue	01/13/09	9:55	A	B	20	4,145,440	47,460	4,736,679	39,578	60	58	2	0	0
153	Fri	01/23/09	13:20	A	B	7	4,201,010	55,570	4,792,249	40,042	61	60	1	0	0
155	Mon	02/02/09	8:18	A	B	2	4,249,440	48,430	4,840,679	40,447	61	61	0	0	0
	Fri	02/06/09	15:38	A	B	10	4,284,360	34,920	4,875,599	40,739	61	61	0	0	0
156	Mon	02/16/09	15:25	A	B	20	4,344,400	60,040	4,935,639	41,240	60	57	3	0	0
157	Thu	02/26/09	14:40	A	B	2	4,408,230	63,830	4,999,469	41,774	62	61	1	0	0
158	Mon	03/02/09	7:55	A	B	2	4,424,300	16,070	5,015,539	41,908	62	62	0	0	0
159	Mon	03/09/09	8:30	A	B	1	4,463,890	39,590	5,055,129	42,239	63	62	1	0	0
161	Wed	03/25/09	11:40	A	B	3	4,546,420	82,530	5,137,659	42,928	60	60	0	0	0
163	Tue	04/06/09	9:37	A	B	34	4,663,180	116,760	5,254,419	43,904	59	43	16	0	0
165	Mon	04/20/09	11:20	A	B	3	4,679,200	16,020	5,270,439	44,038	59	58	1	0	0
167	Mon	05/04/09	11:35	A	B	4	4,768,820	89,620	5,360,059	44,787	59	58	1	0	0
170	Wed	05/27/09	8:41	A	B	5	4,909,080	140,260	5,500,319	45,959	59	58	1	0	0
173	Mon	06/01/09	15:50	A	B	3	4,960,900	51,820	5,552,139	46,392	60	60	0	0	0
179	Fri	07/17/09	8:29	A	B	7	5,175,270	214,370	5,766,509	48,183	61	58	3	0	0
184	Mon	08/17/09	8:40	A	B	1	5,265,510	90,240	5,856,749	48,937	60	62	-2	0	0
185	Wed	08/26/09	8:40	A	B	3	5,298,510	33,000	5,889,749	49,212	61	60	1	0	0

APPENDIX B

ANALYTICAL RESULTS

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR

Sampling Date		01/11/06		01/24/06					2/1/2006[d]					02/14/06[e]					03/01/06				
Sampling Location		IN	TT	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2
Parameter	Unit																						
Bed Volume	10^3	-	0.5	-	0.7	0.7	0.9	0.9	-	0.8	0.8	1.1	1.1	-	1.1	1.1	1.5	1.5	-	1.4	1.4	1.8	1.8
Alkalinity	mg/L[a]	114	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	21.0	30.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	0.5	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	<50[c]	<50[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	31.1	11.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.4	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.3	6.9	NM	NM	NM	NM	NM	7.5	7.0	7.3	7.2	7.4	8.1	7.9	8.1	7.9	8.1	7.7	7.8	8.0	8.0	8.1
Temperature	°C	13.7	13.5	NM	NM	NM	NM	NM	13.3	14.4	13.4	13.9	13.3	73.3	13.8	13.5	13.6	13.2	13.6	13.3	13.5	13.4	13.5
DO	mg/L	4.2	3.3	NM	NM	NM	NM	NM	3.3	3.3	3.6	3.9	3.4	3.5	3.2	2.9	3.2	3.3	3.5	3.5	3.3	3.2	3.3
ORP	mV	340	334	NM	NM	NM	NM	NM	491	466	462	472	462	428	444	448	448	450	319	326	320	344	359
Free Chlorine (as Cl_2)	mg/L	0.3	0.0	NM	NM	NM	NM	NM	0.3	0.0	0.0	0.0	0.1	0.4	0.0	0.1	0.0	0.1	0.3	0.0	0.0	0.0	0.0
Total Hardness	mg/L[a]	77.0	82.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	53.9	57.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	23.1	24.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	29.8 -	0.1 -	31.2 -	0.1 -	0.1 -	<0.1 -	<0.1 -	32.4 -	0.3 -	0.4 -	0.3 -	0.5 -	26.5 -	0.1 -	<0.1 -	<0.1 -	<0.1 -	27.0 -	0.1 -	<0.1 -	<0.1 -	0.2 -
As (soluble)	µg/L	29.7	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	0.6	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	29.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	28.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) Result is measurement of orthophosphate as P.
(d) Water quality readings taken on 02/09/06.
(e) Water quality readings taken on 02/21/06.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		03/14/06		03/29/06					04/12/06					04/26/06					05/09/06	
Sampling Location		IN	TT	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TT
Parameter	Unit																			
Bed Volume	10^3	-	1.9	-	2.0	2.0	2.4	2.4	-	2.4	2.4	2.9	2.9	-	3.0	3.0	3.4	3.4	-	3.6
Alkalinity	mg/L[(a)]	112	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	122	109
Fluoride	mg/L	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
Sulfate	mg/L	21.5	22.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	22
Nitrate (as N)	mg/L	0.7	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9	0.8
Total P (as P)	µg/L[(b)]	<10	<10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<10	<10
Silica (as SiO_2)	mg/L	29.9	24.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31.2	29.6
Turbidity	NTU	0.4	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.8
pH	S.U.	7.8	8.4	8.0	8.2	8.4	8.3	8.4	7.8	7.9	8.1	8.1	8.1	8.1	8.3	8.3	8.2	8.3	8.1	8.0
Temperature	°C	13.3	12.8	17.7	13.0	12.9	12.8	12.9	14.0	13.8	13.6	13.5	13.7	16.1	16.7	16.0	16.4	16.2	20.6	19.0
DO	mg/L	3.9	2.7	4.2	4.2	3.3	3.6	3.3	3.8	3.9	3.4	3.4	3.4	4.8	2.8	3.2	3.4	3.4	4.0	3.4
ORP	mV	432	458	476	456	446	445	442	414	418	405	402	403	581	471	456	465	453	433	364
Free Chlorine (as Cl_2)	mg/L	0.3	0.0	0.2	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.3	0.0	0.1	0.1	0.1	0.3	0.1
Total Hardness	mg/L[(a)]	82.4	80.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	107	106
Ca Hardness	mg/L[(a)]	60.2	57.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79.1	78.5
Mg Hardness	mg/L[(a)]	22.2	22.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27.6	27.4
As (total)	µg/L	31.2	0.2	30.2	<0.1	<0.1	<0.1	<0.1	29.0	0.3	0.2	0.2	0.3	27.4	<0.1	<0.1	<0.1	0.1	28.7	<0.1
		-	-	29.6	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	31.0	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.6	<0.1
As (particulate)	µg/L	0.2	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
As (III)	µg/L	0.6	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	0.2
As (V)	µg/L	30.4	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28.4	<0.1
Fe (total)	µg/L	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25
Fe (soluble)	µg/L	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<25	<25
Mn (total)	µg/L	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
Mn (soluble)	µg/L	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1

(a) as $CaCO_3$.
(b) as P.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		05/24/06					06/07/06		06/21/06					07/05/06		07/19/06				
Sampling Location		IN	TA1	TB1	TA2	TB2	IN	TT	IN	TA1	TB1	TA2	TB2	IN	TT	IN	TA1	TB1	TA2	TB2
Parameter	Unit																			
Bed Volume	10^3	-	3.8	3.8	4.3	4.3	-	4.5	-	4.8	4.8	5.2	5.2	-	5.4	-	5.5	5.5	6.0	6.0
Alkalinity	mg/L[(a)]	-	-	-	-	-	118	101	-	-	-	-	-	113	113	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	22	21	-	-	-	-	-	21	20	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	1.0	0.9	-	-	-	-	-	0.7	0.8	-	-	-	-	-
Total P (as P)	µg/L[(b)]	-	-	-	-	-	<10	<10	-	-	-	-	-	<10	<10	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	31.0	30.6	-	-	-	-	-	31.1	31.5	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	0.3	0.3	-	-	-	-	-	0.5	0.7	-	-	-	-	-
pH	S.U.	7.9	7.8	8.0	8.1	8.1	7.9	7.9	8.0	8.0	8.0	7.9	8.0	8.0	7.9	8.0	8.2	8.0	7.9	8.0
Temperature	°C	20.5	20.6	21.6	21.5	21.3	22.8	22.5	22.6	22.7	22.0	22.0	21.9	23.2	23.0	23.8	23.4	23.4	23.4	23.7
DO	mg/L	3.1	3.3	3.0	3.2	3.0	3.8	3.1	3.1	2.8	3.4	3.6	3.3	NA[(c)]	NA[(c)]	3.1	2.3	3.0	3.2	3.0
ORP	mV	438	425	416	422	456	397	346	508	457	473	454	449	542	438	524	436	419	414	404
Free Chlorine (as Cl_2)	mg/L	0.3	0.2	0.2	0.1	0.1	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.1	0.1	0.1	0.0
Total Hardness	mg/L[(a)]	-	-	-	-	-	86.7	84.9	-	-	-	-	-	72.3	74.2	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	63.4	62.3	-	-	-	-	-	54.5	53.7	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	23.3	22.6	-	-	-	-	-	17.8	20.4	-	-	-	-	-
As (total)	µg/L	25.7 -	<0.1 -	7.0 -	<0.1 -	1.0 -	29.3 -	<0.1 -	32.4 -	0.2 -	5.3 -	<0.1 -	0.9 -	29.3 -	<0.1 -	30.7 31.3	<0.1 <0.1	3.6 3.8	<0.1 <0.1	0.8 0.8
As (soluble)	µg/L	-	-	-	-	-	27.6	<0.1	-	-	-	-	-	30.1	<0.1	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	1.7	<0.1	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	0.2	0.2	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	27.4	<0.1	-	-	-	-	-	30.0	<0.1	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	<25	<25	-	-	-	-	-	<25	<25	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	<25	<25	-	-	-	-	-	<25	<25	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	0.6	0.5	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		08/02/06		08/16/06					08/30/06		09/13/06					09/27/06	
Sampling Location / Parameter	Unit	IN	TT	IN	TA1	TB1	TA2	TB2	IN	TT	IN	TA1	TB1	TA2	TB2	IN	TT
Bed Volume	10^3	-	6.2	-	6.3	6.3	7.0	7.0	-	7.1	-	7.1	7.1	7.8	7.8	-	7.9
Alkalinity	mg/L[(a)]	114	114	-	-	-	-	-	116	123	-	-	-	-	-	120	118
Fluoride	mg/L	0.5	0.5	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	<0.1	0.2
Sulfate	mg/L	22	22	-	-	-	-	-	27	27	-	-	-	-	-	35	20
Nitrate (as N)	mg/L	0.6	0.8	-	-	-	-	-	0.6	0.8	-	-	-	-	-	0.7	<0.05
Total P (as P)	µg/L[(b)]	12.3	<10	-	-	-	-	-	<10	<10	-	-	-	-	-	<10	<10
Silica (as SiO_2)	mg/L	28.0	28.5	-	-	-	-	-	27.9	28.2	-	-	-	-	-	28.9	30.1
Turbidity	NTU	0.4	0.2	-	-	-	-	-	0.1	0.1	-	-	-	-	-	0.2	0.2
pH	S.U.	7.9	7.9	7.9	7.9	8.1	7.9	8.0	8.1	8.2	8.0	7.9	8.1	7.9	7.9	8.0	7.9
Temperature	°C	23.5	23.1	22.8	22.8	22.7	22.8	23.0	23.0	22.8	24.9	24.0	22.7	23.9	23.9	22.5	22.5
DO	mg/L	2.4	2.7	3.2	2.8	3.3	3.1	3.4	3.0	2.7	3.3	3.1	3.3	3.2	3.2	4.5	3.5
ORP	mV	517	264	544	264	255	257	253	485	431	547	451	255	439	439	563	568
Free Chlorine (as Cl_2)	mg/L	0.3	0.1	0.4	0.1	0.1	0.1	0.1	0.2	0.1	0.4	0.1	0.1	0.1	0.1	0.3	0.0
Total Hardness	mg/L[(a)]	76.4	81.4	-	-	-	-	-	77.8	86.7	-	-	-	-	-	83.0	77.8
Ca Hardness	mg/L[(a)]	58.0	60.4	-	-	-	-	-	61.4	63.0	-	-	-	-	-	61.3	57.0
Mg Hardness	mg/L[(a)]	18.4	20.9	-	-	-	-	-	16.5	23.7	-	-	-	-	-	21.7	20.7
As (total)	µg/L	32.6 -	<0.1 -	28.9 -	<0.1 -	2.2 -	<0.1 -	0.5 -	35.5 -	1.9 -	28.7 -	0.2 -	2.2 -	0.1 -	0.6 -	30.3 -	<0.1 -
As (soluble)	µg/L	31.6	<0.1	-	-	-	-	-	33.9	1.9	-	-	-	-	-	31.5	<0.1
As (particulate)	µg/L	1.0	<0.1	-	-	-	-	-	1.6	<0.1	-	-	-	-	-	<0.1	<0.1
As (III)	µg/L	0.1	0.1	-	-	-	-	-	0.3	0.3	-	-	-	-	-	0.1	<0.1
As (V)	µg/L	31.4	<0.1	-	-	-	-	-	33.6	1.6	-	-	-	-	-	31.4	<0.1
Fe (total)	µg/L	<25	<25	-	-	-	-	-	<25	<25	-	-	-	-	-	<25	<25
Fe (soluble)	µg/L	<25	<25	-	-	-	-	-	<25	<25	-	-	-	-	-	<25	<25
Mn (total)	µg/L	0.2	<0.1	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	<0.1	<0.1
Mn (soluble)	µg/L	0.2	0.2	-	-	-	-	-	<0.1	<0.1	-	-	-	-	-	<0.1	<0.1

(a) as $CaCO_3$.
(b) as P.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		10/11/06					01/10/07					03/07/07				
Sampling Location / Parameter	Unit	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2
Bed Volume	10^3	-	8.0	8.0	8.7	8.7	-	10.2	10.2	11.1	11.1	-	11.1	11.1	12.1	12.1
Alkalinity	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[(b)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.8	7.9	7.8	7.8	7.8	8.2	7.5	8.1	7.7	8.2	8.1	8.1	8.0	8.0	8.0
Temperature	°C	22.2	22.1	22.2	22.1	22.1	15.6	16.8	16.5	16.5	18.1	13.0	16.2	13.1	15.4	13.0
DO	mg/L	3.1	3.3	3.3	3.3	3.3	5.1	4.5	5.0	4.3	6.6	4.9	4.4	4.4	4.6	4.4
ORP	mV	569	467	450	445	442	474	416	381	385	372	586	491	488	484	483
Free Chlorine (as Cl_2)	mg/L	0.3	0.02	0.02	0.02	0.02	0.3	0.05	0.05	0.05	0.05	0.3	0.05	0.03	0.01	0.05
Total Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	29.9 29.6	0.2 0.2	1.9 2.1	0.2 0.3	0.6 0.6	32.1 -	0.4 -	2.0 -	0.3 -	1.2 -	26.0 -	<0.1 -	1.6 -	<0.1 -	1.5 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		05/02/07					08/01/07					11/07/07				
Sampling Location / Parameter	Unit	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2
Bed Volume	10^3	-	12.0	12.0	13.0	13.0	-	13.1	13.1	14.2	14.2	-	14.3	14.3	15.4	15.4
Alkalinity	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[(b)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	7.9	7.9	7.9	7.9	8.0	8.0	8.0	8.0	8.0	8.2	8.1	8.2	8.1	8.1
Temperature	°C	18.7	21.6	19.6	20.8	19.2	26.3	24.8	24.6	24.5	24.5	19.5	20.8	20.0	20.5	20.0
DO	mg/L	3.7	3.4	3.6	4.0	4.0	2.9	3.0	3.1	3.0	3.0	3.8	3.2	3.3	4.1	4.1
ORP	mV	585	479	469	459	457	428	367	355	350	346	583	472	463	458	454
Free Chlorine (as Cl_2)	mg/L	0.3	0.05	0.05	0.05	0.05	0.3	0.0	0.0	0.0	0.0	0.4	0.1	0.1	0.1	0.1
Total Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	31.4 -	0.3 -	2.6 -	0.2 -	3.3 -	27.4 -	<0.1 -	2.5 -	<0.1 -	2.8 -	32.0 -	0.2 -	3.6 -	<0.1 -	5.1 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		02/13/08					05/13/08					08/20/08					11/19/08				
Sampling Location / Parameter	Unit	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2
Bed Volume	10^3	-	15.4	15.4	16.6	16.6	-	16.7	16.7	17.8	17.8	-	17.8	17.8	19.0	19.0	-	19.4	19.4	20.7	20.7
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	7.9	7.9	7.9	8.2	8.2	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.1	8.3	8.2	8.2	8.2	8.2
Temperature	°C	12.8	16.2	16.2	12.2	12.1	18.7	19.6	19.9	19.6	19.8	25.4	24.3	24.3	24.1	24.2	22.2	20.7	20.5	20.6	20.5
DO	mg/L	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
ORP	mV	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Free Chlorine (as Cl_2)	mg/L	0.4	0.1	0.1	0.1	0.1	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	30.8 -	1.1 -	8.9 -	0.5 -	11.6 -	29.3 -	0.9 -	12.0 -	0.4 -	14.4 -	29.8 -	0.1 -	13.1 -	0.1 -	14.9 -	33.1 -	0.2 -	20.0 -	0.1 -	21.9 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) DO/ORP not operating correctly.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-1. Analytical Results from Long-Term Sampling, Purvine Hall, Klamath Falls, OR (Continued)

Sampling Date		02/11/09					05/27/09					08/26/09				
Sampling Location / Parameter	Unit	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2	TB2	IN	TA1	TB1	TA2[d]	TB2[d]
Bed Volume	10^3	-	20.8	20.8	22.2	22.2	-	22.4	22.4	23.8	23.8	-	23.5	23.5	24.9	24.9
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.4	8.4	8.3	8.2	8.2	8.3	7.7	8.2	8.2	8.2	8.4	8.3	8.2	8.2	8.2
Temperature	°C	13.9	16.8	16.1	16.2	15.6	20.6	22.2	22.8	22.1	22.4	24.9	24.3	25.2	24.3	24.5
DO	mg/L	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
ORP	mV	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Free Chlorine (as Cl_2)	mg/L	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	30.5	0.3	21.6	0.3	23.1	25.2	<0.1	21.5	<0.1	20.8	26.3	0.4	19.8	0.4	20.4
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) DO/ORP not operating correctly.
Lead Vessels: TB1, TB2; Lag Vessels: TA1, TA2

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR

Sampling Date		01/11/06			01/24/06			02/01/06[d]			02/14/06[e]			03/01/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	1.1	1.1	-	2.8	2.8	-	3.9	3.9	-	5.6	5.6	-	7.6	7.6
Alkalinity	mg/L[a]	114	106	110	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	21	21	21	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	0.5	0.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	<50[c]	<50[c]	<50[c]	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	30.8	2.2	18.6	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.5	0.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.3	6.9	7.1	NM	NM	NM	7.5	7.5	7.6	7.9	8.1	8.1	8.0	8.2	8.2
Temperature	°C	13.7	14.6	14.4	NM	NM	NM	18.1	17.9	17.9	17.1	16.8	16.6	17.6	17.3	17.1
DO	mg/L	4.0	3.3	4.0	NM	NM	NM	2.9	3.3	3.4	3.2	2.3	3.8	2.9	2.7	2.6
ORP	mV	376	442	459	NM	NM	NM	506	496	533	403	498	511	437	472	510
Free Chlorine (as Cl_2)	mg/L	0.3	0.1	0.1	NM	NM	NM	0.3	0.1	0.2	0.4	0.3	0.2	0.3	0.3	0.2
Total Hardness	mg/L[a]	77.6	83.7	78.9	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	54.7	59.1	55.1	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	22.9	24.5	23.9	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	29.0 -	0.9 -	0.2 -	30.9 -	0.1 -	0.2 -	30.2 -	0.3 -	0.5 -	26.7 -	0.1 -	0.9 -	28.4 -	0.1 -	2.2 -
As (soluble)	µg/L	30.0	0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	0.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	0.6	0.4	0.5	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	29.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	44.6	<25	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	1.0	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	<0.1	1.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) Result is measurement of orthophosphate as P
NM = not measured.
Lead Vessel: TB; Lag Vessel: TA

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		03/14/06			03/29/06			04/12/06			04/26/06			05/09/06			05/24/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	9.4	9.4	-	10.9	10.9	-	12.3	12.3	-	14.2	14.2	-	16.5	16.5	-	18.0	18.0
Alkalinity	mg/L[(a)]	112	112	116	-	-	-	-	-	-	-	-	-	110	118	114	-	-	-
Fluoride	mg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-
Sulfate	mg/L	21.7	21.7	21.6	-	-	-	-	-	-	-	-	-	22	22	22	-	-	-
Nitrate (as N)	mg/L	0.7	0.7	0.7	-	-	-	-	-	-	-	-	-	0.9	0.9	0.9	-	-	-
Total P (as P)	μg/L[(b)]	<10	<10	<10	-	-	-	-	-	-	-	-	-	<10	<10	<10	-	-	-
Silica (as SiO_2)	mg/L	29.5	27.9	28.7	-	-	-	-	-	-	-	-	-	31.2	31.7	31.6	-	-	-
Turbidity	NTU	1.1	0.4	0.3	-	-	-	-	-	-	-	-	-	0.5	0.1	0.1	-	-	-
pH	S.U.	8.3	8.5	8.5	7.6	7.8	8.2	7.9	8.1	8.1	7.6	8.0	8.2	8.0	8.1	8.1	8.0	8.0	8.0
Temperature	°C	15.5	15.6	15.6	13.2	13.5	13.6	17.4	17.3	17.3	19.0	19.0	18.9	21.5	21.7	22.0	19.7	19.6	19.1
DO	mg/L	2.5	2.6	2.6	3.7	4.3	3.8	2.9	3.0	2.9	3.0	2.9	2.6	2.9	2.7	2.7	2.7	2.2	2.7
ORP	mV	460	477	520	438	463	464	513	562	571	276	326	405	461	534	566	520	570	571
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	88.5	85.2	86.3	-	-	-	-	-	-	-	-	-	93.8	91.6	103	-	-	-
Ca Hardness	mg/L[(a)]	64.5	62.5	63.2	-	-	-	-	-	-	-	-	-	66.9	65.5	75.8	-	-	-
Mg Hardness	mg/L[(a)]	24.0	22.7	23.1	-	-	-	-	-	-	-	-	-	26.9	26.0	26.9	-	-	-
As (total)	μg/L	30.4	0.1	5.0	30.0	0.1	4.4	29.2	0.3	8.1	29.3	0.2	10.3	30.2	0.2	10.8	30.1	0.3	11.1
		-	-	-	30.0	<0.1	4.2	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	μg/L	30.0	0.1	5.0	-	-	-	-	-	-	-	-	-	28.6	0.2	10.3	-	-	-
As (particulate)	μg/L	0.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-	1.6	<0.1	0.5	-	-	-
As (III)	μg/L	0.3	0.3	0.4	-	-	-	-	-	-	-	-	-	0.2	0.1	0.2	-	-	-
As (V)	μg/L	29.7	<0.1	4.7	-	-	-	-	-	-	-	-	-	28.5	<0.1	10.2	-	-	-
Fe (total)	μg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-
Fe (soluble)	μg/L	<25	<25	<25	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-
Mn (total)	μg/L	0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-
Mn (soluble)	μg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessel: TB; Lag Vessel: TA

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		06/08/06[c]			06/21/06			07/05/06			07/19/06			08/03/06[d]			08/16/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	20.1	20.1	-	21.4	21.4	-	22.2	22.2	-	23.3	23.3	-	24.0	24.0	-	24.7	24.7
Alkalinity	mg/L[a]	121	121	117	-	-	-	113	113	117	-	-	-	114	114	114	-	-	-
Fluoride	mg/L	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-
Sulfate	mg/L	24	22	22	-	-	-	21	21	21	-	-	-	22	22	22	-	-	-
Nitrate (as N)	mg/L	0.8	0.8	0.8	-	-	-	0.8	0.8	0.8	-	-	-	0.7	0.7	0.7	-	-	-
Total P (as P)	µg/L[b]	<10	<10	<10	-	-	-	<10	<10	<10	-	-	-	<10	<10	<10	-	-	-
Silica (as SiO_2)	mg/L	30.9	30.0	30.0	-	-	-	30.4	28.9	30.2	-	-	-	29.9	28.4	28.9	-	-	-
Turbidity	NTU	0.1	0.2	0.2	-	-	-	0.5	0.7	0.4	-	-	-	0.1	0.3	0.1	-	-	-
pH	S.U.	8.0	7.9	7.9	8.0	8.0	8.0	7.8	8.0	8.0	8.0	8.0	8.0	7.9	8.0	8.0	8.0	8.0	8.0
Temperature	°C	22.1	21.8	21.9	22.8	22.9	22.9	22.6	22.6	23.0	24.3	24.3	24.1	21.9	22.0	22.2	22.4	22.3	21.9
DO	mg/L	2.9	2.6	2.7	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	2.7	2.2	2.7	2.6	2.6	2.5	2.7	3.1	2.7
ORP	mV	518	531	537	539	542	550	455	418	472	518	549	561	557	553	546	559	538	571
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.3	0.2	0.1	0.2	0.4	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3
Total Hardness	mg/L[a]	79.2	78.5	79.3	-	-	-	78.6	76.2	78.5	-	-	-	82.9	78.8	82.4	-	-	-
Ca Hardness	mg/L[a]	58.0	56.7	57.3	-	-	-	56.3	54.9	56.9	-	-	-	60.4	57.8	60.3	-	-	-
Mg Hardness	mg/L[a]	21.2	21.9	21.9	-	-	-	22.3	21.3	21.5	-	-	-	22.4	21.0	22.2	-	-	-
As (total)	µg/L	26.9 -	0.6 -	11.8 -	30.1 -	0.7 -	12.2 -	26.2 -	0.4 -	9.9 -	30.3 30.4	0.6 0.6	11.9 11.6	31.1 -	0.6 -	12.0 -	25.7 -	0.5 -	10.4 -
As (soluble)	µg/L	26.6	0.5	11.8	-	-	-	28.6	0.3	9.9	-	-	-	29.8	0.6	11.9	-	-	-
As (particulate)	µg/L	0.4	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	1.4	<0.1	0.1	-	-	-
As (III)	µg/L	0.3	0.2	0.3	-	-	-	0.1	<0.1	<0.1	-	-	-	0.2	0.1	0.2	-	-	-
As (V)	µg/L	26.3	0.3	11.6	-	-	-	28.5	0.2	9.8	-	-	-	29.6	0.5	11.7	-	-	-
Fe (total)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-
Mn (total)	µg/L	0.6	<0.1	<0.1	-	-	-	0.5	0.9	0.6	-	-	-	<0.1	<0.1	<0.1	-	-	-
Mn (soluble)	µg/L	0.3	<0.1	<0.1	-	-	-	<0.1	0.4	<0.1	-	-	-	0.1	<0.1	<0.1	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) Water quality readings taken on 06/07/06.
(d) DO probe not operational.
Lead Vessel: TB Lag Vessel: TA

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		08/30/06			09/13/06			09/27/06			10/11/06			11/16/06			12/07/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	25.5	25.5	-	26.3	26.3	-	27.8	27.8	-	30.1	30.1	-	36.2	36.2	-	39.4	39.4
Alkalinity	mg/L[(a)]	123	116	121	-	-	-	122	122	125	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	26	26	24	-	-	-	22	22	21	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	0.8	0.8	0.8	-	-	-	0.6	0.6	0.6	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[(b)]	<10	<10	<10	-	-	-	<10	<10	<10	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	28.5	27.3	27.9	-	-	-	29.3	29.5	29.4	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.2	0.2	<0.1	-	-	-	0.2	0.1	0.2	-	-	-	-	-	-	-	-	-
pH	S.U.	7.9	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Temperature	°C	22.4	22.7	22.7	23.5	23.7	23.9	23.9	23.9	24.1	22.6	22.8	23	19.0	18.9	18.9	18.0	18.2	18.1
DO	mg/L	2.3	2.8	2.7	2.7	2.5	2.7	4.9	3.8	3.9	4.0	2.7	2.7	3.0	3.5	3.1	3.4	3.3	3.4
ORP	mV	561	560	563	566	583	599	570	600	609	542	576	586	477	521	557	530	569	580
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	90.1	81.7	88.8	-	-	-	83.6	87.4	84.6	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	65.7	60.1	65.1	-	-	-	59.4	63.1	60.2	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	24.5	21.6	23.7	-	-	-	24.2	24.3	24.4	-	-	-	-	-	-	-	-	-
As (total)	µg/L	30.9 -	0.6 -	12.0 -	28.9 -	0.9 -	12.6 -	29.3 -	1.7 -	17.6 -	28.1 29.4	4.0 3.9	0.2 0.2	33.2 -	13.2 -	28.5 -	33.1 -	16.2 -	30.3 -
As (soluble)	µg/L	28.9	0.7	11.3	-	-	-	30.6	1.8	18.7	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	2.1	<0.1	0.6	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
As (III)	µg/L	0.3	0.2	0.3	-	-	-	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-
As (V)	µg/L	28.6	0.4	11.0	-	-	-	30.5	1.8	18.5	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	<0.1	0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	<0.1	0.2	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-

(a) As $CaCO_3$.
(b) As P.
Lead Vessel: TB Lag Vessel: TA

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		12/13/06			01/10/07			02/07/07[c]			03/07/07			04/04/07			05/02/07		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	39.9	39.9	-	42.3	42.3	-	3.2	3.2	-	10.2	10.2	-	15.6	15.6	-	22.5	22.5
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	8.1	8.0	8.0	8.0	8.0	8.0	7.9	8.0	8.0	8.0	7.9	7.9	7.9	8.0	8.1	8.0
Temperature	°C	15.3	15.2	15.2	17.2	17.4	17.4	18.6	18.7	18.7	18.5	18.5	18.4	20.8	20.9	20.8	22.4	22.4	22.2
DO	mg/L	3.4	3.9	3.9	4.3	3.8	5.1	5.2	4.1	4.2	5.2	4.2	4.2	3.2	2.8	3.9	4.2	4.1	3.9
ORP	mV	535	571	582	550	581	594	564	575	582	526	568	580	520	572	580	531	579	613
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.3	0.4	0.2	0.3	0.3	0.25	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	27.8 -	11.8 -	24.7 -	31.8 -	19.5 -	30.1 -	31.1 -	24.6 -	0.4 -	25.4 -	22.2 -	2.5 -	31.4 -	27.8 -	9.5 -	32.5 -	27.5 -	15.1 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) Lead vessel (TB) rebedded with ARM 300 and put into lag position on January 24, 2007. TA is the lead vessel for new test run.
Lead Vessel: TB Lag Vessel: TA

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		06/01/07			12/18/07[c]			02/13/08			05/13/08			08/20/08		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	31.3	31.3	-	18.3	18.3	-	30.9	30.9	-	42.8	42.8	-	47.8	47.8
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	8.0	8.2	8.2	8.8	8.0	8.0	8.0	8.2	8.1	8.1	8.3	8.2	8.2
Temperature	°C	22.1	23.1	23.1	16.1	15.9	15.9	19.0	19.4	18.9	23.0	23.0	22.3	24.2	24.5	24.6
DO	mg/L	3.8	2.9	3.0	3.7	3.1	4.7	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
ORP	mV	503	555	574	562	596	546	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
Free Chlorine (as Cl_2)	mg/L	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.4
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	26.7	24.4	17.7	29.1	1.1	0.1	30.7	9.4	1.2	29.2	9.5	<0.1	30.1	8.4	0.2
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) On October 3, 2007, both lead and lag vessels rebedded with E33-S media. Vessel A continued to be lead vessel and Vessel B lag vessel.
DO and ORP measurements not taken.
Lead Vessel: TA Lag Vessel: TB

Table B-2. Analytical Results from Long-Term Sampling, Residence Hall, Klamath Falls, OR (Continued)

Sampling Date		11/19/08			02/11/09			05/27/09			08/26/09		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	56.5	56.5	-	64.2	64.2	-	76.3	76.3	-	81.3	81.3
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.2	8.1	8.0	8.3	8.3	8.3	8.2	8.2	8.2	8.3	8.3	8.3
Temperature	°C	19.5	19.3	19.4	18.0	18.2	18.2	22.7	22.6	22.3	23.7	23.7	23.6
DO	mg/L	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
ORP	mV	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Free Chlorine (as Cl_2)	mg/L	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	32.8 -	16.3 -	0.9 -	30.2 -	18.0 -	1.6 -	24.7 -	19.1 -	2.9 -	26.2 -	18.3 -	3.1 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) DO and ORP measurements not taken.
Lead Vessel: TA Lag Vessel: TB

Table B-3. Analytical Results from Long-Term Sampling, College Union, Klamath Falls, OR

Sampling Date		03/01/06			03/14/06			03/29/06			04/12/06			04/26/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	0.7	0.7	-	1.3	1.3	-	2.0	2.0	-	2.5	2.5	-	3.2	3.2
Alkalinity	mg/L[(a)]	-	-	-	112	112	103	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	21.5	21.5	21.6	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	0.7	0.7	0.7	-	-	-	-	-	-	-	-	-
Total P (as P)	μg/L[(b)]	-	-	-	<10	<10	<10	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	29.9	32.3	29.9	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	0.7	0.4	0.7	-	-	-	-	-	-	-	-	-
pH	S.U.	8.1	7.9	7.8	8.2	8.6	8.3	8.0	7.8	7.4	8.1	8.3	8.0	8.0	8.2	8.1
Temperature	°C	13.1	12.9	12.9	12.1	11.9	11.9	12.5	11.9	12.0	13.6	13.1	13.0	15.6	15.8	15.7
DO	mg/L	3.3	3.6	3.4	3.4	2.8	7.1	4.1	3.7	3.9	3.6	2.7	3.7	3.6	3.2	3.2
ORP	mV	530	584	607	500	562	596	477	474	460	546	577	611	528	538	559
Free Chlorine (as Cl_2)	mg/L	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	-	-	-	85.6	80.4	74.9	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	62.3	58.8	53.3	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	23.3	21.6	21.6	-	-	-	-	-	-	-	-	-
As (total)	μg/L	27.7 -	0.3 -	<0.1 -	30.4 -	0.4 -	0.2 -	29.6 29.9	0.4 0.4	0.1 0.1	29.1 -	0.4 -	0.2 -	29.2 -	0.2 -	0.1 -
As (soluble)	μg/L	-	-	-	30.2	0.4	0.2	-	-	-	-	-	-	-	-	-
As (particulate)	μg/L	-	-	-	0.2	<0.1	<0.1	-	-	-	-	-	-	-	-	-
As (III)	μg/L	-	-	-	0.5	0.5	0.5	-	-	-	-	-	-	-	-	-
As (V)	μg/L	-	-	-	29.7	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Fe (total)	μg/L	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	-	-
Mn (total)	μg/L	-	-	-	0.1	<0.1	0.1	-	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Ti (total)	μg/L	-	-	-	2.1	2.6	2.5	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessel: TA; Lag Vessel: TB

Sampling Date		05/09/06			05/24/06			6/7/2006[c]			06/21/06			07/05/06		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	3.7	3.7	-	4.0	4.0	-	4.3	4.3	-	4.5	4.5	-	4.6	4.6
Alkalinity	mg/L[a]	118	122	118	-	-	-	127	122	122	-	-	-	113	104	104
Fluoride	mg/L	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
Sulfate	mg/L	22	22	23	-	-	-	21	21	21	-	-	-	21	21	21
Nitrate (as N)	mg/L	0.9	0.9	1.0	-	-	-	0.9	0.9	0.9	-	-	-	0.8	0.7	0.7
Total P (as P)	µg/L[b]	<10	<10	<10	-	-	-	<10	<10	<10	-	-	-	<10	<10	<10
Silica (as SiO_2)	mg/L	31.5	31.3	31.7	-	-	-	31.4	31.1	31.0	-	-	-	30.4	29.2	31.3
Turbidity	NTU	0.4	0.3	0.3	-	-	-	1.5	0.2	0.3	-	-	-	0.5	0.5	0.4
pH	S.U.	7.8	7.8	7.7	7.9	7.9	8.0	7.9	8.0	8.0	7.9	8.0	7.9	8.0	8.0	8.0
Temperature	°C	19.3	19.3	19.3	21.1	20.9	20.8	21.7	21.8	21.8	21.3	21.1	21.2	23.9	24.0	24.0
DO	mg/L	2.6	3.0	3.0	2.7	2.9	2.5	2.6	2.9	3.0	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]
ORP	mV	547	563	554	493	576	577	509	527	529	452	501	522	436	520	524
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Total Hardness	mg/L[a]	106	107	103	-	-	-	83.5	82.8	80.0	-	-	-	79.1	63.9	68.6
Ca Hardness	mg/L[a]	78.2	80.0	75.9	-	-	-	60.8	60.2	58.3	-	-	-	58.3	46.8	50.1
Mg Hardness	mg/L[a]	27.3	27.0	27.0	-	-	-	22.7	22.6	21.8	-	-	-	20.8	17.1	18.5
As (total)	µg/L	29.0 -	0.2 -	0.1 -	28.5 -	0.6 -	0.1 -	28.5 -	0.5 -	0.1 -	34.0 -	0.7 -	0.2 -	28.7 -	0.5 -	0.1 -
As (soluble)	µg/L	28.9	0.2	0.1	-	-	-	27.4	0.5	0.1	-	-	-	28.3	0.5	<0.1
As (particulate)	µg/L	<0.1	<0.1	<0.1	-	-	-	1.1	<0.1	<0.1	-	-	-	0.4	<0.1	<0.1
As (III)	µg/L	0.2	0.1	0.1	-	-	-	0.2	0.2	0.1	-	-	-	0.1	<0.1	<0.1
As (V)	µg/L	28.8	<0.1	<0.1	-	-	-	27.2	0.3	<0.1	-	-	-	28.2	0.4	<0.1
Fe (total)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25
Mn (total)	µg/L	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	0.5	<0.1	0.5
Mn (soluble)	µg/L	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
Ti (total)	µg/L	2.4	2.4	2.2	-	-	-	9.7	10.2	10.6	-	-	-	1.7	1.6	2.0

(a) As $CaCO_3$.
(b) As P.
(c) Water quality readings taken on 06/08/06.
(d) DO probe not operational.
Lead Vessel: TA; Lag Vessel: TB

Sampling Date		07/19/06			08/02/06			08/16/06			08/30/06			09/13/06			09/27/06		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	5.0	5.0	-	5.3	5.3	-	5.7	5.7	-	6.0	6.0	-	6.4	6.4	-	6.9	6.9
Alkalinity	mg/L[(a)]	-	-	-	110	114	114	-	-	-	123	121	118	-	-	-	122	118	122
Fluoride	mg/L	-	-	-	0.5	0.5	0.7	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
Sulfate	mg/L	-	-	-	22	22	20	-	-	-	28	26	26	-	-	-	22	21	24
Nitrate (as N)	mg/L	-	-	-	0.5	0.6	0.7	-	-	-	0.6	0.7	0.7	-	-	-	0.7	0.6	0.6
Total P (as P)	μg/L[(b)]	-	-	-	<10	<10	<10	-	-	-	<10	<10	<10	-	-	-	<10	<10	<10
Silica (as SiO_2)	mg/L	-	-	-	28.3	28.6	28.7	-	-	-	27.8	28.2	27.3	-	-	-	29.9	28.8	28.5
Turbidity	NTU	-	-	-	0.1	0.2	0.2	-	-	-	<0.1	0.2	0.1	-	-	-	0.2	0.2	0.2
pH	S.U.	8.0	7.9	7.9	8.2	8.1	8.0	8.1	8.0	8.0	8.0	8.1	8.2	7.9	8.0	7.9	7.9	7.2	7.9
Temperature	°C	23.9	24.0	24.0	23.3	23.3	23.4	23.5	23.5	23.5	22.7	23.0	22.9	24.0	24.0	24.0	21.9	21.7	21.1
DO	mg/L	2.7	2.9	2.5	3.0	3.5	2.4	2.6	3.1	3.1	3.0	2.8	2.9	2.5	2.7	2.9	3.9	3.9	3.7
ORP	mV	540	567	560	475	534	546	315	544	554	411	492	521	535	565	555	528	600	598
Free Chlorine (as Cl_2)	mg/L	0.3	0.3	0.2	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total Hardness	mg/L[(a)]	-	-	-	67.0	80.7	81.2	-	-	-	80.6	85.3	87.8	-	-	-	85.0	84.6	85.7
Ca Hardness	mg/L[(a)]	-	-	-	54.8	60.4	61.4	-	-	-	65.2	61.8	64.0	-	-	-	60.5	60.6	62.4
Mg Hardness	mg/L[(a)]	-	-	-	12.2	20.2	19.8	-	-	-	15.4	23.4	23.8	-	-	-	24.5	23.9	23.3
As (total)	μg/L	30.4 30.4	0.5 0.5	0.2 0.1	35.8 -	0.4 -	0.1 -	28.5 -	0.4 -	0.1 -	35.2 -	0.5 -	0.1 -	29.0 -	0.6 -	0.2 -	29.6 -	0.4 -	<0.1 -
As (soluble)	μg/L	-	-	-	35.7	0.4	0.1	-	-	-	33.6	0.5	0.1	-	-	-	30.7	0.5	<0.1
As (particulate)	μg/L	-	-	-	<0.1	<0.1	<0.1	-	-	-	1.6	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
As (III)	μg/L	-	-	-	0.1	0.2	0.1	-	-	-	0.3	0.3	0.3	-	-	-	0.1	<0.1	<0.1
As (V)	μg/L	-	-	-	35.6	0.3	<0.1	-	-	-	33.3	0.2	<0.1	-	-	-	30.5	0.4	<0.1
Fe (total)	μg/L	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25
Fe (soluble)	μg/L	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25	-	-	-	<25	<25	<25
Mn (total)	μg/L	-	-	-	0.2	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
Mn (soluble)	μg/L	-	-	-	0.1	0.1	0.2	-	-	-	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	<0.1
Ti (total)	μg/L	-	-	-	2.2	2.0	1.8	-	-	-	2.1	2.7	2.1	-	-	-	1.8	1.8	1.8

(a) as $CaCO_3$.
(b) as P.
Lead Vessel: TA; Lag Vessel: TB

Sampling Date		10/11/06			01/10/07			03/07/07			05/02/07			08/01/07			11/07/07		
Sampling Location / Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	7.7	7.7	-	11.0	11.0	-	13.2	13.2	-	14.9	14.9	-	18.0	18.0	-	21.5	21.5
Alkalinity	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	μg/L[(b)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	7.9	7.9	7.9	8.1	8.0	8.0	8.2	8.2	8.2	8.0	8.0	8.0	8.0	8.1	8.1	8.2	8.1	8.2
Temperature	°C	21.7	21.9	21.8	15.5	15.1	14.6	17.1	17.2	17.2	23.1	22.9	22.8	25.1	25.3	25.4	20.1	20.0	20.2
DO	mg/L	3.2	2.8	2.7	3.6	3.9	3.9	5.4	3.7	3.5	2.5	3.0	3.8	2.9	2.9	2.7	4.3	3.2	3.1
ORP	mV	542	576	586	534	563	579	546	582	591	575	587	596	553	582	589	547	573	581
Free Chlorine (as Cl_2)	mg/L	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Total Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[(a)]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	μg/L	28.9 29.3	0.7 0.7	0.2 0.2	31.7 -	1.1 -	0.4 -	25.1 -	0.6 -	0.1 -	32.2 -	0.9 -	0.3 -	27.6 -	0.6 -	0.1 -	32.4 -	0.9 -	0.2 -
As (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ti (total)	μg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
Lead Vessel: TA; Lag Vessel: TB

Sampling Date		02/13/08			05/15/08			08/20/08			11/19/08			02/11/09			05/27/09		
Sampling Location Parameter	Unit	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB	IN	TA	TB
Bed Volume	10^3	-	25.0	25.0	-	29.6	29.6	-	33.3	33.3	-	37.7	37.7	-	40.7[d]	40.7[d]	-	46.0	46.0
Alkalinity	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/L[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.0	8.0	8.6	8.0	8.1	8.1	8.3	8.2	8.1	8.2	8.2	8.2	8.5	8.2	8.1	8.0	8.0	8.0
Temperature	°C	18.8	18.0	17.4	23.3	23.5	23.5	24.4	24.9	25.1	19.9	19.9	19.7	13.6	15.1	14.6	23.3	23.5	23.4
DO	mg/L	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
ORP	mV	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Free Chlorine (as Cl_2)	mg/L	0.4	0.3	NA	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L[a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	32.0 -	3.0 -	1.3 -	29.6 -	7.2 -	0.1 -	29.9 -	9.4 -	0.3 -	31.8 -	19.7 -	0.4 -	30.6 -	24.3 -	0.5 -	25.3 -	20.2 -	0.2 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ti (total)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) as $CaCO_3$.
(b) as P.
(c) DO/ORP probes not functioning properly.
Lead Vessel: TA; Lag Vessel: TB