

**Arsenic Removal from Drinking Water by Adsorptive Media
U.S. EPA Demonstration Project at
Spring Brook Mobile Home Park in Wales, ME
Final Performance Evaluation Report**

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained for the arsenic removal treatment technology demonstration project at Spring Brook Mobile Home Park (SBMHP) in Wales, Maine. The objectives of the project were to evaluate: 1) the effectiveness of an arsenic removal system using Aquatic Treatment Systems' (ATS) A/P Complex 2002 and A/I Complex 2000 media in removing arsenic (As) to meet the new arsenic maximum contaminant level (MCL) of 10 $\mu\text{g/L}$, 2) the reliability of the treatment system, 3) the required system operation and maintenance (O&M) and operator skills, and 4) the capital and O&M cost of the technology. The project also characterizes water in the distribution system and residuals produced by the treatment process.

The ATS system consisted of two parallel treatment trains, each having four 10-in \times 54-in sealed polyglass columns connected in series to treat up to 7 gal/min (gpm) of water per train. Water supplied from a developed spring was stored in two 120-gal pressure tanks and then passed through a 25- μm sediment filter and one oxidation and three adsorption columns in each train. Each oxidation column was loaded with 1.5 ft^3 of A/P Complex 2002 oxidizing media, which consisted of an activated alumina substrate and metaperiodate complex. Each adsorption column was loaded with 1.5 ft^3 of A/I Complex 2000 adsorptive media, which consisted of an activated alumina substrate and a proprietary iron complex. Based on the design flowrate of 7 gpm for each train, the empty bed contact time (EBCT) in each column was 1.6 min and the hydraulic loading rate to each column was 13 gpm/ft^2 . Because the actual average flowrate through a treatment train over the entire demonstration study was lower at 6.1 gpm (on average), the actual EBCT was longer at 1.9 min per column and the hydraulic loading rate was slightly lower at 11.2 gpm/ft^2 .

Between March 7, 2005, and August 29, 2007, three media runs were evaluated. The system operated an average of 3.7 hr/day for a total of 2,564 hr, treating approximately 1,834,990 gal of water. Source water contained 34.6 to 50.2 $\mu\text{g/L}$ of arsenic, existing predominately as soluble As(III), averaging 91% of the soluble arsenic.

During Media Run 1 (March 7 to September 26, 2005) and Media Run 2 (September 27, 2005 to February 17, 2006), the oxidation columns were loaded with A/P Complex 2002 media and the adsorption columns were loaded with A/I Complex 2000 media. Oxidation of soluble As(III) was achieved through reactions with sodium metaperiodate (IO_4^-) within the oxidation columns, producing soluble As(V) and I $^-$ as end products. The oxidation columns remained effective for soluble As(III) oxidation throughout Media Runs 1 and 2, typically lowering soluble As(III) concentrations to $<1.5 \mu\text{g/L}$ following the oxidation columns. Up to 124 $\mu\text{g/L}$ of iodine (as I $^-$) was measured in the oxidation and adsorption columns effluent, most likely caused by leaching of metaperiodate, which followed an apparent decreasing trend. The oxidizing media also showed a significant adsorptive capacity for arsenic, averaging 0.14 μg of As/mg of dry media. Complete arsenic breakthrough from the oxidation columns occurred after processing about 56,000 gal of water per treatment train (or 5,000 bed volumes [BV], 11.2 gal per BV).

Ten- $\mu\text{g/L}$ arsenic breakthrough following the three adsorption columns occurred after processing approximately 171,000 gal of water (per train), equivalent to 5,100 BV (i.e. 4.5 ft^3 or 33.6 gal per BV) if considering the three adsorption column as one large column. Complete arsenic breakthrough from the three adsorption columns took place after processing approximately 213,000 gal of water (or 6,300 BV if considering the three adsorption column as one large column). Arsenic loadings on the adsorption columns ranged from 0.18 to 0.28 μg of As/mg of dry media (averaged 0.23 $\mu\text{g/mg}$), compared to the measured spent media results of 0.17 $\mu\text{g/mg}$ using inductively coupled plasma-mass spectrometry (ICP-MS). The 0.23 $\mu\text{g/mg}$ result was about 1.6 times of that measured for oxidizing media as mentioned

above, and close to the values observed for the same adsorptive media at another U.S. Environmental Protection Agency (EPA) arsenic demonstration site in Susanville, CA.

For Media Run 3, ATS oxidizing media were replaced with Filox-R™ and adsorptive media were replaced with GFH and CFH-12 (with GFH in Train A and CFH-12 in Train B). Filox-R™ also was effective in converting soluble As(III) to soluble As(V) throughout the 52-week evaluation period; soluble As(III) concentrations were typically lowered to <1.2 µg/L. Unlike the ATS oxidation media, Filox-R™ had little to no adsorptive capacity for arsenic. During Media Run 3, the system effluent reached 10 µg/L of arsenic after treating approximately 391,000 gal (or 11,600 BV if considering the three adsorption columns as one large column) in Train A (GFH) and 516,000 gal (or 15,300 BV if considering the three adsorption columns as one large column) in Train B (CFH).

After Media Run 2, the spent ATS media in one oxidation and three adsorption columns were sampled for Toxicity Characteristic Leaching Procedure (TCLP) test and ICP-MS analyses. The spent ATS oxidizing and adsorptive media passed the TCLP test and could be disposed off at a sanitary landfill. However, the vendor recycled the spent media into another product, thus saving the disposal cost. Spent GFH and CFH media were not subject to TCLP before the end of this performance evaluation study.

Comparison of distribution system water sampling results before and after system startup showed a significant decrease in arsenic concentration at the three sampling locations during the 11 monthly sampling events. Arsenic concentrations were reduced from an average baseline level of 35.8 µg/L to an average of 1.1 µg/L for the first three months after system startup. Afterwards, arsenic concentrations increased to above 10 µg/L and then to the influent levels due to arsenic breakthrough from the treatment system. In general, arsenic concentrations in distribution system water mirrored those in treatment system effluent. Lead and copper levels were low in the distribution system water; however, low pH values could significantly increase lead and copper levels.

The capital investment cost included \$10,790 for equipment, \$1,800 for site engineering, and \$3,885 for installation. Using the system's rated capacity of 14 gpm (or 20,160 gal/day [gpd]), the capital cost was \$1,177/gpm (or \$0.82/gpd). The annualized capital cost was \$1,555/yr based upon a 7% interest rate and a 20-year return. The unit capital cost was \$0.21/1,000 gal assuming the system operated continuously 24 hr/day, 7 days a week at 14 gpm. At the current use rate of 955,450 gal per year, the unit capital cost increased to \$1.63/1,000 gal.

The O&M costs included only incremental cost associated with the adsorption system, such as media replacement and disposal (for both oxidizing and adsorptive media), electricity consumption, and labor. The unit O&M cost was driven by the cost to replace the spent media as a function of the media run length. Supplying water to SBMHP in one year would require \$45,382, \$4,082, and \$2,849 O&M cost when using ATS A/P Complex 2002/A/I Complex 2000, Filox-R™/GFH, and Filox-R™/CFH-12 media, respectively. It is apparent that using either Filox-R™/GFH or Filox-R™/CFH-12 media can result in significant cost savings.

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ABBREVIATIONS AND ACRONYMS

AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
ATS	Aquatic Treatment Systems
BV	bed volume(s)
Ca	calcium
Cd	cadmium
C/F	coagulation/filtration
Cl	chloride
CMHP	Charette Mobile Home Park
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
GFH	Granular Ferric Hydroxide
gpd	gallons per day
gpm	gallons per minute
HIX	hybrid ion exchanger
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IO ₄ ⁻	metaperiodate
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWP	Maine Drinking Water Program
MEI	Magnesium Elektron, Inc.
Mg	magnesium
Mn	manganese
N/A	not analyzed
Na	sodium
ND	not detected
NH ₃	ammonia
Ni	nickel

NO ₂	nitrite
NO ₃	nitrate
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P	phosphorus
Pb	lead
PO ₄	orthophosphate
POU	point-of-use
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RO	reverse osmosis
RPD	relative percent difference
RSSCT	rapid small scale column test
S	sulfide
SBMHP	Spring Brook Mobile Home Park
SDWA	Safe Drinking Water Act
SiO ₂	silica
SO ₄	sulfate
STS	Severn Trent Services
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TO	Task Order
TOC	total organic carbon
U	uranium
V	vanadium
VOC	volatile organic compound
VSWS	very small water system
Zn	zinc

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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). In order to clarify the implementation of the original rule, EPA revised the rule 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 in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 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 from one to six proposals. In April 2003, an independent technical panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration 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 Spring Brook Mobile Home Park (SBMHP) in Wales, Maine, 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 from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again 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. The As/1400CS arsenic treatment system from Aquatic Treatment System, Inc. (ATS) was selected for demonstration at SBMHP in September 2004.

As of November 2009, 39 of the 40 systems were operational and the performance evaluation of 33 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 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, and 17 point-of-use (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, 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 website at <http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html>.

1.3 Project Objectives

The objective of the Round 1 and Round 2 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 ATS system at SBMHP in Wales, ME, from March 7, 2005, through August 29, 2007. The types of data collected included 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.)
<i>Northeast/Ohio</i>							
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)	AdEdge	10	33	<25	6.9
Rollinsford, NH	Rollinsford Water and Sewer District	AM (E33)	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)	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
Newark, 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)	AdEdge	250 ^(e)	25 ^(a)	1,615 ^(c)	7.3
<i>Great Lakes/Interior Plains</i>							
Brown City, MI	City of Brown City	AM (E33)	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)	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
<i>Midwest/Southwest</i>							
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)	STS	150	19 ^(a)	95	7.8
Bruni, TX	Webb Consolidated Independent School District	AM (E33)	AdEdge	40	56 ^(a)	<25	8.0
Wellman, TX	City of Wellman	AM (E33)	AdEdge	100	45	<25	7.7
Anthony, NM	Desert Sands Mutual Domestic Water Consumers Association	AM (E33)	STS	320	23 ^(a)	39	7.7
Nambe Pueblo, NM	Nambe Pueblo Tribe	AM (E33)	AdEdge	145	33	<25	8.5
Taos, NM	Town of Taos	AM (E33)	STS	450	14	59	9.5
Rimrock, AZ	Arizona Water Company	AM (E33)	AdEdge	90 ^(b)	50	170	7.2
Tohono O'odham Nation, AZ	Tohono O'odham Utility Authority	AM (E33)	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.)
<i>Far West</i>							
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)	Filtronic	750	18	69 ^(c)	8.0
Klamath Falls, OR	Oregon Institute of Technology	POE AM (Adsorbisia/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; C/F = coagulation/filtration; GFH = granular ferric hydroxide; HIX = hybrid ion exchanger; IX = ion exchange; 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% after system was switched from parallel to serial configuration.

(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) Faculties upgraded Springfield, OH system from 150 to 250 gpm, Sandusky, MI system from 210 to 340 gpm, and Arnaudville, LA system 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 during the 2 ½ years of operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

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

- A/P Complex 2002 oxidizing media was effective in oxidizing soluble As(III) to soluble As(V). Soluble As(III) concentrations were typically lowered to below 1.5 µg/L. Oxidation was achieved via reactions with NaIO₄. The oxidizing media also showed some adsorptive capacities (~ 0.14 µg of As/mg of dry media), which was about 60% of the capacities of the adsorptive media. Up to 124 µg/L of iodine (as I⁻) was leached from the oxidizing and adsorptive media, but the leaching followed an apparent decreasing trend.
- A/I Complex 2000 adsorptive media was effective in removing arsenic to below its MCL. However, the run length to 10 µg/L breakthrough was short at 5,100 BV (note that one BV equals 4.5 ft³ when considering all three adsorption columns in a treatment train as one large column). Complete breakthrough from the system occurred at 6,300 BV, resulting in an average loading of 0.23 µg of As/mg of dry media.
- Some aluminum was leached from the oxidation and adsorption columns due to the use of alumina-based media.
- Filox-R™ used as a replacement for A/P Complex 2002 oxidizing media also was effective in converting soluble As(III) to soluble As(V). Filox-R™, however, did not show any adsorptive capacity for arsenic.
- GFH and CFH-12 used as replacements for A/I Complex 2000 adsorptive media exhibited significantly longer run lengths than A/I Complex 2000. Breakthrough at 10 µg/L occurred at 11,600 and 15,300 BV, respectively, compared to 5,100 BV for A/I Complex 2000.

Simplicity of required system O&M and operator skill levels:

- Very little attention was needed to operate and maintain the system. The daily demand on the operator was typically 15 min to visually inspect the system and record operational parameters.
- Operation of the treatment system did not require additional skills beyond those necessary to operate the existing water supply equipment.

Process residuals produced by the technology:

- The system did not require backwash to operate. As a result, no backwash residual was produced.
- The only residual produced by the treatment system was spent media, which passed the Toxicity Characteristic Leaching Procedure (TCLP) test and could be disposed of as a non-hazardous material. However, the vendor elected to recycle it into another product to save disposal cost.

Technology Costs:

- Using the system's rated capacity of 14 gal/min (gpm) (or 20,160 gal/day [gpd]), the capital cost was \$1,177/gpm (or \$0.82/gpd).

- Supplying water to SBMHP in one year would require \$45,382, \$4,082, and \$2,849 O&M cost when using ATS A/P Complex 2002/A/I Complex 2000, Filox-R™/GFH, and Filox-R™/CFH-12 media, respectively. It is apparent that using either Filox-R™/GFH or Filox-R™/CFH-12 media can result in significant cost savings.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the ATS treatment system began on March 7, 2005, and ended on August 29, 2007. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to below the MCL of 10 µg/L through the collection of water samples across the treatment train, as described in the Study Plan (Battelle, 2004). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	September 14, 2004
Project Planning Meeting Held	November 17, 2004
Draft Letter of Understanding Issued	December 3, 2004
Final Letter of Understanding Issued	December 20, 2004
Request for Quotation Issued to Vendor	December 22, 2004
Vendor Quotation Received by Battelle	January 25, 2005
Purchase Order Completed and Signed	February 15, 2005
Engineering Package Submitted to MDWP	February 16, 2005
Final Study Plan Issued	February 18, 2005
Permit Issued by MDWP	February 18, 2005
System Installation and Shakedown Completed	March 4, 2005
Performance Evaluation Begun	March 7, 2005

MDWP = Maine Drinking Water Program

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

Evaluation Objectives	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 system 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 of relevant chemical processes and health and safety practices
Residual Management	-Quantity and characteristics of aqueous and solid residuals generated by system process
System Cost	-Capital cost for equipment, engineering, and installation -O&M cost for media replacement, electricity usage, and labor

The 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 preventive 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. The staffing requirements for the system operation were recorded on an Operator Labor Hour Log Sheet.

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, biweekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a regular basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a System Operation Log Sheet and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator would contact the Battelle Study Lead, who determined if ATS should be contacted for troubleshooting. The plant operator recorded all 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 biweekly basis, the plant operator measured several water quality parameters onsite, including temperature, pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on an Onsite Water Quality Parameters Log Sheet.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for media replacement, electricity consumption, and labor. Labor for various activities, such as the routine system O&M, troubleshooting and repairs, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. 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

To evaluate system performance, samples were collected at the wellhead, across the treatment plant, and from the distribution system. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at 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. Source water sample was collected and speciated using an arsenic speciation kit (see Section 3.4.1) during the initial visit to SBMHP on September 16, 2004. Before sampling, the sample tap was flushed for several minutes; special care was taken to avoid agitation, which could cause unwanted oxidation. The samples were analyzed for the analytes listed in Table 3-3.

Table 3-3. Sampling Schedules and Analyses

Sample Type	Sample Locations ^(a)	No. of Samples	Frequency	Analytes	Collection Date(s)
Source Water	IN	1	Once (during initial site visit)	Onsite: pH, temperature, DO, and ORP Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), Sb (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NH ₃ , NO ₃ , NO ₂ , SO ₄ , SiO ₂ , PO ₄ , alkalinity, turbidity, TDS, and TOC	9/16/04
Treatment Plant Water	IN, OA, OB, TA, TB, TC, TD, TE, TF, TT	5–10	Biweekly	Onsite: pH, temperature, DO, and ORP Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), Ca, Mg, F, I, NO ₃ , S ²⁻ , SO ₄ , SiO ₂ , P, turbidity, and/or alkalinity	See Appendix B
Distribution Water	Two LCR and one non-LCR Residences	3	Monthly ^(b)	Total As, Fe, Mn, Al, Cu, and Pb, pH and alkalinity	See Table 4-12
Residual Solids	Spent Media from Oxidation Columns A and B, and Adsorption Columns A to F	8	Once	TCLP and total Al, As, Ca, Cd, Cu, Fe, Pb, Mg, Mn, Ni, P, Si, and Zn	09/08/06

(a) Abbreviations corresponding to sample locations shown in Figure 3-1. IN = at wellhead, OA and OB = after oxidation columns, TA to TF = after the corresponding adsorption columns, and TT = after entire treatment system.

(b) Biweekly sampling except during period of February 14, 2006, to September 18, 2006.

(c) Four baseline sampling events performed before system startup; sampling for distribution system water discontinued after February 14, 2006.

LCR = lead and copper rule; TCLP = toxicity characteristic leaching procedure

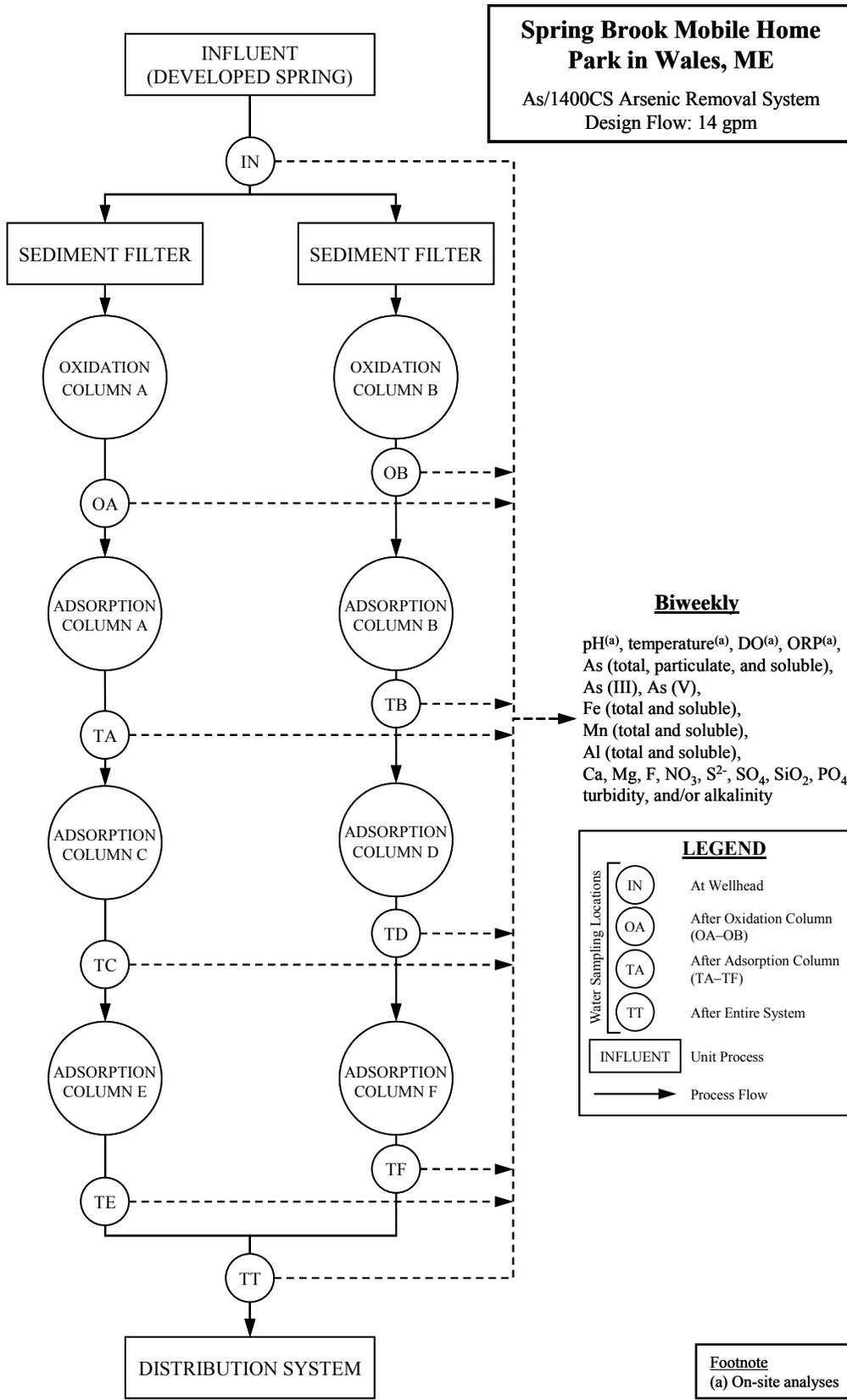


Figure 3-1. Process Flow Diagram and Sampling Locations

3.3.2 Treatment Plant Water. During the system performance evaluation study, treatment plant water samples were collected by the plant operator every other week at five to ten locations across the treatment train, including at the wellhead (IN), after oxidation columns (OA and OB), after adsorption columns (TA to TF), and after the entire system (TT). Sampling, in general, alternated between events with and without speciation samples taken.

During Media Run 1, speciation samples were taken from IN, OA, OB, TA and TB during initial speciation sampling events until the adsorptive capacities of the media in Columns A and B had been reached. Speciation at TA and TB was then discontinued and speciation at TC and TD began. Speciation moved onto TE and TF once Columns C and D had reached their capacities. During Media Runs 2 and 3, speciation samples were taken from IN, OA, OB, and TT (except for two events on October 5 and November 9, 2005, when samples were taken at TA, and TB instead of TT).

Samples taken during the speciation sampling events were analyzed for total and soluble arsenic (including As[III] and As[V]), iron, manganese, and aluminum; calcium; and magnesium. Samples taken during the non-speciation events were analyzed for total arsenic, iron, manganese, and aluminum; calcium; magnesium; fluoride; nitrate; sulfate; silica; phosphorus; turbidity; and alkalinity. pH, temperature, DO, and ORP were measured onsite during all sampling events. A number of exceptions occurred during sampling and are summarized as follows:

- Starting from October 18, 2005, iodine analysis was analyzed for samples taken during all but one (i.e., November 16, 2005) non-speciation sampling events.
- Starting from November 16, 2005, total arsenic was analyzed for samples taken from all sampling locations across the treatment train.
- Starting from November 16, 2005, orthophosphate was replaced with total phosphorus as the analyte. Starting from October 18, 2006, total phosphorus was analyzed for samples taken during all sampling events.
- Starting from November 30, 2005, SiO₂ was analyzed for samples taken during all sampling events.
- Starting from October 18, 2006, speciation was performed at IN, OA, and OB for arsenic only.

3.3.3 Residual Solids. Because the system did not require backwash, no backwash residual was produced during system operations. Therefore, the only residual solid produced from the treatment process was the spent media. After Media Run 2, 1 gal of spent media samples were collected from each of the oxidation and adsorption columns on September 8, 2006, and shipped to Battelle's laboratories in Columbus, Ohio for processing. After being homogenized, approximately 200 g of the spent media from each container were collected and placed in one container. One aliquot was tested for TCLP; another aliquot (approximately 100 g) was air-dried, crushed (using a mortar and pestle), acid-digested, and analyzed for the metals listed in Table 3-3.

3.3.4 Distribution System Water. Samples were collected from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead, and copper levels. Prior to system startup from December 2004 to February 2005, four sets of baseline distribution water samples were collected from two residences within the distribution system that were part of the historic sampling network under the Lead and Copper Rule (LCR) and one residence not part of the LCR sampling network. Following system startup, distribution

system sampling continued on a monthly basis at the same locations for about one year. Distribution system sampling was discontinued after February 14, 2006.

The distribution system water samples were taken following an instruction sheet developed by Battelle according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). First draw samples were collected from cold-water faucets that had not been used for at least six hours to ensure that stagnant water was sampled. The sampler recorded the date and time of last water use before sampling and the date and time of sample collection for calculation of the stagnation time. The samples were analyzed for the analytes listed in Table 3-3. Arsenic speciation was not performed for the distribution water samples.

3.4 Sampling Logistics

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

3.4.1 Preparation of Arsenic Speciation Kits. The arsenic field speciation method uses an anion exchange resin column to separate the soluble arsenic species, As(V) and As(III) (Edwards et al., 1998). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed 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 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 specific water facility, 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 Ziploc[®] bags and packed in the cooler.

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 off-site analyses were packed carefully in the original coolers with wet ice and shipped to Battelle. Upon receipt, the sample custodian verified that all samples indicated on the chain-of-custody forms were included and intact. Sample IDs were checked against the chain-of-custody forms, and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for metal analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. Samples for other water quality parameters were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, Ohio, Belmont Labs in Englewood, Ohio, and TCCI Laboratories in New Lexington, Ohio, all of which were contracted by Battelle for this demonstration study.. Sulfide samples were packed in coolers and shipped via FedEx to DHL Laboratories in Round Rock, TX. The chain-of-custody forms remained with the samples from the time of preparation through collection, 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 EPA-endorsed QAPP (Battelle, 2004) were followed by Battelle ICP-MS, AAL, Belmont Labs, TCCI, and DHL Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The quality assurance (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 WTW Multi 340i handheld meter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Multi-340i probe in the beaker until a stable value was obtained.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

The Spring Brook Mobile Home Park is located at 339 Leeds Junction Rd. Wales, Maine, approximately 15 miles southwest of Augusta, Maine. Prior to and during the EPA arsenic removal technology demonstration, there were 14 mobile homes at SBMHP. The mobile home park was served by a developed spring operating at an estimated flowrate, based on pump data, of approximately 14 gpm. Figure 4-1 shows the pre-existing treatment building located near the entrance of the mobile home park. The average daily use rate was estimated to be 3,500 gpd according to the Park owner.



Figure 4-1. Pre-Existing Treatment Building at Spring Brook Mobile Home Park

There was no pre-existing treatment at the facility. Water from the spring was pumped directly to two 120-gal hydropneumatic tanks located in the pump house prior to the distribution system. Figure 4-2 shows the two pre-existing pressure tanks and related system piping.

4.1.1 Source Water Quality. Source water samples were collected on September 16, 2004, and subsequently analyzed for the analytes shown in Table 3-3. The results of the source water analyses, along with those provided by the facility to EPA for the demonstration site selection and those obtained from the Maine Drinking Water Program (MDWP) are presented in Table 4-1.



Figure 4-2. Pre-Existing Water Supply Pump, System Piping, and Hydropneumatic Tanks (shown in the background)

Total arsenic concentrations of source water ranged from 35 to 39 $\mu\text{g/L}$. Based on the September 16, 2004, sampling results of Battelle, 33.4 $\mu\text{g/L}$ (or 88%) of total arsenic existed as soluble As(III) and 4.6 $\mu\text{g/L}$ (or 12%) as soluble As(V).

pH values of source water ranged between 8.5 and 8.6. The vendor indicated that the A/I Complex 2000 media could effectively remove arsenic as long as the pH values of source water were less than 9.0. As such, no pH adjustment was planned at this site.

Iron concentrations in raw water were below the method detection limit of 25 $\mu\text{g/L}$ so pretreatment prior to the adsorption process was not required. Concentrations of manganese, orthophosphate, and fluoride also were sufficiently low (i.e., <12 $\mu\text{g/L}$, <0.06 mg/L [PO_4], and 0.4 mg/L, respectively) and, therefore, not expected to affect arsenic adsorption on the A/I Complex 2000 media. Silica concentrations were between 9.8 and 10.7 mg/L, similar to the level measured in the source water at the Charette Mobile Home Park (CMHP) site in Dummerston, Vermont (Lipps et al., 2007). Because the A/I Complex 2000 media was shown to be rather selective for silica at the CMHP site, the effect of silica on arsenic adsorption was carefully monitored throughout the study period. Other water quality parameters as presented in Table 4-1 had sufficiently low concentrations and, therefore, were not expected to affect arsenic adsorption on the A/I Complex 2000 media.

4.1.2 Distribution System. The distribution system consists of a looped distribution line constructed primarily of polyvinyl chloride (PVC) pipe. The connections to the distribution system and piping within the residences themselves also are believed to be PVC.

Table 4-1. Source Water and Historic Distribution System Water Quality Data

Parameter	Unit	Facility Data ^(a)	Battelle Data	Historic MDWP Distribution Water Data
<i>Sampling Date</i>		NA	09/16/04	04/29/99–04/13/04
pH	S.U.	8.5	8.6	N/A
Total Alkalinity (as CaCO ₃)	mg/L	64	65	N/A
Hardness (as CaCO ₃)	mg/L	50	53	N/A
Turbidity	NTU	N/A	0.1	N/A
TDS	mg/L	N/A	110	N/A
TOC	mg/L	<0.1	<0.7	N/A
Nitrate (as N)	mg/L	N/A	<0.04	ND
Nitrite (as N)	mg/L	N/A	<0.01	N/A
Ammonia (as N)	mg/L	N/A	<0.05	N/A
Chloride	mg/L	7.5	7.6	7–8
Fluoride	mg/L	N/A	0.4	N/A
Sulfate	mg/L	19.5	18.0	20–21
Silica (as SiO ₂)	mg/L	9.8	10.7	N/A
Orthophosphate (as PO ₄)	mg/L	0.044	<0.06	N/A
As (total)	µg/L	N/A	37.7	35–39
As (total soluble)	µg/L	38.0	38.0	N/A
As (particulate)	µg/L	N/A	<0.1	N/A
As(III)	µg/L	35.0	33.4	N/A
As(V)	µg/L	3.0	4.6	N/A
Fe (total)	µg/L	ND	<25	ND
Fe (soluble)	µg/L	N/A	<25	N/A
Mn (total)	µg/L	11.0	10.3	9–12
Mn (soluble)	µg/L	N/A	9.6	N/A
Al (total)	µg/L	N/A	13.5	N/A
Al (soluble)	µg/L	N/A	<10	N/A
U (total)	µg/L	N/A	0.9	N/A
U (soluble)	µg/L	N/A	0.9	N/A
V (total)	µg/L	N/A	0.4	N/A
V (soluble)	µg/L	N/A	0.1	N/A
Sb (total)	µg/L	N/A	0.8	ND
Sb (soluble)	µg/L	N/A	0.4	N/A
Pb (total)	µg/L	N/A	N/A	ND
Cu (total)	µg/L	N/A	N/A	0.5
Na	mg/L	20.0	21.0	19.9–20.2
Ca	mg/L	17.0	18.0	17.3–17.4
Mg	mg/L	1.9	2.0	1.8–1.9

(a) Provided by facility to EPA for demonstration site selection.

N/A = not analyzed

ND = below detection limit

Compliance samples from the distribution system were collected quarterly for bacterial analysis and every three years for herbicides, pesticides, volatile organic compounds (VOCs), and inorganics. Under the EPA LCR, samples were collected from five customer taps within the distribution system every three years. Tests for gross alpha were conducted every four years.

4.2 Treatment Process Description

The ATS As/1400CS adsorption system used A/P Complex 2002 oxidizing media to oxidize As(III) to As(V) and A/I Complex 2000 adsorptive media to adsorb As(V). The A/P Complex 2002 oxidizing media consisted of activated alumina and sodium metaperiodate and the A/I Complex 2000 adsorptive media consisted of activated alumina and a proprietary iron complex.

Because of short run lengths experienced during two consecutive adsorption runs, A/P Complex 2002 oxidizing media was replaced with Filox-R™ and A/I Complex 2000 adsorptive media was replaced with GFH and CFH-12 (one for each treatment train) based on a series of rapid small-scale column tests (RSSCT) performed under a separate EPA task order. Filox-R™ is a naturally occurring manganese dioxide commonly known as Pyrolusite. Both GFH and CFH-12 are iron-based media, consisting primarily of ferric hydroxide and/or ferric oxide. GFH was produced by GEH Wasserchemie GmbH and marketed by Siemens. CFH-12 was supplied by Kemira Water Solutions, Inc. Tables 4-2a and 4-2b present physical and chemical properties of the oxidizing and adsorptive media. All media tested have NSF International (NSF) Standard 61 listing for use in drinking water.

The ATS As/1400CS system was a fixed-bed downflow adsorption system designed for use at small water systems with flowrates of around 14 gpm. When the media reached capacity, the spent media columns were taken by ATS to its shop in Massachusetts. The spent media after being removed and subjected to the TCLP test was either disposed of or recycled.

The system at SBMHP was configured in series with water being split into two treatment trains. The system was designed for the lead column to be removed upon exhaustion and each of the two lag columns to be moved forward one position (i.e., the first lag column became the lead column, and the second lag column became the first lag column). A new column loaded with virgin media was then placed at the end of each treatment train. Figure 4-3 shows a schematic diagram of the system.

The major system components/treatment steps of the ATS As/1400CS system are described as follows:

- **Pressure Tanks.** One each Well-Rite and Well-X-Trol pressure tanks were located at the inlet of the treatment system. The pre-existing pressure tanks were 120 gal in size, manufactured by Flexcon Industries in Randolph, Maine and Amtrol in West Warwick, Rhode Island, respectively. With a total storage capacity of approximately 240 gal, these pressure tanks served as temporary storage for spring water. The well pump was turned on when the pressure in the tanks had dropped to below 40 pounds per square inch (psi) and the well pump was turned off after the tanks had been refilled and the pressure in the tanks had reached 60 psi.
- **Sediment Filters.** One 25- μ m sediment filter was installed at the head of each treatment train. The 6-in \times 20-in filter was used to remove sediment in the well water and avoid introducing large particles directly into the oxidation columns.
- **Oxidation Columns.** Following the sediment filter was one 10 in \times 54-in sealed polyglass columns in each treatment train (by Park International), each loaded with 1.5 ft³ of A/P Complex 2002 oxidizing media. Each oxidation column had a riser tube and a valved head assembly to control inflow, outflow, and by-pass. Prior to Media Run 3, the A/P Complex 2002 oxidizing media in the oxidation columns were replaced with Filox-R™ (by Matt-Son Inc, Barrington, IL).

Table 4-2a. Physical and Chemical Properties of Oxidizing Media

Parameter	A/P Complex 2002	Filox-R™
<i>Physical Properties</i>		
Matrix	Activated alumina/ metaperiodate complex	Manganese dioxide
Physical Form	Granular solid	Granular solid
Color	White	Grey/black
Bulk Density (lb/ft ³)	51	114
Specific Gravity (dry)	1.5	NA
Hardness (lb/in ²)	14–16	NA
Effective Size (mm)	0.42	NA
BET Surface Area (m ² /g)	320	NA
Attrition (%)	<0.1	NA
Moisture Content (%)	<5	NA
Particle Size Distribution (Tyler Mesh)	28 × 48 (<2% fines)	12 × 40
<i>Chemical Analysis</i>		
Constituents	Weight (%)	
Al ₂ O ₃	96.59	–
NaIO ₄	3.41	–
MnO ₂	–	75–85

NA = not available

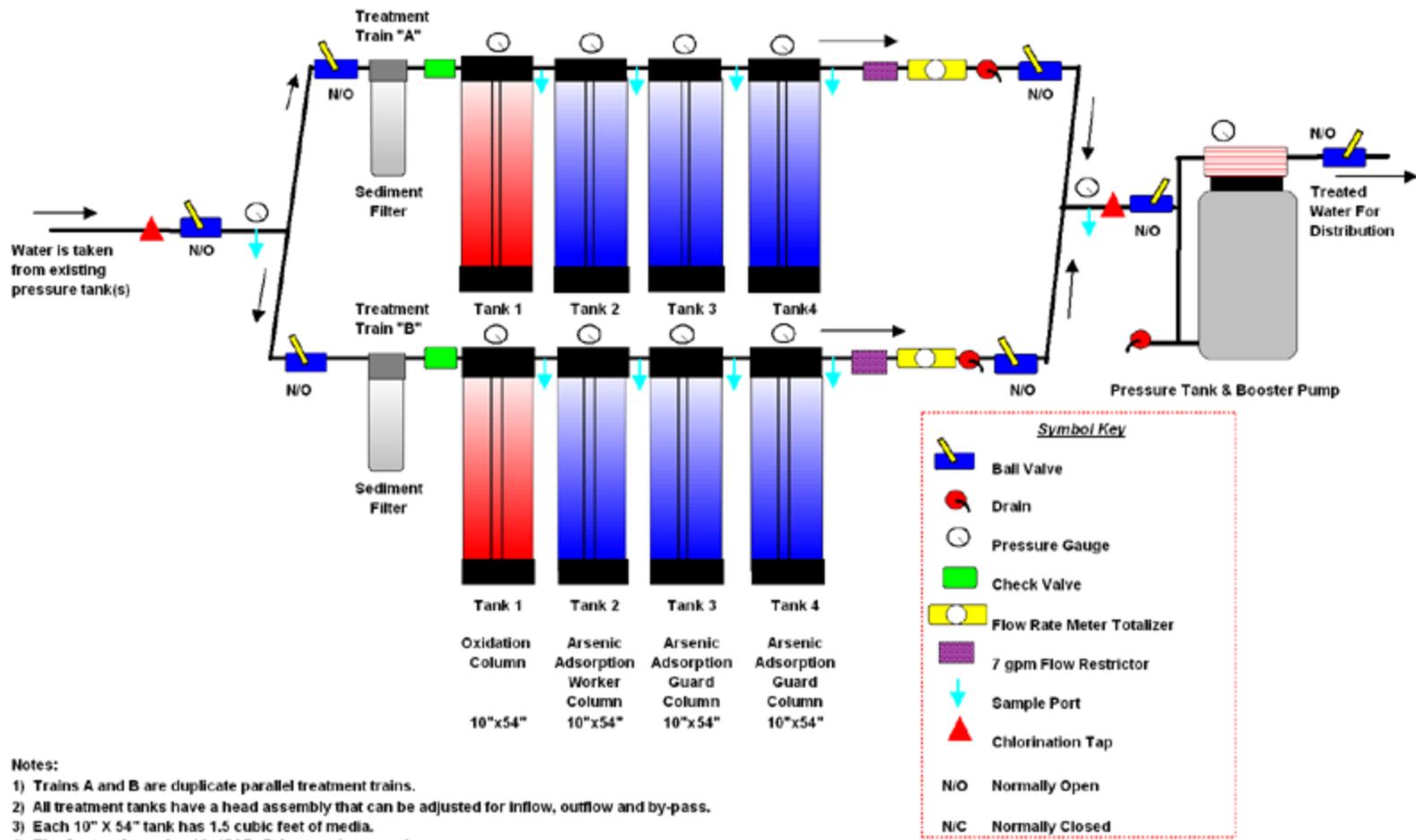
Table 4-2b. Physical and Chemical Properties of Adsorptive Media

Parameter	A/I Complex 2000	GFH	CFH-12
<i>Physical Properties</i>			
Matrix	Activated alumina/iron complex	β-ferric hydroxide and ferric hydroxide	ferric oxide and ferric hydroxide
Physical Form	Granular solid	Granular solid	Granular solid
Color	Light brown/orange	Dark brown to Black	Brown/reddish brown
Bulk Density (lb/ft ³)	51	71.8	74.9
Specific Gravity (dry)	1.5	–	–
Hardness (kg/in ²)	14–16	–	–
Effective Size (mm)	0.42	0.3–2.0	0.8–1.8
BET Surface Area (m ² /g)	320	290	-
Attrition (%)	<0.1	-	9.7
Moisture Content (%)	<5	47	13–19 (16)
Particle Size Distribution	28 × 48 ^(a) (<2% fines)	10 × 50 ^(b)	10 × 18 ^(b)
<i>Chemical Analysis</i>			
Constituents	Weight (%)		
Al ₂ O ₃	90.89	–	–
NaIO ₄	3.21	–	–
Fe(NH ₄) ₂ (SO ₄) ₂ • 6H ₂ O	5.90	–	–
Fe(OH) ₃ and β-FeOOH	–	52–57	–
Iron	–	–	39–48 (44)
Water soluble content	–	–	0.5–3.0 (2.0)

NA = not available

(a) Tyler mesh.

(b) U.S. standard mesh.



Notes:

- 1) Trains A and B are duplicate parallel treatment trains.
- 2) All treatment tanks have a head assembly that can be adjusted for inflow, outflow and by-pass.
- 3) Each 10" X 54" tank has 1.5 cubic feet of media.
- 4) The System is made with 1" I.D. fittings and connections.

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As1400cs wales.wk4

Figure 4-3. Schematic of ATS As/2200CS System with Series Configuration

- **Adsorption Columns.** Following the oxidation column in each treatment train were three 10 in × 54-in sealed polyglass columns (by Park International), each loaded with 1.5 ft³ of A/I Complex 2000 adsorptive media. Similar to the oxidation columns, each adsorption column had a riser tube and a valved head assembly to control inflow, outflow, and by-pass. Prior to Media Run 3 on September 8, 2006, the A/I Complex 2000 adsorptive media were replaced with GFH and CFH12 in Treatment Trains A and B, respectively.
- **Totalizer/Flow Meter.** One Model F-1000 paddlewheel totalizer/flow meter (by Blue-White Industries) was installed on the downstream end of each treatment train to record the flowrate and volume of water treated through the treatment train.
- **Booster Pump and Pressure Tank.** One 180-gal Well-Rite pressure tank (by Flexcon Industries in Randolph, Maine) fitted with a ¾-hp Goulds booster pump (Model No. C48A94A06) was installed at the system outlet. The booster pump/pressure tank was used to “pull” water from the two pressure tanks at the system inlet through the two treatment trains; provide temporary storage of the treated water; and supply the treated water with the needed pressure to the distribution system. The on/off of the booster pump was controlled by the low/high pressure switch set at 40/60 psi on the pressure tank.
- **Pressure Gauges.** One each BII (0-100 psi) pressure gauge was installed at the system inlet just prior to the sediment filter, at the head of each column, and at the system outlet. The pressure gauges were used to monitor the system pressure and pressure drop across the treatment trains.
- **Sampling Taps.** Sampling taps made of PVC (by US Plastics) were located prior to the system and following each oxidation and adsorption tank for water sampling.

The system was constructed using 1-in copper piping and fittings. The design features of the treatment system are summarized in Table 4-3 and a flow diagram along with the sampling/analysis schedule are presented in Figure 3-1. A photograph of the system installed is shown in Figure 4-4 and a close-up view of the oxidation and adsorptive media columns is shown in Figure 4-5.

4.3 System Installation

Engineering plans for the system were prepared by ATS. The plans consisting of a schematic and a written description of the As/1400CS system were submitted to MDWP for approval on February 16, 2005. The approval was granted by MDWP on February 18, 2005.

The system was installed in the existing treatment building, shown in Figure 4-1, without any addition or modifications. Because the system required 20 ft² of floor space, the park owner made several improvements to the interior of the building, including adding a concrete floor and extending the wall of the treatment room inside the building to allow floor space for installation and access to the system.

The As/1400CS system, consisting of factory-packed oxidation and adsorption columns and pre-assembled system valves, gauges, and sample taps, was delivered to the site on March 2, 2005. System installation with re-work of some pre-existing system piping began that same day. The sediment filter was attached to the wall at the head of each treatment train. The media columns were then set into place and plumbed together using copper piping and connections. The mechanical installation was complete on March 3, 2005. Before the system was put online, the system piping was flushed and the columns were filled with water one at a time to check for leaks. Once all columns were filled, the system was operated for a short period with the treated water discharged to the sump. After it was determined that the system had been operating properly, the treated water was directed to the distribution system. Upon reset of the flowmeter/totalizer on each train, the performance evaluation study officially began on March 7, 2005.

Table 4-3. Design Specifications of As/1400CS System

Parameter	Value	Remarks
<i>Oxidation Columns</i>		
Column Size (in)	10 D × 54 H	–
Cross-Sectional Area (ft ² /column)	0.54	–
Number of Columns	2	1 column per train
Media Type	A/P Complex 2002	Activated alumina/metaperiodate complex
Media Quantity (lb/column)	76.5	–
Media Volume (ft ³ /column)	1.5	–
<i>Adsorption Columns</i>		
Column Size (in)	10 D × 54 H	–
Cross-Sectional Area (ft ² /column)	0.54	–
Number of Columns	6	3 columns per train, 2 trains in parallel
Configuration	Series	3 columns in series per train
Media Type	A/I Complex 2000	Activated alumina/iron complex
Media Quantity (lb/column)	76.5	–
Media Volume (ft ³ /column)	1.5	–
<i>Service</i>		
Design Flowrate (gpm)	14	7 gpm per train
Hydraulic Loading (gpm/ft ²)	13	–
EBCT (min/column)	1.6	Per column, 4.8 min total EBCT for 3 adsorption columns in each train
Maximum Use Rate (gpd)	3,500	Based on usage estimate provided by park
Estimated Working Capacity (BV)	32,754	Vendor estimated bed volumes to breakthrough to 10 µg/L from lead column
Throughput to Breakthrough (gal/train)	367,500	Vendor estimated throughput to breakthrough to 10 µg/L from lead column (1 bed volume = 1.5 ft ³ or 11.2 gal)
Estimated Media Life (month)	7	Estimated frequency of media changeout in lead column based on throughput of 1,750 gpd per train
<i>Backwash</i>		
Backwash	–	No system backwash required

4.4 System Operation

4.4.1 Operational Parameters. Three consecutive media runs were performed during the 2½-year performance evaluation study. The operational parameters of the system are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-4.

Media Run 1 began on March 7, 2005, and ended on September 26, 2005, operating for a total of 203 days. After changeout of the media in all columns (Section 4.4.2), Media Run 2 began on September 27, 2005, and continued through February 17, 2006 for 143 days. Because of the short run lengths observed during both media runs, three RSSCTs were conducted onsite as part of an effort to look for alternative media with longer run lengths. Results of the RSSCTs have been reported by Westerhoff, et al. (2008). Based upon the cost and projected media run lengths, Filox-R™ was selected to replace ATS A/P Complex 2002 oxidizing media and GFH and CFH-12 media were selected to replace A/I Complex 2000 adsorptive media in Trains A and B, respectively, for Media Run 3. Media Run 3 began on September 8, 2006 and continued through August 29, 2007, when the performance evaluation study was officially ended. Media run 3 lasted for 355 days.



Figure 4-4. As/2200CS System with Adsorption Columns Shown in Foreground and Sediment Filters Attached to Wall



Figure 4-5. Close-up View of a Sample Tap (TE), a Pressure Gauge, and Copper Piping at End of Treatment Train A

Table 4-4. Summary of As/2200CS System Operation

Parameter		Media Run 1	Media Run 2	Media Run 3	All Runs
Operating Duration		03/07/05– 09/26/05	09/27/05– 02/17/06	09/08/06– 08/29/07	03/07/05– 08/29/07
Cumulative Operating Time ^(a) (hr)		795	613	1,156	2,564
Number of Operating Days (day)		203	143	355	701
Average Daily Operating Time ^(b) (hr/day)		3.9	4.3	3.3	3.7
Throughput (gal)	Train A	258,758	197,552	390,980	847,290
	Train B	262,534	209,072	516,094	987,700
	Combined	521,292	406,624	907,074	1,834,990
Throughput (BV per train) ^(b)	Train A	7,701	5,880	11,636	25,217
	Train B	7,814	6,222	15,359	29,396
Daily Use Rate (gpd)		2,568	2,844	2,555	2,618
Average Calculated Flowrate ^(c) [Range] (gpm)	Train A	5.5 [3.1–5.8]	5.4 [5.0–6.3]	5.6 [5.2–6.8]	5.5 [3.1–6.8]
	Train B	5.6 [2.3–10]	5.7 [5.2–6.6]	7.6 [6.6–8.8]	6.6 [2.3–10]
	Combined	11.3 [6.3–15.6]	11.1 [10.2–12.9]	13.2 [11.8–15.3]	12.1 [6.3–15.6]
Average Instantaneous Flowrate [Range] ^(d) (gpm)	Train A	5.1 [4.3–5.7]	4.9 [4.2–5.9]	5.1 [4.5–6.0]	5.0 [4.2–6.0]
	Train B	5.2 [4.6–5.8]	5.1 [4.4–5.7]	6.0 [4.4–6.9]	5.4 [4.4–6.9]
EBCT (min) ^(e) per Column [Range]	Train A	2.0 [1.9–3.6]	2.1 [1.8–2.2]	2.0 [1.6–2.2]	2.0 [1.6–3.6]
	Train B	2.0 [1.1–4.9]	2.0 [1.7–2.2]	1.4 [1.3–1.7]	1.7 [1.1–4.9]
Average Δp across Trains [Range] ^(f) (psi)	Train A	33 [29–40]	34 [29–42]	30 [24–35]	32 [24–42]
	Train B	34 [31–41]	35 [31–42]	29 [23–34]	33 [23–42] ⁽ⁱ⁾

- (a) Based on booster pump hour meter. Because the booster pump was not setup properly from March 7 to April 5, 2005, the operation time during this period was estimated as described in Section 4.4.1
- (b) Calculated based on 4.5 ft³ (or 33.6 gal) of media in each train.
- (c) Calculated based on totalizer and booster pump hour meter readings, not including data from March 7 to April 5, 2005 (see Section 4.4.4) or on April 6, 2005 (due to an outlier).
- (d) Average not including data from March 7 to April 5, 2005 (see Section 4.4.4).
- (e) Calculated based on 1.5 ft³ (or 11.2 gal) of media per column and average flowrate.
- (f) Calculation not including an outlier on January 11, 2007.

From March 7, 2005, through August 29, 2007, the treatment system operated for 2,564 hr (including 795 hr, 613 hr, and 1,156 hr for Runs 1, 2, and 3, respectively) based on hour meter readings of the booster pump. In the beginning of the demonstration study from March 7 to April 5, 2005, a valve near the booster pump was inadvertently left open, causing the booster pump to run continually (see Section 4.4.4). The system operating time during this period was estimated based on the total throughput and average flowrate through Trains A and B from April 6 through the remainder of Run 1. The operational time represented a utilization rate of approximately 15.4% (on average) over the 701-day study period with the booster pump operating at an average of 3.7 hr/day.

Total system throughput values during Media Runs 1, 2, and 3 were 521,292, 406,624, and 907,074 gal, respectively, corresponding to 1,834,990 gal of water processed through the entire course of the study. Based on the total throughput and total system operating time, daily use rates ranged from 2,555 to 2,844 gpd and averaged 2,618 gpd, compared to the 3,500 gpd maximum use rate provided by the park.

During Media Runs 1 and 2, flows were balanced through Trains A and B, which treated 49.6% and 50.4% of water, respectively, during Media Run 1 and 48.6% and 51.4% of water, respectively, during Media Run 2. During Media Run 3, a significant flow imbalance was observed between Trains A and B, which treated 43.1% and 56.9% of water, respectively. Flow resistance through a packed bed is usually sensitive to the particle size of the media. The higher flowrate observed through Train B was likely due to the relatively larger particle size of the Kimera CFH-12 media than Siemens GFH media (Table 4-2b). Calculated flowrates through Trains A and B were based on volume throughputs recorded by the totalizers installed on Trains A and B and booster pump hour meter readings. Calculated flowrates were

not available for the period from March 7 to April 5, 2005, when a valve near the booster pump was inadvertently left open as discussed above. As shown in Figure 4-6, the calculated flowrates of the system during the first two runs were very similar, ranging from 6.3 to 15.6 gpm and averaging 11.3 gpm for Run 1 and from 10.2 to 12.9 gpm and averaging 11.1 gpm for Run 2. The 11.3- and 11.1-gpm average values are somewhat lower than the design value of 14 gpm. The calculated flowrates during the third run were slightly higher, ranging from 11.8 to 15.3 gpm and averaging 13.2 gpm (Figure 4-6). The higher flowrates observed during the third run were thought to be caused by the differences in media properties. The imbalanced flows between Trains A and B are shown in Figure 4-6. In general, the calculated flowrates were about 10 to 19% higher than the corresponding instantaneous flowrates from the flow meters installed on the treatment trains (Table 4-4).

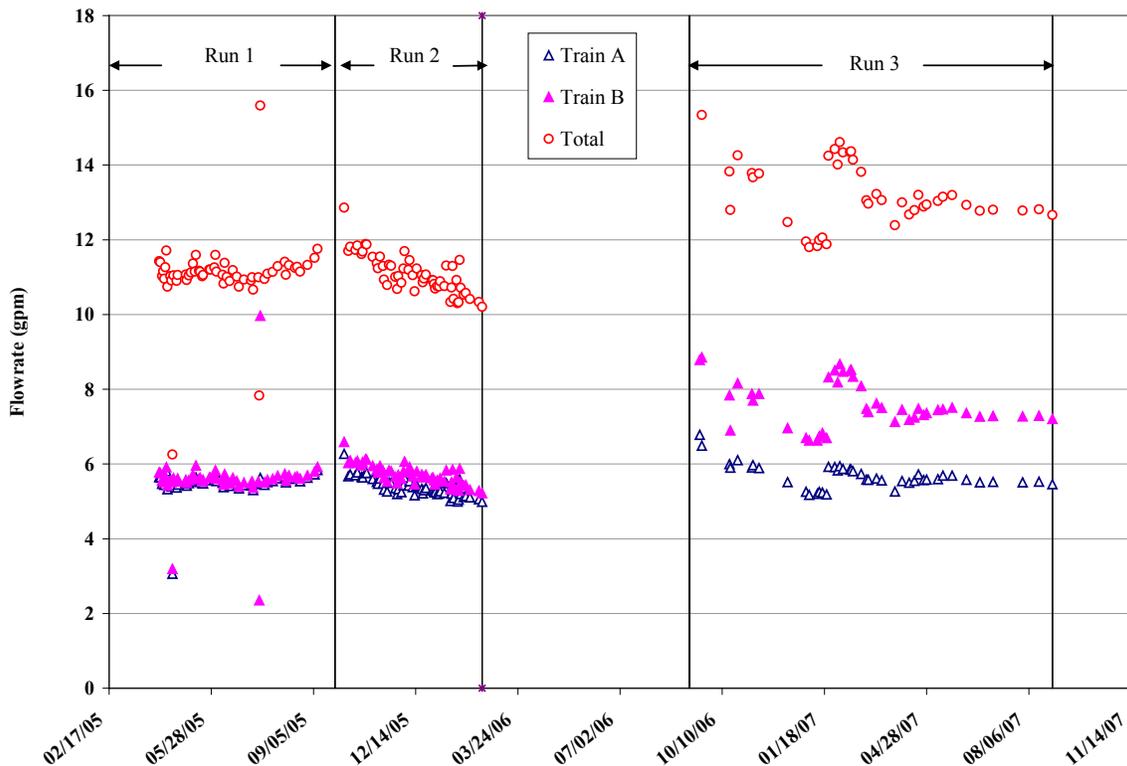


Figure 4-6. Calculated Flowrate of Treatment System

EBCT values for all media runs ranged from 1.6 to 4.9 min and averaged 1.9 min per column (corresponding to a hydraulic loading rate of 11.2 gpm/ft²). The average EBCT was slightly longer than the design value of 1.6 min per column.

Total pressure loss across each treatment train (four columns in series) averaged 33.5, 34.5, and 29.5 psi for Runs 1, 2, and 3, respectively. The average pressure loss across Train A and B was similar, with a difference less than 3.5%.

4.4.2 Media Replacement. Media changeouts were performed by ATS on September 27, 2005, after the first media run and by Air & Quality, Inc. on September 8, 2006, after the second media run. ATS preloaded virgin media into new columns at its warehouse and transported the loaded columns to the

site. The columns containing spent media were then removed from the system piping and replaced with the columns preloaded with virgin media.

Air & Quality, Inc. replaced the ATS media with Filox-R™, GFH, and CFH-12 media using the existing columns. The ATS media was replaced with 1.5 ft³ of Filox-R™ in each of the two oxidation columns and 4.5 ft³ (1.5 ft³/column) of GFH and CFH-12 in the three adsorption columns in Trains A and B, respectively. The columns containing Filox-R™ were backwashed at approximately 7 gpm for 15 min and rinsed at the same rate for 10 min. The water was clear at end of the rinse. The columns containing GFH were backwashed at approximately 4.5 gpm for 10 min and then rinsed at 6.4 gpm for 10 min. The backwash water was clear after approximately 5 min of rinse. The columns containing CFH-12 were backwashed at 4.5 gpm for 10 min and then at 12 gpm for 10 min. They were then rinsed at 6.4 gpm for 5 min. The water ran clear at the end of 5 min.

At 6.4 gpm, the pressure drop was about 4 psi across each Filox-R™ column, 6 psi across all three GFH columns (or 2 psi per column), and 4 psi across all three CFH-12 columns (or 1.3 psi per column). The freeboard was 15 in for GFH and 14 in for CFH-12. Spent ATS samples were collected by the operator at the end of Media Run 2 for the TCLP and metal analyses (Section 3.3.3).

4.4.3 Residual Management. The only residuals produced were spent media (see Section 4.4.2). The spent ATS media passed the TCLP test and could be disposed of as a non-hazardous material. However, the vendor elected to recycle it to save disposal cost.

4.4.4 Reliability and Simplicity of Operation. The only operational difficulty encountered occurred soon after system start-up. The booster pump downstream from the treatment system did not cycle on and off as expected. In turn, the supply pressure from the downstream pressure tank was not sufficient to maintain adequate pressure to the distribution system. After troubleshooting, it was determined that a valve near the booster pump was inadvertently left open during the initial system installation. Once the valve was closed, the downstream booster pump began to work as designed and the pressure to the distribution was maintained. Since then, the system operated uninterrupted throughout the study. Additional discussion regarding system operation and operator skill requirements is provided below.

Pre- and Post-Treatment Requirements. The only pretreatment step was the oxidation of As(III) to As(V) via the oxidizing media installed in the first column of each treatment train. No additional chemical addition or other pre-or post-treatment steps were used at the site.

System Automation. The As/1400CS adsorption system was a passive system, requiring only the operation of the supply well pump and booster pump to send water to the two pressure tanks at the system inlet and through the oxidation and adsorption columns to the pressure tank at the system outlet. The media columns themselves did not have automated parts and all valves were manually activated. The inline flowmeter was battery powered so that the only electrical power required was that needed to run the supply well pump and booster pump. The supply well pump was in place prior to the installation of the ATS treatment system. The system operation was controlled by the pressure switch in the pressure tank at the system outlet.

Operator Skill Requirements. Under normal operating conditions, the skills required to operate the As/1400CS system were minimal. The operation of the system did not appear to require additional skills beyond those necessary to operate the existing water supply system in place at the site.

The level of operator certification is determined by the type and class of the public drinking water systems. MDWP's drinking water rules require all community and non-transient, non-community public

drinking water and distribution systems to be classified based on potential health risks. Classifications range from “very small water system (VSWS)” (lowest) to “Class IV” (highest) for treatment systems and from “VSWS” to “Class IV” for distribution systems, depending on such factors as the system’s complexity, size, and source water. SBMHP is classified as a “VSWS” distribution system and the plant operator has a matching “VSWS” license.

Preventative Maintenance Activities. The only regularly scheduled preventative maintenance activity recommended by ATS was to inspect the sediment filters monthly and replace them as necessary. The treatment system operator visited the site approximately three times per week to check the system for leaks, and record flow, volume, and pressure readings.

4.5 System Performance

The system performance was evaluated based on analyses of samples collected across the treatment trains and distribution system. The system ran from March 7, 2005 to August 29, 2007. All columns, including oxidation columns, were changed out on September 27, 2005, and September 8, 2006, after the first and second media runs. The system operated for 29 weeks before effluent arsenic concentrations had reached influent concentrations during the first media run and 21 weeks during the second media run. After the second run, the owner/operator decided to try GFH and CFH-12 media based on results of three RSSCTs conducted in January, March, and May of 2006 (Westerhoff, et al, 2008). Filox-R™ was chosen to replace the ATS A/P Complex 2002 oxidizing media for converting As(III) to As(V), prior to entering adsorption columns. The third media run lasted 52 weeks before effluent arsenic concentrations had reached approximately 10 µg/L.

4.5.1 Treatment Plant Sampling. Table 4-5 summarizes the arsenic, iron, manganese, and aluminum results from samples collected across the treatment plant. Table 4-6 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results through the 2½ years of system operation. The results of the treatment plant sampling are discussed below.

Arsenic. The key parameter for evaluating the effectiveness of the treatment system was the concentration of arsenic in the treated water. The treatment plant water was sampled on 53 occasions during the evaluation period (with duplicates taken on three and speciation performed on 26 of the 53 occasions).

Figures 4-7 and 4-8 contain four bar charts each showing the concentrations of total As, particulate As, As(III), and As(V) across Treatment Trains A and B, respectively. Total arsenic concentrations in raw water ranged from 34.6 to 50.2 µg/L and averaged 39.1 µg/L (Table 4-5). Soluble As(III) was the predominating species, with concentrations ranging from 21.9 to 38.7 µg/L and averaging 28.5 µg/L. Soluble As(V) also was present, with concentrations ranging from 0.2 to 17.6 µg/L and averaging 10.5 µg/L. Particulate As was low, with concentrations typically less than 1 µg/L. The influent arsenic concentrations measured during this 2½ year period were consistent with those in the raw water sample collected prior to the study on September 14, 2004.

Media Runs 1 and 2. During Media Runs 1 and 2, A/P Complex 2002 and A/I Complex 2000 were loaded in the lead oxidizing columns and the following adsorptive columns, respectively. As shown in Figures 4-7 and 4-8, the A/P Complex 2002 oxidizing media was effective at converting soluble As(III) to soluble As(V), typically lowering the soluble As(III) concentrations to <1.5 µg/L. Soluble As(III) concentrations following the oxidation columns were higher on June 29 and July 27, 2005, and January 31, 2006, ranging from 3.3 to 6.3 µg/L. The cause of these atypical results is not known.

**Table 4-5. Summary of Arsenic, Iron, Manganese, and Aluminum Analytical Results
(Media Runs 1, 2 and 3)**

Parameter (Figure, if any)	Sampling Location	Media Run I.D	Number of Samples	Concentration (µg/L)			Standard Deviation
				Minimum	Maximum	Average	
As (total) (Figure 4-10)	IN	Run 1,2,&3	52	34.6	50.2	39.1	3.0
	OA-OB	Run 1 &2	28	0.3	50.2	-	
		Run 3	24	32.2	42.4		
	TA-TF	Run 1 &2	9-20	<0.1	58.4		
	TA, TC, TE	Run 3	25	<0.1	34.2		
	TB, TD, TF	Run 3	25	<0.1	35.3		
	TT	Run 1 &2	15	<0.1	35.4		
Run 3		2	<0.1	0.1			
As (soluble)	IN	Run 1,2,&3	26	34.4	42.6	-	
	OA-OB	Run 1 &2	13	<0.1	45.5		
		Run 3	13	33.7	42.0		
	TA-TF	Run 1 &2	1-6	<0.1	46.4		
	TT	Run 1 &2	3	<0.1	17.4		
		Run 3	1	<0.1	<0.1		
As (particulate) (Figures 4-7 and 4-8)	IN	Run 1,2,&3	26	<0.1	1.6	0.4	0.5
	OA-OB	Run 1 &2	13	<0.1	0.6	-	
		Run 3	13	<0.1	3.0		
	TA-TF	Run 1 &2	1-6	<0.1	12.1		
	TT	Run 1 &2	3	<0.1	<0.1		
		Run 3	1	<0.1	<0.1		
As (III) (Figures 4-7 and 4-8)	IN	Run 1,2,&3	26	21.9	38.7		28.5
	OA-OB	Run 1 &2	13	0.2	6.3	-	
		Run 3	13	<0.1	1.2		
	TA-TF	Run 1 &2	1-6	0.2	2.3		
	TT	Run 1 &2	3	<0.1	2.4		
		Run 3	1	<0.1	<0.1		
As (V) (Figures 4-7 and 4-8)	IN	Run 1,2, &3	26	0.2	17.6		10.5
	OA-OB	Run 1 &2	13	<0.1	45.0	-	
		Run 3	13	33.6	41.5		
	TA-TF	Run 1 &2	1-6	<0.1	46.0		
	TT	Run 1 &2	3	<0.1	15.1		
		Run 3	1	<0.1	<0.1		
Fe (total)	IN ^(b)	Run 1,2, &3	28	<25	<25		<25
	OA-OB	Run 1,2, &3	30	<25	<25	<25	0.0
	TA-TF ^(c)	Run 1,2, &3	2-13	<25	<25	<25	0.0
	TT ^(d)	Run 1,2, &3	17	<25	42.2	<25	7.0
Fe (soluble)	IN	Run 1,2, &3	14	<25	<25	<25	0.0
	OA-OB	Run 1,2, &3	15	<25	<25	<25	0.0
	TA-TF	Run 1,2, &3	1-6	<25	<25	<25	0.0
	TT	Run 1,2, &3	4	<25	<25	<25	0.0
Mn (total)	IN	Run 1,2, &3	29	6.4	21.9	9.5	3.2
	OA-OB ^(e)	Run 1,2, &3	30	<0.1	2.5	0.2	0.4
	TA-TF ^(c)	Run 1,2, &3	2-13	<0.1	1.2	0.1	0.2
	TT	Run 1,2, &3	18	<0.1	2.1	0.3	0.5
Mn (soluble)	IN	Run 1,2, &3	14	6.1	15.2	9.1	2.5
	OA-OB	Run 1,2, &3	15	<0.1	0.4	0.1	0.1
	TA-TF	Run 1,2, &3	1-6	<0.1	0.5	0.1	0.1
	TT	Run 1,2, &3	3	<0.1	1.9	0.7	1.1

**Table 4-5. Summary of Arsenic, Iron, Manganese, and Aluminum Analytical Results
(Media Runs 1, 2 and 3) (Continued)**

Parameter (Figure, if any)	Sampling Location	Media Run I.D	Number of Samples	Concentration (µg/L)			Standard Deviation
				Minimum	Maximum	Average	
Al (total)	IN	Run 1,2, &3	29	<10	21.4	10.2	5.0
	OA-OB	Run 1,2, &3	30	<10	67.7	33.4	10.8
	TA-TF ^(c)	Run 1,2, &3	2-13	<10	42.6	27.5	10.1
	TT	Run 1,2, &3	18	<10	55.7	22.4	14.7
Al (soluble)	IN	Run 1,2, &3	14	<10	<10	<10	0.0
	OA-OB	Run 1,2, &3	15	12.5	65.9	30.2	12.3
	TA-TF	Run 1,2, &3	1-6	<10	41.1	23.2	12.3
	TT	Run 1,2, &3	4	<10	22.1	15.9	7.5

(a) Statistics not meaningful for data related to breakthrough; see Figure 4-10 for breakthrough curves.

(b) Calculation does not include an outlier on 12/15/05.

(c) Calculation does not include two outliers on 06/29/05.

(d) Calculation does not include an outlier on 06/15/05.

(e) Calculation does not include an outlier on 03/22/05.

IN = at wellhead; OA and OB = after oxidation columns; TA to TF = after corresponding adsorption columns; TT = after entire treatment system

One-half of the detection limit used for samples with concentrations less than the detection limit for calculations.

Duplicate samples are included in the calculations.

**Table 4-6. Summary of Water Quality Parameter Measurements
(Runs 1, 2 and 3)**

Parameter	Sampling Location	Unit	Number of Samples	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity	IN	mg/L	22	64	80	70	3.9
	OA-OB	mg/L	22	58	74	68	2.9
	TA-TF	mg/L	6-13	63	147	70	11.3
	TT	mg/L	15	59	75	65	4.3
Fluoride	IN	mg/L	16	0.4	0.6	0.5	0.1
	OA-OB	mg/L	16	0.4	0.8	0.5	0.1
	TA-TD	mg/L	2-7	<0.1	0.6	0.5	0.2
	TT	mg/L	15	<0.1	0.7	0.5	0.2
Sulfate	IN	mg/L	16	18	39	21	5.1
	OA-OB	mg/L	16	18	38	21	4.7
	TA-TD	mg/L	2-7	16	40	22	6.6
	TT	mg/L	15	18	24	21	1.9
Orthophosphate (as PO ₄)	IN	mg/L	9	<0.05	<0.05	<0.05	0.0
	OA-OB	mg/L	9	<0.05	<0.05	<0.05	0.0
	TA-TD	mg/L	2-7	<0.05	<0.05	<0.05	0.0
	TT	mg/L	8	<0.05	<0.05	<0.05	0.0
Total Phosphorus (as P)	IN	µg/L	31	<10	71	33	12.8
	OA-OB	µg/L	31	<10	72	31	13.4
	TA-TF	µg/L	23-30	<10	36	10	7.8
	TT	µg/L	6	<10	<10	<10	0.0
Silica	IN	mg/L	44	9.6	13.3	10.5	0.6
	OA-OB	mg/L	45	4.5	14.0	9.8	1.4
	TA-TF	mg/L	32-39	0.6	13.6	7.6	2.6
	TT	mg/L	19	0.6	7.9	4.4	2.3
Nitrate (as N)	IN	mg/L	16	<0.05	0.4	0.1	0.1
	OA-OB	mg/L	16	<0.05	0.3	0.1	0.1

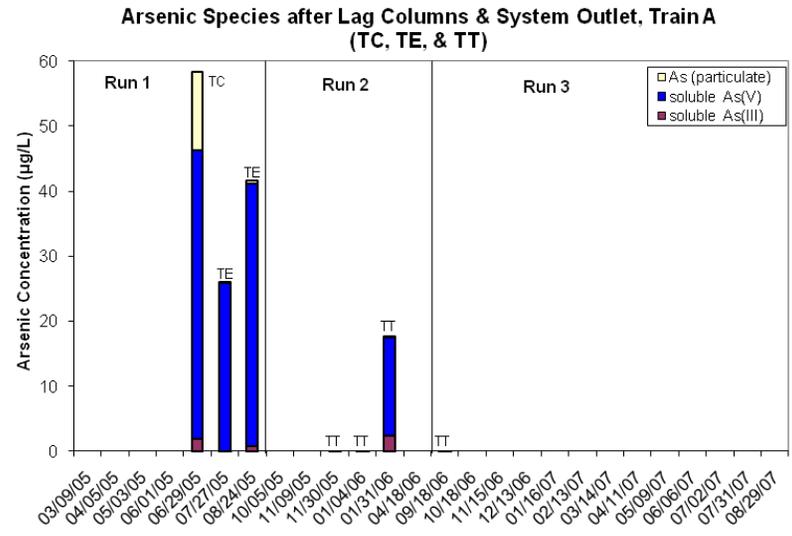
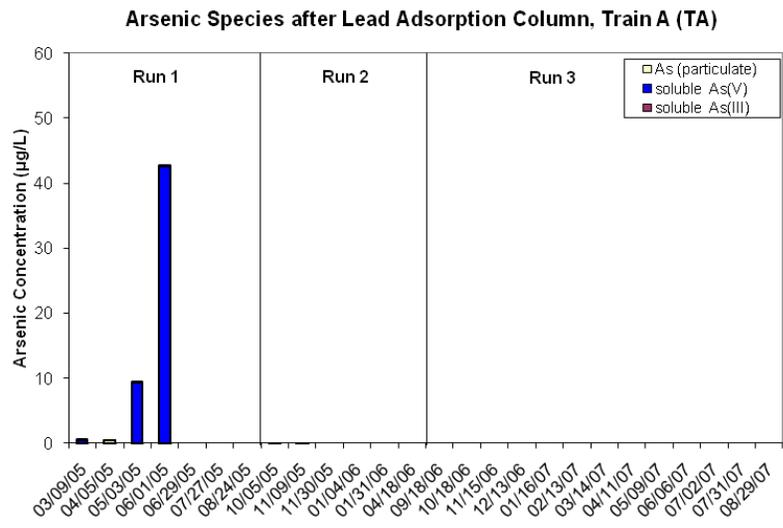
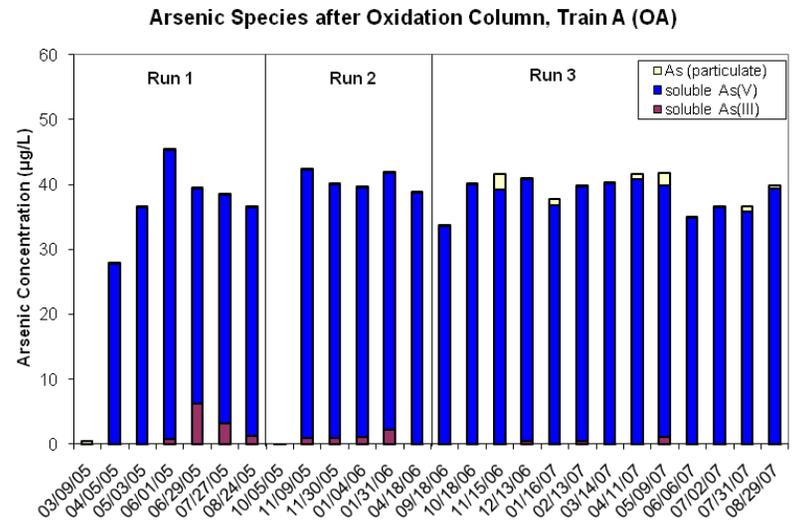
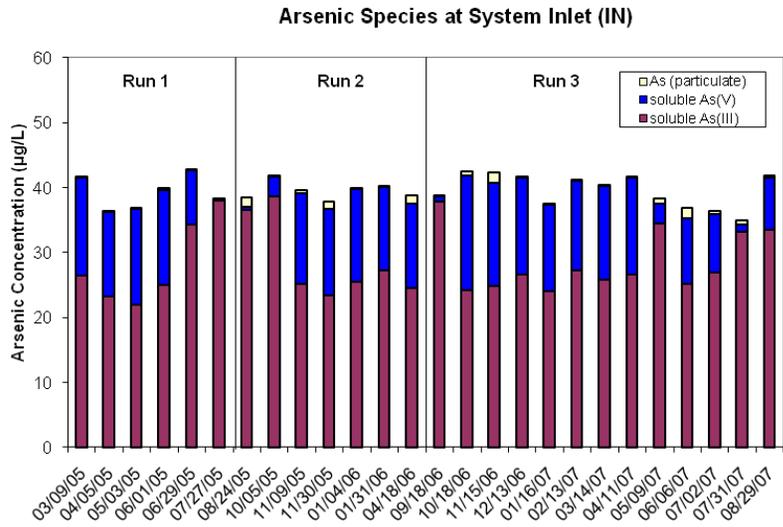
**Table 4-6. Summary of Water Quality Parameter Measurements
(Runs 1, 2 and 3) (Continued)**

Parameter	Sampling Location	Unit	Number of Samples	Concentration			Standard Deviation
				Minimum	Maximum	Average	
	TA-TD	mg/L	2-7	<0.05	1.1	0.2	0.2
	TT	mg/L	15	<0.05	0.3	0.1	0.1
Iodine	IN	µg/L	5	1.2	9.8	5.2	4.0
	OA-OB	µg/L	5	1.6	64.8	17.7	24.0
	TA-TB	µg/L	1	76.9	80.8	78.9	2.8
	TT	µg/L	4	5.8	124	39.7	56.8
Temperature	IN	°C	43	7.5	14.1	10.4	1.7
	OA-OB	°C	43	7.6	14.7	10.3	1.6
	TA-TF	°C	5-20	7.8	14.6	10.7	1.9
	TT	°C	16	8.6	14.0	10.7	1.7
Turbidity	IN	NTU	15	0.1	1.2	0.4	0.3
	OA-OB	NTU	15	<0.1	1.2	0.2	0.3
	TA-TD	NTU	2-7	<0.1	0.4	0.2	0.1
	TT	NTU	13	<0.1	0.7	0.2	0.2
pH	IN	S.U.	43	7.3	8.8	8.5	0.3
	OA-OB	S.U.	43	7.5	8.8	8.5	0.3
	TA-TF	S.U.	5-20	7.6	8.8	8.4	0.3
	TT	S.U.	16	7.0	8.5	8.0	0.4
Dissolved Oxygen	IN	mg/L	42	0.9	4.7	2.5	1.1
	OA-OB	mg/L	42	0.7	4.3	2.0	1.0
	TA-TF	mg/L	4-9	0.6	5.0	2.0	1.1
	TT	mg/L	16	0.9	3.7	1.7	0.7
ORP	IN	mV	43	111	299	175	34.3
	OA-OB	mV	43	117	315	178	37.1
	TA-TF	mV	5-20	99	327	176	38.2
	TT	mV	16	178	242	200	14.8
Total Hardness (as CaCO ₃)	IN	mg/L	24	37.9	58.1	48.9	4.9
	OA-OB	mg/L	24	37.2	64.0	47.6	5.5
	TA-TF	mg/L	2-12	36.7	87.0	47.6	10.1
	TT	mg/L	14	35.1	52.3	44.4	5.3
Ca Hardness (as CaCO ₃)	IN	mg/L	24	31.4	49.8	41.7	4.6
	OA-OB	mg/L	24	30.7	55.0	40.5	5.0
	TA-TF	mg/L	2-12	30.6	74.0	40.5	8.7
	TT	mg/L	14	29.3	44.5	37.8	4.8
Mg Hardness (as CaCO ₃)	IN	mg/L	24	6.3	8.5	7.2	0.6
	OA-OB	mg/L	24	5.7	9.0	7.1	0.8
	TA-TF	mg/L	2-12	5.5	13.0	7.1	1.5
	TT	mg/L	14	5.4	7.8	6.6	0.6

IN = at wellhead; OA and OB = after oxidation columns; TA to TF = after corresponding adsorption columns; TT = after entire treatment system

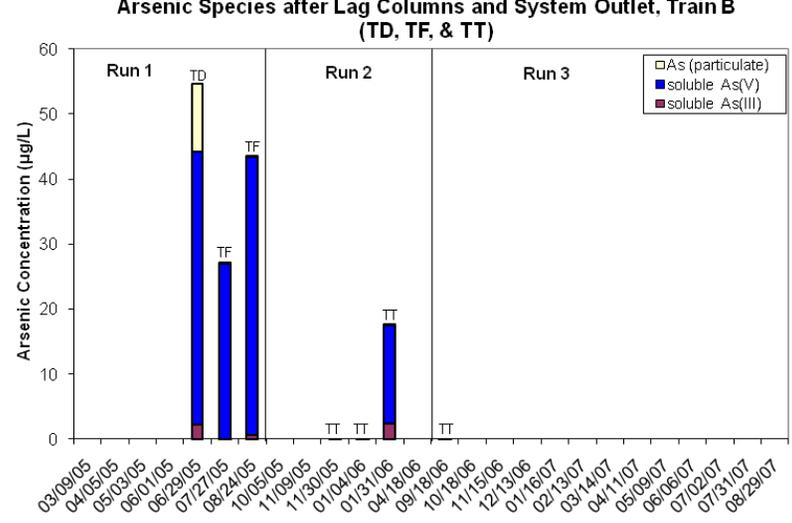
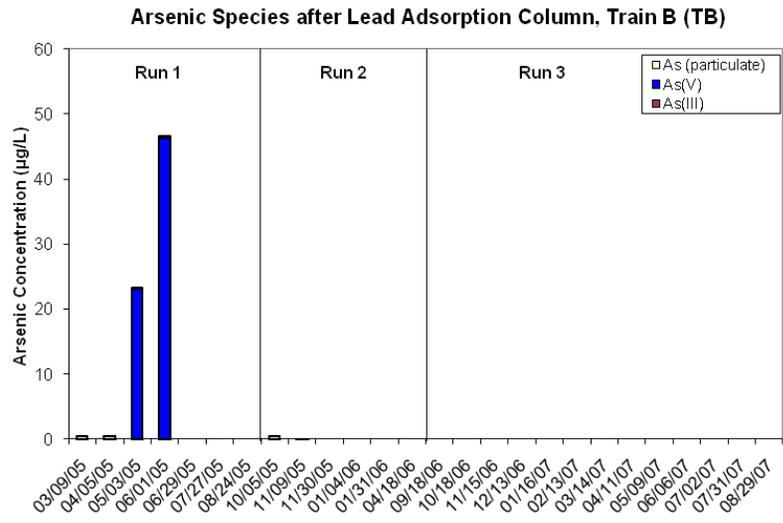
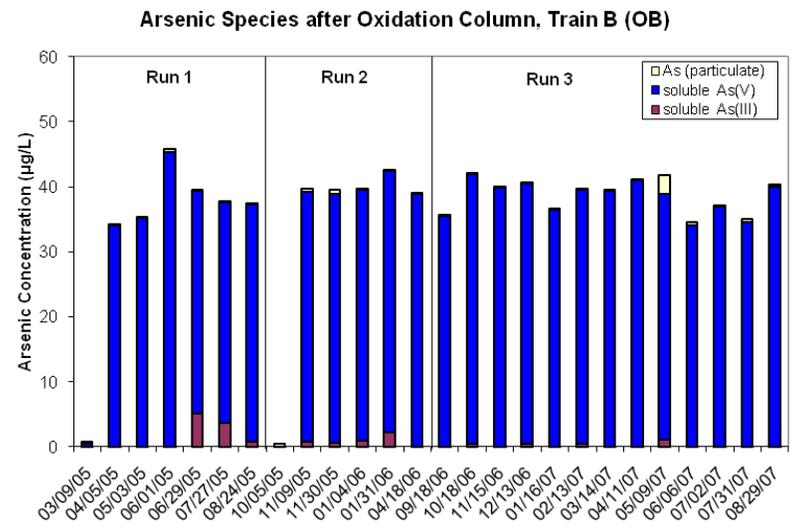
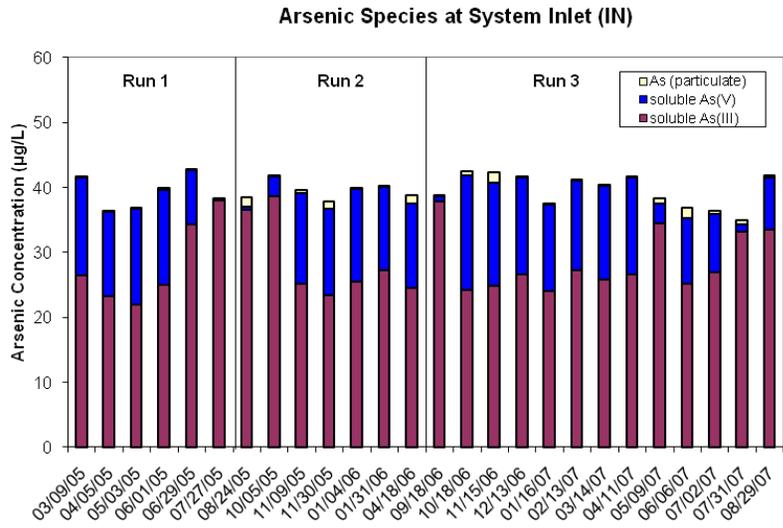
One-half of the detection limit used for samples with concentrations less than the detection limit for calculations.

Duplicate samples included in calculations.



Note: TC sample collected only on 06/29/05; TE samples collected only on 07/27/05 and 08/24/05

Figure 4-7. Concentrations of Various Arsenic Species Across Treatment Train A



Note: TD sample collected only on 06/29/05; TF samples collected only on 07/27/05 and 08/24/05

Figure 4-8. Concentrations of Various Arsenic Species Across Treatment Train B

Oxidation of soluble As(III) to soluble As(V) by the A/P Complex 2002 media was achieved through reactions with sodium metaperiodate, a key ingredient loaded on the media for soluble As(III) oxidation (Table 4-2a). At a pH value between 7.3 to 8.8 (as measured for raw water in Table 4-6), metaperiodate reacted with H₃AsO₃, presumably, following Equation 1:



Further, metaperiodate would react with any soluble iron, existing as Fe(II), and soluble manganese, existing as Mn(II), in raw water following Equations 2 and 3:



Therefore, to oxidize 28.5, <25, and 9.1 µg/L of As(III), Fe(II), and Mn(II), respectively, the average amounts measured in raw water, only 7.1, 3.6 (one half the detection limit used for calculation), and 5.3 µg/L of I⁻ would be produced stoichiometrically and leached into the column effluent. As such, the total amount of iodide (I⁻) produced would be 16 µg/L, which is lower than the Maine maximum exposure guideline (MEG) of 340 µg/L for I⁻ (Maine CDC, 2008) and the analytical reporting limit of 100 µg/L for I⁻ by EPA Method 300.0 by ion chromatography. This observation is consistent with the analytical results (<100 µg/L of I⁻) reported for the samples collected at the wellhead, after the oxidation columns, and after the adsorption columns on October 18, 2005.

Total iodine also was analyzed using ICP-MS on five occasions (including one duplicate) during Media Run 2. At approximately 2,300 BV on October 18, 2005, iodine concentrations following the oxidation and adsorption columns averaged 62.3 and 124 µg/L (as I), respectively, which were significantly higher than that measured in raw water (i.e., 9.2 µg/L [as I]). Because only 16 µg/L of total iodine would exist as I⁻, the iodine present in the column effluent most likely was IO₄⁻ or other reaction intermediates. It was possible that some IO₄⁻ leached from the oxidizing media, but the leaching followed an apparent decreasing trend as shown in Figure 4-9. The iodine concentrations in the treated water were significantly reduced to less than 22.7 µg/L [as I] after about 10 weeks into the system operation. The final sampling event on February 14, 2006, showed only 1.6 µg/L [as I] following the oxidation columns (compared to 1.2 µg/L [as I] in raw water). The iodine leaching also was observed at another ATS arsenic removal demonstration site in Susanville, CA, where 57.5 and 127 µg/L of iodine [as I] were measured following the oxidation and adsorption columns even by the end of the media run (Chen et al., 2009).

The ATS system test results for arsenic removal during Media Runs 1 and 2 are shown in Figures 4-10 with total arsenic concentrations plotted against bed volumes of water treated. Bed volume was calculated based on 1.5 ft³ or 11.2 gal of media per column. The results showed that the oxidizing media A/P Complex 2002 had some capacity for arsenic removal. For the first sampling event taking place about 2 to 8 days after the system startup, total arsenic concentrations in the effluent of the oxidation columns were ≤0.5 µg/L during both Media Runs 1 and 2. Total arsenic concentrations slowly increased thereafter and completely broken through the oxidation columns with arsenic concentrations close to those in raw water at approximately 5,000 BVs for both runs.

Based on the breakthrough curves, arsenic loadings on the oxidation media during Media Runs 1 and 2 ranged from 0.09 to 0.18 µg of As/mg of dry media and averaged 0.14 µg/mg. Arsenic loading was calculated by dividing the arsenic mass represented by the area under the respective breakthrough curve by the dry weight of the media in a column. The results of arsenic loading calculations are summarized in Table 4-7. Detailed calculations are provided in Appendix C.

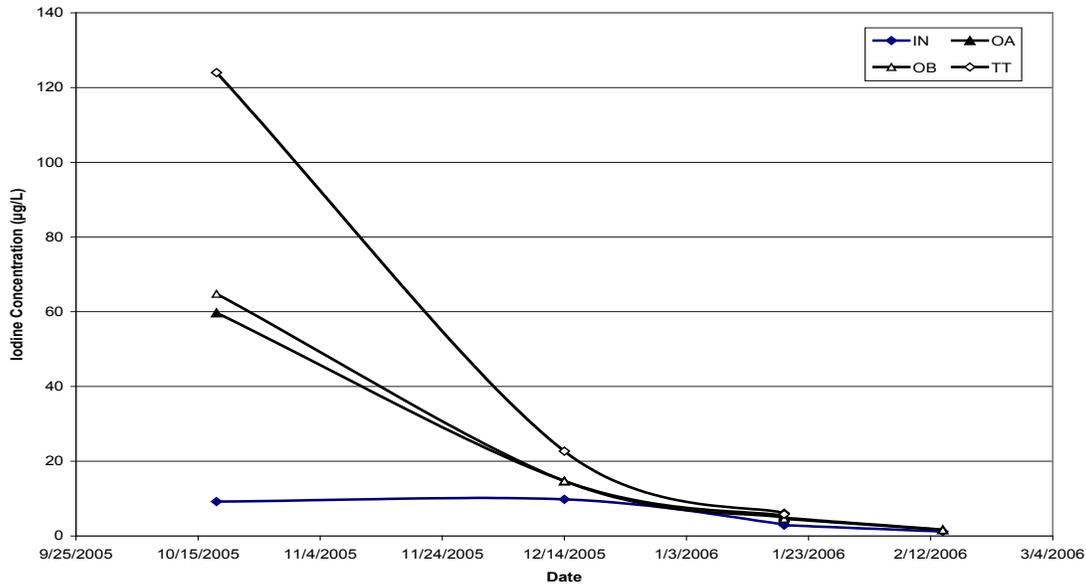
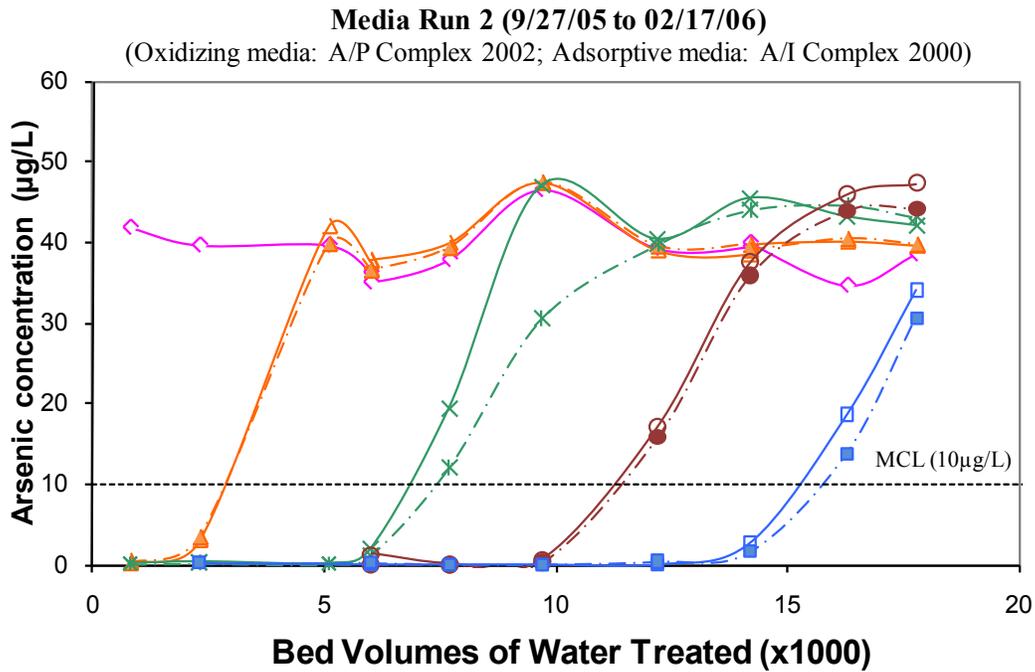
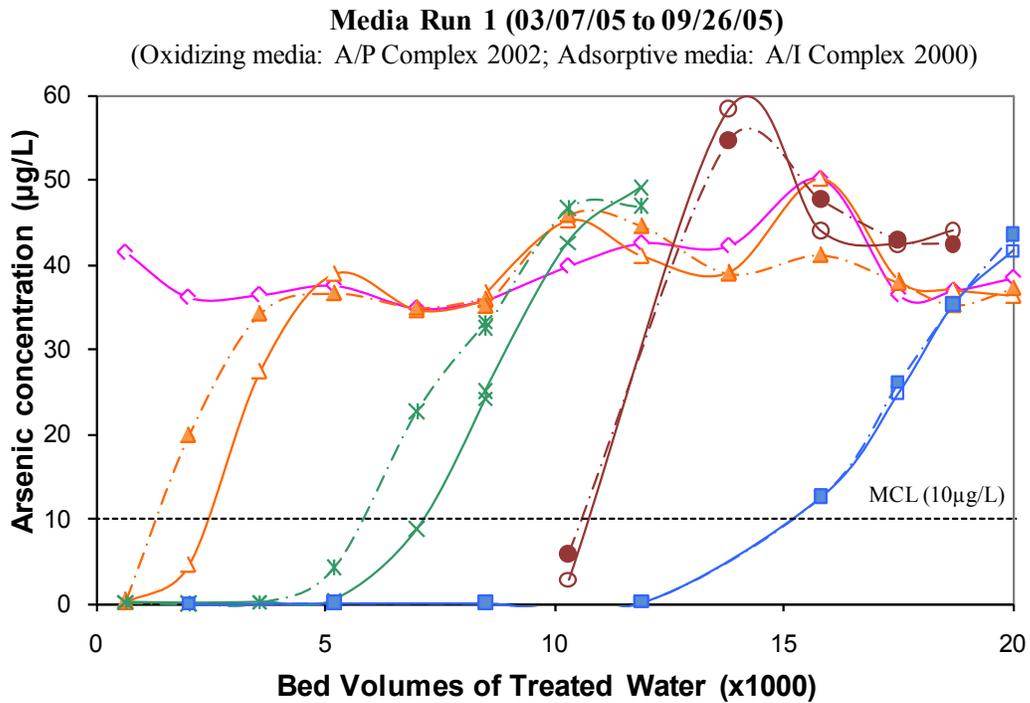


Figure 4-9. Iodine Concentrations Across Treatment Train during Media Run 2

During Media Run 1, total arsenic concentrations in the influent water to the first adsorption column of each treatment train steadily rose from around 0.5 µg/L to just below 40 µg/L (i.e., the level in raw water) during the first 4000 to 5,000 BVs of throughput. During this same period of time, arsenic concentrations in the effluent from the lead adsorption columns were below 0.5 µg/L. At 5,000 BVs for Train A and about 4000 BVs for Train B, the arsenic levels from the lead columns began to increase. The effluent arsenic levels following the lead adsorption columns reached 10 µg/L at 7,100 BVs for Train A (TA) and 5,200 BVs for Train B (TB). Arsenic breakthrough from the lead adsorption columns occurred much sooner than projected by the vendor (i.e., at 32,700 BV). While a number of water quality factors might have played a role in the early breakthrough, high pH values (averaging 8.5; see Table 4-6) were thought to be the major factor. As shown in Figure 4-10, the saturation of the lead adsorption columns occurred at approximately 10,000 BVs for Train A and 9,000 BVs for Train B. All bed volumes were calculated based on 1.5 ft³ of media in each column.

At about 10,000 BVs, arsenic concentrations after the first set of lag columns (second set of media columns) were below 10 µg/L (2.9 and 6.0 µg/L at sampling locations TC and TD in Trains A and B, respectively). By 13,800 BV on June 29, 2005, the concentrations at these two locations increased to above the influent levels at 58.4 and 54.7 µg/L. (The June 29, 2005, samples taken at TC and TD showed elevated levels of arsenic, iron, manganese, aluminum, calcium, and magnesium. The cause of the concentration increase in these metals is not known.) Arsenic concentrations after the second set of lag columns (third set of media columns) reached 10 µg/L at approximately 15,300 BV through both treatment trains. The treatment train reached complete exhaustion at about 19,000 BV. Again, all bed volumes were calculated based on 1.5 ft³ of media in each column.

As compared in Figure 4-11, results of Media Runs 1 and 2 were similar, indicating stable performance for both the oxidizing (C/P Complex 2002) and adsorptive media (C/I Complex 2000). During Media Run 2, arsenic concentrations after the lead adsorption columns reached 10 µg/L at approximately 6,800 BV for Train A (TA) and 7,400 BV for Train B (TB). Arsenic concentrations following the first lag columns reached 10 µg/L at approximately 11,100 and 11,300 BV in Trains A and B, respectively. Arsenic concentrations following the second lag columns in each treatment train reached 10 µg/L at approximately 15,600 BV.



Note: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-10. Total Arsenic Breakthrough Curves during Media Runs 1 and 2

Table 4-7. Arsenic Loadings on Oxidation and Adsorption Columns^(a)

Column		Arsenic Mass Removed (mg)			Capacity (μg of As/mg of media)		
		Run 1	Run 2	Run 3	Run 1 ^(b)	Run 2 ^(b)	Run 3 ^(c)
Oxidation	OA	4,765	5,412	1,040	0.14	0.16	0.01
	OB	3,149	5,936	894	0.09	0.18	0.01
	Average	4,816		967	0.14		0.01
Adsorption Media	TA (Lead)	7,658	6,383	29,011	0.23	0.19	1.08 ^(d)
	TB (Lead)	6,231	9,047	35,905	0.19	0.27	0.87 ^(d)
	TC (1st lag)	5,817	8,533	16,634	0.18	0.26	0.62 ^(d)
	TD (1st lag)	9,357	6,901	21,423	0.28	0.21	0.52 ^(d)
	TE (2nd lag)	8,597	7,196	8,918	0.26	0.22	0.33 ^(d)
	TF (2nd lag)	9,287	7,194	11,321	0.28	0.22	0.27 ^(d)
	Average	7,683		Train A: 18,187 Train B: 22,883	0.23		Train A: 0.67 ^(d) Train B: 0.55 ^(d)

- (a) Detailed calculations provided in Appendix C.
- (b) 33.0 kg of dry media in each column based on a bulk density of 51 lb/ft³ and a moisture content of 5%.
- (c) 77.7 kg of Filox in each column based on a bulk density of 114 lb/ft³ and a moisture content of 0%; 26.9 kg of GFH based on a bulk density of 79 lb/ft³ and a moisture content of 50%; and 41.2 kg of CFH-12 based on a bulk density of 72 lb/ft³ and a moisture content of 16%.
- (d) Columns not at full capacity for arsenic at end of evaluation.

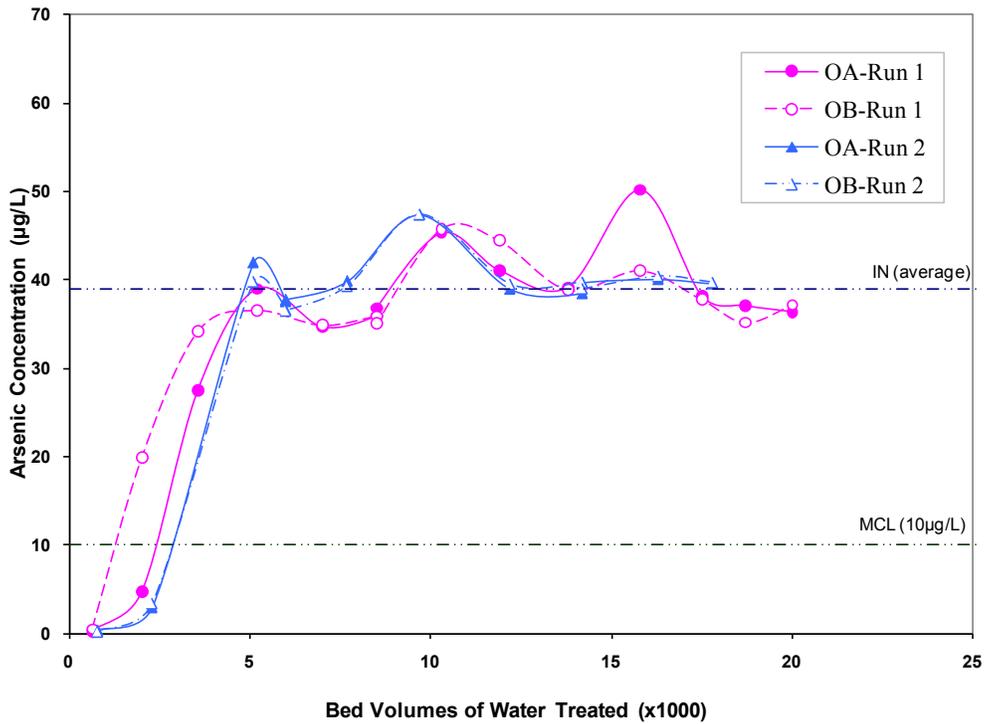
Based on the breakthrough curves, all adsorptive columns were exhausted at the end of Media Run 1. At the end of Media Run 2, the lead (TA and TB) and first lag (TC and TD) columns were exhausted; and the second lag columns were close to exhaustion. Calculated arsenic loadings on the adsorptive media ranged between 0.18 and 0.28 μg of As/mg of dry media and averaged 0.23 $\mu\text{g}/\text{mg}$, which was 1.6 times greater than that on the oxidizing media (Table 4-7).

Because of the sharp breakthrough curves and lower than projected adsorptive capacities, the media changeout did not occur until the treatment train had reached complete exhaustion. Consequently, the finished water from the system had arsenic levels higher than the MCL for over two months for Media Run 1 and for about two weeks for Media Run 2. Operating the system in this way (media changeout for all columns at one time) is equivalent to operating a single vessel system with sample taps along length of the vessel (or between columns). Under these operating conditions, the Media 1 run length to 10 $\mu\text{g}/\text{L}$ of arsenic breakthrough using a media bed volume of 4.5 ft³ (i.e., 1.5 ft³/column for three columns; not including the oxidizing column) was approximately 5,100 BV for Train A and 5,200 BV for Train B. To take advantage of a series design and improve the economics of the system, the lead tanks should be replaced when total arsenic breakthrough (i.e., arsenic concentrations in the effluent reach those in the influent) occurs. Because of early breakthrough during these two runs (which was not expected), changeout of the lead adsorption columns was not done.

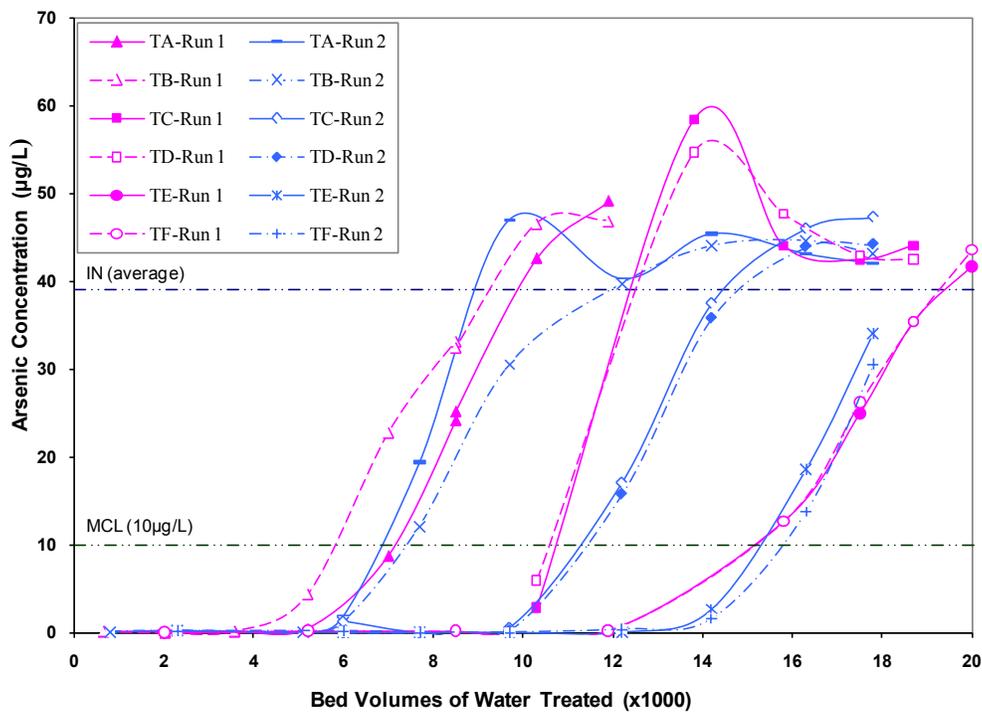
As shown in Figure 4-10, the arsenic breakthrough from the lead and lag columns in both Media Runs 1 and 2 exhibited typical S-shaped curves, which are characteristic for fixed-bed adsorption columns of this type (Weber, 1972). This type of S-shaped curve may have varying degrees of steepness and position of breakpoint, the point of operation where the column is in equilibrium with the influent water and where little additional removal will occur. Factors that may affect the shape of the curve include adsorption kinetics and arsenic concentrations, pH values, and competitive anions in the influent water.

As shown in Figure 4-10, as the columns became exhausted with arsenic, arsenic concentrations measured during the subsequent sampling events were higher than those in the respective influent. This

Runs 1 and 2 Oxidizing Columns



Runs 1 & 2 Adsorptive Columns



Note: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-11. Comparison of Breakthrough Curves for Media Runs 1 and 2

phenomenon, known as the chromatographic effect, was caused by the displacement of arsenic by competing anions with higher selectivity. The chromatographic effect appeared to be present for both the oxidizing and adsorptive media, but was most apparent with the adsorptive media reaching as high as 58 µg/L of arsenic. Among the anions analyzed, silica, sulfate, alkalinity (existing primarily as HCO₃⁻ at pH values between 7.3 and 8.7), and fluoride were present in raw water at significant concentrations (Table 4-6) that could potentially compete with arsenic for adsorption sites. The effects of these competitive anions are discussed below on pages 41 to 44.

Media Run 3. After Media Run 2, three RSSCT tests (Westerhoff, 2008) were conducted onsite on several adsorptive media. Two (i.e., GFH and CFH-12) were chosen to replace the ATS A/I Complex 2000 adsorptive media in Trains A and B adsorption columns, respectively. Filox-R™ was chosen to replace the ATS A/P Complex 2002 oxidizing media. As shown in Figures 4-7 and 4-8, Filox-R™ was effective at oxidizing soluble As(III), reducing its concentrations to <1.2 µg/L during the 52-week media run. Quarterly samples collected after the run (from December 5, 2007, to December 3, 2008) continued to show effective As(III) oxidation, with its concentrations reduced to <1.1 µg/L 16 months after the end of the performance evaluation (see Appendix B).

The breakthrough curves for Media Run 3 are presented in Figure 4-12. Unlike the ATS A/P 2002 media, Filox-R™ had little to no adsorptive capacity for arsenic. Results of samples taken 10 days after media changeout showed arsenic concentrations at 32.2 and 33.3 µg/L after the Filox-R™ oxidation columns, compared to 36.9 µg/L in raw water. The breakthrough curves of A/P Complex 2002 and Filox-R™ oxidizing media are compared in Figure 4-13.

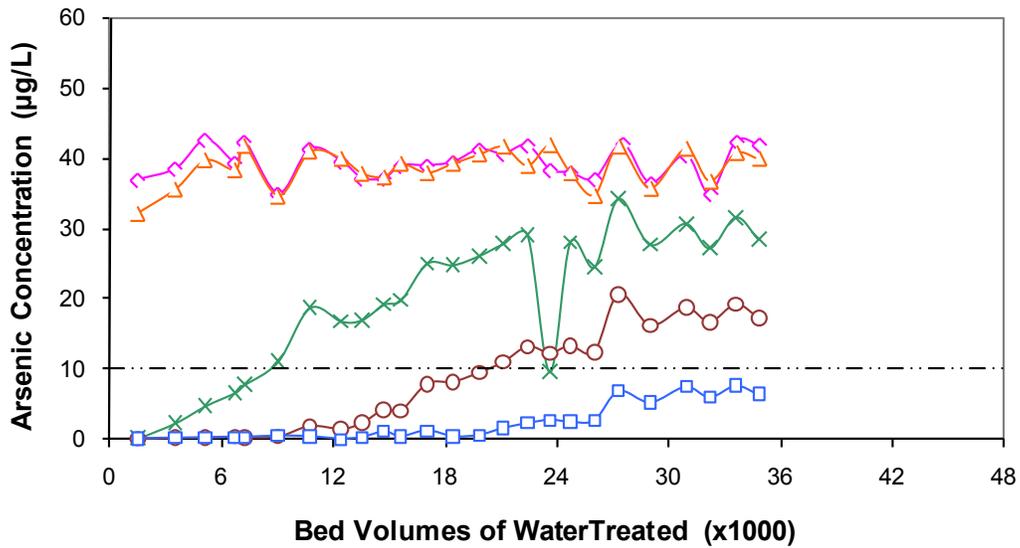
During Media Run 3, GFH media was loaded in Train A. Arsenic breakthrough at 10 µg/L occurred at approximately 8,400, 20,200, and >34,800 BV for the lead (TA), first lag (TC), and second lag (TE) columns, respectively. Similar to the calculations for Media Runs 1 and 2, bed volumes were calculated based on 1.5 ft³ or 11.2 gal of media per column. The lead adsorption columns did not reach saturation capacity for arsenic by the end of the evaluation period (Figure 4-12). During the 52-week performance evaluation, approximately 34,800 BV of water was treated and the effluent of Train A remained below 10 µg/L. When all three adsorption columns are considered as one large column, breakthrough at 10 µg/L occurred at 11,600 BV (based on 4.5 ft³ of media in three columns).

CFH-12 media was loaded in Train B during Media Run 3 and arsenic breakthrough at 10 µg/L occurred at 11,100, 22,400, and 46,000 BV for the lead (TB), first lag (TD), and second lag (TF) columns, respectively. The lead adsorption columns did not reach saturation capacity for arsenic by the end of the evaluation period (Figure 4-12). During the 52-week performance evaluation, approximately 46,000 BV of water was treated and the effluent of Train B was around 10 µg/L at this time. When all three adsorption columns are considered as one large column, breakthrough at 10 µg/L occurred at 15,300 BV (based on 4.5 ft³ of media in three columns).

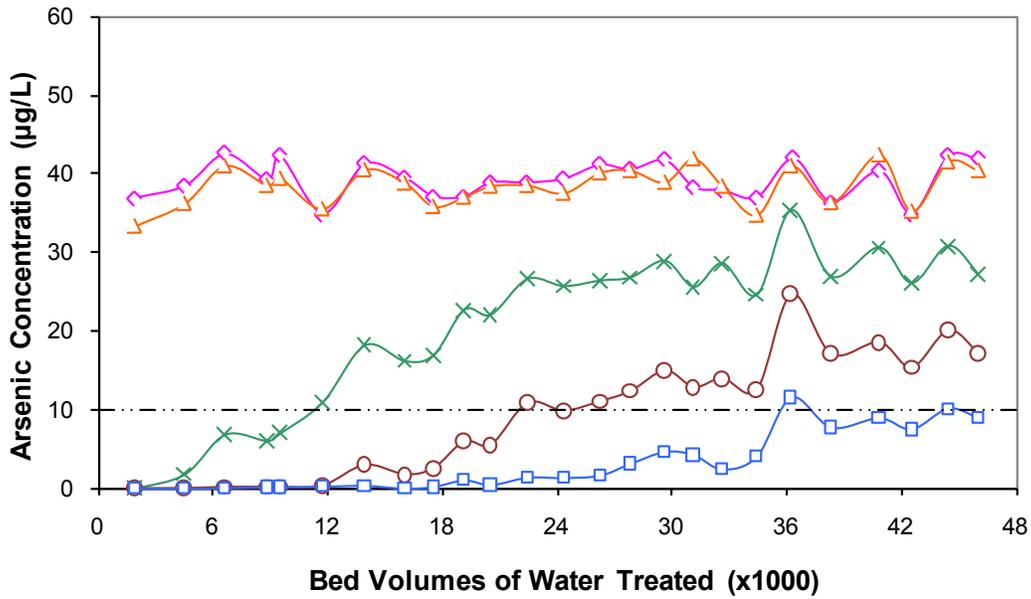
The breakthrough curves of the three adsorptive media are compared in Figure 4-14. The two media (GFH and CFH-12) selected based on the RSSCT results demonstrated significantly improved adsorptive capacities than the ATS A/I Complex 2000 media. Based on the media capacity calculations presented in Table 4-7, arsenic loadings on A/I Complex 2000, GFH, and CFH-12 were 0.23, >1.08, and >0.87 µg of As/mg of dry media, respectively. The adsorptive capacities of GFH and CFH-12 were at least five and four times, respectively, of the capacity of A/I Complex 2000.

ATS Complex 2000 Adsorptive Capacities. As reported above, ATS Complex 2000 media exhibited significantly less adsorptive capacities, averaging at 0.23 µg of As/mg of dry media. These media adsorptive capacities were compared to those at two other arsenic removal demonstration sites, i.e., Susanville, CA and Dummerston, VT, where the ATS media also was used. The system at Susanville,

Media Run 3 (09/08/06 to 08/29/07)
(Oxidizing media: Filox-R™; Adsorptive media: GFH)

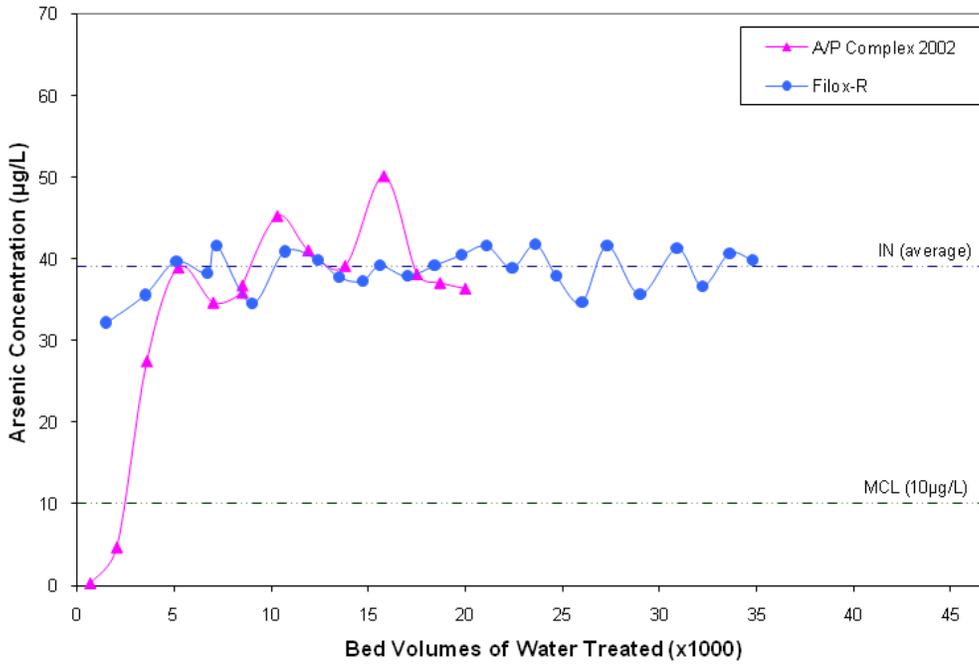


Media Run 3 (09/08/06 to 08/29/07)
(Oxidizing media: Filox-R™; Adsorptive media: CFH-12)



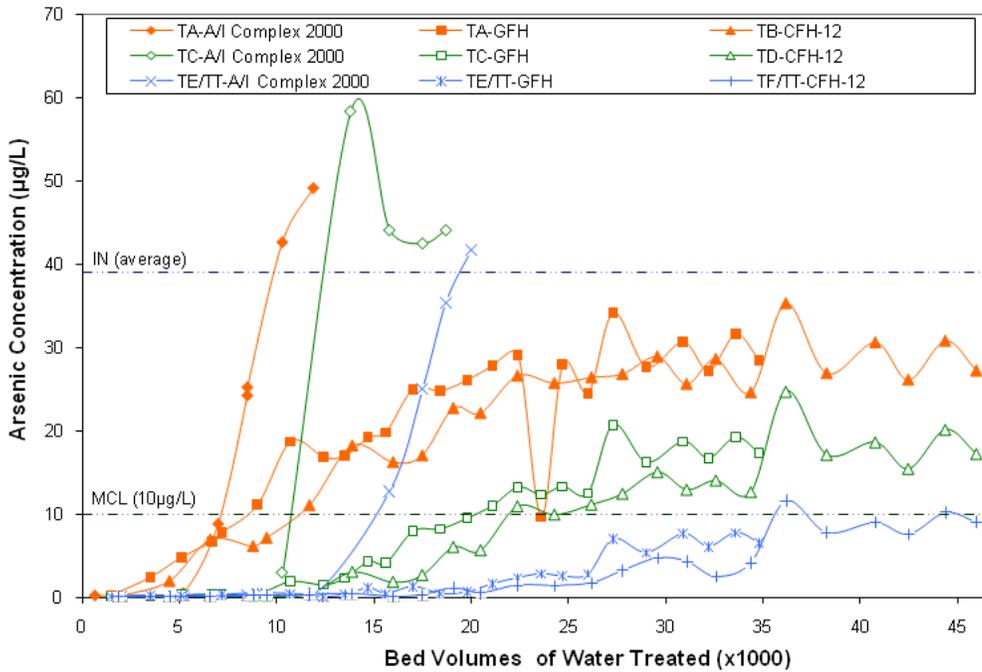
Note: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-12. Total Arsenic Breakthrough Curves during Media Run 3



Note: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-13. Breakthrough Curves for A/P Complex 2002 and Filox-R™ Oxidizing Media



Note: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-14. Breakthrough Curves for A/I Complex 2000, GFH, and CFH-12 Adsorptive Media

CA, had one treatment train consisting of two oxidation columns followed with three adsorption columns in series (Chen et al., 2009). The system at Dummerston, VT consisted of only three adsorption columns in series without oxidizing columns due to the presence of predominately soluble As(V) in that source water (Lipps et al., 2008).

As shown in Table 4-8, A/P Complex 2002 oxidizing media at Wales had an average arsenic capacity of 0.14 µg of As/mg of dry media, which was somewhat lower than that (i.e., 0.19 µg/mg) observed at Susanville, CA. The A/I Complex 2000 adsorptive media at Wales had adsorptive capacities ranging from 0.18 to 0.28 µg/mg and averaging 0.23 µg/mg, which was similar to those observed at Susanville (Table 4-8). The Wales source water had a pH value comparable to that of Susanville (i.e., 8.5 vs. 8.4), but it had higher arsenic and lower silica concentrations.

The adsorptive capacities of A/I Complex 2000 media observed at the Susanville and Wales sites were about half of those (i.e., 0.46 to 0.50 µg/mg) observed at Dummerston, VT. The higher adsorptive capacity observed was believed to have been caused by the lower pH values of the source water, which averaged 7.7 (compared to 8.4 and 8.5, respectively, at Susanville and Wales). The higher arsenic concentrations in source water at Dummerston also might have contributed to the higher adsorptive capacities observed.

Table 4-8. Comparison of Arsenic Adsorptive Capacity on ATS Media at Three Arsenic Demonstration Sites

Column	Arsenic Adsorptive Capacity on Media (µg/mg)	Average Influent Total Arsenic Concentration (µg/L)	Average Influent pH (S.U.)	Average Influent Silica Concentration (mg/L)
Susanville, CA				
OA	0.20	31.7	8.4	14.1
OB	0.18			
TA	0.23			
TB	NA ^(a)			
TC	NA ^(a)			
Dummerston, VT				
TA	0.50	42.2	7.7	12.6
TB	0.46			
TC	NA ^(a)			
TD	NA ^(a)			
TE	NA ^(a)			
TF	NA ^(a)			
Wales, ME				
OA	0.14/0.16 ^(b)	39.1	8.5	10.5
OB	0.09/0.18 ^(b)			
TA	0.23/0.19 ^(b)			
TB	0.19/0.27 ^(b)			
TC	0.18/0.26 ^(b)			
TD	0.28/0.21 ^(b)			
TE	0.26/NA ^(a,b)			
TF	0.28/NA ^(a,b)			

(a) Column not exhausted with arsenic.

(b) Run1/Run2.

Phosphorus, Silica, Alkalinity, Sulfate, and Fluoride. Among the anions analyzed, phosphorus, silica, alkalinity (existing primarily as HCO_3^- at pH values between 7.4 and 8.8), sulfate, and fluoride were present in significant concentrations in raw water (Table 4-6) that could potentially compete with arsenic for adsorptive sites.

As shown in Figures 4-15, A/P Complex 2002 (Run 2) and Filox-R (Run 3) oxidizing media possessed little adsorption capacity for phosphorus. However, phosphorus was removed by the three adsorptive media evaluated and did not reach complete breakthrough by the end of Media Runs 2 and 3. Total phosphorus (as P) was not measured during Media Run 1, therefore, Figure 4-15 only presents the data from Media Runs 2 and 3.

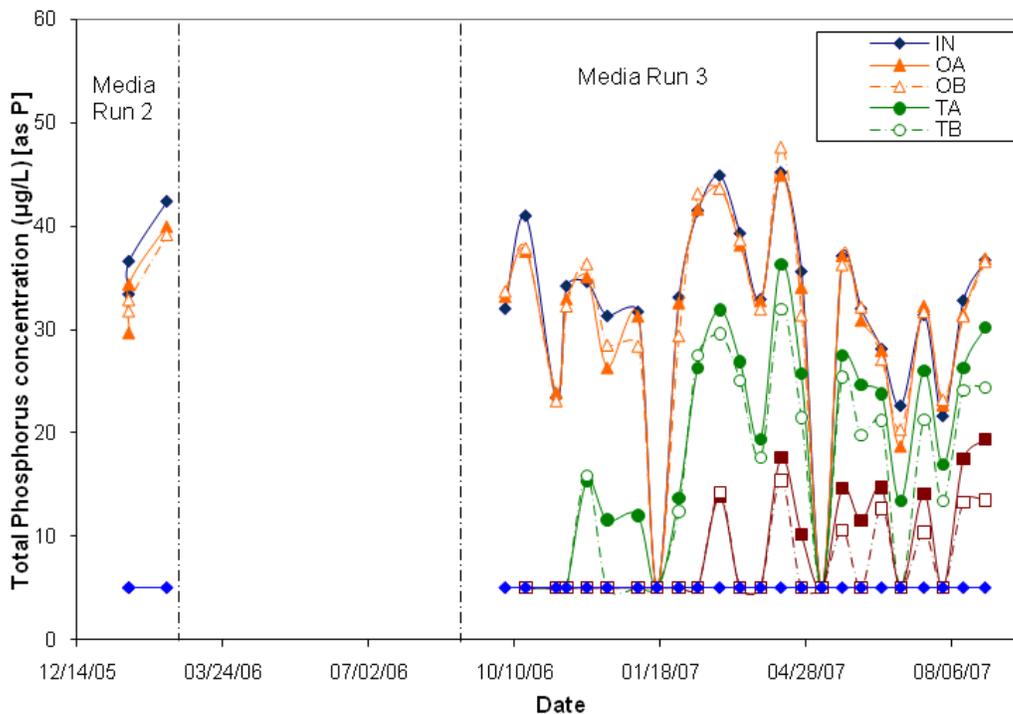
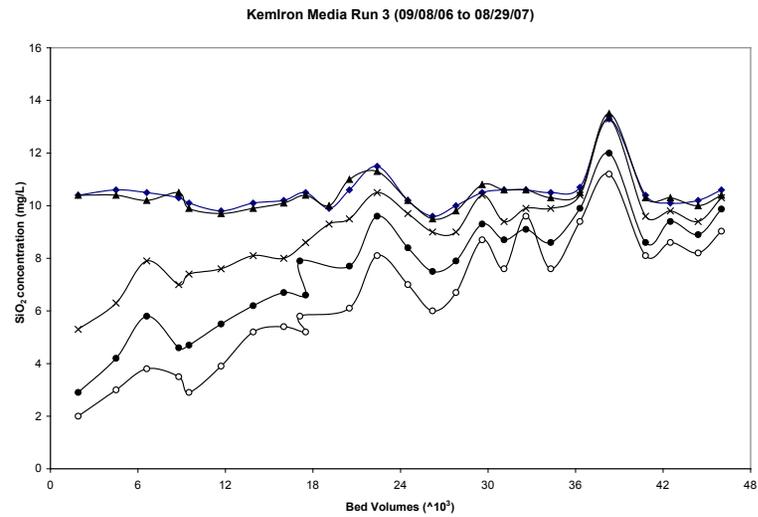
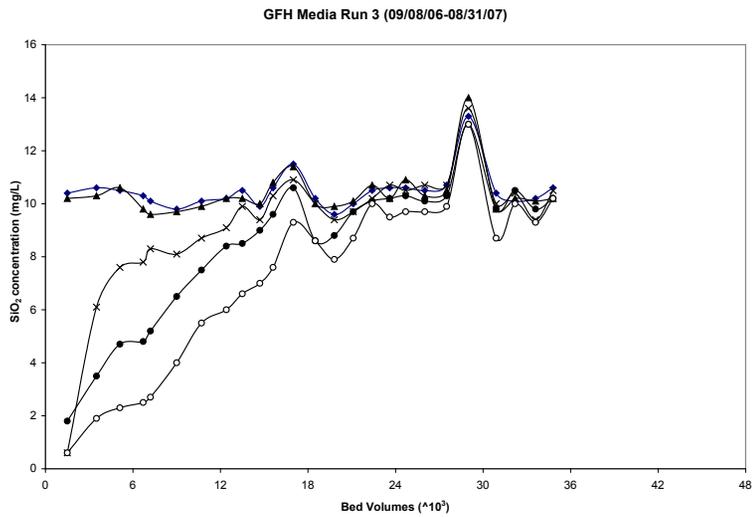
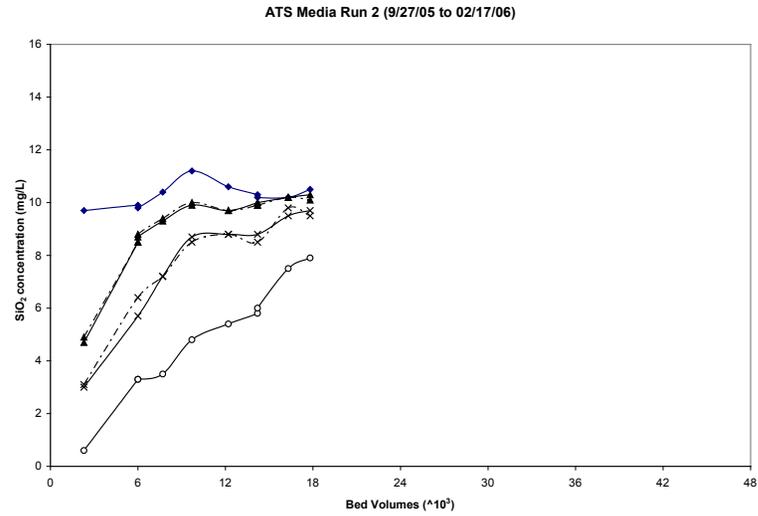
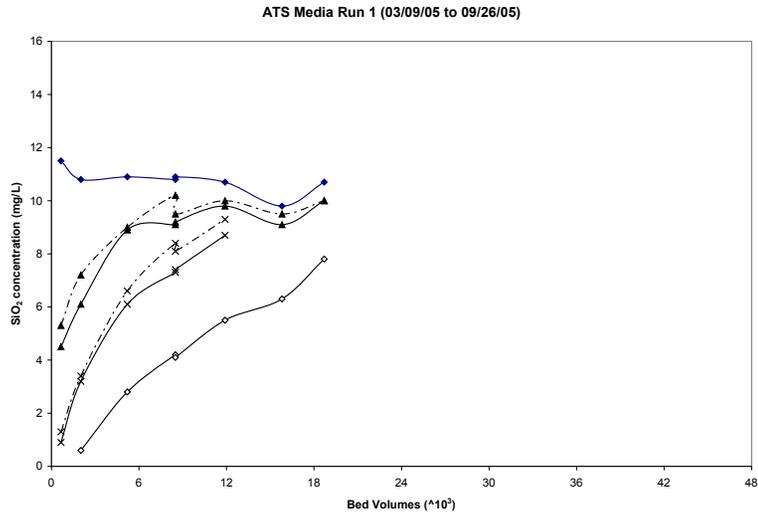


Figure 4-15. Total Phosphorus Concentrations Across Treatment Trains for Media Runs 2 and 3

As shown in Figure 4-16, silica was consistently removed by all three adsorptive media evaluated, and did not reach complete breakthrough from the A/I Complex 2000 or CFH-12 media bed by the end of respectively media runs. During Media Runs 1 and 2; at approximately 18,500 BV, well after the arsenic adsorptive capacities had been exhausted, the ATS A/P Complex 2002 oxidizing media continued to remove silica. Filox-R™, however, showed little capacity for silica.

For the other potentially competitive anions such as alkalinity and sulfate, the oxidizing and adsorptive media showed little or no removal capacity as shown in Figure 4-17. The ATS A/I Complex 2000 adsorptive media, however, did remove some fluoride initially from about 0.5 mg/L to < 0.1 mg/L. Fluoride completely broke through the lead adsorption columns at around 2,000 BV during both Media Runs 1 and 2, and exhibited similar characteristics of the chromatographic effect observed for arsenic. In Media Run 3, only one fluoride measurement was conducted at the beginning of the run. The results showed no fluoride capacity on Filox-R, nor on GFH or CFH-12.



NOTE: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure 4-16. Silica Concentrations Across Treatment Trains for Media Runs 1, 2 and 3

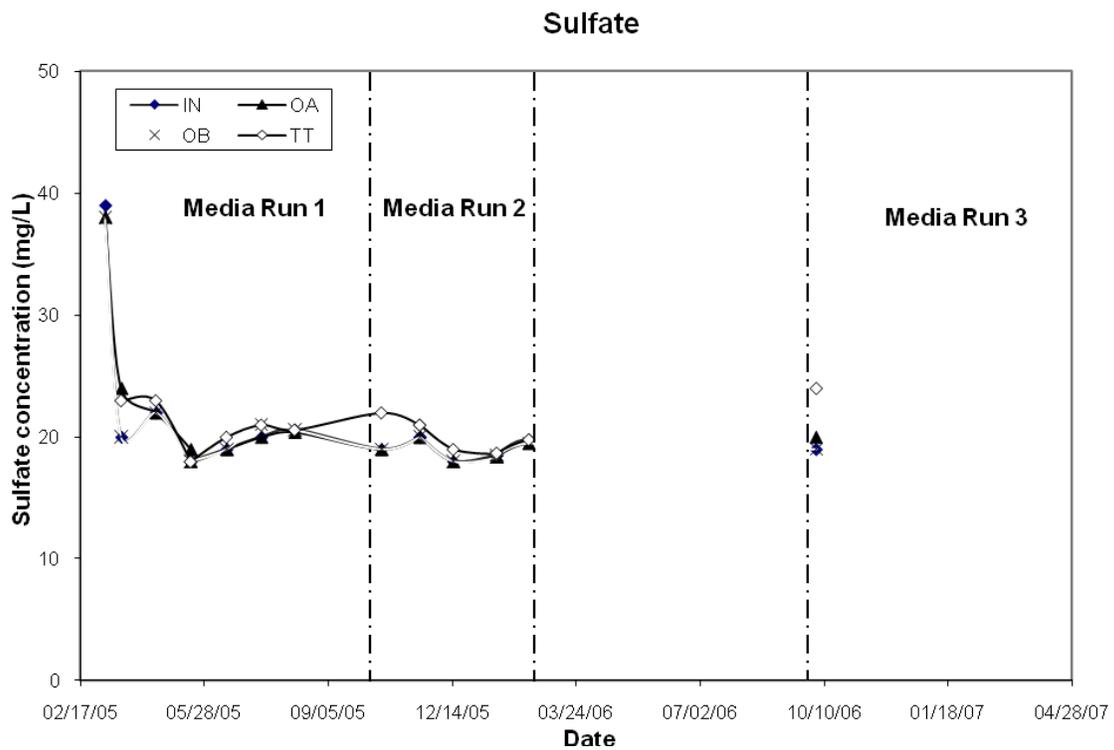
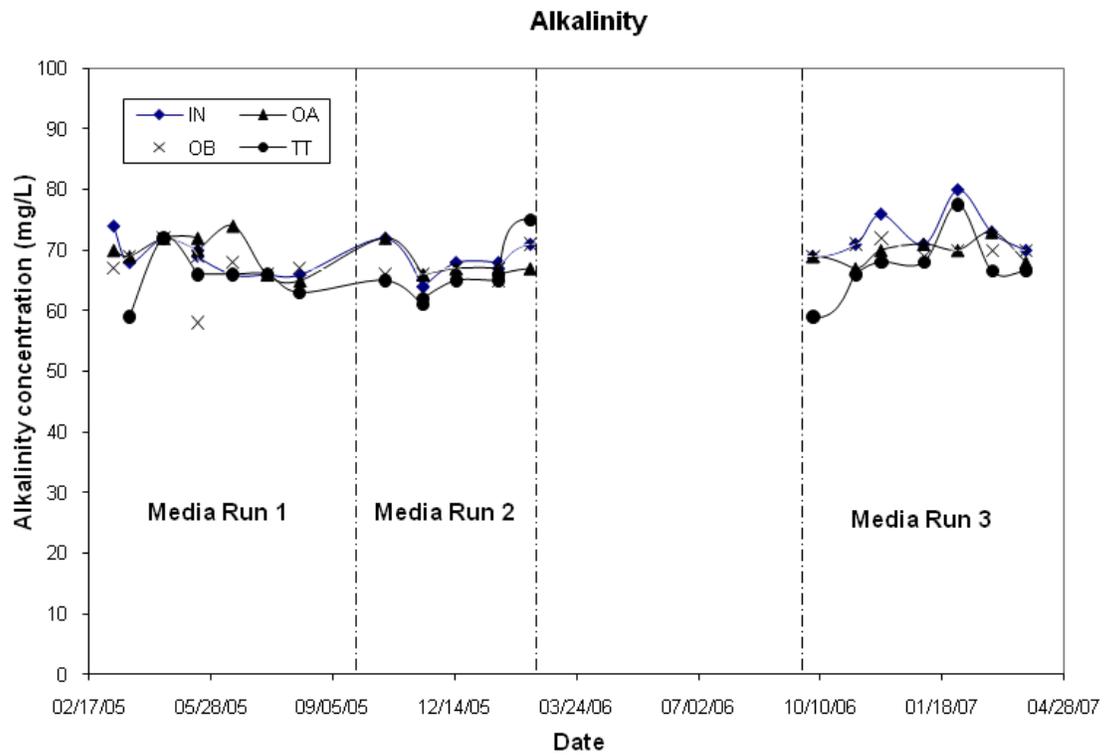


Figure 4-17. Alkalinity and Sulfate Concentrations Across Treatment Trains for Media Runs 1, 2 and 3

Aluminum. Total aluminum concentrations in source water averaged 10.2 µg/L with aluminum existing mainly in the particulate form. During Media Runs 1 and 2, aluminum, existing primarily in the soluble form, was found in the treated water following the ATS A/P Complex 2002 oxidation columns about 20 to 30 µg/L higher than those in raw water, indicating leaching of aluminum from the A/P Complex 2002 media. Initially, the aluminum concentrations following the oxidation columns were consistently higher than those following the adsorption columns (Figure 4-18), suggesting removal of some aluminum by the adsorptive media. After about 7,000 BV in Media Run 1 and 14,000 BV in Media Run 2, this trend discontinued and the aluminum concentrations were about the same. Even with the increase in aluminum concentration following the treatment trains, the concentrations were still below the secondary drinking water standard for aluminum of 50 to 200 µg/L.

Leaching of aluminum continued throughout Media Runs 1 and 2. Aluminum was analyzed for two sampling events during Media Run 3 and, as expected, no aluminum leaching was evident.

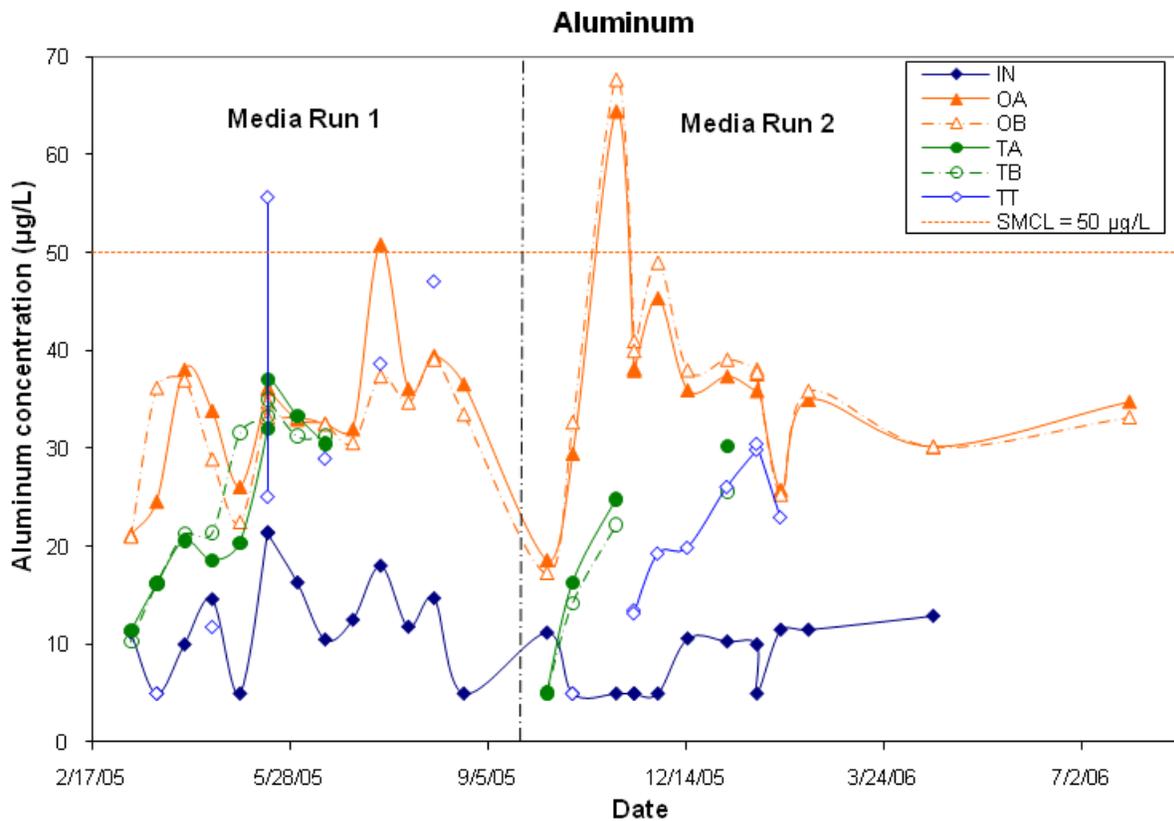


Figure 4-18. Total Aluminum Concentrations Across Entire System for Runs 1 and 2

Iron and Manganese. Iron concentrations, both total and dissolved, were consistently less than the method detection limit of 25 µg/L in source water and across the treatment trains (Table 4-5). Manganese concentrations in source water also were low, ranging from 6.4 to 21.9 µg/L and averaging 9.5 µg/L. Manganese concentrations in the treated water following the adsorption columns typically were below the detection limit (<0.1 µg/L) with an average of 0.3 µg/L (Table 4-5), indicating complete removal of manganese by the oxidizing and adsorptive media.

Other Water Quality Parameters. The results for DO and ORP remained rather consistent throughout the treatment trains, appearing unaffected by the three adsorptive media evaluated. Total hardness ranged from 35.1 to 87.0 mg/L (as CaCO₃), and remained constant across the treatment train. Nitrate concentration also remained relatively constant throughout the treatment train.

4.5.2 Spent Media Sampling. After the second media changeout on September 8, 2006, spent ATS media samples were collected from each oxidation and adsorption column for metals and TCLP analysis (Section 3.3.3).

TCLP. The TCLP results are presented in Table 4-9. The results indicated that the spent ATS media were non-hazardous and could be disposed of in a sanitary landfill. Barium was the only metal detected by the TCLP test at a maximum concentration of 0.64 mg/L, which is well below the limit of 100 mg/L of Ba. All other Resources Conservation and Recovery Act (RCRA) metals were at concentrations less than the respective method detection limits.

Table 4-9. TCLP Results of a Composite Spent Media Sample

Analyte	Media Run	Concentration (mg/L)							
		OA	OB	TA	TB	TC	TD	TE	TF
As	Run 2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ba	Run 2	0.64	0.55	0.30	0.33	0.32	0.32	0.31	0.31
Cd	Run 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cr	Run 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pb	Run 2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	Run 2	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Se	Run 2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Ag	Run 2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Metals. The ICP-MS results of the spent ATS media are presented in Table 4-10. As expected, the spent ATS media contained mostly aluminum. The average aluminum composition in the spent A/P Complex 2002 oxidizing media was 44.4%, equivalent to 83.9% Al₂O₃. The Al₂O₃ content is lower than the 96.6% specified by ATS (Table 4-2a). Although leaching of aluminum was observed from the oxidizing media, leaching itself would not have accounted for the difference between the analytical and vendor-specified values. The average aluminum composition in the spent A/I Complex 2000 adsorptive media was 44.9%, equivalent to 84.9% Al₂O₃, which, again, is lower than the 91% specified by ATS (Table 4-2b). The average iron composition in the spent A/I Complex 2000 media was 0.64%, equivalent to 4.5% of Fe(NH₄)₂(SO₄)₂·6H₂O, which is close to the specified value of 5.9%. Average calcium composition was 0.9%.

The average arsenic loadings on the spent A/P Complex 2002 and A/I Complex 2000 media were both 0.16 µg of As/mg of dry media (Table 4-10).

The first set of spent media samples were collected on September 8, 2006, approximately seven months after the end of Media Run 2. Since the oxidation and adsorption columns had reached or were close to exhaustion by the end of Media Run 2, it is safe to assume that the additional seven months of system operation would not load additional arsenic on the media. The arsenic loadings measured on the spent media, therefore, should be comparable to those calculated based on the breakthrough curves of Media Run 2.

Table 4-10. Spent Media Total Metal Results for ATS Media in Run 2

Sampling Location	Concentration (µg/g)							
	OA	OB	TA	TB	TC	TD	TE	TF
Al	442,186	445,724	445,193	492,665	454,016	449,204	429,402	426,037
As	165	160	162	189	171	156	157	154
Ca	10,753	10,269	8,551	9,269	7,801	9,353	7,559	7,109
Cd	<0.5	<0.5	<0.5	<0.5	<0.4	<0.5	<0.4	<0.5
Cu	329	106	3.7	2.7	4.0	2.7	6.3	1.5
Fe	718	383	6,040	8,285	7,224	6,508	4,992	5,069
Pb	0.4	<0.5	0.4	<0.5	<0.4	<0.5	3.3	<0.5
Mg	1,686	1,612	1,298	1,379	1,203	1,176	1,121	1,112
Mn	1,001	503	39.8	49.6	56.5	53.3	43.9	37.5
Ni	3.3	1.3	1.5	1.3	1.2	1.4	1.2	1.0
P	552	516	531	626	553	521	466	488
Si	1,202	442	453	1,509	777	1,145	1,047	1,608
Zn	<76.9	<49.3	<46.1	<48.4	<43.9	<50.9	<41.8	<52.6

The arsenic loadings measured by ICP-MS are compared to those calculated based on the breakthrough curves in Table 4-11. For the A/P Complex 2002 oxidizing media, the measured and calculated values were comparable, both averaging at 0.17 µg of As/mg of dry media. For the A/I Complex 2000 adsorptive media, the measured values averaged at 0.17 µg of As/mg of dry media, compared to 0.23 µg of As/mg of dry media based on the breakthrough curves. The calculated values are thought to be more reliable, due to the nature of sampling and analysis of the spent media and associated experimental errors.

Table 4-11. Comparison of Calculated and Measured Arsenic Loadings on Spent ATS Media

Column	Media Run 2		
	Breakthrough Curve (Table 4-7 ^(a))	Spent Media (Table 4-10 ^(b))	Recovery
	µg As/mg of dry media		(%)
OA	0.16	0.17	106
OB	0.18	0.16	89
TA	0.19	0.16	84
TB	0.27	0.19	70
TC	0.26	0.17	65
TD	0.21	0.16	76
TE	0.22	0.16	73
TF	0.22	0.15	68

NA = not analyzed.

- (a) Calculations account for 5% moisture content of A/P Complex 2002 and A/I Complex 2000, 50% moisture content of GFH, and 16% moisture content of CFH-12. Moisture content of Filox was unavailable and assumed to be 0%.
- (b) Averages of duplicate analyses.
- (c) Average based on two samples (duplicate analysis) of spent media from TC-TD combined.

4.5.3 Distribution System Water Sampling. Distribution system water samples were collected to determine if water treated by the arsenic removal system would impact the lead, copper, and arsenic levels and some other water quality parameters in the distribution system. Prior to the installation/operation of the treatment system, baseline distribution system water samples were collected from two LCR and one non-LCR residences on December 15, 2004; January 10, 2005; February 2, 2005; and February 23, 2005. Following the treatment startup, distribution water sampling continued on a monthly basis at the same three locations for 11 months from April 4, 2005, to February 14, 2006. The results of the distribution system sampling are summarized in Table 4-12.

As expected, prior to the installation of the treatment system, arsenic concentrations in the distribution system were similar to those measured in raw water, ranging from 29.9 to 40.0 µg/L and averaging 35.8 µg/L. After system startup, arsenic concentrations in the distribution system were reduced significantly to less than 2.4 µg/L (or 1.1 µg/L on average) during the first three months of system operation. Afterwards, arsenic concentrations increased to above the MCL and then to the influent levels following arsenic breakthrough. Figure 4-19 compares arsenic concentrations measured in the distribution system water and in the system effluent. In general, arsenic concentrations in the distribution system water mirrored those in the system effluent.

As shown in Figure 4-19, during the initial period of system operation after virgin media were freshly installed, arsenic concentrations in the distribution system water were somewhat higher than those measured in treatment system effluent. Therefore, some dissolution and/or resuspension of arsenic might have occurred in the distribution system initially.

Similar to those in raw water, iron concentrations were low in the distribution system water, with all, but two measurements (on January 4, 2006), lower than the detection limit of 25 µg/L. Manganese concentrations also were low, with all, but one measurement (on October 5, 2005), lower than 8.4 µg/L. Before system startup, manganese concentrations averaged 2.8 µg/L. After system startup, manganese concentrations averaged 1.9 µg/L (calculation not including the outlier on October 5, 2005). Manganese levels appeared to decrease slightly after the system startup.

With the exception of samples collected on October 5, 2005, pH values also remained relatively constant throughout the distribution system. Changeout of the ATS media occurred on September 27, 2005. The virgin media were somewhat acidic, causing lower pH values in the system effluent and the distribution system water for a short period of time. The pH values of the October 5, 2005, samples ranged between 6.4 and 6.5. The samples collected on November 2, 2005, had pH values ranging between 7.5 and 7.6, which were closer to the average pH value of 7.8 in the distribution system water.

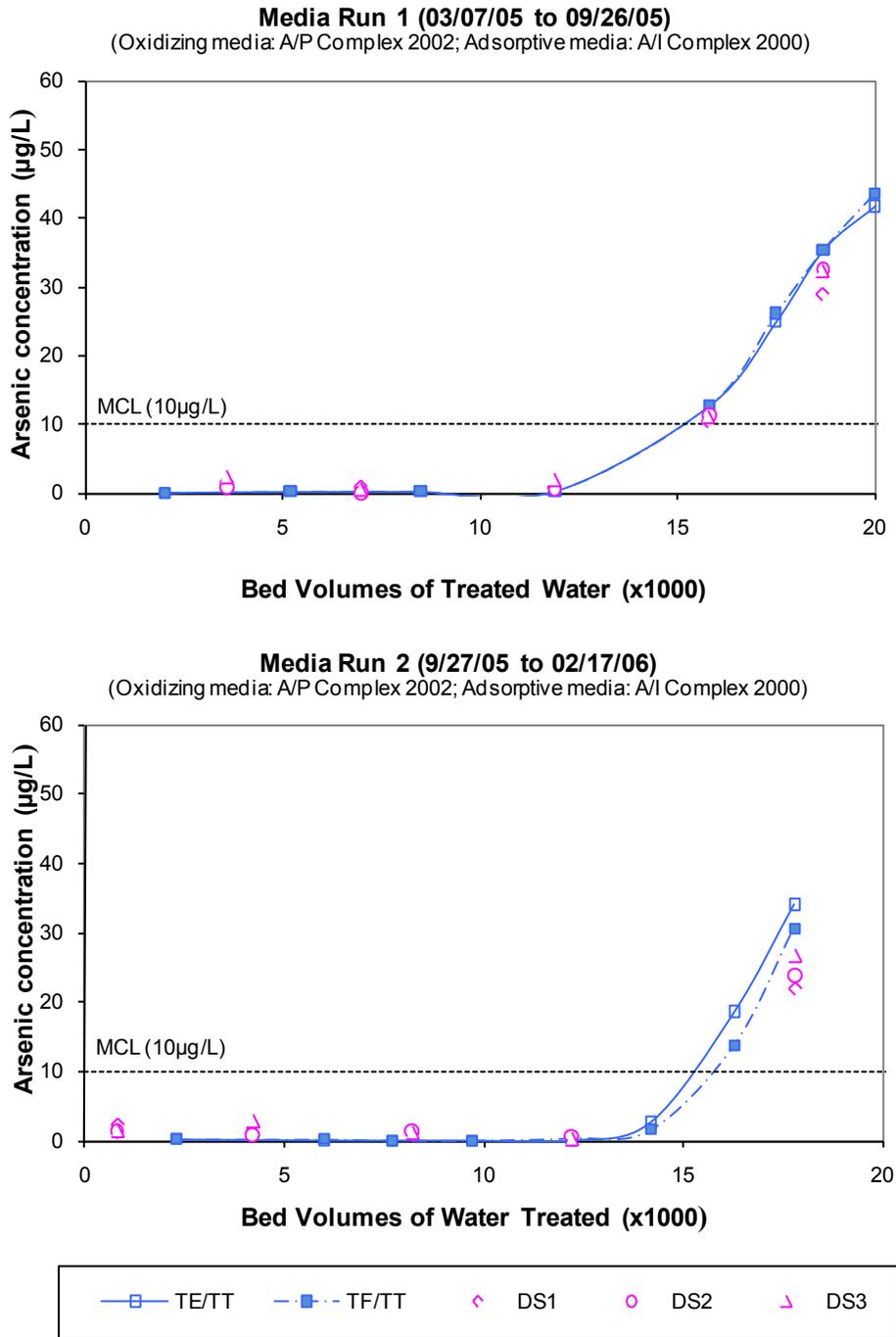
Lead levels ranged from <0.1 to 1.0 µg/L and averaged 0.4 µg/L in the baseline samples and ranged from <0.1 to 1.5 µg/L and averaged 0.6 µg/L in the samples collected after system startup (excluding the October 5, 2005, sample when the lead level spiked to 4.9 µg/L at the DS 2 sampling location). All lead measurements were below the lead action level of 15 µg/L. Copper concentrations ranged from 6.7 to 55.1 µg/L and averaged 22.8 µg/L in the baseline samples and ranged from 0.9 to 208 µg/L and averaged 37.8 µg/L in the samples taken after system startup (excluding the October 5, 2005, sample with 519 µg/L of copper at the DS1 sampling location). All copper concentrations measured were below the copper action level of 1,300 µg/L. Lead and copper concentrations in the distribution system water were sensitive to pH and generally higher than those before system startup. The alkalinity values remained fairly constant throughout the distribution system.

Table 4-12. Distribution System Sampling Results

No. of Sampling Events	DS1										DS2							DS3										
	Address										339 Leeds Junction Rd. Lot #5							339 Leeds Junction Rd. Lot #11										
	Sample Type										LCR							LCR										
	Flushed / 1st Draw										1st Draw							1st Draw										
	Sampling Date	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Al	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Al	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Al	Pb	Cu
Unit	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hrs	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	
BL1	12/15/2004	7.8	7.4	57	36.1	44.5	3.1	<10	1.0	55.1	9.0	7.5	57	38.0	<25	3.5	<10	0.9	11.9	7.6	7.9	57	35.9	<25	2.6	<10	0.5	33.5
BL2	1/10/2005	7.2	8.1	65	30.6	<25	2.1	<10	<0.1	13.8	10.0	8.1	64	29.9	<25	2.1	<10	0.2	6.7	7.8	8.2	66	31.3	<25	1.8	<10	0.3	30.1
BL3	2/2/2005	7.0	7.9	71	39.6	<25	2.8	<10	0.4	26.5	8.0	8.2	69	40.0	<25	3.8	<10	0.2	8.1	8.5	8.2	70	39.5	<25	3.4	<10	0.1	17.9
BL4	2/23/2005	7.3	7.6	73	35.4	<25	2.4	<10	0.4	26.2	9.0	7.7	70	37.1	<25	3.1	<10	0.9	15.8	8.3	8.2	71	36.6	<25	2.2	<10	0.2	27.6
1	4/5/2005	7.0	8.0	63	1.5	<25	0.5	12.2	0.8	114	9.0	7.9	66	0.8	<25	0.6	14.8	0.7	15.1	9.0	7.8	66	2.4	<25	1.6	13.3	1.4	78.2
2	5/4/2005	8.4	7.8	68	0.8	<25	0.6	<10	1.2	65.6	8.3	7.9	72	<0.1	<25	0.2	<10	1.1	4.3	8.3	7.8	70	0.6	<25	0.8	<10	0.3	25.1
3	6/15/2005	7.7	7.7	66	0.7	<25	1.1	24.5	0.6	18.2	10.5	7.8	66	0.5	<25	5.2	21.1	1.1	5.8	9.0	7.8	66	2.0	<25	1.5	29.6	0.7	26.6
4	7/13/2005	7.3	7.5	66	10.4	<25	0.5	<10	0.2	55.2	8.0	8.0	66	11.4	<25	0.5	36.6	0.5	3.5	9.2	8.0	66	11.1	<25	0.7	28.9	0.4	15.3
5	8/9/2005	7.4	8.0	67	29.0	<25	0.5	17.0	0.5	57.4	13.8	8.0	71 ^(b)	32.5	<25	2.5	39.7	0.7	2.0	8.3	8.0	75 ^(b)	32.2	<25	0.7	37.1	0.3	11.0
6	9/7/2005	6.7	8.2	64	50.2	<25	0.1	24.9	0.1	4.1	9.0	8.3	63	49.0	<25	5.4	18.8	0.5	0.9	9.5	8.2	64	50.4	<25	0.3	26.6	<0.1	1.9
7	10/5/2005	7.1	6.4	50	2.3	<25	3.9	<10	0.5	519	10.0	6.5	50	1.4	<25	167	<10	4.9	41.9	6.6	6.4	50	1.5	<25	8.3	<10	0.7	96.3
8	11/2/2005	6.3	7.6	58	1.8	<25	0.3	<10	0.3	125	12.0	7.5	61	0.8	<25	8.4	11.3	1.5	5.6	7.5	7.6	58	2.9	<25	2.0	13.7	1.1	32.5
9	12/7/2005	7.5	7.8	61	0.9	<25	0.2	<10	0.1	144	10.0	7.8	59	1.4	<25	4.2	<10	0.7	22.3	8.8	7.8	59	1.2	<25	0.5	11.6	0.3	6.7
10	1/4/2006	10.0	8.0	62	0.5	<25	0.1	15.3	1.4	25.2	6.8	8.0	62	0.7	93.4	<0.1	14.8	0.8	208	8.8	8.1	65	0.3	34.5	<0.1	32.6	0.5	17.3
11	2/14/2006	7.0	8.4	64	22.0	<25	<0.1	<10	<0.1	38.4	9.5	8.3	64	23.9	<25	0.3	<10	<0.1	2.6	7.5	8.3	63	26.6	<25	<0.1	11.4	<0.1	3.2

BL = Baseline Sampling

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



Note: Bed volumes based upon BV of 1.5 ft³ for each column

Figure 4-19. Comparison of Total Arsenic Concentrations in Distribution System Water and Treatment System Effluent

Aluminum concentrations in all baseline samples were below the detection limit of 10 µg/L. After system startup, aluminum concentrations were as high as 39.7 µg/L, similar to those observed in the treatment system effluent. As mentioned previously, because both A/P Complex 2002 oxidizing media and A/I Complex 2000 adsorptive media are alumina-based, some aluminum leached into the system effluent and the distribution system water.

4.6 System Cost

The cost of the treatment 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 capital cost for the equipment, site engineering, and installation and the O&M cost for media replacement and disposal, replacement parts, chemical supply, electricity consumption, and labor. The cost associated with improvements to the building and any other infrastructure was not included in the capital cost. These activities were funded separately by the facility.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation was \$16,475 (see Table 4-13). The equipment cost was \$10,790 (or 65% of the total capital investment), which included \$4,000 for the treatment system mechanical hardware, \$960 for 3 ft³ of the A/P Complex 2002 oxidizing media (i.e., \$320/ft³ or \$6.27/lb), \$2,880 for 9 ft³ of the A/I Complex 2000 adsorptive media (i.e., \$320/ft³ or \$6.27/lb), \$900 for the pressure tank and booster pump, and \$2,050 for the vendor's labor and shipping cost.

Table 4-13. Summary of Capital Investment Cost

Description	Quantity	Cost	% of Capital Investment Cost
<i>Equipment Cost</i>			
Oxidation/Adsorption Columns	8	\$960	–
A/P Complex 2002 Oxidizing Media (ft ³)	3	\$960	–
A/I Complex 2000 Adsorptive Media (ft ³)	9	\$2,880	–
25-µm Sediment Filters	2	\$750	–
Pressure Tank and Booster Pump	1	\$900	–
Piping and Valves	1	\$1,110	–
Flow Totalizers/Meters	2	\$1,120	–
Hour Meters	1	\$60	–
Procurement, Assembly, Labor	1	\$1,600	–
Freight	1	\$450	–
Equipment Total	–	\$10,790	65%
<i>Engineering Cost</i>			
Design/Scope of System (hr)	10	\$1,500	–
Travel and Miscellaneous Expenses	1	\$300	–
Engineering Total	–	\$1,800	11%
<i>Installation Cost</i>			
Plumbing/Electrical Supplies/Parts	1	\$700	–
Vendor Installation Labor (hr)	10	\$1,300	–
Mechanical Subcontractor Labor (hr)	10	\$850	–
Electrical Subcontractor Labor (hr)	3	\$225	–
Vendor Travel (day)	2	\$710	–
Subcontractor Travel	–	\$100	–
Installation Total	–	\$3,885	24%
Total Capital Investment	–	\$16,475	100%

The engineering cost included the cost for the preparation of the system layout and footprint, design of the piping connections to the entry and distribution tie-in points, design of the additional pressure tank and booster pump, and assembling and submission of the engineering plans for the permit application (Section 4.3). The engineering cost was \$1,800, or 11% of the total capital investment.

The installation cost included the cost of labor and materials to unload and install the treatment system, pressure tank, and booster pump, complete the piping installation and tie-ins, and perform the system start-up and shakedown (Section 4.3). The installation was performed by ATS. The installation cost was \$3,885, or 24% of the total capital investment.

The total capital cost of \$16,475 was normalized to \$1,177/gpm (\$0.82/gpd) of design capacity using the system's rated capacity of 14 gpm (or 20,160 gpd). The capital cost also was converted to an annualized cost of \$1,555/yr using a capital recovery factor of 0.09439 based on a 7% interest rate and a 20-year return period. Assuming that the system operated 24 hr/day, 7 day/week at the design flowrate of 14 gpm to produce 7,400,000 gal of water per year, the unit capital cost would be \$0.21/1,000 gal. However, the system operated only an average of 3.7 hr/day with daily throughput of 2,618 gpd (Table 4-4) and annual throughput of 955,450. At this reduced rate of operation, the unit capital cost increased to \$1.63/1,000 gal of water treated.

4.6.2 Operation and Maintenance Cost. The O&M cost for the As/1400CS treatment system included only incremental cost associated with the treatment system, such as media replacement and disposal, chemical supply, electricity consumption, and labor, as presented in Table 4-14.

In general, for a three-column system operating in series, the media in the lead column is ideally replaced when the effluent arsenic concentration following the lead column equals the raw water concentration, but before the arsenic concentration following the final lag column reaches the 10- $\mu\text{g/L}$ MCL. Once the lead column is exhausted, the first and second lag columns are moved up to the lead and first lag positions, respectively, and a column containing new media is placed in the final lag position. This method allows the media's capacity for arsenic to be fully utilized before its replacement. If the media exhibits a sharp adsorption front (with a typical S-shaped breakthrough curve) and if the anticipated run length is relatively short, it is more cost-effective to wait until the first two, or all three columns, in the treatment train need to be replaced.

Two media replacements were conducted during the performance evaluation study: one on September 27, 2005, after Media Run 1 and the other on September 8, 2006, after Media Run 2. The cost to change out two ATS oxidation columns and six ATS adsorption columns was \$7,569 (including \$1,365 for labor, travel, and delivery) for the first changeout and \$6,148 (including \$3,693 for GFH and \$2,455 for CFH-12) for the second changeout (see cost breakdowns in Table 4-14). The changeout cost of the ATS media reflected the cost savings resulting from recycling of the exhausted media (rather than disposing of it at a landfill that would have a disposal cost).

By averaging the media replacement cost (i.e., \$7,565, \$3,693, and \$2,455) over the life of the media (i.e., when the treatment system/treatment train effluent reached 10 $\mu\text{g/L}$), the media replacement cost per 1,000 gal of water treated was \$22.05, \$9.44 and \$4.76/1,000 gal of water treated.

Additional electricity use associated with the hour meters on the booster pump and well pump and a new booster pump following the treatment system was minimal. The routine, non-demonstration-related labor activities consumed about 45 min/week as noted in Section 4.4.4. Depending on how the system performs and if any additional troubleshooting is required, the labor incurred will vary. The estimated labor cost for operating and maintaining a ATS, GFH, and CFH-12 system was \$0.83, \$1.00, and \$0.76/1,000 gal of water treated.

Table 4-14. Summary of O&M Cost

Cost Category	Runs 1 and 2^(a)	Run 3	Remarks
Volume Processed (gal)	ATS Trains: 343,300 (350,000)	GFH Train: 391,000 CFH-12 Train: 516,100	To 10-µg/L As breakthrough from third adsorption column
Media Replacement and Disposal			
Media (\$/ft ³)	A/P Complex 2002: \$517 A/I Complex 2000: \$517	Filox-R™: \$210 GFH: \$595 CFH-12: \$320	For replacement media
Media Volume (ft ³)	A/P Complex 2002: 3.0 A/I Complex 2000: 9.0	Filox-R™: 3.0 GFH: 4.5 CFH-12: 4.5	Amounts of media in two oxidation and six adsorption columns
Total Media Replacement (\$)	A/P Complex 2002: \$1,551 A/I Complex 2000: \$4,653 Total: \$6,204	Filox-R™: \$630 GFH: \$2,678 CFH-12: \$1,440 Total: \$4,748	Per vendor invoices
Labor (\$)	\$520	\$1,000	Per vendor invoices
Travel and Delivery (\$)	\$845	\$400	Per vendor invoices
Subtotal (\$)	\$7,569	GFH Train: \$3,693 CFH-12 Train: \$2,455	Per vendor invoices
Media Replacement and Disposal (\$/1,000 gal)	\$22.05 (\$21.63)	GFH Train: \$9.44 CFH-12 Train: \$4.76	Based upon media run length at 10-µg/L arsenic breakthrough from third adsorption column
Chemical Usage			
Chemical (\$)	0.0		No additional chemical required
Electricity			
Electricity (\$/1,000 gal)	0.001		Electrical cost assumed negligible
Labor			
Average Weekly Labor (hr)	0.75	0.75	15 min/day, 3 day/week
Labor Cost (\$)	\$286 ^(b)	GFH Train: \$390 ^(c) CFH-12 Train: 390 ^(c)	\$20/hr
Labor Cost (\$/1,000 gal)	\$0.83 (\$0.82)	GFH Train: \$1.00 CFH-12 Train: \$0.76	
Total O&M cost (\$/1,000 gal)	\$22.88 (\$22.45)	GFH Train: \$10.44 CFH-12 Train: \$5.52	To 10-µg/L As breakthrough from third adsorption column

(a) Values for Run 2 (that differ from Run 1) are in parentheses.

(b) 19 weeks to reach 10 µg/L at system effluent.

(c) 52 weeks to reach just <10 µg/L at system effluent.

As shown in Table 4-14, the unit O&M cost is driven by the cost to replace the spent media as a function of the media run length. Therefore, supplying water to SBMHP for one year would require \$45,382, \$4,082, and \$2,849 O&M cost when using ATS A/P Complex 2002/A/I Complex 2000, Filox-R™/GFH, and Filox-R™/CFH-12 media, respectively. The study results indicate that using either Filox-R™/GFH or Filox-R™/CFH-12 media can result in significant cost savings.

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APPENDIX A
OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data

Week No.	Date	Booster Pump Hour Meter		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a) Treated	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a) Treated	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a) Treated	Avg Flowrate
		hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
1	03/07/05	4.3 ^(b)	-	20.22	4,438	396	20.17	4,464	398	8,902	367	-
	03/08/05	4.8	0.5	2.12	5,963	531	2.20	5,981	533	11,944	532	-
	03/09/05	5.3	0.5	0.57	7,250	646	0.54	7,266	648	14,516	647	-
	03/10/05	5.8	0.5	0.91	8,571	764	1.01	8,590	766	17,161	765	-
	03/11/05	6.3	0.5	1.41	10,061	897	1.70	10,082	899	20,143	898	-
	03/12/05	6.9	0.6	0.63	11,250	1,003	0.60	11,301	1,007	22,551	1,005	-
	03/13/05	7.8	0.9	6.21	13,150	1,172	6.35	13,190	1,176	26,340	1,174	-
2	03/14/05	8.3	0.5	0.00	13,659	1,217	0.00	13,696	1,221	27,355	1,219	-
	03/15/05	8.5	0.2	0.35	14,866	1,325	0.30	14,910	1,329	29,766	1,327	-
	03/16/05	8.6	0.1	0.00	16,057	1,431	0.00	16,109	1,436	32,166	1,433	-
	03/17/05	8.7	0.1	0.44	16,867	1,503	0.43	16,922	1,508	33,789	1,506	-
	03/18/05	8.8	0.1	0.00	17,871	1,593	0.00	17,936	1,599	35,807	1,596	-
	03/19/05	8.9	0.1	1.33	18,964	1,690	1.32	19,040	1,697	38,004	1,694	-
	03/20/05	9.8	0.9	1.64	20,228	1,803	1.82	20,312	1,810	40,540	1,807	-
3	03/21/05	10.5	0.7	5.29	21,610	1,926	5.42	21,723	1,936	43,333	1,931	-
	03/22/05	10.6	0.1	3.04	22,557	2,010	3.47	22,694	2,023	45,251	2,017	-
	03/23/05	11.8	1.2	2.48	24,239	2,160	2.80	24,415	2,176	48,654	2,168	-
	03/24/05	11.9	0.1	3.31	25,158	2,242	3.42	25,351	2,259	50,509	2,251	-
	03/25/05	12.5	0.6	2.38	26,483	2,360	2.40	26,705	2,380	53,188	2,370	-
	03/26/05	15.1	2.6	4.06	28,197	2,513	4.13	28,450	2,536	56,647	2,524	-
	03/27/05	16.5	1.4	2.69	29,395	2,620	2.81	29,689	2,646	59,084	2,633	-
4	03/28/05	17.1	0.6	2.58	30,453	2,714	2.72	30,129	2,685	60,582	2,700	-
	03/29/05	18.2	1.1	3.46	31,584	2,815	3.65	31,950	2,848	63,534	2,831	-
	03/30/05	19.5	1.3	3.93	32,801	2,923	4.07	33,208	2,960	66,009	2,942	-
	04/01/05	22.1	2.6	5.20	35,536	3,167	5.33	35,060	3,125	70,596	3,146	-
	04/02/05	22.5	0.4	5.16	36,048	3,213	5.72	36,557	3,258	72,605	3,236	-
	04/03/05	24.7	2.2	4.71	38,038	3,390	4.96	38,610	3,441	76,648	3,416	-
5	04/04/05	25.2	0.5	5.12	39,017	3,477	5.24	39,621	3,531	78,638	3,504	-
	04/05/05	25.5	0.3	4.90	39,950	3,561	4.98	40,175	3,581	80,125	3,571	-
	04/06/05	27.3	1.8	5.21	41,049	3,659	5.48	41,734	3,720	82,783	3,689	-
	04/07/05	31.2	3.9	5.01	42,371	3,776	5.19	43,086	3,840	85,457	3,808	11.4
	04/08/05	34.0	2.8	5.35	43,319	3,861	5.46	44,053	3,926	87,372	3,894	11.4
	04/10/05	43.1	9.1	5.38	46,305	4,127	5.48	47,089	4,197	93,394	4,162	11.0

(a) Bed Volume = 1.5 ft³ = 11.22 gal, (b) From 03/07/05 to 04/05/05, the booster pump was not setup properly; the recorded operational hours were not accurate.

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a)	Avg Flowrate
		hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
6	04/11/05	46.4	3.3	5.35	47,400	4,225	5.44	48,203	4,296	95,603	4,260	11.2
	04/12/05	48.6	2.2	5.68	48,118	4,289	5.79	48,931	4,361	97,049	4,325	11.0
	04/13/05	54.2	5.6	5.19	49,994	4,456	5.30	50,840	4,531	100,834	4,493	11.3
	04/14/05	57.0	2.8	5.23	50,969	4,543	5.30	51,833	4,620	102,802	4,581	11.7
	04/15/05	58.7	1.7	5.07	51,512	4,591	5.07	52,386	4,669	103,898	4,630	10.7
7	04/18/05	74.2	15.5	5.42	56,596	5,044	5.49	57,558	5,130	114,154	5,087	11.0
	04/19/05	78.0	3.8	5.01	57,826	5,154	5.14	58,816	5,242	116,642	5,198	10.9
	04/20/05	84.0	6.0	5.28	58,929	5,252	5.42	59,964	5,344	118,893	5,298	6.3
	04/21/05	87.8	3.8	4.96	60,166	5,362	5.08	61,246	5,459	121,412	5,411	11.0
	04/24/05	100.6	12.8	5.16	64,289	5,730	5.27	65,495	5,837	129,784	5,784	10.9
8	04/25/05	106.3	5.7	5.14	66,153	5,896	5.27	67,413	6,008	133,566	5,952	11.1
9	05/03/05	137.8	31.5	5.27	76,529	6,821	5.40	77,956	6,948	154,485	6,884	11.1
	05/04/05	142.0	4.2	5.21	77,895	6,943	5.35	79,342	7,071	157,237	7,007	10.9
	05/06/05	148.5	6.5	4.88	80,034	7,133	4.93	81,512	7,265	161,546	7,199	11.0
	05/08/05	163.6	15.1	4.91	85,038	7,579	4.97	86,587	7,717	171,625	7,648	11.1
10	05/10/05	170.9	7.3	4.90	87,516	7,800	4.96	89,088	7,940	176,604	7,870	11.4
	05/12/05	177.7	6.8	4.25	89,777	8,002	4.82	91,376	8,144	181,153	8,073	11.1
	05/13/05	178.9	1.2	5.01	90,183	8,038	5.07	91,805	8,182	181,988	8,110	11.6
11	05/16/05	190.4	11.5	4.96	94,018	8,380	5.01	95,677	8,527	189,695	8,453	11.2
	05/17/05	193.0	2.6	5.01	94,879	8,456	5.07	96,555	8,606	191,434	8,531	11.1
	05/19/05	202.1	9.1	5.14	97,874	8,723	5.32	99,578	8,875	197,452	8,799	11.0
	05/20/05	204.5	2.4	4.81	98,663	8,793	4.85	100,381	8,947	199,044	8,870	11.1
12	05/26/05	227.7	23.2	4.58	106,414	9,484	4.64	108,223	9,646	214,637	9,565	11.2
	05/27/05	230.9	3.2	4.88	107,484	9,580	4.93	109,304	9,742	216,788	9,661	11.2
13	05/31/05	247.6	16.7	4.84	113,096	10,080	4.86	114,974	10,247	228,070	10,164	11.3
	06/01/05	250.1	2.5	5.08	113,961	10,157	5.13	115,848	10,325	229,809	10,241	11.6
	06/02/05	255.6	5.5	5.05	115,791	10,320	5.15	117,697	10,490	233,488	10,405	11.1
14	06/08/05	279.3	23.7	5.38	123,612	11,017	5.46	125,611	11,195	249,223	11,106	11.1
	06/09/05	281.5	2.2	5.27	124,322	11,080	5.32	126,330	11,259	250,652	11,170	10.8
	06/10/05	284.6	3.1	5.16	125,374	11,174	5.20	127,395	11,354	252,769	11,264	11.4
	06/12/05	294.8	10.2	5.21	128,721	11,472	5.25	130,785	11,656	259,506	11,564	11.0
15	06/15/05	305.7	10.9	5.13	132,261	11,788	5.21	134,370	11,976	266,631	11,882	10.9
	06/18/05	317.7	12.0	5.10	136,265	12,145	5.21	138,422	12,337	274,687	12,241	11.2

(a) Bed Volume = 1.5 ft³ = 11.22 gal

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a)	Avg Flowrate
		hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
16	06/22/05	336.9	19.2	5.12	142,571	12,707	5.20	144,805	12,906	287,376	12,806	11.0
	06/24/05	348.3	11.4	4.80	146,227	13,033	4.81	148,499	13,235	294,726	13,134	10.7
17	06/29/05	370.8	22.5	5.07	153,568	13,687	5.10	155,922	13,897	309,490	13,792	10.9
18	07/06/05	403.7	32.9	5.10	164,281	14,642	5.14	166,753	14,862	331,034	14,752	10.9
	07/07/05	409.0	5.3	5.53	166,018	14,797	5.44	168,512	15,019	334,530	14,908	11.0
	07/08/05	418.3	9.3	5.07	168,976	15,060	5.12	171,505	15,286	340,481	15,173	10.7
19	07/13/05	438.4	20.1	5.29	175,659	15,656	5.31	178,264	15,888	353,923	15,772	11.1
	07/14/05	443.6	5.2	5.21	177,369	15,808	5.27	179,997	16,043	357,366	15,925	11.0
	07/15/05	447.5	3.9	5.04	178,686	15,926	5.09	181,329	16,161	360,015	16,043	11.3
20	07/19/05	465.0	17.5	5.10	184,403	16,435	5.19	187,111	16,677	371,514	16,556	11.0
	07/22/05	475.1	10.1	5.13	187,745	16,733	5.19	190,489	16,978	378,234	16,855	11.1
21	07/27/05	493.6	18.5	4.95	193,897	17,281	5.04	196,705	17,532	390,602	17,407	11.1
22	08/01/05	507.6	14.0	4.95	198,613	17,702	5.04	201,477	17,957	400,090	17,829	11.3
23	08/08/05	532.7	25.1	5.05	207,163	18,464	5.12	210,114	18,727	417,277	18,595	11.4
	08/09/05	534.9	2.2	4.97	207,890	18,529	4.99	210,847	18,792	418,737	18,660	11.1
	08/12/05	544.2	9.3	5.18	211,033	18,809	5.26	214,021	19,075	425,054	18,942	11.3
24	08/18/05	565.6	21.4	5.24	218,229	19,450	5.27	221,265	19,721	439,494	19,585	11.2
	08/20/05	577.9	12.3	5.14	222,369	19,819	5.08	225,445	20,093	447,814	19,956	11.3
25	08/23/05	583.7	5.8	5.31	224,295	19,991	5.33	227,398	20,267	451,693	20,129	11.1
26	08/30/05	606.6	22.9	5.10	232,034	20,680	5.19	235,225	20,965	467,259	20,823	11.3
27	09/06/05	629.4	22.8	5.25	239,858	21,378	5.32	243,155	21,672	483,013	21,525	11.5
	09/09/05	637.8	8.4	5.16	242,801	21,640	5.23	246,138	21,937	488,939	21,789	11.8

(a) Bed Volume = 1.5 ft³ = 11.22 gal

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a)	Avg Flowrate
		hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
1	09/27/05	699.7	-	-	0	0	-	0	0	0	0	-
2	10/05/05	723.8	24.1	5.18	9,066	808	5.42	9,529	849	18,595	829	12.9
	10/09/05	738.7	14.9	5.21	14,138	1,260	5.44	14,916	1,329	29,054	1,295	11.7
3	10/11/05	744.6	5.9	5.15	16,163	1,441	5.32	17,073	1,522	33,236	1,481	11.8
	10/16/05	766.4	21.8	4.96	23,618	2,105	5.12	24,958	2,224	48,576	2,165	11.7
4	10/18/05	771.5	5.1	5.32	25,384	2,262	5.36	26,818	2,390	52,202	2,326	11.8
	10/22/05	785.3	13.8	4.57	30,067	2,680	4.76	31,754	2,830	61,821	2,755	11.6
	10/23/05	792.4	7.1	5.04	32,468	2,894	5.25	34,330	3,060	66,798	2,977	11.7
5	10/26/05	801.5	9.1	5.37	35,613	3,174	5.57	37,675	3,358	73,288	3,266	11.8
	10/27/05	805.4	3.9	5.18	36,961	3,294	5.38	39,106	3,485	76,067	3,390	11.9
6	11/02/05	830.4	25.0	4.91	45,363	4,043	4.64	48,023	4,280	93,386	4,162	11.5
	11/06/05	847.0	16.6	5.02	50,864	4,533	5.18	53,848	4,799	104,712	4,666	11.4
7	11/07/05	851.6	4.6	5.23	52,374	4,668	5.43	55,439	4,941	107,813	4,805	11.2
	11/09/05	859.9	8.3	5.91	55,167	4,917	5.07	58,399	5,205	113,566	5,061	11.6
	11/12/05	872.6	12.7	4.81	59,340	5,289	5.01	62,835	5,600	122,175	5,445	11.3
	11/13/05	876.3	3.7	5.03	60,519	5,394	5.20	64,084	5,712	124,603	5,553	10.9
8	11/16/05	893.2	16.9	5.09	65,858	5,870	5.18	69,687	6,211	135,545	6,040	10.8
	11/18/05	902.4	9.2	5.16	68,896	6,140	5.29	72,903	6,498	141,799	6,319	11.3
	11/20/05	910.2	7.8	4.96	71,468	6,370	5.07	75,621	6,740	147,089	6,555	11.3
9	11/24/05	926.4	16.2	4.87	76,672	6,834	5.03	81,116	7,230	157,788	7,032	11.0
	11/26/05	935.7	9.3	4.88	79,572	7,092	5.05	84,176	7,502	163,748	7,297	10.7
	11/27/05	940.2	4.5	4.85	81,009	7,220	5.02	85,717	7,640	166,726	7,430	11.0
10	11/30/05	951.1	10.9	5.04	84,441	7,526	5.29	89,381	7,966	173,822	7,746	10.9
	12/02/05	960.2	9.1	4.88	87,405	7,790	5.09	92,550	8,249	179,955	8,019	11.2
	12/03/05	963.8	3.6	5.01	88,621	7,898	5.20	93,860	8,365	182,481	8,132	11.7
11	12/07/05	978.0	14.2	4.91	93,238	8,310	5.12	98,782	8,804	192,020	8,557	11.2
	12/08/05	983.3	5.3	5.12	94,998	8,467	5.33	100,664	8,972	195,662	8,719	11.5
	12/11/05	1,000.5	17.2	5.42	100,549	8,962	5.65	106,519	9,494	207,068	9,228	11.1
12	12/13/05	1,011.6	11.1	4.90	103,987	9,268	5.10	110,156	9,818	214,143	9,543	10.6
	12/15/05	1,017.5	5.9	5.13	105,908	9,439	5.37	112,210	10,001	218,118	9,720	11.2
13	12/20/05	1,039.1	21.6	5.01	112,824	10,056	5.24	119,618	10,661	232,442	10,358	11.1
	12/21/05	1,042.3	3.2	4.65	113,825	10,145	4.79	120,702	10,758	234,527	10,451	10.9
	12/22/05	1,044.2	1.9	4.54	114,429	10,199	4.76	121,348	10,815	235,777	10,507	11.0
	12/24/05	1,050.8	6.6	4.98	116,550	10,388	5.18	123,610	11,017	240,160	10,702	11.1

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a)	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a)	Avg Flowrate
		Hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
14	12/30/05	1,079.9	29.1	4.93	125,796	11,212	5.07	133,432	11,892	259,228	11,552	10.9
	12/31/05	1,083.1	3.2	4.42	126,812	11,302	4.68	134,512	11,989	261,324	11,645	10.9
	01/01/06	1,089.6	6.5	5.13	128,860	11,485	5.32	136,682	12,182	265,542	11,833	10.8
15	01/02/06	1,093.1	3.5	5.21	129,961	11,583	5.35	137,827	12,284	267,788	11,934	10.7
	01/04/06	1,103.0	9.9	4.85	133,046	11,858	5.01	141,132	12,579	274,178	12,218	10.8
	01/06/06	1,112.4	9.4	4.82	135,983	12,120	5.01	144,259	12,857	280,242	12,489	10.8
	01/07/06	1,115.5	3.1	4.85	136,963	12,207	5.03	145,304	12,950	282,267	12,579	10.9
16	01/11/06	1,135.7	20.2	4.82	143,298	12,772	5.04	152,008	13,548	295,306	13,160	10.8
	01/13/06	1,144.2	8.5	4.73	146,095	13,021	4.93	154,980	13,813	301,075	13,417	11.3
17	01/17/06	1,162.2	18.0	4.36	151,507	13,503	4.66	160,732	14,325	312,239	13,914	10.3
	01/18/06	1,168.4	6.2	4.17	153,444	13,676	4.43	162,784	14,508	316,228	14,092	10.7
	01/19/06	1,170.3	1.9	4.54	154,065	13,731	4.75	163,451	14,568	317,516	14,150	11.3
	01/20/06	1,177.1	6.8	4.86	156,142	13,916	5.08	165,625	14,762	321,767	14,339	10.4
18	01/21/06	1,181.8	4.7	4.82	157,632	14,049	5.01	167,215	14,903	324,847	14,476	10.9
	01/22/06	1,184.3	2.5	4.80	158,381	14,116	4.95	168,011	14,974	326,392	14,545	10.3
	01/23/06	1,195.5	11.2	4.65	161,772	14,418	4.79	171,561	15,291	333,333	14,854	10.3
	01/24/06	1,198.1	2.6	4.85	162,644	14,496	5.04	172,477	15,372	335,121	14,934	11.5
	01/25/06	1,204.0	5.9	4.76	164,484	14,660	4.96	174,430	15,546	338,914	15,103	10.7
19	01/30/06	1,221.4	17.4	4.48	169,826	15,136	4.70	180,084	16,050	349,910	15,593	10.5
	02/01/06	1,232.7	11.3	4.69	173,311	15,447	4.86	183,768	16,379	357,079	15,913	10.6
	02/05/06	1,254.0	21.3	4.65	179,834	16,028	4.80	190,552	16,983	370,386	16,506	10.4
21	02/14/06	1,299.7	45.7	4.36	193,692	17,263	4.63	205,032	18,274	398,724	17,768	10.3
	02/17/06	1,312.6	12.9	4.71	197,552	17,607	4.92	209,072	18,634	406,624	18,121	10.2

(a) Bed Volume = 1.5 ft³ = 11.22 gal

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading	Operational Hours	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a) Treated	Flow Rate	Cumulative Volume Treated	Cumulative Bed Volumes ^(a) Treated	Total Cumulative Volume Treated	Total Cumulative Bed Volumes ^(a) Treated	Avg Flowrate
		hr	hr	gpm	gal	BV	gpm	gal	BV	gal	BV	gpm
1	09/07/06	2,371.0	0.0	0.00	0	0	0.00	0	0	0	0	0.0
3	09/18/06	2,411.9	40.9	5.52	16,645	1,484	6.42	21,559	1,921	38,204	1,702	15.6
	09/20/06	2,420.1	8.2	5.77	19,839	1,768	6.54	25,913	2,309	45,751	2,039	15.3
7	10/17/06	2,519.3	99.2	5.36	55,513	4,948	6.15	72,556	6,467	128,069	5,707	13.8
	10/18/06	2,523.3	4.0	5.41	56,929	5,074	6.20	74,212	6,614	131,141	5,844	12.8
8	10/25/06	2,542.0	18.7	5.12	63,774	5,684	6.02	83,367	7,430	147,141	6,557	14.3
10	11/08/06	2,574.0	32.0	5.04	75,116	6,695	5.92	98,487	8,778	173,603	7,736	13.8
	11/09/06	2,577.4	3.4	5.04	76,334	6,803	5.90	100,058	8,918	176,392	7,861	13.7
11	11/15/06	2,591.3	13.9	5.09	81,248	7,241	6.18	106,629	9,503	187,877	8,372	13.8
15	12/13/06	2,709.2	117.9	4.73	120,270	10,719	5.58	155,853	13,891	276,123	12,305	12.5
17	12/31/06	2,760.4	51.2	5.01	136,423	12,159	5.85	176,423	15,724	312,846	13,941	12.0
18	01/03/07	2,769.8	9.4	4.69	139,340	12,419	5.51	180,163	16,057	319,503	14,238	11.8
19	01/11/07	2,795.8	26.0	4.56	147,458	13,142	4.35	190,500	16,979	337,958	15,061	11.8
	01/13/07	2,802.3	6.5	4.86	149,507	13,325	5.70	193,129	17,213	342,636	15,269	12.0
20	01/16/07	2,809.8	7.5	4.88	151,862	13,535	5.77	196,201	17,487	348,063	15,511	12.1
	01/20/07	2,820.5	10.7	5.03	155,189	13,831	5.83	200,501	17,870	355,690	15,851	11.9
21	01/22/07	2,827.0	6.5	5.18	157,500	14,037	6.16	203,746	18,159	361,246	16,098	14.2
	01/28/07	2,840.2	13.2	5.26	162,189	14,455	6.38	210,482	18,760	372,671	16,607	14.4
22	01/31/07	2,848.2	8.0	5.32	164,987	14,705	6.54	214,411	19,110	379,398	16,907	14.0
	02/02/07	2,852.8	4.6	5.29	166,626	14,851	5.82	216,805	19,323	383,431	17,087	14.6
23	02/05/07	2,859.6	6.8	4.96	169,019	15,064	5.98	220,261	19,631	389,280	17,348	14.3
24	02/12/07	2,874.5	14.9	4.68	174,254	15,531	5.72	227,856	20,308	402,110	17,919	14.4
	02/13/07	2,877.7	3.2	5.13	175,376	15,631	6.32	229,492	20,454	404,868	18,042	14.4
	02/15/07	2,882.9	5.2	5.12	177,188	15,792	6.14	232,093	20,686	409,281	18,239	14.1
25	02/23/07	2,904.0	21.1	5.37	184,447	16,439	6.35	242,328	21,598	426,775	19,018	13.8
26	02/28/07	2,923.2	19.2	5.10	190,876	17,012	6.07	250,943	22,366	441,819	19,689	13.1
	03/02/07	2,931.7	8.5	5.01	193,719	17,266	6.07	254,713	22,702	448,432	19,984	13.0
27	03/10/07	2,960.5	28.8	4.93	203,411	18,129	5.91	267,876	23,875	471,287	21,002	13.2
28	03/15/07	2,977.7	17.2	4.49	209,149	18,641	5.64	275,619	24,565	484,768	21,603	13.1
30	03/28/07	3,020.0	42.3	4.97	222,506	19,831	5.99	293,705	26,177	516,211	23,004	12.4
31	04/04/07	3,041.7	21.7	4.92	229,724	20,475	5.79	303,411	27,042	533,135	23,758	13.0
32	04/11/07	3,061.5	19.8	5.23	236,254	21,057	6.21	311,942	27,802	548,196	24,429	12.7

Table A-1. EPA Arsenic Demonstration Project at SBMHP in Wales, ME – Daily System Operational Data (Continued)

Week No.	Date	Supply Well Hour Meter 2		Treatment Train A			Treatment Train B			System		
		Cumulative Hour Meter Reading hr	Operational Hours hr	Flow Rate gpm	Cumulative Volume Treated gal	Cumulative Bed Volumes ^(a) BV	Flow Rate gpm	Cumulative Volume Treated gal	Cumulative Bed Volumes ^(a) BV	Total Cumulative Volume Treated gal	Total Cumulative Bed Volumes ^(a) BV	Avg Flowrate gpm
33	04/16/07	3,076.1	14.6	6.02	241,115	21,490	6.86	318,290	28,368	559,405	24,929	12.8
	04/20/07	3,088.8	12.7	4.95	245,474	21,878	5.88	323,991	28,876	569,465	25,377	13.2
34	04/25/07	3,106.4	17.6	5.27	251,358	22,403	6.25	331,715	29,565	583,073	25,984	12.9
	04/28/07	3,115.1	8.7	5.25	254,271	22,662	6.18	335,558	29,907	589,829	26,285	12.9
36	05/09/07	3,145.5	30.4	4.59	264,469	23,571	5.46	349,139	31,118	613,608	27,344	13.0
37	05/14/07	3,159.4	13.9	5.41	269,213	23,994	-	355,361	31,672	624,574	27,833	13.1
38	05/23/07	3,183.2	23.8	5.39	277,336	24,718	-	366,084	32,628	643,420	28,673	13.2
40	06/06/07	3,226.9	43.7	4.81	291,955	26,021	-	385,381	34,348	677,336	30,184	12.9
42	06/19/07	3,277.0	50.1	5.10	308,509	27,496	-	407,232	36,295	715,741	31,896	12.8
44	07/02/07	3,328.7	51.7	5.38	325,631	29,022	-	429,833	38,310	755,464	33,666	12.8
48	07/31/07	3,436.8	108.1	5.43	361,373	32,208	-	477,012	42,514	838,385	37,361	12.8
50	08/16/07	3,486.9	50.1	4.85	377,978	33,688	-	498,931	44,468	876,909	39,078	12.8
52	08/29/07	3,526.6	39.7	5.33	390,980	34,847	-	516,094	45,998	907,074	40,422	12.7

(a) Bed Volume = 1.5 ft³ = 11.22 gal

Red font indicates estimated values due to broken flow meter/totalizer. Multiplied volume in Train A by 1.32 to estimate Train B volume.

APPENDIX B

ANALYTICAL RESULTS

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME

Sampling Date		03/09/05					03/22/05						04/05/05				
Sampling Location		IN	OA	OB	TA	TB	IN	OA	OB	TA	TB	TT	IN	OA	OB	TA	TB
Parameter	Unit																
Bed Volume	10 ³	-	-	-	0.7	0.7	-	-	-	2.0	2.0	2.0	-	-	-	3.6	3.6
Alkalinity	mg/L ^(a)	74	70	67	65	69	68	69	69	67	67	59	-	-	-	-	-
Fluoride	mg/L	0.6	0.4	0.5	<0.1	<0.1	0.5	0.8	0.7	0.6	0.6	<0.1	-	-	-	-	-
Sulfate	mg/L	39	38	38	39	40	20	24	20	21	21	23	-	-	-	-	-
Sulfide	mg/L	<5	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	-	-	-	-	-
Orthophosphate	mg/L ^(b)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-
Silica (as SiO ₂)	mg/L	11.5	4.5	5.3	0.9	1.3	10.8	6.1	7.2	3.2	3.4	0.6	-	-	-	-	-
Turbidity	NTU	0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.2	<0.1	<0.1	-	-	-	-	-
pH	S.U.	8.4	7.6	7.7	7.6	7.6	8.4	8.1	8.1	7.8	7.7	7.5	8.5	7.8	7.5	7.6	7.7
Temperature	°C	7.5	7.6	7.7	8.1	8.0	11.5	11.4	11.4	11.2	11.2	11.2	9.5	8.5	7.9	8.5	7.8
DO	mg/L	4.7	4.3	4.3	5.0	4.5	2.8	3.5	2.7	2.3	2.5	2.6	2.4	2.4	2.6	1.8	1.8
ORP	mV	185	184	187	210	194	189	196	198	194	194	196	126	138	129	133	130
Total Hardness	mg/L ^(a)	47.3	43.7	43.2	43.3	42.2	54.3	49.8	53.1	50.8	50.3	48.4	53.7	51.5	44.1	45.7	40.0
Ca Hardness	mg/L ^(a)	40.7	37.8	37.4	37.5	36.8	46.6	42.7	45.7	43.4	43.0	41.2	46.5	44.7	37.3	38.1	33.7
Mg Hardness	mg/L ^(a)	6.5	5.9	5.7	5.8	5.5	7.7	7.1	7.4	7.3	7.2	7.2	7.2	6.8	6.8	7.5	6.3
As (total)	µg/L	41.5	0.3	0.5	0.2	0.2	36.2	4.7	19.9	0.1	<0.1	<0.1	36.5	27.5	34.2	0.2	0.2
As (soluble)	µg/L	41.6	<0.1	0.2	0.1	<0.1	-	-	-	-	-	-	36.4	27.8	34.1	0.1	0.1
As (particulate)	µg/L	<0.1	0.2	0.3	0.1	<0.1	-	-	-	-	-	-	0.1	<0.1	<0.1	<0.1	<0.1
As (III)	µg/L	26.5	0.3	0.4	0.4	0.3	-	-	-	-	-	-	23.2	0.3	0.3	0.3	0.3
As (V)	µg/L	15.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	13.1	27.5	33.8	<0.1	<0.1
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Soluble Fe	µg/L	<25	<25	<25	<25	<25	-	-	-	-	-	-	<25	<25	<25	<25	<25
Total Mn	µg/L	7.3	1.5	2.5	1.2	0.8	8.5	0.5	9.5	0.5	0.5	0.5	8.5	<0.1	<0.1	0.1	<0.1
Soluble Mn	µg/L	7.2	<0.1	0.1	<0.1	0.2	-	-	-	-	-	-	7.9	0.1	<0.1	<0.1	<0.1
Total Al	µg/L	11.2	21.2	21.0	11.4	10.3	<10	24.6	36.2	16.2	16.2	<10	10.0	38.1	37.0	20.6	21.3
Soluble Al	µg/L	<10	18.0	18.1	<10	<10	-	-	-	-	-	-	<10	33.8	35.6	17.3	18.9

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		04/19/05						05/04/05					05/17/05					
Sampling Location	Parameter	IN	OA	OB	TA	TB	TT	IN	OA	OB	TA	TB	IN	OA	OB	TA	TB	TT
Bed Volume	10 ³	-	-	-	5.2	5.2	5.2	-	-	-	6.9	7.1	-	-	-	8.5	8.6	8.5
Alkalinity	mg/L ^(a)	72	72	72	72	69	72	-	-	-	-	-	70	72	69	68	68	66
		-	-	-	-	-	-	-	-	-	-	-	69	70	58	66	69	66
Fluoride	mg/L	0.5	0.5	0.5	0.6	0.6	0.6	-	-	-	-	-	0.6	0.6	0.5	0.6	0.6	0.7
		-	-	-	-	-	-	-	-	-	-	-	0.5	0.6	0.5	0.6	0.6	0.7
Sulfate	mg/L	22	22	22	22	22	23	-	-	-	-	-	18	19	18	16	18	18
		-	-	-	-	-	-	-	-	-	-	-	18	18	18	18	18	18
Sulfide	mg/L	-	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	0.07	0.18	0.09	0.07	1.11	0.06
		-	-	-	-	-	-	-	-	-	-	-	0.43	0.21	0.17	<0.05	0.05	0.11
Orthophosphate	mg/L ^(b)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
		-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO ₂)	mg/L	10.9	8.9	9.0	6.1	6.6	2.8	-	-	-	-	-	10.8	9.1	10.2	7.3	8.4	4.2
		-	-	-	-	-	-	-	-	-	-	-	10.9	9.2	9.5	7.4	8.1	4.1
Turbidity	NTU	0.5	0.2	0.1	0.3	0.3	0.3	-	-	-	-	-	0.3	0.1	0.2	<0.1	0.2	0.1
		-	-	-	-	-	-	-	-	-	-	-	0.5	0.2	0.2	0.4	0.2	0.1
pH	S.U.	8.7	8.4	8.6	8.3	8.2	7.9	8.3	8.4	8.5	8.2	8.2	8.5	8.1	8.4	8.4	8.3	7.0
Temperature	°C	10.7	10.6	10.9	11.0	11.1	11.0	9.6	9.1	9.4	9.5	9.4	9.6	9.3	9.4	9.4	9.4	9.5
DO	mg/L	1.5	1.1	1.4	1.0	1.5	1.1	1.9	1.4	2.0	1.6	1.5	4.0	1.6	1.5	1.7	1.5	2.0
ORP	mV	178	182	179	185	184	195	197	195	194	194	193	200	190	188	181	185	195
Total Hardness	mg/L ^(a)	37.9	41.8	37.3	36.7	37.1	35.1	48.5	48.1	49.0	48.3	49.9	49.1	50.2	48.9	48.7	48.8	47.5
		-	-	-	-	-	-	-	-	-	-	-	48.9	49.5	49.7	48.8	49.1	52.3
Ca Hardness	mg/L ^(a)	31.4	34.0	30.9	31.0	31.0	29.3	41.4	41.2	42.0	41.2	42.6	41.3	42.7	41.4	41.2	41.2	40.2
Mg Hardness	mg/L ^(a)	6.4	7.8	6.4	5.7	6.1	5.9	7.0	6.9	7.0	7.1	7.3	7.7	7.6	7.5	7.5	7.6	7.3
As (total)	µg/L	37.6	39.0	36.6	0.5	4.4	0.2	34.9	34.7	34.9	8.8	22.8	35.8	35.9	35.9	24.2	33.2	0.2
		-	-	-	-	-	-	-	-	-	-	-	35.8	36.8	35.1	25.2	32.5	0.2
As (soluble)	µg/L	-	-	-	-	-	-	36.7	36.5	35.3	9.4	23.2	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	21.9	0.4	0.2	0.2	0.2	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	14.8	36.1	35.1	9.2	23.0	-	-	-	-	-	-
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Soluble Fe	µg/L	-	-	-	-	-	-	<25	<25	<25	<25	<25	-	-	-	-	-	-
Total Mn	µg/L	8.3	<0.1	<0.1	<0.1	<0.1	0.1	8.4	0.4	0.4	0.3	0.3	8.6	<0.1	<0.1	0.1	<0.1	<0.1
		-	-	-	-	-	-	-	-	-	-	-	8.8	<0.1	0.1	<0.1	<0.1	<0.1
Soluble Mn	µg/L	-	-	-	-	-	-	8.2	0.3	0.4	0.4	0.5	-	-	-	-	-	-
Total Al	µg/L	14.6	33.9	28.9	18.6	21.4	11.8	<10	26.1	22.5	20.4	31.6	21.4	36.2	34.8	32.0	33.3	55.7
		-	-	-	-	-	-	-	-	-	-	-	21.3	36.1	33.2	37.1	35.0	25.1
Soluble Al	µg/L	-	-	-	-	-	-	<10	23.3	20.4	19.6	20.6	-	-	-	-	-	-

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		06/01/05							06/15/05						06/29/05					
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	IN	OA	OB	TA	TB	TT	IN	OA	OB	TC	TD
Bed Volume		10 ³	-	-	-	10.2	10.3	-	-	-	-	-	11.8	12.0	11.9	-	-	-	13.8	13.8
Alkalinity		mg/L ^(a)	-	-	-	-	-	-	-	66	74	68	66	66	66	-	-	-	-	-
Fluoride		mg/L	-	-	-	-	-	-	-	0.5	0.5	0.5	0.5	0.5	0.6	-	-	-	-	-
Sulfate		mg/L	-	-	-	-	-	-	-	19	19	19	19	19	20	-	-	-	-	-
Sulfide		mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-
Nitrate (as N)		mg/L	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	-	-	-	-	-
Orthophosphate		mg/L ^(b)	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-
Silica (as SiO ₂)		mg/L	-	-	-	-	-	-	-	10.7	9.8	10.0	8.7	9.3	5.5	-	-	-	-	-
Turbidity		NTU	-	-	-	-	-	-	-	0.5	<0.1	0.2	0.2	0.2	<0.1	-	-	-	-	-
pH		S.U.	8.0	8.6	8.4	8.3	8.3	-	-	8.2	8.4	8.4	8.4	8.4	8.1	8.2	8.3	8.3	8.3	8.3
Temperature		°C	10.5	10.5	10.5	11.3	11.3	-	-	10.7	10.7	10.7	10.9	10.9	11.0	12.9	11.9	11.6	12.5	12.9
DO		mg/L	3.6	3.5	3.7	3.8	3.3	-	-	0.9	0.8	0.7	0.8	0.9	0.9	2.1	1.4	1.4	1.2	1.3
ORP		mV	174	229	212	177	195	-	-	209	209	208	203	201	204	190	189	186	185	182
Total Hardness		mg/L ^(a)	51.1	51.5	50.4	48.5	50.8	47.2	48.7	50.8	49.4	54.0	49.9	51.1	47.0	53.7	53.5	52.0	87.0	84.3
Ca Hardness		mg/L ^(a)	44.2	43.5	42.6	40.7	43.4	40.2	41.9	42.6	41.2	45.0	41.7	42.7	40.0	45.7	45.3	44.2	74.0	71.9
Mg Hardness		mg/L ^(a)	6.9	7.9	7.8	7.8	7.4	7.0	6.8	8.2	8.2	9.0	8.2	8.4	7.0	8.0	8.1	7.8	13.0	12.4
As (total)		µg/L	39.9	45.3	45.8	42.6	46.6	2.9	6.0	42.6	41.1	44.5	49.1	46.9	0.3	42.3	39.2	38.9	58.4	54.7
As (soluble)		µg/L	39.6	45.3	45.5	42.6	46.4	-	-	-	-	-	-	-	-	42.6	39.4	39.4	46.3	44.3
As (particulate)		µg/L	0.3	<0.1	0.4	<0.1	0.2	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	12.1	10.4
As (III)		µg/L	25.1	0.8	0.4	0.4	0.4	-	-	-	-	-	-	-	-	34.4	6.3	5.1	2.0	2.3
As (V)		µg/L	14.5	44.6	45.0	42.2	46.0	-	-	-	-	-	-	-	-	8.2	33.1	34.3	44.3	42.0
Total Fe		µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	42.2	<25	<25	<25	80.4	87.1
Soluble Fe		µg/L	<25	<25	<25	<25	<25	-	-	-	-	-	-	-	-	<25	<25	<25	<25	<25
Total Mn		µg/L	10.8	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	13.1	0.1	<0.1	0.1	0.1	0.3	16.1	0.1	0.1	10.1	10.0
Soluble Mn		µg/L	9.8	<0.1	<0.1	0.1	<0.1	-	-	-	-	-	-	-	-	15.2	<0.1	<0.1	<0.1	<0.1
Total Al		µg/L	16.3	33.0	33.2	33.3	31.3	30.4	29.9	10.5	32.6	32.5	30.5	31.3	29.0	12.5	32.0	30.6	138	132
Soluble Al		µg/L	<10	26.7	24.9	41.1	24.5	-	-	-	-	-	-	-	-	<10	29.1	28.8	27.9	27.8

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		7/13/2005						7/27/2005						8/9/2005								
Sampling Location	Parameter	Unit	IN	OA	OB	TC	TD	TT	IN	OA	OB	TC	TD	TE	TF	TT	IN	OA	OB	TC	TD	TT
Bed Volume	BV^3		-	-	-	-	-	15.8	-	-	-	-	-	17.3	17.5	17.4	-	-	-	18.5	18.8	-
Alkalinity	mg/L ^(a)		66	66	66	66	66	66	-	-	-	-	-	-	-	-	66	65	67	67	66	63
Fluoride	mg/L		0.5	0.5	0.5	0.5	0.5	0.5	-	-	-	-	-	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5
Iodine (ICPMS)	µg/L		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L		20	20	21	21	21	21	-	-	-	-	-	-	-	-	20.6	20.4	20.6	20.7	20.7	20.6
Sulfide	µg/L		<5	-	-	-	-	-	<5	-	-	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L		0.1	0.2	0.3	0.2	0.2	<0.05	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	0.1	0.1	0.1
Orthophosphate	mg/L ^(b)		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO ₂)	mg/L		9.8	9.1	9.5	7.5	7.6	6.3	-	-	-	-	-	-	-	-	10.7	10	10.0	8.8	8.8	7.8
Turbidity	NTU		0.2	0.1	0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	0.2	0.2	0.1	<0.1	<0.1	0.1
pH	S.U.		8.7	8.7	8.6	8.3	8.0	7.4	8.5	8.6	8.6	-	-	8.4	8.4	8.4	8.5	8.2	8.6	8.6	8.6	8.5
Temperature	°C		13.5	13.6	12.7	13.6	13.7	13.5	13.7	13.0	12.6	-	-	13.4	13.7	13.7	14.1	14.0	14.7	14.1	14.0	13.9
DO	mg/L		1.1	1.1	1.1	2.1	1.0	1.1	3.8	2.4	3.0	-	-	2.6	2.7	2.0	2.1	1.6	1.3	0.6	0.9	1.1
ORP	mV		178	179	177	179	176	179	184	180	181	-	-	183	183	183	148	168	167	170	170	178
Total Hardness	mg/L ^(a)		58.1	64.0	54.7	47.1	48.8	48.7	46.6	47.0	47.5	45.6	46.0	46.9	46.9	-	39.3	39.2	38.9	39.5	39.6	37.4
Ca Hardness	mg/L ^(a)		49.8	55.0	47.2	40.5	42.0	42.0	39.7	40.1	40.7	39.2	39.5	40.2	40.2	-	32.2	31.9	32.1	32.6	33.4	31.0
Mg Hardness	mg/L ^(a)		8.4	9.0	7.5	6.6	6.8	6.7	6.9	6.9	6.8	6.4	6.5	6.8	6.7	-	7.0	7.3	6.8	6.8	6.2	6.4
As (total)	µg/L		50.2	50.2	41.1	44.1	47.7	12.7	36.5	38.2	37.8	42.5	43.0	25.0	26.2	-	37.0	37.1	35.2	44.1	42.5	35.4
As (soluble)	µg/L		-	-	-	-	-	-	38.3	38.4	37.7	-	-	26.0	26.9	-	-	-	-	-	-	-
As (particulate)	µg/L		-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	<0.1	<0.1	-	-	-	-	-	-	-
As (III)	µg/L		-	-	-	-	-	-	38.0	3.3	3.7	-	-	0.4	0.4	-	-	-	-	-	-	-
As (V)	µg/L		-	-	-	-	-	-	0.2	35.1	33.9	-	-	25.5	26.6	-	-	-	-	-	-	-
Total Fe	µg/L		<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	-	<25	<25	<25	<25	<25	<25
Soluble Fe	µg/L		-	-	-	-	-	-	<25	<25	<25	-	-	<25	<25	-	-	-	-	-	-	-
Total Mn	µg/L		21.9	0.1	0.1	<0.1	<0.1	<0.1	11.8	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	-	10.8	<0.1	0.2	<0.1	<0.1	0.2
Soluble Mn	µg/L		-	-	-	-	-	-	11.7	<0.1	<0.1	-	-	<0.1	<0.1	-	-	-	-	-	-	-
Total Al	µg/L		18.0	50.9	37.4	34.7	35.7	38.7	11.8	36.1	34.7	34.0	36.9	41.1	40.9	-	14.7	39.5	39.1	41.8	42.6	47.1
Soluble Al	µg/L		-	-	-	-	-	-	<10	33.0	30.9	-	-	37.7	38.0	-	-	-	-	-	-	-

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		8/24/2005					10/5/2005 ^(c)						10/18/2005					
Sampling Location		IN	OA	OB	TE	TF	IN	OA	OB	TA	TB	TT	IN	OA	OB	TA	TB	TT
Parameter	Unit																	
Bed Volume	BV ³	-	-	-	20.0	20.2	-	-	-	0.8	0.9	0.8	-	-	-	2.3	2.4	2.3
Alkalinity	mg/L ^(a)	-	-	-	-	-	-	-	-	-	-	-	72	72	66	66	66	65
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	0.5	0.6	0.6	0.5	0.5	<0.1
Iodine (ICPMS)	µg/L	-	-	-	-	-	-	-	-	-	-	-	9.2	59.7	64.8	76.9	80.8	124
Iodine (AAL)	mg/L	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	19	19	19	19	19	22
Sulfide	µg/L	<5	-	-	-	-	-	-	-	-	-	-	<5	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	0.2	<0.05	0.1	0.1	0.3	0.3
Orthophosphate	mg/L ^(b)	-	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO ₂)	mg/L	-	-	-	-	-	-	-	-	-	-	-	9.7	4.7	4.9	3.0	3.1	0.6
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	0.3	0.1	<0.1	<0.1	0.2	<0.1
pH	S.U.	7.3	8.3	8.5	8.5	8.5	8.6	8.0	7.9	7.7	7.6	7.8	8.5	8.2	8.1	7.8	8.0	7.9
Temperature	°C	13.6	13.5	13.7	14.4	14.6	11.9	12.7	12.5	13.3	13.0	14.0	10.6	10.6	10.6	10.7	10.6	10.8
DO	mg/L	1.5	0.9	0.8	1.0	0.7	1.2	1.7	1.3	1.2	1.0	1.4	3.9	1.3	1.7	1.3	1.7	1.4
ORP	mV	177	173	173	173	175	147	179	182	193	195	211	177	187	182	188	189	200
Total Hardness	mg/L ^(a)	42.3	37.2	37.5	36.7	37.1	48.0	43.9	43.8	43.6	44.9	-	48.7	41.3	41.3	39.7	40.6	40.0
Ca Hardness	mg/L ^(a)	35.7	30.7	31.1	30.6	30.8	41.4	37.8	37.9	37.5	38.7	-	41.7	34.9	34.8	33.7	34.6	33.8
Mg Hardness	mg/L ^(a)	6.6	6.5	6.4	6.1	6.3	6.6	6.1	6.0	6.1	6.2	-	6.9	6.3	6.5	6.0	6.1	6.1
As (total)	µg/L	38.5	36.4	37.2	41.7	43.6	41.8	0.4	0.3	0.1	0.1	-	39.6	3.0	3.5	0.3	0.2	0.2
As (soluble)	µg/L	37.0	36.6	37.3	41.2	43.5	41.7	0.3	0.3	<0.1	0.1	-	-	-	-	-	-	-
As (particulate)	µg/L	1.5	<0.1	<0.1	0.4	0.1	0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-
As (III)	µg/L	36.5	1.3	0.8	0.8	0.7	38.7	0.2	0.3	0.2	0.3	-	-	-	-	-	-	-
As (V)	µg/L	0.5	35.2	36.5	40.4	42.8	3.0	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-
Total Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	-	<25	<25	<25	<25	<25	<25
Soluble Fe	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	-	-	-	-	-	-	-
Total Mn	µg/L	11.0	<0.1	<0.1	<0.1	<0.1	9.9	<0.1	<0.1	<0.1	<0.1	-	9.2	<0.1	<0.1	<0.1	<0.1	<0.1
Soluble Mn	µg/L	11.1	<0.1	<0.1	0.2	0.1	10.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-
Total Al	µg/L	<10	36.6	33.5	37.0	38.0	11.2	18.6	17.3	<10	<10	-	<10	29.5	32.7	16.3	14.2	<10
Soluble Al	µg/L	<10	32.6	32.2	36.0	37.7	<10	15.7	16.0	<10	<10	-	-	-	-	-	-	-

(a) TA = as CaCO₃ (b) as PO₄ (c) Media changeout of all 8 tanks on 9/26/05. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		11/9/2005						11/16/2005										11/30/2005									
Sampling Location	Parameter	IN	OA	OB	TA	TB	TT	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT
Bed Volume	BV^3	-	-	-	4.9	5.2	5.1	-	-	-	5.9	6.2	-	-	-	-	6.0	-	-	-	7.5	8.0	-	-	-	-	7.7
Alkalinity	mg/L ^(a)	-	-	-	-	-	-	64	66	66	-	-	-	-	-	-	61	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	64	66	66	-	-	-	-	-	-	-	62	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	-	-	0.5	0.5	0.5	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	0.5	0.5	0.5	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	20	20	20	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	20	20	20	-	-	-	-	-	-	-	21	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	-	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-	-	-
Total P	mg/L ^(b)	0.2	0.1	0.1	<0.03	<0.03	-	0.05	<0.03	<0.03	-	-	-	-	-	-	<0.03	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	0.04	<0.03	<0.03	-	-	-	-	-	-	-	<0.03	-	-	-	-	-	-	-	-	-
Silica (as SiO ₂)	mg/L	-	-	-	-	-	-	9.9	8.5	8.5	5.7	6.4	4.3	4.3	3.3	3.2	3.3	10.4	9.3	9.4	7.2	7.2	4.9	4.7	3.7	3.5	
		-	-	-	-	-	-	9.8	8.7	8.8	-	-	-	-	-	-	-	3.3	-	-	-	-	-	-	-	-	-
Turbidity	NTU	-	-	-	-	-	-	0.1	<0.1	<0.1	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	0.2	<0.1	<0.1	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-
pH	S.U.	8.7	8.6	8.3	8.2	8.4	8.1	7.3	8.2	8.3	8.3	8.2	-	-	-	-	8.1	8.5	8.7	8.7	8.6	8.5	-	-	-	-	8.1
Temperature	°C	9.9	9.6	9.6	9.6	9.4	9.9	8.7	8.8	8.6	8.6	8.7	-	-	-	-	8.7	9.5	9.6	9.5	9.6	9.6	-	-	-	-	9.7
DO	mg/L	4.0	1.9	2.0	1.8	1.7	1.6	3.1	1.7	1.8	1.7	1.6	-	-	-	-	1.8	2.2	1.9	1.5	1.8	1.6	-	-	-	-	1.5
ORP	mV	187	186	192	203	205	215	180	179	180	188	188	-	-	-	-	200	175	176	177	183	187	-	-	-	-	198
Total Hardness	mg/L ^(a)	51.1	50.6	49.8	48.8	49.3	-	52.2	50.7	49.7	-	-	-	-	-	-	49.6	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	50.9	49.6	43.1	-	-	-	-	-	-	-	47.8	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L ^(a)	44.8	44.1	43.4	42.6	42.9	-	45.5	44.4	43.3	-	-	-	-	-	-	43.2	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	44.3	43.2	36.6	-	-	-	-	-	-	-	41.6	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L ^(a)	6.3	6.6	6.4	6.2	6.5	-	6.7	6.3	6.4	-	-	-	-	-	-	6.4	-	-	-	-	-	-	-	-	-	
		-	-	-	-	-	-	6.6	6.4	6.5	-	-	-	-	-	-	-	6.2	-	-	-	-	-	-	-	-	-
As (total)	µg/L	39.6	42.0	39.9	0.1	0.1	-	36.2	37.6	36.7	1.9	1.2	1.3	<0.1	<0.1	0.2	<0.1	37.8	39.9	39.4	19.4	12.1	<0.1	<0.1	<0.1	<0.1	
		-	-	-	-	-	-	35.0	37.8	36.6	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	39.1	42.3	39.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	36.6	40.0	38.8	-	-	-	-	-	<0.1	
As (particulate)	µg/L	0.5	<0.1	0.5	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	1.1	<0.1	0.6	-	-	-	-	-	<0.1	
As (III)	µg/L	25.2	1.0	0.8	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	23.4	1.0	0.6	-	-	-	-	-	0.2	
As (V)	µg/L	14.0	41.3	38.5	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	13.3	39.0	38.3	-	-	-	-	-	<0.1	
Total Fe	µg/L	<25	<25	<25	<25	<25	-	<25	<25	<25	-	-	-	-	-	-	<25	<25	<25	<25	-	-	-	-	-	<25	
		-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	<25	-	-	-	-	-	-	-	-	-
Soluble Fe	µg/L	<25	<25	<25	<25	<25	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	<25	-	-	-	-	-	<25	
Total Mn	µg/L	6.5	<0.1	0.1	<0.1	<0.1	-	8.1	<0.1	<0.1	-	-	-	-	-	-	<0.1	7.3	<0.1	<0.1	-	-	-	-	-	<0.1	
		-	-	-	-	-	-	7.9	<0.1	0.2	-	-	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-
Soluble Mn	µg/L	6.4	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	6.9	<0.1	<0.1	-	-	-	-	-	<0.1	
Total Al	µg/L	<10	64.5	67.7	24.8	22.2	-	<10	38.2	41.0	-	-	-	-	-	-	13.5	<10	45.4	49.0	-	-	-	-	-	19.3	
		-	-	-	-	-	-	<10	38.0	40.0	-	-	-	-	-	-	-	13.2	-	-	-	-	-	-	-	-	
Soluble Al	µg/L	<10	61.1	65.9	26.1	24.6	-	-	-	-	-	-	-	-	-	-	-	<10	44.3	45.9	-	-	-	-	-	18.9	

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA = After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		12/14/2005										1/4/2006										
Sampling Location		IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	
Parameter	Unit																					
Bed Volume	BV ³	-	-	-	9.4	10.0	-	-	-	-	9.7	-	-	-	11.9	12.6	-	-	-	-	-	12.2
Alkalinity	mg/L ^(a)	68	67	67	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	0.4	0.4	0.4	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L	9.8	14.7	14.7	-	-	-	-	-	-	22.7	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	18	18	18	-	-	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-
Sulfide	µg/L	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO ₄)	mg/L ^(b)	0.2	0.2	0.2	-	-	-	-	-	-	<0.03	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO ₂)	mg/L	11.2	9.9	10	8.7	8.5	6.3	6.4	5.0	4.2	4.8	10.6	9.7	9.7	8.8	8.8	7.1	6.8	5.4	5.7	5.4	
Turbidity	NTU	0.5	0.3	0.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	8.1	8.3	8.4	8.3	8.1	-	-	-	-	8.2	8.3	8.4	8.3	8.3	8.2	-	-	-	-	-	8.0
Temperature	°C	9.0	8.6	8.7	8.9	8.9	-	-	-	-	9.5	9.8	9.7	9.8	9.7	10.0	-	-	-	-	-	10.5
DO	mg/L	3.0	2.7	2.8	2.5	2.5	-	-	-	-	1.5	3.5	3.7	3.8	3.7	3.3	-	-	-	-	-	3.7
ORP	mV	192	190	183	193	195	-	-	-	-	203	195	188	185	186	184	-	-	-	-	-	195
Total Hardness	mg/L ^(a)	52.1	52.2	52.4	-	-	-	-	-	-	37.7	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L ^(a)	44.9	45.1	45.3	-	-	-	-	-	-	32.3	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L ^(a)	7.2	7.1	7.1	-	-	-	-	-	-	5.4	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	46.5	47.4	47.5	47.0	30.5	0.6	0.3	<0.1	<0.1	<0.1	39.2	39.0	39.6	40.3	39.7	17.1	15.8	<0.1	0.4	<0.1	
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	39.8	39.7	39.5	-	-	-	-	-	-	-	<0.1
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	<0.1
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	25.5	1.2	1.0	-	-	-	-	-	-	-	<0.1
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	14.3	38.4	38.5	-	-	-	-	-	-	-	<0.1
Total Fe	µg/L	27.8	<25	<25	-	-	-	-	-	-	<25	<25	<25	<25	<25	<25	-	<25	<25	-	<25	
Soluble Fe	µg/L	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	<25
Total Mn	µg/L	6.9	0.2	0.2	-	-	-	-	-	-	<0.1	6.4	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1	-	<0.1	
Soluble Mn	µg/L	-	-	-	-	-	-	-	-	-	-	6.1	<0.1	<0.1	-	-	-	-	-	-	-	<0.1
Total Al	µg/L	10.6	36.0	38.0	-	-	-	-	-	-	19.9	10.3	37.4	39.1	30.2	25.6	-	31.7	29.6	-	-	26.1
Soluble Al	µg/L	-	-	-	-	-	-	-	-	-	-	4.8	34.7	36.4	-	-	-	-	-	-	-	22.1

(a) as CaCO₃ (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		1/19/2006										1/31/2006										
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT
Bed Volume	BV^3		-	-	-	13.7	14.9	-	-	-	-	14.2	-	-	-	15.8	16.7	-	-	-	-	16.3
Alkalinity	mg/L ^(a)		68	67	65	-	-	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-
			67	66	67	-	-	-	-	-	-	-	66	-	-	-	-	-	-	-	-	-
Fluoride	mg/L		0.4	0.4	0.4	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-
			0.4	0.4	0.4	-	-	-	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-
Iodine (ICPMS)	µg/L		3.1	5.4	4.9	-	-	-	-	-	-	6.1	-	-	-	-	-	-	-	-	-	-
			2.9	4.9	4.6	-	-	-	-	-	-	-	5.8	-	-	-	-	-	-	-	-	-
Sulfate	mg/L		18.5	18.4	18.3	-	-	-	-	-	-	18.6	-	-	-	-	-	-	-	-	-	-
			18.5	18.4	18.5	-	-	-	-	-	-	-	18.7	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L		<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-	-	-	-
			<0.05	<0.05	<0.05	-	-	-	-	-	-	-	<0.05	-	-	-	-	-	-	-	-	-
Total P (as PO ₄)	mg/L ^(b)		0.1	0.1	0.1	-	-	-	-	-	-	<0.03	-	-	-	-	-	-	-	-	-	-
			0.1	0.1	0.1	-	-	-	-	-	-	-	<0.03	-	-	-	-	-	-	-	-	-
Silica (as SiO ₂)	mg/L		10.3	10.0	9.9	8.8	8.5	7.8	7.5	6.0	6.1	5.8	10.2	10.2	10.2	9.5	9.8	8.9	8.7	8.0	7.2	7.5
			10.2	10.0	9.9	-	-	-	-	-	-	-	6.0	-	-	-	-	-	-	-	-	-
Turbidity	NTU		0.4	0.1	0.2	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-
			0.3	0.1	0.3	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-
pH	S.U.		8.7	8.8	8.8	-	-	-	-	-	-	8.3	8.7	8.7	8.7	-	-	-	-	-	-	8.5
Temperature	°C		9.8	9.1	9.0	-	-	-	-	-	-	10.5	9.6	9.3	9.1	-	-	-	-	-	-	9.4
DO	mg/L		4.1	1.5	1.7	-	-	-	-	-	-	1.9	1.8	2.0	2.2	-	-	-	-	-	-	1.6
ORP	mV		182	181	182	-	-	-	-	-	-	191	207	228	225	-	-	-	-	-	-	242
Total Hardness	mg/L ^(a)		44.2	44.3	44.8	-	-	-	-	-	-	43.9	-	-	-	-	-	-	-	-	-	-
			43.6	44.3	43.6	-	-	-	-	-	-	-	42.8	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L ^(a)		36.7	36.9	37.2	-	-	-	-	-	-	37.0	-	-	-	-	-	-	-	-	-	-
			36.6	37.2	36.8	-	-	-	-	-	-	-	36.1	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L ^(a)		7.5	7.5	7.6	-	-	-	-	-	-	6.9	-	-	-	-	-	-	-	-	-	-
			7.0	7.0	6.8	-	-	-	-	-	-	-	6.7	-	-	-	-	-	-	-	-	-
As (total)	µg/L		39.4	38.5	39.8	45.4	44.0	37.5	35.8	2.7	1.6	2.0	34.6	40.1	40.5	43.1	44.6	46.0	43.9	18.6	13.8	15.9
			39.9	39.7	39.1	-	-	-	-	-	-	-	2.2	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L		-	-	-	-	-	-	-	-	-	40.2	41.9	42.4	-	-	-	-	-	-	-	17.4
As (particulate)	µg/L		-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	<0.1
As (III)	µg/L		-	-	-	-	-	-	-	-	-	27.2	2.3	2.3	-	-	-	-	-	-	-	2.4
As (V)	µg/L		-	-	-	-	-	-	-	-	-	12.9	39.6	40.2	-	-	-	-	-	-	-	15.1
Total Fe	µg/L		<25	<25	<25	-	-	-	-	-	-	<25	<25	<25	<25	-	-	-	-	-	-	<25
			<25	<25	<25	-	-	-	-	-	-	-	<25	-	-	-	-	-	-	-	-	-
Soluble Fe	µg/L		-	-	-	-	-	-	-	-	-	<25	<25	<25	-	-	-	-	-	-	-	<25
Total Mn	µg/L		7.3	<0.1	<0.1	-	-	-	-	-	-	<0.1	9.0	0.4	0.3	-	-	-	-	-	-	0.2
			7.0	<0.1	<0.1	-	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-
Soluble Mn	µg/L		-	-	-	-	-	-	-	-	-	8.8	0.1	<0.1	-	-	-	-	-	-	-	-
Total Al	µg/L		10.0	35.9	38.1	-	-	-	-	-	-	29.9	11.5	25.8	25.3	-	-	-	-	-	-	23.0
			<10	37.6	37.8	-	-	-	-	-	-	-	30.5	-	-	-	-	-	-	-	-	-
Soluble Al	µg/L		-	-	-	-	-	-	-	-	-	4.8	22.7	21.7	-	-	-	-	-	-	-	17.4

(a) as CaCO₃, (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		2/14/2006										4/18/2006			7/26/2006	
Sampling Location		IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	IN	OA	OB	OA	OB
Parameter	Unit															
Bed Volume	BV^3	-	-	-	17.3	18.3	-	-	-	-	17.8	-	-	-	-	-
Alkalinity	mg/L ^(a)	71	67	71	-	-	-	-	-	-	75	-	-	-	-	-
Fluoride	mg/L	0.5	0.5	0.5	-	-	-	-	-	-	0.5	-	-	-	-	-
Iodine (ICPMS)	µg/L	1.2	1.7	1.6	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	19.8	19.5	19.5	-	-	-	-	-	-	19.8	-	-	-	-	-
Sulfide	µg/L	<5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05	-	-	-	-	-
Total P (as PO ₄)	mg/L ^(b)	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Silica (as SiO ₂)	mg/L	10.5	10.3	10.1	9.7	9.5	8.4	8.4	7.6	7.8	7.9	10.0	9.8	10.0	9.8	10.0
Turbidity	NTU	1.2	1.2	1.2	-	-	-	-	-	-	0.7	-	-	-	-	-
pH	S.U.	8.6	8.6	8.5	-	-	-	-	-	-	8.4	-	-	-	-	-
Temperature	°C	8.2	8.1	8.4	-	-	-	-	-	-	8.6	-	-	-	-	-
DO	mg/L	2.7	1.7	1.6	-	-	-	-	-	-	2.0	-	-	-	-	-
ORP	mV	184	188	186	-	-	-	-	-	-	194	-	-	-	-	-
Total Hardness	mg/L ^(a)	54.9	54.0	55.1	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness	mg/L ^(a)	46.4	45.7	46.7	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness	mg/L ^(a)	8.5	8.3	8.4	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	38.5	39.6	39.8	42.0	43.1	47.3	44.2	34.1	30.6	-	38.8	37.7	38.6	42.6	39.9
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	37.6	38.8	39.0	41.4	41.0
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	1.2	<0.1	<0.1	1.2	<0.1
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	24.6	0.4	0.4	6.0	6.3
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	13.0	38.4	38.6	36.7	33.6
Total Fe	µg/L	<25	<25	<25	-	-	-	-	-	-	-	<25	<25	<25	<25	<25
Soluble Fe	µg/L	-	-	-	-	-	-	-	-	-	-	<25	<25	<25	<25	<25
Total Mn	µg/L	8.1	<0.1	<0.1	-	-	-	-	-	-	-	8.5	0.3	0.2	<0.1	<0.1
Soluble Mn	µg/L	-	-	-	-	-	-	-	-	-	-	7.7	0.3	0.2	0.2	0.1
Total Al	µg/L	11.5	35.0	35.9	-	-	-	-	-	-	-	12.9	30.2	30.2	34.8	33.2
Soluble Al	µg/L	-	-	-	-	-	-	-	-	-	-	<10	30.0	30.5	33.2	32.6

(a) as CaCO₃. (b) as PO₄. IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		09/18/06										10/04/06									
Sampling Location	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT	IN	OA	OB	TA	TB	TC	TD	TE	TF	TT
Bed Volume	BV^3	-	-	-	1.5	1.9	-	-	-	-	1.7	-	-	-	3.5	4.5	-	-	-	-	4.0
Alkalinity (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	69	69	69	-	-	-	-	-	-	59
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	0.6	0.6	0.6	-	-	-	-	-	-	0.6
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	19	20	19	-	-	-	-	-	-	24
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	-	-	-	-	-	-	<0.05
Total P (as P)	µg/L	-	-	-	-	-	-	-	-	-	-	32.0	33.2	33.7	-	-	-	-	-	-	<10
Silica (as SiO ₂)	mg/L	10.4	10.2	10.4	0.6	5.3	1.8	2.9	0.6	2.0	1.4	10.6	10.3	10.4	6.1	6.3	3.5	4.2	1.9	3.0	2.5
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	0.4	0.3	0.3	-	-	-	-	-	-	0.3
Total Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	46.5	46.2	45.8	-	-	-	-	-	-	43.6
Ca Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	39.3	39.0	38.9	-	-	-	-	-	-	37.1
Mg Hardness (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	-	7.2	7.2	6.9	-	-	-	-	-	-	6.5
As (total)	µg/L	36.9	32.2	33.3	0.2	<0.1	0.1	<0.1	0.1	<0.1	<0.1	38.5	35.6	36.2	2.4	1.9	0.2	<0.1	0.2	<0.1	0.1
As (soluble)	µg/L	38.7	33.7	35.6	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	37.8	<0.1	<0.1	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	0.9	33.6	35.5	-	-	-	-	-	-	<0.1	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L	<25	<25	<25	-	-	-	-	-	-	<25	<25	<25	<25	-	-	-	-	-	-	<25
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	-	-	<25	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	9.6	<0.1	<0.1	-	-	-	-	-	-	2.1	11.2	<0.1	<0.1	-	-	-	-	-	-	0.8
Mn (soluble)	µg/L	9.8	0.1	<0.1	-	-	-	-	-	-	1.91	-	-	-	-	-	-	-	-	-	-
Al (total)	µg/L	<10	15.2	13.9	-	-	-	-	-	-	<10	<10	<10	<10	-	-	-	-	-	-	<10
Al (soluble)	µg/L	<10	14.1	12.5	-	-	-	-	-	-	<10	-	-	-	-	-	-	-	-	-	-

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		10/18/06									11/08/06									
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Bed Volume	BV^3		-	-	-	5.1	6.6	-	-	-	-	-	-	-	6.7	8.8	-	-	-	-
Alkalinity (as CaCO ₃)	mg/L		-	-	-	-	-	-	-	-	-	71	67	71	67	65	67	65	69	63
Total P (as P)	µg/L		41.0	37.6	37.9	<10	<10	<10	<10	<10	<10	23.4	23.9	23.1	<10	<10	<10	<10	<10	<10
Silica (as SiO ₂)	mg/L		10.5	10.6	10.2	7.6	7.9	4.7	5.8	2.3	3.8	10.3	9.8	10.5	7.8	7.0	4.8	4.6	2.5	3.5
Turbidity	NTU		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.		-	-	-	-	-	-	-	-	-	8.4	8.7	8.7	8.7	8.5	-	-	-	-
Temperature	°C		-	-	-	-	-	-	-	-	-	9.9	10.3	10.1	10.3	10.4	-	-	-	-
DO	mg/L		-	-	-	-	-	-	-	-	-	1.4	0.9	0.9	1.0	0.9	-	-	-	-
ORP	mV		-	-	-	-	-	-	-	-	-	186	183	180	181	182	-	-	-	-
As (total)	µg/L		42.6	39.7	41.0	4.8	6.9	0.3	0.2	0.2	0.1	39.3	38.3	38.5	6.7	6.1	0.4	0.2	0.3	0.2
As (soluble)	µg/L		41.9	40.0	42.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L		0.6	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L		24.3	0.4	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L		17.6	39.6	41.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sampling Date		11/15/06									11/29/06									
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Bed Volume	BV^3		-	-	-	7.2	9.5	-	-	-	-	-	-	-	9.0	11.7	-	-	-	-
Alkalinity (as CaCO ₃)	mg/L		-	-	-	-	-	-	-	-	-	76	70	72	68	78	70	66	68	147
Total P (as P)	µg/L		34.2	33.0	32.3	<10	14.0	<10	<10	<10	<10	34.6	35.1	36.4	15.3	15.9	<10	<10	<10	<10
Silica (as SiO ₂)	mg/L		10.1	9.6	9.9	8.3	7.4	5.2	4.7	2.7	2.9	9.8	9.7	9.7	8.1	7.6	6.5	5.5	4.0	3.9
pH	S.U.		8.6	8.7	8.7	8.7	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	°C		10.9	11.1	11.2	10.9	11.2	-	-	-	-	-	-	-	-	-	-	-	-	-
DO	mg/L		2.0	2.2	1.8	1.5	1.5	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV		179	174	170	171	173	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L		42.3	41.7	39.4	7.8	7.1	0.3	0.2	0.3	0.2	34.9	34.6	35.5	11.1	11.0	0.4	0.4	0.5	0.3
As (soluble)	µg/L		40.8	39.2	39.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L		1.5	2.5	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L		24.8	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L		16.0	38.9	39.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		12/13/06										01/03/07								
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Bed Volume	BV^3		-	-	-	10.7	13.9	-	-	-	-	-	-	-	12.4	16.0	-	-	-	-
Alkalinity (as CaCO ₃)	mg/L		-	-	-	-	-	-	-	-	-	71	71	69	71	67	71	71	69	67
Total P (as P)	µg/L		31.3	26.3	28.5	11.6	<10	<10	<10	<10	<10	31.7	31.3	28.4	12.0	<10	<10	<10	<10	<10
Silica (as SiO ₂)	mg/L		10.1	9.9	9.9	8.7	8.1	7.5	6.2	5.5	5.2	10.2	10.2	10.1	9.1	8.0	8.4	6.7	6.0	5.4
pH	S.U.		8.8	8.6	8.8	8.8	8.8	-	-	-	-	8.6	8.6	8.7	8.7	8.6	8.6	8.4	-	-
Temperature	°C		9.0	9.2	9.0	9.1	9.0	-	-	-	-	8.4	8.1	8.1	8.1	8.2	8.1	8.1	-	-
DO	mg/L		4.0	3.9	3.4	3.7	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-
ORP	mV		171	176	185	186	183	-	-	-	-	150	157	150	157	156	152	158	-	-
As (total)	µg/L		41.3	40.9	40.5	18.7	18.2	1.9	3.0	0.4	0.4	39.5	37.5	37.3	16.3	15.8	1.4	1.7	<0.1	<0.1
As (soluble)	µg/L		41.5	40.9	40.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L		<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L		26.6	0.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L		14.9	40.4	40.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (total)	µg/L		-	-	-	-	-	-	-	-	-	-	<25	<25	<25	<25	<25	<25	<25	<25

Sampling Date		01/16/07										01/31/07								
Sampling Location	Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Bed Volume	BV^3		-	-	-	13.5	17.5	-	-	-	-	-	-	-	14.7	19.1	-	-	-	-
Alkalinity (as CaCO ₃)	mg/L		-	-	-	-	-	-	-	-	-	80	70	70	73	70	73	70	85	70
Total P (as P)	µg/L		<10	<10	<10	<10	<10	<10	<10	<10	<10	33.1	32.6	29.4	13.7	12.4	<10	<10	<10	<10
Silica (as SiO ₂)	mg/L		10.5	10.2	10.4	9.9	8.6	8.5	6.6	6.6	5.2	9.9	10.0	10.0	9.4	9.3	9.0	7.9	7.0	5.8
pH	S.U.		8.7	8.7	8.7	8.7	8.7	8.7	8.6	8.5	8.3	8.7	8.7	8.7	-	-	-	-	8.7	8.4
Temperature	°C		10.1	9.8	10.1	10.7	10.7	10.7	10.3	10.6	10.9	9.0	9.4	9.3	-	-	-	-	9.0	8.9
DO	mg/L		1.9	1.6	1.6	2.2	1.9	1.9	1.7	1.8	1.5	2.3	2.1	2.0	-	-	-	-	1.9	1.8
ORP	mV		151	147	146	147	146	146	149	149	154	165	158	156	-	-	-	-	157	161
As (total)	µg/L		37.1	37.8	35.8	17.0	17.0	2.3	2.6	0.3	0.3	37.1	37.3	37.0	19.2	22.7	4.3	6.0	1.1	1.1
As (soluble)	µg/L		37.4	36.8	36.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L		<0.1	1.0	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L		24.1	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L		13.3	36.5	36.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		02/13/07										02/28/07									
Sampling Location	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF		
Bed Volume	BV^3	-	-	-	15.6	20.5	-	-	-	-	-	-	-	17.0	22.4	-	-	-	-		
Alkalinity (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	73	73	70	70	70	68	68	70	63		
Total P (as P)	µg/L	41.5	41.7	43.2	26.3	27.5	<10	<10	<10	<10	44.9	43.7	43.7	31.9	29.6	13.8	14.2	<10	<10		
Silica (as SiO ₂)	mg/L	10.6	10.8	11.0	10.3	9.5	9.6	7.7	7.6	6.1	11.5	11.4	11.3	10.9	10.5	10.6	9.6	9.3	8.1		
pH	S.U.	8.0	8.6	8.7	-	-	-	-	8.6	8.5	8.6	8.2	8.6	-	-	-	-	8.6	8.5		
Temperature	°C	8.8	8.8	8.9	-	-	-	-	9.0	9	8.6	8.6	9.0	-	-	-	-	9.0	8.9		
DO	mg/L	2.4	2.3	2.7	-	-	-	-	2.4	2.2	2.1	1.7	2.1	-	-	-	-	1.9	1.9		
ORP	mV	164	163	164	-	-	-	-	163	168	156	154	158	-	-	-	-	162	163		
As (total)	µg/L	38.9	39.2	38.4	19.8	22.1	4.1	5.6	0.4	0.5	38.9	37.9	38.5	25.0	26.6	7.9	10.9	1.3	1.4		
As (soluble)	µg/L	41.0	39.8	39.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (particulate)	µg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (III)	µg/L	27.3	0.5	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (V)	µg/L	13.7	39.3	39.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

Sampling Date		03/14/07										03/28/07									
Sampling Location	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF		
Bed Volume	BV^3	-	-	-	18.5	24.5	-	-	-	-	-	-	-	19.8	26.2	-	-	-	-		
Alkalinity (as CaCO ₃)	mg/L	-	-	-	-	-	-	-	-	-	70	68	70	65	65	65	65	65	68		
Total P (as P)	µg/L	39.3	38.2	38.7	26.9	25.1	<10	<10	<10	<10	32.9	32.8	32.0	19.4	17.6	<10	<10	<10	<10		
Silica (as SiO ₂)	mg/L	10.2	10.0	10.2	10.0	9.7	9.6	8.4	8.6	7.0	9.6	9.9	9.5	9.4	9.0	8.8	7.5	7.9	6.0		
pH	S.U.	8.7	8.7	8.7	-	-	-	-	8.7	8.6	8.7	8.7	8.8	-	-	-	-	8.7	8.7		
Temperature	°C	10.3	9.9	9.8	-	-	-	-	9.7	9.9	8.0	8.7	8.4	-	-	-	-	8.3	8.2		
DO	mg/L	2.1	1.9	1.5	-	-	-	-	1.8	1.8	1.6	1.3	1.3	-	-	-	-	1.6	1.6		
ORP	mV	149	159	144	-	-	-	-	147	147	164	153	150	-	-	-	-	150	151		
As (total)	µg/L	39.4	39.2	37.5	24.8	25.7	8.2	9.9	0.4	1.4	41.2	40.5	40.1	26.1	26.4	9.5	11.1	0.6	1.7		
As (soluble)	µg/L	40.2	40.2	39.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (particulate)	µg/L	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (III)	µg/L	25.9	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
As (V)	µg/L	14.3	40.2	39.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		04/11/07										04/25/07								
Sampling Location																				
Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF	
Bed Volume	BV^3	-	-	-	21.1	27.8	-	-	-	-	-	-	-	22.4	29.6	-	-	-	-	
Total P (as P)	µg/L	45.2	45.0	47.7	36.3	32.0	17.6	15.4	<10	<10	35.6	34.1	31.4	25.7	21.5	10.2	<10	<10	<10	
Silica (as SiO ₂)	mg/L	10.0	10.1	9.8	9.7	9.0	9.7	7.9	8.7	6.7	10.5	10.7	10.8	10.2	10.4	10.1	9.3	10.0	8.7	
Turbidity	NTU	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
pH	S.U.	8.1	8.7	8.8	-	-	-	-	8.8	8.7	8.8	8.8	8.8	-	-	-	-	8.8	8.7	
Temperature	°C	8.2	8.8	9.2	-	-	-	-	8.7	9	9.6	9.7	9.7	-	-	-	-	9.7	10	
DO	mg/L	4.4	4.0	3.9	-	-	-	-	3.9	3.5	1.5	2.8	1.1	-	-	-	-	0.9	1.0	
ORP	mV	150	149	149	-	-	-	-	150	153	139	158	162	-	-	-	-	165	171	
As (total)	µg/L	40.6	41.6	40.4	27.8	26.8	11.0	12.4	1.6	3.2	41.8	38.9	38.9	29.1	28.9	13.2	15.0	2.3	4.7	
As (soluble)	µg/L	41.5	40.8	41.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (particulate)	µg/L	<0.1	0.8	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (III)	µg/L	26.7	0.1	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (V)	µg/L	14.8	40.7	40.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Sampling Date		05/09/07										05/23/07								
Sampling Location																				
Parameter	Unit	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF	
Bed Volume	BV^3	-	-	-	23.6	31.1	-	-	-	-	-	-	-	24.7	32.6	-	-	-	-	
Total P (as P)	µg/L	<10	<10	<10	<10	<10	<10	<10	<10	<10	37.1	37.2	36.3	27.5	25.4	14.6	10.6	<10	<10	
Silica (as SiO ₂)	mg/L	10.6	10.2	10.6	10.7	9.4	10.2	8.7	9.5	7.6	10.6	10.9	10.6	10.5	9.9	10.3	9.1	9.7	9.6	
pH	S.U.	8.7	8.7	8.7	-	-	-	-	8.7	8.6	8.8	8.8	8.8	-	-	-	-	8.8	8.8	
Temperature	°C	10.4	10.2	10.1	-	-	-	-	11.1	10.9	10.5	10.3	10.3	-	-	-	-	10.9	10.1	
DO	mg/L	3.5	3.9	3.4	-	-	-	-	2.7	3.3	1.3	1.1	1.1	-	-	-	-	1.0	1.0	
ORP	mV	156	149	145	-	-	-	-	144	139	123	122	123	-	-	-	-	127	127	
As (total)	µg/L	38.3	41.8	41.9	9.6	25.6	12.3	12.9	2.8	4.3	37.9	37.9	38.4	28.0	28.6	13.3	14.0	2.5	2.5	
As (soluble)	µg/L	37.5	39.9	38.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (particulate)	µg/L	0.8	1.9	3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (III)	µg/L	34.5	1.2	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
As (V)	µg/L	3.0	38.7	37.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

Sampling Date		06/06/07										06/19/07							
Sampling Location		IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Parameter	Unit																		
Bed Volume	BV^3	-	-	-	26.0	34.3	-	-	-	-	-	-	-	27.5	36.3	-	-	-	-
Total P (as P)	µg/L	32.0	30.9	32.2	24.7	19.8	11.5	<10	<10	<10	28.1	28.0	27.1	23.8	21.2	14.7	12.7	<10	<10
Silica (as SiO ₂)	mg/L	10.5	10.3	10.3	10.7	9.9	10.1	8.6	9.7	7.6	10.7	10.5	10.5	10.7	10.4	10.3	9.9	9.9	9.4
pH	S.U.	8.7	8.3	8.8	-	-	-	-	8.7	8.4	8.6	8.7	8.8	-	-	-	-	8.8	8.7
Temperature	°C	10.0	10.5	10.6	-	-	-	-	10.6	14.1	12.0	11.6	11.5	-	-	-	-	11.9	11.4
DO	mg/L	2.3	2.5	2.4	-	-	-	-	2.8	7.1	3.7	3.3	2.7	-	-	-	-	3.1	2.9
ORP	mV	162	159	159	-	-	-	-	158	159	151	149	148	-	-	-	-	148	152
As (total)	µg/L	37.0	34.7	34.7	24.5	24.6	12.5	12.6	2.7	4.1	42.0	41.6	41.0	34.2	35.3	20.7	24.7	7.0	11.6
As (soluble)	µg/L	35.3	34.9	34.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	1.6	<0.1	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	25.2	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	10.1	34.8	34.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sampling Date		07/02/07										07/18/07							
Sampling Location		IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Parameter	Unit																		
Bed Volume	BV^3	-	-	-	29.0	38.3	-	-	-	-	-	-	-	30.9	40.8	-	-	-	-
Total P (as P)	µg/L	22.6	18.7	20.3	13.4	<10	<10	<10	<10	<10	31.4	32.3	31.7	26.0	21.3	14.1	10.4	<10	<10
Silica (as SiO ₂)	mg/L	13.3	14.0	13.5	13.6	13.3	13.0	12.0	13.0	11.2	10.4	9.8	10.3	10.0	9.6	9.8	8.6	8.7	8.1
pH	S.U.	8.2	8.8	8.6	-	-	-	-	8.8	8.7	NA	NA	NA	-	-	-	-	NA	NA
Temperature	°C	10.6	10.5	10.5	-	-	-	-	11.0	11.2	NA	NA	NA	-	-	-	-	NA	NA
DO	mg/L	1.1	1.1	0.9	-	-	-	-	1.3	1.2	NA	NA	NA	-	-	-	-	NA	NA
ORP	mV	155	150	147	-	-	-	-	146	146	NA	NA	NA	-	-	-	-	NA	NA
As (total)	µg/L	36.4	35.7	36.3	27.7	26.9	16.2	17.1	5.3	7.8	40.4	41.3	42.4	30.7	30.6	18.7	18.6	7.6	9.0
As (soluble)	µg/L	36.0	36.5	37.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	0.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	27.0	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	9.0	36.2	36.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

IN = At Wellhead, OA= After Oxidation Column (Train A), OB = After Oxidation Column (Train B), TA = After First Adsorption Column in Series (Train A), TB = After First Adsorption Column in Series (Train B), TC = After Second Adsorption Column in Series (Train A), TD = After Second Adsorption Column in Series (Train B), TE = After Third Adsorption Column in Series (Train A), TF = After Third Adsorption Column in Series (Train B), TT = After the Entire System

Table B-1. Analytical Results from Long-Term Sampling, Wales, ME (Continued)

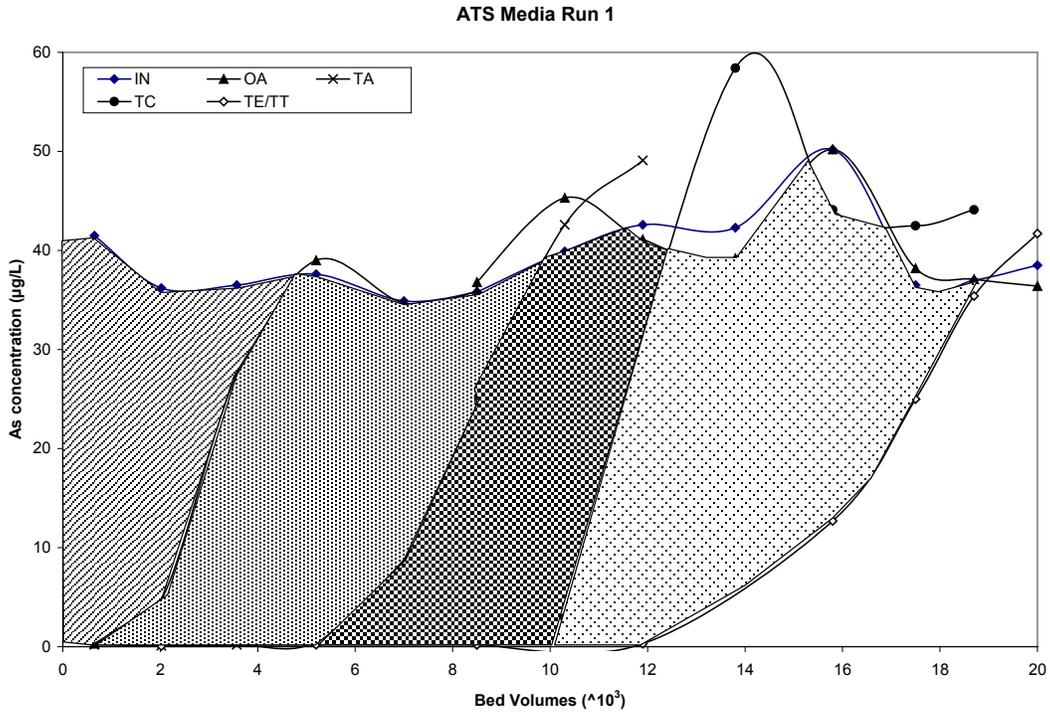
Sampling Date		07/31/07									08/14/07									08/29/07								
Sampling Location		IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF	IN	OA	OB	TA	TB	TC	TD	TE	TF
Parameter	Unit																											
Bed Volume	BV^3	-	-	-	32.2	42.5	-	-	-	-	-	-	-	33.6	44.4	-	-	-	-	-	-	-	34.8	46.0	-	-	-	-
Total P (as P)	µg/L	21.6	22.7	23.2	16.9	13.4	<10	<10	<10	<10	32.8	31.5	31.3	26.3	24.1	17.5	13.3	<10	<10	36.7	36.9	36.6	30.2	24.4	19.4	13.5	<10	<10
Silica (as SiO ₂)	mg/L	10.1	10.2	10.3	10.4	9.8	10.5	9.4	10.0	8.6	10.2	10.1	10.0	9.4	9.4	9.8	8.9	9.3	8.2	10.6	10.2	10.4	10.5	10.3	10.2	9.9	10.2	9.0
pH	S.U.	8.6	8.7	8.8	-	-	-	-	8.8	8.7	8.7	8.6	8.7	-	-	-	-	8.7	8.7	8.7	8.5	8.7	-	-	-	-	8.7	8.7
Temperature	°C	12.5	12.5	12.0	-	-	-	-	12.5	12.5	11.7	11.9	12.1	-	-	-	-	12.0	11.8	12.5	12.3	12.5	-	-	-	-	13.7	12.8
DO	mg/L	1.4	1.3	0.8	-	-	-	-	0.9	0.7	1.6	1.4	1.6	-	-	-	-	1.3	1.3	0.9	1.2	1.0	-	-	-	-	1.1	0.9
ORP	mV	111	117	118	-	-	-	-	104	99	285	315	305	-	-	-	-	308	315	299	307	311	-	-	-	-	319	327
As (total)	µg/L	34.9	36.7	35.2	27.2	26.1	16.7	15.4	6.1	7.6	42.3	40.7	41.5	31.6	30.8	19.2	20.1	7.7	10.2	41.9	39.9	40.4	28.5	27.2	17.3	17.2	6.5	9.0
As (soluble)	µg/L	34.4	35.9	34.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41.6	39.4	40.1	-	-	-	-	-	-
As (particulate)	µg/L	0.6	0.8	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.5	0.3	-	-	-	-	-	-
As (III)	µg/L	33.2	0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33.6	0.3	0.2	-	-	-	-	-	-
As (V)	µg/L	1.2	35.8	34.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.0	39.1	39.9	-	-	-	-	-	-

Sampling Date		12/5/2007		3/25/2008		6/17/2008		9/24/2008		12/3/2008	
Sampling Location											
Parameter	Unit	OA	TT	OA	TT	OA	TT	OA	TT	OB	TT
As (total)	µg/L	40.7	0.6	40.2	9.4	45.8	0.6	38.7	5.2	40.3	7.1
As (soluble)	µg/L	1.6	0.4	1.5	0.1	0.6	<0.1	<0.1	0.1	<0.1	<0.1
As (particulate)	µg/L	39.1	0.2	38.7	9.4	45.2	0.6	40.7	5.1	40.7	7.2
As (III)	µg/L	0.2	0.1	0.8	0.9	1.1	0.5	0.1	0.1	0.3	0.3
As (V)	µg/L	38.9	0.1	37.9	8.5	44.1	0.1	40.6	5.0	40.4	6.9

APPENDIX C

ARSENIC MASS REMOVAL CALCULATIONS

Calculations of arsenic loadings were based on the respective breakthrough curves obtained during the performance evaluation studies. Each arsenic loading value was calculated by dividing the respective arsenic mass represented by the shaded area (see Figure C-1) by the dry weight of the media, i.e., 1.5 ft³, in a column.



NOTE: Breakthrough curves based upon BV of 1.5 ft³ for each column

Figure C-1. Arsenic Mass Removed by ATS and KemIron Media during Runs 1 and 3

The following tables present the calculations of arsenic loadings for each of the oxidation and adsorption columns in each train during the each of the three media runs.

Media Runs 1 and 2 Train A (ATS Media)

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column A	Difference	
0	41.5	0.3	41.1	-
2,000	36.2	4.7	31.5	3,083,155
1,600	36.5	27.5	9.0	1,375,953
1,600	37.6	37.6	0.0	305,767
Total Arsenic Removed by Oxidation Column A				4,764,875

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column A	Difference	
0	41.8	0.4	41.1	-
2,300	39.6	3.0	36.3	3,780,050
2,000	39.6	39.6	0.0	1,632,034
Total Arsenic Removed by Oxidation Column A				5,412,084

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column A	After Adsorption Column A	Difference	
0	0.3	0.2	0.1	-
1,300	4.7	0.1	4.6	129,739
1,600	27.5	0.2	27.3	1,083,776
1,600	39.0	0.5	38.5	2,235,500
1,800	34.7	8.8	25.9	2,461,428
1,500	35.9	24.2	11.7	1,197,589
1,800	45.3	42.6	2.7	550,381
Total Arsenic Removed by Adsorption Column A				7,658,413

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column A	After Adsorption Column A	Difference	
0	3.0	0.3	2.7	-
2,100	42	0.1	41.9	1,988,762
900	37.8	1.9	25.9	1,486,794
1,700	39.9	19.4	20.5	2,035,902
2,000	36.2	36.2	0.0	870,588
Total Arsenic Removed by Adsorption Column A				6,382,046

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column A	After Adsorption Column C	Difference	
0	0.2	0.1	0.1	-
1,800	8.8	0.1	8.7	336,344
1,500	24.2	0.1	24.1	1,044,705
1,800	42.6	2.9	39.7	2,438,495
1,600	49.1	30.0	19.1	1,997,681
Total Arsenic Removed by Adsorption Column C				5,817,225

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column A	After Adsorption Column C	Difference	
0	1.9	1.3	0.6	-
1,700	19.4	0.1	19.3	718,341
2,000	47.0	0.6	46.4	2,790,128
2,500	40.3	17.0	23.3	3,699,998
2,000	45.4	37.5	7.9	1,324,992
Total Arsenic Removed by Adsorption Column C				8,533,459

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column C	After Adsorption Column E	Difference	
0	2.9	0.1	2.8	-
1,600	30.0	0.3	29.7	1,104,160
3,900	44.1	12.7	31.4	5,059,814
1,700	42.5	25.0	17.5	1,765,170
1,200	44.1	35.4	8.7	667,592
Total Arsenic Removed by Adsorption Column E				8,596,736

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column C	After Adsorption Column E	Difference	
0	0.6	0.1	0.5	-
2,500	17.1	0.1	17.0	928,981
2,000	37.5	2.7	34.8	2,199,827
2,100	46.0	18.6	27.4	2,773,565
1,500	47.3	34.1	13.2	1,293,141
Total Arsenic Removed by Adsorption Column E^(c)				7,195,514

Total Run 1

26,837,249

Total Run 2

27,523,103

Media Runs 1 and 2 Train B (ATS Media)

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column B	Difference	
0	41.5	0.5	41.0	-
2,000	36.2	19.9	16.3	2,433,399
1,600	36.5	34.2	2.3	631,919
1,200	37.6	36.6	1.0	84,086
Total Arsenic Removed by Oxidation Column B				3,149,404

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column B	Difference	
0	41.8	0.3	41.5	-
2,300	39.6	3.5	36.1	3,789,818
2,800	39.6	39.6	0.0	2,146,318
Total Arsenic Removed by Oxidation Column B				5,936,136

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column B	After Adsorption Column B	Difference	
0	0.5	0.2	0.3	-
1,300	19.9	0.1	19.8	554,841
1,600	34.2	0.2	34.0	1,827,810
1,200	36.6	4.4	32.2	1,686,817
1,800	34.9	22.8	12.1	1,693,187
1,500	35.1	32.5	2.6	468,206
Total Arsenic Removed by Adsorption Column B				6,230,861

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column B	After Adsorption Column B	Difference	
0	3.5	0.2	3.3	-
2,800	39.9	0.1	39.8	2,562,501
900	36.6	1.2	35.4	1,437,107
1,700	39.4	12.1	27.3	2,263,316
2,000	47.5	30.5	17.0	1,881,319
2,500	39.6	39.6	0.0	902,439
Total Arsenic Removed by Adsorption Column B				9,046,682

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column B	After Adsorption Column D	Difference	
0	0.2	0.1	0.1	-
1,200	4.4	0.1	4.3	112,115
1,800	22.8	0.1	22.7	1,031,965
1,500	32.5	0.5	32.0	3,484,475
1,800	46.6	6.0	40.6	2,774,840
1,600	46.9	30.0	16.9	1,953,514
Total Arsenic Removed by Adsorption Column D				9,356,909

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column B	After Adsorption Column D	Difference	
0	1.2	0.1	1.1	-
1,700	12.1	0.1	12.0	476,488
2,000	30.5	0.3	30.2	1,792,137
2,500	39.7	15.8	23.9	2,871,878
2,000	44.0	35.8	8.2	1,363,213
2,100	44.6	43.9	0.7	396,861
Total Arsenic Removed by Adsorption Column D				6,900,577

Run 1

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column D	After Adsorption Column F	Difference	
0	0.5	0.1	0.4	-
1,800	6.0	0.1	5.9	240,791
1,600	30.3	0.3	29.7	1,209,480
3,900	47.7	12.7	35.0	5,357,937
1,700	43.0	26.2	16.8	1,869,853
1,200	42.5	35.4	7.1	608,987
Total Arsenic Removed by Adsorption Column F				9,287,048

Run 2

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column D	After Adsorption Column F	Difference	
0	0.3	0.1	0.2	-
2,500	15.8	0.4	15.4	828,120
2,000	35.8	1.6	34.2	2,106,398
2,100	43.9	13.8	30.1	2,867,207
1,500	44.2	30.6	13.6	1,391,879
Total Arsenic Removed by Adsorption Column F^(c)				7,193,604

Total Run 1

28,024,222

Total Run 2

29,076,999

Media Run 3 (GFH and CFH-12 Media)

Train A: Filox/GFH

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column A	Difference	
0	36.9	32.2	4.7	-
3,500	38.5	35.6	2.9	564,820
1,600	42.6	39.7	2.9	197,050
1,600	39.3	38.3	1.0	132,499
Total Arsenic Removed by Oxidation Column A				894,369

Train B : Filox/CFH-12

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	Raw	After Oxidation Column B	Difference	
0	36.9	33.3	3.6	-
4,500	38.5	36.2	2.3	563,759
2,100	42.6	41.0	1.6	173,905
2,200	39.3	38.5	0.8	112,115
700	42.3	39.4	2.9	54,996
2,200	35.5	35.5	0.0	135,472
Total Arsenic Removed by Oxidation Column B				1,040,247

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column A	After Adsorption Column A	Difference	
0	32.2	0.2	32.0	-
3,500	35.6	2.4	33.2	4,845,564
1,600	39.7	4.8	34.9	2,313,640
1,600	38.3	6.7	31.6	2,259,282
500	41.7	7.8	33.9	695,409
1,800	34.6	11.1	23.5	2,193,881
1,700	40.9	18.7	22.2	1,649,658
1,700	39.9	16.8	23.1	1,635,219
1,100	37.8	17.0	20.8	1,025,383
1,200	37.3	19.2	18.1	991,196
900	39.2	19.8	19.4	716,642
1,400	37.9	25.0	12.9	960,195
1,400	39.2	24.8	14.4	811,558
1,400	40.5	26.1	14.4	856,149
1,300	41.6	27.8	13.8	778,433
1,300	38.9	29.1	9.8	1,302,909
1,200	41.8	9.6	32.2	1,070,186
1,100	37.9	28.0	9.9	983,340
1,300	34.7	24.5	10.2	554,841
1,300	41.6	34.2	7.4	485,830
1,700	35.7	27.7	8.0	555,902
1,900	41.3	30.7	10.6	750,404
1,300	36.7	27.2	9.5	554,841
1,400	40.7	31.6	8.1	523,202
1,200	39.9	28.5	11.4	496,872
Total Arsenic Removed by Adsorption Column A^(c)				29,010,536

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Oxidation Column B	After Adsorption Column B	Difference	
0	33.3	0.1	33.2	-
4,500	36.2	1.9	34.3	6,449,782
2,100	41.0	6.9	34.1	3,050,030
2,200	38.5	6.1	32.4	3,106,512
700	39.4	7.1	32.3	961,681
2,200	35.5	11.0	24.5	2,653,382
2,200	40.5	18.2	22.3	2,186,237
2,100	38.8	16.2	22.6	2,002,140
1,500	35.8	17.0	18.8	1,318,622
1,600	37.0	22.7	14.3	1,124,545
1,400	38.4	22.1	16.3	909,658
1,900	38.5	26.6	11.9	1,137,710
1,900	37.5	25.7	11.8	956,160
1,900	40.1	26.4	13.7	898,192
1,600	40.4	26.8	13.5	1,028,780
1,800	38.9	28.9	10.0	924,097
1,500	41.9	25.6	16.3	837,675
1,500	38.4	28.6	9.8	831,305
1,800	34.7	24.6	10.1	760,597
1,800	41.0	35.3	5.7	603,891
2,100	36.3	26.9	9.4	673,325
2,500	42.4	30.6	11.8	1,125,394
1,700	35.2	26.1	9.1	754,439
1,900	41.5	30.8	10.7	798,817
1600	40.4	27.2	13.2	811,982
Total Arsenic Removed by Adsorption Column B^(c)				35,904,954

Media Run 3 (GFH and CFH-12 Media)

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column A	After Adsorption Column C	Difference	
0	0.2	0.1	0.1	-
2,000	2.4	0.2	2.2	97,676
1,600	4.8	0.4	4.4	224,229
1,600	6.7	0.4	6.3	363,524
500	7.8	0.3	7.5	146,514
1,800	11.1	0.5	10.6	691,799
1,700	18.7	1.9	16.8	989,073
1,700	16.8	1.5	15.3	1,158,731
1,100	17.0	2.3	14.7	700,717
1,200	19.2	4.3	14.9	754,226
900	19.8	4.1	15.7	584,780
1,400	25.0	7.9	17.1	975,058
1,400	24.8	8.2	16.6	1,001,813
1,400	26.1	9.5	16.6	986,949
1,300	27.8	11.0	16.8	921,974
1,300	29.1	13.2	15.9	902,651
1,200	9.6	12.3	-2.7	336,344
1,100	28.0	13.3	14.7	280,287
1,300	24.5	12.5	12.0	737,027
1,300	34.2	20.7	13.5	920,487
1,700	27.7	16.2	11.5	1,008,608
1,900	30.7	18.7	12.0	948,091
1,300	27.2	16.7	10.5	621,090
1,400	31.6	19.2	12.4	680,757
1,200	28.5	17.3	11.2	601,343
Total Arsenic Removed by Adsorption Column C^(c)				16,633,749

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column B	After Adsorption Column D	Difference	
0	0.1	0.0	0.1	-
2,600	1.9	0.1	1.8	104,895
2,100	6.9	0.2	6.7	379,024
2,200	6.1	0.2	5.9	588,602
700	7.1	0.2	6.9	190,255
2,200	11.0	0.4	10.6	817,503
2,200	18.2	3.0	15.2	1,205,233
2,100	16.2	1.8	14.4	1,319,896
1,500	17.0	2.6	14.4	917,302
1,600	22.7	6.0	16.7	1,056,596
1,400	22.1	5.6	16.5	986,949
1,900	26.6	10.9	15.7	1,299,087
1,900	25.7	9.9	15.8	1,270,846
1,900	26.4	11.1	15.3	1,254,708
1,600	26.8	12.4	14.4	1,009,033
1,800	28.9	15.0	13.9	1,081,652
1,500	25.6	12.9	12.7	847,231
1,500	28.6	14.0	14.6	869,526
1,800	24.6	12.6	12.0	1,016,677
1,800	35.3	24.7	10.6	863,793
2,100	26.9	17.1	9.8	909,658
2,500	30.6	18.6	11.0	1,104,160
1,700	26.1	15.4	10.7	783,317
1,900	30.8	20.1	10.7	863,368
1600	27.2	17.2	10.0	703,265
Total Arsenic Removed by Adsorption Column D^(c)				21,442,579

Run 3 (GFH and CFH-12 Media)

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column C	After Adsorption Column E	Difference	
0	0.5	.04	0.1	-
1,700	1.9	0.4	1.5	57,756
1,700	1.5	0.1	1.4	104,683
1,100	2.3	0.3	2.0	79,415
1,200	4.3	1.1	3.2	132,499
900	4.1	0.4	3.7	131,862
1,400	7.9	1.3	6.6	306,192
1,400	8.2	0.4	7.8	428,074
1,400	9.5	0.6	8.9	496,447
1,300	11.0	1.6	9.4	519,805
1,300	13.2	2.3	10.9	505,153
1,200	12.3	2.8	9.5	560,361
1,100	13.3	2.5	10.8	474,152
1,300	12.5	2.7	9.8	887,575
1,300	20.7	7.0	13.7	992,470
1,700	16.2	5.3	10.9	568,643
1,900	18.7	7.6	11.1	848,292
1,300	16.7	6.1	10.6	599,007
1,400	19.2	7.7	11.5	656,975
1,200	17.3	6.5	10.8	568,218
Total Arsenic Removed by Adsorption Column E^(c)				8,917,580

Total Run 3

54,561,865

Volume Treated (BV) ^(a)	Concentration (µg/L)			Mass Removed (µg) ^(b)
	After Adsorption Column D	After Adsorption Column F	Difference	
0	0.4	0.3	0.1	-
2,200	3.0	0.4	2.6	126,129
2,100	1.8	0.1	1.7	191,742
1,500	2.6	0.3	2.3	127,403
1,600	6.0	1.1	4.9	244,614
1,400	5.6	0.5	5.1	297,274
1,900	10.9	1.4	9.5	589,027
1,900	9.9	1.4	8.5	726,198
1,900	11.1	1.7	9.4	631,919
1,600	12.4	3.2	9.2	722,163
1,800	15.0	4.7	10.3	745,308
1,500	12.9	4.3	8.6	601,980
1,500	14.0	2.5	11.5	768,241
1,800	12.6	4.1	8.5	764,419
1,800	24.7	11.6	13.1	825,572
2,100	17.1	7.8	9.3	998,840
2,500	18.6	9.0	9.6	1,003,299
1,700	15.4	7.6	7.8	628,097
1,900	20.1	10.2	9.9	714,094
1600	17.2	9.0	8.2	614,932
Total Arsenic Removed by Adsorption Column F^(c)				11,321,252

Total Run 3

68,668,785

(a) 1 BV = 1.5 ft³ = 11.22 gal = 42.46771 L

(b) Mass Removed (µg) = average difference in concentration (µg/L) x Volume Treated (BV) x 42.4677 (L/BV)

(c) Column did not reach capacity before end of evaluation.

ATS Media in each column = 33,034,091 mg based on a bulk density of 51 lb/ft³ and a moisture content of 5%.

Filox Media in each column = 77,727,272 mg based on a bulk density of 114 lb/ft³. Moisture content not available.

GFH Media in each column = 26,913,818 mg based on a bulk density of 79 lb/ft³ and a moisture content of 50%.

CFH-12 Media in each column = 41,236,363 mg based on a bulk density of 72 lb/ft³ and a moisture content of 16%.