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Arsenic Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at Bow, NH Final Performance Evaluation Report

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed during and the results obtained from the U.S. Environmental Protection Agency (EPA) arsenic removal treatment technology demonstration project at the White Rock Water Company (WRWC) public water system, a small residential drinking water facility in Bow, NH. The main objective of the project was to evaluate the effectiveness of the ADI International, Inc. (ADI), located in New Brunswick, Canada, G2 media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 μg/L. Additionally, this project evaluated: 1) the reliability of the treatment system for use at small water facilities, 2) the required system operation and maintenance (O&M) and operator skill levels, and 3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and process residuals generated by the treatment system. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

After engineering plan review and approval by the state, the ADI arsenic removal system was installed and put into service on October 13, 2004. The system consisted of two vertical, 72-in-diameter and 72-in-sidewall-height stainless steel vessels configured in series. The adsorption vessels were originally designed to operate in parallel for the Holiday Acres Mobile Home Park in Allenstown, NH, with a flowrate of 70 gal/min (gpm) or 35 gpm per vessel. Due to switching to the site in Bow, which had a total well production of about 40 gpm, the system was reconfigured to operate in series. At 40 gpm, each vessel provided an empty bed contact time (EBCT) of 16 min or 32 min total contact time and a hydraulic loading rate of 1.4-gpm/ft^2. The EBCT was 60% longer and the hydraulic loading rate was about 50% lower than recommended by the manufacturer for the G2 media.

The G2 media is a granular media with a calcined diatomite substrate coated with ferric hydroxide. Because of its inherently high pH value from the manufacturing process, the G2 media had to be conditioned onsite with sulfuric acid (H_2SO_4) before service. In repeated, but unsuccessful, attempts to improve media performance, the raw water pH was progressively lowered from an average of 7.3 to 6.8, 6.4, and 6.0 using a 93% H_2SO_4 solution. The treated water pH was readjusted to 7.5 using 25% caustic sodium hydroxide (NaOH) solution before entering the two 15,000-gal storage tanks and distribution system. Inline pH probes were used to monitor pH values of the feed and treated water but the rates of acid and caustic additions were controlled via manual adjustments to the pump stroke length. The relative feed rates were then flow-paced with a magnetic flow meter located on the discharge line following the treatment system. Operational difficulties with the inline pH probes were encountered throughout the study, with acid inline pH probe readings being about 0.4 pH units lower and the inline caustic probe readings being at least 1.0 pH unit higher throughout the entire study period, compared to those measured by a more reliable handheld field pH meter.

The treatment system was operated in three configurations under three separate test runs. Run 1, with both vessels configured in series, ran for 3,714 hr from October 13, 2004, through November 29, 2005. The system removed arsenic from an average of 46.4 μg/L, present almost entirely as As(V), to <10 μg/L for about 3,890,000 gal or 3,050 bed volumes (BV) of throughput. Treated water arsenic levels spiked to 37.5 μg/L immediately after system startup though they leveled off to about 15 μg/L following the lead vessel and about 5 μg/L following the lag vessel at approximately 800 BV. Arsenic concentrations at >10 μg/L continued to be observed in all samples taken following the lead vessel until reaching the influent level by the end of the test run. Further, elevated manganese (as high as 35.8 μg/L) and silica concentrations (as high as 61.8 mg/L [as SiO_2]) were measured in the effluent of both vessels immediately after system startup. The elevated arsenic, manganese, and silica levels were believed to have been caused, in part, by leaching of the elements present either as impurities (i.e., arsenic and

manganese) or a substrate (silica). Short circuiting in the media bed also was considered a potential cause, but could not be confirmed from the test data.

After rebedding of both vessels in late December 2005, Run 2 with only Vessel A in service ran from January 13 through April 14, 2006, for 119 hr and Run 3 with only Vessel B in service ran from April 15 through September 26, 2006, for 2,705 hr. Similar observations made in Run 1 also were made in Runs 2 and 3. For Run 2, arsenic concentrations, after an initial spike, progressively decreased to <10 μg/L for only two weekly sampling events (1,100 BV) before steadily increasing to 15.2 μg/L. For Run 3, after an initial spike, arsenic concentrations decreased to 1.2 μg/L before breaking through at the 10-μg/L level after treating approximately 1,900,000 gal or 3,000 BV of water. During this run, well flows were reduced 88, 20, and 18% for Wells 1, 2, and 3, respectively, and overall system flows were kept from 15 to 35 gpm on average, depending on which well(s) were running.

The system was backwashed only three times because of low headloss (i.e., 1 to 2 pounds per square inch [psi]) across each filter. Analysis of the backwash water indicated that soluble As concentrations were 11 to 40 μg/L higher than the levels in the finished water. Because the finished water was used for backwash, some arsenic appeared to have been desorbed from the media during backwashing.

Comparison of the distribution system sampling results before and after system startup showed a decrease in arsenic concentration at all three Lead and Copper Rule (LCR) sampling locations until the media reached capacity. Initially, the arsenic concentrations in the distribution system were about twice those at the entry point, suggesting some solubilization, destablization, and/or desorption taking place in the distribution system. Afterwards, arsenic concentrations closely mirrored those measued at the entry point. Manganese concentrations in the distribution system generally followed those measured at the entry point. Immediately after start of the runs, two to five times higher manganese concentrations were observed at the entry point than in the distribution system. Due to slow oxidation kinetics in the presence of chlorine, some soluble managenes might have been precipitated into MnO_2 after water entered the storage tanks and distribution system.

Following a drop in pH of the treated water in December 2004 and an operational error on the caustic feed pump, the lead concentration in the January 12, 2005 sample increased to 9.9 μg/L at one sampling location and copper levels increased across all three sampling locations, with the most noticeable increase exceeding the action level of 1.3 mg/L at one location. During subsequent sampling events, the pH values were better controlled; however, the lead and copper levels continued to be more elevated than those observed before the pH drop in January 2006.

The most significant operational issue during this study was the need for the addition of acid and caustic to maintain the desired pH ranges of the feed water to the treatment system and the finish water to the storage tanks and distribution system. Confounding the proper chemical dosing were continuing discrepancies observed in pH readings from the inline pH probes versus the field meter. In fact, an inadvertent lowering of the caustic addition in late December resulted in the pH drop observed in the distribution system samples collected on January 12, 2005, and the corresponding increase in lead and copper levels in the distribution system as described above.

The capital investment for the treatment system was $166,050, including $105,350 for equipment, $17,200 for site engineering, and $43,500 for installation. Using the system's actual capacity of 40 gpm (57,600 gal per day [gpd]), the capital cost was $4,150/gpm ($2.88/gpd). These calculations did not include the cost of the building construction, which was approximately $25,000 funded by WRWC.

The O&M cost associated with the G2 media system was approximately $5.11/1,000 gal of water treated, including $4.30 for media replacement and disposal, $0.47 for chemical supply, and $0.34 for labor. Incremental costs for electricity were negligible. Media replacement and disposal cost for both vessels was $16,752, with 44% being the media cost. Based on an annual production of 8,530,000 gal of water, it is estimated that the G2 system will require 2.2 media changeouts per year for a total annual cost of $36,680 for the media and $4,009 of chemical cost for pH adjustment.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AA	activated alumina
AAL	American Analytical Laboratories
ADI	ADI International, Inc.
Al	aluminum
AM	adsorptive media
As	arsenic
BV	bed volume(s)
C/F	coagulation/filtration
Ca	calcium
Cl_2	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gal	gallons
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HAMHP	Holiday Acres Mobile Home Park
HDPE	high-density polyethylene
hr	hours
hp	horsepower
H_2SO_4	sulfuric acid
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Consumers Association
Mg	magnesium
mg/L	milligrams per liter
μg/L	micrograms per liter

ABBREVIATIONS AND ACRONYMS (Continued)

min	minutes
Mn	manganese
Mo	molybdenum
mV	millivolts
N/A	not analyzed
Na	sodium
NA	not available
NaOCl	sodium hypochlorite
NaOH	sodium hydroxide
NHDES	New Hampshire Department of Environmental Services
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
NTU	nephlemetric turbidity unit
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
Pb	lead
PM	process modification
PO_4	orthophosphate
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SiO_2	silica
SO_4	sulfate
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
V	vanadium
VOC	volatile organic compound
WRWC	White Rock Water Company

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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 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 text on March 25, 2003, to express the MCL as 0.010 mg/L (10 μg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in 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. Holiday Acres Mobile Home Park (HAMHP) in Allenstown, NH, was originally selected as one of the 17 Round 1 host sites for the demonstration program.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving 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. The ADI International, Inc. (ADI) G2 adsorptive media was selected for the Allenstown site. In January 2004, HAMHP decided to withdraw from the demonstration study due to the facility's decision to switch to an alternate public water supply source.

In March 2004, EPA decided to replace HAMHP with the White Rock Water Company (WRWC) public water system, operated by C&C Water Services, serving the community of Village Shore Estates at Bow, NH. Because the design flowrate for the WRWC system was about half of the flowrate at HAMHP, the ADI adsorption system was reconfigured to operate in series, increasing the empty bed contact time (EBCT) from 16 to 32 min total (i.e., 16 min per vessel, two vessels in series).

Following a series of predemonstration activities including engineering design, permitting, and system installation, startup and shakedown, the performance evaluation of the system began on October 13, 2004, and was completed on September 26, 2006.

1.2 Treatment Technologies for Arsenic Removal

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

Table 1-1. Summary of Arsenic Removal Demonstration Technologies and Source Water Quality Parameters

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

AM = adsorptive media; C/F = coagulation/filtration; IX = ion exchange process;
MDWCA = Mutual Domestic Water Consumer's Association; PM = process modification;
STMGID = South Truckee Meadows General Improvement District;
STS = Severn Trent Services; WRWC = White Rock Water Company
(a) System reconfigured from parallel to series operation due to a lower flowrate of 40 gal/min (gpm) at WRWC site.
(b) Arsenic existing mostly as As(III).
(c) Iron existing mostly as soluble Fe(II).
(d) System reconfigured from parallel to series operation due to reduced flowrate of 30 gpm.

1.3 Project Objectives

The objective of the Round 1 arsenic demonstration program was to conduct 12 full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives of the demonstration study in Bow, NH were to:

- Evaluate the performance of the G2 adsorptive media for arsenic removal on small systems.
- Determine the required system operation and maintenance (O&M) and operator skill levels.

- Characterize process residuals produced by the technology.
- Determine the capital and O&M cost of the technology.

This report summarizes the performance of the ADI G2 system in Bow, NH, from October 13, 2004 through September 26, 2006. 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.

2.0 SUMMARY AND CONCLUSIONS

Based on the information collected during the demonstration, the following is a summary and the conclusions drawn from the performance and cost study of the treatment technology.

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

- ADI's G2 media is not effective in removing arsenic to below 10 μg/L from the water tested. The useful media life is short (i.e., 3,000 bed volumes [BV]) even with the use of pH adjustment to lower the pH values of feed water to 6.0. Lowering the feed water pH appears to have little effect on arsenic concentrations in the treated water.
- Impurities such as arsenic and manganese can be leached from the G2 media. Concentrations as high as 30.6 μg/L for arsenic and 39.1 μg/L for manganese were detected in the treated water immediately after the test runs began. A significant amount of arsenic, possibly over 0.8 mg/g of media, might have been attached onto the media surface before the media was put into service. Arsenic and manganese were introduced to the media via the use of impurity-laden $FeCl_3$ during the media manufacturing process.
- Leaching of silica from the diatomite substrate also can occur. Silica as high as 61.8 mg/L (as SiO_2) was measured in the treated water immediately after the start of each test run. Leaching leveled off after about 2,000 BV of throughput but continued throughout the remainder of the test runs.
- Changing pH conditions at the entry point can cause changes in lead and copper concentrations in the distribution system. A loss of pH control resulted in lower than normal pH values in the distrubution system, causing a significant increase in the lead and copper levels with the copper concentration at one location exceeding its action level of 1.3 mg/L. Other than a few exceptions, arsenic, iron, and manganese concentrations in the distribution system closely mirrored those in the plant effluent.
- The G2 media does not have any chlorine demand, as evident by the similar levels of total and free chlorine residuals measured before and after the adsorption vessels.

Required system O&M and operator's skill levels:

- Generally, the operation of the G2 system does not require additional skills beyond those necessary to operate the preexisting treatment equipment. The daily demand on the system operator is typically about 20 min to inspect the system and record operational parameters.
- Based on the size of the population served and the treatment technology, the State of New Hampshire requires Level 1A Certification for operation of the treatment system and is considering upgrading this requirement to Level 1 certification.
- A significant O&M issue is the need for acid and caustic addition to maintain the desired pH ranges of the feed and finished water.

Process residuals produced by the technology:

- Residuals produced by the G2 system include backwash water and spent media.
- The system does not need to be backwashed if pressure drop across the vessels is low (i.e., 1 to 2 psi). The system was backwashed only three times during the demonstration study.

- The spent media can be disposed of in a non-hazardous waste landfill based on the result of a Toxicity Characteristic Leaching Procedure (TCLP) test.

Cost of the technology:

- The capital cost is $4,150/gpm ($2.88/gpd) based on the system's actual capacity of 40 gal/min (gpm) (57,600 gal/day [gpd]), which does not include the cost of the treatment building.
- Although the G2 media cost is low (i.e., $0.75/lb), the operational cost is high (i.e., $5.11/1,000 gal). The high operational cost is due to the very short media life and high chemical cost for pH adjustment.
- The media replacement cost is the most significant add-on operational cost. Replacing media in both lead and lag vessels at the same time instead of only the lead vessel seems to be necessary due to limited media capacity. The cost of replacing 170 ft^3 of G2 media is $16,752 or $4.30/1,000 gal of water treated.

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 ADI adsorption system began on October 13, 2004. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was determined based on its ability to consistently remove arsenic to the target MCL of 10 μg/L through the collection of water samples across the treatment train. 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.

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

The quantity of aqueous and solid residuals generated was estimated by tracking the volume of backwash water produced during each backwash cycle and the need to replace the media upon arsenic breakthrough. Backwash water was sampled and analyzed for chemical characteristics.

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

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	April 22, 2004
Revised Vendor Quotation Submitted to Battelle	May 10, 2004
Purchase Order Modification Completed	June 10, 2004
Engineering Package Submitted to NHDES	June 14, 2004
Steel Floor for Treatment System Installed	June 25, 2004
Adsorption Vessels Delivered to Site	June 28, 2004
Permit Issued by NHDES	August 23, 2004
Draft Study Plan Issued	September 2, 2004
System Installation Completed	September 13, 2004
Final Study Plan Issued	October 6, 2004
Media Conditioning and System Shakedown Completed	October 11, 2004
Performance Evaluation Begun	October 13, 2004

NHDES = New Hampshire Department of Environmental Services.

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

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a daily basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet; checked the sodium hypochlorite (NaOCl), sulfuric acid (H_2SO_4), and sodium hydroxide (NaOH) levels; and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if the vendor 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 required, on a Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured several water quality parameters on-site, including pH, temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), and total and free chlorine, and recorded the data on a Water Quality Parameters Log Sheet. Backwash data also were recorded on a Backwash 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 the media replacement and spent media disposal, chemical and electricity consumption, and labor. Consumption of NaOCl, H_2SO_4, and NaOH was tracked on the Daily System Operation Log Sheet. Electricity consumption was determined from utility bills. Labor for various activities, such as 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; replenishing the NaOCl, H_2SO_4, and NaOH solutions; 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 the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate system performance, samples were collected at the wellhead, across the treatment plant, during backwash, and from the distribution system. The sampling schedule and analytes measured during each sampling event are listed in Table 3-3. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the initial visit to the site, one set of source water samples was collected and speciated using an arsenic speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water. During the system performance evaluation study, water samples were collected across the treatment train by the plant operator. At the beginning of the study, samples were collected biweekly on an eight-week cycle. For the first three biweekly events, treatment plant samples were collected at four locations, i.e., after wells combined (IN), after chlorination and pH adjustment (AP), after Vessel A (TA), and after Vessel B (TB), and analyzed for the analytes listed under the biweekly treatment plant analyte list (see Table 3-3). For the fourth biweekly event (or once every eight weeks), treatment plant samples collected at the same four locations were speciated for arsenic and analyzed for the analytes listed in Table 3-3 under the bimonthly treatment plant analyte list. The sampling frequency was reduced from weekly as stated in the Study Plan to biweekly following the first month of system operations.

After the media changeout, treatment plant samples were collected on a weekly basis from IN, AP, and the vessel that was on-line (i.e., TA from January 17 through April 17, 2006, and TB from April 18, 2006 through September 26, 2006). For the first three weekly events, samples were collected for the analytes listed under the weekly treatment plant analyte list in Table 3-3. For the fourth weekly event, samples were collected at the same three locations and speciated for arsenic and analyzed for the analytes listed in Table 3-3 under the monthly treatment plant analyte list.

3.3.3 Backwash Water. One set of backwash water samples was collected on January 11 and April 12, 2005, and two sets were collected on June 14, 2005, at both the beginning and the end of the backwash cycle, from the sample taps located at the backwash water discharge line from each vessel. Unfiltered samples were measured on site for pH using a field pH meter (see Section 3.5), and collected in 1-gal sample bottles for total dissolved solids (TDS) and turbidity measurements. Filtered samples using 0.45-µm filters were analyzed for soluble As, Fe, and Mn. Arsenic speciation was not performed for the backwash water samples.

3.3.4 Residual Solids. Residual solids included backwash solids and spent media samples. Due to low solids in the backwash water, solids were not collected from any of the three backwash events.

Two spent G2 media samples were collected from each vessel when the media was removed on December 23, 2005. One media sample was removed from the top and bottom of each media bed using a wet/dry vacuum that was thoroughly cleaned and disinfected prior to use. The media removed from each layer was well-mixed and stored in a 1-gal wide-mouth high-density polyethylene (HDPE) bottle. The spent media sample from the top of the lead vessel (TA) was analyzed for metals detailed in Table 3-3. The plant operator also submitted a sample of the spent media for TCLP tests.

Table 3-3. Sample Collection Schedule and Analyses

Sample Type	Sample Locations[(a)]	No. of Samples	Frequency	Analytes	Date(s) Samples Collected
Source Water	Storage tanks	1	Once during initial site visit	On-site: pH, temperature, DO, and ORP Off-site: As(III), As(V), As (total and soluble), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), Mo (total and soluble), Sb (total and soluble), V(total and soluble), Na, Ca, Mg, Cl, F, SO_4, S^{2-}, SiO_2, PO_4, TOC, and alkalinity	04/22/04
Treatment Plant Water	After wells combined (IN), after chlorination and pH adjustment (AP) , after Vessel A (TA), and after Vessel B (TB)	4	Biweekly	On-site: pH, temperature, DO, ORP, Cl_2 (free and total)[(b)] Off-site: As (total), Fe (total), Mn (total), SiO_2, PO_4, turbidity, and alkalinity	10/19/04, 10/26/04, 11/02/04, 11/16/04, 11/30/04, 01/04/05, 01/18/05, 02/15/05, 03/01/05, 03/15/05, 04/12/05, 04/26/05, 06/07/05, 06/21/05, 08/02/05, 08/16/05, 08/30/05, 09/13/05, 09/27/05, 10/25/05, 11/08/05, 11/29/05
			Bimonthly	On-site: pH, temperature, DO, ORP, and Cl_2 (free and total)[(b)] Off-site: As(III), As(V), As(total and soluble), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, PO_4, turbidity, and alkalinity	10/13/04, 12/14/04, 02/01/05, 03/29/05, 05/10/05, 07/05/05. 10/11/05
	IN, AP, and TA (from 01/17/06 through 04/11/06) IN, AP, and TB (from 04/18/06 through 09/26/06)	3	Weekly	On-site: pH, temperature, DO,ORP, Cl_2 (free and total)[(b)] Off-site: As (total), Fe (total), Mn (total), SiO_2, PO_4, turbidity, and alkalinity	01/31/06, 02/07/06, 02/14/06, 02/28/06, 03/07/06, 03/14/06, 03/28/06, 04/04/06, 04/11/06, 04/25/06, 05/02/06, 05/09/06, 05/23/06, 05/30/06, 06/06/06, 06/20/06, 06/27/06, 07/05/06, 07/11/06, 07/18/06, 07/25/06, 08/01/06, 08/08/06, 08/15/06, 08/22/06, 08/29/06, 09/05/06, 09/12/06, 09/19/06, 09/26/06

Table 3-3. Sample Collection Schedule and Analyses (Continued)

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Date(s) Samples Collected
Treatment Plant Water (continued)	IN, AP, and TA (from 01/17/06 through 04/11/06) IN, AP, and TB (from 04/18/06 through 09/26/06)	3	Monthly	On-site: pH, temperature, DO, ORP, and Cl_2 (free and total)[b] Off-site: As(III), As(V), As(total and soluble), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, PO_4, turbidity, and alkalinity	01/17/06, 01/24/06, 02/21/06, 03/21/06, 04/18/06, 05/16/06, 06/13/06
Distribution Water	Three residences previously used as LCR sampling locations	3	Monthly	pH, alkalinity, As, Fe, Mn, Pb, and Cu	Baseline sampling[c]: 07/21/04, 08/05/04, 08/18/04, 09/08/04 Monthly sampling: 11/03/04, 12/08/04, 01/12/05, 02/09/05, 03/09/05, 04/20/05, 05/11/05, 06/08/05, 07/12/05, 08/03/05, 09/14/05, 10/11/05, 11/02/05, 01/18/06, 02/15/06, 03/15/06, 04/12/06, 06/21/06
Backwash Water	Sample ports on backwash discharge line from each vessel	2	During each backwash event	TDS, turbidity, pH, As (soluble), Fe (soluble), and Mn (soluble)	01/11/05 04/12/05 06/14/05
Spent Media	Top layer of TA (lead vessel)	1	During media changeout	Al, As, Mn, Ca, Mg, Fe, Si, P	12/23/05

(a) Abbreviation in each parenthesis corresponding to sample location in Figure 4-5.
(b) Taken only at AP, TA, and TB locations.
(c) Four baseline sampling events performed before system became operational.

3.3.5 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 arsenic, lead, and copper levels. Prior to start-up from July through September 2004, four sets of baseline distribution water samples were collected at three Lead and Copper Rule (LCR) locations within the distribution system. Following system startup, distribution system sampling continued on a monthly basis at the same three locations for approximately a year and a half.

The homeowners collected samples following an instruction sheet developed according to the *Lead and Copper Rule Reporting Guidance for Public Water Systems* (EPA, 2002). The dates and times of last water usage before sampling and sample collection were recorded for calculation of the stagnation time. All samples were collected from cold-water faucets that had not been used for at least 6 hr to ensure that stagnant water was sampled.

3.4 Sampling Logistics

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

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

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, color-coded label consisting of sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for a specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code 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 ziplock™ bags and packed in a cooler.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/addressed FedEx air bills, ice packs, and bubble wrap, were included. 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 metals analyses were stored at Battelle's inductively coupled plasma-mass spectrometry (ICP-MS) laboratory. Samples for other water quality analyses were packed in a cooler and picked up by a courier from American Analytical Laboratories (AAL) in Columbus, OH, which was under contract with Battelle for this demonstration study. The chain-of-custody forms remained with the samples from the time of preparation through analysis and final disposition. All samples were archived by the appropriate laboratories for the respective duration of the required hold time, and disposed of properly thereafter.

3.5 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle ICP-MS laboratory and AAL. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limit (MDL), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80 to 120%, and completeness of 80%). The 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. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

The WRWC public water system is operated by C&C Water Services and supplies water to 96 homes in the community of Village Shore Estates at Bow, NH. The facility is located on a wooded lot at 6 Rocky Point Drive, Bow, NH. Figure 4-1 shows the small underground structure that housed the existing water system components prior to installation of the ADI adsorption system. The water source is groundwater from three on-site bedrock wells (Wells 1, 2, and 3). The total flowrate from the three wells is approximately 40 gpm at startup, based on the information provided by the plant operator. The well pumps are activated based on the water level in two 15,000-gal storage tanks (Figure 4-2) housed in a separate underground structure located about 50 ft from the treatment and control structure. Prior to the beginning of the demonstration study, the system was estimated to run approximately 6 to 8 hr/day with an average daily use rate of 15,000 to 20,000 gpd. The preexisting treatment process included the addition of a dilute NaOCl solution for disinfection and a caustic solution (NaOH) to raise pH to make the treated water less corrosive in the distribution system. Approximately 10 to 15% of the total flow also was treated with a small activated alumina (AA) system, shown in Figure 4-3, which had been at the site for many years. The AA system was removed from the site prior to installation of the ADI adsorption system.

Figure 4-1. Preexisting Underground Treatment and Control Structure

4.1.1 Source Water Quality. Source water samples were collected on April 22, 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 New Hampshire Department of Environmental Services (NHDES), are presented in Table 4-1.

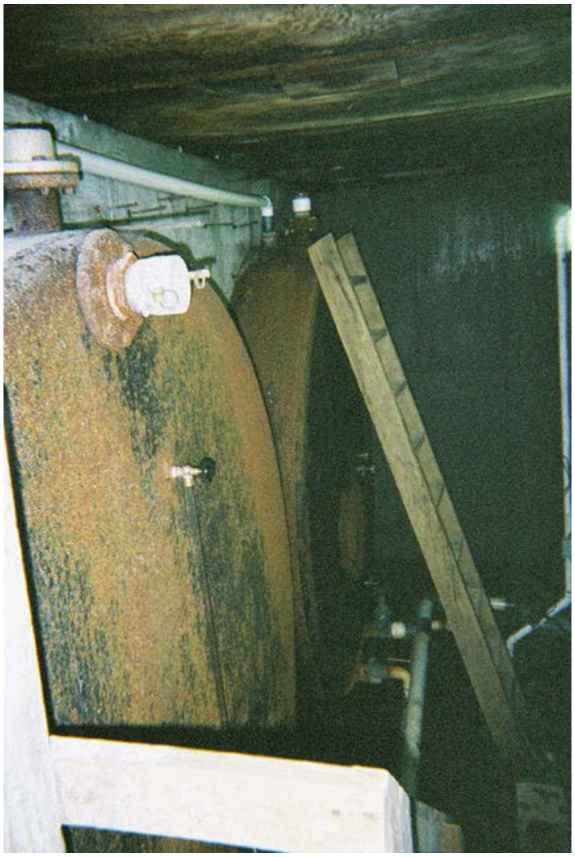


Figure 4-2. Preexisting Storage Tanks in Underground Concrete Structure

Figure 4-3. Preexisting Activated Alumina System in Underground Treatment and Control Structure

Table 4-1. WRWC Water Quality Data

Parameter	Unit	EPA Raw Water Data[a]	Battelle Raw Water Data	NHDES Raw Water Data[b]	NHDES Treated Water Data[c]
Sampling Date		06/10/98	04/22/04	06/02	12/29/99–04/26/04
pH	–	7.7	6.8	N/A	7.6–7.8
Total Alkalinity (as $CaCO_3$)	mg/L	56.0	54.0	N/A	N/A
Hardness (as $CaCO_3$)	mg/L	83.0	92.7	N/A	N/A
Turbidity	mg/L	0.4	N/A	N/A	N/A
Chloride	mg/L	N/A	41.0	N/A	34–35
Fluoride	mg/L	0.8	0.6	N/A	0.9–1.0
Sulfide	mg/L	N/A	N/A	N/A	N/A
Sulfate	mg/L	15.5	12.0	N/A	11–12
Nitrate-Nitrite (as N)	mg/L	0.3	N/A	N/A	N/A
Silica (as SiO_2)	mg/L	N/A	19.7	N/A	N/A
Orthophosphate (as P)	mg/L	N/A	<0.10	0.019–0.076	N/A
TOC	mg/L	1.0	<0.7	<0.5	N/A
As(total)	µg/L	44.2	39.2	32–47	36.3–47
As (soluble)	µg/L	44.9	44.1	N/A	N/A
As (particulate)	µg/L	N/A	<0.1	N/A	N/A
As(III)	µg/L	0.5	0.5	N/A	N/A
As(V)	µg/L	44.4	43.6	N/A	N/A
Fe (total)	µg/L	60.0	<25	N/A	<50
Fe (soluble)	µg/L	N/A	<25	N/A	N/A
Al (total)	µg/L	<400	<10	N/A	N/A
Al (soluble)	µg/L	N/A	<10	N/A	N/A
Mn (total)	µg/L	25.0	2.1	N/A	<5
Mn (soluble)	µg/L	N/A	1.5	N/A	N/A
V (total)	µg/L	N/A	0.6	N/A	N/A
V (soluble)	µg/L	N/A	0.6	N/A	N/A
Mo (total)	µg/L	N/A	1.9	N/A	N/A
Mo (soluble)	µg/L	N/A	3.0	N/A	N/A
Sb (total)	µg/L	N/A	0.2	N/A	<3
Sb (soluble)	µg/L	N/A	0.7	N/A	N/A
Na	mg/L	N/A	17.0	N/A	16.6–17.5
Ca	mg/L	24.7	28.3	18.2–39.7	N/A
Mg	mg/L	5.2	5.3	3.5–7.1	N/A

(a) Results of source water sample collected in 1998.
(b) Raw water samples from Wells 1, 2, and 3 separately.
(c) Blended water from Wells 1, 2, and 3 as treated water.
N/A = not analyzed.

Total arsenic concentrations of source water ranged from 32 to 47 μg/L. Based on the April 22, 2004 speciation results, the majority of arsenic existed as As(V), with only a small amount (i.e., 0.5 μg/L) present as As(III).

pH values of raw water ranged between 6.8 and 7.7, higher than the desired range of 6.0 to 7.0 indicated by ADI for using the G2 media.

Concentrations of iron (<25 to 60 μg/L) and other ions in raw water were low enough that pretreatment prior to the adsorption process would not be required. The concentrations of orthophosphate and silica also were sufficiently low (i.e., <0.1 mg/L [as PO_4] and 19.7 mg/L [as SiO_2], respectively) and, therefore, not expected to affect As adsorption on the G2 media.

4.1.2 Predemonstration Treated Water Quality. Table 4-1 also presents historic treated water quality data collected in compliance with the state monitoring and reporting requirements. Because the treatment process prior to distribution included only chlorination and caustic addition, concentrations in the treated water were very similar to those of raw water. Total arsenic concentrations in the treated water ranged from 36.3 to 47 μg/L. Iron and manganese concentrations were below the respective detection limits of 50 and 5 μg/L. pH values of the treated water ranged from 7.6 to 7.8.

4.1.3 Distribution System. The distribution system serving the community of Village Shore Estates 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 are primarily PVC and some copper pipe. According to the plant operator, a few homes may have pipe with lead solder, but no homes have lead pipe.

Compliance samples from the distribution system are collected monthly for bacterial and yearly for volatile organic compounds (VOCs). Under the EPA LCR, samples are collected from customer taps at five residences every three years.

4.2 Treatment Process Description

The ADI adsorption system uses G2 media for arsenic removal. The media consists of a granular, calcined diatomite substrate coated with ferric hydroxide. Table 4-2 presents physical and chemical properties of the media. The G2 media has NSF International (NSF) Standard 61 listing for use in drinking water applications.

The ADI system is a fixed-bed downflow adsorption system. When the media reaches its capacity, the spent media may be removed and disposed of after being subjected to the EPA TCLP test. The media also can be regenerated using a 1% NaOH solution. However, due to the relatively small size of the treatment facility, spent media was removed and disposed of to simplify system operation.

The adsorption system at the WRWC site consisted of two vertical, 72-in-diameter and 72-in-sidewall-height cylindrical filter vessels, configured in series. The adsorption vessels were originally designed to operate in parallel for HAMHP with a flowrate of 70 gpm (or 35 gpm per vessel). Due to the switch to the site in Bow with a total flowrate of only 40 gpm, the system was reconfigured to operate in series. As a result, each vessel would provide for an EBCT of 16 min, compared to 18 min had the system been installed at HAMHP. Note that these values were much longer than the 10-min EBCT normally recommended by the vendor. Additionally, the hydraulic loading rate of the system was increased slightly from 1.2 to 1.4 gpm/ft^2 with the switch from HAMHP to WRWC. These loading rates were significantly lower than the 2.5 to 3.0 gpm/ft^2 that would normally be applied to the G2 media. ADI

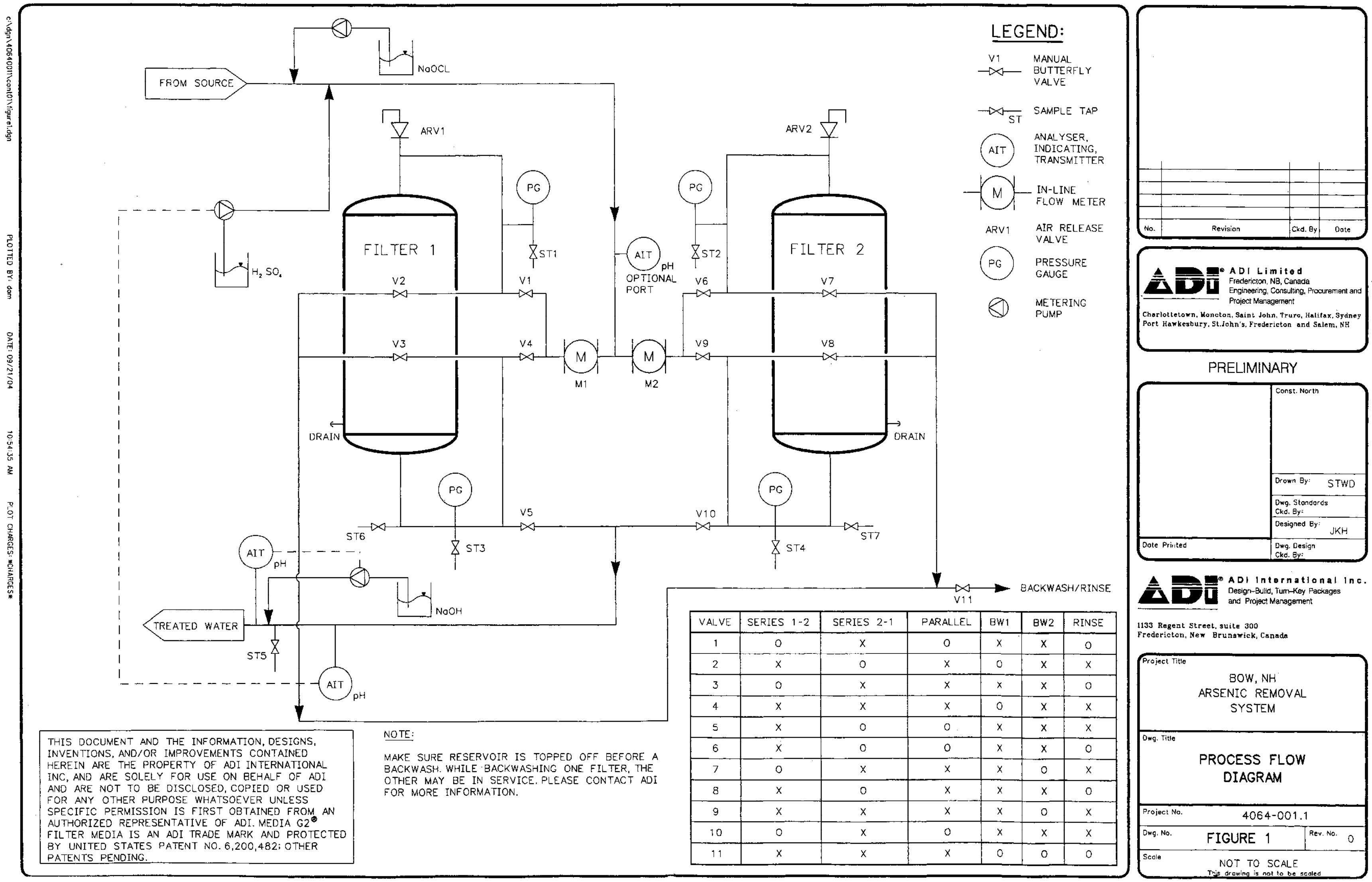
Table 4-2. Physical and Chemical Properties of G2 Media

Physical Properties	
Parameter	**Value**
Matrix	Diatomite impregnated with ferric hydroxide
Physical Form	Dry granules
Color	Dark brown
Bulk Density (lb/ft^3)	47
Specific Gravity (dry)	0.75
Hardness (lb/in^2)	210
Effective Size (mm)	0.32
Uniformity Coefficient	1.8–2.0
Bulk Relative Density	1.073
Adsorption (%)	51.1
Chemical Analysis	
Constituents	**Weight %**
Fe	5– 6
Na	9–10
Al	0.5
Diatomaceous Earth (a silica-based material)	Balance
Trace Elements	< 0.1

Source: ADI

recommended the use of 72-in-diameter vessels with the intent of extending the media run length for HAMHP. Figure 4-4 is a process flow diagram of the adsorption system supplied by ADI. 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 4-5. Key process components include:

- **Intake**. Raw water was pumped from the three on-site bedrock wells (Wells 1, 2, and 3) and fed to the ADI treatment system. The inlet piping consisting of 2-in PVC pipe from the three supply wells was combined into a single line located in the preexisting underground portion of the new treatment building. The single line was extended up through an opening in the floor of the treatment building and connected to the 3-in entry point of the treatment system.
- **Prechlorination**. The existing NaOCl feed system was used to add chlorine ahead of the adsorption vessels to prevent biological growth in the vessels and maintain a target chlorine residual value of 0.5 mg/L (as Cl_2) in the distribution system for disinfection purposes. The chorine addition system consisted of an LMI™ chlorine metering pump, a 50-gal HDPE chemical feed tank, and polyethylene tubing to transfer the NaOCl solution from the tank to the injection point. The NaOCl solution was injected directly into the raw water line after the wells were combined as described above. Operation of the chlorine feed system was tied to the well pumps so that chlorine was injected only when the wells were on. Chlorine consumption was measured using volumetric markings on the outside of the feed tank.
- **pH Adjustment Prior to Adsorption.** Source water pH was adjusted using a 93% H_2SO_4 solution from an average of 7.3 to an initial target value of 6.8 then to 6.4 and 6.0 in order to increase the adsorption capacity of the media. The H_2SO_4 solution was delivered to the site in 15-gal containers (200 lb per container). The acid was metered directly from these containers using a Prominent™ solenoid dosing pump to the injection point located on the



VALVE	SERIES 1-2	SERIES 2-1	PARALLEL	BW1	BW2	RINSE
1	O	X	O	X	X	O
2	X	O	X	O	X	X
3	O	X	X	X	X	O
4	X	X	X	O	X	X
5	X	O	O	X	X	X
6	X	O	O	X	X	O
7	O	X	X	X	O	X
8	X	O	X	X	X	O
9	X	X	X	X	O	X
10	O	X	O	X	X	X
11	X	X	X	O	O	O

Figure 4-4. Schematic of G2 Media Adsorption System (Provided by ADI)

Table 4-3. Design Specifications of G2 Media System

Parameter	Value	Remarks
Adsorption Vessels		
Vessel Size (in)	72 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	28.3	–
Number of Vessels	2	–
Configuration	Series	–
Adsorptive Media		
Media Type	G2	–
Media Quantity (lb)	8,000	4,000 lb/vessel
Media Volume (ft^3)	170	36-in bed depth or 85 ft^3/vessel
Service		
System Flowrate (gpm)	40	System originally designed for 70 gpm at HAMHP in Allenstown, NH
Hydraulic Loading Rate (gpm/ft^2)	1.4	–
EBCT (min)/Vessel	16	32-min EBCT for both vessels
Estimated Working Capacity (BV)	10,300	Vendor-provided estimate based on As breakthrough at 10 μg/L in lead vessel with influent arsenic concentration at 39 μg/L
Throughput to Breakthrough (gal)	6,550,000	1 BV = 636 gal
Average Use Rate (gal/day)	15,000	Based on 6 hr of daily operation at 40 gpm
Estimated Media Life (months)	14	Estimated frequency of media change-out in lead vessel based on average throughput to system
Pre-treatment	NaClO	Prechlorination
	H_2SO_4	pH adjustment before adsorption
Post-treatment	NaOH	pH adjustment after adsorption
Backwash		
Backwash Frequency	As needed	–
Backwash Hydraulic Loading Rate (gpm/ft^2)	4	–
Backwash Flowrate (gpm)	115	–
Backwash Duration (min/vessel)	10–15	–
Wastewater Production (gal/vessel)	1,700	–

raw water line just downstream of the chlorine injection point. These injection points were installed about 3 ft apart and approximately 25 ft upstream of the adsorption system.

- **Arsenic Adsorption**. The two 72-in-diameter, 72-in-sidewall-height vessels were constructed of 304 stainless steel and rated for 50 pounds per square inch (psi) working pressure. The system was delivered to the site with a pre-assembled pipe and valve manifold consisting of 3-in schedule 80 PVC with flanged and solvent weld connections. The manifold was mounted directly on a uni-strut steel frame bolted directly to the front of the adsorption vessels as shown in Figure 4-6. Inlet and outlet pressure gauges, PVC manually-actuated butterfly valves, air release/vacuum valves, and sampling ports were installed as part of the pre-assembled unit. There were no automated controls included as part of the adsorption system; all valves were manually actuated. Initiation of system backwash or other operational adjustments required manual adjustment of valves. Two inline pH probes were installed in the piping manifold in order to measure the pH values of the water following the acid and caustic addition. Additionally, a pH chart recorder was installed for continuous

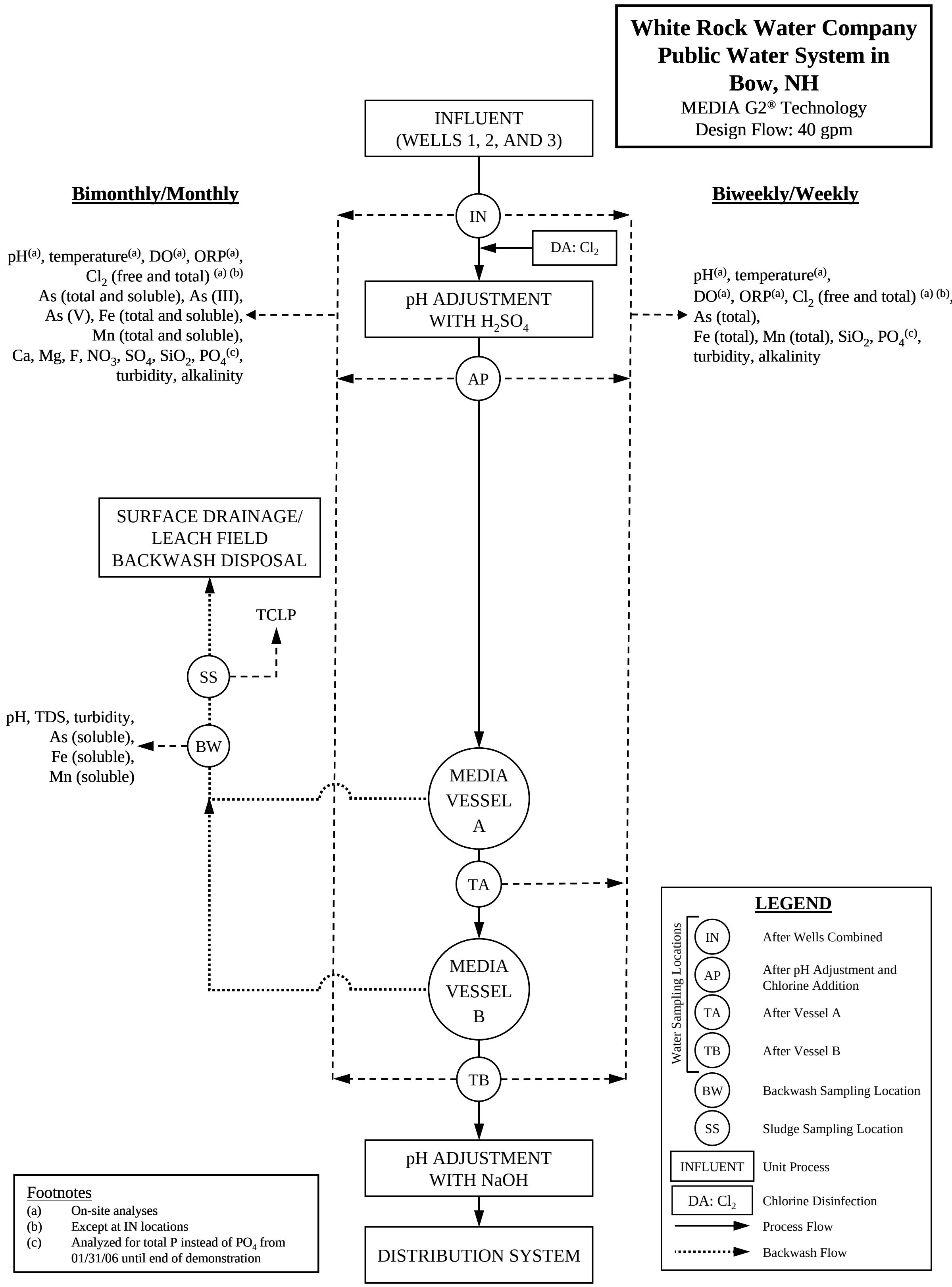


Figure 4-5. Process Flow Diagram and Sampling Locations

logging of the inline probe readings. The addition of the acid and caustic solutions was flow paced based on a 4 to 20 mA control signal from a flowmeter located on the treated water line downstream of the adsorption system. Each vessel was filled with 36 in of G2 media (85 ft^3 or 4,000 lb), which was underlain by 9 in of gravel underbedding (1/8 in × 1/16 in size). Assuming a flowrate of 40 gpm, the system would provide for an EBCT of 16 min (per vessel) and a hydraulic loading rate of 1.4 gpm/ft^2.

- **pH Adjustment Prior to Storage and Distribution**. After passing through the adsorption vessels, the treated water pH was adjusted using a 25% NaOH solution to raise the pH from between 6.0 to 6.5 to a target value of 7.5 before entering the storage tanks and distribution system. The pH was increased to reduce the tendency for dissolution of metals, especially lead and copper, from distribution piping. The 25% NaOH solution was delivered to the site in 15-gal containers (160 lb per container). The caustic solution was metered directly from these containers to the injection point using a Prominent™ solenoid dosing pump. The injection point was located downstream of the adsorption system and before the treated water reached the two 15,000-gal storage tanks.

Figure 4-6. ADI G2 Media Arsenic Adsorption System

- **Storage and Distribution.** The treated water was temporarily stored in two preexisting 15,000-gal storage tanks at atmospheric pressure. The tanks were housed in an underground structure and about 4 ft below the media tanks due to topography. The water in the storage tanks was pumped with a Burkes 50G7-2 and a Goulds 3656-1.5 booster pumps to a 5,000-gal hydropneumatic tank, operating at a high and a low pressure of 48 and 40 psi, respectively.

4.3 System Installation

The installation of the treatment system at the site was completed in September 2004; shakedown and startup activities continued into October 2004. The system installation and building construction activities were carried out by the plant operator, C&C Water Services, as a subcontractor to ADI.

4.3.1 Permitting. Engineering plans for the system permit application were prepared by Lewis Engineering, an ADI subcontractor located in Litchfield, NH. The plans included diagrams and specifications of the G2 media treatment system, as well as site drawings showing the proposed layout of the new treatment building. The plans were submitted to the NHDES (Water Supply Engineering Bureau) for review and approval on June 14, 2004. The NHDES issued a letter of approval on August 23, 2004. The state did not issue a separate permit for discharging the system backwash water at the time of startup.

4.3.2 Building Construction. To house the G2 media treatment system, C&C Water Services constructed an aboveground addition to the existing underground pump house structure (Figure 4-1). Construction included placement of steel support beams on top of the existing concrete structure, and construction of a wood frame building on the steel supports. The new building is roughly the same size as the existing structure, approximately 20 ft by 22 ft. A photograph of the aboveground addition to the treatment building is shown in Figure 4-7. Building construction began on June 14, 2004, with placement of the steel support beams and continued through the end of August 2004, including placement and setting of the vessels, which were put into place before completing the walls and roof of the new treatment building.

Figure 4-7. New Treatment Building Addition

4.3.3 Installation, Shakedown, and Startup. The adsorption vessels arrived on site and were placed on the steel supports of the new treatment building on June 28, 2004. During shipment, some minor damage was made to welds on the bottom flanges of both vessels. The manufacturer arranged for repair of the welds by a local certified welding shop. C&C Water Services performed the system installation, including all plumbing, mechanical, and electrical work. Installation of system piping was completed on September 2, 2004.

The G2 media was loaded into the vessels on September 13, 2004. Prior to system startup, the media was first backwashed at 115 gpm for about 1 hr to remove media fines in the bed. The G2 media was then conditioned using a downflow acid rinse to neutralize the pH of the media from about 12 as a result of the media manufacturing process. To minimize the amount of wastewater produced, conditioning was done by recirculating the rinse water through each vessel at a flowrate of 70 gpm using a 5-horsepower (hp) pump. Meanwhile, a chemical metering pump was used to add a 93% H_2SO_4 solution at the inlet of each vessel. Each vessel was conditioned separately for two 8-hr days and the total acid consumption was about 3 gal per vessel (or 6 gal total). The volume of wastewater produced per vessel per day was equivalent to the volume of one vessel and some additional piping (i.e., about 1,500 gal). The wastewater (about 3,000 gal per vessel over the two-day period) was discharged to a rip-rap lined surface drainage area near the treatment building at the end of each day. The pH of the wastewater as it was discharged ranged from about 10 on the first day to 7 on the second day.

Because of some delay in receiving the required components for the recirculation pump, the media conditioning did not begin until September 28, 2004, and continued for about four days. The system was put into service and the performance evaluation study officially began on October 13, 2004. A Battelle staff member visited the site on this date to inspect the system, provide operator training for data and sample collection, and collect the first set of samples from the treatment system.

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters of the system are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-4. Throughout the two-year study period, the system was operated in three different configurations. Run 1 was operated from October 13, 2004 through November 29, 2005 with two vessels in series (i.e., Vessel A in the lead position and Vessel B in the lag position). During Run 1, arsenic broke through at 10 μg/L following the lag vessel after only 6,100 BV (based on the media volume in the lead vessel) or 3,050 BV (considering the lead and lag vessels as one large vessel) in May 2005 (See Section 4.5.1). The breakthrough occurred much earlier than expected given the influent arsenic concentrations. After repeated, but unsuccessful attempts to improve arsenic removal including lowering the pH and performing a backwash, a decision was made to change out the media in both vessels. Following the spent media removal in December 2005 and virgin media placement in January 2006, only one vessel was operated at a time so that the performance of each vessel could be independently evaluated. As such, Run 2 was in operation with Vessel A only from January 13, 2006 through April 14, 2006 and Run 3 with Vessel B only from April 15, 2006 through September 26, 2006.

Run 1. Run 1 operated for a total of 3,714 hr based on the well pump hour meter readings with the supply wells operating at an average of 9.5 hr/day. The total system throughput from October 13, 2004 through November 29, 2005 was 7,928,750 gal based on the flow totalizer readings from the finished water magnetic meter. The flowrates through the system ranged from 10.6 to 49 gpm and averaged 41.0 gpm, based on the instantaneous flowrate readings (denoted as "•" in Figure 4-8) recorded daily from the finished water magnetic meter. Averaging 41.0 gpm, these flowrate readings were, in general, higher than the total daily well flowrates (denoted as "×" in Figure 4-8) that averaged 31.7 gpm. The well

Table 4-4. Key Operational Parameters

Operational Parameter	Value/Condition			
Run 1 (Both Vessel A and B in Series)				
Duration	10/13/04–11/29/05			
Time Operated (hr)	3,714 (with All 3 wells operating)			
Daily Run Time (hr/day)	9.5 (5.6–20.8[a])			
Throughput (gal)	7,928,746			
Flowrate (gpm)	41 (10.6–49)			
EBCT for both vessels (min)	31 (26–120)			
Vessel Pressure and ΔP (psi)	Vessel	Inlet	Outlet	ΔP
	A	13.0 (1.0–27)	12.9 (2.0–28)	0.2 (-5.0–6)
	B	10.6 (0.5–27)	12.4 (2.0–28)	-1.7 (-4.0–4.0)
pH Adjustment	Pre/Post	Range	Average	
	Pre	6.1–7.8[b]	6.6[b]	
	Post	5.7–9.2[c]	8.1[c]	
Run 2 Vessel A Only				
Duration	01/13/06–04/14/06			
Time Operated (hr)	Well(s) Operating	Time (hr)		
	Wells 1 and 2 Only	119		
	Well 3 Only	83		
	All 3 Wells	642		
	Total	844		
Daily Run Time (hr/day)	Well(s) Operating	Range	Average	
	Wells 1 and 2 Only	16.4–24.0	19.8	
	Well 3 Only	13.8–21.8	16.6	
	All 3 Wells	5.2–17.5	8.0	
Throughput (gal)	1,628,842			
Flowrate (gpm)	Well(s) Operating	Range	Average	
	Wells 1 and 2 Only	15–16	15.8	
	Well 3 Only	17–20	18.5	
	All 3 Wells	33–47	44.0	
EBCT (min)	Well(s) Operating	Range	Average	
	Wells 1 and 2 Only	39.8–42.4	40.2	
	Well 3 Only	31.8–37.4	34.4	
	All 3 Wells	13.5–19.3	14.5	
Vessel A Pressure and ΔP (psi)	Vessel A	Range	Average[d]	
	Inlet	7.0–13.0	10.9 (4.0)	
	Outlet	7.0–13.0	11.0 (5.0)	
	ΔP	-2.0–1.0	-0.1 (-1.0)	
pH Adjustment	Pre/Post	Range	Average	
	Pre	5.8–7.4[b]	6.4[b]	
	Post	6.3–10.5[c]	9.5[c]	
Run 3 Vessel B Only				
Duration	04/15/06–09/26/06			
Time Operated (hr)	Well(s) Operating	Time (hr)		
	Wells 2 and 3 Only	91		
	Well 3 Only	1,436		
	All 3 Wells	1,178		
	Total	2,705		
Daily Run Time (hr/day)	Well(s) Operating	Range	Average	
	Wells 2 and 3 Only	19.6–24	22.7	
	Well 3 Only	14.3–24	21.4	
	All 3 Wells	5.5–24	13.1	

Table 4-4. Key Operational Parameters (Continued)

Operational Parameter	Value/Condition		
Throughput (gal)	3,558,337		
Flowrate (gpm)	Well(s) Operating	Range	Average
	Wells 2 and 3 Only	12–19	15
	Well 3 Only	13–37	17
	All 3 Wells	19–46	35
EBCT (min)	Well(s) Operating	Range	Average
	Wells 1 and 2 Only	33.5–53	42.4
	Well 3 only	17.2–48.9	37.4
	All 3 Wells	13.8–33.5	18.2
Vessel B Pressure and ΔP (psi)	Vessel B	Range	Average[d]
	Inlet	3–13	8.3 (4)
	Outlet	5–14	9.8 (6)
	ΔP	1–3	1.5 (2)
pH Adjustment	Pre/Post	Range	Average
	Pre	5.9–7.6[b]	6.3[b]
	Post	6.4–10.4[c]	8.0[c]

(a) Not including two data points when well pumps were left on overnight.
(b) Field probe readings.
(c) Inline probe readings; data suspicious as discussed in Section 4.4.2.
(d) Value in parentheses for average pressure or differential pressure (ΔP) reading corresponding to reduced flowrates.

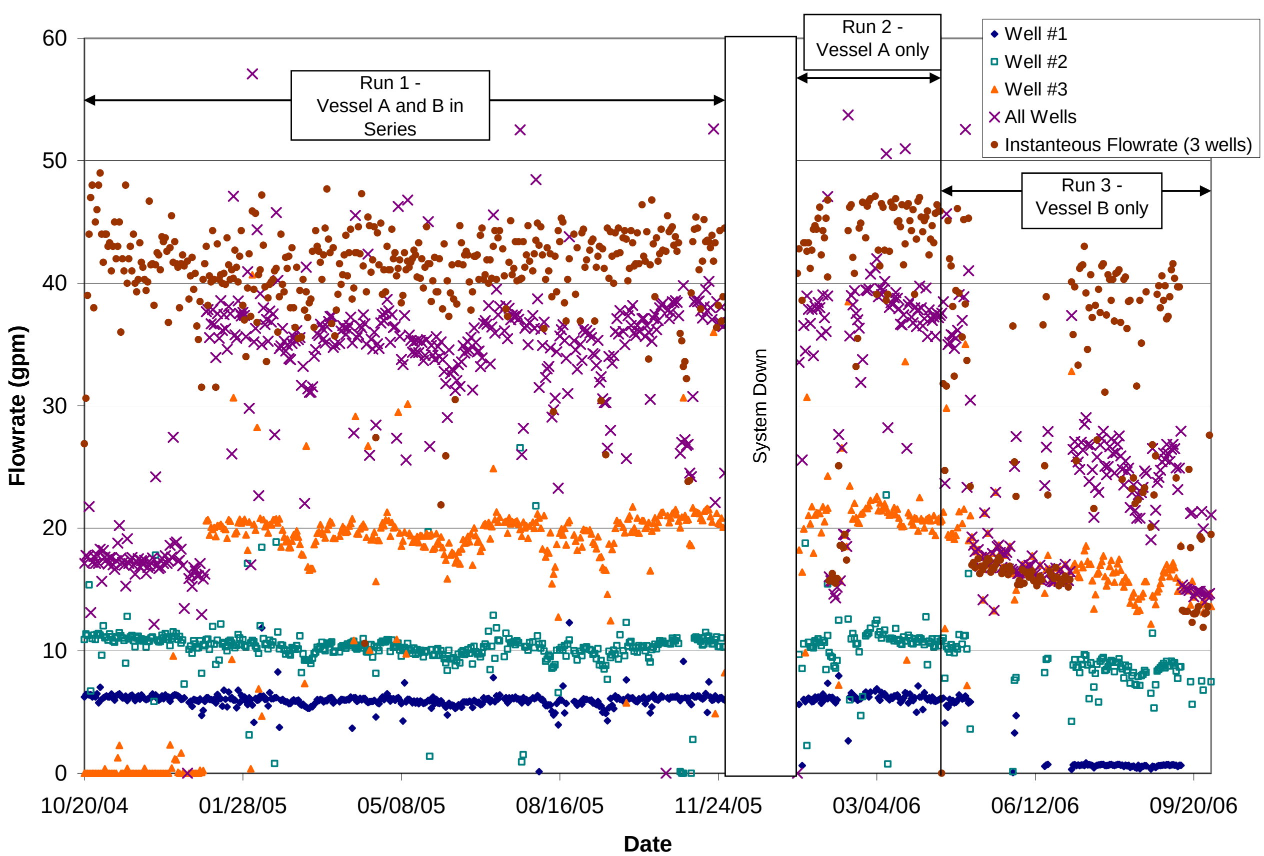


Figure 4-8. Flowrates of Wells During Runs 1, 2, and 3

flowrates were calculated based on the readings on the individual wellhead flow totalizers and respective hour meters. As shown in Figure 4-8, Wells 1, 2, and 3 yielded, for the most part, rather constant flowrates, averaging 6.0, 10.2, and 19.5 gpm, respectively, during the entire Run 1 study period. The only exception was from system startup on October 13, 2004, through January 4, 2005, during which the Well 3 totalizer did not register flow and had to be replaced on January 4, 2005. Using the 41 gpm average flowrate as the basis for calculations, it would result in an average EBCT of 16 min per vessel or 31 min through the entire system. These values are essentially the same as the design values presented in Table 4-3.

Pressure readings at the exit side of Vessel B (or the entry point to the storage tanks) averaged 12.4 psi. Pressure drops (Δp) were negligible across the adsorption vessels and the system due largely to the low hydraulic loading rates (i.e., 1.4 gpm/ft^2) applied. The pressure gauges used are in 0 to 30 psi graduations.

Run 2. After the media changeout, Vessel A was operated from January 13, 2006 through April 14, 2006, for a total of 844 hr. The total system throughput for Run 2 was approximately 1,628,800 gal based on the flow totalizer readings from the finished water magnetic meter. To yield this throughput, all three wells were operating during most of this study period, except for two short time intervals, i.e., from February 2 through 8, 2006, when only Wells 1 and 2 were operating and from February 9 through 13, 2006, when only Well 3 was operating. When all three wells were in operation, the average flowrate was 44 gpm, which resulted in an average EBCT of 14.5 min. The average flowrate was 15.8 when both Wells 1 and 2 were operating and 18.5 gpm when only Well 3 was operating (each equivalent to an average EBCT of 40.2 or 34.4 min in Vessel A alone). These instantaneous flowrate readings, again, were higher than the calculated total daily well flowrates. The calculated flowrates for individual wells followed the similar trend as observed during Run 1 with flowrates averaging 6.1, 10.6, and 21.0 gpm for Wells 1, 2, and 3, respectively.

During February 2 through 13, 2006, the system flowrates were lowered from the average of 44.0 gpm to a range of 15.8 to 18.5 gpm (on average) to determine if reduced flowrates would result in any increase in arsenic concentration in the G2 media effluent. This was done to verify the speculation made by the vendor that premature arsenic breakthrough from the G2 media during Run 1 might have been caused by short-circuiting of flow within the media bed operating at extremely low flowrates. Well 3 was turned off from February 2 through 8, 2006, for a total of 119 hr and Wells 1 and 2 turned off from February 9 through 13, 2006, for a total of 83 hr, resulting in 57 to 64% flow reduction. As to be discussed in Section 4.5.1, lowering the flowrates, in fact, improved arsenic removal, an observation that contradicted to the short-circuiting speculation.

System pressure readings and pressure drops across Vessel A were similar to those observed during Run 1.

Run 3. On April 15, 2006, Run 3 was initiated with Vessel B only until the end of the demonstration study on September 26, 2006. The system operated for a total of 2,705 hr with 45% of the time utilizing all three wells and the remaining time utilizing only Well 3 (except for 91 hr when Well 2 was turned on to help replenish the storage tank). The total system throughput for Run 3 was 3,558,300 gal based on the flow totalizer readings from the finished water magnetic meter.

Shortly after the start of Run 3 on May 2, 2006, there were noticeable drops in flowrate as reflected by both instantaneous system flowrate readings and calculated total well flowrates. The average decreases were 88, 20, and 18% for Wells 1, 2, ad 3, respectively, i.e., from 6.0, 10.3, and 19.8 gpm before May 2, 2006, to 0.7, 8.2, and 16.3 gpm after May 2, 2006. The cause of the decrease in flowrate is unknown; however, low precipitation might have been a contributing factor. During this time, the instantaneous flowrate readings averaged 35 gpm with all three wells in operation and 17 gpm with just Well 3 in operation. The corresponding average EBCTs were 18.2 and 37.4 min, respectively.

Pressure loss across the vessels averaged less than 2 psi for all three runs. The differential pressure between the vessels did not seem to be affected by the varying flowrates or configurations. Because the observed pressure drop was low and did not change significantly during system operation, the system was backwashed only three times during the course of the demonstration study.

4.4.2 pH Adjustments. Throughout the demonstration study, the system experienced operational problems with the inline pH meters. As shown in Figure 4-9, during the first six months of system operation, the inline probe located after the acid addition point prior to the adsorption vessels read approximately 0.4 pH units lower than the corresponding measurements using a WTW field pH probe. Meanwhile, the inline probe located after the caustic addition point following the adsorption vessels read about 1.3 pH units higher than the corresponding measurements using the same field pH probe. These field pH readings after the caustic addition were, for the most part, similar to those of the distribution water samples measured in the laboratory by AAL (i.e., 6.4 to 7.8 using the field pH probe versus 6.6 to 8.1 by AAL), suggesting that the field pH probe was more accurate than the inline probes.

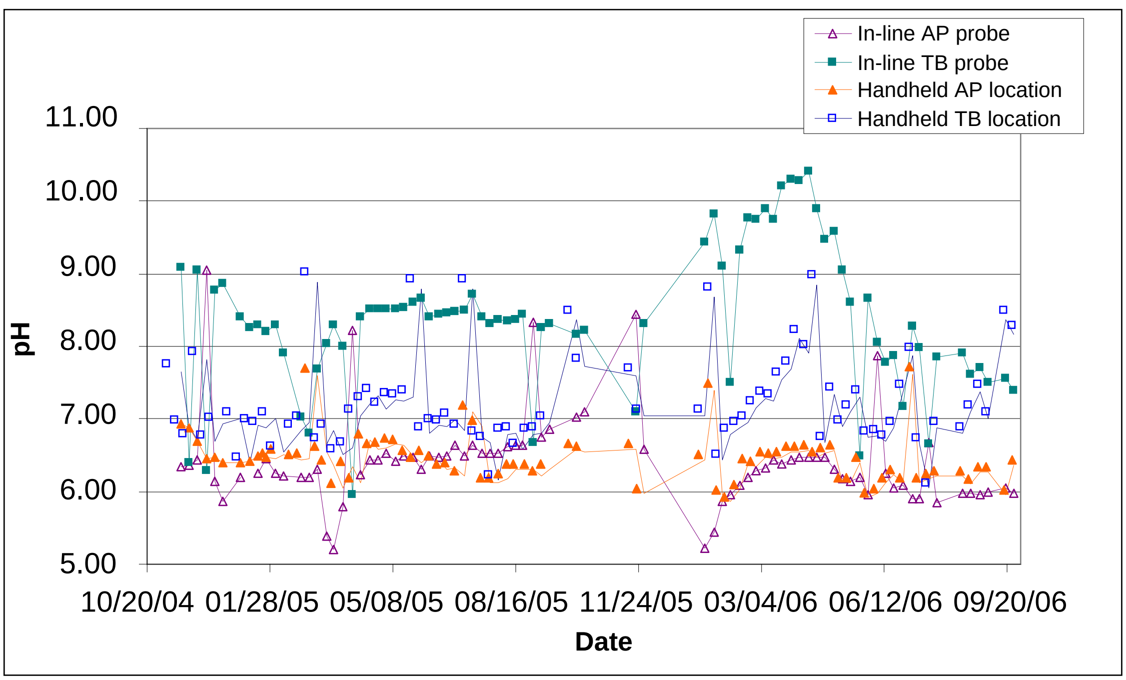


Figure 4-9. Comparison of pH Readings from Inline Probes and WTW Field Meter

Efforts made to correct the problems during the first six-month study period included cleaning and calibrating the probes, consulting with the vendor and manufacturer, switching the "acid" inline probe (which seemed to read more accurately) with the "caustic" inline probe, and conducting an on-site service call by the vendor to investigate and replace the "acid" inline probe with a new probe. These efforts seemed to have improved the correlation between the "acid" inline probe and the field meter readings during some of the remainder months under Run 1, and the entire duration under Run 2. However, the correlation between the "caustic" inline probe and the field meter readings continued to be poor throughout the entire study period.

Initially, the vendor recommended having the pH of raw water reduced to 6.4. After a series of tests with raw water in November 2005, the vendor recommended that the raw water pH be further reduced to 6.0 in order to increase media's adsorptive capacity (with the arsenic concentration in the treated water decreased from about 5 to <1 μg/L per vendor's tests). pH values of the water after H_2SO_4 addition averaged 6.6, 6.4 and 6.3 for Run 1, 2, and 3, respectively (Table 4-4).

4.4.3 Backwash. During the entire demonstration period, the system was backwashed three times, one time each on January 11, April 12, and June 14, 2005, after about three, six, and eight months of system operation, respectively. Backwash was performed manually using finished water from the storage tanks. During backwash, the system was taken offline and treated water was drawn via a booster pump from the storage tanks at a flowrate of approximately 115 gpm (or about 4 gpm/ft^2). The backwash lasted for 20 min per vessel for the first and 10 min per vessel for the second and third backwash events, producing approximately 2,200 and 1,200 gal of wastewater from each vessel.

4.4.4 Media Changeout. The system was taken offline on November 29, 2005, to allow the vessels to drain in preparation for media changeout, which was performed by C&C Water Services. The virgin media was delivered to the site on December 9, 2005; however, due to weather conditions at the site and scheduling conflicts with the vacuum truck, spent media removal was not carried out until December 23, 2005. Before removal, the heights of the freeboard from the lower rim of the manway to the media bed surface were measured and summarized in Table 4-5. The spent media then was sampled and removed from each vessel as described in Section 3.3.4. The replacement media was installed on January 11, 2006. Both vessels were properly backwashed before freeboard measurements were obtained. Freeboard measurements were taken from the lower rim of the manway on the top of each vessel. For Vessel A, there was 75.5 in to the top of the underbedding and 47 in to the top of the virgin media. For Vessel B, there was 75 in to the top of the underbedding and 45 in to the top of the media. The resulting bed depths were 28.5 and 30 in, respectively, which were 21 and 17% shorter than the design value of 36 in (Table 4-3). The vessels were conditioned from January 11 through 12, 2006, and from April 14 through 15, 2006, respectively, as described in Section 4.3.3, and put into service on January 13, 2006, for Vessel A and April 15, 2006, for Vessel B.

Table 4-5. Freeboard Measurements and Media Loss After Run 1

Parameter	Vessel A	Vessel B
Volume Loaded (ft^3)	85.0	85.0
Initial Freeboard (in)	38.0	38.0
Final Freeboard (in)	50.0	48.0
Bed Reduction due to Media Loss (in)	12.0	10.0
Volume of Media Loss (ft^3)	28.3	23.5
Total Media Loss (%)	33.3	27.6

4.4.5 Residuals Management. Residuals produced by the operation of the treatment system include spent media and backwash water. Backwash water was discharged to a rip-rap lined surface drainage and allowed to infiltrate into the ground. The spent media was removed from the vessels on December 23, 2005. Analytical results from the EPA TCLP test showed that the spent media was non-hazardous and was disposed of in a landfill (see Section 4.5.3).

4.4.6 System Operation Reliability and Simplicity. A significant O&M need for this system was the acid and caustic addition to maintain the desired pH values of the feed water to the adsorption vessels and the finished water to the distribution system. Confounding the proper dosing of acid and caustic were the continuing discrepancies observed in pH readings from the inline probes versus the field probe as discussed in Section 4.4.2. Further discussion on the impact of pH adjustment in the distribution system is included in Section 4.5.4.

Additional discussion regarding system operation and operator skill requirements are provided below in relation to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventive maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Pre-treatment consisted of the addition of a 6% NaOCl solution for disinfection, which was already performed at the site prior to the installation of the arsenic treatment system, and a 93% H_2SO_4 solution for lowering the water pH in order to maximize the arsenic removal capacity of the G2 media. Post-treatment included the addition of a 25% NaOH solution to raise the pH values back to approximately 7.5 to reduce corrosivity prior to entering the storage tanks and distribution system. The rate of chemical consumption is provided below under chemical handling and inventory requirements.

System Controls. The G2 media adsorption system was a passive system, requiring only the operation of the well pumps and chemical metering pumps for chlorination and acid and caustic addition. The adsorption system itself required no automated parts and all valves were manually activated. Power supply to the chemical metering pumps was tied into the supply well pumps so that when the supply wells were started, triggered by a level switch in the storage tanks, the chemical metering pumps also were energized to dispense chlorine, acid, and caustic. For chlorine addition, the metering pump was set at a pre-determined rate. For acid and caustic additions, the system had the capability to adjust the chemical feed rates to maintain a specified pH value based on the inline probe readings. However, this control setup was disabled during the course of the demonstration period. Instead, the acid and caustic feed rates were controlled by manually setting the pump stroke-length and automatically pacing the pump based on a 4 to 20 mA control signal provided by a Badger™ magnetic flowmeter located on the treated water line. The magnetic meter became stuck on one setting on June 2, 2005, causing both acid and caustic pumps to stay on until the meter could be reset. This caused a drop in pH of the treated water, which was consequently seen in the distribution samples.

Additionally, a two-pen pH chart recorder was installed for continuous logging of the pH values after the acid and caustic additions. Although useful for tracking the operation of the system, the pH chart recorder proved somewhat problematic to operate as it was initially installed without the proper relays to allow it to communicate with the inline pH probes. As a result, the system operated for several weeks with the pH recorder giving erroneous readings. In early January 2005, the proper relays were installed and the chart recorder was adjusted so that the readings better reflected the inline probe readings. However, the inline probes continued to give erroneous readings as shown in Figure 4-9.

Backwash cycles were initiated manually and required the operator to adjust system valves accordingly prior to initiating the system backwash.

Operator Skill Requirements. Generally, the operation of the treatment system did not require additional skills beyond those necessary to operate the original treatment equipment used at the site prior to the demonstration. The daily demand on the system operator was typically 20 min to visually inspect the system and record operating parameters, such as totalizer and hour meter readings, flowrates, and system pressure readings on the field log sheets.

In addition to the standard checks and data recording performed daily for the system, C&C Water Services personnel typically spent 3 to 4 hr/week troubleshooting various problems associated with the system, especially during the first few months of system operation. This time was primarily spent making adjustments to acid and caustic additions. Because the system was not set to make these adjustments automatically, all adjustments were made by manually adjusting the stroke-length of the chemical metering pumps. Adding to the complexity of achieving the proper balance of acid and caustic additions was the disagreement in readings between the inline pH probes and the WTW field probe, as discussed in Section 4.4.2. In early December 2004, acid addition was increased to further lower the pH of the feed water to attempt to increase arsenic removal by the G2 media. To counterbalance this increase in acid addition, intuitively, the caustic addition also would have to be increased. In fact, in late December 2004, the caustic metering pump was inadvertently ramped down such that the pH values of water going to the storage tanks were lower than what had been measured historically at the site. The drop in pH values was noticeable in the subsequent distribution system samples collected on January 12, 2005. Further discussion on the impact of this pH drop in the distribution system is included in Section 4.5.4.

Based on the size of the population served and the treatment technology, the State of New Hampshire requires Grade IA Certification for operation of the WRWC system and is considering upgrading this requirement to Grade I. The State of New Hampshire has five grades of certifications based on the complexity of the treatment and distribution system. The grades range from Grade IA, the least complex, to Grade IV, the most complex. The C&C Water Services operator is a certified Grade III operator.

Preventive Maintenance Activities. Regular maintenance activities consisted primarily of daily visual inspection of the system to ensure that it appeared to be operating appropriately, maintaining chemical supply for feed chemicals, collecting routine water samples, cleaning and calibrating the inline pH probes, and system backwashing as necessary.

Chemical/Media Handling and Inventory Requirements. Chemicals required for system operation included a 6% NaOCl, a 93% H_2SO_4, and a 25% NaOH solution. Proper handling and storage of these chemicals were required, including secondary containment for the chemical storage area and proper safety equipment for plant operators, including eye wash station and use of personal protective equipment (gloves, chemical apron, and face shield as required). During the demonstration period, approximately two 15-gal containers (160 lb per container) of 25% NaOH and one 15-gal container (200 lb per container) of 93% H_2SO_4 were consumed per month for pH control purposes. The average chemical consumption was 0.27 lb/1,000 gal of water treated for H_2SO_4 and 0.57 lb/1,000 gal for NaOH.

4.5 System Performance

The system performance was evaluated based on analyses of samples collected from the raw and finished water from the treatment plant, backwash lines, and distribution system.

4.5.1 Treatment Plant. Sampling taps were installed at four locations through the treatment train: at the inlet (IN), after chlorination and pH adjustment (AP), at the effluent of Vessel A (TA), and at the effluent of Vessel B (TB). Samples were collected at the four locations during Run 1 and at three locations during Runs 2 and 3 (i.e., IN, AP, and TA during Run 2 and IN, AP, and TB during Run 3). Field-speciated samples at each location were collected once every eight weeks throughout Run 1 and once every four weeks during Runs 2 and 3. Table 4-6 summarizes the arsenic and iron analytical results. Table 4-7 summarizes the manganese and the results of other water quality parameters. Appendix B contains a complete set of analytical results. The results of the water samples collected throughout the treatment plant are discussed below.

Arsenic. The key parameter for evaluating the effectiveness of the G2 media treatment system was the concentration of arsenic in the treated water. The treatment system was run in three different configurations. Run 1 had both Vessels A and B in operation with Vessel A being placed in the lead position and Vessel B in the lag position. Runs 2 and 3 had only one vessel in operation at a time with

Table 4-6. Summary of Arsenic and Iron Analytical Results

Parameter	Sample Location[(a)]	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	μg/L	72	35.3	91.3	46.4	6.8
	AP	μg/L	72	12.7	96.1	46.2	8.4
	TA (Lead)	μg/L	34	12.6	46.2	-[(b)]	-[(b)]
	TB (Lag)	μg/L	34	1.7	50.9	-[(b)]	-[(b)]
	TA only	μg/L	13	6.2	30.6	-[(b)]	-[(b)]
	TB only	μg/L	25	2.2	23.6	-[(b)]	-[(b)]
As (soluble)	IN	μg/L	14	41.3	54.6	47.9	3.5
	AP	μg/L	14	43.7	55.7	48.5	3.7
	TA (Lead)	μg/L	7	15.5	38.4	-[(b)]	-[(b)]
	TB (Lag)	μg/L	7	3.6	32.1	-[(b)]	-[(b)]
	TA only	μg/L	4	9.9	31.2	-[(b)]	-[(b)]
	TB only	μg/L	3	4.0	18.4	-[(b)]	-[(b)]
As (particulate)	IN	μg/L	14	<0.1	40.8	3.2	10.8
	AP	μg/L	14	<0.1	43.8	3.4	11.7
	TA (Lead)	μg/L	7	<0.1	12.2	-[(b)]	-[(b)]
	TB (Lag)	μg/L	7	<0.1	47.2	-[(b)]	-[(b)]
	TA only	μg/L	4	<0.1	0.3	-[(b)]	-[(b)]
	TB only	μg/L	3	<0.1	0.8	-[(b)]	-[(b)]
As (III)	IN	μg/L	14	0.2	0.7	0.5	0.2
	AP	μg/L	14	<0.1	0.9	0.4	0.2
	TA (Lead)	μg/L	7	0.3	0.8	-[(b)]	-[(b)]
	TB (Lag)	μg/L	7	0.3	1.1	-[(b)]	-[(b)]
	TA only	μg/L	4	0.3	0.5	-[(b)]	-[(b)]
	TB only	μg/L	3	0.1	0.3	-[(b)]	-[(b)]
As (V)	IN	μg/L	14	40.7	54.1	47.5	3.5
	AP	μg/L	14	43.3	55.1	48.1	3.6
	TA (Lead)	μg/L	7	14.8	38.0	-[(b)]	-[(b)]
	TB (Lag)	μg/L	7	3.0	31.7	-[(b)]	-[(b)]
	TA only	μg/L	4	9.5	30.9	-[(b)]	-[(b)]
	TB only	μg/L	3	3.7	18.3	-[(b)]	-[(b)]
Fe (total)	IN	μg/L	67	<25	33.3	13.0	2.8
	AP	μg/L	67	<25	60.0	13.7	7.0
	TA (Lead)	μg/L	29	<25	<25	<25	-
	TB (Lag)	μg/L	29	<25	39.0	13.4	4.9
	TA only	μg/L	13	<25	<25	<25	-
	TB only	μg/L	25	<25	<25	<25	-
Fe (soluble)	IN	μg/L	14	<25	<25	<25	-
	AP	μg/L	14	<25	<25	<25	-
	TA (Lead)	μg/L	7	<25	<25	<25	-
	TB (Lag)	μg/L	7	<25	<25	<25	-
	TA only	μg/L	4	<25	<25	<25	-
	TB only	μg/L	3	<25	<25	<25	-

(a) "TA (Lead)" and "TB (Lag)" for Run 1; "TA only" for Run 2; and "TB only" for Run 3.
(b) Average concentration and standard deviation not calculated; see Figure 4-11 for As breakthrough curves

Note: One-half of detection limit used for samples with concentrations less than detection limit for calculations. Duplicate samples included in the calculations.

Table 4-7. Summary of Manganese and Water Quality Parameter Measurements

Parameter	Sample Location[a]	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Mn (total)	IN	μg/L	67	0.1	15.7	2.3	3.8
	AP	μg/L	67	<0.1	16.1	2.5	3.9
	TA (Lead)	μg/L	29	<0.1	27.0	-[b]	-[b]
	TB (Lag)	μg/L	29	<0.1	35.8	-[b]	-[b]
	TA only	μg/L	13	0.4	39.1	-[b]	-[b]
	TB only	μg/L	25	<0.1	13.1	-[b]	-[b]
Mn (soluble)	IN	μg/L	14	0.2	11.4	1.6	2.9
	AP	μg/L	14	0.2	11.0	1.5	2.8
	TA (Lead)	μg/L	7	<0.1	9.0	-[b]	-[b]
	TB (lag)	μg/L	7	<0.1	12.5	-[b]	-[b]
	TA only	μg/L	4	1.4	32.9	-[b]	-[b]
	TB only	μg/L	3	0.9	6.2	-[b]	-[b]
Alkalinity (as $CaCO_3$)	IN	mg/L	69	55.0	88.0[c]	66.3[c]	5.0[c]
	AP	mg/L	72	12.0	67.0	34.5	12.4
	TA (Lead)	mg/L	34	22.0	62.0	41.0	8.1
	TB (Lag)	mg/L	34	22.0	68.0	41.5	8.6
	TA only	mg/L	13	21.0	57.0	34.7	9.4
	TB only	mg/L	25	15.0	66.0	28.9	11.9
Fluoride	IN	mg/L	14	0.6	1.1	0.8	0.1
	AP	mg/L	14	0.6	1.0	0.8	0.2
	TA (Lead)	mg/L	7	0.7	1.1	0.8	0.1
	TB (Lag)	mg/L	7	0.3	0.8	0.7	0.2
	TA only	mg/L	4	0.5	0.8	0.6	0.1
	TB only	mg/L	3	0.5	0.5	0.5	0.0
Sulfate	IN	mg/L	15	10.0	24.0	11.9	3.4
	AP	mg/L	15	26.0	52.0	39.8	8.5
	TA (Lead)	mg/L	8	12.0	48.0	34.4	11.7
	TB (Lag)	mg/L	8	9.6	48.0	33.7	12.1
	TA only	mg/L	4	35.0	43.0	40.5	3.7
	TB only	mg/L	3	35.0	55.0	46.3	10.3
Nitrate (as N)	IN	mg/L	14	0.2	1.0	0.3	0.2
	AP	mg/L	14	0.1	0.5	0.3	0.1
	TA (Lead)	mg/L	7	0.2	1.3	0.4	0.4
	TB (Lag)	mg/L	7	0.2	1.4	0.4	0.4
	TA only	mg/L	4	0.2	0.3	0.3	0.0
	TB only	mg/L	3	0.2	0.4	0.3	0.1
Orthophosphate (as P)	IN	mg/L	10	<0.05	<0.05	<0.05	-
	AP	mg/L	10	<0.05	<0.05	<0.05	-
	TA (Lead)	mg/L	8	<0.05	<0.05	<0.05	-
	TB (Lag)	mg/L	8	<0.05	<0.05	<0.05	-
	TA only	mg/L	2	<0.05	<0.05	<0.05	-
Total P (as PO_4)	IN	mg/L	35	<0.03	0.13	0.05	0.03
	AP	mg/L	35	<0.03	0.14	0.04	0.03
	TA (Lead)	mg/L	2	0.04	0.04	0.04	-
	TB (Lag)	mg/L	2	<0.03	<0.03	<0.03	-
	TA only	mg/L	9	<0.03	<0.03	<0.03	-
	TB only	mg/L	24	<0.03	0.05	<0.03	0.01

Table 4-7. Summary of Water Quality Parameter Measurements (Continued)

Parameter	Sample Location[(a)]	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Silica (as SiO_2)	IN	mg/L	64	18.1	21.4	19.7	0.7
	AP	mg/L	64	17.9	37.2	20.0	2.3
	TA (Lead)	mg/L	26	19.8	50.8	24.6	6.6
	TB(Lag)	mg/L	26	21.9	61.8	28.2	9.8
	TA only	mg/L	13	24.7	51.2	31.1	7.2
	TB only	mg/L	25	21.5	53.1	27.5	7.1
Turbidity	IN	NTU	64	0.05	1.6	0.4	0.4
	AP	NTU	64	0.05	1.5	0.4	0.4
	TA (Lead)	NTU	26	0.05	0.6	0.1	0.1
	TB (Lag)	NTU	26	0.05	0.5	0.2	0.1
	TA only	NTU	13	0.2	3.0	0.9	0.8
	TB only	NTU	25	0.05	1.2	0.3	0.3
pH	IN	S.U.	66	6.7	7.7	7.3	0.2
	AP	S.U.	66	5.8	7.8	6.4	0.4
	TA (Lead)	S.U.	29	6.1	7.9	6.5	0.4
	TB (Lag)	S.U.	29	6.1	8.0	6.5	0.4
	TA only	S.U.	13	6.0	7.3	6.5	0.4
	TB only	S.U.	24	5.9	7.3	6.3	0.3
Temperature	IN	°C	66	9.7	12.9	11.9	0.7
	AP	°C	66	10.1	12.9	11.9	0.6
	TA (Lead)	°C	29	11.2	12.9	12.0	0.5
	TB (Lag)	°C	29	11.2	13.2	12.0	0.5
	TA only	°C	13	10.1	11.5	11.1	0.5
	TB only	°C	24	11.5	12.9	12.2	0.4
Dissolved Oxygen	IN	mg/L	59	3.1[(d)]	7.9[(d)]	4.8	1.0[(d)]
	AP	mg/L	62	1.9	7.5	3.5	1.0
	TA (Lead)	mg/L	25	3.2	5.3	4.0	0.6
	TB (Lag)	mg/L	25	3.0	5.4	3.9	0.6
	TA only	mg/L	13	2.1	7.6	3.4	1.4
	TB only	mg/L	24	1.7	4.5	2.9	0.8
ORP	IN	mV	64	172	498	348	127
	AP	mV	65	190	730	550	122
	TA (Lead)	mV	28	183	703	511	132
	TB (Lag)	mV	28	173	714	521	123
	TA only	mV	13	341	708	611	100
	TB only	mV	22	386	728	624	83.5
Free Chlorine (as Cl_2)	AP	mg/L	68	0.0	0.8	0.4	0.2
	TA (Lead)	mg/L	31	0.1	0.7	0.3	0.2
	TB (Lag)	mg/L	30	0.1	0.6	0.3	0.2
	TA only	mg/L	13	0.0	0.5	0.4	0.1
	TB only	mg/L	24	0.2	0.6	0.4	0.1
Total Chlorine (as Cl_2)	AP	mg/L	68	0.0	0.9	0.4	0.2
	TA (Lead)	mg/L	31	0.1	0.7	0.3	0.1
	TB(Lag)	mg/L	31	0.1	0.7	0.3	0.2
	TA only	mg/L	13	0.1	0.5	0.4	0.1
	TB only	mg/L	24	0.2	1.0	0.5	0.2

Table 4-7. Summary of Water Quality Parameter Measurements (Continued)

Parameter	Sample Location	Unit	Sample Count	Concentration Minimum	Concentration Maximum	Concentration Average	Standard Deviation
Total Hardness (as $CaCO_3$)	IN	mg/L	14	79.8	164	100	20.0
	AP	mg/L	14	81.5	129	97.7	12.3
	TA (Lead)	mg/L	7	85.0	167	105	27.8
	TB (Lag)	mg/L	7	86.8	102	95.2	5.6
	TA only	mg/L	4	91.8	109	101	7.2
	TB only	mg/L	3	77.4	123	97.9	23.4
Ca Hardness (as $CaCO_3$)	IN	mg/L	14	57.2	126	77.4	15.6
	AP	mg/L	14	60.1	99.2	75.5	9.9
	TA (Lead)	mg/L	7	66.6	122	80.2	19.1
	TB (Lag)	mg/L	7	41.4	79.2	70.0	12.9
	TA only	mg/L	4	70.5	82.0	77.2	4.8
	TB only	mg/L	3	48.7	95.9	72.9	23.6
Mg Hardness (as $CaCO_3$)	IN	mg/L	14	18.1	37.8	22.7	4.7
	AP	mg/L	14	17.5	29.3	22.2	2.9
	TA (Lead)	mg/L	7	18.4	44.4	24.9	8.8
	TB (Lag)	mg/L	7	19.6	45.4	25.2	9.0
	TA only	mg/L	4	21.3	27.3	23.9	2.6
	TB only	mg/L	3	19.2	28.6	25.1	5.1

(a) "TA (Lead)" and "TB (Lag)" for Run 1 only; "TA only" for Run 2 only; and "TB only" for Run 3 only.
(b) Average concentration and stand deviation not calculated. See Figures 4-15 and 4-16 for alkalinity, sulfate, pH, and silica measurements.
(c) Not including three data points with usually high values (i.e., 120, 154, and 265 mg/L [as $CaCO_3$]).
(d) Not including three data points considered to be outliers (i.e., 1.8, 2.8, and 9.4 mg/L).
Note: One-half of detection limit used for samples with concentrations less than detection limit for calculations. Duplicate samples included in calculations.

Run 2 utilizing Vessel A and Run 3 utilizing Vessel B. The treatment plant water was sampled on 34 occasions (including three duplicates) during Run 1, 13 times during Run 2, and 25 times (including one duplicate) during Run 3. Field speciation was performed on seven of the 34 occasions for Run 1, four of the 13 for Run 2, and three of the 25 occasions for Run 3. Samples were collected at IN and AP at each of the 72 sampling events with samples being collected at TA and TB when they were utilized.

Figure 4-10 contains four bar charts showing the concentrations of total As, particulate As, As(III), and As(V) at the IN, AP, TA , and/or TB sampling locations for each of the field speciation events. Total arsenic concentrations in raw water ranged from 35.3 to 91.3 μg/L and averaged 46.4 μg/L (Table 4-6). As(V) was the predominating species, ranging from 40.7 to 54.1 μg/L and averaging 47.5 μg/L. Only trace amounts of As(III) existed with concentrations averaging 0.5 μg/L. Particulate As also was low with concentrations typically less than 5 μg/L. During the system startup on October 13, 2004, an unusually high concentration of particulate As (i.e., greater than 40 μg/L, or almost 50% of total As) was measured. It was not clear why such a high particulate As concentration was detected during this sampling event. The arsenic concentrations measured during this demonstration were generally consistent with those in the raw water sample collected on April 22, 2004 (Table 4-1).

As expected, arsenic concentrations at the AP location were similar to those in raw water. Because the majority of arsenic present in raw water was already in the As(V) oxidation state and because little or no iron was present in raw water, chlorination had little or no effect on the concentration or oxidation state of

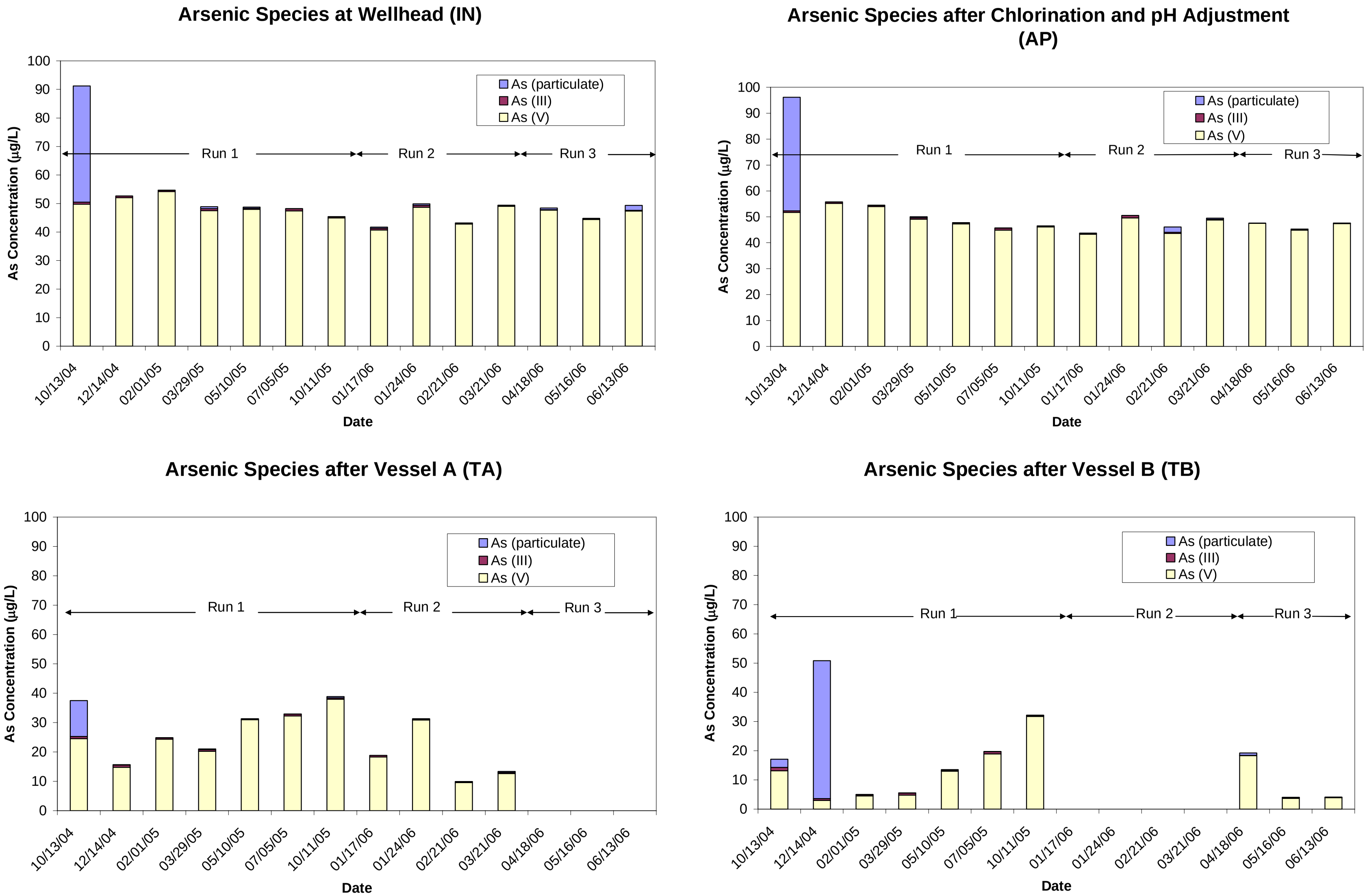


Figure 4-10. Concentration of Arsenic Species at IN, AP, TA, and TB Sampling Location

arsenic entering the adsorption vessels. Similar to those at the IN location, total arsenic concentrations at the AP location ranged from 12.7 to 96.1 μg/L and averaged 46.2 μg/L.

Total As concentrations at the wellhead and immediately before and after the adsorption vessels during Runs 1, 2, and 3 are plotted against bed volumes of water treated in Figure 4-11. Note that one BV is equal to 85 ft^3 which is the amount of media in one adsorption vessel. During Run 1, greater than 30 μg/L of total As was unexpectedly detected in samples collected following the lead vessel just after system startup on October 13 and about one week later on October 19, 2004. Since then, total As concentrations gradually decreased to 12.6 μg/L after treating approximately 1,584,800 gal (or 2,500 BV) of water on January 4, 2005, before beginning a steadily increasing trend. Total arsenic concentrations reached the media's capacity, as indicated by a similar level of arsenic in the influent to (i.e., 43.6 μg/L) and the effluent from the adsorption vessel (i.e., 46.2 μg/L), on October 25, 2005.

Total As concentrations after the lag vessel also were high during the first two weeks of system operation, with 16.7 to 21.8 μg/L of arsenic measured on October 13 and October 19, 2004, respectively. Afterwards, the concentrations dropped to 1.7 μg/L on January 4, 2005, the day when the arsenic concentrations following the lead vessel also reached the lowest level, and then increased steadily to 10 μg/L after treating approximately 3,890,000 gal (or 6,100 BV) of water. Considering the lead and lag vessels as one large vessel that housed 170 ft^3 of media, arsenic breakthrough at 10 μg/L would have occurred at about 3,050 BV. This underachieved media performance was with a long EBCT of 31 min (on average, see Table 4-4) and a low loading rate of 1.4 gpm/ft^2 (on average).

The total As concentration measured after the lag vessel (B) on December 14, 2004 was unusually high at 50.9 μg/L, of which 47.3 μg/L existed as particulate As (See Figure 4-10). It was not clear what caused the elevated particulate As concentration.

The vendor attributed the elevated arsenic concentrations just after system startup to the leaching of arsenic from the G2 media that was prepared with a $FeCl_3$ solution containing arsenic and manganese as impurities. While this might explain the elevated arsenic levels observed in the treated water during the first two weeks of system operation, it did not explain why the arsenic concentrations remained high (i.e., 12.6 μg/L or greater) following the lead vessel throughout the entire Run 1 study period.

Arsenic breakthrough occurred much earlier than expected, compared to vendor's estimate of 10,300 BV based on breakthrough at 10 μg/L following the lead vessel and an influent arsenic concentration of 39 μg/L. Decreasing the pH of the influent to the adsorption vessels did not appear to be useful in reversing the trend of steady increase in arsenic concentration in the treated water. As shown in Figure 4-12, as influent pH was reduced to the target value of 6.8 (from October 19 through November 30, 2004), and then 6.4 (through June 7, 2005), arsenic concentrations in the vessel effluent continued to rise. Further decrease in pH to about 6.0 (through September 13, 2005) did not seem to have any effect either. In theory, lowering the pH of feed water should help result in decreased arsenic concentrations in the treated water, as observed at a separate Round 1 site at Valley Vista, AZ where an iron-modified activated alumina media, AAFS50, was used for arsenic removal (Valigore, et al., 2006). The reduced concentrations were caused by the additional positively-charged adsorptive sites made available due to decreased pH. Since no apparent reduction in arsenic concentration was realized at pH values as low as 6.0 at Bow, there might be a limited number of amphoteric ferric hydroxide sites available on this modified diatomite media.

Because of the unexpectedly poor media performance, a decision was made in early June 2005 to backwash the media as an attempt to improve the media performance by redistributing the media within the adsorption vessels. A backwash was thus performed on June 14, 2005, and the results indicated that

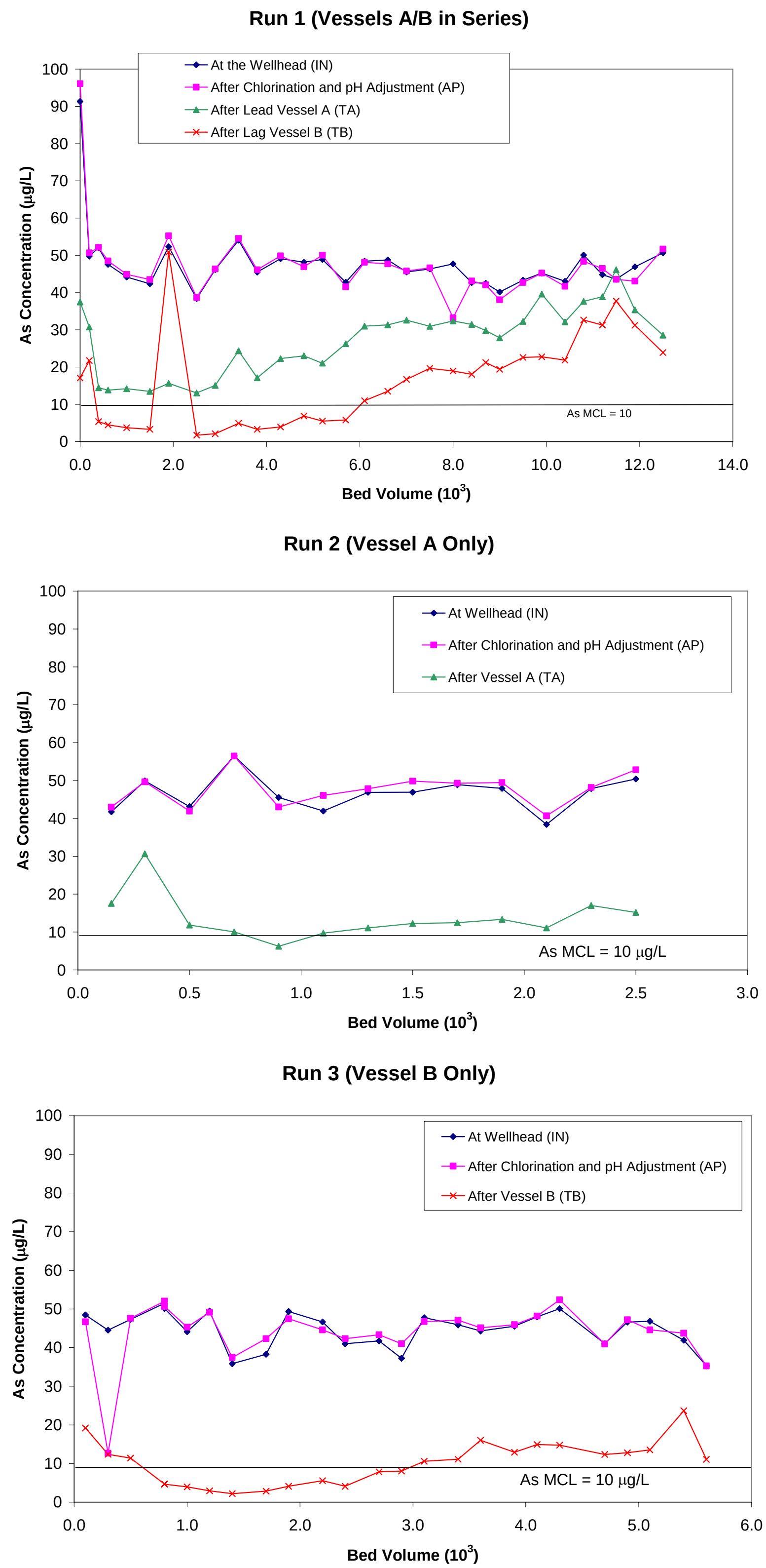


Figure 4-11. Total Arsenic Breakthrough Curves
(BV Calculated Based on Media Volume in One Vessel)

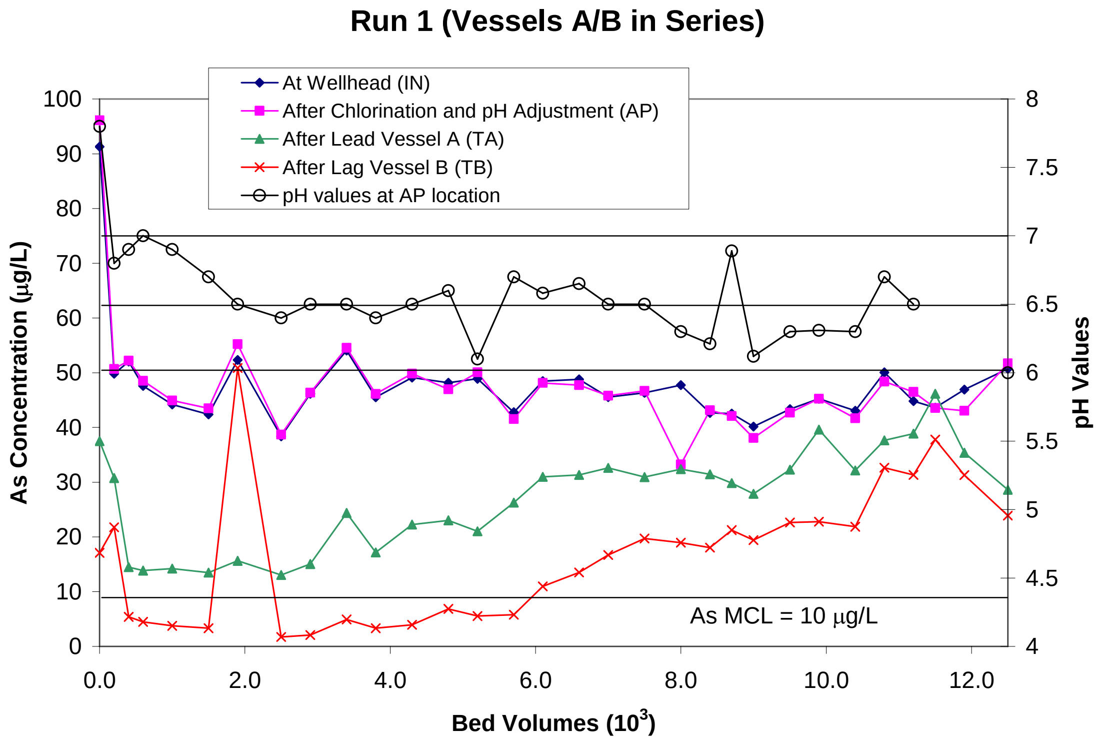


Figure 4-12. Run 1 Total Arsenic Breakthough Versus Influent pH

backwash did not improve arsenic removal in any way. Because the system could not be optimized for arsenic removal, it was rebedded in January 2006.

The rebedded and reconditioning media was put into operation under Run 2 on January 13, 2006, with only Vessel A in service. Similarly to Run 1, arsenic concentrations in the treated water, as shown in Figure 4-11, went up to 17.6, and then to 30.6 µg/L immediately after system startup, presumably due to arsenic leaching. Afterwards, arsenic concentrations decreased sharply to 11.8 on January 31, 2006, and then to 10.0 µg/L on February 7, 2006, before reaching <10 µg/L levels during two consecutive sampling events on February 14 (6.2 µg/L) and February 28, 2006 (9.7 µg/L). From this point on, arsenic concentrations steadily increased to as high as 17.0 µg/L, after treating about 1,437,000 gal (or 2,260 BV) of water, before the run was stopped on April 14, 2006. pH of the influent water was lowered to 6.0 to 6.5 (6.3 on average) for almost the entire study duration.

From February 2 through 14, 2006, the system flowrate was reduced intentionally from the 44 gpm typically seen to 15.8 to 18.5 gpm in order to determine if low flowrates would cause short-circuiting through the media bed, as speculated by the vendor. The speculation was that low flowrates could have caused short-circuiting along the vessel walls, thus resulting in the higher-than-expected arsenic concentrations observed in the treated water. Because the arsenic concentrations actually decreased during this low-flow period, short-circuiting was determined not to be a problem.

After reconditioning, Vessel B was put into service on April 15, 2006, under Run 3. For the first two weeks of system operation, flowrates and pH values similar to those of Runs 1 and 2 were used. Arsenic concentrations following the adsorption vessel were 19.2 and 12.4 µg/L during the first two sampling events, similar to those observed in Runs 1 and 2. Starting from May 2, 2006, only Well 3 was operating most of the time until July 4, 2006, when all three wells resumed operation through the remainder of this demonstration study. As discussed in Section 4.4.1, there were noticeable drops in flowrate from all three wells starting from May 2, 2006; the average flowrate was 35 gpm (based on instantaneous flowrate readings) when all three wells were running and 17 gpm (based on calculated flowrates) when only Well 3 was running. Meanwhile, the pH of the influent to the adsorption vessel was kept around 6.3 (based on field meter readings denoted as "○" on Figure 4-13) or around 6.0 (based on inline probe readings denoted as "●" on Figure 4-13) most of the time. At these lower flowrates and lower pH values, arsenic concentrations following the adsorption vessel were reduced to the lowest point of 1.2 μg/L before beginning to rebound to 11.1 μg/L by the end of Run 3. Arsenic broke through at 10 μg/L just before July 18, 2006, after treating approximately 1,900,000 gal (or 3,000 BV) of water. As shown in Figure 4-13, changing flowrates and influent pH values did not appear to have any noticeable impact on the rising trend for arsenic in the treated water. For easy comparison, the flowrate and pH value plot is presented side by side with the Run 3 arsenic breakthrough curve copied from Figure 4-11.

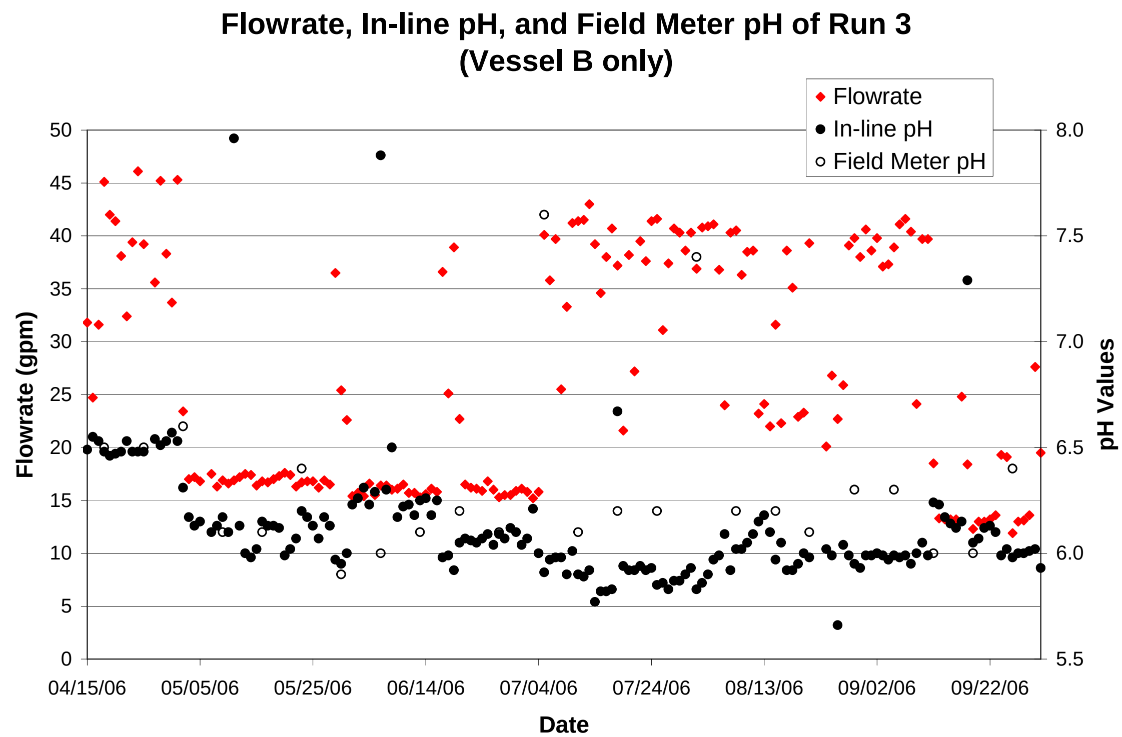
Iron. Iron concentrations in source water were low. With the exception of only a few data points, the iron concentrations, both total and dissolved, were below the analytical reporting limit of 25 μg/L at all sampling locations throughout the demonstration period (Table 4-6).

Manganese. Treatment plant water samples were analyzed for total manganese during all sampling events and for soluble manganese during speciation sampling events. Figure 4-14 shows total manganese concentrations over time at each of the four sampling locations across the treatment train. Similar to iron, manganese concentrations in raw water were low, ranging from 0.1 to 15.7 μg/L (Table 4-7). However, manganese concentrations in the treated water were significantly elevated to over 35 μg/L immediately after system startup, and then reduced sharply to the intake levels after about 2,000 to 3,000 BV of throughput in both Runs 1 and 2. As noted above, manganese was an impurity present in the $FeCl_3$ solution used for manufacturing the G2 media. Apparently, some manganese was leached from the media during system operation. For Run 3, manganese concentrations in the vessel effluent varied, ranging from <0.1 to 13.1 μg/L. The varying and lower manganese concentrations could be due to the lower flowrates used during Run 3, compared to those utilized during Runs 1 and 2. Further, uncharacteristically high manganese concentrations (i.e., as much as 16.1 μg/L) also were detected in about 50% of the samples taken at the wellhead and after pH adjustment. Naturally occurring manganese most likely was the source of these elevated concentrations.

Other Water Quality Parameters. Figure 4-15 summaries the results of pH (based on the readings from the handheld pH meter), alkalinity, and sulfate measurements collected across the treatment train.

The first few samples taken during October 13 through November 2, 2004, showed somewhat erratic pH results across the treatment train, which were thought to have been caused, in part, by erroneous on-site measurements using the WTW handheld meter. The plant operators were retrained for the use of the meter on November 9, 2004, and the results obtained since then appeared to follow a steadier trend.

pH values of source water typically ranged from 6.7 to 7.7 and averaged 7.3. At the suggestion of the vendor, the pH of the feed water was targeted at 6.8 at system startup, and then reduced to 6.4 by mid-December 2004. The target pH was furthered reduced to 6.0 during later part of Run 1 and most of Run 3. The target pH value for the treated water following caustic addition was set at 7.5. For the most part, the measured pH values after acid addition and after Vessels A and B were very close to the target value of 6.8, 6.4, and 6.0, with values after acid addition averaged at 6.6, 6.4, and 6.3 for Runs 1, 2, and 3, respectively. The measured pH values after the caustic addition, however, deviated by more than 1.0 pH unit from the target value of 7.5. As described in Section 4.4.2, the operator had some difficulties in adjusting the rate of caustic addition to account for the increased acid addition.



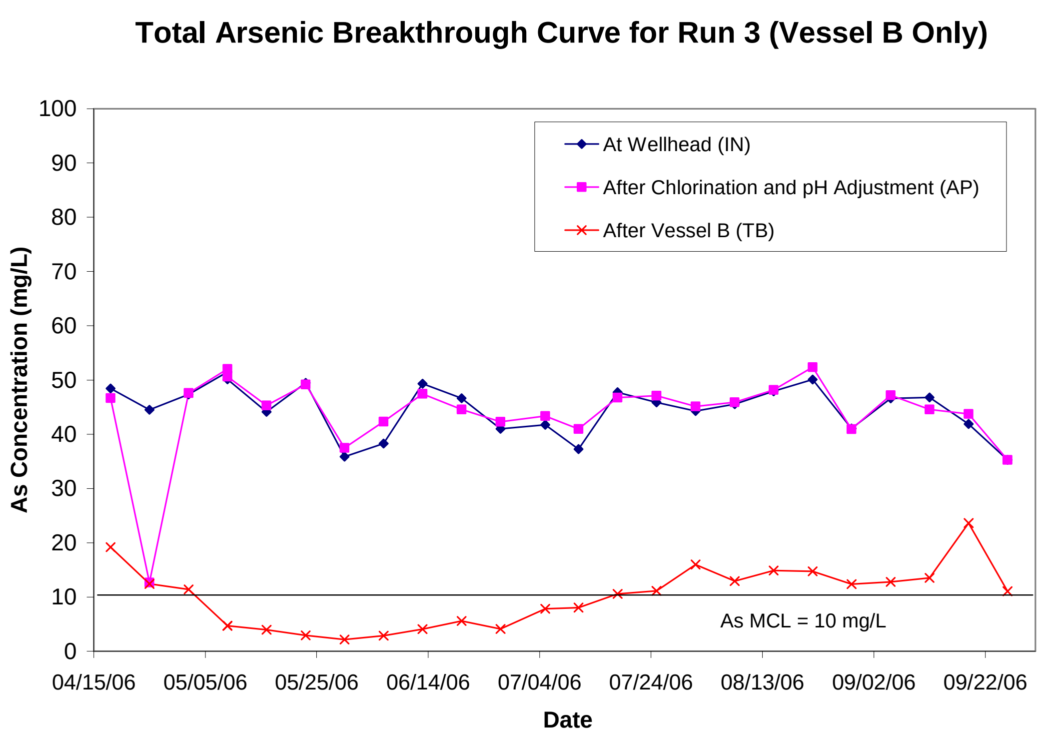


Figure 4-13. Run 3 Total Arsenic Breakthrough Curve and Corresponding pH and Flowrates

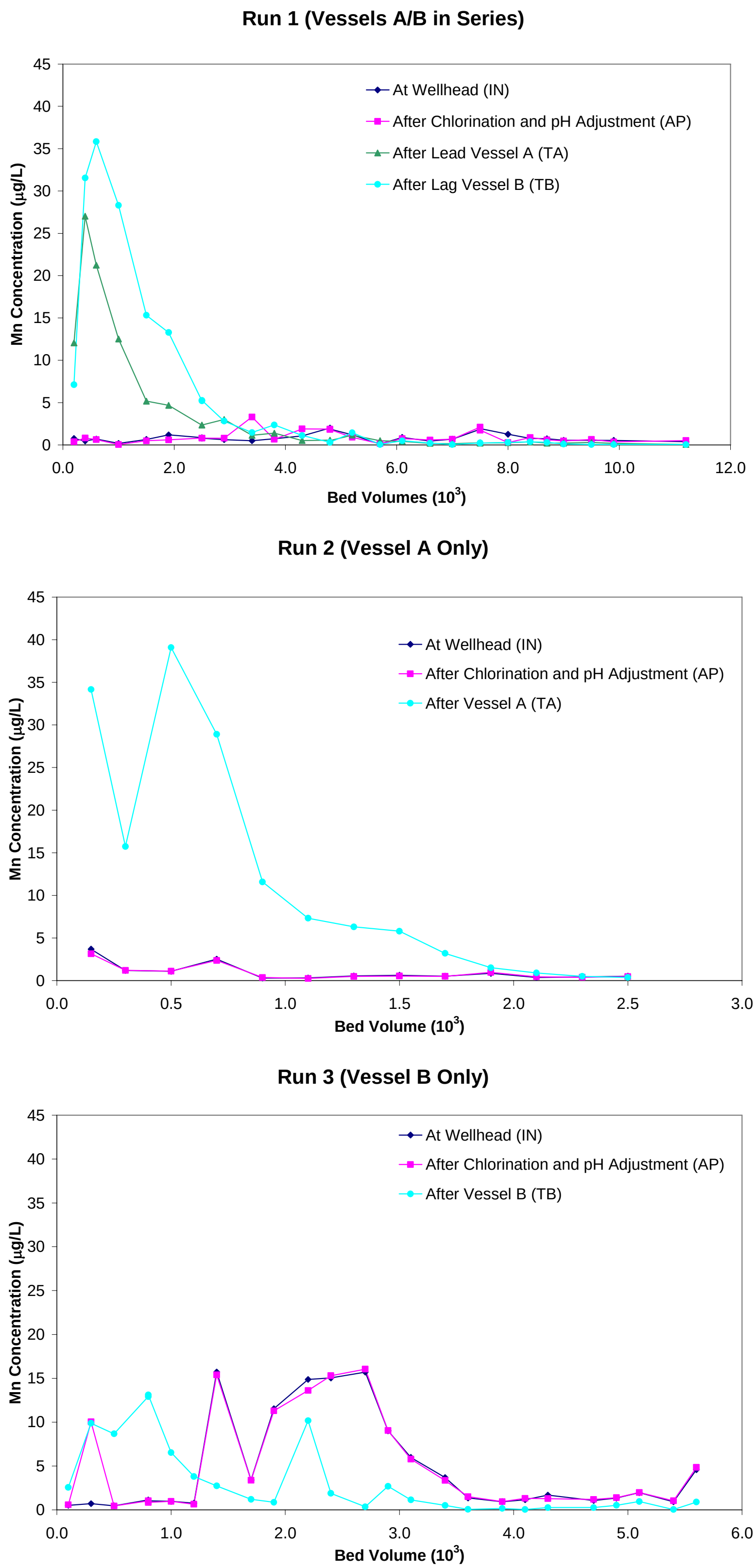


Figure 4-14. Total Manganese Breakthrough Curves
(BV Calculated Based on Media Volume in One Vessel)

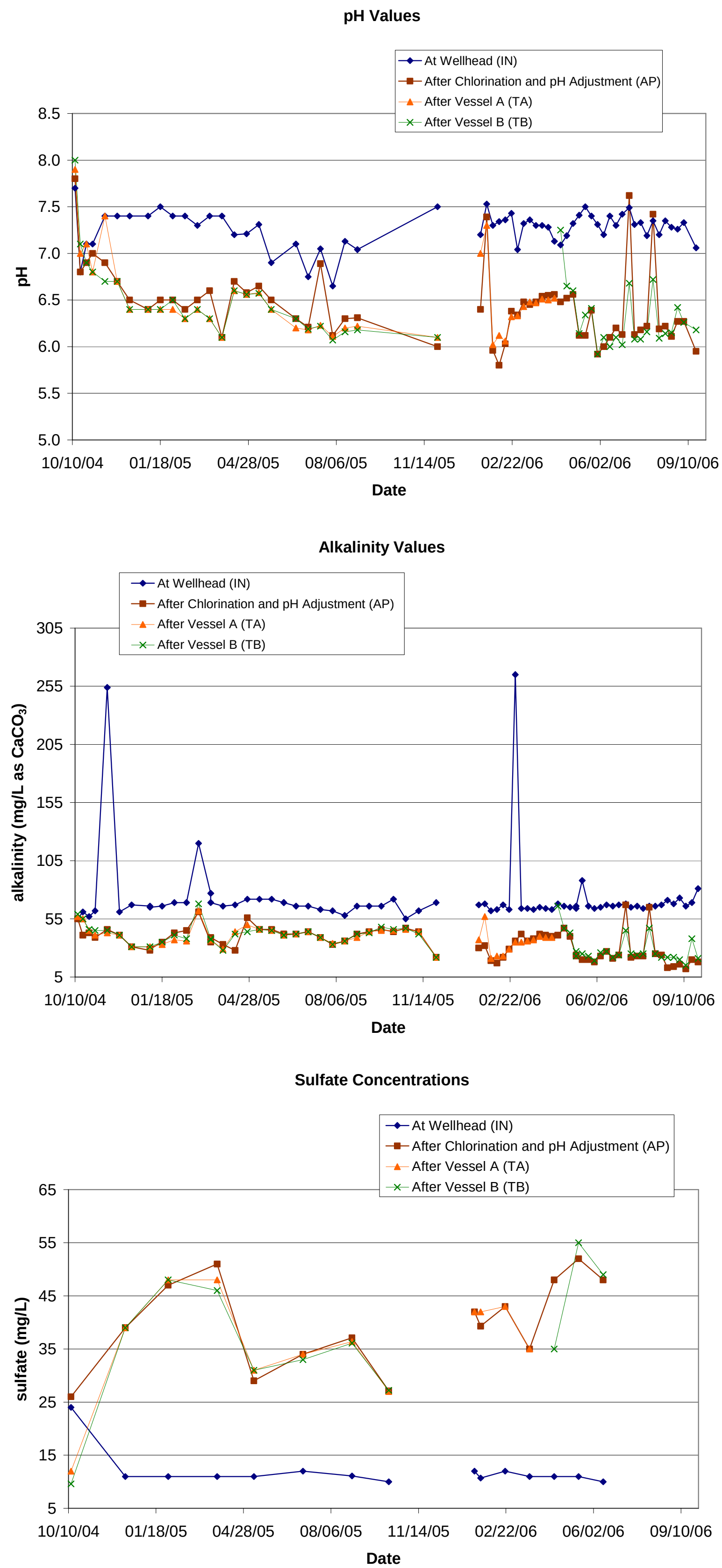


Figure 4-15. pH, Alkalinity, and Sulfate Values Over Time

Total alkalinity values in source water ranged from 55 to 88 mg/L (as $CaCO_3$) and averaged 66.3 mg/L (as $CaCO_3$) (Table 4-7 and Figure 4-15). Three abnormally high values measured on November 16, 2004, March 1, 2005, and February 28, 2006, at 254, 120, and 265 mg/L (as $CaCO_3$), respectively, were considered as outliers and excluded from the statistical analysis. [It is not clear why these values were so high.] After the acid addition, the water pH was reduced from 7.3 to 6.4 (on average) whereas the alkalinity values were decreased to an average of 34.5 mg/L (as $CaCO_3$) after pH adjustment.

Sulfate concentrations in source water ranged from 10 to 24 mg/L and averaged 11.9 mg/L (Table 4-7 and Figure 4-15). Immediately after system startup during Run 1, sulfate concentrations were reduced to 12.0 and 9.6 mg/L following the lead and lag vessels, respectively, apparently being removed by the G2 media. The addition of H_2SO_4 raised the sulfate concentrations to an average of 39.8 mg/L (for the entire study period), which was 27.9 mg/L higher than that of raw water. The actual amount of acid used for pH adjustment was 32 mg/L (or 0.27 lb/1,000 gal) based on the amount of acid used and the volume of water treated during the entire study period. This acid addition would have increased the sulfate concentration by 31.3 mg/L, slightly higher than the measured value of 27.9 mg/L.

Based on the pH and/or total alkalinity of raw and treated water, theoretical acid consumption required for pH adjustment can be calculated using a set of pH curves developed as a function of total alkalinity and free CO_2 (Rubel, 2003). The results of these calculations, as shown in Table 4-8, not only allow comparison of actual and theoretical acid consumption rates, but also verify the accuracy of total alkalinity and sulfate measurements. For example, lowering the pH from 7.3 to 6.4 would theoretically decrease alkalinity from 66.3 to 40 mg/L (as $CaCO_3$), which was slightly higher than the measured value of 34.5 mg/L (as $CaCO_3$) as discussed above. To achieve the theoretical and actual levels of alkalinity reduction, i.e., 26.3 and 31.8 mg/L (as $CaCO_3$), 27.7 and 33.5 mg/L of 93% H_2SO_4, respectively, would need to be added to the water, which would result in an increase of 25.2 and 30.5 mg/L in sulfate concentration (compared to the actual measured value of 27.9 mg/L as noted above). Further, the actual acid consumption (i.e., 0.27 lb/1,000 gal) was similar to that derived from the theoretical calculations (i.e., 0.23 and 0.28 lb/1,000 gal). Therefore, the pH, total alkalinity, sulfate, and acid consumption measurements correlate well with each other and are consistent with theoretical calculations.

Table 4-8. Theoretical Acid Consumption Requirements for Raw Water pH Adjustment

Parameter	Unit	Raw Water	Treated Water
pH	S.U.	7.3 (actual)	6.4 (actual)
Total Alkalinity	mg/L (as $CaCO_3$)	66.3 (actual)	40 (theoretical) 34.5 (actual)
Free CO_2	mg/L	6 (theoretical)	29 (theoretical)
Total Alkalinity Reduction	mg/L (as $CaCO_3$)	26.3 (theoretical) 31.8 (actual)	
Acid Required	meq/L	0.526 (theoretical) 0.635 (actual)	
93% H_2SO_4 Required	mg/L	27.7 (theoretical) 33.5 (actual)	
93% H_2SO_4 Required	lb/1,000 gal	0.23 (theoretical) 0.28 (actual)	

Figure 4-16 presents silica concentrations over time across the treatment train. Silica concentrations in source water ranged from 18.7 to 21.4 mg/L (as SiO_2) and averaged 19.7 mg/L (as SiO_2), which were similar to those in samples collected at the AP location following chlorination and pH adjustment, (excluding one data point observed on April 25, 2006, at 37.2 mg/L [as SiO_2]). Elevated silica concentrations as high as 61.8 mg/L (as SiO_2) were measured in the treated water immediately after startup of each test run, suggesting leaching of silica from the media. As discussed in Section 4.2, the G2 media is a silica-based material and, therefore, could very well be the source of the elevated silica observed. As seen in Figure 4-16, the highest silica concentrations were detected following Vessel B, the lag vessel, when the system was running in series under Run 1. Silica concentrations averaging 51 mg/L (as SiO_2) were measured after the lead vessel during Run 1 and during Runs 2 and 3 where only one vessel was in operation. Leaching of silica leveled off at about 2,000 BV (calculated based on the media volume in one vessel), but continued throughout the remainder of the respective study period. After leveling off, the increases in silica concentration ranged from 1.6 to 3.0 mg/L (as SiO_2) following the lead vessel and from 3.7 to 6.2 mg/L (as SiO_2) following the lag vessel when the vessels were configured in series under Run 1. The increases averaged 3.0 mg/L (as SiO_2) following Vessel B under Run 3. The run length for Run 2 was short and the run was discontinued as silica was still being leached at a relatively higher rate. It appears that silica after being leached passed through the lead and, then, lag vessels without being retained by the media. This observation was evidenced by the data that showed almost twice as high concentration increases following the lag than the lead vessels.

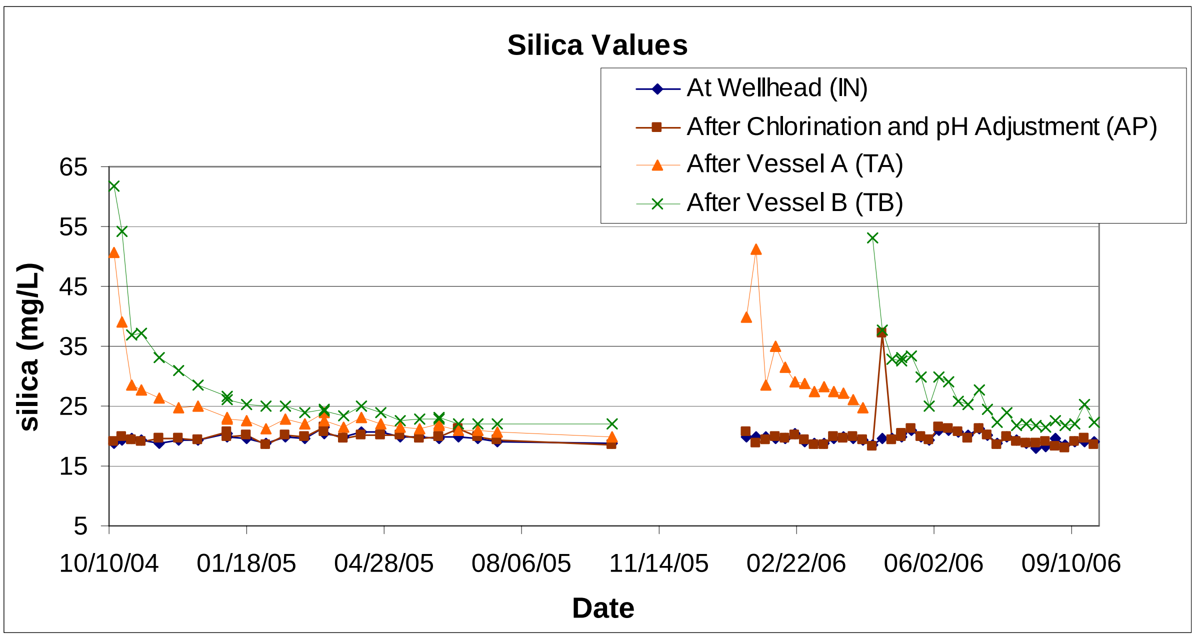


Figure 4-16. Silica Concentrations Over Time

Orthophosphate was not detected above the method reporting limit of 0.05 mg/L [as P]. Similarly, total phosphorous concentrations were low, ranging from below the method reporting limit (0.03 mg/L [as PO_4]) to 0.13 mg/L (as PO_4). The small amount of phosphorus was removed by the media.

Total hardness results ranged from 79.8 to 164 mg/L (as $CaCO_3$) and averaged 100 mg/L (as $CaCO_3$), which existed predominantly (i.e., 77%) as calcium hardness. Fluoride concentrations ranged from 0.6 to 1.1 mg/L and averaged 0.8 mg/L. Nitrate ranged from 0.1 to 1.4 mg/L (as N) and averaged 0.3 mg/L (as N). Levels of hardness, fluoride, and nitrate were consistent across the treatment train and did not appear to have been affected by any of the steps involved in the treatment process.

Free and total chlorine was measured at the AP, TA, and TB sampling locations. Typically, free chlorine levels were measured from non detect to 0.8 mg/L at the AP location, with total chlorine levels ranging from non detect to 0.9 mg/L. Residual chlorine levels measured at the TA and TB locations were similar to those measured at the AP location, indicating little or no chlorine consumption by the G2 media.

DO levels ranged from 3.1 to 7.9 mg/L across the treatment train and were consistent at each location excluding three values that were considered outliers (1.8, 2.8, and 9.4 mg/L). The wide variance in the DO values was probably caused, in part, by inadvertent aeration of the samples during sampling. ORP readings at the IN location varied from 172 to 498 mV and averaged 348 mV. After chlorination, the ORP readings increased significantly, ranging from 173 to 730 mV and averaging 550, 511, 521, 611, and 624 mV, respectively, at the AP, TA (lead), TB (lag), TA (only) and TB (only) locations.

4.5.2 Backwash Water. Backwash was performed using finished water in the storage tanks. Backwash water was sampled on January 11, April 12, and June 14, 2005. On June 14, 2005, two sets of grab samples were collected - one at the beginning of the backwash cycle and the other one after 6 min into the backwash. Samples were collected from the sample port located on the backwash effluent discharge line from each vessel. Unfiltered samples were analyzed for pH, turbidity, and TDS. Filtered samples, using 0.45-μm disc filters, were analyzed for soluble As, Fe, and Mn.

Soluble iron was low, ranging from below the method reporting limit of 25 μg/L to 66 μg/L. Soluble manganese concentrations also were low and comparable to the levels observed in raw water and the treated water after leaching of manganese had been ceased. Soluble arsenic concentrations in the Vessel A backwash water were 20.6 to 42.8 μg/L; soluble arsenic concentrations in the Vessel B backwash water were lower, ranging from 11.4 to 30.4 μg/L. Arsenic levels in finished water were about 2 μg/L on January 11, 2005; 5.8 μg/L on April 12, 2005; and about 19 μg/L on June 14, 2005. Because finished water was used for backwash, the elevated arsenic concentrations in backwash water suggest desorption. pH values of backwash water ranged from 6.2 and 6.9, which mirrored the daily pH values of the finished water, i.e., 6.8, 6.4, and 6.5. The analytical results from the three backwash water sampling events are summarized in Table 4-9.

Table 4-9. Backwash Water Sampling Results

Date/Vessel		pH	Turbidity	TDS	Soluble As[a]	Soluble Fe[a]	Soluble Mn[a]
		S.U.	NTU	mg/L	μg/L	μg/L	μg/L
Vessel A	01/11/05	6.9	140	38.0	40.3	<25	0.8
	04/12/05	6.2	200	244	42.8	<25	2.0
	06/14/05[b]	6.6	220	214	40.4	<25	0.8
	06/14/05[c]	6.6	34	198	20.6	66.0	6.0
Vessel B	01/11/05	6.7	390	72.0	11.4	<25	2.3
	04/12/05	6.6	120	240	26.1	<25	0.7
	06/14/05[c]	6.6	140	220	30.4	<25	0.3
	06/14/05[b]	6.6	58	218	18.0	50.0	4.6

(a) Samples filtered with 0.45 μm disc filters.
(b) Sample collected at beginning of backwash cycle.
(c) Sample collected 6 min into backwash cycle.

4.5.3 Spent Media. Spent media samples were collected according to Section 3.3.5. Although samples were collected at the top, middle and bottom of both vessels, only the sample collected from the top of Vessel A was analyzed for total metals. The results are presented in Table 4-10.

As expected, arsenic on the G2 media was low, amounting to only 1.1 mg/g of dry media (or 0.1%) at the top of the lead vessel. This amount, however, was more than 3.5 times higher than that removed from raw water by the lead vessel, i.e., 0.31 mg/g, estimated based on the breakthrough curve shown on Figure 4-11. Recall that arsenic was leached from the media in the beginning of the three test runs due to its presence as an impurity from the media manufacturing process. Therefore, the balance (i.e., 0.8 mg/g) plus the amount leached could have come with the media even before it was put into service. A sample of the virgin media used during the initial media loading and during the rebedding of the vessels was analyzed and the results are summarized in Table 4-10. The virgin media had arsenic concentrations ranging from 0.03 to 0.24 mg/g, which is more than four times less than the 0.8 mg/g discussed above.

Iron and aluminum levels were high, but silica levels were low. The iron level was over 12.3%, significantly higher than the 5 to 6% provided in the vendor's specification sheet. The iron levels in the virgin media were 2.6 to 4.3%, lower than but closer to that in the vendor's specification sheet. The aluminum level was 3.0%, six times higher than the vendor-provided 0.5%. The silica level was 0.3%, apparently due to incomplete dissolution of silica during HNO_3 digestion.

Table 4-10. Total Metal Contents of Virgin and Spent Media

Analyte	Spent Media				Virgin Media					
	Top of Vessel A (μg/g)				*Initial Media(μg/g)*			*Rebedded media(μg/g)*		
	A	**B**	**C**	**Average**	**A**	**B**	**Average**	**A**	**B**	**Average**
Aluminum	29,429	30,472	29,085	29,662	31,109	28,008	29,559	33,979	33,005	33,492
Antimony	1.1	1.5	1.2	1.3	8.7	2.1	5.4	1.3	1.6	1.4
Arsenic	1,124	1,161	1,109	1,131	132	31	81	244	134	189
Barium	185	197	200	194	147	140	144	144	146	145
Calcium	5,171	5,328	5,133	5,211	2,196	2,222	2,209	2,696	2,486	2,591
Copper	189	202	191	194	NA	NA	NA	NA	NA	NA
Iron	192,813	93,151	84,584	123,516	35,963	15,955	25,959	44,733	41,199	42,966
Lead	98.6	97.9	99.2	98.6	NA	NA	NA	NA	NA	NA
Magnesium	962	1,066	1,011	1,013	1303	1217	1,260	1587	1380	1,484
Manganese	284	308	300	297	165	142	154	193	204	199
Nickel	15.8	17.6	16.6	16.7	16.7	16.5	17	19.2	19	19
Phosphorous	810	819	764	798	179	<25	90	233	132	183
Silica	3,319	3,229	2,326	2,958	6,016	9,764	7,890	4,497	6,249	5,373
Vanadium	100	103	106	103	NA	NA	NA	NA	NA	NA
Zinc	501	496	473	490	NA	NA	NA	NA	NA	NA

A TCLP test conducted on the top sample from Vessel A indicated that the spent media could be disposed of as a non-hazardous waste. Only barium was detected at 0.6 mg/L (Table 4-11).

4.5.4 Distribution System. Distribution system water samples were collected to determine if the water treated by the arsenic removal system would impact the lead and copper levels and water chemistry in the distribution system. Prior to system startup, baseline distribution system water samples were

Table 4-11. TCLP Results of Spent Media

Analyte (mg/L)	Vessel A
Arsenic	<0.5
Barium	0.6
Cadmium	<0.1
Chromium	<0.1
Lead	<0.5
Mercury	<0.01
Selenium	<0.1
Silver	<0.1

(a) Source: Eastern Analytical Inc.

collected at three homes on July 21, August 5, August 18, and September 8, 2004. Following system startup, distribution system water sampling continued on a monthly basis at the same three locations. The samples were analyzed for pH, alkalinity, arsenic, iron, manganese, lead, and copper. The results of the distribution system sampling are summarized in Table 4-12.

Prior to system startup, arsenic concentrations in the distribution system were, as expected, similar to those measured in raw water, ranging from 36.9 to 52.3 μg/L. As shown in Figure 4-17, arsenic concentrations in the distribution system decreased significantly after system startup. During the first three sampling events, higher concentrations were measured in the distribution system than at the entry point (i.e., from 3.9 to 11.2 μg/L versus from 1.9 to 4.2 μg/L), suggesting some solubilization, destabilization, and/or desorption of arsenic-laden particles/scales in the distribution system (Lytle, 2005). Afterwards, arsenic concentrations closely mirrored those measured at the entry point.

Iron concentrations were similar to those observed in raw water and typically below the method reporting limit of 25 μg/L. The iron concentration in the DS1 sample collected on January 12, 2005 was high (174 μg/L); it was not clear why this concentration was significantly higher than the other relevant data points.

Manganese concentrations in the distribution system generally followed those measured at the entry point with the highest concentration (i.e., 16.0 μg/L) observed at the sampling location DS3 during the first sampling event soon after system startup (Figure 4-18). Increases in manganese were not as significant at the DS2 sampling location as at the other two locations. Manganese concentrations declined steadily to levels only slightly higher than those observed at the entry point after about three months of system operation. After switching to rebedded Vessel A in January 2006 (Run 2) and rebedded Vessel B in April 2006 (Run 3), an increase in manganese concentration was once again observed, although the increase was not as high as when the system was initially started in October 2004. This could be due to the fact that only one vessel was operating in Runs 2 and 3. Once again, manganese concentrations decreased steadily as observed during Run 1.

Although elevated, the manganese concentrations in the distribution system samples collected at the beginning of the runs were two to five times lower than those measured at the entry point. Due to the slow oxidation kinetics, soluble manganese most likely would have been oxidized to MnO_2 by chlorine and subsequently dropped out from the treated water after entering the storage tanks and distribution system given additional contact time. Similar observations also were made at several other arsenic demonstration sites, including Sabin, MN, where manganese concentrations were reduced from as high as 370 μg/L at the entry point to as low as 4 μg/L in the distribution system.

Table 4-12. Distribution System Sampling Results

Sampling Event		As (Estimated Concentration at Entry Point)	DS1 (3 Shoreview)								DS2 (7 West Gate)								DS3 (29 RPD)							
			Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	07/21/04	N/A	8.5	7.4	80	44.1	<25	1.1	2.5	93.7	7.8	7.4	68	41.1	<25	0.5	1.1	163	6.3	7.4	60	41.4	<25	0.4	2.0	150
BL2	08/05/04	N/A	7.5	7.2	68	52.3	<25	5.0	4.6	88.7	8.0	7.2	66	45.8	<25	0.6	2.7	240	7.0	7.3	60	48.2	<25	1.6	2.2	62.1
BL3	08/18/04	N/A	7.0	7.7	60	36.9	28	0.7	1.9	122	7.5	7.6	60	41.3	38	1.8	3.8	62.8	7.0	7.6	60	39.5	34	0.5	2.4	129
BL4	09/08/04	N/A	9.3	7.8	64	51.0	<25	0.9	0.8	92.7	7.8	7.8	64	49.1	<25	0.5	0.8	75.9	8.2	7.7	64	50.0	<25	0.6	1.0	129
1	11/03/04	4.2	8.8	7.5	62	11.2	<25	11.7	1.5	107	8.8	7.6	66	8.5	<25	3.0	0.8	94.9	8.3	7.8	62	9.3	<25	16.0	1.4	41.0
2	12/08/04	2.5	10.0	8.1	61	5.6	<25	7.5	0.9	35.4	7.8	8.1	61	12.4	<25	2.4	1.6	111	8.8	8.0	61	9.6	<25	4.0	2.4	147
3	01/12/05	1.9	9.0	6.8	44	3.9	174	7.7	3.1	375	7.7	6.8	55	5.7	<25	3.5	3.7	747	10.7	6.6	43	5.3	30	10.4	9.9	1,345
4	02/09/05	4.2	5.5	7.5	54	4.4	<25	2.6	5.9	379	7.8	7.4	61	4.8	28	2.7	1.9	731	8.3	7.2	64	5.1	<25	6.3	6.7	814
5	03/09/05	5.4	7.0	7.6	70	7.1	<25	2.1	1.6	56.0	7.7	7.4	57	5.3	<25	2.2	4.2	882	9.0	7.4	71	7.3	<25	2.1	5.0	461
6	04/20/05	8.4	7.4	7.3	72	7.7	<25	2.6	3.7	262	7.7	7.1	67	4.2	<25	2.4	3.6	739	8.3	7.1	64	9.9	26	3.0	5.0	430
7	05/11/05	15.2	10.0	7.4	66	12.6	59	2.5	4.6	157	7.3	7.3	63	12.7	39	2.2	4.3	397	9.1	7.2	72	10.1	41	1.2	3.8	478
8	06/08/05	19.7	7.0	7.0	63	12.2	<25	0.3	0.5	4.3	7.8	6.9	63	15.6	<25	1.3	4.2	340	10.1	6.9	119	16.7	<25	1.2	4.3	577
9	07/12/05	19.6	10.5	6.9	50	17.9	<25	3.3	1.9	201	7.0	6.7	64	10.5	<25	0.9	1.6	640	10.3	7.0	61	26.8	<25	1.6	7.1	813
10	08/03/05	19.4	9.7	7.2	58	17.8	<25	3.5	6.4	157	8.5	7.0	61	13.1	<25	2.3	3.0	912	8.4	7.0	58	16.3	<25	1.6	5.0	511
11	09/14/05	21.9	8.7	7.1	62	22.1	<25	1.5	5.2	131	8.0	7.0	63	21.4	<25	0.9	4.2	285	9.8	7.7	63	23.6	<25	0.9	3.4	338
12	10/11/05	34.6	10.0	7.5	44	33.0	<25	0.9	1.0	17	7.8	7.5	69	29.2	<25	0.2	0.9	32	8.2	7.6	68	30.7	<25	0.2	0.8	22
13	11/02/05	34.6	9.0	7.6	64	37.6	<25	0.8	1.3	35	7.8	7.6	62	35.2	<25	0.4	1.2	120	8.0	7.6	62	35.2	<25	0.4	1.4	95
14	01/18/06	17.6	Homeowner not available.								8.0	7.1	63	24.6	66.7	6.2	2.1	208	8.5	7.0	58	21.5	<25	6.7	4.8	605
15	02/15/06	6.2	10.5	7.0	67	7.5	<25	2.2	1.7	189	8.0	7.0	62	7.0	<25	3.2	1.4	642	8.5	7.0	57	7.5	<25	4.1	1.8	525
16	03/15/06	12.5	8.9	7.4	61	9.9	<25	3.7	1.9	24.3	NA	7.3	60	10.3	<25	2.1	3.1	322	NA	7.3	61	11.1	<25	2.0	4.0	472
17	04/12/06	15.2	10.3	7.8	70	17.1	<25	1.3	0.9	26.9	7.1	7.6	68	12.4	<25	0.8	0.7	132	10.0	7.9	70	18.6	<25	1.0	2.1	130
18	06/21/06	5.6	NA	7.0	61	4.8	<25	4.3	2.4	267	NA	6.9	54	4.3	25.1	2.5	5.1	1,061	NA	6.8	54	4.4	<25	3.3	5.7	1,048

BL = baseline sampling; DS = distribution sampling; NA = not available; lead action level = 15 µg/L; copper action level = 1.3 mg/L
(a) Sample at DS2 taken on 11/08/04; (b) Sample at DS1 taken on 07/06/05 and DS3 taken on 07/21/05.
(c) Sample at DS1taken on 09/21/05; (d) Sample at DS1 taken on 10/18/05; (e) Sample at DS1 taken on 03/10/06.

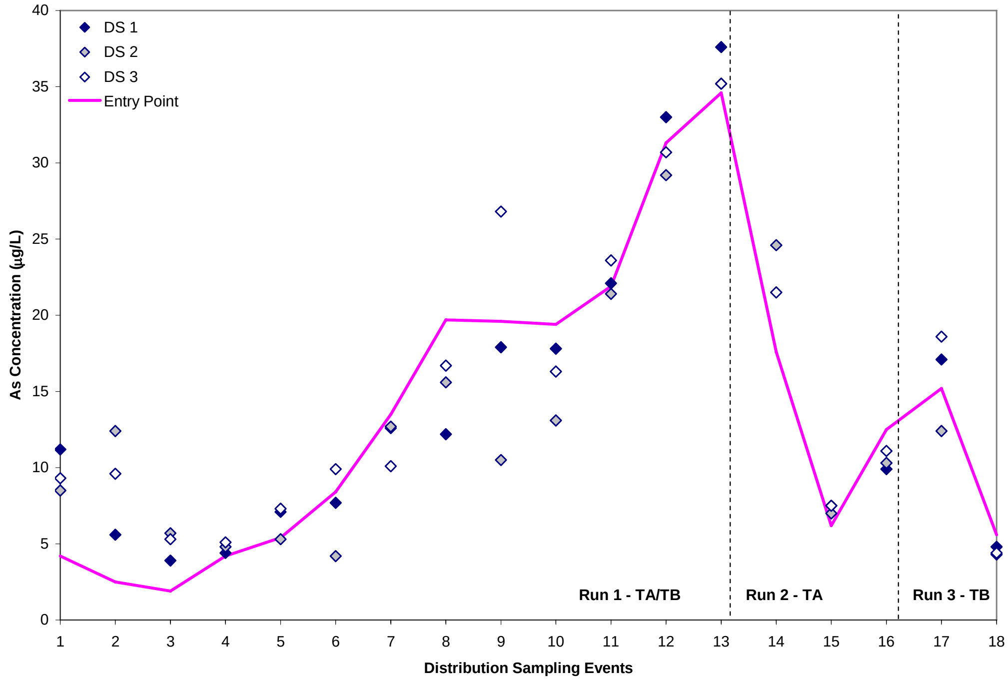


Figure 4-17. Comparison of Arsenic Concentrations at Entry Point and in Distribution System

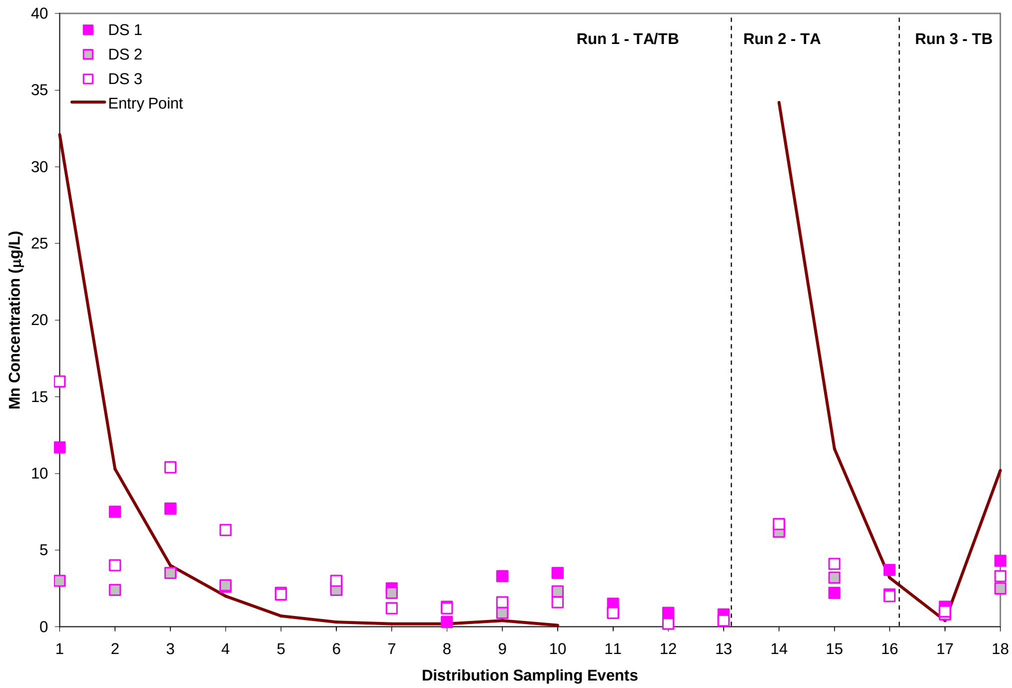


Figure 4-18. Comparison of Manganese Concentrations at Entry Point and in Distribution System

pH values measured during the baseline sampling ranged from 7.2 to 7.8. After the system was in operation, pH values ranged from 6.6 to 8.1. pH values across all three sampling locations were high during the sampling event on December 8, 2004. During the next sampling event on January 12, 2005, however, pH values were significantly lower, ranging from 6.6 to 6.8. This swing in pH was caused by difficulties encountered with adjustments to the rate of caustic addition as described under *Operator Skill Requirements* in Section 4.4.6. In addition, low pH values were measured during sampling events on June 8, 2005, at 6.9 to 7.0; July 12, 2005 at 6.7 to 7.0; and June 21, 2006 at 6.8 to 7.0. The causes behind the low pH values included operational difficulties with the magnetic meter on June 2, 2005, causing the acid and caustic chemical pumps to stay on until the meter had been reset, and a delay in replacing empty caustic containers.

The lower pH values appeared to have had a significant impact on the lead and copper levels in the distribution system. Prior to the January 2005 sampling event, the lead and copper levels measured at the three sampling locations ranged from 0.8 to 2.4 μg/L for lead and from 35.4 to 147.0 μg/L for copper, which were consistent with the baseline values of 0.8 to 4.6 μg/L for lead and 62.1 to 240.1 μg/L for copper. With the pH drop in January 2005, the lead concentration increased to 9.9 μg/L at the DS3 location; copper levels increased across all three sampling locations, with the most noticeable increase exceeding the action level of 1.3 mg/L at the DS3 location. During the subsequent monthly sampling events, the pH values were better controlled; however, the lead and copper levels continued to be elevated when compared to the levels before the pH drop in January. The same trend was seen in the other low pH sampling events although the action level for either lead or copper was not exceeded during these events.

For the most part, alkalinity levels were consistent both before and after system startup, averaging 62.5 mg/L (as $CaCO_3$). In January 2005, alkalinity values were lower (i.e., 43 to 55 mg/L), consistent with the low pH values measured during this sampling event. The alkalinity value for the sample collected on June 8, 2005 at the DS3 location was high; it was not clear why this concentration was significantly higher than the other relevant data points.

4.6 System Cost

The system cost was evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. The capital cost included cost for equipment, site engineering, and system installation. The O&M cost included cost for media replacement and disposal, chemical supplies, electrical power use, and labor. The cost incurred for treatment building construction was funded by WRWC and was not included in the cost evaluation.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation was $166,050 (see Table 4-13). The equipment cost was $105,350 (or 64% of the total capital investment), which included $76,100 for the adsorption vessels and piping, $6,000 for the G2 media (i.e., $35/ft^3 or $0.75/lb to fill two vessels), $3,900 for a backwash booster pump, $2,750 for a pH chart recorder, and $16,600 for vendor's labor and travel for system shakedown and startup. The backwash booster pump and the pH chart recorder were not included in the original proposal and added as a change order.

The engineering cost included the cost for the preparation of the system layout and footprint, design of the piping connections up to the distribution tie-in points, design of the electrical connections, and assembling and submission of the engineering plans for the permit application (Section 4.3.1). The engineering cost was $17,200 (or 10% of the total capital investment), including a change order of $4,700 for incorporating the backwash booster pump and the pH chart recorder into the engineering plan.

The installation cost included the cost for the equipment and labor to unload and install the adsorption system, perform the piping tie-ins and electrical work, and load and condition the media (Section 4.3.3).

System installation was conducted by Lewis Engineering and C&C Water Services subcontracted to ADI. The installation cost was $43,500 (or 26% of the total capital investment), including a change order of $3,900 for installing the backwash pump and pH chart recorder.

C&C Water Services constructed an aboveground addition to the existing underground pump house structure to house the G2 media system (Section 4.3.2). The cost of building the addition was approximately $25,000, including placement of a steel support on top of the existing concrete structure and construction of a wooden frame building on this steel support.

Table 4-13. Capital Investment for G2 Media System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
Adsorption System	1 unit	$76,100	–
G2 Media	170 ft^3	$6,000	–
Backwash Booster Pump	1	$3,900	–
pH Chart Recorder	1	$2,750	
Field Services (Vendor Labor and Travel)	–	$16,600	–
Equipment Total	–	**$105,350**	**64%**
Engineering Cost			
Vendor Labor	–	$12,500	–
Change Order	–	$4,700	–
Engineering Total	–	**$17,200**	**10%**
Installation Cost			
Subcontractor	–	$32,500	–
Vendor Labor	–	$3,550	–
Vendor Travel	–	$3,550	–
Change Order	–	$3,900	–
Installation Total	–	**$43,500**	**26%**
Total Capital Investment	–	**$166,050**	**100%**

The capital cost of $166,050 was normalized to $4,150/gpm ($2.88/gpd) of design capacity using the system's rated capacity of 40 gpm (or 57,600 gpd). The capital cost also was converted to an annualized cost of $15,673/year by multiplying by a capital recovery factor (CRF) 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 40 gpm to produce 21,024,000/year, the unit capital cost would be $ 0.75/1,000 gal. During the Run 1 study period when both vessels were placed into service, the system operated an average of 9.5 hr/day at an average flowrate of 41 gpm, producing 8,530,000 gal of water annually. Therefore, the unit capital cost increased to $1.84/1,000 gal at this reduced rate of usage.

4.6.2 Operation and Maintenance Costs. The O&M cost included only the incremental cost associated with the G2 system, such as media replacement and disposal, chemical supply, electricity, and labor, as summarized in Table 4-14. As discussed in Section 4.4, the spent media in both vessels were removed in December 2005 and virgin media was loaded in January 2006 followed by conditioning of media in Vessel A. Media conditioning of vessel B was performed in April 2006. The virgin G2 media was supplied by ADI, but the field work was performed by C&C Water Services. The total cost incurred

Table 4-14. O&M Costs for G2 Media System

Cost Category	Value	Remarks
Media Replacement and Disposal		
Media Cost ($/ft^3)	40	-
Total Media Volume (ft^3)	170	Replacing spent media in both vessels
Virgin Media Cost ($)	6,800	Supplied by ADI
Freight ($)	580	-
Media Removal Cost ($)	3,916	Labor costs and vacuum truck rental
Media Installation Cost ($)	4,356	Media installation and conditioning
Waste Analysis, TCLP ($)	300	-
Media Disposal Fee ($)	800	-
Subtotal ($)	16,752	
Media Replacement and Disposal Cost ($/1,000 gal)	See Figure 4-19	$4.30 for a media life of 3,896,000 gal or 3,064 BV
Chemical Usage		
Acid Unit Price ($/lb)	0.40	200 lb container at $80
Acid Consumption Rate (lb/1,000 gal)	0.27	3,600 lb used to treat 13,154 kgal
Acid Cost ($/1,000 gal)	0.11	-
Caustic Unit Price ($/lb)	0.63	160 lb container at $100
Caustic Consumption Rate (lb/1,000 gal)	0.57	7,520 lb used to treat 13,154 kgal
Caustic Cost ($/1,000 gal)	0.36	-
Total Chemical Cost ($/1,000 gal)	0.47	Cost for chlorination not included
Electricity		
Electricity Cost ($/1,000 gal)	0.001	Electrical costs assumed negligible
Labor		
Average Weekly Labor (hrs)	2.33	20 min/day
Labor Cost ($/1,000 gal)	0.34	Labor rate = $20/hr
Total O&M Cost ($/1,000 gal)	5.11	Sum of $4.30, $0.47, and $0.34

was $16,752, which included cost for 170 ft^3 of new media, freight, rental of vacuum truck, labor for removing and installing the new media, media conditioning, and spent media profiling and disposal. Although a lead/lag vessel design typically replaces the spent media in the lead vessel only, the limited arsenic removal capacity of the G2 media at WRWC (i.e., ~3,000 BV) would require rather frequent media changeout. Therefore, it would be more cost-effective to replace the media in both vessels at the same time in order to save cost for labor and logistics associated with two separate changeouts. By averaging the media replacement cost of $16,752 over the media life, the unit cost per 1,000 gal of water treated is plotted as a function of the media life, as shown in Figure 4-19. The media life in BV was calculated by dividing the system throughput (gal) by 170 ft^3 (or 1,272 gal) of media. In the case of WRWC, the arsenic concentration in the system effluent exceeded the MCL at 3,896,000 gal or 3,064 BV, so the corresponding media replacement cost was $4.30/1,000 gal. Assuming the system operated an average of 9.5 hr/day, producing 8,530,000 gal of water annually (see Section 4.6.1), it would require 2.2 times of media changeout for a total of $36,680 annually.

Chemical costs included NaOCl for chlorination and H_2SO_4 and NaOH for pH adjustment. Chlorination was in use prior to the installation of the G2 system to maintain chlorine residuals in the distribution system. Because the treatment system did not change the use rate of the NaOCl solution, the chemical cost of NaOCl was unchanged with zero incremental cost. During the demonstration study, 18 containers (15-gal, 200 lb per container) of 93% H_2SO_4 and 47 containers (15-gal, 160 lb per container) of 25% NaOH were consumed for pH adjustment. Based on the price per drum of approximately $80 and $100 for acid and caustic, respectively, the total chemical cost during the study period was about $6,140 or

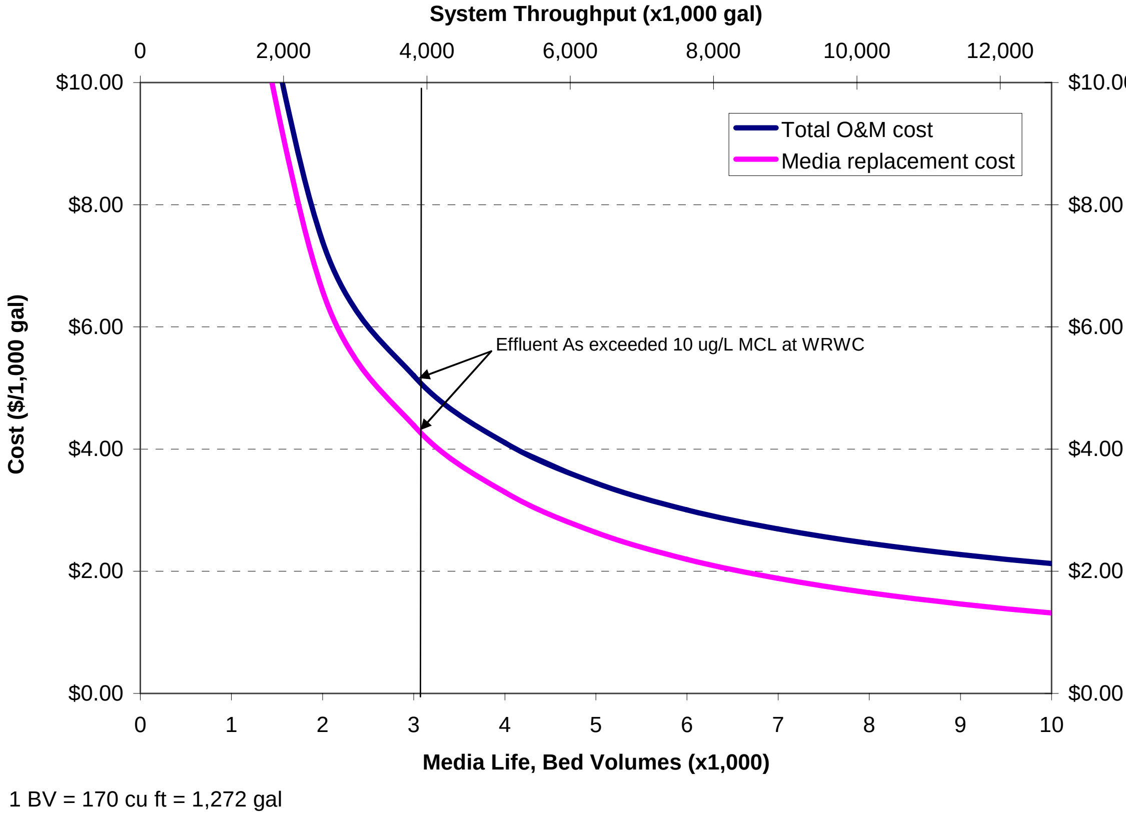


Figure 4-19 Media Replacement Cost Curves for Bow System.

$0.47/1,000 gallons. Applying this unit cost to an annual water production of 8,530,000 gal, the annual chemical cost associated with the pH adjustment was $4,009.

The electricity consumption for the pump station averaged 131 kWh per day during the study period. Comparison of electrical bills prior to system installation and since startup indicated that the treatment system did not cause a noticeable increase in electricity consumption. Therefore, electricity cost associated with operation of the G2 media system was negligible.

The routine, non-demonstration-related labor activities consumed about 20 minutes per day, as noted in Section 4.4.6. Therefore, the estimated labor cost was $0.34/1,000 gal of water treated.

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APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 1 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
1	10/13/04	6.7	6.7	36	537,160	NA	NA	NA	3	5	NA	2	5	NA
2	10/19/04	7.3	14.0	38.6	643,625	106,465	106,465	167	2.0	3.0	-1.0	1.0	2.0	-1.0
	10/20/04	8.4	22.4	26.9	664,300	20,675	127,140	200	1.0	2.0	-1.0	0.5	2.0	-1.5
	10/21/04	6.6	29.0	30.6	680,661	16,361	143,501	226	1.0	3.0	-2.0	1.0	2.0	-1.0
	10/22/04	8.9	37.9	39.0	702,593	21,932	165,433	260	2.0	2.0	0.0	1.0	2.0	-1.0
	10/23/04	7.8	45.7	44.0	721,837	19,244	184,677	290	2.0	2.0	0.0	1.0	2.0	-1.0
	10/24/04	7.2	52.9	47.0	739,366	17,529	202,206	318	3.0	4.0	-1.0	2.0	3.0	-1.0
3	10/25/04	8.8	61.7	48.0	760,847	21,481	223,687	352	2.0	3.0	-1.0	2.0	3.0	-1.0
	10/26/04	6.8	68.5	38.0	777,478	16,631	240,318	378	2.0	3.0	-1.0	1.0	2.0	-1.0
	10/27/04	8.4	76.9	45.0	797,624	20,146	260,464	410	2.0	4.0	-2.0	2.0	3.0	-1.0
	10/28/04	7.5	84.4	46.0	816,002	18,378	278,842	439	2.0	4.0	-2.0	2.0	3.0	-1.0
	10/29/04	7.6	92.0	48.0	834,796	18,794	297,636	468	2.0	3.0	-1.0	2.0	3.0	-1.0
	10/30/04	9.6	101.6	49.0	858,346	23,550	321,186	505	2.0	3.0	-1.0	1.0	2.0	-1.0
	10/31/04	9.7	111.3	44.0	880,781	22,435	343,621	540	2.0	3.0	-1.0	1.0	2.0	-1.0
4	11/01/04	7.9	119.2	41.7	899,790	19,009	362,630	570	5.0	5.0	0.0	4.0	5.0	-1.0
	11/02/04	9.2	128.4	44.0	921,975	22,185	384,815	605	8.0	10.0	-2.0	8.0	10.0	-2.0
	11/03/04	6.9	135.3	44.0	938,108	16,133	400,948	631	8.0	10.0	-2.0	6.0	8.0	-2.0
	11/04/04	8.6	143.9	43.0	957,946	19,838	420,786	662	8.0	10.0	-2.0	6.0	8.0	-2.0
	11/05/04	8.8	152.7	43.3	978,591	20,645	441,431	694	8.0	10.0	-2.0	6.0	8.0	-2.0
	11/06/04	8.1	160.8	41.0	997,718	19,127	460,558	724	8.0	8.0	0.0	6.0	8.0	-2.0
	11/07/04	8.8	169.6	43.0	1,017,767	20,049	480,607	756	8.0	10.0	-2.0	6.0	8.0	-2.0
5	11/08/04	9.2	178.8	45.0	1,038,441	20,674	501,281	788	10.0	10.0	0.0	8.0	10.0	-2.0
	11/09/04	7.7	186.5	42.0	1,056,213	17,772	519,053	816	10.0	11.0	-1.0	8.0	10.0	-2.0
	11/10/04	7.2	193.7	43.0	1,073,299	17,086	536,139	843	10.0	10.0	0.0	9.0	10.0	-1.0
	11/11/04	7.7	201.4	45.0	1,091,607	18,308	554,447	872	10.0	10.0	0.0	8.0	10.0	-2.0
	11/12/04	9.8	211.2	36.0	1,114,759	23,152	577,599	908	6.0	8.0	-2.0	4.0	8.0	-4.0
	11/13/04	7.7	218.9	42.0	1,132,453	17,694	595,293	936	8.0	10.0	-2.0	8.0	10.0	-2.0
	11/14/04	8.3	227.2	41.0	1,151,444	18,991	614,284	966	8.0	9.0	-1.0	5.0	8.0	-3.0
6	11/15/04	8.9	236.1	48.0	1,171,547	20,103	634,387	998	9.0	10.0	-1.0	8.0	9.0	-1.0
	11/16/04	8.2	244.3	40.0	1,198,461	26,914	661,301	1,040	12.0	12.0	0.0	11.0	12.0	-1.0
	11/17/04	7.9	252.2	42.0	1,208,577	10,116	671,417	1,056	10.0	12.0	-2.0	9.0	11.0	-2.0
	11/18/04	7.5	259.7	43.0	1,226,155	17,578	688,995	1,084	12.0	12.0	0.0	11.0	12.0	-1.0
	11/19/04	8.6	268.3	41.0	1,246,352	20,197	709,192	1,115	10.0	12.0	-2.0	9.0	11.0	-2.0
	11/20/04	9.7	278.0	44.0	1,268,470	22,118	731,310	1,150	10.0	11.0	-1.0	8.0	10.0	-2.0
	11/21/04	8.4	286.4	40.0	1,286,856	18,386	749,696	1,179	10.0	11.0	-1.0	10.0	11.0	-1.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 2 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	Hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
7	11/22/04	8.6	295.0	39.3	1,306,700	19,844	769,540	1,210	10.0	11.0	-1.0	8.0	10.0	-2.0
	11/23/04	7.3	302.3	40.3	1,323,674	16,974	786,514	1,237	10.0	11.0	-1.0	9.0	11.0	-2.0
	11/24/04	9.7	312.0	43.3	1,345,911	22,237	808,751	1,272	11.0	12.0	-1.0	10.0	12.0	-2.0
	11/25/04	8.2	320.2	41.7	1,364,685	18,774	827,525	1,302	11.0	12.0	-1.0	9.0	11.0	-2.0
	11/26/04	8.8	329.0	41.3	1,384,761	20,076	847,601	1,333	12.0	12.0	0.0	10.0	11.0	-1.0
	11/27/04	8.4	337.4	40.3	1,403,810	19,049	866,650	1,363	10.0	11.0	-1.0	10.0	11.0	-1.0
	11/28/04	11.0	348.4	39.4	1,427,681	23,871	890,521	1,401	10.0	11.0	-1.0	9.0	10.0	-1.0
8	11/29/04	7.6	356.0	40.1	1,444,834	17,153	907,674	1,428	10.0	11.0	-1.0	10.0	12.0	-2.0
	11/30/04	8.5	364.5	46.7	1,463,974	19,140	926,814	1,458	12.0	13.0	-1.0	10.0	12.0	-2.0
	12/01/04	7.1	371.6	41.5	1,480,492	16,518	943,332	1,484	12.0	13.0	-1.0	10.0	12.0	-2.0
	12/02/04	8.1	379.7	41.6	1,499,233	18,741	962,073	1,513	12.0	13.0	-1.0	10.0	12.0	-2.0
	12/03/04	9.1	388.8	38.2	1,520,747	21,514	983,587	1,547	9.0	9.0	0.0	7.0	9.0	-2.0
	12/04/04	7.4	396.2	41.5	1,537,957	17,210	1,000,797	1,574	10.0	10.0	0.0	8.0	10.0	-2.0
	12/05/04	9.2	405.4	42.5	1,558,903	20,946	1,021,743	1,607	9.0	9.0	0.0	7.0	8.0	-1.0
9	12/06/04	7.3	412.7	42.3	1,575,151	16,248	1,037,991	1,633	12.0	12.0	0.0	10.0	12.0	-2.0
	12/07/04	7.6	420.3	41.1	1,592,399	17,248	1,055,239	1,660	12.0	12.0	0.0	9.0	12.0	-3.0
	12/08/04	7.7	428.0	43.8	1,610,551	18,152	1,073,391	1,688	13.0	13.0	0.0	11.0	12.0	-1.0
	12/09/04	8.0	436.0	43.4	1,628,928	18,377	1,091,768	1,717	13.0	13.0	0.0	11.0	12.0	-1.0
	12/10/04	8.2	444.2	43.7	1,648,334	19,406	1,111,174	1,748	11.0	12.0	-1.0	9.0	11.0	-2.0
	12/11/04	8.4	452.6	42.6	1,667,441	19,107	1,130,281	1,778	12.0	12.0	0.0	13.0	12.0	1.0
	12/12/04	10.2	462.8	36.8	1,690,927	23,486	1,153,767	1,815	9.0	9.0	0.0	7.0	9.0	-2.0
10	12/13/04	7.2	470.0	42.9	1,706,789	15,862	1,169,629	1,840	13.0	12.0	1.0	12.0	12.0	0.0
	12/14/04	9.4	479.4	45.5	1,728,436	21,647	1,191,276	1,874	10.0	10.0	0.0	7.0	9.0	-2.0
	12/15/04	6.5	485.9	41.7	1,744,098	15,662	1,206,938	1,898	9.0	9.0	0.0	7.0	8.0	-1.0
	12/16/04	7.0	492.9	43.4	1,760,533	16,435	1,223,373	1,924	10.0	10.0	0.0	7.0	9.0	-2.0
	12/17/04	9.2	502.1	41.6	1,782,219	21,686	1,245,059	1,958	8.0	8.0	0.0	6.0	7.0	-1.0
	12/18/04	8.1	510.2	41.3	1,800,894	18,675	1,263,734	1,988	9.0	8.0	1.0	6.0	7.0	-1.0
	12/19/04	9.4	519.6	38.0	1,822,426	21,532	1,285,266	2,021	7.0	7.0	0.0	5.0	7.0	-2.0
11	12/20/04	9.1	528.7	41.6	1,842,688	20,262	1,305,528	2,053	7.0	8.0	-1.0	6.0	7.0	-1.0
	12/21/04	7.2	535.9	42.3	1,854,450	11,762	1,317,290	2,072	10.0	10.0	0.0	7.0	9.0	-2.0
	12/22/04	8.7	544.6	41.4	1,878,671	24,221	1,341,511	2,110	10.0	10.0	0.0	7.0	9.0	-2.0
	12/24/04	20.8	565.4	41.8	1,924,958	NA	NA	NA	10.0	10.0	0.0	7.0	9.0	-2.0
	12/25/04	9.9	575.3	38.7	1,946,344	21,386	1,362,897	2,144	10.0	9.0	1.0	7.0	9.0	-2.0
	12/26/04	10.6	585.9	40.6	1,969,074	22,730	1,385,627	2,179	10.0	9.0	1.0	7.0	8.0	-1.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 3 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
12	12/27/04	9.7	595.6	42.1	1,988,059	18,985	1,404,612	2,209	9.0	9.0	0.0	7.0	8.0	-1.0
	12/28/04	8.8	604.4	39.5	2,008,591	20,532	1,425,144	2,241	9.0	9.0	0.0	7.0	8.0	-1.0
	12/29/04	9.8	614.2	40.8	2,030,335	21,744	1,446,888	2,276	8.0	7.0	1.0	6.0	8.0	-2.0
	12/30/04	10.1	624.3	36.5	2,052,360	22,025	1,468,913	2,310	7.0	7.0	0.0	5.0	7.0	-2.0
	12/31/04	11.7	636.0	35.4	2,077,382	25,022	1,493,935	2,350	7.0	7.0	0.0	5.0	6.0	-1.0
	01/01/05	7.4	643.4	38.5	2,093,961	16,579	1,510,514	2,376	9.0	9.0	0.0	7.0	8.0	-1.0
	01/02/05	23.5	666.9	31.5	2,134,111	40,150	1,550,664	2,439	6.0	4.0	2.0	3.0	6.0	-3.0
13	01/03/05	7.3	674.2	40.3	2,149,653	15,542	1,566,206	2,463	10.0	10.0	0.0	7.0	9.0	-2.0
	01/04/05[a]	8.5	682.7	41.6	2,168,274	18,621	1,584,827	2,493	11.0	10.0	1.0	8.0	10.0	-2.0
	01/05/05	8.1	690.8	43.0	2,186,659	18,385	1,603,212	2,522	11.0	11.0	0.0	8.0	10.0	-2.0
	01/06/05	10.5	701.3	38.2	2,210,604	23,945	1,627,157	2,559	7.0	7.0	0.0	5.0	7.0	-2.0
	01/07/05	8.9	710.2	40.6	2,229,746	19,142	1,646,299	2,589	9.0	8.0	1.0	7.0	9.0	-2.0
	01/08/05	8.5	718.7	40.1	2,248,542	18,796	1,665,095	2,619	10.0	10.0	0.0	7.0	9.0	-2.0
	01/09/05	9.6	728.3	44.3	2,269,572	21,030	1,686,125	2,652	10.0	10.0	0.0	7.0	9.0	-2.0
14	01/10/05	9.5	737.8	40.3	2,290,483	20,911	1,707,036	2,685	9.0	8.0	1.0	7.0	8.0	-1.0
	01/11/05	12.4	750.2	31.5	2,317,137	26,654	1,733,690	2,727	7.0	8.0	-1.0	6.0	8.0	-2.0
	01/12/05	6.6	756.8	43.2	2,331,891	14,754	1,748,444	2,750	15.0	15.0	0.0	13.0	15.0	-2.0
	01/13/05	9.4	766.2	40.3	2,352,893	21,002	1,769,446	2,783	12.0	13.0	-1.0	11.0	13.0	-2.0
	01/14/05	7.8	774.0	40.7	2,369,333	16,440	1,785,886	2,809	15.0	15.0	0.0	13.0	15.0	-2.0
	01/15/05	9.8	783.8	40.0	2,391,115	21,782	1,807,668	2,843	14.0	15.0	-1.0	12.0	14.0	-2.0
	01/16/05	10.3	794.1	40.8	2,413,979	22,864	1,830,532	2,879	12.0	13.0	-1.0	11.0	13.0	-2.0
15	01/17/05	9.5	803.6	39.9	2,434,854	20,875	1,851,407	2,912	11.0	13.0	-2.0	10.0	12.0	-2.0
	01/18/05	8.5	812.1	43.7	2,452,751	17,897	1,869,304	2,940	15.0	16.0	-1.0	13.0	11.0	2.0
	01/19/05	7.9	820.0	41.5	2,470,822	18,071	1,887,375	2,969	14.0	15.0	-1.0	12.0	15.0	-3.0
	01/20/05	8.6	828.6	40.3	2,490,330	19,508	1,906,883	2,999	14.0	15.0	-1.0	12.0	15.0	-3.0
	01/21/05	9.1	837.7	41.1	2,510,687	20,357	1,927,240	3,031	12.0	13.0	-1.0	10.0	13.0	-3.0
	01/22/05	9.4	847.1	40.4	2,531,399	20,712	1,947,952	3,064	12.0	13.0	-1.0	10.0	13.0	-3.0
	01/23/05	9.6	856.7	42.7	2,552,097	20,698	1,968,650	3,096	13.0	13.0	0.0	11.0	14.0	-3.0
16	01/24/05	9.1	865.8	41.3	2,571,909	19,812	1,988,462	3,127	14.0	15.0	-1.0	12.0	15.0	-3.0
	01/25/05	8.1	873.9	40.1	2,590,546	18,637	2,007,099	3,157	15.0	16.0	-1.0	14.0	16.0	-2.0
	01/26/05	8.0	881.9	42.2	2,608,795	18,249	2,025,348	3,186	15.0	16.0	-1.0	14.0	16.0	-2.0
	01/27/05	8.4	890.3	44.3	2,627,629	18,834	2,044,182	3,215	16.0	16.0	0.0	14.0	16.0	-2.0
	01/28/05	10.1	900.4	38.2	2,650,511	22,882	2,067,064	3,251	11.0	12.0	-1.0	9.0	12.0	-3.0
	01/29/05	8.0	908.4	37.0	2,668,851	18,340	2,085,404	3,280	11.0	12.0	-1.0	10.0	12.0	-2.0
	01/30/05	12.3	920.7	34.0	2,695,129	26,278	2,111,682	3,321	8.0	8.0	0.0	6.0	9.0	-3.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH – Daily System Operation Log Sheet (Page 4 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter: Outlet Flowrate	Outlet Magnetic Meter: Outlet Totalizer	Outlet Magnetic Meter: Daily Flow Totalizer	Outlet Magnetic Meter: Cumulative Flow Totalizer	Outlet Magnetic Meter: Cumulative Bed Volume Treated	Vessel A: Inlet Pressure	Vessel A: Outlet Pressure	Vessel A: Δp	Vessel B: Inlet Pressure	Vessel B: Outlet Pressure	Vessel B: Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
17	01/31/05	8.0	928.7	39.6	2,711,222	16,093	2,127,775	3,347	16.0	16.0	0.0	14.0	16.0	-2.0
	02/01/05	7.9	936.6	42.4	2,729,013	17,791	2,145,566	3,375	15.0	16.0	-1.0	14.0	15.0	-1.0
	02/02/05	8.3	944.9	37.3	2,747,686	18,673	2,164,239	3,,404	16.0	16.0	0.0	14.0	16.0	-2.0
	02/03/05	8.3	953.2	45.9	2,766,522	18,836	2,183,075	3,434	16.0	16.0	0.0	14.0	15.0	-1.0
	02/04/05	8.7	961.9	39.5	2,786,021	19,499	2,202,574	3,464	16.0	16.0	0.0	14.0	15.0	-1.0
	02/05/05	9.8	971.7	45.7	2,807,547	21,526	2,224,100	3,498	15.0	15.0	0.0	13.0	14.0	-1.0
	02/06/05	11.3	983.0	36.8	2,831,725	24,178	2,248,278	3,536	10.0	10.0	0.0	8.0	9.0	-1.0
18	02/07/05	7.5	990.5	40.7	2,848,555	16,830	2,265,108	3,563	16.0	16.0	0.0	14.0	15.0	-1.0
	02/08/05	7.9	998.4	41.1	2,866,591	18,036	2,283,144	3,591	16.0	16.0	0.0	14.0	15.0	-1.0
	02/09/05	8.4	1,006.8	47.2	2,885,410	18,819	2,301,963	3,621	16.0	16.0	0.0	14.0	15.0	-1.0
	02/10/05	9.1	1,015.9	43.1	2,906,231	20,821	2,322,784	3,653	13.0	13.0	0.0	10.0	11.0	-1.0
	02/11/05	8.9	1,024.8	39.7	2,925,923	19,692	2,342,476	3,684	13.0	13.0	0.0	11.0	12.0	-1.0
	02/12/05	9.9	1,034.7	33.6	2,948,119	22,196	2,364,672	3,719	11.0	12.0	-1.0	9.0	11.0	-2.0
	02/13/05	10.0	1,044.7	38.8	2,969,745	21,626	2,386,298	3,753	13.0	13.0	0.0	11.0	13.0	-2.0
19	02/14/05	8.9	1,053.6	39.9	2,989,704	19,959	2,406,257	3,785	13.0	13.0	0.0	10.0	12.0	-2.0
	02/15/05	7.8	1,061.4	40.1	3,007,034	17,330	2,423,587	3,812	10.0	9.0	1.0	7.0	8.0	-1.0
	02/16/05	8.4	1,069.8	40.3	3,026,039	19,005	2,442,592	3,842	10.0	9.0	1.0	7.0	7.0	0.0
	02/17/05	8.5	1,078.3	41.0	3,045,281	19,242	2,461,834	3,872	10.0	9.0	1.0	7.0	8.0	-1.0
	02/18/05	9.1	1,087.4	41.2	3,066,022	20,741	2,482,575	3,905	9.0	8.0	1.0	6.0	7.0	-1.0
	02/19/05	11.0	1,098.4	36.0	3,090,622	24,600	2,507,175	3,943	7.0	7.0	0.0	4.0	6.0	-2.0
	02/20/05	11.0	1,109.4	38.9	3,114,486	23,864	2,531,039	3,981	7.0	7.0	0.0	4.0	6.0	-2.0
20	02/21/05	8.6	1,118.0	44.0	3,133,287	18,801	2,549,840	4,010	9.0	8.0	1.0	7.0	8.0	-1.0
	02/22/05	9.1	1,127.1	39.9	3,153,152	19,865	2,569,705	4,042	20.0	21.0	-1.0	17.0	20.0	-3.0
	02/23/05	10.4	1,137.5	39.3	3,175,292	22,140	2,591,845	4,077	19.0	19.0	0.0	16.0	18.0	-2.0
	02/24/05	9.6	1,147.1	42.1	3,195,313	20,021	2,611,866	4,108	19.0	19.0	0.0	17.0	19.0	-2.0
	02/25/05	10.5	1,157.6	41.2	3,217,543	22,230	2,634,096	4,143	21.0	22.0	-1.0	19.0	21.0	-2.0
	02/26/05	12.5	1,170.1	42.2	3,243,080	25,537	2,659,633	4,183	17.0	18.0	-1.0	15.0	17.0	-2.0
	02/27/05	11.4	1,181.5	38.0	3,266,391	23,311	2,682,944	4,220	17.0	17.0	0.0	15.0	17.0	-2.0
21	02/28/05	9.1	1,190.6	42.9	3,285,641	19,250	2,702,194	4,250	20.0	20.0	0.0	17.0	19.0	-2.0
	03/01/05	10.0	1,200.6	38.0	3,307,138	21,497	2,723,691	4,284	16.0	16.0	0.0	14.0	16.0	-2.0
	03/02/05	10.4	1,211.0	36.4	3,329,356	22,218	2,745,909	4,319	16.0	16.0	0.0	14.0	16.0	-2.0
	03/03/05	8.0	1,219.0	41.3	3,346,888	17,532	2,763,441	4,346	20.0	20.0	0.0	17.0	19.0	-2.0
	03/04/05	11.5	1,230.5	35.5	3,371,421	24,533	2,787,974	4,385	15.0	15.0	0.0	12.0	14.0	-2.0
	03/05/05	11.0	1,241.5	39.4	3,394,246	22,825	2,810,799	4,421	17.0	18.0	-1.0	15.0	17.0	-2.0
	03/06/05	13.2	1,254.7	35.6	3,420,533	26,287	2,837,086	4,462	15.0	16.0	-1.0	13.0	15.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 5 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter: Outlet Flowrate	Outlet Magnetic Meter: Outlet Totalizer	Outlet Magnetic Meter: Daily Flow Totalizer	Outlet Magnetic Meter: Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Vessel A: Inlet Pressure	Vessel A: Outlet Pressure	Vessel A: Δp	Vessel B: Inlet Pressure	Vessel B: Outlet Pressure	Vessel B: Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
22	03/07/05	10.6	1,265.3	40.3	3,441,728	21,195	2,858,281	4,496	19.0	19.0	0.0	17.0	18.0	-1.0
	03/08/05	13.2	1,278.5	37.8	3,467,373	25,645	2,883,926	4,536	17.0	18.0	-1.0	15.0	18.0	-3.0
	03/09/05	14.1	1,292.6	39.3	3,494,579	27,206	2,911,132	4,579	17.0	18.0	-1.0	15.0	17.0	-2.0
	03/10/05	14.1	1,306.7	37.2	3,521,436	26,857	2,937,989	4,621	25.0	25.0	0.0	23.0	25.0	-2.0
	03/11/05	14.3	1,321.0	38.4	3,548,297	26,861	2,964,850	4,663	22.0	23.0	-1.0	19.0	22.0	-3.0
	03/12/05	11.0	1,332.0	38.7	3,568,879	20,582	2,985,432	4,696	27.0	28.0	-1.0	25.0	27.0	-2.0
	03/13/05	11.0	1,343.0	42.6	3,590,313	21,434	3,006,866	4,729	27.0	28.0	-1.0	25.0	27.0	-2.0
23	03/14/05	8.2	1,351.2	36.4	3,606,707	16,394	3,023,260	4,755	NA	27.0	NA	27.0	28.0	-1.0
	03/15/05	9.1	1,360.3	44.3	3,625,853	19,146	3,042,406	4,785	20.0	21.0	-1.0	16.0	20.0	-4.0
	03/16/05	8.1	1,368.4	43.0	3,643,284	17,431	3,059,837	4,813	22.0	22.0	0.0	19.0	21.0	-2.0
	03/17/05	8.4	1,376.8	42.6	3,661,488	18,204	3,078,041	4,841	22.0	23.0	-1.0	19.0	21.0	-2.0
	03/18/05	8.7	1,385.5	41.7	3,680,954	19,466	3,097,507	4,872	17.0	17.0	0.0	15.0	16.0	-1.0
	03/19/05	9.2	1,394.7	40.3	3,700,919	19,965	3,117,472	4,903	15.0	16.0	-1.0	13.0	15.0	-2.0
	03/20/05	10.7	1,405.4	42.3	3,723,897	22,978	3,140,450	4,939	12.0	13.0	-1.0	10.0	12.0	-2.0
24	03/21/05	8.0	1,413.4	44.5	3,740,922	17,025	3,157,475	4,966	21.0	22.0	-1.0	18.0	20.0	-2.0
	03/22/05	8.0	1,421.4	47.7	3,758,479	17,557	3,175,032	4,994	22.0	27.0	-5.0	19.0	21.0	-2.0
	03/23/05	9.8	1,431.2	43.6	3,780,333	21,854	3,196,886	5,028	15.0	15.0	0.0	12.0	14.0	-2.0
	03/24/05	7.1	1,438.3	42.5	3,796,412	16,079	3,212,965	5,053	16.0	16.0	0.0	13.0	15.0	-2.0
	03/25/05	9.5	1,,447.8	36.7	3,817,763	21,351	3,234,316	5,087	13.0	13.0	0.0	10.0	12.0	-2.0
	03/26/05	9.8	1,457.6	42.9	3,838,499	20,736	3,255,052	5,120	15.0	15.0	0.0	12.0	14.0	-2.0
	03/27/05	13.2	1,470.8	35.7	3,866,379	27,880	3,282,932	5,163	10.0	9.0	1.0	7.0	9.0	-2.0
25	03/28/05	8.2	1,479.0	37.8	3,883,085	16,706	3,299,638	5,190	15.0	16.0	-1.0	13.0	15.0	-2.0
	03/29/05	8.5	1,487.5	39.1	3,902,013	18,928	3,318,566	5,220	14.0	14.0	0.0	12.0	13.0	-1.0
	03/30/05	9.6	1,497.1	41.6	3,922,384	20,371	3,338,937	5,252	16.0	16.0	0.0	13.0	15.0	-2.0
	03/31/05	8.9	1,506.0	39.9	3,941,732	19,348	3,358,285	5,282	16.0	16.0	0.0	13.0	15.0	-2.0
	04/01/05	8.5	1,514.5	40.7	3,960,622	18,890	3,377,175	5,312	16.0	16.0	0.0	14.0	15.0	-1.0
	04/02/05	9.8	1,524.3	42.3	3,982,195	21,573	3,398,748	5,346	15.0	15.0	0.0	13.0	14.0	-1.0
	04/03/05	9.8	1,534.1	43.9	4,003,448	21,253	3,420,001	5,379	14.0	13.0	1.0	12.0	14.0	-2.0
26	04/04/05	8.7	1,542.8	40.6	4,022,552	19,104	3,439,105	5,409	14.0	13.0	1.0	12.0	13.0	-1.0
	04/05/05	7.7	1,550.5	42.5	4,038,787	16,235	3,455,340	5,435	16.0	10.0	6.0	13.0	16.0	-3.0
	04/06/05	8.0	1,558.5	44.4	4,056,802	18,015	3,473,355	5,463	16.0	10.0	6.0	13.0	15.0	-2.0
	04/07/05	7.8	1,566.3	38.7	4,074,577	17,775	3,491,130	5,491	11.0	11.0	0.0	13.0	15.0	-2.0
	04/08/05	8.5	1,574.8	39.6	4,093,908	19,331	3,510,461	5,521	14.0	10.0	4.0	12.0	12.0	0.0
	04/09/05	9.1	1,583.9	42.5	4,113,962	20,054	3,530,515	5,553	16.0	10.0	6.0	13.0	15.0	-2.0
	04/10/05	10.2	1,594.1	42.5	4,135,968	22,006	3,552,521	5,587	15.0	10.0	5.0	12.0	14.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 6 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
27	04/11/05	9.2	1,603.3	44.6	4,155,862	19,894	3,572,415	5,619	16.0	10.0	6.0	13.0	15.0	-2.0
	04/12/05	10.2	1,613.5	42.4	4,178,409	22,547	3,594,962	5,654	15.0	15.0	0.0	12.0	14.0	-2.0
	04/13/05	7.5	1,621.0	47.3	4,195,027	16,618	3,611,580	5,680	16.0	16.0	0.0	14.0	15.0	-1.0
	04/14/05	8.8	1,629.8	41.4	4,214,799	19,772	3,631,352	5,711	15.0	14.0	1.0	12.0	13.0	-1.0
	04/15/05	9.4	1,639.2	10.6	4,235,652	20,853	3,652,205	5,744	13.0	13.0	0.0	10.0	12.0	-2.0
	04/16/05	10.6	1,649.8	39.3	4,258,123	22,471	3,674,676	5,780	13.0	13.0	0.0	10.0	12.0	-2.0
	04/17/05	10.8	1,660.6	45.4	4,280,778	22,655	3,697,331	5,815	14.0	13.0	1.0	11.0	13.0	-2.0
28	04/18/05	9.6	1,670.2	44.7	4,300,836	20,058	3,717,389	5,847	15.0	15.0	0.0	13.0	14.0	-1.0
	04/19/05	10.0	1,680.2	40.9	4,321,862	21,026	3,738,415	5,880	16.0	15.0	1.0	13.0	15.0	-2.0
	04/20/05	10.2	1,690.4	41.9	4,343,599	21,737	3,760,152	5,914	15.0	15.0	0.0	13.0	15.0	-2.0
	04/21/05	9.0	1,699.4	44.6	4,363,147	19,548	3,779,700	5,945	16.0	15.0	1.0	13.0	15.0	-2.0
	04/22/05	24.7	1,724.1	27.4	4,405,545	42,398	3,822,098	6,011	8.0	7.0	1.0	4.0	7.0	-3.0
	04/23/05	7.8	1,731.9	44.1	4,422,047	16,502	3,838,600	6,037	13.0	13.0	0.0	11.0	13.0	-2.0
	04/24/05	9.0	1,740.9	41.5	4,440,999	18,952	3,857,552	6,067	14.0	13.0	1.0	12.0	13.0	-1.0
29	04/25/05	7.2	1,748.1	44.9	4,456,994	15,995	3,873,547	6,092	16.0	16.0	0.0	13.0	15.0	-2.0
	04/26/05	10.2	1,758.3	39.1	4,479,919	22,925	3,896,472	6,128	10.0	10.0	0.0	8.0	10.0	-2.0
	04/27/05	5.6	1,763.9	41.1	4,492,476	12,557	3,909,029	6,148	13.0	13.0	0.0	10.0	12.0	-2.0
	04/28/05	8.7	1,772.6	39.3	4,512,216	19,740	3,928,769	6,179	11.0	12.0	-1.0	9.0	11.0	-2.0
	04/29/05	7.5	1,780.1	43.0	4,529,763	17,547	3,946,316	6,207	16.0	15.0	1.0	13.0	15.0	-2.0
	04/30/05	7.2	1,787.3	41.1	4,546,122	16,359	3,962,675	6,233	16.0	15.0	1.0	13.0	15.0	-2.0
	05/01/05	11.4	1,798.7	41.1	4,570,358	24,236	3,986,911	6,271	14.0	13.0	1.0	11.0	13.0	-2.0
30	05/02/05	7.2	1,805.9	44.4	4,586,648	16,290	4,003,201	6,296	16.0	16.0	0.0	14.0	15.0	-1.0
	05/03/05	8.6	1,814.5	42.0	4,605,520	18,872	4,022,073	6,326	17.0	17.0	0.0	14.0	16.0	-2.0
	05/04/05	8.8	1,823.3	42.5	4,624,967	19,447	4,041,520	6,357	17.0	16.0	1.0	14.0	15.0	-1.0
	05/05/05	9.2	1,832.5	40.6	4,645,176	20,209	4,061,729	6,388	16.0	16.0	0.0	13.0	15.0	-2.0
	05/06/05	9.1	1,841.6	41.2	4,665,530	20,354	4,082,083	6,420	14.0	13.0	1.0	11.0	13.0	-2.0
	05/07/05	9.6	1,851.2	41.9	4,686,213	20,683	4,102,766	6,453	15.0	15.0	0.0	13.0	14.0	-1.0
	05/08/05	13.6	1,864.8	38.4	4,713,963	27,750	4,130,516	6,497	14.0	13.0	1.0	11.0	12.0	-1.0
31	05/09/05	7.9	1,872.7	39.0	4,730,671	16,708	4,147,224	6,523	16.0	15.0	1.0	13.0	15.0	-2.0
	05/10/05	8.6	1,881.3	42.5	4,749,359	18,688	4,165,912	6,552	16.0	16.0	0.0	13.0	15.0	-2.0
	05/11/05	10.5	1,891.8	41.1	4,771,623	22,264	4,188,176	6,587	15.0	15.0	0.0	13.0	15.0	-2.0
	05/12/05	9.9	1,901.7	41.8	4,793,498	21,875	4,210,051	6,622	12.0	12.0	0.0	9.0	12.0	-3.0
	05/13/05	8.7	1,910.4	41.3	4,812,279	18,781	4,228,832	6,651	13.0	12.0	1.0	10.0	12.0	-2.0
	05/14/05	11.8	1,922.2	41.7	4,837,476	25,197	4,254,029	6,691	13.0	13.0	0.0	11.0	14.0	-3.0
	05/15/05	10.4	1,932.6	42.0	4,859,138	21,662	4,275,691	6,725	14.0	14.0	0.0	12.0	8.0	4.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 7 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
32	05/16/05	9.3	1,941.9	42.7	4,878,851	19,713	4,295,404	6,756	14.0	14.0	0.0	12.0	13.0	-1.0
	05/17/05	9.8	1,951.7	42.3	4,899,283	20,432	4,315,836	6,788	15.0	15.0	0.0	13.0	15.0	-2.0
	05/18/05	11.4	1,963.1	40.5	4,923,579	24,296	4,340,132	6,826	13.0	12.0	1.0	10.0	12.0	-2.0
	05/19/05	9.0	1,972.1	43.3	4,942,210	18,631	4,358,763	6,856	15.0	15.0	0.0	13.0	14.0	-1.0
	05/20/05	9.3	1,981.4	40.4	4,962,065	19,855	4,378,618	6,887	15.0	15.0	0.0	13.0	15.0	-2.0
	05/21/05	10.5	1,991.9	42.0	4,984,451	22,386	4,401,004	6,922	13.0	13.0	0.0	10.0	12.0	-2.0
	05/22/05	11.4	2,003.3	39.6	5,007,657	23,206	4,424,210	6,958	14.0	13.0	1.0	11.0	14.0	-3.0
33	05/23/05	9.1	2,012.4	41.3	5,026,370	18,713	4,442,923	6,988	15.0	15.0	0.0	12.0	14.0	-2.0
	05/24/05	9.0	2,021.4	44.6	5,045,586	19,216	4,462,139	7,018	16.0	16.0	0.0	13.0	15.0	-2.0
	05/25/05	8.8	2,030.2	41.6	5,064,476	18,890	4,481,029	7,048	16.0	16.0	0.0	13.0	15.0	-2.0
	05/26/05	9.7	2,039.9	41.6	5,085,206	20,730	4,501,759	7,080	15.0	15.0	0.0	13.0	15.0	-2.0
	05/27/05	12.9	2,052.8	38.5	5,112,946	27,740	4,529,499	7,124	8.0	8.0	0.0	7.0	8.0	-1.0
	05/28/05	10.4	2,063.2	40.2	5,133,993	21,047	4,550,546	7,157	10.0	10.0	0.0	7.0	10.0	-3.0
	05/29/05	10.5	2,073.7	42.1	5,155,402	21,409	4,571,955	7,191	13.0	13.0	0.0	10.0	8.0	2.0
34	05/30/05	9.3	2,083.0	39.3	5,175,514	20,112	4,592,067	7,223	12.0	13.0	-1.0	10.0	12.0	-2.0
	05/31/05	10.0	2,093.0	39.3	5,196,495	20,981	4,613,048	7,256	13.0	12.0	1.0	10.0	12.0	-2.0
	06/01/05	9.2	2,102.2	42.0	5,215,404	18,909	4,631,957	7,285	15.0	15.0	0.0	13.0	15.0	-2.0
	06/02/05	12.0	2,114.2	21.9	5,225,218	9,814	4,641,771	7,301	10.0	10.0	0.0	7.0	10.0	-3.0
	06/03/05	11.2	2,125.4	37.9	5,235,009	9,791	4,651,562	7,316	11.0	12.0	-1.0	9.0	11.0	-2.0
	06/04/05	11.4	2,136.8	43.2	5,257,479	22,470	4,674,032	7,351	14.0	13.0	1.0	11.0	13.0	-2.0
	06/05/05	14.6	2,151.4	25.9	5,285,518	28,039	4,702,071	7,396	7.0	7.0	0.0	4.0	6.0	-2.0
35	06/06/05	12.3	2,163.7	40.2	5,307,243	21,725	4,723,796	7,430	15.0	14.0	1.0	12.0	13.0	-1.0
	06/07/05	11.8	2,175.5	37.3	5,331,825	24,582	4,748,378	7,468	8.0	8.0	0.0	6.0	8.0	-2.0
	06/08/05	10.9	2,186.4	39.2	5,353,315	21,490	4,769,868	7,502	10.0	10.0	0.0	8.0	10.0	-2.0
	06/09/05	10.3	2,196.7	41.5	5,373,936	20,621	4,790,489	7,535	13.0	13.0	0.0	10.0	12.0	-2.0
	06/10/05	12.4	2,209.1	38.7	5,398,513	24,577	4,815,066	7,573	12.0	12.0	0.0	8.0	12.0	-4.0
	06/11/05	14.6	2,223.7	30.5	5,426,175	27,662	4,842,728	7,617	7.0	7.0	0.0	4.0	6.0	-2.0
	06/12/05	12.0	2,235.7	38.3	5,449,431	23,256	4,865,984	7,653	11.0	11.0	0.0	8.0	11.0	-3.0
36	06/13/05	9.6	2,245.3	41.6	5,468,879	19,448	4,885,432	7,684	12.0	12.0	0.0	10.0	11.0	-1.0
	06/14/05	15.0	2,260.3	44.7	5,497,350	28,471	4,913,903	7,729	13.0	13.0	0.0	10.0	13.0	-3.0
	06/15/05	8.1	2,268.4	43.3	5,513,917	16,567	4,930,470	7,755	15.0	15.0	0.0	13.0	15.0	-2.0
	06/16/05	9.0	2,277.4	41.5	5,532,883	18,966	4,949,436	7,785	15.0	15.0	0.0	13.0	15.0	-2.0
	06/17/05	10.5	2,287.9	42.3	5,554,707	21,824	4,971,260	7,819	15.0	15.0	0.0	13.0	14.0	-1.0
	06/18/05	10.7	2,298.6	42.6	5,577,004	22,297	4,993,557	7,854	14.0	14.0	0.0	12.0	13.0	-1.0
	06/19/05	8.6	2,307.2	42.3	5,595,339	18,335	5,011,892	7,883	15.0	15.0	0.0	12.0	14.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 8 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
37	06/20/05	8.7	2,315.9	40.1	5,613,577	18,238	5,030,130	7,911	15.0	15.0	0.0	13.0	15.0	-2.0
	06/21/05	11.4	2,327.3	37.8	5,638,097	24,520	5,054,650	7,950	8.0	8.0	0.0	7.0	8.0	-1.0
	06/22/05	11.4	2,338.7	39.3	5,659,552	21,455	5,076,105	7,984	14.0	14.0	0.0	12.0	14.0	-2.0
	06/23/05	8.4	2,347.1	42.2	5,678,017	18,465	5,094,570	8,013	12.0	12.0	0.0	9.0	11.0	-2.0
	06/24/05	7.9	2,355.0	42.2	5,694,891	16,874	5,111,444	8,039	15.0	14.0	1.0	12.0	14.0	-2.0
	06/25/05	11.5	2,366.4	42.3	5,718,731	23,840	5,135,284	8,077	13.0	13.0	0.0	10.0	13.0	-3.0
	06/26/05	10.1	2,376.5	40.3	5,739,845	21,114	5,156,398	8,110	13.0	13.0	0.0	11.0	14.0	-3.0
38	06/27/05	11.4	2,387.9	43.9	5,762,703	22,858	5,179,256	8,146	14.0	14.0	0.0	12.0	13.0	-1.0
	06/28/05	9.5	2,397.4	44.5	5,782,099	19,396	5,198,652	8,177	15.0	15.0	0.0	13.0	15.0	-2.0
	06/29/05	7.1	2,404.5	40.3	5,797,891	15,792	5,214,444	8,201	16.0	15.0	1.0	13.0	15.0	-2.0
	06/30/05	7.9	2,412.4	40.7	5,815,563	17,672	5,232,116	8,229	15.0	15.0	0.0	13.0	15.0	-2.0
	07/01/05	8.2	2,420.6	41.9	5,833,735	18,172	5,250,288	8,258	14.0	13.0	1.0	12.0	13.0	-1.0
	07/02/05	9.2	2,429.8	40.0	5,854,381	20,646	5,270,934	8,290	10.0	10.0	0.0	8.0	10.0	-2.0
	07/03/05	7.7	2,437.5	41.9	5,870,556	16,175	5,287,109	8,316	15.0	15.0	0.0	13.0	15.0	-2.0
39	07/04/05	8.2	2,445.7	40.4	5,888,691	18,135	5,305,244	8,344	15.0	15.0	0.0	13.0	15.0	-2.0
	07/05/05	7.5	2,453.2	43.0	5,909,122	20,431	5,325,675	8,376	15.0	15.0	0.0	13.0	15.0	-2.0
	07/06/05	6.4	2,459.6	44.3	5,923,644	14,522	5,340,197	8,399	17.0	17.0	0.0	14.0	15.0	-1.0
	07/07/05	7.3	2,466.9	40.3	5,940,737	17,093	5,357,290	8,426	13.0	13.0	0.0	11.0	13.0	-2.0
	07/08/05	7.2	2,474.1	43.7	5,956,882	16,145	5,373,435	8,451	16.0	16.0	0.0	13.0	15.0	-2.0
	07/09/05	7.4	2,481.5	44.3	5,973,817	16,935	5,390,370	8,478	16.0	16.0	0.0	14.0	16.0	-2.0
40	07/11/05	14.7	2,496.2	42.8	6,007,845	NA	NA	NA	14.0	14.0	0.0	11.0	13.0	-2.0
	07/12/05	8.4	2,504.6	40.6	6,026,585	18,740	5,409,110	8,508	15.0	15.0	0.0	12.0	14.0	-2.0
	07/13/05	10.5	2,515.1	37.9	6,050,254	23,669	5,432,779	8,545	9.0	9.0	0.0	7.0	9.0	-2.0
	07/14/05	10.2	2,525.3	37.3	6,072,238	21,984	5,454,763	8,579	9.0	9.0	0.0	7.0	9.0	-2.0
	07/15/05	7.9	2,533.2	41.7	6,090,322	18,084	5,472,847	8,608	11.0	11.0	0.0	9.0	11.0	-2.0
	07/16/05	5.8	2,539.0	45.1	6,103,324	13,002	5,485,849	8,628	15.0	15.0	0.0	12.0	14.0	-2.0
	07/17/05	8.1	2,547.1	40.7	6,121,597	18,273	5,504,122	8,657	13.0	13.0	0.0	10.0	12.0	-2.0
41	07/18/05	8.4	2,547.4	41.2	6,140,510	18,913	5,504,762	8,658	12.0	12.0	0.0	9.0	12.0	-3.0
	07/19/05	6.2	2,553.6	43.4	6,154,432	13,922	5,518,684	8,680	16.0	16.0	0.0	14.0	15.0	-1.0
	07/20/05	10.5	2,564.1	40.2	6,178,233	23,801	5,542,485	8,717	10.0	10.0	0.0	7.0	10.0	-3.0
	07/21/05	7.2	2,571.3	43.4	6,194,410	16,177	5,558,662	8,743	14.0	14.0	0.0	12.0	14.0	-2.0
	07/22/05	10.1	2,581.4	40.3	6,216,531	22,121	5,580,783	8,778	12.0	12.0	0.0	9.0	12.0	-3.0
	07/23/05	9.1	2,590.5	40.4	6,235,786	19,255	5,600,038	8,808	16.0	16.0	0.0	13.0	15.0	-2.0
	07/24/05	8.9	2,599.4	43.4	6,255,894	20,108	5,620,146	8,839	12.0	12.0	0.0	9.0	12.0	-3.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 9 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
42	07/25/05	7.1	2,597.6	41.3	6,271,570	15,676	5,615,714	8,833	13.0	13.0	0.0	11.0	13.0	-2.0
	07/26/05	10.8	2,608.4	42.3	6,295,442	23,872	5,639,586	8,870	9.0	9.0	0.0	7.0	9.0	-2.0
	07/27/05	9.3	2,617.7	44.7	6,315,162	19,720	5,659,306	8,901	15.0	15.0	0.0	12.0	11.0	1.0
	07/28/05	8.6	2,626.3	41.8	6,334,295	19,133	5,678,439	8,931	16.0	15.0	1.0	13.0	15.0	-2.0
	07/30/05	15.4	2,641.7	41.0	6,369,063	34,768	5,713,207	8,986	13.0	13.0	0.0	10.0	13.0	-3.0
	07/31/05	7.8	2,649.5	42.4	6,386,215	17,152	5,730,359	9,013	16.0	16.0	0.0	13.0	15.0	-2.0
43	08/01/05	7.1	2,648.8	43.5	6,402,260	16,045	5,729,252	9,011	17.0	17.0	0.0	14.0	15.0	-1.0
	08/02/05	6.1	2,654.9	44.9	6,416,485	14,225	5,743,477	9,033	17.0	17.0	0.0	14.0	16.0	-2.0
	08/03/05	10.3	2,665.2	43.1	6,436,113	19,628	5,763,105	9,064	16.0	16.0	0.0	13.0	15.0	-2.0
	08/04/05	9.3	2,674.5	44.6	6,456,549	20,436	5,783,541	9,096	15.0	15.0	0.0	13.0	15.0	-2.0
	08/05/05	9.3	2,683.8	42.3	6,477,172	20,623	5,804,164	9,129	13.0	13.0	0.0	9.0	12.0	-3.0
	08/06/05	10.7	2,685.2	36.3	6,500,090	22,918	5,827,082	9,165	10.0	10.0	0.0	7.0	10.0	-3.0
	08/07/05	11.5	2,695.3	40.3	6,522,497	22,407	5,849,489	9,200	13.0	13.0	0.0	10.0	13.0	-3.0
44	08/08/05	11.1	2,696.3	42.9	6,544,793	22,296	5,871,785	9,235	14.0	14.0	0.0	12.0	13.0	-1.0
	08/09/05	11.4	2,707.7	41.0	6,567,620	22,827	5,894,612	9,271	14.0	14.0	0.0	12.0	14.0	-2.0
	08/10/05	11.2	2,718.9	42.4	6,590,098	22,478	5,917,090	9,307	15.0	14.0	1.0	12.0	13.0	-1.0
	08/11/05	18.5	2,737.4	38.9	6,623,549	33,451	5,950,541	9,359	10.0	10.0	0.0	7.0	10.0	-3.0
	08/12/05	15.2	2,752.6	29.5	6,650,944	27,395	5,977,936	9,402	6.0	5.0	1.0	4.0	6.0	-2.0
	08/13/05	8.1	2,760.7	42.2	6,665,937	14,993	5,992,929	9,426	14.0	13.0	1.0	11.0	13.0	-2.0
	08/14/05	10.3	2,771.0	39.3	6,687,339	21,402	6,014,331	9,459	10.0	10.0	0.0	7.0	10.0	-3.0
45	08/15/05	10.4	2,781.4	44.3	6,702,053	14,714	6,029,045	9,483	15.0	15.0	0.0	12.0	14.0	-2.0
	08/16/05	8.1	2,789.5	43.4	6,719,481	17,428	6,046,473	9,510	16.0	15.0	1.0	13.0	15.0	-2.0
	08/17/05	7.3	2,796.8	45.3	6,735,487	16,006	6,062,479	9,535	16.0	16.0	0.0	13.0	15.0	-2.0
	08/18/05	9.8	2,806.6	45.0	6,756,433	20,946	6,083,425	9,568	15.0	15.0	0.0	12.0	14.0	-2.0
	08/19/05	10.4	2,817.0	38.4	6,779,275	22,842	6,106,267	9,604	8.0	9.0	-1.0	7.0	8.0	-1.0
	08/20/05	10.3	2,827.3	36.9	6,800,577	21,302	6,127,569	9,638	11.0	11.0	0.0	8.0	10.0	-2.0
	08/21/05	6.8	2,834.1	40.3	6,815,760	15,183	6,142,752	9,661	13.0	13.0	0.0	10.0	12.0	-2.0
46	08/22/05	6.9	2,841.0	42.0	6,831,522	15,762	6,158,514	9,686	13.0	12.0	1.0	11.0	12.0	-1.0
	08/25/05	21.5	2,862.5	44.0	6,877,373	45,851	6,204,365	9,758	15.0	14.0	1.0	12.0	14.0	-2.0
	08/26/05	16.5	2,879.0	39.1	6,911,833	34,460	6,238,825	9,813	12.0	12.0	0.0	12.0	11.0	1.0
	08/27/05	10.1	2,889.1	42.9	6,932,069	20,236	6,259,061	9,844	15.0	14.0	1.0	12.0	14.0	-2.0
47	08/29/05	20.1	2,909.2	36.9	6,974,740	42,671	6,301,732	9,912	10.0	10.0	0.0	7.0	9.0	-2.0
	08/30/05	7.3	2,916.5	44.1	6,989,614	14,874	6,316,606	9,935	16.0	15.0	1.0	13.0	15.0	-2.0
	08/31/05	7.8	2,924.3	44.4	7,006,664	17,050	6,333,656	9,962	16.0	15.0	1.0	13.0	15.0	-2.0
	09/01/05	8.7	2,933.0	41.3	7,025,653	18,989	6,352,645	9,992	15.0	14.0	1.0	12.0	14.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 10 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
47	09/02/05	8.9	2,941.9	41.9	7,045,050	19,397	6,372,042	10,022	13.0	12.0	1.0	10.0	12.0	-2.0
	09/04/05	15.5	2,957.4	42.7	7,078,801	33,751	6,405,793	10,075	17.0	16.0	1.0	14.0	15.0	-1.0
48	09/05/05	9.8	2,967.2	43.4	7,099,881	21,080	6,426,873	10,108	15.0	14.0	1.0	12.0	9.0	3.0
	09/06/05	9.8	2,977.0	43.6	7,120,280	20,399	6,447,272	10,140	16.0	15.0	1.0	12.0	14.0	-2.0
	09/07/05	11.6	2,988.6	36.9	7,144,239	23,959	6,471,231	10,178	12.0	12.0	0.0	9.0	11.0	-2.0
	09/08/05	9.8	2,998.4	41.3	7,164,006	19,767	6,490,998	10,209	15.0	15.0	0.0	12.0	9.0	3.0
	09/09/05	10.0	3,008.4	42.2	7,185,321	21,315	6,512,313	10,243	12.0	11.0	1.0	8.0	12.0	-4.0
	09/10/05	12.8	3,021.2	43.0	7,210,109	24,788	6,537,101	10,282	14.0	13.0	1.0	10.0	13.0	-3.0
	09/11/05	12.5	3,033.7	30.4	7,234,542	24,433	6,561,534	10,320	7.0	7.0	0.0	4.0	7.0	-3.0
49	09/12/05	11.0	3,044.7	42.8	7,254,919	20,377	6,581,911	10,352	12.0	11.0	1.0	9.0	11.0	-2.0
	09/13/05	13.9	3,058.6	41.2	7,280,433	25,514	6,607,425	10,392	14.0	13.0	1.0	10.0	13.0	-3.0
	09/14/05	16.1	3,074.7	26.0	7,296,937	16,504	6,623,929	10,418	5.0	5.0	0.0	3.0	5.0	-2.0
	09/15/05	13.7	3,088.4	44.5	7,318,892	21,955	6,645,884	10,453	15.0	13.0	2.0	11.0	14.0	-3.0
	09/16/05	7.7	3,096.1	40.4	7,334,953	16,061	6,661,945	10,478	16.0	15.0	1.0	12.0	15.0	-3.0
	09/17/05	9.0	3,105.1	44.2	7,353,882	18,929	6,680,874	10,508	15.0	14.0	1.0	11.0	13.0	-2.0
	09/18/05	11.9	3,117.0	42.2	7,377,538	23,656	6,704,530	10,545	14.0	13.0	1.0	10.0	12.0	-2.0
50	09/19/05	7.8	3,124.8	40.0	7,393,638	16,100	6,720,630	10,570	15.0	14.0	1.0	12.0	14.0	-2.0
	09/20/05	7.7	3,132.5	44.1	7,410,283	16,645	6,737,275	10,597	16.0	15.0	1.0	13.0	15.0	-2.0
	09/21/05	7.2	3,139.7	42.4	7,426,303	16,020	6,753,295	10,622	17.0	16.0	1.0	13.0	15.0	-2.0
	09/22/05	7.7	3,147.4	44.5	7,443,217	16,914	6,770,209	10,648	17.0	15.0	2.0	13.0	15.0	-2.0
	09/23/05	8.7	3,156.1	42.5	7,462,438	19,221	6,789,430	10,679	13.0	12.0	1.0	10.0	12.0	-2.0
	09/25/05	16.0	3,172.1	43.7	7,497,176	34,738	6,824,168	10,733	15.0	14.0	1.0	12.0	12.0	0.0
51	09/26/05	8.0	3,180.1	44.3	7,514,321	17,145	6,841,313	10,760	17.0	16.0	1.0	13.0	15.0	-2.0
	09/27/05	11.0	3,191.1	43.6	7,531,785	17,464	6,858,777	10,788	17.0	16.0	1.0	13.0	15.0	-2.0
	09/28/05	7.4	3,198.5	40.2	7,548,366	16,581	6,875,358	10,814	17.0	16.0	1.0	13.0	15.0	-2.0
	09/29/05	8.6	3,207.1	41.2	7,567,976	19,610	6,894,968	10,845	16.0	15.0	1.0	12.0	15.0	-3.0
	09/30/05	6.5	3,213.6	44.3	7,582,656	14,680	6,909,648	10,868	17.0	17.0	0.0	14.0	16.0	-2.0
	10/01/05	8.1	3,221.7	43.3	7,600,840	18,184	6,927,832	10,896	16.0	15.0	1.0	13.0	15.0	-2.0
	10/02/05	9.2	3,230.9	41.4	7,620,699	19,859	6,947,691	10,927	15.0	14.0	1.0	12.0	13.0	-1.0
52	10/03/05	8.3	3,239.2	41.6	7,638,464	17,765	6,965,456	10,955	14.0	13.0	1.0	11.0	13.0	-2.0
	10/04/05	8.1	3,247.3	44.1	7,655,891	17,427	6,982,883	10,983	16.0	15.0	1.0	13.0	15.0	-2.0
	10/05/05	8.0	3,255.3	41.6	7,673,475	17,584	7,000,467	11,010	17.0	16.0	1.0	14.0	15.0	-1.0
	10/07/05	15.1	3,270.4	46.4	7,706,999	33,524	7,033,991	11,063	17.0	16.0	1.0	13.0	15.0	-2.0
	10/08/05	8.6	3,279.0	42.2	7,725,865	18,866	7,052,857	11,093	16.0	15.0	1.0	13.0	15.0	-2.0
	10/09/05	9.0	3,288.0	41.8	7,745,257	19,392	7,072,249	11,123	15.0	14.0	1.0	12.0	14.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 11 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter: Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Vessel A: Inlet Pressure	Outlet Pressure	Δp	Vessel B: Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
53	10/10/05	7.7	3,295.7	44.2	7,762,226	16,969	7,089,218	11,150	17.0	16.0	1.0	13.0	15.0	-2.0
	10/11/05	10.8	3,306.5	33.8	7,785,877	23,651	7,112,869	11,187	8.0	8.0	0.0	6.0	7.0	-1.0
	10/12/05	13.4	3,319.9	41.5	7,809,745	23,868	7,136,737	11,225	15.0	14.0	1.0	12.0	14.0	-2.0
	10/13/05	7.6	3,327.5	46.8	7,826,042	16,297	7,153,034	11,250	17.0	16.0	1.0	13.0	15.0	-2.0
	10/14/05	7.6	3,335.1	43.2	7,842,642	16,600	7,169,634	11,277	17.0	16.0	1.0	14.0	16.0	-2.0
	10/15/05	7.6	3,342.7	38.9	7,859,709	17,067	7,186,701	11,303	15.0	14.0	1.0	12.0	13.0	-1.0
	10/16/05	8.7	3,351.4	43.7	7,878,485	18,776	7,205,477	11,333	16.0	15.0	1.0	13.0	14.0	-1.0
54	10/17/05	7.3	3,358.7	41.8	7,894,632	16,147	7,221,624	11,358	17.0	16.0	1.0	14.0	15.0	-1.0
	10/18/05	7.1	3,365.8	42.4	7,910,677	16,045	7,237,669	11,384	17.0	16.0	1.0	14.0	15.0	-1.0
	10/19/05	6.9	3,372.7	44.4	7,926,485	15,808	7,253,477	11,408	17.0	16.0	1.0	14.0	15.0	-1.0
	10/20/05	6.8	3,379.5	42.7	7,942,159	15,674	7,269,151	11,433	17.0	16.0	1.0	14.0	15.0	-1.0
	10/22/05	14.9	3,394.4	42.6	7,976,119	NA	NA	NA	17.0	16.0	1.0	14.0	15.0	-1.0
	10/23/05	8.5	3,402.9	45.5	7,995,286	19,167	7,288,318	11,463	16.0	15.0	1.0	13.0	14.0	-1.0
55	10/24/05	7.4	3,410.3	44.2	8,011,830	16,544	7,304,862	11,489	17.0	16.0	1.0	14.0	15.0	-1.0
	10/25/05	8.2	3,418.5	44.4	8,030,265	18,435	7,323,297	11,518	15.0	14.0	1.0	12.0	13.0	-1.0
	10/26/05	6.8	3,425.3	44.6	8,045,879	15,614	7,338,911	11,543	17.0	16.0	1.0	14.0	15.0	-1.0
	10/27/05	7.2	3,432.5	43.1	8,062,444	16,565	7,355,476	11,569	17.0	16.0	1.0	14.0	15.0	-1.0
	10/28/05	7.4	3,439.9	43.8	8,079,639	17,195	7,372,671	11,596	17.0	17.0	0.0	14.0	15.0	-1.0
	10/29/05	7.7	3,447.6	42.6	8,097,323	17,684	7,390,355	11,624	17.0	15.0	2.0	13.0	15.0	-2.0
	10/30/05	8.5	3,456.1	43.3	8,116,291	18,968	7,409,323	11,654	17.0	16.0	1.0	13.0	15.0	-2.0
56	10/31/05	12.8	3,468.9	35.9	8,135,960	19,669	7,428,992	11,684	8.0	7.0	1.0	6.0	6.0	0.0
	11/01/05	9.8	3,478.7	35.3	8,151,552	15,592	7,444,584	11,709	8.0	8.0	0.0	6.0	7.0	-1.0
	11/02/05	7.2	3,485.9	33.2	8,168,493	16,941	7,461,525	11,736	9.0	8.0	1.0	6.0	7.0	-1.0
	11/03/05	10.3	3,496.2	33.6	8,185,038	16,545	7,478,070	11,762	9.0	8.0	1.0	6.0	8.0	-2.0
	11/04/05	11.0	3,507.2	32.2	8,202,393	17,355	7,495,425	11,789	8.0	8.0	0.0	6.0	7.0	-1.0
	11/05/05	12.4	3,519.6	23.8	8,221,971	19,578	7,515,003	11,820	5.0	5.0	0.0	3.0	5.0	-2.0
	11/06/05	14.9	3,534.5	23.9	8,243,593	21,622	7,536,625	11,854	5.0	5.0	0.0	3.0	5.0	-2.0
57	11/07/05	12.0	3,546.5	39.2	8,260,896	17,303	7,553,928	11,881	9.0	8.0	1.0	5.0	7.0	-2.0
	11/08/05	8.5	3,555.0	43.4	8,276,337	15,441	7,569,369	11,905	18.0	16.0	2.0	14.0	15.0	-1.0
	11/09/05	6.8	3,561.8	44.4	8,291,951	15,614	7,584,983	11,930	19.0	17.0	2.0	14.0	16.0	-2.0
	11/10/05	7.2	3,569.0	45.4	8,308,600	16,649	7,601,632	11,956	18.0	17.0	1.0	14.0	16.0	-2.0
	11/11/05	7.5	3,576.5	44.5	8,325,926	17,326	7,618,958	11,983	18.0	17.0	1.0	14.0	16.0	-2.0
	11/12/05	8.9	3,585.4	41.1	8,346,439	20,513	7,639,471	12,016	14.0	12.0	2.0	10.0	11.0	-1.0
	11/13/05	7.9	3,593.3	37.9	8,364,209	17,770	7,657,241	12,043	14.0	12.0	2.0	10.0	12.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 12 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
58	11/14/05	7.0	3,600.3	41.8	8,379,794	15,585	7,672,826	12,068	18.0	16.0	2.0	14.0	15.0	-1.0
	11/15/05	7.1	3,607.4	45.2	8,396,171	16,377	7,689,203	12,094	18.0	16.0	2.0	14.0	15.0	-1.0
	11/16/05	7.1	3,614.5	43.4	8,412,879	16,708	7,705,911	12,120	18.0	17.0	1.0	15.0	16.0	-1.0
	11/17/05	7.3	3,621.8	43.5	8,429,823	16,944	7,722,855	12,147	18.0	17.0	1.0	15.0	16.0	-1.0
	11/18/05	8.2	3,630.0	43.4	8,448,988	19,165	7,742,020	12,177	15.0	13.0	2.0	11.0	13.0	-2.0
	11/19/05	7.4	3,637.4	42.9	8,465,764	16,776	7,758,796	12,203	17.0	16.0	1.0	13.0	15.0	-2.0
	11/20/05	9.0	3,646.4	43.9	8,485,732	19,968	7,778,764	12,235	17.0	16.0	1.0	13.0	15.0	-2.0
59	11/21/05	8.5	3,654.9	41.8	8,504,580	18,848	7,797,612	12,264	17.0	16.0	1.0	13.0	15.0	-2.0
	11/22/05	8.1	3,663.0	43.3	8,523,106	18,526	7,816,138	12,293	15.0	15.0	0.0	13.0	15.0	-2.0
	11/23/05	9.3	3,672.3	36.4	8,544,471	21,365	7,837,503	12,327	11.0	12.0	-1.0	9.0	12.0	-3.0
	11/24/05	7.9	3,680.2	38.2	8,561,933	17,462	7,854,965	12,354	12.0	13.0	-1.0	10.0	12.0	-2.0
	11/25/05	7.9	3,688.1	44.3	8,579,245	17,312	7,872,277	12,382	15.0	16.0	-1.0	13.0	15.0	-2.0
	11/26/05	8.9	3,697.0	36.9	8,599,454	20,209	7,892,486	12,413	12.0	12.0	0.0	10.0	12.0	-2.0
	11/27/05	9.5	3,706.5	38.9	8,620,197	20,743	7,913,229	12,446	12.0	12.0	0.0	10.0	12.0	-2.0
60	11/28/05[(b)]	7.1	3,713.6	44.5	8,635,714	15,517	7,928,746	12,471	16.0	16.0	0.0	14.0	15.0	-1.0
61	01/13/06[(c)]	9.4	0.0	40.8	9,501,211	0	0	NA	7.0	8.0	-1.0	off	off	NA
	01/14/06	12.2	12.2	42.8	9,526,145	24,934	24,934	39	10.0	10.0	0.0	off	off	NA
62	01/16/06	32.2	44.4	38.6	9,583,201	57,056	81,990	129	9.0	9.0	0.0	off	off	NA
	01/17/06	6.0	50.4	43.3	9,596,349	13,148	95,138	150	11.0	11.0	0.0	off	off	NA
	01/18/06	7.9	58.3	43.3	9,613,678	17,329	112,467	177	11.0	11.0	0.0	off	off	NA
	01/19/06	8.1	66.4	42.6	9,631,514	17,836	130,303	205	11.0	11.0	0.0	off	off	NA
	01/20/06	6.7	73.1	43.3	9,646,699	15,185	145,488	229	12.0	12.0	0.0	off	off	NA
	01/21/06	9.7	82.8	41.2	9,667,987	21,288	166,776	262	10.0	10.0	0.0	off	off	NA
	01/22/06	9.4	92.2	42.7	9,688,332	20,345	187,121	294	10.0	10.0	0.0	off	off	NA
63	01/23/06	8.3	100.5	44.4	9,706,287	17,955	205,076	323	11.0	11.0	0.0	off	off	NA
	01/24/06	7.4	107.9	44.7	9,723,101	16,814	183,590	289	11.0	11.0	0.0	off	off	NA
	01/25/06	7.2	115.1	44.4	9,739,563	16,462	200,052	315	11.0	12.0	-1.0	off	off	NA
	01/26/06	7.6	122.7	45.3	9,756,979	17,416	217,468	342	12.0	12.0	0.0	off	off	NA
	01/27/06	7.5	130.2	46.2	9,774,079	17,100	234,568	369	12.0	12.0	0.0	off	off	NA
	01/28/06	9.6	139.8	42.3	9,795,387	21,308	255,876	402	10.0	11.0	-1.0	off	off	NA
	01/29/06	8.3	148.1	44.3	9,814,052	18,665	274,541	432	10.0	11.0	-1.0	off	off	NA
64	01/30/06	7.5	155.6	43.7	9,830,775	16,723	291,264	458	11.0	11.0	0.0	off	off	NA
	01/31/06	7.5	163.1	45.3	9,848,032	17,257	308,521	485	12.0	12.0	0.0	off	off	NA
	02/01/06	5.9	169.0	46.8	9,863,582	15,550	324,071	510	12.0	13.0	-1.0	off	off	NA

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 13 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
64	02/02/06	19.3	188.3	15.7	9,884,087	20,505	344,576	542	4.0	5.0	-1.0	off	off	NA
	02/03/06	16.4	204.7	15.8	9,901,010	16,923	361,499	569	4.0	5.0	-1.0	off	off	NA
	02/04/06	16.9	221.6	16.3	9,918,375	17,365	378,864	596	4.0	5.0	-1.0	off	off	NA
	02/05/06	24.0	245.6	15.6	9,941,205	22,830	401,694	632	4.0	5.0	-1.0	off	off	NA
65	02/06/06	24.1	269.7	15.5	9,963,640	22,435	424,129	667	4.0	5.0	-1.0	off	off	NA
	02/07/06	18.1	287.8	15.9	9,981,527	17,887	442,016	695	4.0	5.0	-1.0	off	off	NA
	02/08/06	8.9	296.8	25.1	9,996,989	15,462	457,478	720	4.0	5.0	-1.0	off	off	NA
	02/09/06	17.7	314.5	18.6	10,019,581	22,592	480,070	755	4.0	5.0	-1.0	off	off	NA
	02/10/06	13.9	328.4	18.6	10,037,467	17,886	497,956	783	4.0	5.0	-1.0	off	off	NA
	02/11/06	15.8	344.2	18.4	10,056,718	19,251	517,207	813	4.0	5.0	-1.0	off	off	NA
	02/12/06	13.8	358.0	19.5	10,073,539	16,821	534,028	840	4.0	5.0	-1.0	off	off	NA
66	02/13/06	21.8	379.7	17.4	10,098,715	25,176	559,204	880	4.0	5.0	-1.0	off	off	NA
	02/14/06	5.2	384.9	44.3	10,114,551	15,836	575,040	904	12.0	12.0	0.0	off	off	NA
	02/15/06	6.4	391.3	46.2	10,129,508	14,957	589,997	928	12.0	12.0	0.0	off	off	NA
	02/16/06	7.6	398.9	46.4	10,147,143	17,635	607,632	956	12.0	12.0	0.0	off	off	NA
	02/17/06	7.6	406.5	42.1	10,165,028	17,885	625,517	984	10.0	11.0	-1.0	off	off	NA
	02/18/06	8.3	414.8	40.8	10,184,108	19,080	644,597	1,014	10.0	10.0	0.0	off	off	NA
	02/19/06	10.6	425.4	33.2	10,207,974	23,866	668,463	1,051	7.0	7.0	0.0	off	off	NA
67	02/20/06	8.8	434.2	35.5	10,227,475	19,501	687,964	1,082	7.0	7.0	0.0	off	off	NA
	02/21/06	6.4	440.6	44.5	10,241,570	14,095	702,059	1,104	11.0	11.0	0.0	off	off	NA
	02/22/06	7.8	448.4	44.9	10,259,229	17,659	719,718	1,132	11.0	11.0	0.0	off	off	NA
	02/23/06	7.2	455.6	46.6	10,275,879	16,650	736,368	1,158	12.0	12.0	0.0	off	off	NA
	02/01/06	8.0	463.6	40.5	10,294,714	18,835	755,203	1,188	9.0	10.0	-1.0	off	off	NA
	02/25/06	6.4	470.0	43.7	10,309,696	14,982	770,185	1,211	11.0	11.0	0.0	off	off	NA
	02/26/06	6.6	476.6	46.3	10,325,200	15,504	785,689	1,236	12.0	12.0	0.0	off	off	NA
68	02/27/06	6.4	483.0	46.7	10,340,418	15,218	800,907	1,260	12.0	12.0	0.0	off	off	NA
	02/28/06	6.2	489.2	46.9	10,355,574	15,156	816,063	1,284	13.0	13.0	0.0	off	off	NA
	03/03/06	17.5	506.7	47.1	10,398,903	43,329	859,392	1,352	13.0	13.0	0.0	off	off	NA
	03/04/06	7.6	514.3	39.1	10,417,967	19,064	878,456	1,382	9.0	9.0	0.0	off	off	NA
	03/05/06	8.7	523.0	42.7	10,438,264	20,297	898,753	1,414	11.0	11.0	0.0	off	off	NA
69	03/06/06	6.5	529.5	41.4	10,453,938	15,674	914,427	1,438	10.0	10.0	0.0	off	off	NA
	03/07/06	6.8	536.3	46.5	10,469,660	15,722	930,149	1,463	12.0	12.0	0.0	off	off	NA
	03/08/06	7.2	543.5	46.2	10,486,726	17,066	947,215	1,490	12.0	12.0	0.0	off	off	NA
	03/09/06	7.7	551.2	42.7	10,505,205	18,479	965,694	1,519	10.0	10.0	0.0	off	off	NA
	03/10/06	8.0	559.2	38.6	10,524,113	18,908	984,602	1,549	8.0	8.0	0.0	off	off	NA

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 14 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter: Outlet Flowrate	Outlet Magnetic Meter: Outlet Totalizer	Outlet Magnetic Meter: Daily Flow Totalizer	Outlet Magnetic Meter: Cumulative Flow Totalizer	Outlet Magnetic Meter: Cumulative Bed Volume Treated	Vessel A: Inlet Pressure	Vessel A: Outlet Pressure	Vessel A: Δp	Vessel B: Inlet Pressure	Vessel B: Outlet Pressure	Vessel B: Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
69	03/11/06	8.9	568.1	39.1	10,544,576	20,463	1,005,065	1,581	9.0	9.0	0.0	off	off	NA
	03/12/06	7.9	576.0	42.6	10,562,610	18,034	1,023,099	1,609	10.0	10.0	0.0	off	off	NA
70	03/13/06	6.8	582.8	46.6	10,578,248	15,638	1,038,737	1,634	12.0	12.0	0.0	off	off	NA
	03/14/06	7.7	590.5	46.2	10,595,977	17,729	1,056,466	1,662	12.0	12.0	0.0	off	off	NA
	03/15/06	7.1	597.6	46.2	10,612,699	16,722	1,073,188	1,688	12.0	12.0	0.0	off	off	NA
	03/16/06	7.9	605.5	46.9	10,630,903	18,204	1,091,392	1,717	12.0	12.0	0.0	off	off	NA
	03/17/06	7.4	612.9	45.0	10,648,137	17,234	1,108,626	1,744	12.0	12.0	0.0	off	off	NA
	03/18/06	8.7	621.6	45.1	10,667,874	19,737	1,128,363	1,775	11.0	11.0	0.0	off	off	NA
	03/19/06	9.3	630.9	44.6	10,688,460	20,586	1,148,949	1,807	11.0	11.0	0.0	off	off	NA
71	03/20/06	8.4	639.3	46.4	10,706,884	18,424	1,167,373	1,836	12.0	12.0	0.0	off	off	NA
	03/21/06	8.1	647.4	41.5	10,725,499	18,615	1,185,988	1,865	10.0	10.0	0.0	off	off	NA
	03/22/06	7.4	654.8	43.2	10,742,458	16,959	1,202,947	1,892	11.0	11.0	0.0	off	off	NA
	03/23/06	7.1	661.9	46.3	10,758,641	16,183	1,219,130	1,917	12.0	13.0	-1.0	off	off	NA
	03/24/06	7.4	669.3	46.5	10,775,745	17,104	1,236,234	1,944	13.0	12.0	1.0	off	off	NA
	03/25/06	8.3	677.6	45.1	10,794,761	19,016	1,255,250	1,974	12.0	11.0	1.0	off	off	NA
	03/26/06	8.8	686.4	44.3	10,814,462	19,701	1,274,951	2,005	11.0	11.0	0.0	off	off	NA
72	03/27/06	8.2	694.6	46.0	10,832,594	18,132	1,293,083	2,034	12.0	12.0	0.0	off	off	NA
	03/28/06	9.1	703.7	39.1	10,853,226	20,632	1,313,715	2,066	9.0	9.0	0.0	off	off	NA
	03/29/06	7.0	710.7	43.6	10,869,001	15,775	1,329,490	2,091	10.0	10.0	0.0	off	off	NA
	03/30/06	7.0	717.7	46.7	10,884,983	15,982	1,345,472	2,116	12.0	12.0	0.0	off	off	NA
	03/31/06	7.4	725.1	47.0	10,902,161	17,178	1,362,650	2,143	12.0	12.0	0.0	off	off	NA
	04/01/06	8.2	733.3	45.4	10,920,875	18,714	1,381,364	2,173	11.0	11.0	0.0	off	off	NA
	04/02/06	8.4	741.7	44.2	10,939,719	18,844	1,400,208	2,202	11.0	11.0	0.0	off	off	NA
73	04/03/06	8.9	750.6	45.1	10,959,143	19,424	1,419,632	2,233	12.0	12.0	0.0	off	off	NA
	04/04/06	7.7	758.3	45.4	10,976,440	17,297	1,436,929	2,260	12.0	12.0	0.0	off	off	NA
	04/05/06	7.9	766.2	45.9	10,994,306	17,866	1,454,795	2,288	12.0	12.0	0.0	off	off	NA
	04/06/06	8.5	774.7	42.3	11,013,655	19,349	1,474,144	2,319	10.0	10.0	0.0	off	off	NA
	04/07/06	8.0	782.7	43.6	11,031,576	17,921	1,492,065	2,347	11.0	11.0	0.0	off	off	NA
	04/08/06	8.2	790.9	44.7	11,050,223	18,647	1,510,712	2,376	12.0	12.0	0.0	off	off	NA
	04/09/06	9.7	800.6	43.3	11,071,452	21,229	1,531,941	2,409	11.0	11.0	0.0	off	off	NA
74	04/10/06	8.5	809.1	45.7	11,089,885	18,433	1,550,374	2,438	12.0	12.0	0.0	off	off	NA
	04/11/06	8.2	817.3	46.4	11,108,037	18,152	1,568,526	2,467	12.0	12.0	0.0	off	off	NA
	04/12/06	7.7	825.0	45.9	11,125,369	17,332	1,585,858	2,494	12.0	12.0	0.0	off	off	NA
	04/13/06	8.2	833.2	45.9	11,143,691	18,322	1,604,180	2,523	12.0	12.0	0.0	off	off	NA
	04/14/06	11.1	844.3	0.0	11,168,353	24,662	1,628,842	2,562	2.0	4.0	-2.0	off	off	NA

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 15 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
74	04/15/06[(d)]	6.5	6.5	31.8	11,183,597	15,244	0	0	3.0	5.0	-2.0	4.0	7.0	-3.0
	04/16/06	24.3	30.8	24.7	11,223,128	39,531	39,531	62	3.0	5.0	-2.0	4.0	6.0	-2.0
75	04/17/06	7.9	38.7	31.6	11,239,763	16,635	56,166	88	3.0	5.0	-2.0	5.0	6.0	-1.0
	04/18/06	7.4	46.1	45.1	11,255,498	15,735	71,901	113	3.0	5.0	-2.0	10.0	12.0	-2.0
	04/19/06	10.3	56.4	42.0	11,277,148	21,650	93,551	147	3.0	5.0	-2.0	8.0	10.0	-2.0
	04/20/06	8.9	65.3	41.4	11,296,163	19,015	112,566	177	3.0	5.0	-2.0	8.0	10.0	-2.0
	04/21/06	10.1	75.4	38.1	11,317,781	21,618	134,184	211	3.0	5.0	-2.0	8.0	9.0	-1.0
	04/22/06	11.7	87.1	32.4	11,342,446	24,665	158,849	250	3.0	5.0	-2.0	5.0	7.0	-2.0
	04/23/06	7.1	94.2	39.4	11,357,219	14,773	173,622	273	3.0	5.0	-2.0	8.0	10.0	-2.0
76	04/24/06	6.9	101.1	46.1	11,372,314	15,095	188,717	297	3.0	5.0	-2.0	10.0	12.0	-2.0
	04/25/06	7.8	108.9	39.2	11,390,462	18,148	206,865	325	2.0	5.0	-3.0	7.0	9.0	-2.0
	04/27/06	17.9	126.8	35.6	11,430,122	39,660	246,525	388	2.0	5.0	-3.0	7.0	9.0	-2.0
	04/28/06	5.5	132.3	45.2	11,443,036	12,914	259,439	408	2.0	5.0	-3.0	10.0	12.0	-2.0
	04/29/06	8.9	141.2	38.3	11,463,428	20,392	279,831	440	2.0	5.0	-3.0	7.0	9.0	-2.0
	04/30/06	9.7	150.9	33.7	11,484,616	21,188	301,019	473	2.0	5.0	-3.0	6.0	7.0	-1.0
77	05/01/06	8.5	159.4	45.3	11,502,252	17,636	318,655	501	2.0	5.0	-3.0	10.0	12.0	-2.0
	05/02/06	8.8	168.2	23.4	11,521,574	19,322	337,977	532	2.0	5.0	-3.0	7.0	8.0	-1.0
	05/03/06	19.3	187.5	17.0	11,543,488	21,914	359,891	566	2.0	5.0	-3.0	3.0	5.0	-2.0
	05/04/06	16.3	203.8	17.2	11,561,408	17,920	377,811	594	off	off	NA	3.0	5.0	-2.0
	05/05/06	19.3	223.1	16.8	11,582,091	20,683	398,494	627	off	off	NA	3.0	5.0	-2.0
	05/07/06	34.7	257.8	17.5	11,619,603	37,512	436,006	686	off	off	NA	2.0	5.0	-3.0
78	05/08/06	23.9	281.7	16.3	11,643,733	24,130	460,136	724	off	off	NA	2.0	5.0	-3.0
	05/09/06	19.5	301.2	16.9	11,664,171	20,438	480,574	756	off	off	NA	3.0	5.0	-2.0
	05/10/06	20.3	321.5	16.6	11,685,223	21,052	501,626	789	off	off	NA	2.0	5.0	-3.0
	05/11/06	19.0	340.5	16.9	11,705,209	19,986	521,612	820	off	off	NA	3.0	5.0	-2.0
	05/12/06	19.4	359.9	17.2	11,725,666	20,457	542,069	853	off	off	NA	3.0	5.0	-2.0
	05/13/06	14.3	374.2	17.5	11,741,268	15,602	557,671	877	off	off	NA	3.0	5.0	-2.0
	05/14/06	19.5	393.7	17.4	11,761,992	20,724	578,395	910	off	off	NA	3.0	5.0	-2.0
79	05/15/06	24.3	418.0	16.4	11,785,803	23,811	602,206	947	off	off	NA	3.0	5.0	-2.0
	05/16/06	17.8	435.8	16.8	11,804,713	18,910	621,116	977	off	off	NA	2.0	5.0	-3.0
	05/17/06	17.2	453.0	16.7	11,823,159	18,446	639,562	1,006	off	off	NA	3.0	5.0	-2.0
	05/18/06	17.7	470.7	17.0	11,842,236	19,077	658,639	1,036	off	off	NA	2.0	5.0	-3.0
	05/19/06	15.3	486.0	17.3	11,858,936	16,700	675,339	1,062	off	off	NA	2.0	5.0	-3.0
	05/20/06	15.3	501.3	17.6	11,875,786	16,850	692,189	1,089	off	off	NA	2.0	5.0	-3.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 16 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter			Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer			Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
79	05/21/06	19.4	520.7	17.4	11,896,557	20,771	712,960	1,121	off	off	NA	2.0	5.0	-3.0
80	05/22/06	24.7	545.4	16.3	11,921,349	24,792	737,752	1,160	off	off	NA	2.0	5.0	-3.0
	05/23/06	16.9	562.3	16.7	11,939,347	17,998	755,750	1,189	off	off	NA	3.0	5.0	-2.0
	05/24/06	19.3	581.6	16.8	11,959,524	20,177	775,927	1,220	off	off	NA	3.0	5.0	-2.0
	05/25/06	18.1	599.7	16.8	11,978,697	19,173	795,100	1,251	off	off	NA	3.0	5.0	-2.0
	05/26/06	23.8	623.5	16.2	12,002,196	23,499	818,599	1,288	off	off	NA	2.0	5.0	-3.0
	05/27/06	16.0	639.5	16.9	12,019,439	17,243	835,842	1,315	off	off	NA	2.0	5.0	-3.0
	05/28/06	22.0	661.5	16.5	12,041,117	21,678	857,520	1,349	off	off	NA	2.0	5.0	-3.0
81	05/29/06	24.3	685.8	36.5	12,065,109	23,992	881,512	1,386	off	off	NA	4.0	6.0	-2.0
	05/30/06	23.5	709.3	25.4	12,103,567	38,458	919,970	1,447	off	off	NA	3.0	5.0	-2.0
	05/31/06	14.3	723.6	22.6	12,127,391	23,824	943,794	1,484	off	off	NA	3.0	5.0	-2.0
	06/01/06	23.5	747.1	15.4	12,149,796	22,405	966,199	1,520	off	off	NA	2.0	5.0	-3.0
	06/02/06	20.3	767.4	15.7	12,169,328	19,532	985,731	1,550	off	off	NA	2.0	5.0	-3.0
	06/03/06	23.9	791.3	15.4	12,196,641	27,313	1,013,044	1,593	off	off	NA	2.0	5.0	-3.0
	06/04/06	17.6	808.9	16.6	12,209,190	12,549	1,025,593	1,613	off	off	NA	3.0	6.0	-3.0
82	06/05/06	23.8	832.7	15.5	12,231,852	22,662	1,048,255	1,649	off	off	NA	3.0	6.0	-3.0
	06/06/06	20.6	853.3	16.4	12,252,145	20,293	1,068,548	1,681	off	off	NA	3.0	6.0	-3.0
	06/07/06	19.4	872.7	16.4	12,270,813	18,668	1,087,216	1,710	off	off	NA	4.0	7.0	-3.0
	06/08/06	19.6	892.3	16.0	12,290,642	19,829	1,107,045	1,741	off	off	NA	3.0	6.0	-3.0
	06/09/06	19.6	911.9	16.1	12,310,379	19,737	1,126,782	1,772	off	off	NA	3.0	6.0	-3.0
	06/10/06	19.3	931.2	16.5	12,330,192	19,813	1,146,595	1,803	off	off	NA	3.0	6.0	-3.0
	06/11/06	22.2	953.4	15.7	12,351,616	21,424	1,168,019	1,837	off	off	NA	2.0	5.0	-3.0
83	06/12/06	23.8	977.2	15.7	12,374,318	22,702	1,190,721	1,873	off	off	NA	3.0	5.0	-2.0
	06/13/06	22.0	999.2	15.3	12,395,012	20,694	1,211,415	1,905	off	off	NA	2.0	5.0	-3.0
	06/14/06	25.5	1,024.7	15.6	12,418,740	23,728	1,235,143	1,943	off	off	NA	3.0	6.0	-3.0
	06/15/06	18.4	1,043.1	16.1	12,437,091	18,351	1,253,494	1,972	off	off	NA	3.0	6.0	-3.0
	06/16/06	22.7	1,065.8	15.8	12,458,093	21,002	1,274,496	2,005	off	off	NA	2.0	5.0	-3.0
	06/17/06	26.5	1,092.3	36.6	12,483,286	25,193	1,299,689	2,044	off	off	NA	4.0	6.0	-2.0
	06/18/06	19.3	1,111.6	25.1	12,516,674	33,388	1,333,077	2,097	off	off	NA	4.0	6.0	-2.0
84	06/19/06	9.7	1,121.3	38.9	12,535,387	18,713	1,351,790	2,126	off	off	NA	6.0	7.0	-1.0
	06/20/06	9.6	1,130.9	22.7	12,554,389	19,002	1,370,792	2,156	off	off	NA	3.0	5.0	-2.0
	06/21/06	23.7	1,154.6	16.5	12,578,821	24,432	1,395,224	2,194	off	off	NA	3.0	5.0	-2.0
	06/22/06	22.4	1,177.0	16.2	12,600,646	21,825	1,417,049	2,229	off	off	NA	3.0	5.0	-2.0
	06/23/06	25.2	1,202.2	16.1	12,624,992	24,346	1,441,395	2,267	off	off	NA	3.0	6.0	-3.0
	06/24/06	24.6	1,226.8	15.9	12,648,649	23,657	1,465,052	2,304	off	off	NA	3.0	6.0	-3.0
	06/25/06	17.5	1,244.3	16.8	12,666,742	18,093	1,483,145	2,333	off	off	NA	3.0	6.0	-3.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 17 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter: Outlet Flowrate	Outlet Magnetic Meter: Outlet Totalizer	Outlet Magnetic Meter: Daily Flow Totalizer	Outlet Magnetic Meter: Cumulative Flow Totalizer	Outlet Magnetic Meter: Cumulative Bed Volume Treated	Vessel A: Inlet Pressure	Vessel A: Outlet Pressure	Vessel A: Δp	Vessel B: Inlet Pressure	Vessel B: Outlet Pressure	Vessel B: Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
85	06/26/06	23.8	1,268.1	16.0	12,690,253	23,511	1,506,656	2,370	off	off	NA	3.0	6.0	-3.0
	06/27/06	24.2	1,292.3	15.3	12,713,156	22,903	1,529,559	2,406	off	off	NA	5.0	7.0	-2.0
	06/28/06	18.5	1,310.8	15.5	12,731,200	18,044	1,547,603	2,434	off	off	NA	5.0	7.0	-2.0
	06/29/06	24.1	1,334.9	15.5	12,753,633	22,433	1,570,036	2,469	off	off	NA	5.0	6.0	-1.0
	06/30/06	23.9	1,358.8	15.9	12,775,605	21,972	1,592,008	2,504	off	off	NA	5.0	7.0	-2.0
	07/01/06	16.1	1,374.9	16.1	12,791,747	16,142	1,608,150	2,529	off	off	NA	5.0	7.0	-2.0
	07/02/06	24.0	1,398.9	15.8	12,814,291	22,544	1,630,694	2,565	off	off	NA	5.0	7.0	-2.0
86	07/03/06	23.8	1,422.7	15.2	12,836,261	21,970	1,652,664	2,599	off	off	NA	5.0	6.0	-1.0
	07/04/06	19.3	1,442.0	15.8	12,854,900	18,639	1,671,303	2,629	off	off	NA	5.0	7.0	-2.0
	07/05/06	9.9	1,451.9	40.1	12,877,991	23,091	1,694,394	2,665	off	off	NA	9.0	10.0	-1.0
	07/06/06	13.4	1,465.3	35.8	12,902,703	24,712	1,719,106	2,704	off	off	NA	7.0	8.0	-1.0
	07/07/06	10.8	1,476.1	39.7	12,923,321	20,618	1,739,724	2,736	off	off	NA	9.0	10.0	-1.0
	07/08/06	14.1	1,490.2	25.5	12,948,697	25,376	1,765,100	2,776	off	off	NA	4.0	5.0	-1.0
	07/09/06	11.4	1,501.6	33.3	12,969,247	20,550	1,785,650	2,809	off	off	NA	6.0	8.0	-2.0
87	07/10/06	13.8	1,515.4	41.2	12,992,936	23,689	1,809,339	2,846	off	off	NA	9.0	10.0	-1.0
	07/11/06	11.7	1,527.1	41.4	13,014,988	22,052	1,831,391	2,880	off	off	NA	10.0	11.0	-1.0
	07/12/06	11.8	1,538.9	41.5	13,036,794	21,806	1,853,197	2,915	off	off	NA	10.0	11.0	-1.0
	07/13/06	9.1	1,548.0	43.0	13,054,972	18,178	1,871,375	2,943	off	off	NA	10.0	12.0	-2.0
	07/14/06	10.4	1,558.4	39.2	13,076,081	21,109	1,892,484	2,977	off	off	NA	9.0	10.0	-1.0
	07/15/06	13.4	1,571.8	34.6	13,101,178	25,097	1,917,581	3,016	off	off	NA	7.0	8.0	-1.0
	07/16/06	10.7	1,582.5	38.0	13,121,417	20,239	1,937,820	3,048	off	off	NA	8.0	9.0	-1.0
88	07/17/06	10.9	1,593.4	40.7	13,141,839	20,422	1,958,242	3,080	off	off	NA	9.0	10.0	-1.0
	07/18/06	16.2	1,609.6	37.2	13,169,951	28,112	1,986,354	3,124	off	off	NA	8.0	9.0	-1.0
	07/19/06	23.9	1,633.5	21.6	13,204,150	34,199	2,020,553	3,178	off	off	NA	5.0	6.0	-1.0
	07/20/06	12.7	1,646.2	38.2	13,224,882	20,732	2,041,285	3,211	off	off	NA	10.0	11.0	-1.0
	07/21/06	13.5	1,659.7	27.2	13,249,139	24,257	2,065,542	3,249	off	off	NA	5.0	7.0	-2.0
	07/22/06	10.9	1,670.6	39.5	13,268,962	19,823	2,085,365	3,280	off	off	NA	9.0	10.0	-1.0
	07/23/06	10.4	1,681.0	37.6	13,288,506	19,544	2,104,909	3,311	off	off	NA	10.0	11.0	-1.0
89	07/24/06	9.3	1,690.3	41.4	13,306,411	17,905	2,122,814	3,339	off	off	NA	10.0	12.0	-2.0
	07/25/06	9.7	1,700.0	41.6	13,325,368	18,957	2,141,771	3,369	off	off	NA	11.0	13.0	-2.0
	07/26/06	17.3	1,717.3	31.1	13,355,677	30,309	2,172,080	3,416	off	off	NA	7.0	8.0	-1.0
	07/27/06	14.0	1,731.3	37.4	13,379,452	23,775	2,195,855	3,454	off	off	NA	10.0	11.0	-1.0
	07/28/06	11.9	1,743.2	40.7	13,400,353	20,901	2,216,756	3,487	off	off	NA	11.0	13.0	-2.0
	07/29/06	10.3	1,753.5	40.3	13,419,737	19,384	2,236,140	3,517	off	off	NA	11.0	13.0	-2.0
	07/30/06	10.5	1,764.0	38.6	13,439,863	20,126	2,256,266	3,549	off	off	NA	10.0	12.0	-2.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 18 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
90	07/31/06	12.5	1,776.5	40.3	13,462,543	22,680	2,278,946	3,584	off	off	NA	11.0	13.0	-2.0
	08/01/06	15.3	1,791.8	36.9	13,488,847	26,304	2,305,250	3,626	off	off	NA	10.0	11.0	-1.0
	08/02/06	10.5	1,802.3	40.8	13,508,192	19,345	2,324,595	3,656	off	off	NA	12.0	14.0	-2.0
	08/03/06	10.3	1,812.6	40.9	13,527,787	19,595	2,344,190	3,687	off	off	NA	12.0	14.0	-2.0
	08/04/06	10.0	1,822.6	41.1	13,546,993	19,206	2,363,396	3,717	off	off	NA	12.0	13.0	-1.0
	08/05/06	14.2	1,836.8	36.8	13,572,736	25,743	2,389,139	3,758	off	off	NA	10.0	11.0	-1.0
	08/06/06	13.5	1,850.3	24.0	13,596,605	23,869	2,413,008	3,795	off	off	NA	4.0	6.0	-2.0
91	08/07/06	11.8	1,862.1	40.3	13,615,628	19,023	2,432,031	3,825	off	off	NA	12.0	13.0	-1.0
	08/08/06	12.1	1,874.2	40.5	13,637,169	21,541	2,453,572	3,859	off	off	NA	12.0	13.0	-1.0
	08/09/06	14.9	1,889.1	36.3	13,662,825	25,656	2,479,228	3,899	off	off	NA	9.0	10.0	-1.0
	08/10/06	11.9	1,901.0	38.5	13,683,597	20,772	2,500,000	3,932	off	off	NA	10.0	12.0	-2.0
	08/11/06	19.3	1,920.3	38.6	13,712,502	28,905	2,528,905	3,978	off	off	NA	11.0	12.0	-1.0
	08/12/06	17.8	1,938.1	23.2	13,740,803	28,301	2,557,206	4,022	off	off	NA	4.0	5.0	-1.0
	08/13/06	13.0	1,951.1	24.1	13,762,174	21,371	2,578,577	4,056	off	off	NA	4.0	6.0	-2.0
92	08/14/06	17.9	1,969.0	22.0	13,788,724	26,550	2,605,127	4,097	off	off	NA	4.0	5.0	-1.0
	08/15/06	18.8	1,987.8	31.6	13,815,691	26,967	2,632,094	4,140	off	off	NA	7.0	9.0	-2.0
	08/16/06	15.2	2,003.0	22.3	13,839,652	23,961	2,656,055	4,178	off	off	NA	4.0	5.0	-1.0
	08/17/06	15.8	2,018.8	38.6	13,862,463	22,811	2,678,866	4,213	off	off	NA	11.0	12.0	-1.0
	08/18/06	15.3	2,034.1	35.1	13,886,960	24,497	2,703,363	4,252	off	off	NA	9.0	10.0	-1.0
	08/19/06	15.7	2,049.8	22.9	13,912,365	25,405	2,728,768	4,292	off	off	NA	4.0	6.0	-2.0
	08/20/06	12.1	2,061.9	23.3	13,933,294	20,929	2,749,697	4,325	off	off	NA	4.0	6.0	-2.0
93	08/21/06	8.5	2,070.4	39.3	13,947,875	14,581	2,764,278	4,348	off	off	NA	11.0	13.0	-2.0
	08/24/06	74.3	2,144.7	20.1	14,043,021	95,146	2,859,424	4,497	off	off	NA	4.0	5.0	-1.0
	08/25/06	10.8	2,155.5	26.8	14,060,642	17,621	2,877,045	4,525	off	off	NA	6.0	7.0	-1.0
	08/26/06	14.4	2,169.9	22.7	14,083,109	22,467	2,899,512	4,560	off	off	NA	5.0	6.0	-1.0
	08/27/06	16.6	2,186.5	25.9	14,107,770	24,661	2,924,173	4,599	off	off	NA	5.0	6.0	-1.0
94	08/28/06	12.6	2,199.1	39.1	14,128,660	20,890	2,945,063	4,632	off	off	NA	11.0	12.0	-1.0
	08/29/06	11.8	2,210.9	39.8	14,148,669	20,009	2,965,072	4,664	off	off	NA	12.0	13.0	-1.0
	08/30/06	12.0	2,222.9	38.0	14,169,402	20,733	2,985,805	4,696	off	off	NA	12.0	14.0	-2.0
	08/31/06	11.4	2,234.3	40.6	14,189,830	20,428	3,006,233	4,728	off	off	NA	12.0	14.0	-2.0
	09/01/06	11.0	2,245.3	38.6	14,209,982	20,152	3,026,385	4,760	off	off	NA	12.0	13.0	-1.0
	09/02/06	12.4	2,257.7	39.8	14,232,291	22,309	3,048,694	4,795	off	off	NA	12.0	13.0	-1.0
	09/03/06	10.4	2,268.1	37.1	14,251,870	19,579	3,068,273	4,826	off	off	NA	10.0	11.0	-1.0

Table A-1. EPA Arsenic Demonstration Project at Bow, NH - Daily System Operation Log Sheet (Page 19 of 19)

Week No.	Date	Avg Operation Time	Cumulative Operation Time	Outlet Magnetic Meter					Vessel A			Vessel B		
				Outlet Flowrate	Outlet Totalizer	Daily Flow Totalizer	Cumulative Flow Totalizer	Cumulative Bed Volume Treated	Inlet Pressure	Outlet Pressure	Δp	Inlet Pressure	Outlet Pressure	Δp
		hr	hr	gpm	gal	gal	gal		psi	psi	psi	psi	psi	psi
95	09/04/06	11.8	2,279.9	37.3	14,273,572	21,702	3,089,975	4,860	off	off	NA	10.0	11.0	-1.0
	09/05/06	11.4	2,291.3	38.9	14,293,943	20,371	3,110,346	4,892	off	off	NA	12.0	14.0	-2.0
	09/06/06	10.2	2,301.5	41.1	14,312,811	18,868	3,129,214	4,922	off	off	NA	12.0	14.0	-2.0
	09/07/06	10.2	2,311.7	41.6	14,332,192	19,381	3,148,595	4,952	off	off	NA	13.0	14.0	-1.0
	09/08/06	12.2	2,323.9	40.4	14,354,769	22,577	3,171,172	4,988	off	off	NA	12.0	13.0	-1.0
	09/09/06	15.0	2,338.9	24.1	14,381,015	26,246	3,197,418	5,029	off	off	NA	4.0	5.0	-1.0
	09/10/06	13.8	2,352.7	39.7	14,403,247	22,232	3,219,650	5,064	off	off	NA	12.0	13.0	-1.0
96	09/11/06	12.3	2,365.0	39.7	14,424,725	21,478	3,241,128	5,098	off	off	NA	12.0	14.0	-2.0
	09/12/06	10.4	2,375.4	18.5	14,444,531	19,806	3,260,934	5,129	off	off	NA	6.0	7.0	-1.0
	09/13/06	22.2	2,397.6	13.3	14,462,666	18,135	3,279,069	5,157	off	off	NA	3.0	5.0	-2.0
	09/14/06	23.8	2,421.4	13.2	14,481,832	19,166	3,298,235	5,188	off	off	NA	3.0	5.0	-2.0
	09/15/06	24.8	2,446.2	13.2	14,501,733	19,901	3,318,136	5,219	off	off	NA	3.0	5.0	-2.0
	09/16/06	23.3	2,469.5	13.2	14,520,451	18,718	3,336,854	5,248	off	off	NA	3.0	5.0	-2.0
	09/17/06	23.3	2,492.8	24.8	14,539,252	18,801	3,355,655	5,278	off	off	NA	3.0	5.0	-2.0
97	09/18/06	24.8	2,517.6	18.4	14,568,241	28,989	3,384,644	5,323	off	off	NA	5.0	7.0	-2.0
	09/19/06	19.6	2,537.1	12.3	14,591,036	22,795	3,407,439	5,359	off	off	NA	3.0	5.0	-2.0
	09/20/06	25.1	2,562.2	13.0	14,610,346	19,310	3,426,749	5,390	off	off	NA	3.0	5.0	-2.0
	09/21/06	23.2	2,585.4	13.0	14,628,605	18,259	3,445,008	5,418	off	off	NA	3.0	5.0	-2.0
	09/22/06	24.9	2,610.3	13.2	14,648,444	19,839	3,464,847	5,450	off	off	NA	3.0	5.0	-2.0
	09/23/06	23.1	2,633.4	13.6	14,666,924	18,480	3,483,327	5,479	off	off	NA	3.0	5.0	-2.0
	09/24/06	24.7	2,658.1	19.3	14,687,107	20,183	3,503,510	5,510	off	off	NA	3.0	5.0	-2.0
98	09/25/06	23.9	2,682.0	19.1	14,716,300	29,193	3,532,703	5,556	off	off	NA	4.0	6.0	-2.0
	09/26/06	22.6	2,704.6	11.9	14,741,934	25,634	3,558,337	5,597	off	off	NA	4.0	6.0	-2.0

NA = Not Available
Note: 1 bed volume = 85 ft^3 or 636 gal in one vessel
(a) Totalizer replaced on January 4, 2005.
(b) Treatment system bypassed between November 28, 2005 and January 13, 2006.
(c) Media replaced on January 11, 1006 and Vessel A put into operation on January 13, 2006.
(d) Switched so Vessel B only in operation on April 15, 2006.

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire

Sampling Date		10/13/04[a][b]				10/19/04				10/26/04				11/02/04[c]			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	0		–	–	0.2		–	–	0.4		–	–	0.6	
Alkalinity (as $CaCO_3$)	mg/L	55	55	57	59	61	41	55	55	57	43	45	46	62	39	41	45
Fluoride	mg/L	0.7	0.7	1.1	0.8	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	1.0	0.5	1.3	1.4	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate (as P)	mg/L	<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	18.8	19.1	50.8	61.8	19.4	19.8	39.1	54.2	19.5	19.4	28.5	36.8	19.4	19.0	27.8	37.1
Sulfate	mg/L	24.0	26.0	12.0	9.6	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.7	0.1	0.2	0.2	0.7	0.5	0.4	0.5	0.4	0.2	<0.1	<0.1	0.3	0.5	0.2	0.3
pH	S.U.	7.7	7.8	7.9	8.0	6.8	6.8	7.0	7.1	7.1	6.9	7.1	6.9	7.1	7.0	6.8	6.8
Temperature	°C	12.3	12.7	12.9	13.0	11.7	11.7	11.7	11.8	12.1	11.9	11.8	11.7	11.8	11.9	11.8	11.7
DO	mg/L	5.5	2.9	4.1	4.0	5.8	3.6	3.8	4.3	5.5	3.9	3.6	4.5	6.5	4.6	4.2	4.7
ORP	mV	198	190	183	173	234	233	227	231	–	–	–	–	215	228	224	217
Free Chlorine (as Cl_2)	mg/L	–	0.2	0.1	0.1	–	0.7	0.3	0.6	–	0.1	0.2	0.1	–	0.2	0.1	0.1
Total Chlorine (as Cl_2)	mg/L	–	0.1	0.1	0.1	–	0.4	0.3	0.5	–	0.1	0.2	0.1	–	0.1	0.1	0.1
Total Hardness (as $CaCO_3$)	mg/L	163.3	128.4	166.6	86.8	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	125.5	99.1	122.2	41.4	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	37.8	29.3	44.4	45.4	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	91.3/ 89.5	96.1/ 90.2	37.5/ 34.4	17.1/ 16.7	49.8	50.7	30.7	21.8	52.0	52.2	14.5	5.4	47.6	48.5	13.8	4.5
As (soluble)	µg/L	50.5/ 46.9	52.3/ 47.8	25.3/ 23.3	14.3/ 14.6	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	40.8/ 42.6	43.8/ 42.4	12.2/ 11.1	2.8/ 2.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.7	0.6	0.8	1.1	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	49.8/ 46.2	51.7/ 47.2	24.5/ 22.5	13.2/ 13.5	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25/ <25	60/ 56	<25	39/ 38	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	1.8/ 1.2	7.2/ 4.6	19.3/ 19.1	5.1/ 6.0	0.8	0.4	12.0	7.1	0.5	0.8	27.0	31.5	0.7	0.6	21.2	35.8
Mn (soluble)	µg/L	0.4/ 0.6	0.3/ 0.5	9.0/ 10.4	4.1/ 4.9	–	–	–	–	–	–	–	–	–	–	–	–

(a) samples re-run with original result/re-run result.
(b) System start-up on October 13, 2004; acid addition not yet operational.
(c) Relocated acid and chlorine injection points.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		11/16/04[a]				11/30/04				12/14/04[b]				01/04/05[c]			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–			1.0	–	–		1.5	–	–		1.9	–	–		2.5
Alkalinity (as $CaCO_3$)	mg/L	254	46	43	45	61	41	41	41	67	31	31	31	66 65	28 29	31 31	31 31
Fluoride	mg/L	–	–	–	–	–	–	–	–	1.1	1.0	0.8	0.7	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	–	–	–	–	0.2	0.1	0.2	0.2	–	–	–	–
Orthophosphate (as P)	mg/L	<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	18.9	19.5	26.4	33.0	19.4	19.6	24.8	30.9	19.2	19.4	25.0	28.4	20.4 20.0	20.6 19.9	23.2 22.9	26.6 26.2
Sulfate	mg/L	–	–	–	–	–	–	–	–	11.0/ 11.1	39.0/ 46.7	39.0/ 45.7	39.0/ 46.6	–	–	–	–
Turbidity	NTU	0.3	0.4	0.3	0.3	1.1	0.3	0.1	0.4	0.5	0.2	0.3	0.4	0.3 0.2	0.1 0.2	0.2 0.6	0.2 0.4
pH	S.U.	7.4	6.9	6.8	6.8	7.4	6.7	6.7	6.7	7.4	6.5	6.4	6.4	7.4	6.4	6.4	6.4
Temperature	°C	11.9	11.8	11.7	11.5	11.8	11.9	11.7	11.5	11.5	11.6	11.5	11.5	11.8	11.8	11.9	12.1
DO	mg/L	5.7	4.4	4.5	4.4	4.7	4.7	4.7	4.7	5.6	4.6	4.4	4.5	6.8	4.7	4.5	4.7
ORP	mV	218	219	221	222	208	524	542	450	211	548	554	553	498	484	553	558
Free Chlorine (as Cl_2)	mg/L	–	0.1	0.1	0.1	–	0.2	0.1	0.1	–	0.2	0.1	0.1	–	0.2	0.2	0.1
Total Chlorine (as Cl_2)	mg/L	–	0.1	0.1	0.1	–	0.2	0.2	0.1	–	0.2	0.1	0.1	–	0.2	0.2	0.1
Total Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	92.1	98.7	93.5	101.8	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	72.3	77.5	72.6	79.2	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	19.8	21.2	20.9	22.6	–	–	–	–
As (total)	µg/L	44.2	44.9	14.2	3.8	42.4	43.5	13.5	3.3	52.3	55.2	15.6	50.9/ 50.8	38.4 38.0	38.7 38.9	13.0 12.6	1.7 1.7
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	52.6	55.7	15.5	3.6	–	–	–	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	<0.1	<0.1	0.1	47.3	–	–	–	–
As (III)	µg/L	–	–	–	–	–	–	–	–	0.6	0.6	0.7	0.6	–	–	–	–
As (V)	µg/L	–	–	–	–	–	–	–	–	52.0	55.1	14.8	3.0	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25/ <25	<25 <25	<25 <25	<25 <25	<25 <25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	<25	<25	<25	<25	–	–	–	–
Mn (total)	µg/L	0.2	<0.1	12.5	28.3	0.7	0.5	5.2	15.3	1.2	0.6	5.0	13.3/ 12.8	0.9 0.8	0.8 0.8	2.3 2.4	5.2 5.3
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	0.4	0.4	4.8	12.5	–	–	–	–

(a) Began bi-weekly sampling instead of weekly sampling.
(b) Samples re-run with original result/re-run result.
(c) Duplicate sampling week.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		01/18/05				02/01/05				02/15/05				03/01/05			
Parameter (Sampling Location)	**Unit**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**
Bed Volume	10^3	–	–		2.9	–	–		3.4	–	–		3.8	–	–		4.3
Alkalinity (as $CaCO_3$)	mg/L	66	35	33	35	69	43	37	41	69	45	36	38	120	61	62	68
Fluoride	mg/L	–	–	–	–	0.9	1.0	0.7	0.3	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.22	0.19	0.23	0.24	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	19.7	20.1	22.7	25.3	18.7	18.5	21.1	24.9	20.0	20.1	22.9	24.9	19.7	19.9	22.0	23.9
Sulfate	mg/L	–	–	–	–	11.0	47.0	48.0	48.0	–	–	–	–	–	–	–	–
Turbidity	NTU	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
pH	S.U.	7.5	6.5	6.4	6.4	7.4	6.5	6.4	6.5	7.4	6.4	6.3	6.3	7.3	6.5	6.4	6.4
Temperature	°C	12.4	12.6	12.3	12.3	11.5	11.6	11.4	11.2	11.5	11.5	11.5	11.2	11.9	12.0	11.8	11.5
DO	mg/L	6.0	4.5	4.0	3.9	6.6	5.6	5.3	5.4	–	–	–	–	5.1	3.9	3.9	3.9
ORP	mV	238	207	548	584	211	587	591	586	212	580	594	595	195	607	610	608
Free Chlorine (as Cl_2)	mg/L	–	0.3	0.2	0.2	–	0.2	0.2	0.2	–	0.3	0.3	0.2	–	0.5	0.5	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.2	–	0.2	0.2	0.2	–	0.3 .	0.2	0.2	–	0.5	0.4	0.5
Total Hardness (as $CaCO_3$)	mg/L	–	–	–	–	84.0	81.5	85.0	89.6	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	–	–	–	–	65.9	64.0	66.6	70.0	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	–	–	–	–	18.1	17.5	18.4	19.6	–	–	–	–	–	–	–	–
As (total)	µg/L	46.1	46.3	15.1	2.1	54.1	54.5	24.4	5.0	45.5	46.1	17.2	3.3	49.1	49.8	22.3	3.9
As (total soluble)	µg/L	–	–	–	–	54.6	54.4	24.8	5.0	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	<0.1	0.1	<0.1	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	0.5	0.5	0.4	0.4	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	54.1	53.9	24.4	4.6	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	–	–	–	–	<25	<25	<25	<25	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.6	0.8	3.0	2.8	0.5	3.3	1.1	1.5	0.7	0.7	1.4	2.4	1.1	1.9	0.5	1.1
Mn (soluble)	µg/L	–	–	–	–	0.5	0.5	1.2	1.3	–	–	–	–	–	–	–	–

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		03/15/05				03/29/05[a][b]				04/12/05				04/26/05			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	4.8		–	–	5.2		–	–	5.7		–	–	6.1	
Alkalinity(as $CaCO_3$)	mg/L	77 69	35 39	37 37	38 37	66	33	29	28	67	28	44	42	72	56	50	44
Fluoride	mg/L	–	–	–	–	0.9	1.0	0.9	0.8	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	–	–	–	–	0.2	0.2	0.2	0.3	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	21.4 20.3	21.4 20.8	23.9 22.7	24.4 24.3	19.8	19.7	21.4	23.5	20.7	20.1	23.0	25.1	20.6	20.2	22	23.9
Sulfate	mg/L	–	–	–	–	11.0	51.0	48.0	46.0	–	–	–	–	–	–	–	–
Turbidity	NTU	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1	<0.1	<0.1	0.3	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
pH	S.U.	7.4	6.6	6.3	6.3	7.4	6.1	6.1	6.1	7.3	6.1	6.4	6.5	7.2	6.6	6.6	6.6
Temperature	°C	11.9	11.9	11.7	11.6	11.7	11.5	11.4	11.4	11.7	11.6	11.7	11.5	12.0	11.9	11.8	11.8
DO	mg/L	–	–	–	–	5.3	4.3	4.7	4.4	4.8	3.9	4.8	4.6	5.5	4.2	3.6	3.4
ORP	mV	213	608	606	608	212	577	590	594	192	560	577	578	207	576	585	589
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.3	0.4	–	0.4	0.4	0.3	–	0.4	0.3	0.4	–	0.5	0.5	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.4	–	0.4	0.3	0.3	–	0.3	0.4	0.3	–	0.5	0.4	0.4
Total Hardness (as $CaCO_3$)	mg/L	–	–	–	–	95.4	93.4	101.4	98.5	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	–	–	–	–	75.8	72.7	77.2	75.7	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	–	–	–	–	19.6	20.7	24.2	22.8	–	–	–	–	–	–	–	–
As (total)	µg/L	48.1 47.8	46.9 47.0	23.0 23.1	6.9 6.8	48.9	50.0	21.0	5.5	42.8	41.5	26.3	5.8	48.4	48.1	31.0	11.0
As (total soluble)	µg/L	–	–	–	–	48.2	49.7	20.8	5.5	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	0.7	0.3	0.2	<0.1	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	0.7	0.6	0.6	0.7	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	47.5	49.1	20.2	4.8	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25 <25	<25 <25	<25 <25	<25 <25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	–	–	–	–	<25	<25	<25	<25	–	–	–	–	–	–	–	–
Mn (total)	µg/L	2.0 1.9	1.9 1.8	0.6 0.5	0.3 0.3	1.2	0.9	1.2	1.5	0.1	0.1	0.5	<0.1	0.9	0.7	0.4	0.5
Mn (soluble)	µg/L	–	–	–	–	1.2	1.0	1.4	1.4	–	–	–	–	–	–	–	–

(a) On-site water quality parameters measured on March 28, 2005.
(b) For AP location, because water not filtered into bottle B, it had to be re-filled with filtered water. The initial content of bottle B including preservative discarded.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		05/10/05				05/24/05				06/07/05				06/21/05			
Parameter / Sampling Location	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	6.6		–	–	7.0		–	–	7.5		–	–	8.0	
Alkalinity (as $CaCO_3$)	mg/L	72	46	46	46	72	46	45	45	69 69	42 42	41 41	41 41	66	42	42	42
Fluoride	mg/L	0.9	1.0	0.8	0.8	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	0.2	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	19.8	20.2	21.5	22.7	19.9	19.7	21.1	22.8	19.7 20.0	19.9 20.0	22.1 21.8	22.8 23.1	19.9	21.1	21.0	21.9
Sulfate	mg/L	11	29	31	31	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.7	0.3	<0.1	0.3	0.3	0.4	<0.1	0.1	<0.1 0.2	0.2 0.1	<0.1 <0.1	<0.1 0.2	0.2	0.2	0.1	<0.1
pH	S.U.	7.3	6.7	6.6	6.6	6.9	6.5	6.4	6.4	7.2	6.5	6.4	6.4	7.1	6.3	6.2	6.3
Temperature	°C	12.1	12.1	12.0	11.8	11.3	12.0	11.9	11.8	12.9	12.7	12.6	12.6	12.4	12.4	12.4	12.3
DO	mg/L	3.9	3.4	3.5	3.3	4.5	3.2	3.3	3.6	4.7	2.8	3.9	3.4	–	–	–	–
ORP	mV	198	577	544	523	195	471	491	484	198	521	481	517	182	542	515	535
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.1	–	0.5	0.4	0.3	–	0.5	0.4	0.4	–	0.5	0.4	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.4	0.1	–	0.4	0.4	0.3	–	0.5	0.5	0.4	–	0.5	0.5	0.4
Total Hardness (as $CaCO_3$)	mg/L	87.0	84.0	89.8	92.5	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	67.5	65.1	68.8	72.2	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	19.5	18.9	20.9	20.3	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	48.8	47.7	31.3	13.5	45.5	45.8	32.6	16.7	46.3 46.5	46.7 46.3	30.9 31.0	19.7 19.2	47.7	33.3	32.4	19.0
As (total soluble)	µg/L	48.4	47.7	31.3	13.3	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.4	<0.1	<0.1	0.2	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.4	0.4	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	48.0	47.3	31.0	13.0	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25 <25	<25 <25	<25 <25	<25 <25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.5	0.6	0.2	0.2	0.7	0.7	0.2	<0.1	1.9 1.9	2.1 1.7	0.3 0.2	0.2 0.2	1.3	0.3	0.3	0.3
Mn (soluble)	µg/L	0.5	0.5	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		07/05/05				07/19/05				08/02/05				08/16/05			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	8.4		–	–	8.7		–	–	9.0		–	–	9.5	
Alkalinity (as $CaCO_3$)	mg/L	66	44	44	44	63	39	39	39	62	33	34	33	58	36	36	36
Fluoride	mg/L	0.8	0.8	0.8	0.8	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.3	0.3	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	19.5	19.8	20.9	22.0	19.1	19.4	20.7	21.9	–	–	–	–	–	–	–	–
Sulfate	mg/L	12	34	34	33	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	–	–	–	–	–	–	–	–
pH	S.U.	6.8	6.2	6.2	6.2	7.1	6.9	6.2	6.2	6.7	6.1	6.1	6.1	7.1	6.3	6.2	6.2
Temperature	°C	12.3	12.2	12.2	12.3	12.5	12.5	12.6	12.7	12.4	12.4	12.5	12.6	12.8	12.6	12.5	12.4
DO	mg/L	–	–	–	–	–	–	–	–	4.8	3.2	3.2	3.1	4.1	3.0	3.3	3.3
ORP	mV	174	568	584	587	190	553	565	569	196	523	517	556	181	521	537	547
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.3	0.4	–	0.5	0.5	0.5	–	0.3	0.3	0.3	–	0.4	0.3	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.4	0.3	–	0.5	0.5	0.5	–	0.4	0.4	0.4	–	0.4	0.4	0.3
Total Hardness (as $CaCO_3$)	mg/L	100	99.3	102.0	97.8	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	76.6	76.9	79.1	75.2	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	23.7	22.4	22.5	22.5	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	42.7	43.1	31.5	18.0	42.5	42.1	29.8	21.2	40.2	38.1	27.9	19.4	43.3	42.7	32.3	22.6
As (total soluble)	µg/L	48.1	45.6	32.9	19.7	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	<0.1	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.7	0.7	0.6	0.8	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	47.5	44.9	32.3	18.9	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
Fe (soluble)	µg/L	<25	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.8	0.9	0.4	0.4	0.7	0.6	0.2	0.3	0.6	0.5	0.2	0.1	0.5	0.6	0.3	<0.1
Mn (soluble)	µg/L	0.6	0.6	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		08/30/05				09/13/05				09/27/05				10/11/05			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	9.9		–	–	10.4		–	–	10.8		–	–	11.2	
Alkalinity (as $CaCO_3$)	mg/L	66	42	39	42	66	44	44	43	66	46	45	48	72	44	45	46
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.8	0.8	0.8	0.8
Nitrate (as N)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.3	0.3	0.3
Total P (as PO_4)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.06	0.06	0.04	<0.03
Orthophosphate(as P)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	18.7	18.6	19.8	21.9
Sulfate	mg/L	11	37	36	36	–	–	–	–	–	–	–	–	10	27	27	27
Turbidity	NTU	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.2	0.2	0.1
pH	S.U.	7.0	6.3	6.2	6.2	7.2	6.3	6.2	6.2	7.0	6.7	6.5	6.5	7.1	6.5	6.5	6.5
Temperature	°C	12.8	12.7	12.6	12.5	12.9	12.9	12.8	12.6	11.7	12.3	13.0	13.2	12.7	12.6	12.5	12.5
DO	mg/L	4.7	3.5	3.6	3.8	5.7	6.4	3.8	3.5	4.1	2.7	5.2	3.0	5.0	3.3	3.7	3.6
ORP	mV	172	547	537	541	182	540	555	560	186	549	530	516	178	529	536	545
Free Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.3	–	0.4	0.4	0.4	–	0.3	0.1	NA	–	0.4	0.4	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.3	0.2	–	0.4	0.4	0.3	–	0.4	0.2	0.1	–	0.4	0.3	0.4
Total Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	96.8	98.0	97.9	99.4
Ca Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	74.3	75.3	74.7	76.3
Mg Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	22.4	22.7	23.2	23.1
As (total)	µg/L	45.3	45.3	39.6	22.8	43.0	41.7	32.1	21.9	50.1	48.4	37.6	32.7	44.8	46.5	38.9	31.3
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	45.4	46.4	38.4	32.1
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	<0.1	0.5	<0.1
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.4	0.4	0.5	0.4
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	44.9	46.1	38.0	31.7
Fe (total)	µg/L	<25	<25	<25	<25	–	–	–	–	–	–	–	–	<25	<25	<25	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<25	<25	<25	<25
Mn (total)	µg/L	0.5	0.4	0.2	<0.1	–	–	–	–	–	–	–	–	0.4	0.5	<0.1	<0.1
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.3	<0.1	<0.1

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		10/25/05				11/08/05				11/29/05[a]				01/17/06[b]			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA[c]	TB
Bed Volume	10^3	–	–	11.5		–	–	11.9		–	–	–		–	–	0.15	
Alkalinity (as $CaCO_3$)	mg/L	55	47	46	47	62	44	42	42	69	22	22	22	67	30	37	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.6	0.6	0.5	–
Nitrate (as N)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.3	0.3	–
Total P (as PO_4)	mg/L	–	–	–	–	0.1	0.04	0.04	<0.03	–	–	–	–	–	–	–	–
Orthophosphate(as P)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05	–
Silica (as SiO_2)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	19.9	20.6	39.8	–
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	12	42	42	–
Turbidity	NTU	–	–	–	–	–	–	–	–	–	–	–	–	0.6	1.0	0.5	–
pH	S.U.	–	–	–	–	–	–	–	–	7.5	6.0	6.1	6.1	7.2	6.4	6.6	–
Temperature	°C	–	–	–	–	–	–	–	–	11.5	11.6	11.5	11.5	10.7	11.2	11.3	–
DO	mg/L	4.6	3.3	3.5	3.1	–	–	–	–	4.0	3.3	3.3	3.4	–	–	–	–
ORP	mV	–	–	–	–	–	–	–	–	449	676	703	714	414	648	688	–
Free Chlorine (as Cl_2)	mg/L	–	0.4	0.4	0.4	–	0.8	0.7	0.6	–	0.4	0.5	0.4	–	0.6	0.5	–
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	0.4	–	0.9	0.7	0.7	–	0.5	0.5	0.5	–	0.5	0.4	–
Total Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	106	100	103	–
Ca Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	83.7	78.1	78.5	–
Mg Hardness (as $CaCO_3$)	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	22.6	21.9	24.4	–
As (total)	µg/L	43.6	43.5	46.2	37.8	46.9	43.1	35.4	31.3	50.7	51.7	28.6	23.9	41.7	43.0	17.6	–
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	41.3	43.7	18.8	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.4	<0.1	<0.1	–
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.6	0.4	0.5	–
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	40.7	43.3	18.3	–
Fe (total)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<25	<25	<25	–
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<25	<25	<25	–
Mn (total)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	3.7	3.2	34.2	–
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	3.3	3.1	32.9	–

(a) System bypassed between 11/28/05 to 01/13/06 for media rebedding.
(b) Replacement media installed on 01/11/06 and Vessel A only resumed operations on 01/13/06.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		01/24/06				01/31/06[a]			02/07/06[b]				02/14/06[c]			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	0.3		–	–	0.5	–	–	0.7		–	–	0.9	
Alkalinity (as $CaCO_3$)	mg/L	68	32	57	–	62	19	21	63	17	23		67	22	23	–
Fluoride	mg/L	0.7	0.7	0.6	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	0.2	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	–	–	–	–	<0.03	<0.03	<0.03	0.1	0.1	<0.03	–	<0.03	<0.03	<0.03	–
Orthophosphate (as P)	mg/L	<0.05	<0.05	<0.05	–	–	–	–	–	–	–	–	–	–	–	–
Silica (as SiO_2)	mg/L	19.9	18.9	51.2	–	19.8	19.3	28.6	19.7	19.9	34.9	–	19.7	19.7	31.5	–
Sulfate	mg/L	10.7	39.3	42.0	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.2	0.3	0.2	–	0.1	0.4	0.2	0.6	1.0	1.1	–	1.5	1.5	1.5	–
pH	S.U.	7.5	7.4	7.3	–	7.3	6.0	6.0	7.3	5.8	6.1	–	7.4	6.0	6.1	–
Temperature	°C	12.1	11.6	11.5	–	11.3	11.3	11.3	11.4	11.5	11.3	–	10.8	11.1	11.0	–
DO	mg/L	3.7	2.9	2.7	–	4.6	3.2	3.2	5.2	5.2	2.1	–	4.5	3.1	2.8	–
ORP	mV	448	560	572	–	460	530	622	434	494	497	–	481	670	708	–
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.5	–	–	0.4	0.3	–	0.0	0.0	–	–	0.5	0.5	–
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.4	–	–	0.4	0.4	–	0.0	0.1	–	–	0.5	0.5	–
Total Hardness (as $CaCO_3$)	mg/L	93.9	94.4	109	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	71.7	71.8	82.0	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	22.1	22.6	27.3	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	μg/L	49.9	49.6	30.6	–	43.1	41.9	11.8	56.5	56.5	10.0	–	45.5	43.0	6.2	–
As (total soluble)	μg/L	49.4	50.5	31.2	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	μg/L	0.5	<0.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	μg/L	0.7	0.9	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	μg/L	48.7	49.6	30.9	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	μg/L	<25	<25	<25	–	<25	<25	<25	<25	<25	<25	–	<25	<25	<25	–
Fe (soluble)	μg/L	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	μg/L	1.2	1.2	15.8	–	1.1	1.1	39.1	2.5	2.4	28.9		0.3	0.4	11.6	–
Mn (soluble)	μg/L	1.2	1.1	15.5	–	–	–	–	–	–	–	–	–	–	–	–

(a) From 01/31/06 until end of demonstration, samples analyzed for total P instead of orthophosphate due to holding time issues.
(b) From 02/02–07/06, only Wells 1 and 2 operating at about 16 gpm).
(c) From 02/08–14/06, only Well 3 operating at about 19 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		02/21/06[a]				02/28/06				03/07/06			03/14/06			
Parameter	Unit (Sampling Location)	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	IN	AP	TA	TB
Bed Volume	10^3	–	–	1.1		–	–	1.3		–	–	1.5	–	–	1.7	
Alkalinity (as $CaCO_3$)	mg/L	63	29	29	–	265	36	35	–	64	42	35	64	36	36	–
Fluoride	mg/L	0.7	0.8	0.7	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.3	0.2	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	–	–	–	–	0.1	0.1	<0.03	–	<0.03	<0.03	<0.03	0.04	0.04	<0.01	–
Silica (as SiO_2)	mg/L	20.3	20.2	29.1	–	19.0	19.3	28.7	–	18.7	18.6	27.4	18.7	18.5	28.2	–
Sulfate	mg/L	12	43	43	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	1.6	1.3	3	–	0.3	0.3	0.3	–	0.7	0.4	0.7	0.2	0.4	0.4	–
pH	S.U.	7.4	6.4	6.3	–	7.0	6.3	6.3	–	7.3	6.5	6.4	7.4	6.5	6.5	–
Temperature	ºC	9.7	10.1	10.2	–	9.7	10.2	10.1	–	10.2	10.6	10.6	11.3	11.4	11.4	–
DO	mg/L	5.5	2.8	3.0	–	2.8	2.6	2.5	–	4.6	3.0	3.7	9.4	4.1	4.0	–
ORP	mV	469	601	585	–	472	629	652	–	478	648	688	381	550	614	–
Free Chlorine (as Cl_2)	mg/L	–	0.3	0.3	–	–	0.3	0.3	–	–	0.5	0.4	–	0.3	0.3	–
Total Chlorine (as Cl_2)	mg/L	–	0.3	0.3	–	–	0.3	0.3	–	–	0.5	0.4	–	0.3	0.3	–
Total Hardness (as $CaCO_3$)	mg/L	95.2	93.0	91.8	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	73.3	72.2	70.5	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	21.9	20.8	21.3	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	41.9	46.1	9.7	–	46.9	47.8	11.1	–	46.9	49.8	12.3	48.9	49.3	12.5	–
As (total soluble)	µg/L	43.1	44.0	9.9	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	2.1	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.3	0.4	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	42.8	43.6	9.5	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	<25	<25	<25	–
Fe (soluble)	µg/L	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.3	0.3	7.3	–	0.6	0.5	6.3	–	0.6	0.5	5.8	0.5	0.5	3.2	–
Mn (soluble)	µg/L	0.2	0.2	7.5	–	–	–	–	–	–	–	–	–	–	–	–

(a) 02/14/06 all three wells operating at 40 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		03/21/06				03/28/06			04/04/06				04/11/06			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	1.9		–	–	2.1	–	–	2.3		–	–	2.5	
Alkalinity (as $CaCO_3$)	mg/L	63	38	37	–	65	42	40	64	41	39	–	63	40	39	–
Fluoride	mg/L	0.8	0.8	0.8	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.3	0.3	0.3	–	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	–	–	–	–	0.1	0.1	<0.01	<0.01	<0.01	<0.01	–	<0.01	<0.03	<0.01	–
Silica (as SiO_2)	mg/L	19.6	20.0	27.5	–	19.9	19.6	27.1	19.7	19.9	26.1	–	19.3	19.4	24.7	–
Sulfate	mg/L	11	35	35	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.3	1.1	1.6	–	0.8	1.3	0.8	1.5	1.1	0.4	–	0.9	0.9	1.0	–
pH	S.U.	7.3	6.5	6.5	–	7.3	6.5	6.5	7.3	6.6	6.5	–	7.1	6.6	6.5	–
Temperature	ºC	10.8	10.8	11.0	–	11.2	11.3	11.1	11.2	11.4	11.4	–	11.3	11.6	11.5	–
DO	mg/L	5.2	2.3	3.0	–	4.3	2.8	3.2	7.9	4.1	3.7	–	4.6	3.0	3.0	–
ORP	mV	479	610	630	–	450	684	685	306	354	341	–	460	612	666	–
Free Chlorine (as Cl_2)	mg/L	–	0.5	0.4	–	–	0.6	0.5	–	0.4	0.4	–	–	0.5	0.5	–
Total Chlorine (as Cl_2)	mg/L	–	0.5	0.5	–	–	0.6	0.5	–	0.4	0.4	–	–	0.5	0.5	–
Total Hardness (as $CaCO_3$)	mg/L	99.4	101	101	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	76.8	77.8	77.9	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	22.6	22.9	22.7	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	47.9	49.5	13.3	–	38.4	40.7	11.1	47.8	48.2	17.0	–	50.4	52.8	15.2	–
As (total soluble)	µg/L	49.3	49.1	13.0	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	0.4	0.3	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.3	0.3	0.4	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	49.1	48.8	12.7	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	<25	–	<25	<25	<25	<25	<25	<25	–	<25	<25	<25	–
Fe (soluble)	µg/L	<25	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.9	1.0	1.5	–	0.4	0.5	0.9	0.4	0.4	0.5	–	0.5	0.5	0.4	–
Mn (soluble)	µg/L	0.7	0.7	1.4	–	–	–	–	–	–	–	–	–	–	–	–

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		04/18/06[a]				04/25/06			05/02/06[b]				05/09/06			
Parameter	Sampling Location / Unit	IN	AP	TA	TB	IN	AP	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–		0.1	–	–	0.3	–	–		0.5	–	–		0.8
Alkalinity (as $CaCO_3$)	mg/L	68	41	–	66	66	47	47	65	40	–	43	64 66	23 24	–	23 27
Fluoride	mg/L	0.8	0.7	–	0.5	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	0.2	–	0.2	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	–	–	–	–	<0.03	<0.01	<0.01	<0.01	<0.01	–	<0.03	<0.03 <0.03	<0.03 <0.03	–	<0.01 <0.01
Silica (as SiO_2)	mg/L	18.6	18.3	–	53.1	19.6	37.2	37.8	19.5	19.2	–	32.9	20.0 20.3	20.0 20.3	–	32.7 33.2
Sulfate	mg/L	11	48	–	35	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.5	0.6	–	0.2	0.1	0.2	0.2	0.3	0.3	–	0.1	0.2 0.1	0.2 0.3	–	0.2 0.1
pH	S.U.	7.1	6.5	–	7.3	7.2	6.5	6.7	7.3	6.6	–	6.6	7.4	6.1	–	6.1
Temperature	°C	11.6	11.8	–	11.6	11.3	11.5	11.5	11.7	11.7	–	11.7	12.0	12.0	–	11.9
DO	mg/L	4.0	3.1	–	2.8	4.3	3.2	3.5	4.4	3.4	–	3.7	3.2	2.0	–	2.3
ORP	mV	432	670	–	615	467	581	6.1	462	450	–	673	419	471	–	460
Free Chlorine (as Cl_2)	mg/L	–	0.5	–	0.4	–	0.4	0.3	–	0.5	–	0.4	–	0.5	–	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.5	–	0.3	–	0.4	0.3	–	0.4	–	0.4	–	0.5	–	0.4
Total Hardness (as $CaCO_3$)	mg/L	79.8	83.6	–	77.4	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	57.2	60.1	–	48.7	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	22.6	23.5	–	28.6	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	48.4	46.7	–	19.2	44.5	12.7	12.4	47.3	47.6	–	11.4	51.5 50.1	52.0 50.6	–	4.7 4.7
As (total soluble)	µg/L	47.8	47.5	–	18.4	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.6	<0.1	–	0.8	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.2	<0.1	–	0.1	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	47.7	47.4	–	18.3	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	–	<25	<25	<25	<25	<25	<25	–	<25	<25 <25	<25 <25	–	<25 <25
Fe (soluble)	µg/L	<25	<25	–	<25	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	0.5	0.6	–	2.6	0.7	10.0	9.9	0.5	0.4	–	8.7	1.1 1.0	1.0 0.9	–	12.9 13.1
Mn (soluble)	µg/L	0.4	0.4	–	2.3	–	–	–	–	–	–	–	–	–	–	–

(a) System reconfigured for Vessel B treatment only since 04/15/06.
(b) pH 6.0; only Well 3 operating at 19 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		05/16/06				05/23/06			05/30/06[(a)]				06/06/06			
Parameter (Sampling Location)	Unit	IN	AP	TA	TB	IN	AP	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–		1.0	–	–	1.2	–	–		1.4	–	–		1.7
Alkalinity (as $CaCO_3$)	mg/L	88	20	–	25	66	20	23	64	18	–	19	65	23	–	26
Fluoride	mg/L	0.7	0.6	–	0.5	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.4	0.3	–	0.4	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	<0.01	<0.01	–	<0.01	<0.01	<0.01	<0.01	0.1	0.1	–	<0.01	<0.01	0.1	–	<0.01
Silica (as SiO_2)	mg/L	21	21.1	–	33.4	20.0	19.9	29.9	19.4	19.3	–	25.0	21.0	21.4	–	30.0
Sulfate	mg/L	11	52	–	55	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	1.1	0.3	–	0.4	0.1	0.3	0.2	0.5	0.8	–	0.3	0.2	0.5	–	0.1
pH	S.U.	7.5	6.1	–	6.3	7.4	6.4	6.4	7.3	5.9	–	5.9	7.2	6.0	–	6.1
Temperature	ºC	11.6	11.6	–	11.6	11.8	11.8	11.7	12.5	12.3	–	12.4	12.1	11.9	–	12.3
DO	mg/L	4.9	3.6	–	11.6	3.9	2.5	2.0	3.8	2.6	–	2.5	4.1	2.8	–	2.4
ORP	mV	461	7.0	–	718	445	636	–	457	651	–	683	467	696	–	706
Free Chlorine (as Cl_2)	mg/L	–	0.4	–	0.5	–	0.4	0.4	–	0.5	–	0.5	–	0.5	–	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.3	–	0.5	–	0.5	0.4	–	0.4	–	0.5	–	0.5	–	0.5
Total Hardness (as$CaCO_3$)	mg/L	112	115	–	123	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	86.4	89.2	–	95.9	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	25.4	25.9	–	27.5	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	44.1	45.3	–	4.0	49.5	49.2	2.9	35.9	37.5	–	2.2	38.3	42.3	–	2.9
As (total soluble)	µg/L	44.7	45.2	–	4.0	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	<0.1	–	<0.1	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.3	0.3	–	0.3	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	44.4	44.9	–	3.7	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	–	<25	<25	<25	<25	33.3	44.8	–	<25	<25	<25	–	<25
Fe (soluble)	µg/L	<25	<25	–	<25	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	1.0	1.0	–	6.5	0.8	0.6	3.8	15.7	15.4	–	2.7	3.4	3.4	–	1.2
Mn (soluble)	µg/L	0.6	0.5	–	6.2	–	–	–	–	–	–	–	–	–	–	–

(a) Turned on Wells 1 and 2 from 05/29–31/06 at 40 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		06/13/06				06/20/06[a,b]				06/27/06				07/05/06[c]			
Sampling Location Parameter	**Unit**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**	**IN**	**AP**	**TA**	**TB**
Bed Volume	10^3	–	–		1.9	–	–		2.2	–	–		2.4	–	–		2.7
Alkalinity (as $CaCO_3$)	mg/L	67	27	–	27	66	21	–	22	67	24	–	24	68	67		45
Fluoride	mg/L	0.6	0.6	–	0.5	–	–	–	–	–	–	–	–	–	–	–	–
Nitrate (as N)	mg/L	0.2	0.2	–	0.2	–	–	–	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L	<0.01	<0.01	–	<0.01	0.1	0.1	–	<0.01	<0.01	<0.01	–	<0.01	<0.01	<0.01	–	<0.01
Silica (as SiO_2)	mg/L	21.0	21.2	–	29.1	20.6	20.7	–	25.9	20.2	19.7	–	25.2	21.2	21.1	–	27.7
Sulfate	mg/L	10	48	–	49	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.2	0.6	–	0.3	0.2	0.5	–	0.2	0.3	0.3	–	0.3	0.2	0.4	–	0.3
pH	S.U.	7.4	6.1	–	6.0	7.3	6.2	–	6.1	7.4	6.1	–	6.0	7.5	7.6	–	6.7
Temperature	°C	12.8	12.5	–	12.5	12.3	12.2	–	12.1	12.7	12.7	–	12.6	12.8	12.7	–	12.8
DO	mg/L	3.1	1.9	–	1.7	3.5	2.8	–	2.9	1.8	2.1	–	2.1	3.6	2.9	–	2.1
ORP	mV	456	730	–	728	467	598	–	609	469	646	–	668	455	559	–	636
Free Chlorine (as Cl_2)	mg/L	–	0.7	–	0.6	–	0.4	–	0.2	–	0.5	–	0.5	–	0.4	–	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.7	–	0.6	–	0.4	–	0.3	–	0.5	–	0.5	–	0.4	–	0.5
Total Hardness (as $CaCO_3$)	mg/L	97.1	97.4	–	93.1	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness (as $CaCO_3$)	mg/L	77.0	77.5	–	73.9	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness (as $CaCO_3$)	mg/L	20.1	19.9	–	19.2	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	49.3	47.5	–	4.1	46.6	44.6	–	5.6	41.0	42.3	–	4.1	41.8	43.4	–	7.8
As (total soluble)	µg/L	47.6	47.5	–	4.0	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	1.7	<0.1	–	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	0.2	0.2	–	0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	47.4	47.4	–	3.9	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25
Fe (soluble)	µg/L	<25	<25	–	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	11.5	11.3	–	0.9	14.9	13.6	–	10.2	15.0	15.3	–	1.9	15.7	16.1	–	0.4
Mn (soluble)	µg/L	11.4	11.0	–	0.9	–	–	–	–	–	–	–	–	–	–	–	–

(a) From 06/20/06 until end of demonstration, samples only analyzed for alkalinity, total P, silica, turbidity, total As, total Fe, and total Mn.
(b) From 06/17–20/06, all three wells operating at 40 gpm.
(c) pH 6.0; all 3 wells operating at 40 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		07/11/06				07/18/06				07/25/06				08/01/06			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	2.9		–	–	3.1		–	–	3.4		–	–	3.6	
Alkalinity (as $CaCO_3$)	mg/L	65	22	–	25	66	23	–	24	64	23	–	25	66	65	–	47
Total P (as PO_4)	mg/L	0.1	0.1	–	<0.03	0.1	0.1	–	<0.01	0.1	0.1	–	<0.01	<0.03	<0.03	–	<0.01
Silica (as SiO_2)	mg/L	20.2	20.1	–	24.5	18.9	18.6	–	22.3	19.9	19.9	–	23.8	19.2	19.1	–	21.8
Turbidity	NTU	0.5	0.3	–	1	0.5	0.6	–	0.6	0.9	1.1	–	1.2	0.2	0.1	–	0.1
pH	S.U.	7.3	6.1	–	6.1	7.3	6.2	–	6.1	7.2	6.2	–	6.2	7.4	7.4	–	6.7
Temperature	ºC	12.4	12.2	–	12.1	12.6	12.4	–	12.3	12.2	12.1	–	12.1	12.7	12.4	–	12.3
DO	mg/L	5.1	3.3	–	3.2	43.9	3.1	–	2.9	5.2	3.9	–	3.3	5.4	4.6	–	4.5
ORP	mV	478	655	–	676	466	657	–	674	448	591	–	632	446	559	–	620
Free Chlorine (as Cl_2)	mg/L	–	0.5	–	0.5	–	0.6	–	0.5	–	0.6	–	0.4	–	0.5	–	0.4
Total Chlorine (as Cl_2)	mg/L	–	0.5	–	0.5	–	0.6	–	0.5	–	0.5	–	0.5	–	0.7	–	0.5
As (total)	µg/L	37.3	41.0	–	8.0	47.7	46.7	–	10.6	45.9	47.1	–	11.1	44.3	45.1	–	16.0
Fe (total)	µg/L	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25
Mn (total)	µg/L	9.0	9.1	–	2.7	6.0	5.8	–	1.1	3.7	3.4	–	0.5	1.4	1.5	–	<0.1

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		08/08/06				08/15/06				08/22/06				08/29/06			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	3.9		–	–	4.1		–	–	4.3[(a)]		–	–	4.7	
Alkalinity (as $CaCO_3$)	mg/L	66	25	–	25	67	24	–	22	71	13	–	22	68	14	–	22
Total P (as PO_4)	mg/L	<0.03	<0.01	–	<0.01	<0.03	<0.01	–	<0.01	<0.03	<0.01	–	<0.01	0.1	0.1	–	<0.03
Silica (as SiO_2)	mg/L	18.9	18.9	–	22.1	18.1	18.9	–	21.8	18.3	19.0	–	21.5	19.6	18.3	–	22.5
Turbidity	NTU	0.2	0.1	–	0.1	0.3	0.4	–	0.1	0.2	0.2	–	0.1	0.3	0.2	–	<0.1
pH	S.U.	7.2	6.2	–	6.1	7.4	6.2	–	6.1	7.3	6.1	–	6.2	7.3	6.3	–	6.4
Temperature	ºC	12.6	12.5	–	12.4	12.8	12.7	–	12.6	12.9	12.6	–	12.7	12.5	12.3	–	12.2
DO	mg/L	6.7	4.0	–	4.5	3.6	2.6	–	2.3	4.3	3.6	–	4.2	4.2	2.9	–	3.2
ORP	mV	–	546	–	–	469	62.4	–	575	441	621	–	669	461	615	–	641
Free Chlorine (as Cl_2)	mg/L	–	0.4	–	0.3	–	0.5	–	0.5	–	0.2	–	0.5	–	0.4	–	0.3
Total Chlorine (as Cl_2)	mg/L	–	0.4	–	0.3	–	0.5	–	0.6	–	0.4	–	0.6	–	0.5	–	0.4
As (total)	µg/L	45.5	45.9	–	12.9	47.9	48.2		14.9	50.1	52.4	–	14.8	41.1	40.9	–	12.4
Fe (total)	µg/L	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25
Mn (total)	µg/L	0.9	0.9	–	0.2	1.2	1.3	–	<0.1	1.7	1.3	–	0.3	1.1	1.2	–	0.3

(a) Bed volume recorded on 08/21/06.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.

Table B-1. Analytical Results from Long-Term Sampling, Bow, New Hampshire (Continued)

Sampling Date		09/05/06				09/12/06[a]				09/19/06				09/26/06			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	–	–	4.9		–	–	5.1		–	–	5.4		–	–	5.6	
Alkalinity (as $CaCO_3$)	mg/L	73	16	–	20	66	12	–	15	69	20	–	38	81	18	–	21
Total P (as PO_4)	mg/L	0.1	0.1	–	<0.01	0.04	0.04	–	<0.01	<0.01	<0.01	–	<0.01	0.1	0.1	–	<0.01
Silica (as SiO_2)	mg/L	18.5	17.9	–	21.7	19	19	–	22	19	19.5	–	25.4	19.1	18.5	–	22.4
Turbidity	NTU	0.1	0.2	–	0.1	0.2	0.2	–	0.1	0.2	0.1	–	0.2	<0.1	0.1	–	0.1
pH	S.U.	7.3	6.3	–	6.3	7.1	6.0	–	6.0	7.1	6.0	–	6.2	7.0	6.4	–	6.4
Temperature	ºC	12.3	12.2	–	12.1	12.2	12.1	–	12.0	12.7	12.8	–	12.9	12.6	12.5	–	12.5
DO	mg/L	4.3	3.7	–	3.5	4.5	3.1	–	3.1	3.7	2.2	–	2.1	3.5	2.5	–	2.0
ORP	mV	461	659	–	666	480	610	–	564	459	503	–	512	335	346	–	386
Free Chlorine (as Cl_2)	mg/L	–	0.4	–	0.3	–	0.3	–	0.3	–	0.2	–	0.3	–	0.3	–	0.2
Total Chlorine (as Cl_2)	mg/L	–	0.5	–	0.4	–	0.2	–	1.0	–	0.2	–	0.2	–	0.3	–	0.7
As (total)	μg/L	46.6	47.2	–	12.8	46.8	44.6	–	13.5	41.9	43.7	–	23.6	35.3	35.3	–	11.1
Fe (total)	μg/L	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25	<25	<25	–	<25
Mn (total)	μg/L	1.3	1.4	–	0.5	2.0	2.0	–	1.0	1.0	1.0	–	<0.1	4.6	4.8	–	0.9

(a) Reduced flow to approximately 16 gpm.

IN = inlet; AP = after pH adjustment and after pre-chlorination; TA = after Vessel A; TB = after Vessel B.