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

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from the arsenic removal treatment technology demonstration project in Brown City, MI. The objectives of the project were to evaluate (1) the effectiveness of a Severn Trent Services (STS) adsorptive media system – Arsenic Package Unit (APU) – with the use of SORB 33™ media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L, (2) the reliability of the treatment system, (3) the simplicity of required system operation and maintenance (O&M) and operator skills, and (4) the cost-effectiveness of the technology. The project also characterized water in the distribution system and process residuals produced by the treatment system.

The STS system consisted of two APU-300 units each comprising two 63-in-diameter, 86-in-tall fiberglass reinforced plastic (FRP) vessels in parallel configuration. Each adsorption vessel contained approximately 80 ft^3 of SORB 33™ media, which is an iron-based adsorptive media developed by Bayer AG and packaged under the name SORB 33™ by STS. The system was designed for a flowrate of 640 gal/min (gpm) (160 gpm to each vessel), corresponding to a design empty bed contact time (EBCT) of about 3.7 min and a hydraulic loading rate of 7.4 gpm/ft^2. Actual flowrate through the system averaged 564 gpm during the performance evaluation study, corresponding to an EBCT of 4.2 min.

The STS treatment system started on May 11, 2004, and continued to operate through May 2, 2007, with a total operating time of 4,547 hr. Averaged daily operating time was approximately 4.5 hr/day or a 19% utilization rate. During the performance evaluation, approximately 154,000,000 gal or 64,370 bed volumes (BV) of water were treated. The system continued to operate through the three-year demonstration study with only a few minor repairs and adjustments. The flowrate, pressure data and other operational parameters were within the vendor specifications after a system retrofit that was completed before system startup on May 11, 2004. The system continued to operate within the vendor equipment specifications through May 2, 2007.

Arsenic in source water existed primarily as soluble As(III) (i.e., 85% at 13.1 µg/L), with a small amount also present as soluble As(V) (i.e., 0.7 µg/L) and particulate As (i.e., 1.6 µg/L). Per the vendor's recommendations, raw water was fed directly through the adsorption vessels without prechlorination to evaluate the capacity of the SORB 33™ media for As(III) adsorption from May 11, 2004, through May 15, 2005. Because of premature arsenic breakthrough over 10 µg/L, prechlorination was implemented on May 16, 2005, to extend the media bed life through oxidation of As(III) to As(V). Since then, the system operated with prechlorination through the end of the performance evaluation on May 2, 2007.

From May 11, 2004, to May 10, 2005, without prechlorination, concentrations of total arsenic in the treated water primarily as As(III) ranged from 0.7 to 12.8 µg/L, with >10-µg/L breakthrough occurring at 20,800 BV. From May 16, 2005, to May 2, 2007, with prechlorination, concentrations of arsenic in the treated water primarily as As[V] ranged from 0.6 to 7.5 µg/L. The amount of water treated during the entire study period was 64,370 BV, representing about 80% of the vendor-estimated working capacity. Prechlorination was effective in extending the media bed life by removing soluble As(V) and particulate As (about 19% of the arsenic removed) by the media beds. Particulate iron averaged 144 µg/L after prechlorination was removed to below the method detection limit of 25 µg/L.

Distribution system water samples were collected to determine any impact of arsenic treatment on the lead and copper levels and water chemistry in the distribution system. Comparison of the distribution system sampling results before and after the operation of the STS system showed a decrease in arsenic concentration at all three sampling locations. Total aresnic levels in the distribution system decreased from an average of 10.3 to 5.3 µg/L, and generally mirrored those in the treatment plant effluent. Iron

levels decreased to the non-detect level, while manganese levels increased slightly. Lead concentrations did not appear to have been affected by the operation of the system. Copper concentrations were generally lower.

Backwash wastewater contained lower-than-raw-water-level of soluble arsenic, indicating removal of soluble As(III) by the media during backwash. (Note that raw water was used for backwash.) As expected, particulate arsenic, iron, and manganese concentrations were considerably higher than respectively soluble concentrations. Particulate As might be associated with either iron particles intercepted by the media beds during the service cycle or media fines. Based on the total suspended solid (TSS) values, approximately 15.6 lb of suspended solids were produced in 20,000 gal of backwash wastewater during each backwash event.

The capital investment cost of $305,000 included $218,000 for equipment, $35,500 for site engineering, and $51,500 for installation. Using the system's rated capacity of 640 gpm, the capital cost was $477/gpm ($0.33/gpd) and equipment-only cost was $340/gpm ($0.24/gpd). These calculations did not include the cost of a building addition to house the treatment system. The unit annualized capital cost was $0.09/1,000 gal, assuming the system operated 24 hours a day, 7 days a week, at the system design flowrate of 640 gpm. The system operated only 4.5 hr/day on average, producing an average of 51,333,670 gal of water per year. At this reduced usage rate, the unit annualized capital cost increased to $0.56/1,000 gal.

O&M cost included only incremental cost associated with the APU-300 system, such as media replacement and disposal, chemical supply, electricity, and labor. The estimated media changeout cost is $53,600 for both APU-300 units, which would represent the majority of the O&M cost. Media changeout did not occur during the performance evaluation period.

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AA	activated alumina
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
APU	arsenic package unit
As	arsenic
BET	Brunauer, Emmett, and Teller
bgs	below ground surface
BV	bed volume(s)
Ca	calcium
C/F	coagulation/filtration
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FRP	fiberglass reinforced plastic
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HCl	hydrochloric acid
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
KWh	kilowatt hours
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDEQ	Michigan Department of Environmental Quality
Mg	magnesium
Mn	manganese

Mo	molybdenum
Na	sodium
NA	not applicable
NaOCl	sodium hypochlorite
NR	no reading
NRMRL	National Risk Management Research Laboratory
NTU	nephelometric turbidity units
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
P&ID	piping and instrumentation diagram
PLC	process logic controller
psi	pounds per square inch
psig	pounds per square inch (gage)
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SM	system modification
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
V	vanadium
WRWC	White Rock Water Company

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Section 1.0: INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that the U.S. Environmental Protection Agency (EPA) identify and regulate drinking water contaminants that may have adverse human health effects and that are known or anticipated to occur in public water supply systems. In 1975 under the SDWA, EPA established a maximum contaminant level (MCL) for arsenic (As) at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule 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 cost. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, 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, including the Brown City water system in Brown City, MI.

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. Severn Trent Services (STS), using the Bayoxide E33 media developed by Bayer AG, was selected for the Brown City, MI facility. STS has given the E33 media the designation "SORB 33™."

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 systems, one anion exchange system, one coagulation/filtration system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, and key source water quality parameters of the 12 demonstration sites. An overview of the technology selection and system design (Wang et al., 2004) and the associated capital cost for each site (Chen et al., 2004) are provided on the EPA Website at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/. As of June 2008, all 12 systems were operational, and the performance evaluation of 11 systems was completed.

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

Demonstration Site	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
				As (µg/L)	Fe (µg/L)	pH
WRWC, NH	AM (G2)	ADI	70[(a)]	39	<25	7.7
Rollinsford, NH	AM (E33)	AdEdge	100	36[(b)]	46	8.2
Queen Anne's County, MD	AM (E33)	STS	300	19[(b)]	270[(c)]	7.3
Brown City, MI	AM (E33)	STS	640	14[(b)]	127[(c)]	7.3
Climax, MN	C/F (Macrolite)	Kinetico	140	39[(b)]	546[(c)]	7.4
Lidgerwood, ND	SM	Kinetico	250	146[(b)]	1,325[(c)]	7.2
Desert Sands MDWCA, NM	AM (E33)	STS	320	23[(b)]	39	7.7
Nambe Pueblo, NM	AM (E33)	AdEdge	145	33	<25	8.5
Rimrock, AZ	AM (E33)	AdEdge	90[(a)]	50	170	7.2
Valley Vista, AZ	AM (AAFS50/ARM 200)	Kinetico	37	41	<25	7.8
Fruitland, ID	IX (A300E)	Kinetico	250	44	<25	7.4
STMGID, NV	AM (GFH/Kemiron)	Siemens	350	39	<25	7.4

AM = adsorptive media; C/F = coagulation/filtration; GFH = granular ferric hydroxide; IX = ion exchange; SM = system modification

MDWCA = Mutual Domestic Water Consumer's Association; STMGID = South Truckee Meadows General Improvement District; WRWC = White Rock Water Company; STS = Severn Trent Services

(a) Design flowrate reduced by 50% due to system reconfiguration from parallel to series operation.

(b) Arsenic exists mostly as As(III).

(c) Iron exists mostly as soluble Fe(II).

1.3 Project Objectives

The objective of the Round 1 arsenic demonstration program is to conduct full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking water supplies. The specific objectives are to:

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

This report summarizes the performance of the STS system at the Brown City facility from May 11, 2004, through May 2, 2007. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

Section 2.0: SUMMARY AND CONCLUSIONS

Based on the information collected during three years of system operation, the following conclusions were made relating to the overall objectives of the treatment technology demonstration study.

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

- Chlorine was effective in oxidizing As(III) to As(V), reducing As(III) concentrations from 13.1 µg/L (on average) in raw water to 2.1 µg/L (on average).
- SORB 33™ media had some adsorptive capacity for As(III). Without the use of prechlorination, total arsenic, existing primarily as As(III), broke through at 10 µg/L after treating approximately 20,800 bed volumes (BV) of water.
- Prechlorination significantly extended the media bed life. Removal was achieved primarily through As(V) adsorption and, to a lesser extent (i.e., 19%), arsenic-laden iron particles filtration. By the end of the performance evaluation, an additional 43,570 BV of water was treated, with only 3.1 µg/L of arsenic in the treated water. The total amount of water treated during the entire study period was 64,370 BV, representing 80% of the vendor estimated working capacity.
- The throughput between consecutive backwash events decreased significantly with prechlorination, from just under 3,000 BV to as little as 150 BV. Media attrition during backwash appeared to have caused more frequent backwash.
- Arsenic concentrations in the distribution system were reduced from an average of 10.3 µg/L before system startup to 5.3 µg/L after system startup. Arsenic concentrations mirrored those in the plant effluent. Lead concentration did not appear to have been affected by the operation of the system. Copper concentration was generally lower than those before system startup.

Required system O&M and operator skill levels:

- The APU-300 system experienced higher than expected pressure drops across the adsorption vessels and the entire treatment system during system shakedown. The system was retrofitted before system startup on May 11, 2004. Since then the system was able to operate according to the original design specifications through the end of the evaluation study. There was no unscheduled downtime during the performance evaluation period.
- Under normal operating conditions, the skill requirements to operate the system were minimal, with a typical daily demand on the operator of 30 minutes. Normal operation of the system did not appear to require additional skills beyond those necessary to operate the existing water supply equipment. A Class D-3 state-certified operator was required for operation of the water system at Brown City.

Characteristics of residuals produced by the technology:

- Residuals produced by the operation of the treatment system included only backwash wastewater. The media were not exhausted during the performance evaluation.

- Each backwash event produced approximately 20,000 gal of wastewater and 15.6 lb of solids. Backwash wastewater contained less soluble arsenic than raw water (water used for backwash), indicating removal of arsenic, mostly as As(III), by the media during backwash.

Capital and O&M cost of the technology:

- The unit annualized capital cost was $0.09/1,000 gal if the system operated at a 100% utilization rate. The system's actual unit annualized capital cost was $0.56/1,000 gal, based on 4.5 hr/day of system operation and 51,333,670 gal/year of water production.
- The estimated media changeout cost is $53,600 for both APU-300 units. Media changeout did not occur during the performance evaluation period. O&M cost is therefore reported in graphical form as a function of projected run length.

Section 3.0: MATERIALS AND METHODS

3.1 General Project Approach

Following the pre-demonstration activities summarized in Table 3-1, the performance evaluation study of the STS treatment system began on May 11, 2004. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall performance of the system was evaluated based on its ability to consistently remove arsenic to below 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.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	07/24/03
Request for Quotation Issued to Vendor	07/28/03
Vendor Quotation Submitted to Battelle	08/26/03
Purchase Order Completed and Signed	09/24/03
Letter of Understanding Issued	08/15/03
Letter Report Issued	10/20/03
Engineering Package Submitted to MDEQ	11/26/03
Building Construction Initiated	12/01/04
Permit Issued by MDEQ	02/11/04
Final Study Plan Issued	02/12/04
Building Construction Completed	02/12/04

MDEQ = Michigan Department of Environmental Quality

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

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

The O&M and operator skill requirements were evaluated based on a combination of quantitative data and qualitative considerations, including the need for any 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 system staffing requirements were recorded on an Operator Labor Hour Log Sheet.

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

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection following the instructions provided by STS 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) tank level; and conducted visual inspections to ensure normal system operations. If any problems occurred, the plant operator contacted the Battelle Study Lead, who determined if STS needed to be contacted for troubleshooting. The plant operator recorded all relevant information on the Repair and Maintenance Log Sheet. Biweekly, the plant operator measured temperature, pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on a Weekly On-site Water Quality Parameters Log Sheet. Total and free chlorine residuals also were measured biweekly by the operator since switching to prechlorination. STS originally recommended a backwash every 45 days; however, since switching to prechlorination, the system was backwashed whenever differential pressure (Δp) across each adsorption vessel had reached a set point of 10 psi. Backwash data 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 media replacement and spent media disposal, chemicals and electricity consumption, replacement parts, and labor. The NaOCl and electricity consumption was tracked using the Daily System Operation Log Sheet. Labor for various activities, such as the routine system O&M, troubleshooting and repair, and demonstration-related work, were tracked using an Operator Labor Hour Log Sheet. The routine O&M included activities such as completing daily field logs, replenishing the NaOCl solution, ordering inventory, performing regular system inspection, and others as recommended by the vendor. The 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 the system performance, samples were collected from the source water, treatment plant, and distribution system. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Figure 3-1 presents a flow diagram of the treatment system along with the analytes and schedules at each sampling location. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003). The procedure for arsenic speciation is described in Appendix A of the QAPP.

Table 3-3. Sampling Locations, Schedules, and Analytes

Sample Type	Sampling Locations[(a)]	No. of Samples	Frequency	Analytes	Collection Date(s)
Source Water	IN	1	Once (during initial site visit)	On-site: pH Off-site: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn(total and soluble), Al(total and soluble), V (total and soluble), Mo(total and soluble), Sb(total and soluble), Na, Ca, Mg, Cl, F, SO_4, sulfide, SiO_2, PO_4, TOC, and alkalinity	07/24/03
Treatment Plant Water	IN, AC, TA, TB, TC, and TD	6	Monthly (Once every four weeks, measurements discontinued after 10/18/05)	On-site: pH, temperature, DO, ORP, and Cl_2 (free and total) [(b)] Off-site: As (total), Fe (total), and Mn (total), SiO_2, PO_4[(c)], alkalinity, and turbidity	05/18/04, 06/08/04, 07/06/04, 08/03/04, 08/31/04, 09/28/04, 11/02/04, 11/30/04, 01/18/05, 02/15/05, 03/15/05, 03/29/05, 04/13/05, 05/10/05, 06/07/05, 07/05/05, 08/02/05, 09/06/05, 09/13/05, 10/18/05
	IN, AC, and TT	3	Monthly (Once every four weeks)	On-site: pH, temperature, DO, ORP, and Cl_2 (free and total) [(d)] Off-site[(e)]: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, PO_4[(c)], total P[(f)], alkalinity, and turbidity	05/25/04, 06/24/04, 07/20/04, 08/17/04, 09/14/04, 10/12/04, 11/16/04, 12/14/04, 01/05/05, 02/01/05, 03/07/05, 04/26/05, 05/24/05, 06/22/05, 07/19/05, 08/16/05, 09/28/05, 10/25/05, 12/19/05, 01/17/06, 03/01/06,03/21/06, 04/18/06, 05/16/06, 06/14/06, 07/11/06, 08/14/06,09/19/06, 10/17/06, 11/28/06, 12/12/06, 01/22/07, 02/27/07, 03/27/07, 05/02/07
Backwash Wastewater	Backwash discharge line from Vessels A, B, C, and D	4	Once every one to four months for a total of 17 times	Before 02/01/06: pH, TDS, turbidity, soluble As, Fe, and Mn After 02/01/06: pH, TDS, and TSS, As (total, and soluble), Fe (total and soluble), Mn (total and soluble)	06/15/04, 07/28/04, 09/09/04, 10/22/04, 01/14/05, 02/22/05, 04/08/05, 05/23/05, 07/06/05, 10/12/05, 02/01/06, 02/28/06, 04/06/06, 04/29/06, 06/01/06, 07/26/06, 09/12/06

Table 3-3. Sampling Locations, Schedules, Analytes (Continued)

Sample Type	Sampling Locations[(a)]	No. of Samples	Frequency	Analytes	Collection Date(s)
Backwash Solids	At backwash discharge point	2	Once	Total Al, As, Ba, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Sb,Si, V, and Zn	07/12/06
Distribution Water	Three homes (LCR sampling locations)	3	Monthly	pH, alkalinity, total As, Cu, Fe, Mn, and Pb	Baseline sampling: 12/04/03, 12/18/03, 01/08/04, 01/21/04 Monthly sampling: 06/15/04, 07/13/04, 08/10/04, 09/08/04, 10/05/04, 11/02/04, 12/08/04, 01/12/05, 02/09/05, 03/08/05, 04/13/05, 05/10/05, 06/07/05, 07/06/05, 08/03/05, 09/07/05, 10/05/05, 01/25/06

(a) Abbreviation corresponding to sample locations in Figure 3-1: IN = at wellhead, AC = after chlorination (prechlorination began on May 16, 2005), TA = after Vessel A, TB = after Vessel B, TC = after Vessel C, TD = after Vessel D, TT = comined effluent, and BW = at backwash wastewater discharge line
(b) Onsite chlorine measurements not performed at IN; measurements at AC, TA, TB, TC, and TD conducted on June 7, July 5, August 2, September 6, and October 18, 2005.
(c) PO_4 measured from May 18 to December 14, 2004
(d) Onsite chlorine measurements not performed at IN; measurements at AC and TT conducted from August 16, 2005, through May 2, 2007, except for September 28 and October 25, 2005.
(e) Since August 14, 2006, analyses for F, NO_3, SO_4, and alkalinity discontinued; SO_4 analyses resumed on January 22, February 27, and May 2, 2007.
(f) Total P measured from October 25, 2005, through November 28, 2006, except for October 17, 2006.

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

3.3.2 Treatment Plant Water. Treatment plant water samples were collected by the plant operator biweekly, on a four-week cycle, for on- and off-site analyses. For the first week of each four-week cycle, water samples were collected at six locations across the treatment train, including at wellhead (IN), after chlorination (AC), and after Vessels A, B, C, and D (TA, TB, TC, and TD), and analyzed for the analytes listed in Table 3-3. For the third week of each four-week cycle, water samples were collected at IN, AC, and the combined effluent of Vessels A, B, C and D (TT) and analyzed for the analytes shown in Table 3-3. Sampling at AC started only after prechlorination had been initiated on May 16, 2005. The sampling frequency was reduced from weekly, as stated in the Study Plan, to biweekly due to the low water demand and resulting low volume throughput to the system (Battelle, 2004).

Over the course of the demonstration study, several changes were made to the sampling schedules:

- Sampling at TA, TB, TC, and TD was discontinued after October 18, 2005. Since then, the sampling frequency was reduced from bi-weekly to monthly.

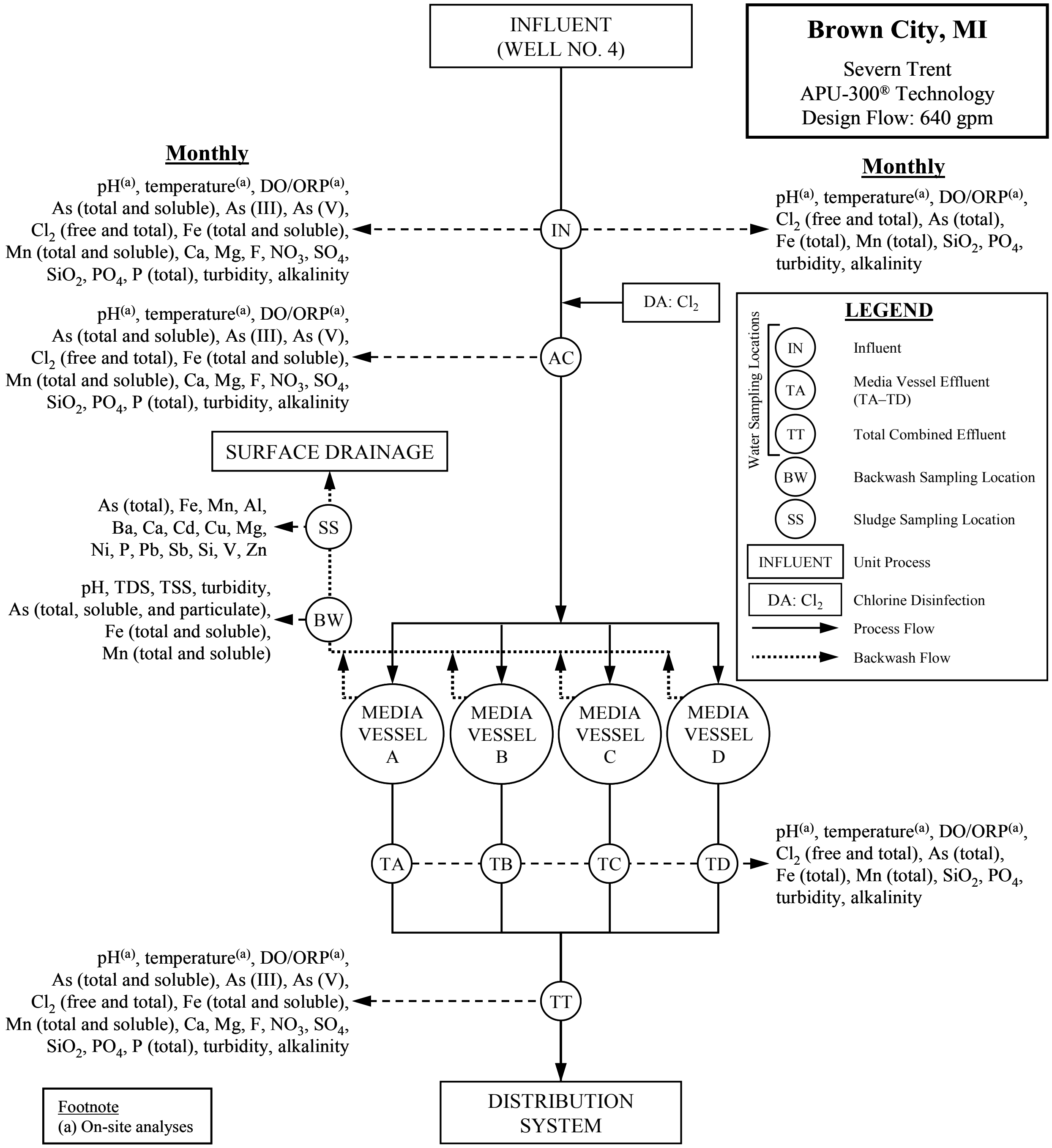


Figure 3-1. Process Flow Diagram and Sampling Locations

- Since August 14, 2006, monthly analyses for fluoride, NO_3, SO_4, and alkalinity at IN, AC, and TT were discontinued. SO_4 analyses were resumed on January 22, February 27, and May 2, 2007.
- Beginning on October 25, 2005, orthophosphate analyses were replaced with total phosphorus analyses, which were discontinued since November 28, 2006.

3.3.3 Backwash Wastewater. Periodic grab samples were collected by the plant operator from June 15, 2004, through October 12, 2005, from a tap on the backwash wastewater discharge line. Filtered samples using 0.45-µm filters were analyzed for soluble As, Fe, and Mn and non-filtered samples analyzed for pH, total dissolved solids (TDS), and turbidity. Since February 1, 2006, composite samples were collected periodically using a revised procedure to allow collection of more representative samples during backwash. Tubing, connected to the tap on the discharge line, directed a portion of backwash wastewater at approximately 1 gpm into a clean, 32-gal container over the duration of the backwash for each vessel. After the content in the container was thoroughly mixed, composite samples were collected and/or filtered on-site with 0.45-µm disc filters. Filtered and non-filtered samples were analyzed for the grab-sample analytes plus total suspended solids (TSS) and total As, Fe, and Mn.

3.3.4 Residual Solids. Residual solids included backwash solids and spent media. On July 12, 2006, backwash solids samples were collected after solids had settled in the 32-gal backwash containers and the supernatant carefully decanted. Each aliquot of the samples was air-dried, acid-digested, and analyzed for the analytes listed in Table 3-3.

Since the adsorption media was not changed out during the performance evaluation study, no media samples were collected and analyzed.

3.3.5 Distribution System Water. 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 on lead, copper, and arsenic levels. From December 2003 to January 2004, prior to the startup of the treatment system, four monthly baseline distribution system water samples were collected at each of three homes that had been included for the Lead and Copper Rule (LCR) sampling at Brown City. Following system startup, distribution system sampling continued on a monthly basis at the same three locations until January 2006.

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

3.4 Sampling Logistics

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

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 cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded, waterproof label consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the 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 separately in a ziplock bag (each corresponding to a specific sample location) and packed in the cooler. When needed, the sample cooler also included bottles for the distribution system sampling.

In addition, all sampling- and shipping-related materials, such as disposable gloves, sampling instructions, chain-of-custody forms, prepaid/pre-addressed FedEx air bills, and bubble wrap, were placed in each cooler. The chain-of-custody forms and air bills were completed except for the operator's signature and the sample dates and times. After preparation, sample coolers were 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 checked sample IDs against the chain-of-custody forms and verified that all samples indicated on the forms were included and intact. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead. The shipment and receipt of all coolers by Battelle were recorded on a cooler tracking log.

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

3.5 Analytical Procedures

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limit (MDL), and completeness met the criteria established in the QAPP (i.e., 20% relative percent difference [RPD], 80 to 120% percent recovery and 80% completeness). 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 the standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the WTW 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.

Section 4.0: RESULTS AND DISCUSSION

4.1 Facility Description

The Brown City, MI water system supplys water to 1,334 community members via 664 service connections. Figure 4-1 shows a map of the service area and the locations of the supply wells (No. 3 and 4), water tower, treatment plant, which is located at the end of Maple Street. Figure 4-2 shows the former pump house prior to the demonstration study.

4.1.1 Preexisting System. The source water was groundwater from three supply wells. However, the water demand was met primarily with Wells No. 3 and No. 4 (see Figure 4-1 for the locations). Prior to the demonstration study, Well No. 3 was the primary well, operating on an intermittent basis for approximately 4 hr/day. Since commencement of the demonstration study, Well No. 3 was used only as an emergency backup well with Well No. 4 as the main supply well. Well No. 4 was 16-in in diameter and installed at a depth of approximately 315 ft below ground surface (bgs). The static water level was approximately 23 to 27 ft bgs. Well No. 4 was equipped with a 75 horsepower (hp) submersible pump rated for approximately 640 gpm at a discharge pressure of 59 lb/in^2 (psi).

Figure 4-3 shows the preexisting piping configuration in Well No. 4 pump house, including a pump motor, several pressure gauges, a flow totalizer, and a chlorine addition assembly. The chlorine addition assembly was used to provide chlorine residuals in the distribution system. Residuals levels were targeted at 0.3 mg/L for free chlorine (as Cl_2) and 0.4 mg/L for total chlorine (as Cl_2). The treated water was stored in a nearby 200,000 gal water tower.

4.1.2 Source Water Quality. Source water samples were collected from Well No. 4 on July 24, 2003, 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 independently collected and analyzed by EPA, are presented in Table 4-1.

As shown in Table 4-1, total arsenic concentrations in raw water ranged from 10 to 31 μg/L. Based on the July 24, 2003 sampling results, arsenic existed primarily as soluble As(III) (i.e., 79% at 11.2 μg/L), with small amounts also present as soluble As(V) (i.e., 5.5% at 0.8 μg/L) and particulate As (i.e., 15.5% at 2.2 μg/L). During the first year of system operation, chlorine was added after the adsorption vessels so that the capacity of the adsorptive media for As(III) might be evaluated. Because of the short run length observed, prechlorination was initiated to oxidize As(III) to As(V) prior to adsorption starting from May 16, 2005.

Raw water pH values ranged from 7.3 to 7.5, which were within the STS recommended range between 6.0 and 8.0. Therefore, pH adjustment was not required.

Concentrations of iron (127 to 263 μg/L) and manganese (13.0 to 18.7 μg/L) in raw water were sufficiently low so that pre-treatment prior to adsorption was not recommended. Phosphate and silica concentrations also were low (i.e., ≤0.1 and ≤8.1 mg/L, respectively), therefore, their effects on arsenic adsorption should be minimal. Although relatively elevated at 74 to 128 mg/L, sulfate should not interfere with arsenic adsorption.

4.1.3 Distribution System. During the three-year demonstration study, the distribution system was supplied primarily by Well No. 4. Well No. 3, the emergency backup well, was operated only five times on October 13 and November 7, 2004, and June 18, November 10, and December 11, 2005. The water from the two wells was blended in the 200,000 gal water tower. The well pumps were activated by

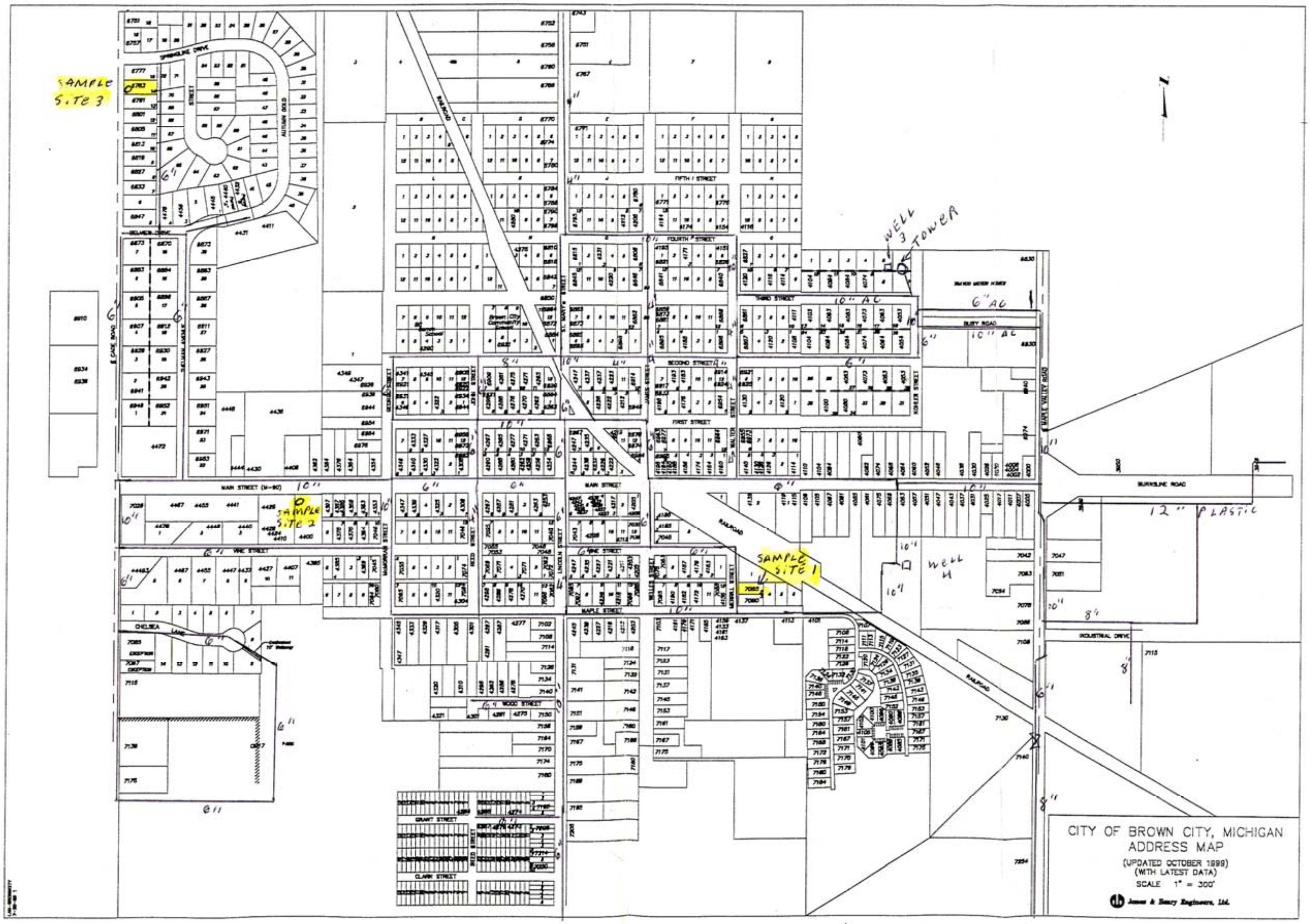


Figure 4-1. Map of the Brown City Service Area

Figure 4-2. Former Well No. 4 Pump House at Brown City

Figure 4-3. Pump Motor, System Piping, and Chlorine Addition Point at Wellhead No. 4

Table 4-1. Brown City Water Quality Data

Parameter	Unit	Raw Water				Historic Utility Distribution Water Data	
		Utility Data	EPA Data	Battelle Data		Min	Max
Sampling Date		NA	07/23/02	07/24/03	07/23/02	2000-2003	2000-2003
pH	–	7.5	NS	7.3	NS	NS	NS
Alkalinity (as $CaCO_3$)	mg/L	267[(a)]	244	235	NS	NS	NS
Hardness (as $CaCO_3$)	mg/L	90.0	108	83.2	NS	90.0	144
Chloride	mg/L	314	NS	51.0	NS	ND	314
Fluoride	mg/L	NS	NS	1.9	NS	1.4	1.9
Sulfate	mg/L	128	109	74.0	NS	50.0	128
Silica (as SiO_2)	mg/L	7.7	7.4	8.1	NS	NS	NS
Orthophosphate (as P)	mg/L	<0.01[(a)]	0.06	<0.10	NS	NS	NS
TOC	mg/L	NS	NS	<0.50	NS	NS	NS
As (total)	μg/L	31	10	14.2	11.9	10.0	36.0
As (soluble)	μg/L	NS	NS	12.0	12.0	NS	NS
As (particulate)	μg/L	NS	NS	2.2	<0.1	NS	NS
As(III)	μg/L	NS	NS	11.2	7.9	NS	NS
As(V)	μg/L	NS	NS	0.8	4.2	NS	NS
Fe (total)	μg/L	200[(a)]	193	127	263	200	400
Fe (soluble)	μg/L	NS	NS	118	148	NS	NS
Al (total)	μg/L	NS	NS	<10	12.6	NS	NS
Al (soluble)	μg/L	NS	NS	<10	1.3	NS	NS
Mn (total)	μg/L	18.0[(a)]	18.7	13.0	16.9	NS	NS
Mn (soluble)	μg/L	NS	NS	15.0	16.3	NS	NS
V (total)	μg/L	NS	NS	<0.1	NS	NS	NS
V (soluble)	μg/L	NS	NS	<0.1	NS	NS	NS
Mo (total)	μg/L	NS	NS	7.9	NS	NS	NS
Mo (soluble)	μg/L	NS	NS	6.9	NS	NS	NS
Sb (total)	μg/L	NS	<25	<0.1	NS	ND	ND
Sb (soluble)	μg/L	NS	NS	<0.1	NS	NS	NS
Na	mg/L	168[(a)]	240	115	NS	60.0	289
Ca	mg/L	14.0[(a)]	30.6	20.6	NS	NS	NS
Mg	mg/L	7.0[(a)]	7.7	7.7	NS	NS	NS

(a) Data provided by EPA.
NA = not available; NS = not sampled; ND = not detected

the level sensors in the water tower, which signaled the designated pump to turn on and off when the water level reached a pre-set low and high setting. The distribution system was constructed primarily of asbestos cement pipe with some ductile iron and plastic pipe. The sizes of water main ranged from 4 to 12 in. Table 4-1 provides a summary of the treated water quality from historic samples collected within the distribution system from 2000 to 2003. Based on the June 1998 to September 2000 monitoring results, the 90th percentile concentrations for lead and copper were 6 and 150 μg/L, respectively, which were below the respective action levels of 15 and 1,300 μg/L.

4.2 Treatment Process Description

STS' Arsenic Package Unit (APU) systems are designed for arsenic removal for small systems with flowrates greater than 100 gpm. They use Bayoxide® E33 (branded as SORB 33™ by STS), an iron-based adsorptive media developed by Bayer AG, for arsenic removal from drinking water supplies. Table 4-2 presents vendor-provided physical and chemical properties of the media. The SORB 33™ media are delivered in a dry crystalline form and listed by NSF International under Standard 61 for use in drinking water applications. The media are provided in both granular and pelletized forms, which have similar physical and chemical properties, except that pellets are 25% denser than granules (i.e., 35 vs. 28 lb/ft^3). The granular media were used at Brown City.

Table 4-2. Physical and Chemical Properties of SORB 33™ Media

SORB 33™ Media	
Physical Properties	
Parameter	**Values**
Matrix	Iron oxide composite
Physical Form	Dry granular media
Color	Amber
Bulk Density (lb/ft^3)	28.1
BET Surface Area (m^2/g)	142
Attrition (%)	0.3
Moisture Content (%)	<15% (by wt.)
Particle Size Distribution (U.S. Standard Mesh)	10 × 35
Crystal Size (Å)	70
Crystal Phase	α – FeOOH
Chemical Analysis	
Constituents	**Weight (%)**
FeOOH	90.1
CaO	0.27
SiO_2	0.06
MgO	1.00
Na_2O	0.12
SO_3	0.13
Al_2O_3	0.05
MnO	0.23
TiO_2	0.11
P_2O_5	0.02
Cl	0.01

Note: BET = Brunauer, Emmett, and Teller Method
Source: STS

The Brown City treatment system consisted of two APU-300 units arranged in a parallel configuration to meet the design flowrate of 640 gpm (i.e., 320 gpm for each unit). During the initial system hydraulic testing, difficulties in system operation, including excessive flow restriction and elevated Δp across the adsorption vessels and entire system, were encountered. The system was retrofitted (see Section 4.3.3) before startup on May 11, 2004.

Figure 4-4 is a simplified piping and instrumentation diagram (P&ID) of an APU-300 unit after system retrofit. Each APU-300 unit consisted of two adsorption vessels, an electrically actuated valve tree, and associated piping and instrumentation. Electrically actuated butterfly valves diverted raw water downward through the two fixed-bed adsorption vessels operating in parallel. As water passed through the adsorbers, arsenic concentrations were reduced to below 10 µg/L. When reaching 10-µg/L arsenic breakthrough, the spent media are to be removed and disposed of after being subjected to the EPA Toxicity Characteristic Leaching Procedure (TCLP) test. The design features of the APU-300 system are summarized in Table 4-3.

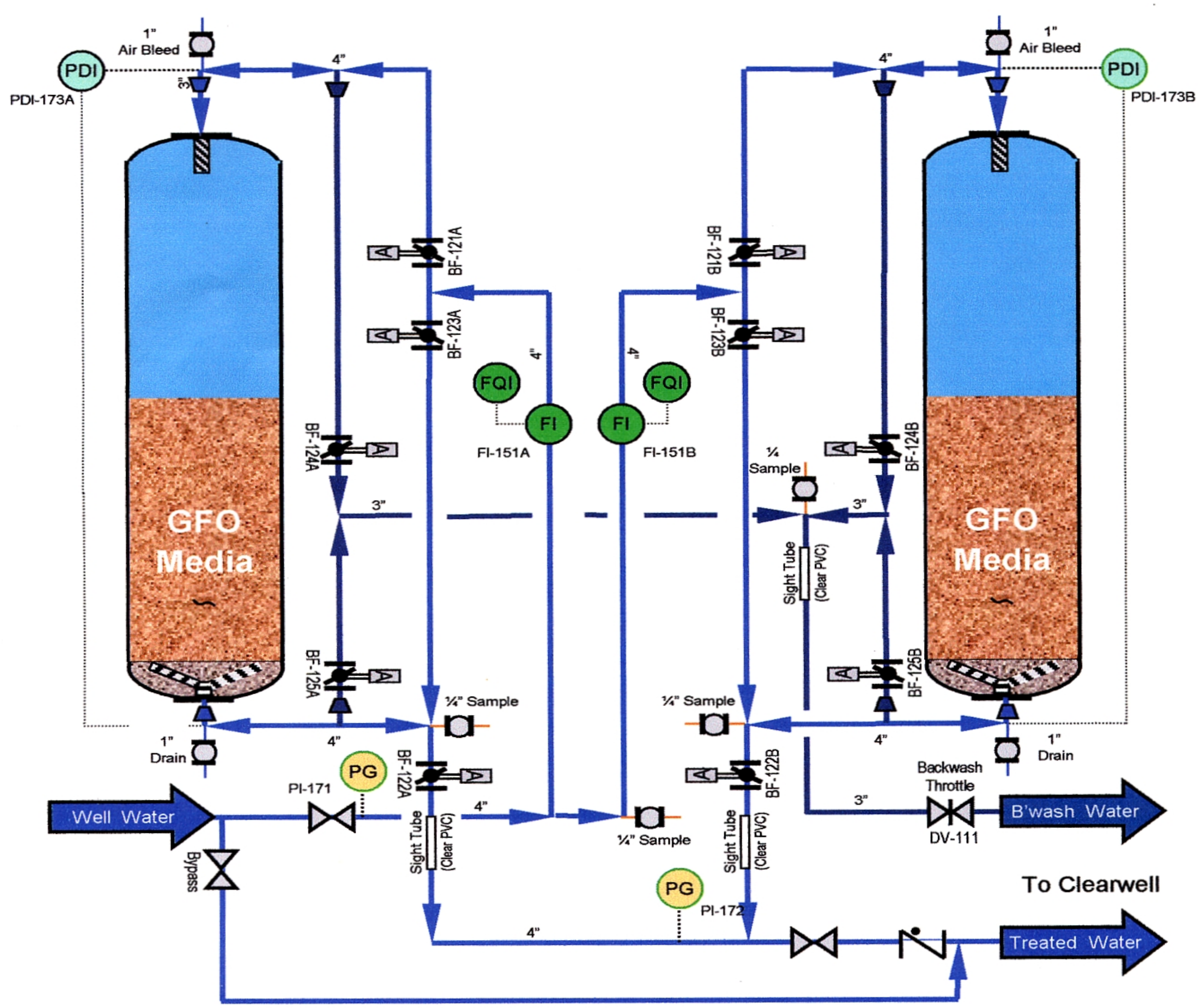


Figure 4-4. Schematic Diagram of an APU-300 Unit after System Retrofit

Table 4-3. Design Specifications of APU-300 System

Parameter	Value	Remarks
Pretreatment		
NaOCl Dosage (mg/L)	0.4–0.5	Prechlorination initiated on May 16, 2005
Adsorption Vessels and Media Beds		
Number of Vessels	4	Two APU-300 units each with 2 vessels
Vessels Configuration	Parallel	
Vessel Size (in)	63 D × 86 H	21.6 ft^2 cross-sectional area
Type of Media	SORB 33™	Granular form
Media Volume (ft^3/vessel)	80	320 ft^3 total
Media Bed Depth (in)	44	–
Service		
Design Flowrate (gpm/vessel)	160	640 gpm total
Hydraulic Loading (gpm/ft^2)	7.4	Based on vessel cross-sectional area of 21.6 ft^2
EBCT (min)	3.7	Based on design flowrate
Average Use Rate (gpd)	153,600	Based on 640 gpm for 4 hr/day
Estimated Working Capacity (BV)	80,000[(a)]	Based on influent As concentration of 31 μg/L and arsenic breakthrough at 10 μg/L
Estimated Breakthrough Throughput (1000 gal)	191,488[(a)]	Four vessels combined
Estimated Media Life (month)	40	Based on average use rate
Backwash		
Flowrate (gpm)	200	Recommended by STS
Hydraulic Loading (gpm/ft^2)	9.2	Based on backwash flowrate and vessel cross sectional area of 21.6 ft^2
Frequency (time/45 days)	1	Manually or based on a Δp threshold
Duration (min/vessel)	20	Recommended by STS
Rinse Duration (min/vessel)	4	Recommended by STS

(a) Based on STS proposal dated January 7, 2003, with an influent As concentration of 31 μg/L.

Four key process components are discussed as follows:

- **Intake**. Raw water from Well No. 4 was chlorinated and fed into the APU-300 system for operation with prechlorination. Raw water was fed directly into the APU-300 system for operation without prechlorination. The amount of water pumped was tracked with a totalizer installed at the wellhead.
- **Chlorination**. During the first year of system operation, a 12.5% NaOCl solution was added at the end of the treatment train to evaluate the media's adsorptive capacity for As(III). Upon arsenic breakthrough at 10 μg/L, the NaOCl solution was added to the raw water to oxidize As(III). The NaOCl dosage was controlled at 0.4 to 0.5 mg/L (as Cl_2) for a target chlorine residual level of 0.3 mg/L (as Cl_2) for free chlorine and 0.4 mg/L (as Cl_2) for total chlorine in the distribution system. Actual dosages were monitored directly by measuring solution consumption rates in the chemical day tank and indirectly by measuring total and free chlorine residual levels at the AC sampling location, which was located at a common feed line to the adsorption vessels.
- **Adsorption**. Each APU-300 unit consisted of two 63-in-diameter, 86-in-tall vertical pressure vessels. The vessels were fiberglass reinforced plastic (FRP) construction, rated for 75 psi working pressure, skid mounted, and piped to a valve rack mounted

on a polyurethane coated, welded frame. Each vessel contained approximately 80 ft^3 of SORB 33™ media supported by a gravel underbed. Empty bed contact time (EBCT) for the system was 3.7 min based on a design flowrate of 320 gpm. Hydraulic loading to each vessel was approximately 7.4 gpm/ft^2. Figure 4-5 shows the two APU-300 units that were installed in a parallel configuration at the Brown City, MI site.

Figure 4-5. Photograph of an APU-300 Unit at Brown City

As illustrated in Figure 4-4, the two adsorption vessels were interconnected with schedule 80 polyvinyl chloride (PVC) piping and 10 electrically actuated butterfly valves using a valve tree design (Figure 4-6). During normal operation, the feed valves (i.e., BF-121 A and B) and effluent valves (i.e., BF-122 A and B) were opened and the other six valves were closed to divert water downward through the two adsorption vessels. Flow through the two vessels was balanced by throttling the effluent valves, if needed. During backwash, the feed and effluent valves were closed and the backwash feed valves (i.e., BF-123 A and B) and backwash effluent valves (i.e., BF-124 A and B) were opened to divert water upward through the two adsorption vessels. During backwash rinse process, the feed valves (i.e., BF-121 A and B) and rinse valves (i.e., BF-125 A and B) were opened and the other six valves were closed to rinse the media with downward water flow.

Flowmeters (+GF+SIGNET 8550 ProcessPro™ Flow Transmitter) installed in the supply line of each adsorption vessel monitored instantaneous flowrates through the vessels. The flowmeters also tracked the volume of water treated in each vessel. Δp readings across each vessel were monitored by differential pressure gauges (WIKA Differential Pressure Gauge). The adsorption vessels were backwashed sequentially whenever the Δp across one vessel had reached 10 psi. The system controller (Figure 4-6) controlled the operation of the actuated valve tree for the adsorption, backwash, and forward fast rinse cycles.

Figure 4-6. System Components
(Control Panel & Color Coded Sample Taps [left];
and APU-300 System Valve Tree [right])

- **Backwash**. STS recommended that the SORB 33™ media be backwashed approximately once every 45 days using raw water to loosen up the media bed, and remove particulates and media fines accumulating in the beds. The APU-300 system was designed and programmed with an automatic backwash feature that would place the vessels into backwash based on a set timer or when the Δp across a vessel had reached a set point. Controllers for the backwash system included actuated valves for adsorption, backwash and forward flush (fast rinse) cycles, timers, and pressure sensors. The backwash water was directly discharged into a drainage ditch adjacent to the treatment building.

4.3 System Installation

The building was completed by the City in early February 2004 and the two STS APU-300 units were installed in March 2004 by a subcontractor to STS. Hydraulic shakedown and startup activities continued into late April 2004, and the system was retrofitted in early May 2004.

4.3.1 Permitting. Engineering plans for the system permit application were prepared by Boss Engineering, a subcontractor to STS located in Howell, MI. The plans included diagrams of and specifications for the treatment system, as well as drawings detailing the connection of the new units to the preexisting facility infrastructure. After incorporating comments on the plans from STS and Battelle, the permit application was submitted by the City to the MDEQ for review on November 26, 2003. The MDEQ approved the permit application package on February 11, 2004.

4.3.2 Building Construction. The City constructed an addition to its existing Well No. 4 pump house to house the two APU-300 units. The addition is a 28 ft × 28 ft concrete block structure with a 10-ft-wide roll-top metal door and access hatches in the roof for media loading. A photograph of the new structure adjacent to the preexisting block pump house is shown in Figure 4-7. The scope of work for the building construction included excavation, masonry, carpentry, concrete floor pouring, building trim and

Figure 4-7. New Building Adjacent to Preexisting Pump House (on left)

painting, and associated heating and electrical work. Also, included in the building construction was installation of an overhead door, roof deck, and roofing, including overhead roof hatches. Building construction started in December of 2003 with the installation of building footers and walls and was completed by February of 2004.

4.3.3 System Installation, Shakedown, and Startup. The two APU-300 units were delivered to the site on February 23, 2004. A subcontractor to STS off-loaded and installed the system, including piping connections to the existing entry and distribution piping. Installation was completed on March 18, 2004, and the system hydraulic shakedown before media loading was initiated on March 19, 2004.

The system configuration as delivered included system components such as the piping inlet, an automatic variable diaphragm valve (to control flow), a strainer, a programmable Fleck valve controller (to switch flow from a service to a backwash mode), an FRP vessel with top diffuser and bottom laterals, a restrictive orifice, and an outlet for each vessel. This configuration was later modified to a valve-tree configuration, as described below in this subsection, to address relevant pressure loss and flow issues.

STS began hydraulic testing of the two APU-300 units on March 19, 2004, with no media loaded in the vessels in order to troubleshoot issues related to low and imbalanced flow as well as excessive pressure losses noted on an identical APU-300 unit installed at Desert Sands Mutual Domestic Water Consumers Association (MDWCA) in Anthony, NM, in December 2003 (Chen et al., 2008a). Water from Well No. 4 was pumped through the two empty APU-300 units with flowrates ranging from 105 to 115 gpm per vessel, which were well below the design flowrate of 160 gpm. The corresponding pressure losses were 7 to 8 psi across each vessel and 24 to 26 psi across the entire system. These results suggested that the system components and plumbing most likely were the sources of the high pressure losses.

To address these issues, STS performed a series of systematic hydraulic tests at its Torrance, CA, fabrication shop and at the Brown City, MI, site. The results are provided in the Final Performance Evaluation Report for Deserts Sands MDWCA (Chen et al., 2008a). The results of the Brown City testing performed on April 6, 2004, showed that, after removing the restrictive orifices, strainers, and top diffusers, significant pressure losses were observed across the variable diaphragm valves (from 80 to 71 psi) and across Fleck valve controllers and bottom laterals (from 71 to 58 psi). These results were consistent with those observed during testing at Torrance, CA, except for the 1-psi loss (from 44 to 43 psi) across the variable diaphragm valve. The results of the Brown City, MI, and Torrance, CA, testing were further confirmed during a separate test in Torrance, CA, on April 14, 2004. It was concluded that the main source of pressure losses originated from the Fleck valve controllers. Upon completion of the hydraulic testing, STS recommended retrofitting the system.

STS developed a revised plumbing design, which included replacing the 3-in-diameter pipe with 4-in-diameter pipe; removing the diaphragm valves, restrictive orifices, and valve controllers; and installing a nested system of fully ported actuated butterfly valves and a new control panel. STS completed the system retrofit of the two APU-300 units, and the media were loaded on May 5, 2004. The flowrate, and pressure data and other operational parameters were within established specifications after the system retrofit. On May 7, 2004, STS conducted operator training for system operations and Battelle conducted operator training for system sampling and data collection. Water samples were taken from the vessels on May 10, 2004, and the system passed the coliform test. The performance evaluation study officially began on May 11, 2004.

4.4 System Operation

Table 4-4 presents timelines of key activities/events that occurred during the system performance evaluation. These demonstration activities are described in more details in the following sections.

Table 4-4. Demonstration Study Activities and Completion Dates

Activity	Date
APU-300 Units Shipped by STS	02/18/04
APU-300 Units Delivered to Brown City	02/23/04
System Installation Completed (before Media Loading)	03/18/04
Initial Hydraulic Testing/System Shakedown Performed	03/19/04
System Retrofit Completed	05/05/04
Media Loading and Initial Backwash Events Performed	05/07/04
Final Hydraulic Testing/System Shakedown Performed	05/07/04
Performance Evaluation Begun	05/11/04
Prechlorination Initiated	05/16/05
Performance Evaluation Ended	05/02/07

4.4.1 Operational Parameters. The operational parameters of the system are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-5. The plant operations were initiated on May 11, 2004, and continued through May 2, 2007. Relevant system operational parameters are discussed in detail as follows:

A well pump hour meter was installed on June 7, 2004, approximately one month after system startup. Between June 7, 2004 and May 2, 2007, Well No. 4 operated for a total of 4,430 hr, equivalent to a utilization rate of approximately 19%, or an average daily operating time of 4.5 hr/day. The low utilization rate experienced was due primarily to relatively low water demand. Using the daily operating time of 4.5 hr/day, the operating time between the system startup and June 7, 2004 was estimated to be 117 hr, which increased the total cumulative operating time to 4,547 hr for the entire period of performance evaluation study.

Table 4-5. Summary of Treatment System Operation at Brown City

Operational Parameter	Value/Condition				
Duration	05/11/04–05/02/07				
Cumulative Operating Time (hr)	4,547				
Average Daily Operating Time (hr)	4.5				
	Vessel A	**Vessel B**	**Vessel C**	**Vessel D**	**System**
Throughput (1,000 gal)	40,834	42,846	36,389	33,931	154,001
Throughput (BV)	68,274	71,640	60,843	56,732	64,372
Average Flowrate (gpm) [(a)]	154	162	137	128	564
Range of Flowrate (gpm)	118–186[(b)]	127–196[(b)]	99–170[(b)]	86–182[(b)]	382–666[(c)]
Average EBCT (min)[(d)]	3.9	3.7	4.4	4.7	4.2
Range of EBCT (min)[(e)]	3.2–5.1	3.1–4.7	3.5–6.0	3.3–7.0	3.6–6.3
Δp across Vessel – without Cl_2 (psi)	2.2–5.4	2.6–5.0	2.2–4.0	1.0–4.2	NA
Δp across Vessel – with Cl_2 (psi)	2.8–15	2.5–15	2.0–14	2.0–13	
Δp across Each APU-300 Unit – without Cl_2 (psi)	1.0–8		2.0–8		NA
Δp across Each APU-300 Unit – with Cl_2 (psi)	3.0–20		2.0–19		NA
Backwash Interval – without Cl_2 (day)	34–45				
Backwash Interval – with Cl_2 (day)	3–25				

(a) Calculated based on cumulative throughput and corresponding operating time.
(b) Based on instantaneous flowrates measured at Vessels A, B, C, and D.
(c) Sum of instantaneous flowrates measured at Vessels A, B, C, and D.
(d) Based on average flowrate and 80 ft^3 of media per vessel.
(e) Based on instantaneous flowrates and 80 ft^3 of media per vessel.
NA = not applicable

The total system throughput from May 11, 2004, to May 2, 2007, was approximately 154,001,000 gal based on digital readings of the flow totalizers installed on the four vessels. This throughput value corresponds to 64,372 BV of water processed through the entire system. Based on the readings for the individual vessels, the throughput values were 40,834,000; 42,846,000; 36,389,000; and 33,931,000 gal through Vessels A, B, C, and D, respectively. Significant flow imbalance was observed between Unit 1 (Vessels A and B) and Unit 2 (Vessels C and D), each receiving approximately 54.3 and 45.7% of flow, respectively. For each unit, there also was slight flow imbalance between two vessels, i.e., 48.8 and 51.2% through Vessels A and B, respectively, and 51.7 and 48.3% through Vessels C and D, respectively.

Beginning on June 22, 2004, the total system throughput also was recorded from the master flowmeter at the wellhead. Based on this flowmeter, 167,441,000 gal of water was treated from June 22, 2004, through May 2, 2007. The total system throughput for the entire period of performance study was estimated to be 173,729,000 gal by adding 6,288,000 gal for the period between system startup and June 21, 2004, based on the totalizer readings for the individual vessels. The total system throughput recorded from the master flowmeter was approximately 13% higher than that recorded from the totalizers at individual vessels (154,001,000 gal). Throughput values from the individual totalizers were used for this performance evaluation.

Figure 4-8 presents instantaneous flowrates measured at Vessels A, B, C, and D during the performance evaluation. The imbalanced flow through the two APU-300 units was clearly reflected, with flowrates through Unit 1 (Vessels A and B) consistantly higher than those through Unit 2 (Vessels C and D). The average flowrates were 154, 162, 137 and 128 gpm through Vessels A, B, C, and D, respectively. The flowrates through Vessels A and B were closer to the design flowrate of 160 gpm, while the flowrates through Vessels C and D were 14 to 20% lower than the design flowrate. Because of the imbalanced

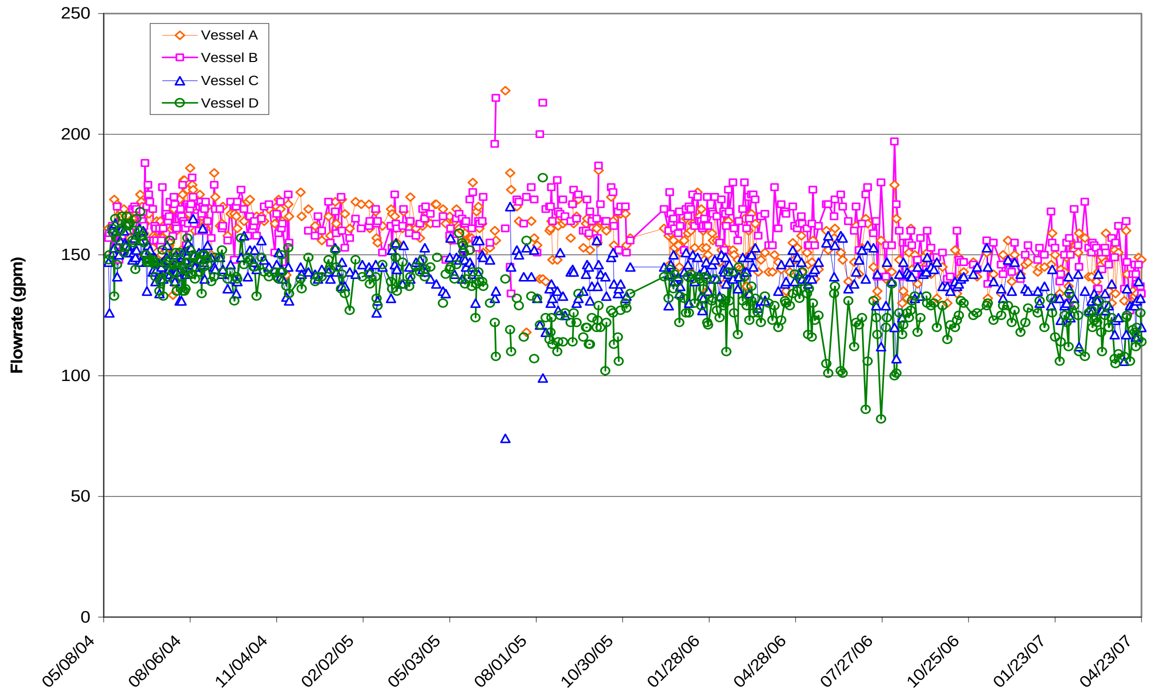


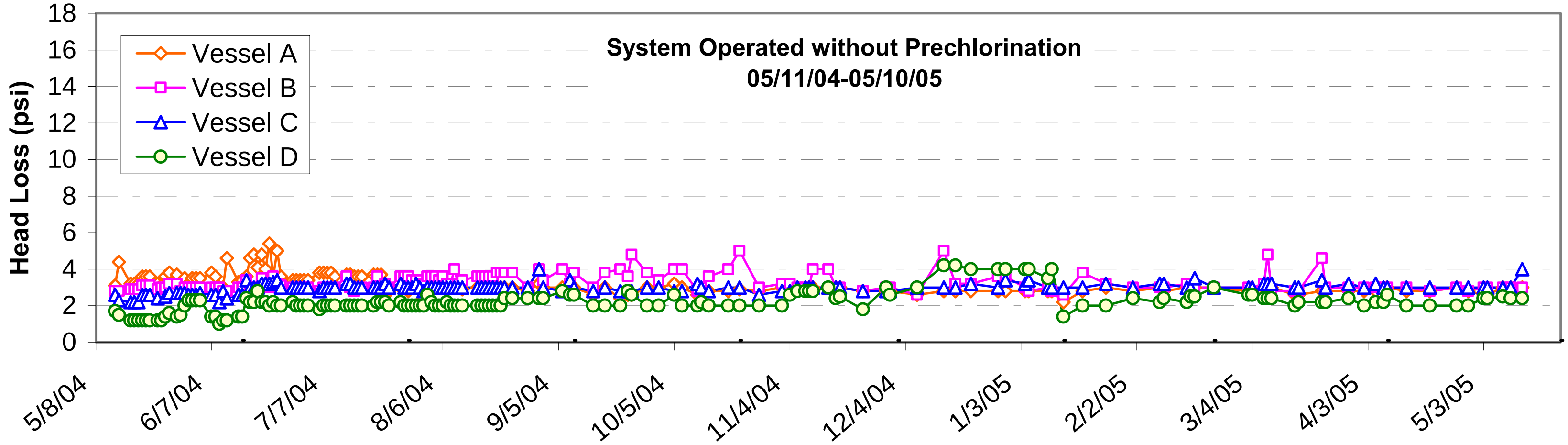
Figure 4-8. Instantaneous Flowrates through Vessels A, B, C, and D

flow, EBCT values varied significantly between the two units, averaging 3.8 min for Unit 1 and 4.6 min for Unit 2.

Figure 4-9 (top) presents Δp readings measured across Vessels A, B, C, and D before switching to prechlorination on May 16, 2005. During this period, Δp across each vessel varied from 1.0 to 5.4 psi and remained low throughout; Δp across each APU-300 unit also was low, ranging from 1 to 8 psi. Figure 4-9 (bottom) presents Δp readings measured across Vessels A, B, C, and D after switching to prechlorination. Since then, Δp across each vessel increased significantly to as high as 15 psi; Δp across each APU-300 unit also increased correspondingly to as high as 20 psi. The increases in Δp were caused by the accumulation of iron solids in the media beds due to the addition of NaOCl before the adsorption vessels. Δp readings across each vessel were restored to as low as 2 psi after backwash.

4.4.2 Backwash. STS recommended that the SORB 33™ media be backwashed manually or automatically approximately every 45 days to loosen up the media bed and remove media fines and particles accumulating in the beds. Automatic backwash was initiated either by a timer or whenever the pressure drop across an adsorption vessel exceeded a set point, e.g., 10 psi. During the first year of system operation without prechlorination, backwash was never triggered by the 10-psi Δp set point because Δp across each vessel remained low throughout the duration. Instead, backwash was initiated manually eight times with backwash intervals ranging from 34 to 45 days and averaging 41 days.

After the system was switched to prechlorination, due to a faster than anticipated increase in Δp during system operation, backwash was conducted far more frequently than without prechlorination. During the two-year operation with prechlorination, backwash was conducted 69 times with backwash intervals ranging from 3 to 25 days and averaging 10 days.



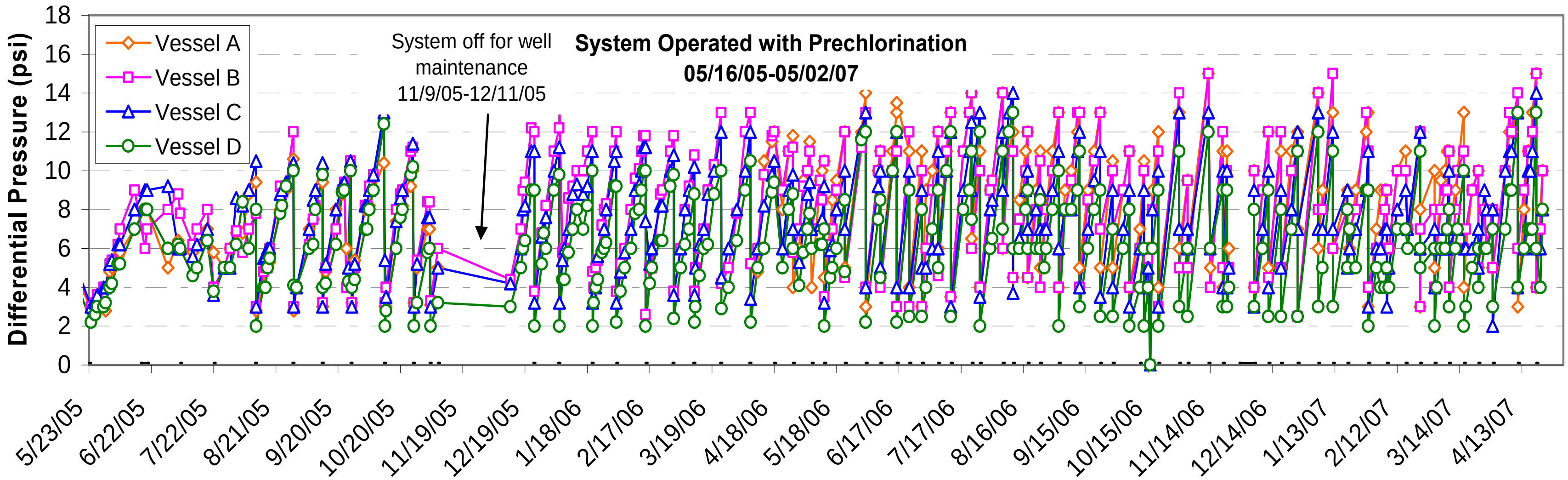


Figure 4-9. Differential Pressure Across Vessels A, B, C, D during Operation Without (Top) and with (Bottom) Prechlorination

The amount of water treated (in bed volume) between two consecutive backwash events is presented in Figure 4-10. During the first-year operation without prechlorination, the amount treated fluctuated between approximately 2,000 to 3,300 BV. After it was switched to prechlorination, the amount decreased progressively from just under 3,000 BV immediately after the switch to less than 500 BV about halfway through the remainder of the demonstration study. Since then, the amount treated could be as little as 150 BV.

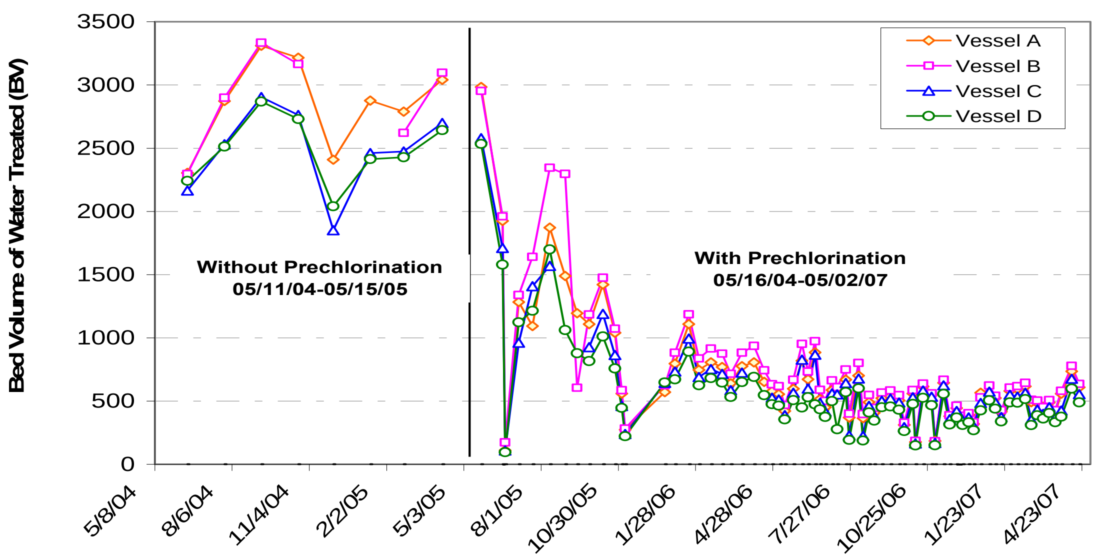


Figure 4-10. Amounts of Water Treated Between Backwash Events

Media attrition during backwash appeared to be the main reason for the increasingly more frequent backwashes observed. During the first-year operation without prechlorination, Δp across the media beds was low at 1 to 5.4 psi, and backwash was initiated manually at vendor recommended intervals. After switching to prechlorination, backwashes had to be conducted more frequently to remove iron particles formed following prechlorination. The more backwashes that were performed, the more media fines that were generated, causing run times between backwashes to shorten. Similar deteriorating media integrity also was observed at other EPA arsenic demonstration sites, including Rollinsford (Cumming et al., 2008), Desert Sands (Chen et al., 2008a), and Queen Anne's County (Chen et al., 2008b). It is not clear, however, if chlorine would have any adverse effects on media integrity. All of the demonstration sites referenced added chlorine prior to the adsorption vessels.

Backwash was performed at approximately 200 gpm, or 9.2 gpm/ft^2, as set by STS using the manual valves on the backwash discharge line from each unit. Based on the backwash logs, backwash flowrates for all four vessels ranged from 185 to 229 gpm. Each backwash event lasted for approximately 20 min, followed by a four-min filter-to-waste rinse, thereby producing approximately 4,800 gal of wastewater per vessel. Based on the backwash logs, the amount of backwash water produced ranged from 3,900 to 5,300 gal/ vessel and averaged 4890 gal/vessel, which was very close to the design value of 4,800 gal/vessel.

4.4.3 Residual Management. Residuals produced by the operation of the APU-300 system included backwash wastewater and spent media. Because the media were not replaced during the performance evaluation period, the only residual produced was backwash wastewater.

Aboveground piping for backwash wastewater from both APU-300 units was combined before extending outside the treatment plant building. The pipe emerged from the building and discharged after an air gap onto the ground during the first four months of system operation (left of Figure 4-11), and into a subsurface concrete vault that discharged via an underground pipe to a nearby drainage ditch during the remainder of the study (right of Figure 4-11).

4.4.4 System/Operation Reliability and Simplicity. After the system retrofit, no major operational problems were encountered. The only O&M issues encountered were the temporary failure of a digital flowmeter, the failure of a differential pressure gauge, and a loose switch on an automatic valve. Neither scheduled nor unscheduled downtime had been required since the completion of the system retrofit. The simplicity of system operation and operator skill requirements are discussed according to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Pre-treatment was not initially implemented in order to evaluate the capacity of the SORB 33™ media for As(III). From May 11, 2004 to May 10, 2005 only post-chlorination was implemented for disinfection. From May 16, 2005 to May 2, 2007, prechlorination was implemented to oxidize As(III) to As(V) to determine if the media bed life could be further extended.

System Automation. For the most part, backwash was automatically triggered by a 10-psi Δp setting across each vessel. Backwash was initiated manually during the first-year system operation without prechlorination and when backwash wastewater sampling was required. All other major functions of the APU-300 system were automated and it required only minimal operator oversight and intervention. Automated processes included system startup in the forward feed mode when the well energized, backwash cycling based on time or pressure triggers, fast rinse cycling, and system shutdown when the well pump shut down.

Operator Skill Requirements. Under normal operating conditions, the skill sets required to operate the APU-300 system were basic and limited to observation of the process equipment integrity and operating parameters such as pressure, flow, and system alarms. The process logic controller (PLC) interface was intuitive, and all major system operations were automated as described above. The daily demand on the operator was 30 min to allow the operator to visually inspect the system and record the operating parameters on the log sheets. The operation of the system did not appear to require additional skills beyond those necessary to operate the existing production equipment.

Based on the size of the population served and the treatment technology, the State of Michigan requires Class D-3 Certification for operation of the STS treatment system at the Brown City facility. The State of Michigan divides water treatment systems into two categories for operating certification, i.e., complete treatment system and limited treatment system. A complete treatment system uses disinfection, coagulation, sedimentation, and filtration to produce finished water that meets the requirements of the state drinking water standards. The STS treatment system installed at the Brown City facility is considered limited treatment system. The State of Michigan has five levels of certification for operations of limited water treatment systems based on population served by the public water supplies or rated treatment capacities of the treatment systems. The levels range from Class D-5 for noncommunity supplies and Class D-4 for community supplies serving a population of less than 1,000 to Class D-1 for community supplies serving a population greater than 20,000.

Figure 4-11. Backwash Wastewater Discharge unto the Ground (left) and into an Underground Concrete Vault (right)

Preventative Maintenance Activities. Preventative maintenance tasks recommended by STS included monthly inspection of the control panel; quarterly checking and calibration of the flowmeters; biannual inspection of the actuator housings, fuses, relays, and pressure gauges; and annual inspection of the butterfly valves. STS recommended checking the actuators during each backwash event to ensure that the valves were opening and closing in the proper sequence. Further, inspection of the adsorber laterals and replacement of the gravel underbedding were recommended concurrent with the media replacement. The operator also compared the flowmeter and totalizer data from the STS system to his existing meters on a consistent basis, which did not require any appreciable time expenditure. During the performance evaluation study, maintenance activities performed by the operator included cleaning and repairing the flowmeter paddle wheels, replacing one differential pressure gauge, and replacing plastic pressure line fittings/elbows on sampling taps. Maintenance also was required on an automated valve to repair a loose limit switch. This repair was made by STS and beyond routine maintenance activities that could be performed by the operator.

Chemical/Media Handling and Inventory Requirements. Chemical use was not required beyond the liquid NaOCl chlorination system already in place. Media changeout was not required during the performance evaluation.

4.5 System Performance

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

4.5.1 Treatment Plant Sampling. Water samples were collected at seven locations through the treatment process: including IN, AC, TA, TB, TC, TD, and TT (Table 3-3). The treatment plant water was sampled on 59 occasions (including four duplicate events) during the study, with field speciation performed during 35 (12 times in the first year without prechlorination and 23 times in the remaining two years with prechlorination) of the 59 occasions. Field-speciation samples at the IN and TT sampling locations were collected once every four weeks from system startup through the end of performance evaluation. Field-speciation samples at the AC location were collected once every four weeks since the system was switched to prechlorination.

Table 4-6 provides a summary of analytical results for arsenic, iron, and manganese during the performance evaluation study from May 11, 2004, through May 2, 2007. Table 4-7 summarizes the results of the 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. Figure 4-12 contains three bar charts showing the concentrations of total As, particulate As, and soluble As(III) and As(V) at the IN, AC, and TT sampling locations for each speciation sampling event. Total arsenic concentrations in raw water ranged from 9.5 to 29.6 μg/L and averaged 15.3 μg/L. Soluble As(III) was the predominating species with its concentrations ranging from 9.0 to 30.2 μg/L and averaging 13.1 μg/L. The remainder of soluble arsenic was As(V) with concentrations averaging 0.7 μg/L. Some particulate arsenic also existed, with concentrations averaging 1.6 μg/L. Concentrations of various arsenic species measured during the three-year study period were consistent with those collected during the initial site visit on July 24, 2003 (Table 4-1).

The key parameter for evaluating the effectiveness of the SORB 33™ system was the concentration of arsenic in the treated water. The arsenic breakthrough curves for the four adsorption vessels and the entire system are presented in Figure 4-13 with total arsenic concentrations plotted against the volume of water treated in BV. As shown in the figure, from May 11, 2004, to May 15, 2005, chlorine was added only after the adsorption vessels to provide chlorine residuals to the distribution system. Total As existing mostly as As(III) broke through from the adsorption vessels immediately after system startup with concentrations increasing steadily as observed at the TA, TB, TC, TD, and TT sampling locations. Total arsenic concentrations exceeded the target level of 10 μg/L at approximately 20,800 BV, representing 25% of the vendor estimated working capacity of 80,000 BV. Because arsenic existed primarily as As(III) in source water and because As(V) would have much higher adsorptive affinity than As(III), prechlorination was implemented on May 16, 2005, to continue the treatment process.

One week after switching to prechlorination, total arsenic concentrations in the treated water remained almost as high as those at the pre-switching levels, with soluble As(III) continuing to be the predominant species (e.g., 7.5 μg/L of total As measured on May 24, 2005 with 84% present as As(III), compared to 6.9 to 9.3 μg/L of total As measured on May 10, 2005). The continuing presence of As(III) in the treated water after switching to prechlorination seems to suggest that, while As(V) along with some chlorine residuals were being fed to the top of the adsorption vessels, As(III) began to be desorbed or displaced from the bottom of the adsorption vessels. The desorption or displacement seems to last for at least three weeks (or approximately 23,700 BV), as indicated by the 1.5 to 8.5 μg/L of total arsenic in effluent of the four adsorption vessels on June 7, 2005. It is also interesting to note that even three weeks after switching to prechlorination, only one out of four vessels had effluent with measurable chlorine (i.e., 0.4 and 0.5 mg/L [as Cl_2] of free and total chlorine at TA on June 7, 2005). Because SORB 33™ was known to have little or no chlorine demand, chlorine fed to the adsorption vessels most likely was consumed by the reducing species, such as As(III), Fe(II), and Mn(II), previously removed by the media. As these reducing species on the media had been oxidized, chlorine began to emerge from the vessel (such as Vessel A), and As(III) desorption or displacement ceased to occur.

One month after switching to prechlorination on June 7, 2005 (or after approximately 2,800 BV), total arsenic concentration in the system effluent decreased sharply to 0.9 μg/L. Since then, total As concentrations in the treated water remained low at levels mostly less than 3 μg/L through the end of the

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

Parameter	Sampling Location[b]	Number of Samples (w/o/with Cl_2)	Concentration (µg/L) Minimum (w/o/with Cl_2)	Maximum (w/o/with Cl_2)	Average (w/o/with Cl_2)	Std. Dev. (w/o/with Cl_2)
As (total) (see Figure 4-13)	IN	59	9.5	29.6	15.3	4.5
	AC	0/20	NM/11.3	NM/16.0	NM/13.0	NM/1.3
	TA	18/6	0.6/0.6	8.7/1.5	-[a]	-[a]
	TB	18/6	0.5/0.6	9.6/2.7	-[a]	-[a]
	TC	18/6	0.7/0.5	10.6/7.8	-[a]	-[a]
	TD	18/6	0.4/0.6	11.0/8.5	-[a]	-[a]
	TT	12/23	0.7/0.6	12.8/7.5	-[a]	-[a]
As (soluble)	IN	35	9.6	29.8	13.7	3.5
	AC	0/20	NM/7.9	NM/12.2	NM/10.1	NM/1.2
	TT	12/23	0.6/0.5	12.1/6.7	-[a]	-[a]
As (particulate)	IN	35	<0.1	7.7	1.6	1.7
	AC	0/20	NM/0.7	NM/4.3	NM/2.9	NM/0.9
	TT	12/23	<0.1/<0.1	1.1/1.4	-[a]	-[a]
As(III)	IN	34	9.0	30.2	13.1	3.6
	AC	0/20	NM/0.3	NM/12.0	NM/2.1	NM/3.4
	TT	12/23	0.5/0.3	10.2/6.3	-[a]	-[a]
As(V)	IN	34	<0.1	2.5	0.7	0.6
	AC	0/20	NM/<0.1	NM/10.6	NM/8.0	NM/2.8
	TT	12/23	<0.1/<0.1	1.9/2.4	-[a]	-[a]
Fe (total) (see Figure 4-14)	IN	59	101	312	177	47.6
	AC	0/20	NM/97.2	NM/205	NM/144	NM/27.8
	TA	18/6	<25/<25	149/<25	-[a]/<25	-[a]/NA
	TB	18/6	<25/<25	139/68.2	-[a]/<25	-[a]/22.7
	TC	18/6	<25/<25	235/<25	-[a]/<25	-[a]/ NA
	TD	18/6	<25/<25	134/255	-[a]/53.0	-[a]/99.2
	TT	12/23	<25/<25	79.0/39.4	-[a]/<25	-[a]/5.6
Fe (soluble)	IN	35	98.9	285	151	35.0
	AC	0/20	NM/<25	NM/129	NM/28.5	NM/35.3
	TT	12/23	<25/<25	54.3/<25	-[a]/<25	-[a]/NA
Mn (total) (see Figure 4-15)	IN	59	12.3	25.9	16.2	2.4
	AC	0/20	NM/12.6	NM/18.1	NM/15.3	NM/1.7
	TA	18/6	<0.5/7.6	22.7/8.4	-[a]/8.0	-[a]/0.3
	TB	18/6	<0.5/7.2	22.2/8.7	-[a]/7.9	-[a]/0.5
	TC	18/6	1.5/6.0	27.4/8.2	-[a]/7.2	-[a]/0.9
	TD	18/6	2.1/5.5	25.0/8.6	-[a]/6.9	-[a]/1.3
	TT	12/23	1.3/6.0	22.4/14.8	-[a]/10.3	-[a]/2.4
Mn (soluble)	IN	35	12.4	19.7	15.8	1.8
	AC	0/20	NM/3.3	NM/15.5	NM/9.8	NM/3.1
	TT	12/23	1.6/6.0	22.6/14.7	-[a]/10.2	-[a]/2.2

(a) Not meaningful for data related to breakthrough curves; see Figures 4-13, 4-14, and 4-15 and Appendix B for results.
(b) See Table 3-3.
NM = not measured
NA = not applicable
One-half of detection limit used for nondetect results for calculations.
Duplicate samples included for calculations.

Table 4-7. Summary of Water Quality Parameter Measurements

Parameter	Sampling Location[(a)]	Unit	Number of Samples	Minimum	Maximum	Average	Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	50	218	284	242	11.9
	AC	mg/L	11	238	264	250	8.5
	TA	mg/L	24	214	273	240	16.0
	TB	mg/L	24	214	268	242	11.4
	TC	mg/L	24	202	268	243	11.6
	TD	mg/L	24	214	272	247	8.7
	TT	mg/L	26	164	271	245	16.6
Fluoride	IN	mg/L	26	0.9	3.3	1.4	0.3
	AC	mg/L	11	<0.1	1.6	1.2	0.4
	TT	mg/L	26	<0.1	1.9	1.4	0.3
Orthophosphate (as PO_4)	IN	mg/L	19	<0.1	<0.1	<0.1	NA
	TA	mg/L	11	<0.1	<0.1	<0.1	NA
	TB	mg/L	11	<0.1	<0.1	<0.1	NA
	TC	mg/L	11	<0.1	<0.1	<0.1	NA
	TD	mg/L	11	<0.1	<0.1	<0.1	NA
	TT	mg/L	8	<0.1	<0.1	<0.1	NA
Total Phosphorus (as P)	IN	μg/L	12	<10	<10	<10	NA
	AC	μg/L	12	<10	<10	<10	NA
	TT	μg/L	12	<10	<10	<10	NA
Silica (as SiO_2)	IN	mg/L	50	6.5	14.6	9.0	1.6
	AC	mg/L	11	7.0	10.4	8.2	0.9
	TA	mg/L	24	7.2	17.4	8.1	1.0
	TB	mg/L	24	2.3	8.3	7.6	0.8
	TC	mg/L	24	2.7	8.5	7.7	0.7
	TD	mg/L	24	3.1	8.4	7.6	0.7
	TT	mg/L	26	3.0	10.0	7.8	0.7
Sulfate	IN	mg/L	29	43.9	136	75.2	25.6
	AC	mg/L	14	50.7	146	93.3	25.2
	TT	mg/L	29	60.8	140	97.8	23.5
Nitrate (as N)	IN	mg/L	26	<0.05	2.7	0.3	0.7
	AC	mg/L	11	<0.05	<0.05	<0.05	NA
	TT	mg/L	26	<0.05	0.6	0.1	0.1
Turbidity	IN	NTU	50	0.2	2.3	1.0	0.5
	AC	NTU	11	0.1	0.8	0.4	0.2
	TA	NTU	24	<0.1	0.8	0.3	0.3
	TB	NTU	24	<0.1	0.9	0.2	0.2
	TC	NTU	24	<0.1	1.1	0.3	0.3
	TD	NTU	24	<0.1	0.9	0.3	0.2
	TT	NTU	26	<0.1	1.3	0.4	0.3
pH	IN	S.U.	45	7.6	8.5	7.9	0.1
	AC	S.U.	15	7.6	7.8	7.7	0.0
	TA	S.U.	18	7.6	8.1	8.0	0.1
	TB	S.U.	18	7.6	8.1	8.0	0.2
	TC	S.U.	18	7.6	8.0	7.9	0.1
	TD	S.U.	18	7.6	8.0	7.9	0.2
	TT	S.U.	27	7.5	8.0	7.8	0.1

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

Parameter	Sampling Location[(a)]	Unit	Number of Samples	Minimum	Maximum	Average	Standard Deviation
Temperature	IN	ºC	46	10.3	15.8	12.1	1.1
	AC	ºC	15	11.7	15.4	12.6	1.4
	TA	ºC	19	10.4	13.8	11.6	0.9
	TB	ºC	19	10.5	13.5	11.6	0.9
	TC	ºC	19	10.5	13.5	11.6	1.0
	TD	ºC	19	10.5	13.9	11.7	1.0
	TT	ºC	27	10.2	15.2	12.2	1.1
DO	IN	mg/L	43	1.0	5.6	1.9	0.5
	AC	mg/L	15	1.4	1.9	1.6	0.2
	TA	mg/L	17	1.3	4.4	1.8	0.6
	TB	mg/L	17	1.2	4.7	1.6	0.5
	TC	mg/L	17	0.7	2.7	1.6	0.2
	TD	mg/L	17	1.1	2.3	1.6	0.3
	TT	mg/L	26	0.7	1.9	1.5	0.2
ORP	IN	mV	25/21	-51.0/97.0	106/389	21.7/267	42.4/91.9
	AC	mV	0/15	NM/300	NM/419	NM/345	NM/34.5
	TA	mV	14/5	-50.0/99.0	99.0/232	12.7/158	42.1/48.0
	TB	mV	14/5	-47.0/100	102/245	11.4/161	40.4/52.8
	TC	mV	14/5	-49.0/98.0	104/248	10.4/161	40.4/54.5
	TD	mV	14/5	-49.0/95.0	104/252	9.1/162	39.9/57.0
	TT	mV	11/16	-20.0/152	77.0/421	21.5/337	25.6/58.4
Free Chlorine (as Cl_2)	AC	mg/L	0/20	NM/0.3	NM/0.8	NM/0.4	NM/0.1
	TA	mg/L	0/5	NM/0.3	NM/0.7	NM/0.4	NM/0.2
	TB	mg/L	0/5	NM/0.0	NM/0.4	NM/0.3	NM/0.2
	TC	mg/L	0/5	NM/0.0	NM/0.4	NM/0.3	NM/0.2
	TD	mg/L	0/5	NM/0.0	NM/0.4	NM/0.3	NM/0.2
	TT	mg/L	0/16	NM/0.3	NM/0.5	NM/0.4	NM/0.1
Total Chlorine (as Cl_2)	AC	mg/L	0/21	NM/0.4	NM/0.9	NM/0.5	NM/0.1
	TA	mg/L	0/5	NM/0.3	NM/0.5	NM/0.5	NM/0.1
	TB	mg/L	0/5	NM/0.0	NM/0.5	NM/0.4	NM/0.2
	TC	mg/L	0/5	NM/0.0	NM/0.5	NM/0.4	NM/0.2
	TD	mg/L	0/5	NM/0.0	NM/0.5	NM/0.4	NM/0.2
	TT	mg/L	0/16	NM/0.4	NM/0.6	NM/0.4	NM/0.1
Total Hardness (as $CaCO_3$)	IN	mg/L	28	65.1	133	98.2	17.2
	AC	mg/L	13	77.7	118	101	15.9
	TT	mg/L	28	82.4	151	104	15.6
Ca Hardness (as $CaCO_3$)	IN	mg/L	28	39.4	91.5	64.9	14.3
	AC	mg/L	13	49.9	87.9	70.8	13.6
	TT	mg/L	28	58.6	103	74.0	11.4
Mg Hardness (as $CaCO_3$)	IN	mg/L	28	22.5	55.5	33.4	8.1
	AC	mg/L	13	25.3	37.1	30.1	3.7
	TT	mg/L	28	22.5	48.0	30.4	5.8

(a) See Table 3-3.
NM = not measured
NA = not applicable
NTU = nephelometric turbidity unit
SU = standard units
One-half of detection limit used for nondetect results for calculations.
Duplicate samples included for calculations.

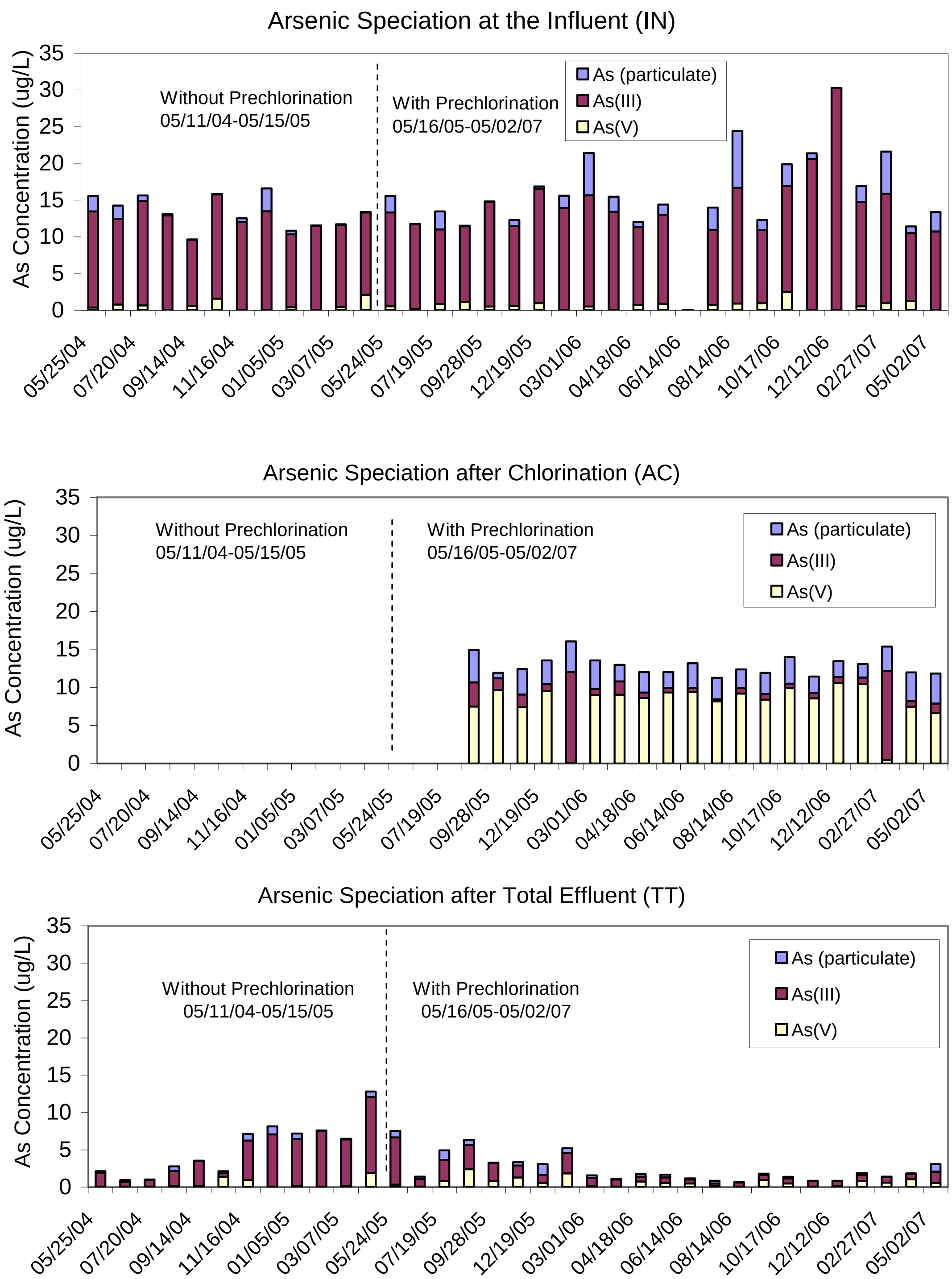


Figure 4-12. Concentrations of Arsenic Species at Wellhead, After Chlorination, and After Combined Effluent

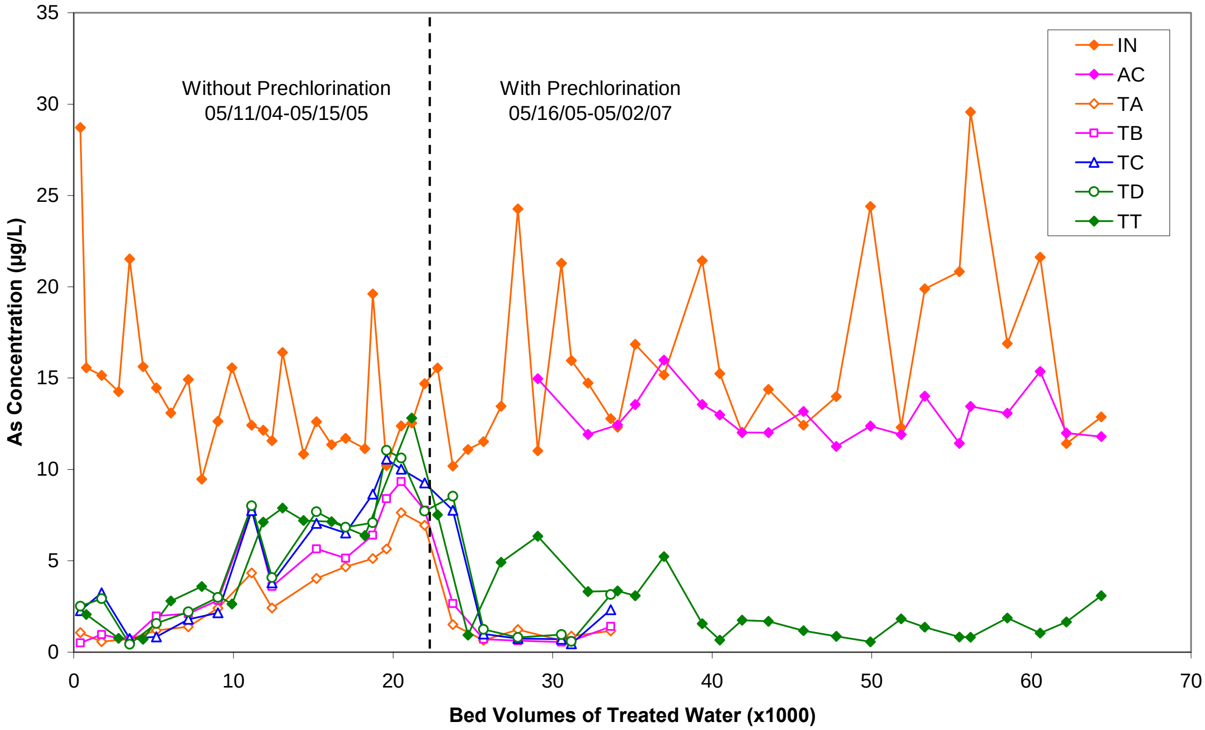


Figure 4-13. Total Arsenic Breakthrough Curves

performance evaluation. By the end of the study, the APU system had treated approximately 154,001,000 gal of water, equivalent to 64,500 BV or 81% of the vendor-estimated working capacity of 80,000 BV.

Prechlorination oxidized As(III) to As(V) and provided required chlorine residuals to the distribution system. As shown in Figure 4-12, most samples collected after prechlorination at the AC location contained mostly As(V) and particulate arsenic, indicating effective oxidation of As(III) with chlorine. (The trace amounts of As(III) measured were believed to have been caused primarily by the speciation method.) The exceptions were the two samples collected on January 17, 2006, and February 27, 2007, during which arsenic oxidation did not appear to occur. Onsite free and total chlorine measurements indicated the presence of residual chlorine; therefore, sampling or analytical errors were suspected for these samples. Typically at the AC location, free chlorine levels were measured at 0.4 to 0.9 mg/L (as Cl_2), which were very similar to total chlorine levels ranging from 0.3 to 0.8 mg/L (Table 4-7). Except for the first three weeks, average chlorine residuals measured at the TA, TB, TC, TD, and TT locations were similar to or slightly lower than those at the AC location, indicating little or no chlorine consumption through the adsorption vessels.

The performance evaluation study demonstrated that, while SORB 33™ media has some adsorptive capacity for soluble As(III), the media life can be significantly increased by oxidizing As(III) to As(V) with chlorine before adsorption. The media bed effectively removed soluble As(V) and particulate As (about 19% of the arsenic removed). Some As(III) previously removed by the media can be desorbed or displaced, but the desorption or displacement ceases to occur as soon as As(III) on the media is oxidized by the incoming chlorine.

Iron. Total iron concentrations in raw water ranged from 101 to 312 µg/L and averaged 177 µg/L (Table 4-6). Iron existed primarily in the soluble form ranging from 98.9 to 285 µg/L and averaging 151 µg/L. Although existing as a cation, soluble iron was removed by SORB 33™ as demonstrated by the breakthrough curves shown in Figure 4-14 before switching to prechlorination. It is not clear what mechanisms govern the removal of cationic species by iron-based media, but a similar observation was made at the other arsenic demonstration site at Queen Anne's County in MD, where iron-based media E33 was used to remove arsenic (Chen et al., 2008b).

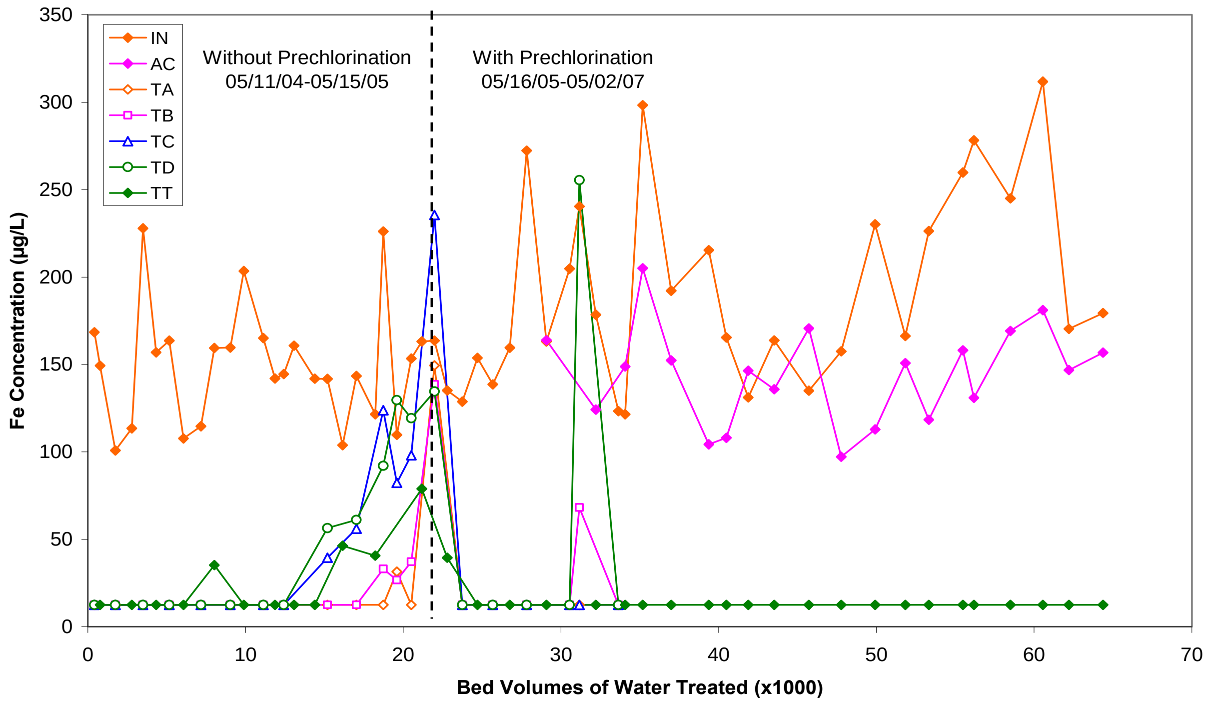


Figure 4-14. Total Iron Concentrations vs. Bed Volumes

The breakthrough curves shown in Figure 4-14 indicate that soluble iron was removed to below the method detection limit of 25 µg/L up to about 12,400 BV and then broke through from the four adsorption vessels rather quickly, as shown at TA, TB, TC, TD, and TT, with concentrations reaching those in raw water at about 22,000 BV. After switching to prechlorination on May 16, 2005, unlike arsenic, iron concentrations were quickly reduced to below the detection limit of 25 µg/L and stayed at the non-detectable level, except for one sampling event on September 13, 2005, through the remainder of the evaluation study. Upon chlorination, soluble iron in source water was oxidized to Fe(III) and precipitated as iron solids, which were removed by SORB 33™ media via filtration. As a result, the differential pressure across the media beds began to rise steadily, thus requiring more frequent backwash of the media beds as discussed in Section 4.4.2.

Manganese. Figure 4-15 shows total Mn concentrations versus BV of water treated across the treatment train. Total Mn concentrations in raw water ranged from 12.3 to 25.9 µg/L and averaged 16.2 µg/L (Table 4-6). Manganese existed almost entirely in the soluble form with concentrations ranging from 12.4 to 19.7 µg/L and averaging 15.8 µg/L.

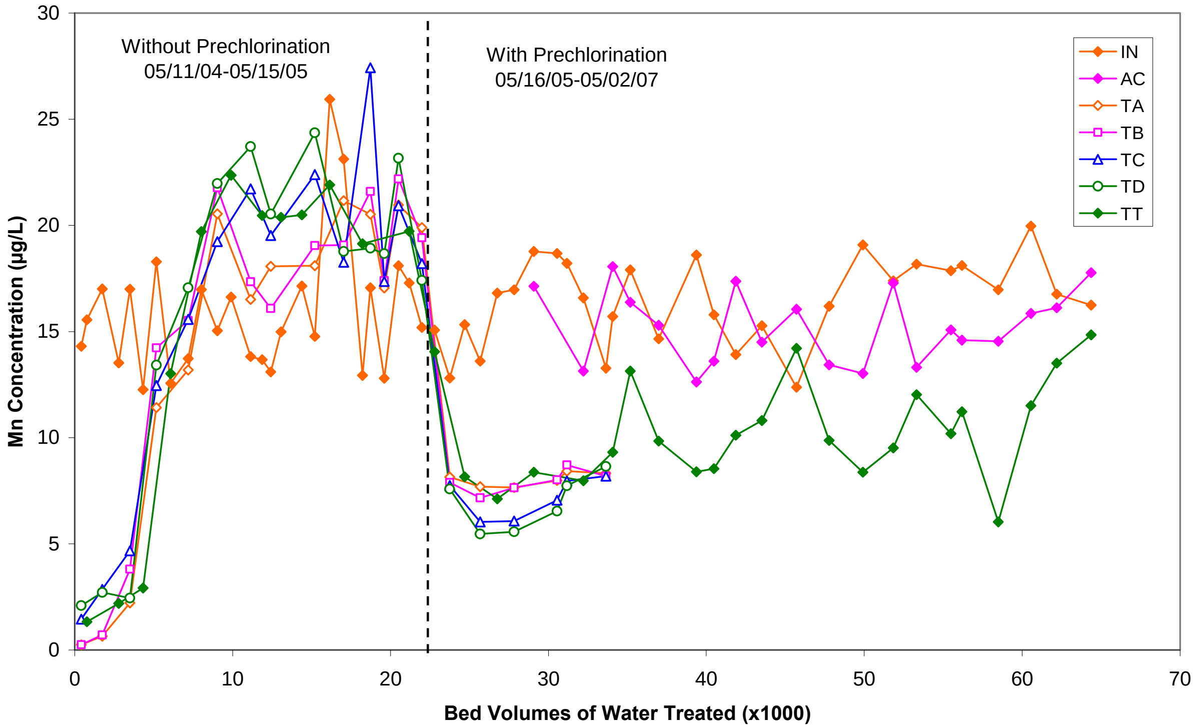


Figure 4-15. Total Manganese Concentrations Versus Bed Volumes

From May 11, 2004 to May 10, 2005 without prechlorination, total manganese, existing mainly as soluble manganese, broke through from the adsorption vessels almost immediately after system startup, with concentrations increasing from <3 µg/L to the levels in raw water within about 6,000 BV. After this point manganese concentrations in the treated water became higher than those in raw water until the system was switched to prechlorination. It is not clear why manganese concentrations increased in the treated water, although it was possible that Mn(II) with less adsorptive affinity was displaced by other more strongly adsorbed cations, such as Fe(II), thus exhibiting this chromatographic-like effect. Similar observations with higher manganese concentrations in the system effluent also were made at another arsenic removal demonstration site at Queen Anne's County in MD (Chen et al., 2008b).

After switching to prechlorination on May 16, 2005, through the end of the performance evaluation, total manganese concentrations in the treated water were reduced by 33 to 55%. As indicated in Table 4-6, chlorination oxidized and precipitated approximately 40% of soluble Mn (i.e., Mn[II]) in source water, presumably, to MnO_2. Previous studies revealed that the amount of Mn(II) that precipitated upon chlorination varied significantly (Knocke et al., 1987; Knocke et al., 1990; Condit and Chen, 2006; McCall et al., 2007), probably due to varying oxidation kinetics. At EPA arsenic removal demonstration sites, <10% Mn(II) precipitation was observed at two sites (i.e., Delavan, WI and Bruni, TX), 14.6 to 55.0% at seven sites, and 93.5% at one site (Alvin, TX). At Chateau Estates in Springfield, OH, 1.1 to 98% of soluble manganese was precipitated during 13 speciation events (McCall et al., 2007). It is not clear why precipitation rates varied so widely and why some raw waters had slower oxidation kinetics than others. The contact time did not seem to correlate directly with the precipitation rate (McCall et al., 2007).

Other Water Quality Parameters. In addition to arsenic, iron, and manganese, other water quality parameters were analyzed to provide insight into the chemical processes occurring within the treatment system. The results of the water quality parameters are included in Appendix B and are summarized in Table 4-7.

Onsite measurements of pH remained consistent at all sampling locations, with average values ranging from 7.7 to 8.0 across the treatment train. Average alkalinity results ranged from 240 to 250 mg/L (as $CaCO_3$) across the treatment train. The average value of total hardness was 98.2 mg/L (as $CaCO_3$) in raw water and 104 mg/L (as $CaCO_3$) in the treated water. The samples contained predominantly calcium hardness (approximately 66% to 71%).

Averaged fluoride concentrations ranged from 1.2 to 1.4 mg/L at all sampling locations and were not affected by SORB 33™ media. Orthophosphate and total phosphorus were below the detection limit in all samples. The average silica concentration was 9.0 mg/L (as SiO_2) in raw water and 7.8 in the system effluent (TT), indicating some removal by SORB 33™ media. Sulfate concentrations ranged from 44 to 136 mg/L (averaged 75.2 mg/L) in raw water, 51 to 146 mg/L (averaged 93.3 mg/L) after chlorination, and 61 to 140 mg/L (averaged 97.8 mg/L) in the effluent. As shown in Figure 4-16, sulfate concentrations at AC and TT were higher than those in raw water, both before and after switching to prechlorination (although the increases appear to be even more significantly during the second half of performance evaluation). Several attempts were made to examine the cause of the increases, including the analysis of NaOCl solution and the analysis for sulfide (dissolved hydrogen sulfide) across the treatment train. The operator reported the presence of dark slime/black precipitates in the City's water heater, coffee machine, and other equipment using water from the distribution system. This can be an indication of the presence of sulfur-oxidizing bacteria, which can convert sulfide into sulfate. However, no detectable levels of sulfide were found in the samples taken across the treatment train. Despite all of the efforts made, the cause of the observation remained unknown.

DO levels ranged from 1.0 to 5.6 and averaged 1.9 mg/L in raw water and ranged from 0.7 to 4.7 mg/L and averaged 1.6 mg/L in the treated water. There did not appear to be any significant difference in DO level in raw water, after chlorination, or after adsorption vessels. ORP readings at the IN location varied from -51 to 389 mV. As expected, with prechlorination, ORP readings at the AC location increased, ranging from 300 to 419 mV. ORP readings following adsorption at the TA, TB, TC, TD, and TT sampling locations ranged from 95 to 421 mV, somewhat lower than those measured at the AC location, indicating some effect from the media.

4.5.2 Backwash Water Sampling. Backwash was performed one vessel at a time using raw water (non-chlorinated). Backwash wastewater was sampled periodically from the sample ports located in the backwash effluent discharge lines from each vessel. The unfiltered samples were analyzed for pH, turbidity, and TDS/TSS. Filtered samples using 0.45-μm disc filters were analyzed for soluble arsenic, iron, and manganese. For the last seven backwash wastewater sampling events (taking place since February 1 through September 12, 2006), TSS and total As, Fe, and Mn concentrations also were measured. The analytical results are summarized in Table 4-8.

pH values of backwash wastewater ranged from 7.4 to 8.4 and averaged 7.8, similar to those of raw water. Soluble arsenic concentrations in backwash wastewater averaged 11 μg/L for backwash events conducted during the period without prechlorination. This average concentration was slightly lower than that in raw water (i.e., 13.7 μg/L [on average]). It appears that, although existing as soluble As(III), some arsenic was removed by the media during backwash. Soluble arsenic concentrations in backwash wastewater averaged 6 μg/L for backwash events conducted during the period with prechlorination. This average concentration was less than half of that in raw water, indicating significant removal of soluble arsenic, existing again as As(III), by the media during backwash. Soluble iron concentrations ranged from <25 to

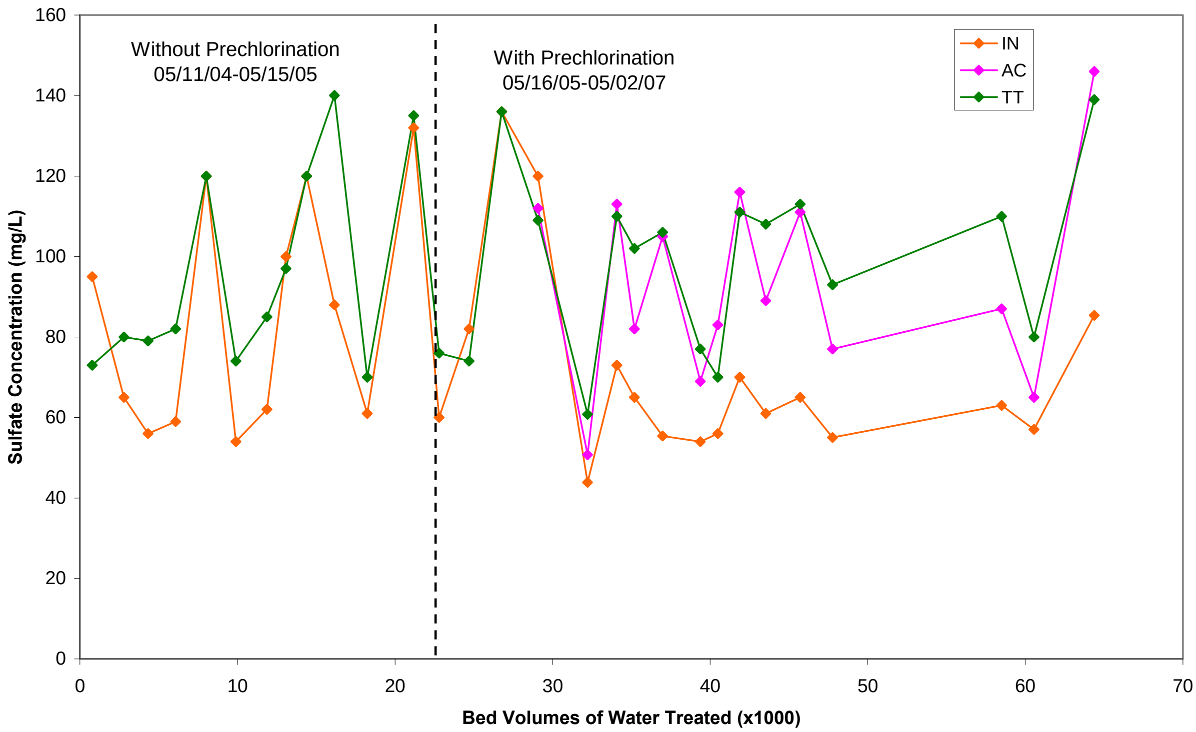


Figure 4-16. A Comparison of Sulfate Concentrations at IN, AC, and TT Locations

384 µg/L and averaged 96.4 µg/L, which was also less than that in raw water (i.e., 151 µg/L [on average]), indicating some removal by the media during backwash. Soluble manganese concentrations were about the same as those in raw water, ranging from 9.1 to 23.2 µg/L and averaged 16.4 µg/L. In general, the results measured from Vessels A, B, C, and D were consistent among one another.

As expected, total arsenic, iron, and manganese concentrations were significantly higher than the respective soluble fractions, averaging 157, 21,950, and 497 µg/L, respectively. Measured particulate As in backwash wastewater averaged 147µg/L. Particulate As might be associated with either iron particles filtered out by the media beds during the service cycle or the media fines. Assuming the average backwash flowrate was 200 gpm and the backwash duration was 25 min per vessel, the total amount of backwash wastewater generated during each backwash event would be 20,000 gal. Assuming that 94 mg/L of TSS (i.e., the average of TSS values measured on seven backwash events from February 1 to September 12, 2006) was produced in 20,000 gal of backwash wastewater from the vessels, approximately 15.6 lb of solids would be discharged during each backwash event. Based on the average particulate metal data collected during the last seven backwash events (i.e., 147 µg/L of particulate arsenic, 21,847 µg/L of particulate iron, and 481 µg/L of particulate manganese), the solids discharged would be composed of 0.03 lb of arsenic (i.e. 0.2% by weight), 3.6 lb of iron (i.e. 23% by weight), and 0.08 lb of manganese (i.e. 0.5% by weight).

Table 4-8. Backwash Wastewater Sampling Results

Sampling Event		BW1 Vessel A											BW2 Vessel B										
		pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn	pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn
No.	Date	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	06/15/04	7.4	28	648	NS	NS	4.9	NS	NS	<25	NS	11.6	7.6	27	1,010	NS	NS	6.1	NS	NS	<25	NS	13.2
2	07/28/04	7.9	55	770	NS	NS	6.5	NS	NS	<25	NS	15.7	7.9	36	852	NS	NS	8.5	NS	NS	<25	NS	17.2
3	09/09/04	7.4	33	392	NS	NS	6.1	NS	NS	<25	NS	16.8	7.7	28	698	NS	NS	8.8	NS	NS	<25	NS	15.8
4	10/22/04[(a)]	7.9	24	612	NS	NS	9.1	NS	NS	38.2	NS	17.5	7.9	10	816	NS	NS	15.6	NS	NS	120	NS	15.0
5	01/14/05	7.6	4	534	NS	NS	20.0	NS	NS	280	NS	19.2	7.8	2	740	NS	NS	11.8	NS	NS	123	NS	16.6
6	02/22/05	7.7	4	396	NS	NS	14.7	NS	NS	110	NS	16.5	7.8	3	800	NS	NS	11.3	NS	NS	113	NS	17.8
7	04/08/05	8.0	3	398	NS	NS	12.4	NS	NS	91.9	NS	17.3	8.0	8	742	NS	NS	11.5	NS	NS	75.7	NS	18.0
8	05/23/05[(b)]	7.4	8	1000	NS	NS	5.1	NS	NS	47.2	NS	11.5	7.5	26	1030	NS	NS	5.4	NS	NS	59.2	NS	14.5
9	07/06/05	7.9	40	948	NS	NS	7.5	NS	NS	88.5	NS	12.4	7.8	41	998	NS	NS	5.7	NS	NS	31.1	NS	9.5
10	10/12/05	7.8	270	462	NS	NS	3.2	NS	NS	59.1	NS	15.4	7.9	270	764	NS	NS	6.3	NS	NS	112	NS	13.9
11	02/01/06	8.0	NS	880	150	257	7.2	250	54766	138	1479	19.7	8.0	NS	920	190	331	10.1	321	51699	384	1384	28.7
12	02/28/06	8.1	NS	866	98	202	5.7	196	38115	125	903	14.9	8.1	NS	922	106	161	4.7	156.8	24516	54.5	615	14.6
13	04/06/06	8.0	NS	606	16	36.8	3.6	33.2	3241	46.8	84.0	13.7	8.0	NS	856	71	143	6.8	137	12301	176	324	18.1
14	04/29/06	8.4	NS	938	74	126	5.5	121	14117	81.0	342	15.7	8.3	NS	922	64	119	6.3	112	12465	140	308	16.4
15	06/01/06	8.0	NS	538	80	133	4.2	129	20694	46.9	164	16.9	8.0	NS	830	108	210	5.6	205	28622	51.7	213	20.4
16	07/26/06	8.0	NS	880	56	54.4	6.5	47.9	9892	27.1	330	12.8	8.1	NS	904	44	115	6.0	109	11815	<25	398	9.7
17	09/12/06	7.9	NS	480	240	276	4.9	271	31179	90.4	839	23.2	8.0	NS	636	80	201	5.8	195	21545	145	593	14.0

Sampling Event		BW3 Vessel C											BW4 Vessel D										
		pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn	pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn
No.	Date	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	06/15/04	7.6	38	864	NS	NS	7.4	NS	NS	<25	NS	15.2	7.6	39	678	NS	NS	7.0	NS	NS	<25	NS	14.4
2	07/28/04	7.9	50	808	NS	NS	9.1	NS	NS	28.7	NS	19.0	7.9	62	888	NS	NS	9.9	NS	NS	<25	NS	18.2
3	09/09/04	7.6	28	798	NS	NS	9.7	NS	NS	35.7	NS	18.0	7.4	25	862	NS	NS	9.7	NS	NS	60.0	NS	17.9
4	10/22/04[(a)]	7.9	16	838	NS	NS	18.8	NS	NS	154	NS	17.4	8.1	2	410	NS	NS	19.5	NS	NS	225	NS	17.3
5	01/14/05	7.8	2	914	NS	NS	11.4	NS	NS	161	NS	17.5	7.9	1	910	NS	NS	11.2	NS	NS	157	NS	17.8
6	02/22/05	7.9	2	862	NS	NS	11.0	NS	NS	175	NS	18.2	7.9	10	914	NS	NS	11.4	NS	NS	115	NS	18.2
7	04/08/05	8.0	3	882	NS	NS	11.9	NS	NS	165	NS	19.5	8.0	7	898	NS	NS	11.6	NS	NS	108	NS	18.8
8	05/23/05[(b)]	7.7	89	886	NS	NS	6.6	NS	NS	139	NS	16.8	7.8	31	926	NS	NS	6.9	NS	NS	149	NS	15.1
9	07/06/05	7.8	55	912	NS	NS	8.3	NS	NS	98.9	NS	12.1	7.8	210	906	NS	NS	6.9	NS	NS	124	NS	12.7
10	10/12/05	7.9	320	870	NS	NS	7.1	NS	NS	126	NS	15.5	7.9	21	880	NS	NS	8.0	NS	NS	149	NS	16.2
11	02/01/06	8.0	NS	904	178	382	6.9	375	61712	96.9	1605	19.6	8.0	NS	886	116	30.8[(c)]	5.3	25.5	9801[(c)]	<25	79.9[(c)]	15.6
12	02/28/06	8.1	NS	922	66	118	5.4	113	16530	104	421	16.6	8.2	NS	908	76	129	5.5	123	16839	89.1	440	15.2
13	04/06/06	8.0	NS	894	20	41.1	4.6	36.5	3278	43.7	75.6	18.4	8.0	NS	878	33	57.2	4.1	53.1	5454	89.2	176	17.3
14	04/29/06	8.4	NS	924	44	97.2	6.8	90.4	9735	222	202	19.3	8.4	NS	924	44	103	7.2	95.4	11059	224	229	17.8
15	06/01/06	8.0	NS	876	120	189	5.3	183	31030	59.0	203	17.8	8.1	NS	862	130	185	5.2	180	32997	73.6	231	21.0
16	07/26/06	8.1	NS	898	56	32.8	4.4	28.4	5431	<25	174	12.6	8.1	NS	922	72	138	4.9	133	19717	<25	600	9.1
17	09/12/06	8.0	NS	850	74	169	7.3	162	16830	222	416	18.1	8.1	NS	868	226	240	6.4	234	29883	147	758	14.2

TDS = total dissolved solids; TSS = total suspended solids; NS = not sampled
(a) Vessel B did not fast rinse properly during backwash, possibly affecting BW2 sample.
(b) Prechlorination began 05/16/05.
(c) Reanalysis indicated similar results.

The particulate iron present in the backwash wastewater might have come from at least two separate sources, i.e., the iron from raw water or media fines. The amount of iron attributable to both sources was estimated using the data of the last seven backwash sampling events conducted from February 1 to September 12, 2006 (Table 4-8). The amount of iron attributable to the iron removed from raw water was estimated based on the average throughput between backwash events (i.e., 1,513,900 gal) and the average total iron concentration (i.e., 171 µg/L) in source water during the same period. Assuming complete removal of iron solids by the media beds and complete discharge of iron solids during the backwash events, there would have been 980 g of iron solids, as part of TSS discharged per backwash event, originating from the iron in source water. Using an average TSS value of 94 mg/L in 20,000 gal of backwash wastewater, approximately 7,117 g of solids would have been discharged as TSS. Based on the wastewater metal analyses, 23% of the solids would be iron, thus amounting to 1637 g. This amount is much higher than the 980 g derived from the iron in raw water, indicating a significant amount of media fines in backwash wastewater.

Backwash solid samples were collected on July 12, 2006, from Vessels A and B. No backwash solid samples were collected from Vessels C and D. The samples were analyzed for total metals and the results are presented in Table 4-9. Arsenic, iron, and manganese levels in the solids were averaged 0.022 mg/g (or 0.002%), 2.5 mg/g (or 0.25%), and 0.3 mg/g (or 0.03%), respectively. These amounts were low when compared to those based on backwash wastewater metal analysis. Calcium levels in the solids were high, averaging 375 mg/g (or 37.5%). The significantly high calcium content suggested that the solid samples taken for metal analysis might contain sediments. A high percentage of sediments in solid samples, in turn, could cause an under estimation of arsenic, iron, and manganese in the solids. The ratio of iron to arsenic measured in backwash solid samples was 114, which is consistent with that measured in backwash wastewater samples of around 120.

Table 4-9. Backwash Solids Total Metal Results (µg/g)

Analyte	Mg	Al	Si	P	Ca	V	Mn	Fe	Ni	Cu	Zn	As	Cd	Sb	Ba	Pb
Vessel A	22,916	305	1,028	92	367,332	<1.4	328	3,333	25.0	268	117	35.0	<0.5	<0.5	124	3.0
Vessel B	31,736	170	730	386	381,977	0.7	261	1,612	217	913	338	9.0	<0.5	<0.5	72.0	18.0

Note: Solids collected on July 12, 2006, from Vessels A and B for total metal analysis.
Average compositions calculated from triplicate analyses.

4.5.3 Distribution System Water Sampling. Distribution system water samples were collected to determine if water treated by the arsenic removal system would impact the lead, copper, and arsenic levels and other water chemistry in the distribution system. Prior to system startup, baseline distribution water samples were collected on December 4 and 18, 2003, and January 8 and 21, 2004. Since system startup, distribution water sampling continued monthly at the same three locations until January 25, 2006. The samples were analyzed for pH, alkalinity, arsenic, iron, manganese, lead, and copper and the results are presented in Table 4-10.

The main differences observed between the baseline samples and samples collected after system startup were decreases in arsenic concentration at each of the three sampling locations. Arsenic concentrations were reduced from a pre-startup level of 10.3 µg/L (on average) to 6.2 µg/L before implementing prechlorination and to 4.9 µg/L following prechlorination. In Figure 4-17, arsenic concentrations measured in distribution system water were compared to those measured in system effluent. In general, concentrations in distribution system water mirrored those in system effluent, except two apparent outliers at throughput around 13,000 BV.

Measured pH values ranged from 7.3 to 8.3, and alkalinity levels ranged from 229 to 268 mg/L (as $CaCO_3$). Iron concentrations ranged from <25 to 94.5 μg/L, with the majority of the samples being <25 μg/L. In general, iron concentrations in the distribution system samples decreased since system startup. Manganese concentrations in the distribution system averaged 6.7 μg/L for baseline samples, and averaged 12.9 and 7.7 μg/L, respectively, for samples taken during the operation without and with prechlorination. Manganese levels appeared to decrease initially after the system startup, but have since increased to above baseline levels starting from August 10, 2004. The manganese levels measured in the distribution system mirrored those in the system effluent results.

Lead levels ranged from <0.1 to 3.0 μg/L, which were less than the action level of 15 μg/L. The average lead level was 1.1 μg/L in baseline samples and 0.9 μg/L for samples taken after system startup. Lead concentrations in the distribution system appeared to have not been affected by the operation of the arsenic treatment system. Copper concentrations ranged from 4.9 to 242 μg/L, with no samples exceeding the 1,300 μg/L action level. The average copper level was 132 μg/L in baseline samples and 60.8 μg/L for samples taken after system startup. Copper concentrations in the distribution system were generally lower than those before treatment.

4.6 System Cost

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

4.6.1 Capital Cost. The capital investment cost for equipment, site engineering, and installation was $305,000 (see Table 4-11). The equipment cost included the cost for the two skid-mounted APU-300 units ($144,400), SORB 33™ media ($150/ft^3 or $5.34/lb to fill four vessels with a total cost of $48,000), miscellaneous materials and supplies ($3,400), and vendor's labor and travel for the system shakedown and startup ($22,200). The equipment cost is 71% of the total capital investment.

The engineering cost included the cost for the design work necessary to develop the final system layout and footprint within the building, design of the piping connections up to the distribution tie-in points in the building, and the design of the electrical connection and conduit plan. The engineering cost also included the cost for the submission of the plans to MDEQ for permit review and approval. Engineering cost amounted to $35,500, or 12% of the total capital investment.

The installation cost included equipment and labor to unload and install the system, perform piping tie-ins and electrical work, and load and backwash the media. Piping tie-ins were completed using ductile iron pipe, valves, and fittings. Installation cost was $51,500, or 17% of the total capital investment.

The capital cost of $305,000 was normalized to $477/gpm ($0.33/gpd) of design capacity using the system's rated capacity of 640 gpm (or 921,600 gpd). The capital cost also was converted to an annualized cost of $28,790/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-yr return period (Chen et al., 2004). Assuming that the system operated 24 hr/day, 7 day/wk at the design flowrate of 640 gpm to produce 336,384,000 gal/yr, the unit capital cost would be $0.09/1,000 gal. During the performance evaluation study, the system operated only 4.5 hr/day and produced an average of 51,333,670 gal of water in one year, so the unit capital cost increased to $0.56/1,000 gal at this reduced rate of usage. These calculations did not include the building construction cost.

Table 4-10. Distribution System Sampling Results

Sampling Event		DS1 4397 Main Street LCR 1st Draw								DS2 6783 Cade Road LCR 1st Draw								DS3 7065 Merrill Street LCR 1st Draw							
		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	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	12/04/03	7.0	7.9	246	11.5	75.6	4.9	1.8	44.6	8.0	7.6	244	9.0	33.8	6.5	0.5	128	15.0	7.3	252	10.4	70.5	9.7	2.1	183
BL2	12/18/03	7.0	8.0	254	10.1	88.6	6.1	1.1	51.4	6.7	7.9	246	7.2	49.8	6.3	<0.1	218	14.5	7.9	282	8.8	94.5	10.0	1.0	156
BL3	01/08/04	7.0	7.7	268	11.8	44.8	5.3	1.0	53.9	7.0	7.6	256	8.8	<25	6.2	0.1	183	15.0	7.3	260	11.7	34.9	10.2	1.0	194
BL4	01/21/04	6.0	8.1	258	13.3	92.8	6.7	2.7	72.7	7.5	8.2	249	9.0	30.6	5.0	0.5	242	15.0	8.2	256	11.8	44.1	4.1	0.9	56.4
1	06/15/04	6.0	7.6	232	4.8	<25	1.7	0.5	9.1	6.2	7.6	245	5.5	<25	2.6	<0.1	6.3	14.9	7.6	232	3.8	<25	2.4	0.3	4.9
2	07/13/04	6.0	7.8	263	3.8	<25	3.4	0.8	27.3	6.0	7.8	243	4.8	<25	4.7	0.3	93.5	14.9	7.8	239	4.1	<25	4.7	2.3	74.5
3	08/10/04	6.0	7.8	239	3.0	<25	9.6	0.4	21.4	8.3	7.7	235	3.0	<25	6.5	0.3	62.3	15.0	7.8	239	3.1	<25	11.5	1.4	70.1
4	09/08/04	6.0	7.9	234	3.9	<25	11.4	0.4	24.8	6.5	7.9	234	4.3	<25	13.8	<0.1	94.8	15.0	7.9	242	4.2	<25	14.0	<0.1	73.3
5	10/05/04	6.0	7.6	244	4.1	<25	16.1	0.9	31.0	6.0	7.8	244	4.5	<25	17.6	1.7	55.1	15.0	7.9	244	5.0	<25	20.4	2.2	62.1
6	11/02/04	6.0	7.8	242	5.3	<25	10.2	1.2	45.0	8.3	8.1	246	6.1	<25	17.8	0.6	33.5	15.0	8.0	246	5.8	<25	16.9	0.9	53.9
7	12/08/04	8.3	8.0	244	11.8	63.6	10.9	1.2	49.4	6.7	8.0	244	12.1	62.4	18.0	0.5	65.5	15.5	8.1	244	6.8	<25	19.6	0.4	13.6
8	01/12/05	6.0	7.8	240	6.1	<25	7.8	1.7	56.0	6.8	7.8	240	5.2	<25	16.5	0.5	108	14.8	7.8	244	6.8	32.8	17.1	1.6	63.0
9	02/09/05	6.0	8.0	259	5.6	27.4	7.0	1.5	53.7	7.0	8.0	268	4.8	<25	13.1	0.4	130	15.0	8.0	268	5.9	25.3	16.0	1.8	90.5
10	03/08/05	6.0	8.3	254	7.6	<25	8.2	2.0	57.6	6.8	8.2	254	7.1	28.2	14.7	0.3	197	15.0	8.1	259	9.8	84.5	31.1	0.7	103
11	04/13/05	6.0	8.2	251	8.2	62.4	10.6	1.6	39.4	7.0	8.1	268	7.8	35.9	12.8	0.3	118	15.0	8.0	260	10.4	79.0	25.3	2.7	220
12	05/10/05	6.0	7.9	268	9.0	67.9	15.7	0.7	13.1	7.5	8.0	268	7.7	34.0	13.7	0.6	140	15.0	7.9	268	11.3	93.4	19.6	3.0	110
13	06/07/05[(a)]	6.0	7.8	255	6.7	<25	9.7	0.4	21.8	5.8	7.8	251	8.5	<25	15.3	0.4	68.2	15.0	7.9	255	7.8	<25	15.6	1.0	53.1
14	07/06/05	6.0	7.6	255	4.5	<25	5.9	0.5	27.5	6.8	7.7	255	5.5	<25	8.7	0.5	109	15.3	7.8	242	4.0	<25	5.1	0.6	56.3
15	08/03/05	6.0	7.8	233	7.0	<25	8.0	0.8	29.3	7.1	7.8	242	5.4	<25	7.5	0.5	77.0	15.0	7.8	246	3.5	<25	5.0	1.9	66.4
16	09/07/05	6.0	7.8	229	4.0	<25	4.4	0.6	9.6	8.8	7.9	246	4.7	<25	7.8	0.4	30.6	15.0	7.8	246	4.6	<25	6.0	0.6	21.8
17	10/05/05	6.0	7.9	251	2.9	<25	5.8	0.7	25.7	6.5	7.7	264	3.4	<25	7.6	0.4	86.7	12.0	7.8	264	3.1	<25	7.0	1.5	82.0
18	01/25/06	6.0	8.2	246	4.5	<25	1.8	0.4	24.3	8.5	8.0	251	3.7	<25	9.1	0.1	11.9	16.0	8.0	255	3.5	<25	8.9	0.1	9.4

Notes: (a) Prechlorination began on May 16, 2005

Alkalinity measured in mg/L as $CaCO_3$. Action levels: 15 µg/L Pb and 1.3 mg/L Cu. BL = baseline sampling; DS = Distribution Sampling

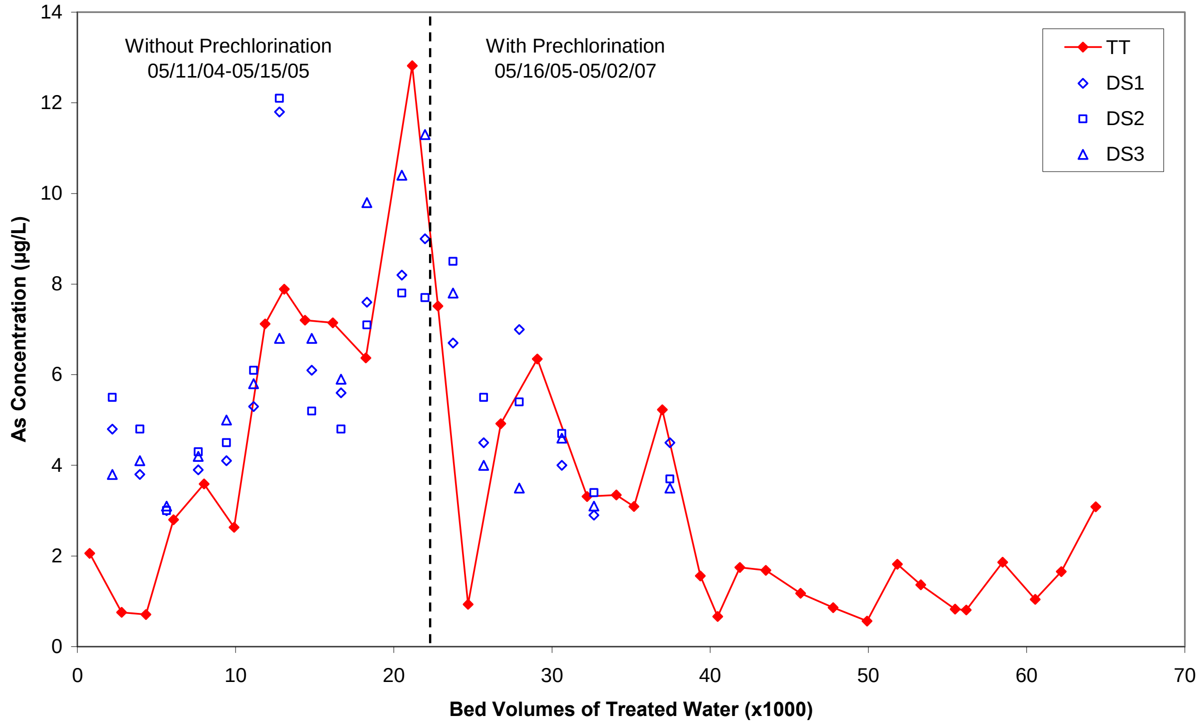


Figure 4-17. Comparsion of Total Arsenic Concentrations in Distribution System Water and APU-300 System Effluent

Table 4-11. Capital Investment for APU-300 System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment			
APU-300 Skid-Mounted System	2	$144,400	–
SORB-33™ Media	320 ft^3	$48,000	–
Misc. Equipment and Materials	–	$3,400	–
Vendor Labor	–	$17,500	–
Vendor Travel	–	$4,700	–
Equipment Total	–	**$218,000**	**71%**
Engineering			
Subcontractor	–	$27,740	–
Vendor Labor	–	$6,680	–
Vendor Travel	–	$1,080	–
Engineering Total	–	**$35,500**	**12%**
Installation			
Subcontractor	–	$42,000	–
Vendor Labor	–	$5,600	–
Vendor Travel	–	$3,900	–
Installation Total	–	**$51,500**	**17%**
Total Capital Investment	–	**$305,000**	**100%**

The total cost for the addition to the existing concrete block well house was $62,602. The primary construction cost totaled $41,468 and included excavation, masonry, carpentry, and concrete floor pouring. The overhead door cost was $1,400. The building cost also included $13,048 for the roof deck work and roofing, including the overhead roof hatches. The building was finished with a wood and aluminum trim and painted white. The cost for painting was $2,135, and the heating and electrical work for the building totaled $4,550.

4.6.2 Operation and Maintenance Cost. O&M cost included only incremental cost associated with media replacement and disposal, chemical supply, electricity, and labor and is summarized in Table 4-12. Because media replacement and disposal did not take place during the performance evaluation period, its cost per 1,000 gal of water treated was calculated as a function of projected media run length using the vendor-estimate of $53,600 for media replacement for all four vessels. This replacement cost included the cost for new media, freight, labor, travel expenses, and media profiling and disposal fee. At the vendor-estimated media capacity of 80,000 BV for As(V) or a throughput of 192,000,000 gal (see Table 4-4), the media replacement cost is projected to be $0.28/1,000 gal (Figure 4-18).

Table 4-12. O&M Cost for APU-300 System

Cost Category	Value	Remarks
Media Replacement and Disposal		
Media Cost ($/ft^3)	$150	Vendor quote
Total Media Volume (ft^3)	320	Four vessels
Media Replacement Cost ($)	$48,000	Vendor quote
Labor Cost ($)	$4,240	Vendor quote
Media Disposal Fee ($)	$1,360	Vendor quote
Subtotal	$53,600	Vendor quote
Media Replacement and Disposal Cost ($/1,000 gal)	See Figure 4-18	Based upon media run length at 10 µg/L arsenic breakthrough
Equipment Replacement		
Replacement Parts Cost ($)	$0.00	Cost related to parts replacement was negligible.
Labor and Travel Cost ($)	$0.00	–
Equipment Replacement Cost ($/1,000 gal)	$0.00	Total system throughput = 154,001,Kgal
Chemical Usage		
Chemical Cost ($)	$0.00	No additional chemicals required.
Electricity		
Electric Utility Charge ($/kWh)	$0.0812	Based on 2003 Detroit Edison Rate
Incremental Daily Usage (kWh)	131	Based on average daily incremental usage from May to November 2004
Estimated Incremental Electricity Cost ($)	$11,647	From May 2004 to May 2007
Incremental Cost ($/1,000 gal)	$0.08	Total system throughput = 154,001,Kgal
Labor		
Average Weekly Labor (hr/week)	3.5	30 minutes/day
Total Labor (hr)	546	156 weeks of performance evaluation
Labor cost ($/1,000 gal)	$0.05	Labor rate = $15/hr and Total system throughput = 154,001 Kgal
Total O&M Cost/1,000 gallons	See Figure 4-18	–

The chemical cost associated with the operation of the treatment system included chlorine addition prior to the adsorption vessels. This treatment step was in use at the site prior to installation of the APU-300 treatment system. The APU-300 treatment system did not have a significant effect on the NaOCl usage based on the data collected during the performance evaluation study. Therefore, the incremental chemical cost due to the APU-300 system was negligible.

The incremental electrical consumption was reviewed. From May to November of 2003, the utility bill totaled $2,610.45 before the treatment plant was installed. From May to November of 2004, the utility bill totaled $4,770.50 after the treatment plant was installed and operational. The incremental utility cost over running the well alone before treatment is approximately $10.64/day or an additional 131 kilowatt hours (KWh) each day at $0.0812 per KWh. The incremental electricity cost over the before-treatment cost was approximately $0.08/1000 gal.

The routine, non-demonstration related labor activities consume only 30 min/day, as noted in Section 4.4.4. The labor cost was $0.05/1,000 gallons of water treated based on this time commitment and a labor rate of $15/hr.

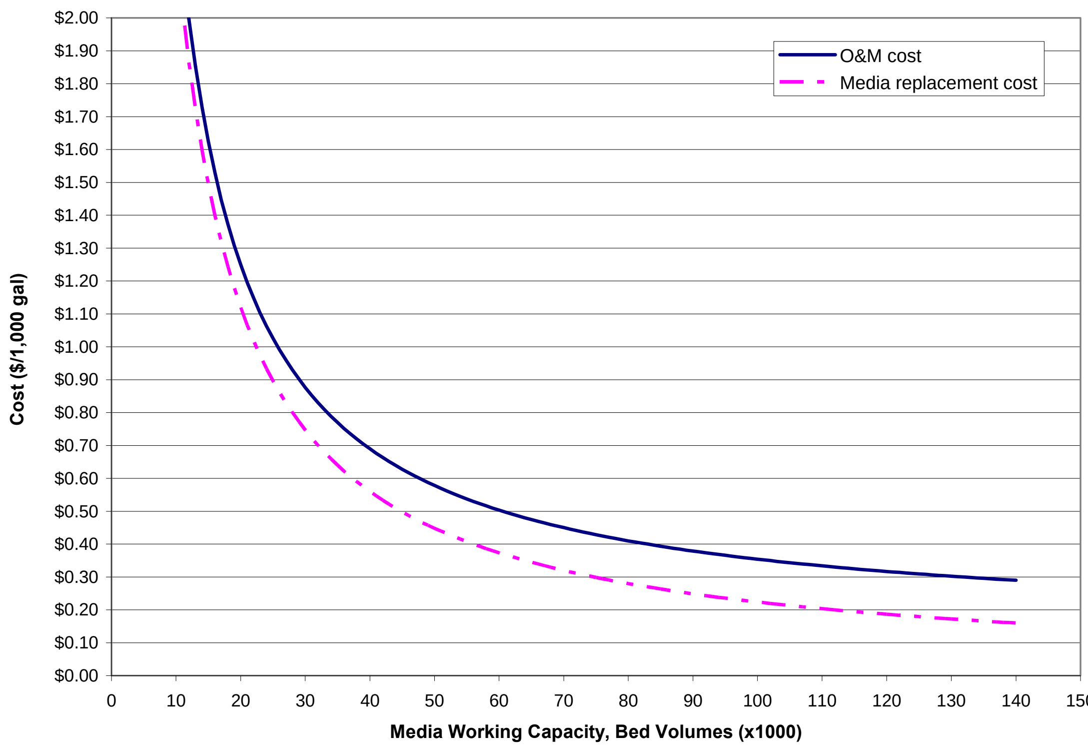


Figure 4-18. Media Replacement and O&M Cost for Brown City, MI, System (Two APU-300 Units)

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APPENDIX A

Operational Data

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
1	05/12/04	NA	NA	107.229	125.518	109.790	114.571	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/13/04	NA	NA	119.759	136.316	119.673	125.300	3.1	2.8	61	56	5	2.6	1.7	52	56	NA
	05/14/04	NA	NA	178.436	196.577	175.054	184.938	4.4	2.8	66	60	6	2.3	1.5	64	62	2
	05/15/04	NA	NA	183.837	201.828	179.684	189.859	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/16/04	NA	NA	228.270	246.131	220.452	233.650	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
2	05/17/04	NA	NA	272.865	290.377	262.550	277.445	3.2	2.9	65	58	7	2.2	1.2	64	60	4
	05/18/04	NA	NA	313.825	331.255	300.841	317.329	3.2	2.9	65	59	6	2.2	1.2	64	60	4
	05/19/04	NA	NA	318.571	335.899	305.065	321.661	3.2	2.9	60	54	6	2.2	1.2	60	54	6
	05/20/04	NA	NA	372.478	389.394	355.552	373.048	3.6	3.1	64	58	6	2.6	1.2	62	58	4
	05/21/04	NA	NA	414.647	431.453	395.179	414.685	3.6	3.1	65	60	5	2.6	1.2	66	60	6
	05/22/04	NA	NA	416.054	432.858	396.406	416.038	3.6	3.1	60	55	5	2.6	1.2	63	58	5
	05/23/04	NA	NA	465.207	481.841	442.715	463.226	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
3	05/24/04	NA	NA	495.832	512.374	491.501	492.931	3.2	2.9	62	58	4	2.4	1.2	64	59	5
	05/25/04	NA	NA	542.984	559.458	515.886	538.692	3.1	3	62	58	4	NR	1.2	64	59	5
	05/26/04	NA	NA	551.846	568.312	524.235	547.306	3.6	3	62	57	5	2.5	1.4	62	57	5
	05/27/04	NA	NA	598.829	615.068	568.329	593.048	3.8	3.2	62	56	6	2.7	1.6	62	56	6
	05/28/04	NA	NA	646.928	662.993	613.441	639.870	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/29/04	NA	NA	689.973	705.651	654.642	681.960	3.7	3.2	66	60	6	2.7	1.4	66	62	4
	05/30/04	NA	NA	704.951	720.591	668.179	696.401	3.2	2.8	62	57	5	2.7	1.5	62	58	4
4	05/31/04	NA	NA	739.799	755.361	701.103	730.179	3.5	3.0	63	57	6	2.7	2	63	58	5
	06/01/04	NA	NA	785.052	800.464	743.762	773.887	3.2	3.0	58	56	2	2.6	2.3	60	56	4
	06/02/04	NA	NA	830.267	845.019	786.476	817.877	3.5	3.0	58	57	1	2.6	2.3	60	56	4
	06/03/04	NA	NA	887.743	902.285	840.696	873.881	3.5	3.0	59	56	3	2.6	2.3	60	56	4
	06/04/04	NA	NA	932.469	946.932	882.967	917.388	3.5	3.0	58	57	1	2.7	2.3	63	58	5
	06/05/04	NA	NA	978.901	993.219	926.814	962.458	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/06/04	NA	NA	1029.094	1043.325	974.219	1011.296	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
5	06/07/04	5.1	NA	1076.384	1090.546	1019.011	1057.645	3.8	3.0	62	56	6	2.6	1.4	62	56	6
	06/08/04	5.8	NA	1129.432	1143.459	1069.078	1109.166	3.6	3.0	63	57	6	2.6	1.4	63	58	5
	06/09/04	5.5	NA	1180.313	1194.214	1117.091	1158.868	3.0	3.0	64	60	4	2.2	1	64	60	4
	06/10/04	3.1	NA	1209.263	1223.006	1144.636	1187.023	3.0	2.8	64	58	6	2.8	1.2	64	60	4
	06/11/04	4.9	NA	1259.343	1273.014	1191.852	1235.582	4.6	2.8	64	58	6	2.4	1.2	65	60	5
	06/12/04	NA	NA	1273.504	1287.035	1204.935	1249.005	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/13/04	NA	NA	1323.025	1336.439	1251.707	1297.311	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
6	06/14/04	5.6	NA	1373.086	1386.065	1298.811	1345.953	3.3	3	64	59	5	2.6	1.4	64	60	4
	06/15/04	4.5	NA	1414.744	1427.542	1338.089	1386.452	3.4	3	65	60	5	2.6	1.4	66	61	5
	06/16/04	2.6	NA	1438.503	1451.468	1361.052	1408.409	3.6	3.4	62	56	6	3.4	2.4	61	56	5
	06/17/04	5.5	NA	1491.156	1504.426	1407.619	1454.439	4.6	3	64	56	8	3	2.2	62	57	5
	06/18/04	5.4	NA	1537.023	1550.457	1448.061	1494.498	4.8	3	65	58	7	3	2.2	64	59	5
	06/19/04	3.7	NA	1571.981	1585.942	1479.695	1525.727	4.1	3	64	59	5	3	2.8	64	60	4
	06/20/04	6.1	NA	1631.160	1645.949	1531.712	1577.346	4.8	3.5	65	59	6	3.2	2.2	65	59	6

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
7	06/21/04	2.2	NA	1652.422	1667.722	1550.962	1596.585	4	3.2	64	58	6	3.2	2.2	64	58	6
	06/22/04	2.8	63005400	1679.876	1695.329	1575.022	1620.202	5.4	3	63	56	7	3.2	2	62	58	4
	06/23/04	5.6	63250100	1740.701	1756.855	1628.973	1673.389	3.6	3.6	64	58	6	3.3	2.2	64	58	6
	06/24/04	4.7	63426100	1784.262	1800.935	1667.542	1711.392	5	3.2	66	60	6	3.4	2	66	60	6
	06/25/04	0.3	63437900	1787.186	1803.885	1670.122	1713.949	3.6	3.1	68	62	6	3	2	68	62	6
	06/26/04	NA	63640100	1837.227	1854.253	1714.283	1757.673	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/27/04	NA	63835800	1885.586	1903.133	1757.023	1799.960	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
8	06/28/04	NA	64039500	1936.024	1954.016	1801.423	1844.034	3.4	3	64	58	6	3	2.2	66	59	7
	06/29/04	4.5	64209400	1978.058	1996.398	1838.395	1880.729	3.4	3	66	60	6	3	2	66	60	6
	06/30/04	0.2	64219700	1980.588	1998.944	1840.622	1882.934	3.4	3	66	60	6	3	2	66	60	6
	07/01/04	4.5	64421300	2030.435	2049.123	1884.502	1926.365	3.4	3	64	58	6	3	2	64	58	6
	07/02/04	6	64634600	2083.219	2102.226	1930.917	1972.479	3.4	3	62	56	6	3	2	62	56	6
	07/03/04	5.6	64847800	2135.890	2155.313	1977.272	2018.462	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/04/04	5.2	65042600	2184.052	2203.936	2019.592	2060.456	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
9	07/05/04	2.6	65109500	2199.704	2219.753	2033.632	2074.436	3.8	2.8	62	56	6	2.8	1.8	64	58	6
	07/06/04	3.6	65243800	2233.734	2254.023	2068.245	2103.766	3.8	3	62	56	6	3	2	62	58	4
	07/07/04	5.6	65450500	2284.732	2305.502	2108.073	2148.215	3.8	3	62	56	6	3	2	62	58	4
	07/08/04	4.5	65625100	2327.858	2349.120	2145.983	2185.787	3.8	3	64	59	5	3	2	64	59	5
	07/09/04	0	65625100	2338.512	2359.932	2155.540	2195.326	3.6	3	62	58	4	3	2	62	58	4
	07/10/04	5.3	65825900	2377.569	2399.256	2189.552	2229.099	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/11/04	5.5	66032000	2428.535	2450.728	2234.232	2273.498	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
10	07/12/04	5.5	66234900	2478.721	2501.298	2278.147	2317.292	3.7	3.6	64	58	6	3.2	2	64	58	6
	07/13/04	4.7	66416400	2522.278	2545.293	2316.276	2355.290	3.7	3	64	59	5	3.2	2	64	59	5
	07/14/04	3.5	66544400	2555.110	2578.485	2345.305	2384.199	3.6	2.8	64	58	6	3	2	64	60	4
	07/15/04	1.9	66614900	2572.546	2596.063	2360.291	2399.060	3.6	3	62	57	5	3	2	62	57	5
	07/16/04	5.3	66811300	2621.027	2645.117	2402.747	2441.387	3.6	3	61	56	5	3	2	62	57	5
	07/17/04	5.5	NR	2671.860	2696.327	2447.251	2485.806	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/18/04	4.8	NR	2716.725	2741.592	2486.541	2524.969	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
11	07/19/04	4.2	67352300	NA	2778.792	2518.928	2557.272	3.7	3	64	60	4	3	2	66	62	4
	07/20/04	0.7	67380100	2761.547	2786.859	2525.844	2564.104	3.7	3.6	60	54	6	3	2.2	60	55	5
	07/21/04	0.6	67403600	2767.358	2792.739	2530.954	2569.184	3.7	3	63	59	4	3	2.2	62	60	2
	07/22/04	7.4	67475800	2785.192	2810.777	2546.569	2584.818	2.8	3.2	63	56	7	3.2	2.2	60	56	4
	07/23/04	5.4	67679100	2835.338	2861.406	2590.503	2628.701	2.8	3	62	58	4	3	2	64	58	6
	07/24/04	5.7	67893400	2888.310	2915.004	2636.838	2675.008	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/25/04	0.4	68107000	2940.996	2968.242	2683.016	2721.097	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
12	07/26/04	6	68332700	2996.551	3024.475	2731.768	2769.864	3	3.6	64	58	6	3.2	2.2	64	58	6
	07/27/04	5	68516400	3041.739	3069.980	2771.298	2809.497	3	3.6	64	58	6	3	2	64	58	6
	07/28/04	1	68525600	3044.011	3072.286	2773.293	2811.501	2.8	3.6	62	56	6	3	2	62	56	6
	07/29/04	5.2	68747400	3098.278	3127.310	2821.301	2859.811	3.2	3.4	62	58	4	3	2	62	58	4
	07/30/04	5.1	68942600	3146.499	3175.843	2863.298	2901.906	3.2	3.4	62	58	4	3.2	2	62	58	4
	07/31/04	4.8	69121100	3190.561	3220.191	2901.722	2940.348	3.2	3.4	62	58	4	3	2	62	58	4
	08/01/04	4.1	69275700	3228.229	3258.260	2934.860	2973.537	2.4	3.2	64	58	6	2.8	2	64	60	4

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	08/02/04	1.4	69327700	3241.637	3271.628	2946.287	2984.870	2.8	3.6	60	56	4	3	2.6	60	56	4
	08/03/04	5.8	69545300	3295.618	3325.930	2993.284	3031.829	3	3.6	64	57	7	3	2.2	63	58	5
	08/04/04	6.3	69779600	3353.549	3384.293	3044.037	3082.475	3	3.6	66	60	6	3	2	66	60	6
13	08/05/04	4.8	69959000	3397.916	3428.890	3082.787	3120.938	3	3.4	68	62	6	3	2	68	62	6
	08/06/04	0.1	69961400	3398.509	3429.493	3083.211	3121.447	3	3.6	62	58	4	3	2	62	56	6
	08/07/04	5.5	70164600	3448.819	3480.127	3127.336	3165.239	3	3.2	62	58	4	3	2.2	64	58	6
	08/08/04	5.3	70365100	3498.296	3530.098	3170.709	3208.196	3	3.2	64	60	4	3	2	66	60	6
	08/09/04	5.2	70560900	3546.467	3578.485	3212.662	3249.779	3	4	63	58	5	3	2	64	58	6
	08/10/04	5	70745700	3592.056	3624.430	3252.673	3289.447	3	3.2	64	58	6	3	2	64	58	6
	08/11/04	1.2	70794000	3604.023	3636.553	3263.457	3300.282	2.9	3.4	61	56	5	3	2	62	56	6
14	08/12/04	4.1	70952300	3643.034	3675.998	3297.430	3333.858	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/13/04	5.2	71143500	3690.203	3723.375	3338.839	3374.953	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/14/04	5	71332200	3736.696	3770.260	3379.776	3415.491	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/15/04	4.8	71513000	3781.307	3815.255	3419.003	3454.295	3	3.6	65	58	7	3	2	65	58	7
	08/16/04	4.7	71690100	3825.047	3859.337	3457.362	3492.315	3	3.6	62	57	5	3	2	62	57	5
	08/17/04	5.2	71877100	3871.220	3905.800	3497.878	3532.431	3	3.6	66	59	7	3	2	66	59	7
	08/18/04	1	71913300	3880.057	3914.767	3505.859	3540.358	3	3.6	60	56	4	3	2	60	56	4
15	08/19/04	6.3	72113900	3929.629	3964.661	3549.140	3583.137	3	3.6	62	57	5	3	2	62	57	5
	08/20/04	5.8	72331600	3983.447	4018.874	3596.454	3629.658	3	3.8	65	59	6	3	2	65	59	6
	08/21/04	5.4	72533900	4033.436	4069.234	3640.357	3673.056	3	3.8	62	57	5	3	2	62	57	5
	08/22/04	5.6	72743700	4085.240	4121.514	3865.934	3717.985	3	3.8	60	56	4	3	2.4	60	56	4
	08/23/04	5.8	72961300	4138.999	4175.703	3733.177	3764.599	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/24/04	4.6	73163600	4189.020	4226.111	3777.147	3807.769	3	3.8	65	59	6	3	2.4	66	60	6
	08/25/04	5.8	73383000	4243.217	4280.706	3824.736	3854.657	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
16	08/26/04	15	73938800	4381.027	4419.407	3945.532	3973.532	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/27/04	6	74163100	4436.595	4475.420	3994.336	4021.487	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/28/04	3.1	74280300	4464.967	4504.061	4019.491	4046.256	2.8	3	64	59	5	3	2.4	64	60	4
	08/29/04	1.8	74348000	4482.336	4521.507	4034.531	4060.927	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/30/04	5.3	74545800	4531.284	4570.822	4077.545	4102.983	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/31/04	5.3	74739700	4579.144	4619.151	4119.722	4144.285	3.2	4	64	60	4	4	2.4	66	62	4
	09/01/04	0.7	74761500	4584.525	4624.574	4124.468	4148.936	3	3.4	62	54	8	3	2.4	62	54	8
17	09/02/04	5.2	74955600	4632.531	4672.952	4166.658	4190.162	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/03/04	5.4	75159600	4682.929	4723.924	4210.961	4233.471	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/04/04	4.8	75339700	4727.469	4768.626	4250.125	4271.783	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/05/04	4.7	75518500	4771.724	4813.205	4288.982	4309.724	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/06/04	0.7	75548500	4779.803	4821.392	4296.299	4316.920	3	4	60	56	4	2.8	2.8	62	56	6
	09/07/04	5.5	75755200	4830.332	4872.174	4340.479	4360.036	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/08/04	4.5	75914600	4869.733	4911.832	4375.129	4393.808	3	3.2	62	56	6	3.4	2.6	62	56	6
18	09/09/04	5.6	76123800	4921.357	4963.877	4420.622	4438.204	3	3.8	65	60	5	3	2.6	65	60	5
	09/10/04	1.9	76194300	4938.969	4980.815	4436.103	4453.543	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/11/04	5.4	76396100	4989.458	5030.742	4479.699	4496.667	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/12/04	5.1	76586900	5037.255	5077.936	4521.038	4537.540	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
19	09/13/04	4.9	76771600	5083.534	5123.582	4560.992	4577.018	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/14/04	3.1	76890900	5113.468	5153.076	4586.943	4602.683	2.6	3	64	58	6	2.8	2	64	60	4
	09/15/04	2.4	76980700	5136.039	5175.191	4606.198	4621.603	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/16/04	8.1	77193700	5189.433	5227.659	4652.188	4666.941	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/17/04	3.7	77415500	5245.048	5282.371	4700.133	4714.237	3	3.8	63	57	6	3	2	64	58	6
	09/18/04	4.9	77599000	5291.023	5327.558	4739.762	4753.419	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/19/04	4.6	77771300	5334.175	5369.943	4776.941	4790.161	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
20	09/20/04	5	77955300	5380.325	5415.248	4816.589	4829.483	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/21/04	3.7	78046300	5416.220	5450.568	4847.701	4860.336	2.4	4	65	60	5	2.8	2	65	60	5
	09/22/04	3.7	78235900	5451.256	5484.917	4877.839	4890.151	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/23/04	5.8	78456400	5506.044	5538.703	4924.836	4936.737	2.6	3.6	64	58	6	2.8	2.8	64	59	5
	09/24/04	6	78680100	5562.250	5593.930	4973.144	4984.586	2.6	4.8	64	58	6	2.8	2.6	64	59	5
	09/25/04	7.4	78955300	5631.430	5662.127	5032.222	5043.251	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/26/04	4.7	79130800	5675.510	5705.434	5070.088	5080.753	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
21	09/27/04	4.9	79315200	5721.823	5750.926	5109.803	5120.154	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/28/04	5.8	79521400	5773.682	5801.817	5154.303	5164.104	3	3.8	64	58	6	3	2	64	58	6
	09/29/04	0.5	79558200	5782.936	5810.924	5162.268	5171.954	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/30/04	6.2	79755100	5832.344	5859.629	5204.704	5213.948	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/01/04	5	79958900	5883.586	5910.058	5248.719	5257.398	3	3.4	62	57	5	3	2	62	57	5
	10/02/04	5.4	80161900	5934.522	5960.125	5292.486	5300.683	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/03/04	5.4	80332000	5977.235	6002.108	5329.143	5337.010	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
22	10/04/04	0	80332000	5977.235	6002.108	5329.143	5337.010	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/05/04	5.2	80526700	6026.088	6050.130	5371.084	5378.646	3.2	4	60	56	4	2.8	2.6	60	56	4
	10/06/04	5.3	80725200	6075.869	6099.067	5413.814	5420.918	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/07/04	4.3	80911300	6122.481	6145.029	5453.892	5460.528	3	4	64	58	6	2.8	2	64	58	6
	10/08/04	4.8	81093000	6168.076	6189.880	5492.938	5499.203	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/09/04	4.5	81264000	6210.960	6232.058	5529.687	5535.516	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/10/04	0	81264000	6210.960	6232.058	5529.687	5535.516	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
23	10/11/04	5.3	81463600	6261.015	6281.302	5572.569	5577.978	2.6	2.8	60	56	4	3.2	2	60	56	4
	10/12/04	8	81763200	6336.357	6355.360	5637.080	5641.777	2.8	3	64	59	5	3	2.2	64	59	5
	10/13/04	4.2	81919800	6373.468	6391.866	5668.856	5673.190	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/14/04	9.5	82271900	6461.988	6470.542	5745.047	5748.336	2.8	3.6	65	62	3	2.8	2	68	64	4
	10/15/04	4.5	82448800	6506.433	6523.402	5783.000	5785.583	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/16/04	0	82448800	6506.433	6523.402	5783.000	5785.583	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/17/04	5.3	82647300	6556.288	6572.713	5825.824	5827.575	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
24	10/18/04	5.1	82840100	6604.728	6620.624	5867.410	5868.414	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/19/04	5.3	83010200	6647.529	6662.841	5904.081	5904.385	2.8	4	66	59	7	3	2	66	59	7
	10/20/04	0.3	83023800	6650.931	6666.199	5907.003	5907.250	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/21/04	5	83211700	6698.260	6712.851	5947.517	5946.919	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/22/04	5.1	83399200	6745.434	6759.491	5987.913	5986.486	2.9	5	64	58	6	3	2	64	58	6
	10/23/04	2.1	83480200	6765.973	6777.897	6006.032	6004.418	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/24/04	7.3	83674400	6814.714	6826.266	6047.648	6045.656	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
25	10/25/04	5	83862200	6861.857	6872.979	6087.794	6085.656	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/26/04	4.4	84026900	6903.227	6913.946	6122.979	6120.678	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/27/04	0	84026900	6903.227	6913.946	6122.979	6120.678	2.8	3	64	60	4	2.6	2	64	60	4
	10/28/04	5	84213400	6949.989	6960.326	6162.830	6160.377	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/29/04	5.1	84406700	6998.465	7008.371	6204.150	6201.478	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/30/04	4.4	84572400	7039.997	7049.552	6239.645	6236.714	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/31/04	0	84572400	7039.997	7049.552	6239.645	6236.714	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
26	11/01/04	3.6	84959000	7089.632	7098.683	6281.918	7098.683	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/02/04	5	84770000	7137.105	7145.650	6322.362	6318.872	3	3.2	64	60	4	2.8	2	64	60	4
	11/03/04	1.2	85004400	7148.444	7156.908	6332.059	6328.497	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/04/04	5	85189200	7194.811	7202.886	6391.641	6367.823	3	3.2	64	58	6	2.8	2.6	64	58	6
	11/05/04	4.9	85374400	7241.365	7249.096	6411.334	6407.247	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/06/04	0.2	85388500	7246.114	7253.858	6415.579	6411.543	3	3	62	52	10	3	2.8	62	56	6
	11/07/04	4.7	85564300	7289.078	7296.407	6452.052	6447.715	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
27	11/08/04	5.1	85755800	7337.275	7344.173	6493.121	6483.547	3	3	62	56	6	3	2.8	62	56	6
	11/09/04	5	85931700	7381.504	7388.015	6530.875	6526.007	3	3	66	60	6	3	2.8	66	60	6
	11/10/04	0.6	85958700	7388.376	7394.869	6536.912	6532.062	3	4	66	62	4	3	2.8	62	56	6
	11/11/04	4.7	86128100	7430.962	7436.970	6573.001	6567.877	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/12/04	4.9	86312100	7477.247	7482.808	6612.485	6607.015	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/13/04	4.5	86481600	7519.882	7525.004	6648.888	6643.101	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/14/04	1.6	86542300	7535.594	7540.687	6662.613	6656.767	3	4	62	59	3	3	3	61	58	3
28	11/15/04	3.6	86672300	7567.866	7572.517	6689.849	6683.665	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/16/04	4.9	86855300	7613.893	7618.088	6729.132	6722.580	3	3	64	58	6	3	2.4	64	58	6
	11/17/04	4.5	87026700	7657.378	7661.282	6766.423	6759.578	3	3	62	60	2	3	2.5	63	60	3
	11/18/04	0.9	87058800	7665.106	7668.862	6772.783	6765.839	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/19/04	5	87246400	7712.296	7715.604	6813.090	6805.788	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/20/04	4.9	87428700	7758.117	7761.055	6815.830	6844.607	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/21/04	4.6	87600700	7801.389	7803.942	6815.830	6881.211	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
29	11/22/04	0	87600700	7801.389	7803.942	6815.830	6881.211	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/23/04	0	87730000	7826.418	7836.342	6815.831	6909.036	2.8	2.8	62	56	6	2.8	1.8	62	56	6
	11/24/04	1.8	87799700	7851.447	7836.652	NR	6923.572	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/25/04	5.2	87996100	7900.857	7836.652	6857.973	6965.326	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/26/04	0	87996100	7900.857	7836.652	6857.973	6965.326	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/27/04	6.8	88252800	7965.340	NR	6913.039	7019.942	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/28/04	4.8	88433600	8010.916	NR	6951.789	7058.368	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
30	11/29/04	0	88433600	8021.543	7836.652	6961.023	7067.549	2.8	3	62	56	6	2.8	3	62	58	4
	11/30/04	9.2	88633600	8061.260	7836.652	6994.733	7100.799	2.8	3	64	58	6	2.8	2.6	64	58	6
	12/01/04	5.4	88836000	8112.190	NR	7038.098	7143.729	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/02/04	0	88836000	8112.190	NR	7038.098	7143.729	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/03/04	6.3	89071000	8170.696	7853.309	7089.329	7194.476	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/04/04	5	89257900	8217.843	7899.604	7129.282	7234.047	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/05/04	0	89257900	8217.843	7899.604	7129.282	7234.047	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
31	12/06/04	5.5	89463200	8269.609	7950.531	7173.267	7277.566	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/07/04	5.2	89655400	8318.061	7998.236	7214.423	7318.351	2.6	2.6	66	60	6	3	3	66	60	6
	12/08/04	0.2	89664300	8320.288	8000.434	7216.320	7320.234	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/09/04	5.1	89856400	8368.719	8048.107	7258.493	7360.848	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/10/04	5.1	90042400	8415.567	8094.164	7297.320	7400.319	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/11/04	0	90042400	8415.567	8094.164	7297.320	7400.319	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/12/04	5.3	90242800	8466.210	8143.873	7340.225	7442.859	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
32	12/13/04	4.8	90421300	8510.989	8188.052	7378.504	7480.590	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/14/04	0	90421300	8510.989	8188.052	7378.504	7480.590	2.8	5	62	56	6	3	4.2	62	56	6
	12/15/04	5.3	90621100	8561.237	8237.540	7421.354	7522.794	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/16/04	5.1	90812000	8609.399	8284.817	7462.349	7563.102	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/17/04	0.4	90828800	8613.690	8289.081	7466.174	7566.908	2.8	3.2	62	56	6	3	4.2	62	56	6
	12/18/04	5.4	91016900	8661.082	8335.549	7506.408	7606.419	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/19/04	5.1	91207800	8709.139	8382.770	7547.479	7646.742	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
33	12/20/04	4.9	91390900	8755.308	8428.066	7586.845	7685.432	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/21/04	4.1	91551500	8795.739	8467.808	7621.504	7719.523	2.8	3.2	66	62	4	3.2	4	66	62	4
	12/22/04	0.4	91566000	8799.445	8471.390	7624.547	7722.462	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/23/04	5.5	91774500	8851.942	8523.004	7669.450	7766.504	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/24/04	5.6	91981300	8903.985	8574.263	7714.019	7810.180	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/25/04	5.2	92174800	8952.654	8622.188	7755.104	7851.163	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/26/04	4.9	92357500	8998.543	8667.459	7795.635	7889.767	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
34	12/27/04	4.7	9253300	9042.716	8710.929	7832.854	7926.791	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/28/04	4.5	92703500	9085.608	8753.194	7869.654	7962.752	2.8	3.6	68	61	7	3	4	68	61	7
	12/29/04	4.7	92879800	9129.988	8796.843	7907.736	7999.875	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/30/04	1.5	92935100	9143.844	8809.942	7919.788	8011.705	2.8	3.6	64	58	6	3.4	4	62	58	4
	12/31/04	3.5	93068100	9177.382	8841.874	7948.366	8039.603	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/01/05	5.3	93269600	9228.083	8891.926	7991.638	8082.007	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/02/05	5.1	93461300	9276.352	8939.433	8032.982	8122.404	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
35	01/03/05	4.8	93642000	9321.919	8984.277	8071.950	8160.583	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/04/05	4.9	93812200	9364.789	9026.570	8108.710	8196.447	2.8	3	66	60	6	3.2	4	66	60	6
	01/05/05	0.2	93819900	9366.707	9028.468	8110.364	8198.054	2.8	2.8	66	60	6	3.4	4	66	60	6
	01/06/05	5.5	94018600	9416.746	9077.958	8153.346	8239.865	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/07/05	5.2	94213200	9465.808	9126.060	8195.365	8280.795	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/08/05	4.7	94396100	9511.811	9171.439	8234.793	8319.191	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/09/05	4.6	94567600	9554.958	9213.934	8271.785	8355.189	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
36	01/10/05	4.6	94737700	9597.834	9256.100	8308.443	8390.964	2.8	3	64	58	6	3	3.5	64	58	6
	01/11/05	0.2	94740100	9598.585	9256.840	8309.086	8391.590	2.8	2.8	64	58	6	3	4	64	58	6
	01/12/05	5.3	94937500	9648.101	9305.736	8351.480	8432.919	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/13/05	5.2	95132600	9697.174	9354.127	8393.524	8473.819	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/14/05	4.9	95318700	9744.010	9400.288	8433.552	8512.834	2.2	2.6	68	64	4	3	1.4	68	64	4
	01/15/05	2	95394000	9762.570	9418.653	8450.041	8529.149	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/16/05	5.3	95593500	9812.741	9468.082	8492.882	8571.195	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
37	01/17/05	5.3	95781600	9812.842	9517.206	8535.499	8612.972	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/18/05	4.7	95970300	9857.727	9561.459	8573.895	8650.656	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/19/05	3.2	96091600	9888.120	9591.513	8600.087	8676.473	2.8	3.8	64	58	6	3	2	64	58	6
	01/20/05	2.4	96179300	9910.160	9613.202	8618.742	8694.783	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/21/05	5.1	96372500	9958.594	9961.065	8660.268	8735.523	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/22/05	5.4	96571000	10008.332	9710.234	8702.818	8777.402	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/23/05	5.3	96769800	10058.241	9759.463	8745.608	8819.293	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
38	01/24/05	5.1	96962500	10106.528	9807.209	8787.023	8859.927	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/25/05	5	97147300	10152.861	9852.927	8826.724	8898.903	3	3.2	66	60	6	3.2	2	66	60	6
	01/26/05	4.7	97324300	10197.139	9896.731	8864.748	8936.239	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/27/05	4.5	97493200	10239.302	9938.612	8901.044	8971.930	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/28/05	4.3	97655300	10279.759	9978.747	8935.884	9006.124	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/29/05	4.6	972828700	10323.092	10021.739	8973.206	9042.673	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/30/05	4.6	98002100	10366.424	10064.675	9010.516	9079.207	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
39	01/31/05	4.8	98175000	10409.683	10107.550	9047.714	9115.752	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/01/05	6.8	98428600	10473.152	10170.502	9102.251	9169.456	2.8	3	66	58	8	3	2.4	66	58	8
	02/02/05	5.3	98630400	10523.528	10220.540	9145.673	9212.143	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/03/05	4.1	98786200	10562.438	10259.219	9179.257	9245.072	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/04/05	4.4	98945000	10602.359	10298.937	9213.759	9278.946	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/05/05	4.4	99104700	10642.726	10339.105	9248.634	9313.202	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/06/05	4.4	99271300	10684.630	10380.843	9284.864	9348.679	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
40	02/07/05	4.4	99435800	10726.010	10422.020	9320.552	9383.699	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/08/05	4.5	99598700	10766.990	10462.801	9355.958	9418.370	3	3	66	59	7	3.2	2.2	66	59	7
	02/09/05	4.4	99763400	10808.458	10504.166	9392.008	9453.765	2.8	3	66	62	4	3.2	2.4	66	62	4
	02/10/05	0.4	99778800	10812.317	10507.947	9395.172	9456.773	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/11/05	5.1	99968600	10860.014	10555.761	9436.405	9497.211	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/12/05	5.1	158200	10907.673	10603.271	9477.506	9537.562	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/13/05	5	345600	10954.743	10650.289	9518.095	9577.457	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
41	02/14/05	4.9	529500	11001.041	10696.449	9557.971	9616.619	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/15/05	4.8	700900	11044.163	10739.569	9595.058	9653.115	3	3.2	66	60	6	3	2.2	66	60	6
	02/16/05	2.9	810400	11071.972	10767.393	9619.246	9676.915	3	3	63	60	3	3	2.5	64	60	4
	02/17/05	2.6	907800	11106.768	10802.074	9649.046	9706.193	3	3	62	56	6	3.5	2.5	62	58	4
	02/18/05	5.1	1096900	11143.826	10838.925	9680.760	9737.317	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/19/05	5.2	1287500	11191.742	10886.692	9722.036	9777.824	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/20/05	5	1475800	11239.123	10886.896	9762.659	9817.807	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
42	02/21/05	4.8	1651800	11283.478	10886.896	9800.640	9855.165	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/22/05	4.4	1818500	11325.369	10886.896	9836.689	9890.526	3	3	66	61	5	3	3	66	61	5
	02/23/05	1.9	1892500	11343.653	10905.076	9853.044	9906.581	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/24/05	4.9	2077400	11390.299	10951.225	9893.142	9945.926	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/25/05	4.9	2262600	11436.935	10997.345	9933.340	9985.213	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/26/05	5	2450700	11483.973	11043.946	9973.976	10024.885	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/27/05	5	2637800	11530.796	11090.306	10014.424	10064.435	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	02/28/05	4.7	2815100	11575.122	11134.243	10052.714	10101.928	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/01/05	4.9	2983600	11617.267	11176.045	10089.148	10137.451	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/02/05	4.5	3152400	11659.436	11217.891	10125.564	10173.077	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
43	03/03/05	1.2	3198400	11671.362	11229.791	10136.050	10183.360	2.8	3	62	56	6	3	2.6	62	58	4
	03/04/05	3.9	3344700	11707.430	11265.613	10167.149	10213.646	2.8	2.8	61	56	5	3	2.6	61	56	5
	03/05/05	5.2	3539400	11756.064	11313.835	10209.181	10254.722	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/06/05	5.2	3732200	11804.192	11361.687	10250.864	10295.402	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/07/05	5.1	3925100	11852.332	11409.548	10292.472	10336.204	3	3.2	66	59	7	3.2	2.4	66	59	7
	03/08/05	5	4110100	11898.496	11455.453	10332.393	10375.303	3	4.8	66	59	7	3.2	2.4	66	59	7
	03/09/05	3.6	4246900	11932.582	11489.353	10362.052	10404.405	3	2.8	66	60	6	3.2	2.4	66	60	6
44	03/10/05	1.4	4300600	11946.047	11502.655	10373.506	10415.626	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/11/05	5.1	4494200	11994.362	11550.647	10415.203	10456.660	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/12/05	5.1	4688700	12042.903	11598.813	10457.155	10497.908	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/13/05	4.9	4874800	12089.381	11644.908	10497.307	10537.357	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/14/05	4.7	5051300	12133.470	11688.710	10535.401	10574.762	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/15/05	4.9	5221200	12175.965	11730.759	10572.049	10610.655	2.6	2.8	67	61	6	3	2	67	61	6
	03/16/05	1.3	5273500	12189.026	11743.704	10583.447	10621.880	2.6	2.8	64	56	8	3	2.2	62	58	4
45	03/17/05	4.2	5432900	12228.945	11783.143	10617.693	10655.411	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/18/05	5.3	5627400	12277.637	11831.297	10659.660	10696.521	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/19/05	5.3	5824900	12278.874	11880.281	10702.410	10738.282	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/20/05	5	6020500	12327.809	11928.659	10744.591	10779.642	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/21/05	4.8	6192600	12370.917	11971.270	10781.727	10816.023	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/22/05	4.7	6366500	12414.481	12014.432	10819.324	10852.773	2.8	4.6	66	60	6	3.4	2.2	66	60	6
	03/23/05	3.4	6495800	12446.854	12046.491	10847.318	10880.216	2.8	3	64	60	4	3	2.2	64	60	4
46	03/24/05	2	6570400	12465.570	12064.956	10863.277	10895.804	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/25/05	5.3	6772400	12516.108	12114.931	10906.834	10938.398	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/26/05	5.2	6970200	12565.517	12163.887	10949.455	10980.080	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/27/05	5.2	7168000	12614.902	12212.035	10992.128	11021.291	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/28/05	5	7343400	12658.740	12256.199	11030.017	11058.706	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/29/05	4.7	7521500	12703.220	12300.279	11068.467	11096.315	2.8	3	68	62	6	3.2	2.4	68	62	6
	03/30/05	0.5	7540500	12707.966	12304.975	11072.572	11100.328	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
47	03/31/05	5.2	7735700	12756.852	12353.356	11114.763	11141.704	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/01/05	4.7	7928500	12805.103	12401.184	11156.366	11182.545	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/02/05	3.9	8063900	12839.437	12435.233	11186.155	11211.753	2.8	3	66	60	6	3	2	66	60	6
	04/03/05	5.1	8109000	12850.261	12445.904	11195.317	11220.696	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/04/05	2	8316400	12902.170	12497.267	11240.126	11264.612	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/05/05	5.3	8517200	12952.356	12547.120	11283.518	11307.032	2.8	3	66	59	NA	3.2	2.2	66	59	7
	04/06/05	5	8706500	12999.763	12594.114	11324.482	11347.071	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
48	04/07/05	2.7	8811200	13026.401	12620.614	11347.677	11369.756	2.8	3	66	58	8	3	2.2	64	59	5
	04/08/05	2.7	8905900	13049.591	12643.570	11367.593	11389.117	3	3	62	57	5	3	2.6	62	57	5
	04/09/05	6.2	9141000	13108.147	12701.366	11418.429	11439.254	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/10/05	4.2	9296200	13147.002	12739.597	11451.814	11472.227	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	04/11/05	5.5	9505200	13199.343	12791.167	11496.710	11516.632	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/12/05	5.3	9706800	13249.753	12840.989	11540.126	11559.476	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/13/05	4.7	9878400	13292.623	12883.318	11577.006	11595.959	2.8	3	68	62	6	3	2	68	62	6
49	04/14/05	1	9918000	13302.517	12893.089	11585.498	11604.385	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/15/05	5.5	10127300	13354.774	12944.801	11630.479	11648.858	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/16/05	4.8	10308900	13400.099	12987.650	11669.499	11687.479	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/17/05	4.6	10483300	13443.627	13032.730	11706.849	11724.609	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/18/05	4.6	10656900	13487.031	13075.662	11744.233	11761.551	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/19/05	2.3	10746000	13509.219	13097.667	11763.529	11780.698	2.8	2.8	64	58	6	3	2	64	60	4
	04/20/05	5.1	10850600	NA	NA	NA	NA	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
50	04/21/05	5.1	11054200	13583.247	13170.852	11827.211	11843.593	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/22/05	4.5	11223500	13625.518	13212.622	11863.720	11879.645	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/23/05	0	11223500	13625.518	13212.622	11863.720	11879.645	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/24/05	5.3	11425500	13675.977	13262.526	11907.267	11922.573	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/25/05	4.9	11614100	13722.100	13308.044	11947.082	11961.784	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/26/05	0.1	11614100	13723.265	13309.249	11948.247	11962.963	3	3	62	56	6	3	2	62	56	6
	04/27/05	5.1	11807600	13771.690	13357.207	11989.941	12003.969	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
51	04/28/05	3.6	12003000	13820.615	13405.755	12032.212	12045.573	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/29/05	3.9	12153100	13858.175	13442.968	12064.851	12077.696	2.8	2.8	66	62	4	3	2	66	62	4
	04/30/05	0.8	12186900	13866.618	13451.267	12072.010	12084.707	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/01/05	5.5	12383300	13915.750	13499.871	12114.404	12126.453	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/02/05	4.7	12560100	13959.977	13543.722	12152.702	12164.045	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/03/05	3.7	12700500	13995.085	13578.464	12183.005	12193.958	2.6	3	66	60	6	3	2.4	66	60	6
	05/04/05	0.4	12717300	13999.291	13582.625	12186.633	12197.558	2.6	3	63	58	5	3	2.4	63	58	5
52	05/05/05	5.4	12918500	14049.479	13632.373	12230.124	12240.552	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/06/05	5.2	13114900	14098.599	13681.055	12272.602	12282.585	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/07/05	5	13304300	14145.863	13728.080	12313.594	12323.144	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/08/05	3.1	13421800	14175.512	13757.694	12339.639	12348.833	3	3	63	60	3	3	2.5	63	60	3
	05/09/05	1.8	13491280	14192.595	13774.650	12354.219	12363.156	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/10/05	5.7	13696000	14243.950	13825.580	12398.730	12406.998	3	3	64	58	6	3	2.4	64	58	6
	05/11/05	6.1	13925100	14301.347	13882.711	12448.344	12456.118	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
53	05/12/05	0	13925100	14301.347	13882.711	12448.344	12456.118	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/13/05	5.4	14125200	14351.481	13932.576	12491.680	12498.903	3	3	64	52	12	4	2.4	64	52	12
	05/14/05	5.2	14317100	14400.300	13981.113	12534.101	12540.998	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/15/05	4	14467300	14438.548	14019.139	12567.334	12574.034	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/16/05	1.3	14517400	14451.711	14032.291	12578.977	12585.630	3	3	62	59	3	4	2	62	59	3
	05/17/05	3.7	14654100	14485.970	14066.375	12608.539	12614.814	3.4	3.4	64	58	6	3.8	2.8	64	58	6
	05/18/05	5.7	14866700	14539.890	14119.725	12655.292	12660.312	3.4	3.8	66	62	4	4.2	3.4	66	62	4
54	05/19/05	1.4	14922600	14554.089	14133.798	12667.743	12672.395	3	3.6	62	56	6	3.6	3.4	64	58	6
	05/20/05	5.3	15118600	14604.069	14182.841	12710.794	12713.701	3.8	4	64	58	6	4.2	3.4	64	58	6
	05/21/05	5.5	15327100	14657.255	14235.015	12756.775	12757.472	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/22/05	4.5	15492700	14699.594	14276.512	12793.538	12792.018	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	05/23/05	3.9	15658700	14742.081	14318.077	12830.375	12826.331	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/24/05	2.9	15748100	14765.503	14340.155	12850.167	12844.685	3	3	64	58	6	3	2.2	64	58	6
	05/25/05	5.5	15956300	14817.900	14392.511	12895.609	12889.464	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
55	05/26/05	5.1	16110100	14856.967	14431.569	12929.723	12922.965	3	3.2	66	62	4	3.2	2.6	66	62	4
	05/27/05	0.8	16140400	14864.292	14438.909	12936.097	12929.213	3.2	3.6	62	56	6	3.6	3	62	56	6
	05/28/05	5.9	16332300	14912.488	14486.959	12977.707	12969.784	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/29/05	3.6	16523700	14960.717	14534.872	13019.846	13010.438	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/30/05	3.7	16663800	14996.336	14570.399	13051.626	13040.905	3	4	63	60	3	4	3	63	60	3
	05/31/05	3.4	16787100	15026.786	14600.572	13078.186	13066.251	2.8	4	66	58	8	4	3.2	64	58	6
	06/01/05	3.9	16932700	15063.530	14636.875	13110.475	13096.781	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
56	06/02/05	3.3	17055300	15094.348	14667.306	13137.732	13122.402	4.8	5.2	68	59	9	5.2	4	68	59	9
	06/03/05	8.2	17358900	15170.741	14742.544	13205.514	13185.859	5	5.4	66	50	16	5.4	4.2	66	50	16
	06/04/05	5.9	17572800	15224.617	14795.522	13253.712	13230.492	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/05/05	6	17798100	15281.445	14851.131	13304.712	13277.259	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/06/05	5.5	18004200	15333.462	14901.836	13351.365	13319.876	5.6	6.2	70	60	10	6.2	5.2	70	60	10
	06/07/05	5.2	18198800	15382.636	14949.970	13395.492	13360.226	5.8	7	70	62	8	6.2	5.2	70	62	8
	06/08/05	6.1	18423900	15439.687	15005.601	13446.474	13406.409	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
57	06/09/05	5.2	18617000	15488.716	15053.341	13490.391	13446.111	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/10/05	5.4	18816700	15539.356	15102.725	13535.724	13486.927	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/11/05	5.7	19020800	15591.333	15153.042	13582.228	13528.732	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/12/05	5.4	19232000	15645.177	15205.012	13630.461	13571.719	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/13/05	5.2	19425800	15695.078	15252.252	13674.468	13610.681	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/14/05	2.8	19530700	15722.082	15278.013	13698.679	13632.238	7	9	70	58	12	8	7	70	60	10
	06/15/05	3	19641700	15750.535	15305.059	13723.697	13654.306	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
58	06/16/05	5.5	19847800	15796.232	15372.794	13765.746	13691.481	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/17/05	2.6	20019100	15833.596	15430.000	13800.684	13722.086	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/18/05	NA	NA	NA	NA	NA	NA	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/19/05	5.6	2011600	15854.995	15462.450	13820.829	13739.941	8	6	66	58	8	9	8	70	58	12
	06/20/05	5.4	20317600	15895.997	15528.073	13862.085	13776.218	8	7	70	58	12	9	8	68	58	10
	06/21/05	3.1	20429700	15920.983	15564.944	13885.136	13796.184	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/22/05	5.5	20641200	15968.483	15633.655	13928.943	13834.597	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
59	06/23/05	6.0	20862400	16018.708	15704.623	13974.894	13874.470	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/24/05	5.1	21042400	16061.286	15763.475	14013.338	13907.988	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/25/05	5.4	21247500	16101.279	15820.796	14044.975	13965.960	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/26/05	5.3	21442300	16140.289	15877.099	14074.832	14022.544	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/27/05	5.1	21632800	16178.672	15932.021	14104.370	14077.033	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/28/05	6.0	21853500	16223.676	15995.653	14139.315	14139.097	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/29/05	5.6	22061100	16289.688	16044.324	14167.060	14189.872	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
60	06/30/05	2.6	22124500	16306.598	16056.829	14174.124	14203.068	5	8	62	56	6	9.2	6	64	56	8
	07/01/05	6.5	22341800	16378.444	16110.155	14205.981	14257.310	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/02/05	5.7	22553900	16445.505	16159.985	14236.187	14307.321	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/03/05	5.6	22761400	16504.439	16201.718	14298.024	14343.059	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
61	07/04/05	5.2	22956300	16560.004	16241.552	14346.555	14375.683	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/05/05	11.5	23153600	16616.074	16282.203	14400.496	14408.503	6.4	8.8	70	60	10	6	6.2	70	60	10
	07/06/05	0.7	23181800	16623.999	16288.048	14408.120	14413.181	6	7.8	72	62	10	6	6	72	62	10
	07/07/05	6.8	23434300	16693.925	16344.041	14474.220	14456.090	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/08/05	5.5	23638400	16745.505	16395.970	14517.819	14498.983	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/09/05	5.8	23853700	16799.818	16451.247	14563.973	14543.544	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/10/05	6.2	24084100	16857.742	16510.762	14613.509	14590.631	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
62	07/11/05	7.5	24352200	16925.019	16580.433	14671.470	14644.665	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/12/05	8.7	24671600	17005.271	16663.695	14741.265	14708.173	5.8	6.2	66	56	10	5.6	4.6	66	56	10
	07/13/05	6.9	24926600	17069.075	16730.702	14797.592	14758.152	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/14/05	7.0	25181600	17132.753	16798.055	14853.986	14807.293	6.2	7	68	60	8	6.2	5	68	60	8
	07/15/05	7.7	25464700	17133.432	16873.313	14916.898	14861.484	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/16/05	7.4	25732000	17133.432	16944.718	14976.759	14912.137	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/17/05	5.2	25922500	17133.432	16995.658	15019.556	14947.972	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
63	07/18/05	4.9	26101700	17133.432	17043.693	15059.941	14981.473	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/19/05	3.4	26230100	17133.432	17077.924	15088.999	15005.893	7	8	70	60	10	7	6.4	70	60	10
	07/20/05	2.3	26314900	17133.432	17100.421	15107.867	15021.580	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/21/05	6.1	26539400	17190.179	17160.592	15158.530	15063.127	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/22/05	5.9	26755000	17244.601	17218.968	15207.298	15102.152	5.8	4	63	58	5	3.6	3.8	63	58	5
	07/23/05	7.6	27034800	17313.965	17292.476	15267.227	15159.508	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/24/05	6.7	27281600	17376.881	17356.701	15319.280	15209.541	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
64	07/25/05	5.1	27469400	17424.699	17406.105	15359.062	15247.012	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/26/05	5.5	27673900	17462.947	17460.340	15402.500	15287.415	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/27/05	0.5	27676400	17463.505	17460.973	15403.111	15288.025	5	5	64	56	8	5	5	62	56	6
	07/28/05	4.7	27858700	17509.898	17509.609	15441.976	15323.686	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/29/05	7.0	28115500	17574.938	17578.771	15497.175	15373.298	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/30/05	2.3	28168800	17589.263	17594.123	15509.800	15384.540	6	6	62	56	6	5	5	50	55	NA
	07/31/05	18.0	28433700	17655.318	17665.315	15565.852	15433.585	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
65	08/01/05	7.9	28717200	17726.688	17742.766	15627.201	15486.871	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/02/05	7.8	29001700	17798.425	17821.239	15688.765	15539.793	6.8	6.9	70	60	10	8.6	6.2	70	60	10
	08/03/05	7.9	29286700	17870.209	17899.879	15750.502	15592.063	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/04/05	7.6	29564200	17940.225	17976.991	15810.832	15642.557	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/05/05	2.4	29654600	17963.072	18002.020	15830.519	15658.978	6.8	5.8	66	56	10	8.2	8.4	66	56	10
	08/06/05	8.4	29959500	18032.002	18107.898	15891.108	15708.502	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/07/05	5.5	30162400	18070.317	18172.860	15920.031	15764.812	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
66	08/08/05	6.9	30399800	18115.670	18249.580	15953.467	15830.052	8.8	7	66	56	10	9	6	64	56	8
	08/09/05	10.2	30773400	18189.967	18368.883	16008.808	15927.202	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/10/05	9.5	31107500	18257.450	18475.466	16060.183	16010.722	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/11/05	6.4	31340200	18306.045	18548.950	16097.663	16066.346	9.4/2.8	7.8/3	69	59	10	10.5/3	8/2	69	59	10
	08/12/05	4.9	31603300	18372.364	18616.541	16152.850	16119.242	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/13/05	7.1	31780500	18417.192	18662.906	16189.981	16154.656	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/14/05	4.8	31957500	18462.037	18709.715	16227.269	16189.380	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
67	08/15/05	2.5	32051000	18485.755	18734.491	16247.171	16207.626	4	4.8	66	59	7	5.5	4	64	59	5
	08/16/05	4.6	32220700	18528.796	18779.742	16283.040	16240.102	5	5	66	58	8	5.6	4	65	58	7
	08/17/05	4.9	32401800	18574.839	18828.410	16321.376	16274.306	5	5	66	58	8	6	5	65	58	7
	08/18/05	5.0	32585000	18621.790	18878.389	16360.518	16308.685	5.3	6	66	56	10	6	5.5	64	56	8
	08/19/05	5.1	32773300	18669.484	18929.312	16400.043	16342.871	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/20/05	5.9	32970400	18719.891	18983.425	16441.830	16378.624	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/21/05	5.4	33169800	18770.950	19038.361	16484.260	16414.291	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
68	08/22/05	5.3	33365900	18821.186	19092.653	16526.176	16449.051	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/23/05	5.0	33548900	18868.128	19143.486	16565.371	16481.243	8	9.2	68	60	8	8.8	7.8	68	60	8
	08/24/05	5.0	33730300	18914.644	19193.995	16604.564	16512.862	8.2	8.8	70	60	10	9	8.2	70	60	10
	08/25/05	4.9	33910500	18960.943	19244.337	16643.644	16543.908	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/26/05	5.1	34095500	19008.584	19296.351	16683.641	16575.489	9	9.2	68	58	10	9.4	9.2	68	58	10
	08/27/05	5.6	34292200	19059.457	19351.704	16726.178	16608.989	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/28/05	4.9	34470600	19105.702	19402.071	16764.683	16639.005	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
69	08/29/05	4.9	34646200	19151.254	19851.697		16668.429	10.6/2.8	12/3	70	58	12	10.4/3	10/4.1	70	58	12
	08/30/05	4.8	34715800	19169.544	19471.590	16817.225	16680.152	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/31/05	1.8	34914300	19219.921	19522.936	16858.392	16720.614	0	4	65	57	8	4	4	65	57	8
	09/01/05	6.4	35121100	19272.026	19577.273	16901.222	16761.934	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/02/05	5.5	3532400	19322.890	19631.379	16943.418	16801.791	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/03/05	4.8	35497900	19366.285	19678.297	16979.661	16835.486	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/04/05	4.8	35673600	19410.070	19726.130	17016.281	16869.657	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
67	09/05/05	4.8	35850200	19453.982	19774.580	17053.171	16902.333	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/06/05	5.3	36046300	19502.715	19828.218	17094.175	16938.846	7	6.2	69	60	9	7	6	69	60	9
	09/07/05	5.8	36260300	19556.012	19888.041	17138.944	16978.037	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/08/05	5.6	36460900	19606.014	19944.112	17181.158	17014.111	7.5	7.5	69	60	9	8.5	6.2	69	60	9
	09/09/05	5.4	36655300	19654.561	19998.740	17222.180	17048.535	8.2	8.2	68	58	10	9	8	68	58	10
	09/10/05	5.4	36851100	19703.658	20054.034	17263.743	17082.648	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/11/05	6.0	37070000	19758.524	20116.044	17310.340	17120.106	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
68	09/12/05	7.7	37348400	19828.726	20195.129	17369.823	17166.979	9.4/3	9.8/3.2	68	56	12	10.4/3	9.8/4	68	56	12
	09/13/05	NA	37673400	19911.910	20279.584	17437.018	17229.679	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/14/05	15.9	37931900	19976.802	20347.588	17490.328	17280.536	4.8	5	65	57	8	5.2	4.2	65	57	8
	09/15/05	5.5	38136100	20027.913	20401.437	17532.550	17320.046	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/16/05	5.6	38343400	20079.746	20457.066	17575.647	17359.639	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/17/05	4.6	38513900	20122.371	20502.957	17611.258	17391.800	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/18/05	4.7	38686900	20165.571	20549.667	17647.509	17423.967	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
69	09/19/05	3.3	38794900	20192.598	20579.045	17670.458	17444.030	8	7	70	58	12	8	6.2	68	60	8
	09/20/05	2.3	38878800	20213.541	20601.797	17687.969	17459.156	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/21/05	5.4	39077800	20263.524	20656.030	17730.088	17495.146	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/22/05	6.1	39300900	20319.675	20717.118	17779.695	17535.022	8.8	9	68	58	10	9.3	8.9	68	58	10
	09/23/05	5.3	39495200	20368.790	20770.381	17819.525	17569.225	9	9.4	69	59	10	9.4	9	69	59	10
	09/24/05	4.1	39668600	20412.729	20817.890	17856.995	17599.375	6	4	63	64	NA	NR	NR	NR	NR	NA
	09/25/05	5.1	39822900	20452.415	20861.014	17891.117	17626.566	NR	NR	NR	NR	NA	5	4.3	72	69	3

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
70	09/26/05	0.6	39846200	20457.960	20867.021	17895.393	17629.918	10/3.2	10.5/3.2	70	56	14	10.5/3	10.0/4	70	56	14
	09/27/05	8.1	40144200	20534.930	20945.328	17957.923	17685.713	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/28/05	6.9	40391400	20596.381	21009.558	18009.289	17734.775	5.4	5	66	57	9	5.2	4.4	66	57	9
	09/29/05	5.9	40617000	20652.606	21068.681	18056.355	17778.878	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/30/05	5.3	40813300	20701.700	21120.325	18097.572	17816.788	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/01/05	5.0	40996300	20747.509	21168.634	18136.038	17851.664	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/02/05	4.5	41173100	20791.971	21215.558	18173.438	17884.893	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
71	10/03/05	4.8	41349300	20836.451	21262.472	18210.867	17917.559	8	8.2	68	60	8	8.2	7	68	60	8
	10/04/05	4.1	41500700	20874.928	21302.874	18243.442	17945.395	8	8.2	68	60	8	8.2	7	68	60	8
	10/05/05	1.1	41541400	20885.311	21313.816	18252.176	17952.802	8.2	9.2	66	56	10	9	8	66	56	10
	10/06/05	5.7	41748900	20938.175	21369.101	18296.567	17989.844	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/07/05	5.5	41950200	20989.691	21422.899	18339.991	18025.430	9	9.8	68	58	10	9.8	9	68	58	10
	10/08/05	8.5	42225700	21060.876	21496.437	18399.650	18073.284	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/09/05	5.4	42422600	21112.166	21548.936	18442.567	18106.911	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
72	10/10/05	5.6	42625700	21165.183	21603.182	18487.152	18141.007	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/11/05	5.2	42815800	21215.091	21653.765	18529.078	18177.596	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/12/05	5.3	43002600	21264.344	21703.498	18570.424	18203.223	10.4/3	12.8/3.2	76/68	60/62	16/6	13/5.4	12.4/2	76/68	60/62	16/6
	10/13/05	3.0	43100300	21290.985	21729.134	18590.552	18220.100	3	4	64	54	10	3.5	2.8	62	58	4
	10/14/05	4.7	43274600	21334.857	21773.589	18626.719	18254.811	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/15/05	5.7	43486300	21387.923	21828.118	18670.521	18296.525	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/16/05	5.8	43701800	21441.729	21884.070	18715.368	18338.451	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
73	10/17/05	5.9	43919700	21496.045	21940.871	18760.957	18380.204	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/18/05	5.8	44134500	21549.709	21997.119	18806.215	18420.824	7.4	8	68	58	10	7.4	6	68	58	10
	10/19/05	5.7	44341900	21601.788	22051.796	18850.287	18459.466	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/20/05	4.7	44515700	21645.561	22097.948	18887.350	18491.303	7.8	8.8	70	60	10	8.6	7.6	70	60	10
	10/21/05	1.1	44559100	21656.635	22109.463	18896.756	18499.338	8.2	9	70	58	12	9	8	70	58	12
	10/22/05	4.8	44728600	21699.571	22154.430	18932.834	18529.699	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/23/05	5.5	44929800	21751.149	22207.888	18976.250	18565.269	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
74	10/24/05	5.3	45125100	21801.803	22259.767	19018.313	18599.190	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/25/05	3.3	45245900	21834.015	22291.969	19044.578	18620.225	9.2	11	74	60	14	10	9.8	72	60	12
	10/26/05	2.3	45324600	21854.576	22312.522	19061.089	18633.266	10/3.2	11.2/3.2	72/64	58/58	14/6	11.4/3	10.2/2	72/64	58/58	14/6
	10/27/05	6.1	45544800	21912.875	22369.885	19106.766	18673.026	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/28/05	5.2	45738200	21960.793	22419.635	19146.149	18712.127	5	5.4	66	59	7	5.2	3.2	66	59	7
	10/29/05	4.8	45915600	22004.477	22465.570	19182.212	18747.997	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/30/05	0.0	45915600	22004.477	22465.570	19182.212	18747.997	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
75	10/31/05	6.1	46127100	22056.129	22520.525	19225.146	18790.778	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/01/05	5.1	46322800	22103.847	22571.517	19264.942	18830.208	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/02/05	4.9	46503400	22147.950	22618.564	19301.601	18866.477	7	8.4	68	60	8	7.6	5.8	68	60	8
	11/03/05	2.7	46604100	22172.056	22644.741	19322.151	18886.736	7/3.1	8.4/3.3	65	58	7	7.6/3	6/2	68	59	9
	11/04/05	4.2	46759200	22211.927	22684.230	19353.550	18917.229	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/05/05	6.8	46995700	22261.014	22734.868	19394.112	18957.077	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/06/05	4.7	47171700	22304.067	22780.154	19430.538	18992.854	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
76	11/07/05	2.5	47267400	22327.368	22804.742	19458.784	19012.482	5	6	68	60	8	5	3.2	66	60	6
	11/08/05	3.5	47397900	22359.366	22837.368	19478.110	19038.762	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/09/05	NA	NR	NR	NR	NR	NR	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	System Down for Well Maintenance 11/10/05 - 12/11/05																
84	12/12/05	NA	47539400	22377.200	22838.166	19493.934	19054.396	NA	4.4	66	61	5	4.2	3	66	61	5
	12/13/05	0.2	47542500	22377.721	22838.648	19494.190	19054.601	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/14/05	5.2	47736500	22378.473	22888.327	19534.447	19094.844	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/15/05	5.0	47926600	22424.023	22904.390	19574.203	19134.871	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/16/05	5.0	48110400	22424.344	22904.390	19613.290	19173.917	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/17/05	3.9	48258300	22459.836	22943.286	19645.013	19205.526	NA	7	70	61	9	6	5	70	61	9
	12/18/05	0.7	48225000	22466.198	22950.172	19650.674	19211.167	NA	9	70	55	15	8	6	70	59	11
85	12/19/05	5.3	48479400	22511.589	22999.782	19691.707	19251.542	NA	9.4	68	58	10	8.2	6.4	68	58	10
	12/20/05	6.3	48712200	22565.388	23060.099	19741.932	19300.446	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/21/05	4.7	48886800	22605.207	23105.724	19779.827	19337.066	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/22/05	4.8	49059900	22644.420	23151.499	19817.507	19373.259	NA	12.2	74	60	14	11	9	74	60	14
	12/23/05	0.6	49090200	22651.304	23159.555	19824.248	19379.718	NA	12/3.8	76	56	20	11/3.2	9/2	76	58	18
	12/24/05	5.5	49291500	22700.641	23211.713	19866.522	19419.786	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/25/05	5.5	49497440	22750.118	23265.304	19909.370	19461.873	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
86	12/26/05	5.0	49685300	22794.705	23314.392	19949.066	19499.947	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/27/05	5.0	49863600	22836.503	23361.087	19987.215	19535.777	NA	6.8	69	59	10	6.6	5.2	69	59	10
	12/28/05	4.8	49986800	22865.304	23393.420	20013.997	19560.590	NA	6.8	69	60	9	7	6.8	69	60	9
	12/29/05	0.2	50048300	22879.637	23409.532	20027.232	19572.666	NA	8.2	69	58	11	7.6	6	69	58	11
	12/30/05	5.2	50249200	22926.154	23462.333	20071.539	19612.609	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/31/05	5.5	50445100	22971.433	23513.772	20115.065	19651.403	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/01/06	4.9	50627100	23013.618	23561.432	20155.726	19687.083	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
87	01/02/06	3.3	50748200	23042.366	23593.595	20183.248	19711.122	NA	11	71	60	11	10	9	70	60	10
	01/03/06	1.7	50809100	23056.244	23609.155	20196.317	19722.448	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/04/06	5.4	51007400	23103.306	23660.631	20240.572	19760.605	NA	12.2/13.8	72	58	14	11.2/3.2	9.8/2	72	58	14
	01/05/06	6.7	51259900	23165.704	23726.038	20293.318	19810.323	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/06/06	4.8	51435500	23207.354	23771.740	20330.284	19845.890	NA	5.8	68	58	10	5.4	4.4	68	58	10
	01/07/06	1.4	51490100	23220.643	23786.504	20342.342	19857.408	NA	6	66	58	8	6	4.4	66	58	8
	01/08/06	3.7	51630100	23252.947	23822.750	20371.696	19885.751	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
88	01/09/06	5.8	51840500	23301.625	23872.985	20416.938	19927.262	NA	8.6	68	58	10	7	5.8	68	58	10
	01/10/06	5.6	52048800	23349.572	23932.684	20461.805	19968.658	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/11/06	4.9	52230800	23391.554	23980.145	20501.368	20004.549	NA	9.2	70	60	10	8.8	7	70	60	10
	01/12/06	4.9	52414100	23434.289	24027.860	20541.460	20040.351	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/13/06	1.1	52457600	23444.677	24039.219	20551.177	20049.005	NA	10	70	58	12	9.3	8	68	58	10
	01/14/06	4.3	52613700	23481.160	24079.499	20585.289	20079.075	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/15/06	5.6	52818300	23529.922	24131.954	20629.646	20118.143	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
89	01/16/06	5.4	53018600	23578.430	24182.713	20673.082	20155.793	NA	10	68	58	10	8.8	7	68	58	10
	01/17/06	5.0	53202300	23624.128	24228.678	20712.905	20189.110	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/18/06	2.2	53284300	23645.576	24249.577	20731.205	20205.317	NA	11	57	70	NA	9.2	8.2	57	70	NA
	01/19/06	3.8	53424400	23680.324	24283.680	20760.979	20230.236	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/20/06	5.4	53625700	23731.783	24333.341	20804.765	20266.521	NA	12/4.8	72	58	14	11/3.2	10/2	72	58	14
	01/21/06	4.8	53807000	23777.643	24380.243	20842.698	20301.183	NA	4	69	60	9	3.5	3.2	68	60	8
	01/22/06	1.8	53873900	23793.172	24397.011	20855.944	20313.921	NA	5	64	59	5	4	4	62	59	3
90	01/23/06	5.5	54082400	23842.207	24450.921	20899.222	20355.092	NA	5.4	65	56	9	5.6	4.4	65	56	9
	01/24/06	5.3	54284100	23888.946	24503.391	20941.740	20394.572	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/25/06	5.1	54472300	23932.500	24552.440	20981.840	20431.225	NA	7.2	68	58	10	6.2	5.8	68	58	10
	01/26/06	5.1	54659800	23974.952	24601.365	21022.296	20467.780	NA	8	72	62	10	7	6	70	62	8
	01/27/06	0.2	5466800	23976.840	24603.520	21024.173	20469.360	NA	8.3	66	56	10	8	6.3	66	56	10
	01/28/06	5.4	54869400	24022.455	24656.002	21067.601	20508.168	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/29/06	5.6	55078500	24069.760	24710.511	21113.312	20548.385	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
91	01/30/06	5.1	55269400	24112.987	24760.228	21155.299	20584.843	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/31/06	4.7	55444300	24152.835	24805.594	21193.770	20617.990	NA	11	74	62	12	10.5	9.2	74	62	12
	02/01/06	0.2	55456300	24155.636	24808.684	21196.511	20620.586	NA	12/3.8	72	56	16	11/3.2	9.2/2.2	74	56	18
	02/02/06	6.0	55676500	24209.660	24864.826	21242.253	20661.604	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/03/06	5.3	55878100	24257.006	24916.664	21283.567	20701.800	NA	5.2	68	59	9	4.8	3.8	68	59	9
	02/04/06	5.0	56053200	24297.463	24961.991	21320.216	20736.541	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/05/06	2.0	56132100	24315.765	24982.785	21337.196	20752.425	NA	6	66	58	8	5.8	5	64	58	6
92	02/06/06	3.3	56256800	24343.916	25014.955	21363.179	20776.733	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/07/06	4.9	56443400	24386.097	25063.580	21402.882	20813.259	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/08/06	1.5	5650200	24399.630	25079.268	21415.842	20825.107	NA	8	68	58	10	7	6	66	58	8
	02/09/06	3.6	56639200	24430.093	25114.789	21444.983	20851.390	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/10/06	5.2	56833100	24473.345	25165.720	21487.235	20888.900	NA	9.6	70	58	12	9	7.8	70	58	12
	02/11/06	4.7	57010600	24513.010	25212.363	21526.154	20922.891	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/12/06	3.9	57160800	24547.009	25252.134	21559.760	20952.014	NA	10.1	70	60	10	9.3	8	70	60	10
93	02/13/06	1.6	57219600	24559.746	25267.127	21572.349	20962.781	NA	11	70	58	12	10	9	70	58	12
	02/14/06	5.4	57415000	24604.036	25317.856	21615.327	20999.507	NA	11.8	72	58	14	11.2	10	72	58	14
	02/15/06	1.0	57454300	24613.252	25328.002	21624.024	21006.932	NA	11.8/2.6	70	58	12	11.2/7.4	10/2	70	58	12
	02/16/06	5.0	57640700	24658.560	25375.503	21663.477	21040.856	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/17/06	5.2	57834900	24704.460	25425.605	21703.100	21078.945	NA	5	68	58	10	5.2	4.2	68	58	10
	02/18/06	3.2	57958600	24733.629	25458.100	21729.120	21103.539	NA	5	70	60	10	6	5	69	60	9
	02/19/06	1.7	58022700	24748.153	25474.426	21741.939	21115.521	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
94	02/20/06	5.6	58232500	24796.322	25529.168	21785.840	21156.325	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/21/06	5.2	58425100	24840.046	25579.616	21826.000	21193.865	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/22/06	4.6	58598100	24879.169	25624.814	21863.690	21227.618	NA	8.8	70	59	11	8.2	6.4	70	59	11
	02/23/06	2.2	58684900	24898.847	25647.731	21882.634	21244.719	NA	9	70	59	11	8.2	6.4	70	60	10
	02/24/06	3.0	58794700	24923.063	25676.170	21906.030	21265.576	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/25/06	5.4	58995100	24967.808	25728.620	21949.595	21304.010	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/26/06	5.0	59182000	25009.422	25777.475	21990.630	21339.716	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
95	02/27/06	4.4	59346500	25046.239	25820.365	22026.992	21371.106	NA	11	76	62	14	10	9.2	74	62	12
	02/28/06	0.3	59360500	25049.353	25823.971	22029.943	21373.601	NA	11.8/3.8	72	58	14	10.8/3.6	9.8/2.4	72	58	14
	03/01/06	6.3	59382000	25103.167	25880.505	22076.308	21414.907	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/02/06	5.5	59793900	25153.273	25934.655	22119.829	21456.272	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/03/06	4.5	59966400	25193.496	25979.063	22155.645	21489.786	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/04/06	1.5	60026600	25207.733	25994.961	22168.659	21501.867	NA	6	66	58	8	6	5	64	58	6
	03/05/06	3.9	60173800	25241.388	26032.723	22199.100	21529.937	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
96	03/06/06	5.3	60373500	25286.989	26084.607	22241.313	21568.428	NA	8	68	57	11	8	6.2	68	57	11
	03/07/06	4.7	60552900	25327.633	26131.196	22279.766	21602.922	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/08/06	2.7	60657400	25351.145	26158.370	22302.433	21623.130	NA	9.2	72	59	13	9	7	68	60	8
	03/09/06	2.2	60738600	25369.343	26179.466	22319.844	21638.583	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/10/06	5.1	60932700	25412.774	26229.625	22362.121	21675.755	NA	10.8/3.8	70	57	13	10.2/3.6	8.8/2.2	70	57	13
	03/11/06	6.1	61157200	25468.133	26286.895	22408.644	21718.776	NA	5	70	60	10	5	3	69	60	9
	03/12/06	0.7	61183700	25474.110	26293.251	22413.561	21723.390	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
97	03/13/06	5.5	61390800	25522.803	26346.362	22456.285	21763.449	NA	6	66	58	8	6.2	4.6	66	58	8
	03/14/06	5.1	61586500	25568.312	26396.714	22497.239	21801.105	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/15/06	2.2	61668100	25587.542	26418.385	22515.115	21817.405	NA	7	66	60	6	7	6	66	60	6
	03/16/06	2.9	61781800	25613.048	26447.191	22538.654	21838.641	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/17/06	5.5	61978300	25657.543	26498.127	22580.559	21876.418	NA	9	66	58	8	8.8	6.2	66	58	8
	03/18/06	5.2	62174700	25701.496	26549.133	22622.737	21914.180	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/19/06	4.5	62346200	25739.542	26593.965	22659.894	21946.985	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
98	03/20/06	2.0	62423700	25756.484	26614.132	22676.814	21961.810	NA	10.3	72	58	14	10	8.8	70	58	12
	03/21/06	3.3	62546000	25783.411	26646.389	22703.443	21985.026	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/22/06	5.9	62759900	25830.311	26702.672	22750.404	22025.613	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/23/06	2.7	62863700	25853.083	26730.107	22773.461	22045.402	NA	13/4.2	76	60	16	12/4.5	10/2.9	72	60	12
	03/24/06	3.0	62974900	25880.395	26758.581	22796.882	22065.899	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/25/06	5.1	63168000	25926.430	26807.774	22836.067	22102.620	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/26/06	4.6	63344000	25967.570	26853.031	22872.290	22136.655	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
99	03/27/06	11.0	63391600	25978.825	26865.334	22882.212	22146.017	NA	5	66	56	10	6	4	64	58	6
	03/28/06	4.1	63546300	26014.486	26905.417	22914.264	22175.825	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/29/06	5.2	63744900	26059.418	26959.710	22955.991	22214.213	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/30/06	5.1	63938800	26102.681	27007.808	22997.111	22251.619	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/31/06	3.2	64060500	26129.563	27039.751	22997.442	22275.283	NA	7.8	70	60	10	8	6.4	70	60	10
	04/01/06	3.8	64128500	26144.474	27057.572	22997.442	22288.256	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/02/06	3.3	64328700	26188.069	27110.234	22997.442	22326.925	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
100	04/03/06	4.6	64504600	26226.045	27156.625	22997.442	22360.931	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/04/06	0.5	64526900	26230.840	27162.493	NR	22365.345	NA	12	70	56	14	10	9	70	58	12
	04/05/06	1.0	64704800	26268.861	27209.454	22997.443	22399.521	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/06/06	2.0	64902400	26310.632	27261.772	NR	22437.562	NA	13/5.2	72	60	12	12/3.4	10.5/2.2	72	60	12
	04/07/06	7.8	64975700	26329.879	27280.067	NR	22450.136	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/08/06	NA	65172100	26376.734	27330.009	23037.895	22487.951	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/09/06	4.8	65358100	26420.233	27377.605	23076.679	22523.544	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	04/10/06	0.8	65390400	26427.747	27385.995	23083.680	22529.934	4.8	6	66	56	10	6	5	64	58	6
	04/11/06	4.4	65557500	26466.002	27429.006	23118.815	22561.664	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/12/06	5.2	65754300	26510.422	27479.934	23160.935	22599.264	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
101	04/13/06	4.6	65928500	26549.174	27525.201	23198.553	22632.584	10.5	9.8	70	61	9	8.2	6	70	61	9
	04/14/06	0.1	65932600	26550.089	27526.268	23199.441	22633.369	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/15/06	5.6	66139600	26595.632	27580.165	23244.626	22672.966	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/16/06	5.4	66342200	26639.609	27633.110	23289.324	22711.679	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/17/06	5.1	66453600	26663.673	27662.377	23314.410	22733.172	11.5	11.8	70	62	8	9.8	8.9	70	60	10
	04/18/06	2.1	66533400	26680.674	27683.166	23331.909	22748.124	12	12	70	56	14	10.5	9.4	70	56	14
	04/19/06	3.8	66760500	26735.432	27740.211	23379.426	22790.320	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
102	04/20/06	4.9	66964100	26783.631	27791.386	23421.226	22829.156	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/21/06	5.4	67148500	26826.846	27837.979	23459.512	22864.319	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/22/06	4.1	67305300	26863.663	2787.173	23493.125	22895.046	8	9	70	60	10	6	5	70	61	9
	04/23/06	0.9	67338800	26870.689	27886.174	23499.416	22900.681	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/24/06	5.6	67550000	26918.629	27939.790	23544.202	22941.001	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/25/06	5.5	67754700	26964.451	27991.903	23588.030	22980.097	11	11	70	60	10	9	8	70	60	10
	04/26/06	4.9	67941400	27005.728	28034.398	23628.376	23015.775	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
103	04/27/06	0.4	67954000	27008.482	28042.624	23631.245	23018.343	11.8/4.0	11.2/5.8	70	56	14	9.8/7.0	8.8/6.0	66	56	10
	04/28/06	5.8	68174700	27059.312	28098.391	23678.377	23059.331	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/29/06	5.3	68377000	27106.856	28149.058	23719.407	23097.914	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/30/06	0.8	68411100	27115.035	28157.965	23726.774	23104.798	6	7	66	56	10	5.3	4.1	64	58	6
	05/01/06	4.6	68581400	27153.959	28200.590	23761.490	23136.885	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/02/06	5.5	68789300	27201.073	28253.288	23804.939	23176.448	9.5	9.2	68	58	10	7	5.8	68	58	10
	05/03/06	5.1	68980700	27243.895	28301.946	23845.377	23212.822	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
104	05/04/06	4.8	69162800	27284.403	28348.284	23884.287	23247.519	10	10	68	58	10	8.8	7	68	58	10
	05/05/06	4.8	69340300	27322.941	28393.451	23922.564	23281.234	11.5/4	11/7	70	60	10	9.4/7	7.8/6	70	60	10
	05/06/06	1.8	69408400	27339.625	28410.058	23936.814	23293.419	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/07/06	5.0	69615400	27387.653	28461.831	23979.046	23332.670	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/08/06	6.0	69827700	27436.017	28515.258	24023.085	23373.163	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/09/06	5.2	70021000	27479.436	28563.983	24063.657	23410.188	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/10/06	4.8	70204400	27520.157	28610.310	24102.419	23445.352	9.5	9.5	70	60	10	7.2	6.2	70	60	10
105	05/11/06	3.3	70370300	27556.619	28652.328	24138.003	23477.355	10	8.5	70	62	8	7.5	6.2	70	62	8
	05/12/06	1.8	70397700	27562.684	28659.310	24143.768	23482.850	10.5/4.5	10.5/3.5	68	56	12	9.2/3.2	7/2	68	56	12
	05/13/06	6.0	70624100	27615.783	28715.588	24190.630	23525.135	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/14/06	5.0	70812900	27659.097	28762.788	24229.436	23561.132	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/15/06	3.7	70955100	27691.236	28798.385	24259.164	23588.410	7	6.2	68	60	8	5.9	4.5	68	60	8
	05/16/06	2.0	71027300	27707.461	28816.427	24274.144	23602.000	8.5	7	68	58	10	6.2	5	68	58	10
	05/17/06	6.2	71262600	27759.873	28875.568	24323.822	23646.676	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
106	05/18/06	1.8	71333300	27775.458	28893.306	24339.031	23660.255	9.5	9	68	58	10	8	6	66	58	8
	05/19/06	3.6	71467100	27804.864	28926.864	24367.585	23685.532	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/20/06	5.4	71669300	27848.920	28977.571	24411.350	23723.978	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/21/06	4.8	71848600	27887.663	29022.540	24450.541	23758.037	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	05/22/06	1.8	71916200	27901.799	29039.100	24465.131	23770.735	12/5	12/4.5	72	58	14	10/7	8.5/4.8	72	58	14
	05/23/06	4.2	72073400	27942.665	29081.687	24502.268	23789.827	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/24/06	5.4	72277200	27993.328	29137.876	24552.068	23812.786	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
107	05/25/06	4.9	72462200	28038.400	29188.969	24596.920	23834.869	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/26/06	5.1	72671200	28088.447	29246.737	24647.205	23861.843	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/27/06	0.0	72671200	28088.447	29246.737	24647.205	23861.043	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/28/06	6.7	72907000	28144.081	29311.677	24703.506	23891.685	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/29/06	6.0	73131000	28196.267	29373.197	24756.778	23921.683	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/30/06	6.6	73378200	28252.942	29440.919	24815.396	23955.387	12	11.2	70	58	12	12	11.6	70	58	12
	05/31/06	6.3	73610200	28305.427	29504.354	24870.499	23987.528	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
108	06/01/06	7.4	73883900	28366.571	29579.451	24935.155	24025.898	14/3	13/4	70	56	14	13/4	12/2.2	70	56	14
	06/02/06	7.9	74181500	28438.830	29654.346	24995.960	24077.676	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/03/06	5.8	74400100	28484.879	29708.692	25039.806	24117.929	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/04/06	5.3	74599100	28535.837	29758.355	25080.029	24154.519	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/05/06	5.6	74812900	28584.586	29811.862	25123.462	24193.740	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/06/06	6.6	75060300	28640.418	29873.999	25174.144	24239.023	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/07/06	6.8	75312700	28696.724	29937.608	25226.286	24285.153	10	10	70	59	11	9.2	7.5	70	59	11
109	06/08/06	NA	NR	28747.732	29996.069	25274.533	24327.311	11/4.5	11/4.0	70	58	12	10/5	8.5/4.5	70	58	12
	06/09/06	NA	NR	28814.728	30058.774	25336.631	24358.248	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/10/06	20.5	76079600	28882.980	30132.804	25402.414	24390.378	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/11/06	6.5	76322200	28941.757	30197.717	25459.619	24420.192	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/12/06	6.4	76558000	28998.018	30260.641	25514.651	24450.498	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/13/06	6.2	76789600	29052.928	30322.252	25568.461	24481.025	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/14/06	6.7	77038400	29111.077	30388.754	25626.549	24513.654	11	10	70	58	12	10	10	70	58	12
110	06/15/06	7.7	77327900	29178.551	30465.417	25693.997	24553.702	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/16/06	8.4	77638000	29249.502	30548.304	25766.593	24595.988	13/3.5	11/3	70	56	14	12/4	12/2.2	70	58	12
	06/17/06	9.1	77978500	29327.846	30632.794	25836.130	24656.688	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/18/06	9.3	78326200	29404.094	30719.417	25907.035	24721.594	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/19/06	6.3	78562900	29455.049	30778.790	25956.133	24765.716	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/20/06	6.1	78786700	29502.739	30835.135	26003.109	24807.398	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/21/06	4.9	78971400	29541.606	30881.807	26042.135	24841.734	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
111	06/22/06	NA	78976200	29542.345	30882.727	26042.969	24842.507	11/4	12/3	64	56	8	10/4	9/2.5	63	57	6
	06/23/06	NA	79238300	29602.070	30947.979	26097.163	24890.152	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/24/06	NA	79461600	29652.469	31002.696	26142.064	24931.573	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/25/06	NA	79646700	29693.681	31048.339	26179.652	24965.846	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/26/06	NA	79831300	29734.267	31093.993	26217.524	24999.977	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/27/06	NA	80015700	29774.442	31139.700	26255.741	25034.164	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/28/06	NA	80126100	29798.441	31167.415	26279.279	25055.095	11/3	10/3	70	60	10	9/5	8/2.5	70	60	10
112	06/29/06	NA	80260900	29828.994	31200.128	26306.479	25078.778	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	06/30/06	NA	80465800	29875.092	31250.078	26347.463	25116.915	9	6	65	59	6	5	4	65	59	6
	07/01/06	NA	80691900	29924.946	31305.501	26393.506	25158.954	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/02/06	NA	80880200	29965.940	31351.816	26432.403	25193.977	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	07/03/06	NA	81087600	30010.668	31402.874	26475.816	25232.546	10	9	70	60	10	6	7	70	60	10
	07/04/06	NA	81289400	30053.889	31452.541	26518.599	25270.106	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/05/06	NA	81477500	30094.058	31498.861	26559.043	25305.198	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
113	07/06/06	NA	81658900	30132.102	31543.565	26598.242	25338.913	12/5	12/4.5	NR	NR	NA	11/6	9/5	72	60	12
	07/07/06	NA	81902000	30192.321	31607.281	26656.633	25365.750	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/08/06	NA	82118900	30244.659	31664.953	26709.679	25389.617	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/09/06	NA	82337800	30296.359	31723.003	26762.443	25415.334	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/10/06	NA	82556900	30347.287	31780.980	26814.777	25442.444	11	11	75	60	15	10	10	70	60	10
	07/11/06	NA	82765000	30394.875	31835.915	26864.250	25469.353	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/12/06	NA	82968000	30440.633	31889.446	26912.331	25496.373	13/3.5	13/3.5	74	60	14	12/3	12/2.5	74	60	14
114	07/13/06	NA	83036300	30457.748	31906.415	26927.025	25506.150	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/14/06	NA	83247500	30505.137	31957.131	26969.322	25545.584	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/15/06	NA	83461900	30552.506	32008.810	27012.826	25585.712	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/16/06	NA	83666400	30597.117	32058.247	27054.855	25624.011	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/17/06	NA	83910800	30649.948	32117.573	27105.541	25669.664	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/18/06	NA	84127400	30696.354	32170.320	27150.810	25710.070	11	11	72	59	13	9	8	72	59	13
	07/19/06	5.2	84317600	30736.697	32216.719	27190.891	25745.450	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
115	07/20/06	5.1	84506800	30776.569	32263.060	27231.174	25780.714	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/21/06	3.5	84637100	30804.123	32295.340	27259.574	25805.323	13	13	73	60	13	11	9	72	60	12
	07/22/06	2.2	84719200	30820.994	32315.232	27276.739	25820.097	14/6.5	14/6	72	56	16	12.5/9	11/7.5	72	56	16
	07/23/06	6.3	84954300	30885.893	32382.601	27314.592	25852.221	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/24/06	5.8	85167200	30942.879	32444.651	27349.263	25881.420	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/25/06	5.4	85370400	30995.970	32503.332	27383.398	25909.998	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/26/06	3.6	85505200	31030.920	32542.589	27406.970	25929.709	11/4	10/4	75	60	15	13/3.5	12/2	72	60	12
116	07/27/06	3.0	85612000	31057.835	32570.879	27426.160	25945.149	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/28/06	5.6	85822700	31104.514	32621.923	27468.709	25984.535	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/29/06	5.2	86018800	31147.266	32669.672	27508.774	26021.289	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/30/06	5.0	86207800	31188.008	32715.771	27547.796	26056.657	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	07/31/06	4.3	86367600	31222.431	32755.222	27581.591	26086.988	9	9	70	60	10	8	6	69	60	9
	08/01/06	1.5	86422400	31233.807	32768.244	27592.541	26096.757	9.5	9.5	68	58	10	8.5	6.5	68	58	10
	08/02/06	6.5	86663600	31284.954	32827.329	27643.255	26141.794	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
117	08/03/06	4.1	86818600	31317.532	32865.385	27676.171	26170.716	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/04/06	5.7	87030800	31361.785	32917.642	27721.598	26210.241	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/05/06	5.4	87229900	31402.995	32966.782	27764.503	26247.387	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/06/06	3.3	87351900	31428.439	32997.485	27791.451	26270.636	14/6	14/6	74	59	15	12/9	11/7	74	59	15
	08/07/06	2.8	87455800	31456.967	33026.302	27807.585	26284.317	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/08/06	5.8	87673600	31516.356	33090.556	27841.880	26313.187	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/09/06	5.7	87885300	31572.226	33152.291	27876.541	26342.268	11	11	72	59	13	13	12	70	59	11
118	08/10/06	5.2	88077900	31622.036	33207.747	27909.116	26369.417	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/11/06	1.4	88131200	31635.896	33223.388	27918.667	26377.356	12/4.5	11/4.5	71	58	13	14/3.7	13/6	70	59	11
	08/12/06	5.4	88332600	31684.154	33275.157	27956.861	26409.896	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/13/06	5.8	88550200	31731.774	33327.461	28001.139	26450.515	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
	08/14/06	5.9	88769300	31779.095	33380.205	28046.311	26491.372	8.5	7.5	69	59	10	6.5	6	69	59	10
	08/15/06	5.7	88983700	31824.791	33431.846	28091.119	26531.122	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/16/06	5.4	89184200	31867.152	33480.167	28133.153	26568.334	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
119	08/17/06	3.1	89303600	31892.611	33509.357	28158.787	26590.921	11	10	71	60	11	9	8	70	60	10
	08/18/06	2.9	89409200	31914.681	33534.685	28180.864	26610.355	12/4.5	12/4.5	69	58	11	10/7	9/6	69	58	11
	08/19/06	6.4	89649500	31968.040	33591.498	28229.403	26653.360	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/20/06	5.7	89861700	32014.442	33641.820	28272.206	26692.706	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/21/06	4.9	90047500	32054.500	33685.904	28310.193	26727.104	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/22/06	3.8	90191400	32085.547	33720.352	28340.249	26754.169	9	8	71	60	11	8	6	69	60	9
	08/23/06	1.7	90251700	32098.172	33734.325	28352.276	26764.926	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
120	08/24/06	6.0	90476400	32145.858	33787.654	28398.910	26806.499	11/5	10.5/4	68	57	11	9/7	8.5/6	68	57	11
	08/25/06	6.8	90734200	32203.498	33847.518	28450.696	26853.427	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/26/06	0.1	90738900	32203.678	33847.774	28451.076	26853.813	7	7	62	57	5	7	5	62	58	4
	08/27/06	5.7	90951100	32250.725	33898.304	28495.116	26894.125	8	8	69	59	10	7	6	64	60	4
	08/28/06	5.5	91157900	32294.802	33946.073	28537.100	26932.125	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/29/06	5.0	91345200	32334.456	33989.687	28575.845	26966.880	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	08/30/06	0.1	91348100	32334.632	33989.924	28576.189	26967.245	11	10	68	59	9	9	8	68	59	9
121	08/31/06	5.8	91563400	32380.463	34040.527	28621.514	27007.310	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/01/06	5.6	91772800	32424.403	34089.367	28665.774	27046.081	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/02/06	2.3	91859200	32442.749	34109.906	28684.578	27062.491	13/4	13/4	72	58	14	11/6	10/2	72	58	14
	09/03/06	4.2	92017500	32478.654	34146.199	28716.100	27090.062	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/04/06	5.2	92212300	32521.099	34191.297	28755.657	27125.772	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/05/06	0.5	92233500	32525.957	34196.552	28760.401	27130.051	9	8	63	58	5	8	8	60	57	3
	09/06/06	5.4	92434400	32568.949	34243.016	28801.231	27166.497	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
122	09/07/06	5.4	92637600	32612.382	34290.475	28843.293	27203.672	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/08/06	0.6	92660400	32617.472	34296.116	28848.457	27208.229	10	9.5	69	58	11	8	8	63	59	4
	09/09/06	5.6	92869300	32661.340	34344.409	28891.655	27246.044	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/10/06	5.4	93069400	32703.309	34390.917	28933.723	27282.603	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/11/06	0.1	93074400	32703.475	34391.153	28934.069	27282.941	12	13	70	58	12	11	9	70	58	12
	09/12/06	5.8	93286700	32748.563	34441.521	28979.820	27322.329	13/5	13/4	72	58	14	12/4	11/3	72	58	14
	09/13/06	1.8	93357800	32765.466	34457.925	28994.231	27334.067	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
123	09/14/06	5.6	93567700	32810.972	34506.491	29036.387	27372.634	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/15/06	5.3	93766800	32853.633	34552.619	29077.026	27409.059	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/16/06	0.9	93801000	32861.135	34560.823	29084.490	27415.750	9	8.5	68	58	10	7	6	68	58	10
	09/17/06	5.0	93987200	32900.328	34603.499	29122.425	27449.357	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/18/06	5.4	94189200	32942.806	34650.084	29164.226	27486.290	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/19/06	1.3	94240000	32954.083	34662.446	29175.382	27496.132	11	10.5	68	57	11	9.5	8	68	57	11
	09/20/06	4.5	94405000	32987.971	34699.909	29209.227	27525.782	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
124	09/21/06	5.7	94617900	33031.986	34748.862	29253.955	27564.585	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/22/06	0.3	94631600	33034.990	34752.261	29257.191	27567.391	13/5	13/7	70	57	13	11/3.5	9/2.5	69	58	11
	09/23/06	6.1	94857400	33084.335	34803.416	29302.990	27607.054	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/24/06	5.1	95052800	33126.485	34847.743	29341.981	27642.695	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
125	09/25/06	0.0	95052800	33126.485	34877.430	29341.981	27642.695	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/26/06	5.8	95270200	33172.918	34897.292	29386.092	27682.447	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/27/06	5.0	95455000	33212.187	34939.487	29423.924	27716.268	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/28/06	0.0	95455000	33212.187	34939.487	29423.924	27716.268	10.5/5	10/7	68	58	10	9/4	7/2.5	68	58	10
	09/29/06	6.1	95687900	33263.210	34992.396	29471.096	27758.260	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	09/30/06	4.8	95868400	33302.085	35033.179	29507.083	27791.483	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/01/06	0.0	95868400	33302.085	35033.179	29507.083	27791.483	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
126	10/02/06	5.7	96081700	33347.619	35081.140	29550.284	27830.853	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/03/06	3.5	96214700	33376.024	35111.452	29577.927	27855.807	9	9	70	60	10	7	6	68	60	8
	10/04/06	1.8	96279100	33389.444	35125.637	29590.771	27867.336	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/05/06	5.4	96482300	33432.209	35171.291	29632.735	27904.899	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/06/06	3.5	96644400	33466.488	35208.156	29666.900	27935.195	11/4	11/4	75	61	14	9/3	8/2	70	61	9
	10/07/06	3.4	96741400	33488.041	35229.424	29686.234	27951.595	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/08/06	5.1	96934900	33529.878	35272.835	29724.701	27986.959	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
127	10/09/06	0.0	96934900	33529.878	35272.835	29724.701	27986.959	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/10/06	9.0	97273100	33603.837	35349.890	29792.834	28049.021	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/11/06	3.2	97396900	33630.609	35378.219	29818.293	28072.125	7	6	70	60	10	6	4	69	60	9
	10/12/06	2.2	97474900	33646.840	35395.381	29833.590	28085.889	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/13/06	8.5	97794000	33714.251	35466.877	29898.812	28144.290	10.5/4	10/4	68	58	10	9/4	6/2	68	58	10
	10/14/06	8.2	98101600	33781.954	35535.097	29960.562	28199.834	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/15/06	0.7	98129700	33788.423	35546.757	29966.654	28205.496	6	5.5	66	56	10	5	4	66	56	10
128	10/16/06	5.0	98319400	33828.970	35583.212	30004.006	28239.687	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/17/06	5.8	98537200	33875.402	35631.203	30048.123	28279.705	9	8	70	60	10	8	6	70	60	10
	10/18/06	0.9	98569600	33882.242	35638.321	30054.690	28285.616	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/19/06	7.0	98831300	33937.419	35695.915	30108.272	28333.512	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/20/06	5.4	99033500	33979.750	35740.174	30150.123	28370.481	12/4	11/3	72	60	12	10/3	9/2	72	60	12
	10/21/06	1.8	99101500	33995.559	35754.819	30163.742	28381.910	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/22/06	7.8	99392300	34058.474	35818.022	30222.024	28434.599	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
129	10/23/06	0.0	99392300	34058.474	35818.022	30222.024	28434.599	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/24/06	6.7	99644800	34112.437	35872.769	30273.615	28480.373	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/25/06	6.0	99867300	34159.510	35920.996	30319.512	28520.649	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/26/06	0.0	99867300	34159.510	35920.996	30319.512	28520.649	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/27/06	5.8	85700	34205.406	35968.635	30365.114	28560.168	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/28/06	5.2	279800	34245.905	36010.927	30406.002	28595.248	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	10/29/06	0.0	279800	34245.905	36010.927	30406.002	28595.248	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
130	10/30/06	6.0	502200	34292.083	36058.748	30453.294	28635.458	13/6	14/5	72	58	14	13/7	11/3	72	58	14
	10/31/06	1.9	572100	34308.719	36073.830	30467.329	28646.660	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/01/06	5.6	785300	34354.864	36119.985	30509.940	28685.355	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/02/06	5.2	980000	34396.602	36162.460	30549.305	28720.782	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/03/06	0.0	980000	34396.602	36162.460	30549.305	28720.782	9.5/6	9.5/5	70	59	11	7/6	6/2.5	70	59	11
	11/04/06	10.1	1359700	34479.336	36245.172	30625.729	28789.575	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/05/06	0.0	1359700	34479.336	36245.172	30625.729	28789.575	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
131	11/06/06	7.1	1626400	34536.548	36303.693	30679.494	28838.416	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/07/06	5.7	1838700	34581.514	36350.430	30722.879	28877.341	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/08/06	0.0	1838700	34581.514	36350.430	30722.879	28877.341	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/09/06	6.2	2068800	34629.899	36400.781	30770.191	28919.623	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/10/06	5.9	2289200	34675.919	36449.275	30816.074	28960.075	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/11/06	0.0	2289200	34675.919	36449.275	30816.074	28960.075	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/12/06	6.7	2536800	34727.196	36503.995	30868.032	29005.467	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
132	11/13/06	4.6	2707600	34762.459	36541.800	30904.184	29036.601	15/5	15/4.5	74	58	16	13/4	12/6	74	58	16
	11/14/06	1.8	2777500	34779.223	36557.313	30918.240	29047.775	5	4	65	59	6	6	6	60	58	2
	11/15/06	4.9	2963600	34819.738	36598.375	30955.267	29081.492	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/16/06	4.9	3149400	34859.898	36639.417	30992.689	29115.069	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/17/06	4.5	3318100	34896.123	36676.625	31027.131	29145.507	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/18/06	0.0	3318100	34896.123	36676.625	31027.131	29145.507	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/19/06	5.3	3515600	34938.189	36720.220	31067.721	29181.090	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
133	11/20/06	5.0	3704100	34978.035	36761.871	31106.794	29215.027	11/4	12/5	70	58	12	10/4	9/3	70	68	2
	11/21/06	1.8	3773900	34994.251	36777.335	31120.807	29226.588	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/22/06	5.2	3969100	35036.662	36820.975	31159.389	29261.513	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/23/06	5.1	4161100	35077.877	36863.786	31197.876	29295.848	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/24/06	4.3	4324800	35112.659	36900.256	31230.968	29325.109	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/25/06	0.0	4324800	35112.659	36900.256	31230.968	29325.109	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/26/06	5.3	4522000	35154.438	36944.177	31271.439	29360.412	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
134	11/27/06	5.2	4716300	35195.334	36987.398	31311.694	29395.308	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/28/06	4.4	4882000	35230.221	37024.780	31346.149	29425.029	11/4	10/4	72	62	10	10/4	9/3	72	62	10
	11/29/06	2.3	4967300	35249.707	37043.610	31363.425	29439.360	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	11/30/06	4.9	5154200	35291.074	37086.074	31400.248	29473.255	6	5	70	60	10	5	4	68	60	8
	12/01/06	4.4	5322900	35327.859	37123.763	31433.597	29503.689	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/02/06	0.0	5322900	35327.859	37123.763	31433.597	29503.689	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/03/06	9.3	5426100	35350.192	37146.649	31454.171	29522.321	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
135	12/04/06	0.0	5672400	35403.030	37201.247	31503.983	29566.913	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/05/06	5.1	5865100	35444.007	37243.065	31543.326	29601.680	10/4	10/4	72	60	12	9/3	8/3	72	60	12
	12/06/06	1.8	5934700	35459.901	37259.100	31557.325	29613.465	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/07/06	5.1	6128300	35501.905	37301.843	31595.736	29648.591	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/08/06	4.7	6304000	35539.555	37340.606	31630.943	29680.570	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/09/06	3.5	6439800	35568.672	37370.888	31658.767	29705.688	9	9	68	60	8	7	6	68	60	8
	12/10/06	1.7	6502000	35581.621	37384.239	31671.005	29716.642	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
136	12/11/06	5.5	6705700	35624.611	37429.175	31712.787	29753.893	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/12/06	5.3	6903700	35666.036	37472.740	31753.766	29790.043	12/5	12/4.5	70	58	12	10/4	9/25	70	58	12
	12/13/06	2.2	6987700	35685.151	37491.240	31770.705	29804.232	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/14/06	5.2	7185100	35728.066	37535.509	31810.115	29840.198	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/15/06	5.2	7377000	35769.612	37578.890	31849.281	29875.450	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/16/06	4.6	7551400	35806.617	37617.894	31884.869	29907.173	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/17/06	4.6	7722600	35842.640	37656.155	31920.133	29938.388	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
137	12/18/06	0.6	7745700	35847.681	37661.576	31925.252	29942.958	11/5	12/5	70	58	12	9/5	8/2.5	69	59	10
	12/19/06	5.5	7951500	35892.993	37707.235	31966.549	29978.770	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/20/06	5.3	8152300	35936.602	37752.031	32006.641	30014.969	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/21/06	5.1	8344500	35977.992	37794.907	32045.493	30049.610	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/22/06	4.6	8515700	36014.549	37833.011	32004.760	30080.531	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/23/06	1.3	8565200	36025.503	37844.547	32091.267	30090.041	11	10	69	57	12	8	7	69	57	12
	12/24/06	4.3	8723200	36058.566	37879.074	32123.132	30117.978	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
138	12/25/06	5.3	8921800	36100.447	37923.131	32164.379	30153.843	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/26/06	4.7	9095700	36168.630	37961.642	32200.694	30185.287	12/7	11/2.5	74	59	15	12/7	11/2.5	74	59	15
	12/27/06	1.8	9165400	36153.446	37977.153	32214.684	30196.569	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/28/06	5.4	9367300	36197.416	38022.499	32254.322	30233.108	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/29/06	5.1	9559700	36238.890	38065.431	32292.683	30268.032	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/30/06	4.6	9732300	36275.816	38103.061	32327.594	30299.252	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	12/31/06	0.0	9732300	36275.816	38103.061	32327.594	30299.252	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
139	01/01/07	5.4	9935600	36319.033	38149.001	32369.202	30336.057	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/02/07	5.5	10137900	36361.799	38193.858	32410.964	30372.655	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/03/07	5.1	10327000	36401.619	38235.784	32450.369	30406.931	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/04/07	4.8	10506500	36439.218	38275.445	32487.995	30439.552	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/05/07	4.9	10688000	36476.981	38315.451	32526.366	30472.527	14/6	14/8	74	60	14	13/7	12/3	74	60	14
	01/06/07	1.8	10754700	36493.191	38330.280	32539.631	30483.137	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/07/07	10.7	11158100	36581.422	38420.926	32619.894	30556.868	9	8	67	56	11	7	5	67	56	11
140	01/08/07	8.5	11473400	36649.024	38490.885	32682.801	30613.727	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/09/07	4.9	11656900	36688.096	38531.799	32720.285	30647.077	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/10/07	0.0	11656900	36688.096	38531.799	32720.285	30647.077	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/11/07	5.6	11863100	36731.685	38577.773	32762.809	30684.588	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/12/07	5.5	12068200	36774.756	38623.356	32805.602	30722.002	13/6	15/6	74	58	16	12/7	11/3	74	58	16
	01/13/07	1.9	12138000	36791.505	38638.943	32819.482	30733.405	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/14/07	5.6	12348300	36837.695	38686.139	32860.798	30771.459	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
141	01/15/07	5.3	12548100	36881.839	38731.827	32900.337	30807.836	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/16/07	4.9	12731100	36922.510	38774.120	32936.920	30841.265	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/17/07	0.0	12731100	36922.510	38774.120	32936.920	30841.265	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/18/07	5.4	12933300	36967.324	38820.762	32977.062	30678.194	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/19/07	5.3	13132300	37011.500	38866.793	33016.964	30914.612	9/5	8/5	66	58	8	9/5	8/5	66	58	8
	01/20/07	4.2	13294400	37048.268	38904.036	33049.634	30944.197	6	7	66	59	7	6	7	66	59	7
	01/21/07	3.2	13411400	37073.634	38929.954	33072.264	30965.035	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
142	01/22/07	5.4	13613800	37117.606	38975.551	33112.671	31001.780	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/23/07	2.2	13700500	37136.463	38995.384	33130.467	31017.886	9	8	64	59	5	7	5	63	59	4
	01/24/07	3.8	13841100	37166.335	39026.727	33158.607	31043.133	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/25/07	5.5	14043600	37209.552	39072.310	33206.095	31080.056	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/26/07	5.5	14249400	37253.148	39118.602	33242.444	31117.567	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/27/07	4.8	14427200	37290.661	39158.516	33279.456	31150.003	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/28/07	3.4	14553600	37317.570	39187.240	33306.277	31173.430	12	13	78	60	18	9	9	70	60	10

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
143	01/29/07	2.9	14662600	37340.393	39211.561	33328.859	31193.030	13/3	11/4	70	58	12	11/3	9/2	70	58	12
	01/30/07	4.6	14834100	37379.252	39250.342	33363.219	31222.964	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	01/31/07	5.4	15033900	37423.515	39295.963	33402.515	31258.923	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/01/07	5.2	15228900	37466.806	39341.083	33441.144	31294.511	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/02/07	4.6	15402400	37505.312	39381.355	33475.667	31326.290	7	6	70	60	10	6	5	69	60	9
	02/03/07	4.8	15582600	37545.773	39423.102	33511.650	31359.131	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/04/07	3.6	15720400	37576.178	39455.432	33539.642	31384.755	9	6	68	60	8	6	4	68	60	8
144	02/05/07	1.6	15778600	37588.623	39468.279	33550.893	31394.955	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/06/07	5.4	15979900	37633.049	39514.883	33591.253	31431.680	9	8	64	59	5	7	4	63	59	4
	02/07/07	5.5	16184600	37678.104	39562.085	33632.312	31468.958	9/6	9/6	66	58	8	7/3	5/5	66	58	8
	02/08/07	6.5	16428800	37733.001	39617.920	33680.446	31513.013	6	6	66	59	7	5	4	64	60	4
	02/09/07	0.9	16464900	37741.073	39626.264	33687.478	31519.573	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/10/07	5.4	16665400	37785.174	39671.823	33726.921	31556.166	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/11/07	5.6	16875200	37830.779	39719.293	33768.523	31594.581	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
145	02/12/07	5.5	17077800	37874.474	39765.019	33809.214	31631.650	10	10	70	59	11	8	7	65	59	6
	02/13/07	5.3	17277200	37917.153	39810.012	33849.765	31668.188	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/14/07	4.8	17452500	37955.339	39850.406	33885.628	31700.354	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/15/07	4.5	17620600	37992.062	39889.220	33919.965	31731.361	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/16/07	4.5	17786300	38028.297	39927.503	33954.009	31761.984	11	10	68	58	10	9	7	68	58	10
	02/17/07	3.8	17928900	38065.017	39964.446	33978.828	31783.939	7	7	68	58	10	7	6	68	58	10
	02/18/07	2.6	18010200	38085.246	39985.123	33992.074	31795.575	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
146	02/19/07	4.8	18201700	38133.079	40034.676	34024.781	31824.494	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/20/07	5.0	18389400	38179.023	40082.648	34057.558	31853.374	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/21/07	5.1	18575800	38223.904	40129.884	34090.799	31882.497	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/22/07	4.8	18752300	38266.601	40174.911	34123.035	31910.613	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/23/07	4.6	18920600	38307.268	40217.720	34153.998	31937.630	11/3	12/3	73	59	14	12/6	11/6	78	59	19
	02/24/07	1.8	18989400	38324.321	40234.269	34167.286	31948.360	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/25/07	5.1	19177600	38366.470	40277.567	34204.326	31981.906	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
147	02/26/07	4.8	19359100	38407.488	40320.183	34240.433	32014.687	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	02/27/07	4.9	19539300	38447.160	40361.475	34276.254	32046.857	8	7	68	58	10	6	5	68	58	10
	02/28/07	6.8	19710000	38503.012	40420.097	34326.873	32092.248	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/01/07	4.7	19967600	38542.073	40461.080	34362.430	32124.187	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/02/07	5.1	20153500	38583.231	40504.449	34400.014	32157.878	10/5	8/4	69	59	10	7/4	6/2	64	59	5
	03/03/07	2.7	20256300	38606.982	40528.140	34420.933	32176.238	6	6	64	56	8	6	4	64	56	8
	03/04/07	4.8	20435800	38646.331	40568.542	34455.910	32208.535	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
148	03/05/07	5.4	20634000	38689.599	40613.502	34495.422	32244.280	9.5	8	69	59	10	6	6	63	59	4
	03/06/07	5.6	20842700	38734.984	40661.158	34537.418	32283.004	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/07/07	4.3	21002000	38770.261	40698.377	34570.190	32312.854	10	9	70	59	11	6	6	70	59	11
	03/08/07	1.9	21071300	38784.772	40713.608	34583.736	32325.042	11	9	71	61	10	7	7	70	60	10
	03/09/07	5.6	21280400	38830.281	40761.746	34626.286	32363.506	11/7	11/4	70	58	12	10/6	8/3	70	58	12
	03/10/07	7.2	21550100	38890.953	40822.870	34679.050	32411.963	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/11/07	5.0	21734200	38931.381	40864.586	34715.827	32445.225	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
149	03/12/07	3.9	21880200	38963.891	40897.650	34745.299	32471.670	9	8	70	60	10	7	6	70	60	10
	03/13/07	1.5	21934100	38974.762	40909.768	34756.084	32481.306	10	10	73	61	12	7	7	71	61	10
	03/14/07	5.2	22127200	39016.289	40953.380	34795.266	32516.316	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/15/07	5.8	22339600	39061.531	41001.247	34838.680	32554.745	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/16/07	5.8	22554700	39107.199	41049.649	34883.072	32593.591	13/4	11/6	72	58	14	10/6	10/2	72	58	14
	03/17/07	2.3	22641400	39128.064	41069.851	34900.512	32608.444	6	7	64	56	8	6	3	64	56	8
	03/18/07	5.6	22848300	39173.278	41116.601	34940.399	32645.175	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
150	03/19/07	5.9	23069200	39222.250	41167.877	34984.297	32684.958	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/20/07	5.3	23265200	39265.495	41213.314	35023.816	32720.765	9	9	71	62	9	6	5	71	61	10
	03/21/07	0.2	23275200	39267.602	41215.493	35025.621	32722.369	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/22/07	5.9	23493400	39315.685	41266.212	35069.590	32761.849	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/23/07	3.2	23607400	39340.437	41292.298	35092.563	32782.347	10/5	10/5	72	60	12	7/5	6/4	72	60	12
	03/24/07	6.9	23863900	39397.958	41352.190	35143.671	32827.813	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/25/07	5.8	24079000	39450.750	41406.733	35180.919	32860.835	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
151	03/26/07	4.0	24229900	39487.744	41445.348	35208.211	32885.086	8	8	69	60	9	9	6	70	60	10
	03/27/07	1.7	24292000	39502.688	41460.808	35219.020	32894.633	8	6	68	58	10	8	6	68	58	10
	03/28/07	6.1	24519700	39557.819	41518.371	35259.823	32930.704	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/29/07	5.9	24738300	39610.368	41573.512	35299.221	32965.289	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	03/30/07	5.2	24931800	39656.778	41622.140	35334.165	32996.077	8/5	8/5	70	58	12	8/2	7/3	70	58	12
	03/31/07	1.9	25001800	39673.522	41638.643	35347.636	33007.216	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/01/07	6.0	25225300	39722.962	41689.839	35390.862	33046.773	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
152	04/02/07	1.5	25280100	39735.152	41702.591	35401.541	33056.500	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/03/07	6.0	25506500	39784.430	41754.694	35445.754	33096.678	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/04/07	4.0	25653100	39816.638	41788.861	35474.519	33122.743	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/05/07	6.7	25900500	39869.695	41844.576	35523.785	33166.763	10	10	78	62	16	10	7	71	62	9
	04/06/07	0.8	25928300	39875.955	41851.958	35529.309	33171.605	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/07/07	5.2	26121800	39917.621	41896.533	35568.537	33206.191	12	13	70	60	10	11	9	70	60	10
	04/08/07	2.6	26219900	39939.066	41919.566	35588.532	33223.815	12	12	70	58	12	11	9	70	59	11
153	04/09/07	4.3	26378200	39972.456	41955.344	35620.198	33257.448	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/10/07	7.6	26658700	40032.086	42019.604	35677.540	33301.293	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/11/07	5.4	26854900	40073.890	42064.196	35717.896	33335.971	13/3	14/6	74	60	14	13/4	13/4	74	60	14
	04/12/07	5.2	27047000	40115.534	42105.433	35753.556	33366.311	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/13/07	1.0	27085100	40123.967	42114.220	35760.868	33373.030	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/14/07	6.3	27324100	40177.835	42169.901	35808.162	33416.155	8	9	66	57	9	6	6	66	57	9
	04/15/07	6.8	27575700	40232.256	42226.790	35856.884	33460.051	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
154	04/16/07	4.0	27725100	40264.612	42268.924	35886.610	33486.598	11	11	70	60	10	10	7	70	60	10
	04/17/07	4.8	27903000	40302.962	42301.602	35922.304	33518.093	11	11	71	59	12	10	7	70	60	10
	04/18/07	4.7	28074900	40340.355	42341.347	35957.117	33548.596	13	12	72	60	12	11	7	71	61	10
	04/19/07	5.6	28281300	40384.831	42388.635	35999.231	33585.137	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/20/07	4.4	28443000	40419.335	42425.336	36032.489	33613.701	15/4	15/4	78	62	16	14/6	13/6	78	62	16
	04/21/07	4.6	28611600	40458.042	42463.876	36065.414	33642.241	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/22/07	4.4	28791100	40497.891	42505.515	36100.274	33674.505	8	7	70	60	10	6	4	70	61	9

Table A-1. U.S. EPA Arsenic Demonstration Project at Brown City, MI – Daily System Operation Log Sheet (Continued)

Week No.	Date	Operation Hours	Master Flow Meter	Vessel Flow Totalizer				Head Loss		Unit 1 (Vessels A & B)			Head Loss		Unit 2 (Vessels C & D)		
				Vessel A	Vessel B	Vessel C	Vessel D	Vessel A	Vessel B	Influent	Effluent	ΔP	Vessel C	Vessel D	Influent	Effluent	ΔP
		hr	gal	kgal	kgal	kgal	kgal	psi	psi	psig	psig	psi	psi	psi	psig	psig	psi
155	04/23/07	5.2	28967300	40536.348	42545.984	36134.178	33706.310	10	10	72	60	12	8	8	70	61	9
	04/24/07	5.5	29166400	40580.007	42592.225	36173.788	33742.261	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/25/07	4.7	29336800	40616.534	42631.767	36208.072	33772.995	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/26/07	4.6	29506800	40652.572	42671.226	36242.545	33803.651	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/27/07	4.8	29679400	40688.934	42711.587	36277.811	33834.764	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/28/07	5.8	29903600	40739.315	42764.028	36322.778	33873.406	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	04/29/07	5.2	30084300	40779.536	42805.908	36357.155	33906.096	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
156	04/30/07	4.9	30267000	40819.971	42848.246	36392.332	33939.211	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/01/07	4.6	30436800	40857.170	42887.740	36425.044	33970.059	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA
	05/02/07	4.7	30610100	40895.134	42928.037	36459.020	34001.562	NR	NR	NR	NR	NA	NR	NR	NR	NR	NA

APPENDIX B

ANALYTICAL DATA

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI

Sampling Date		5/18/04					5/25/04		6/08/04					6/24/04[e]	
Sampling Location Parameter	Unit	IN	TA	TB	TC	TD	IN	TT	IN	TA	TB	TC	TD	IN	TT
Bed Volume	10^3	–	0.4	0.4	0.4	0.4	–	0.8	–	1.9	1.9	1.8	1.8	–	2.9
Alkalinity	mg/L[a]	238	234	217	234	234	246	246	228	236	236	240	236	227	240
Fluoride	mg/L	–	–	–	–	–	1.5	1.5	–	–	–	–	–	1.4	1.5
Sulfate	mg/L	–	–	–	–	–	95	73	–	–	–	–	–	65	80
Orthophosphate	mg/L[b]	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silica (as SiO_2)	mg/L	10.2	17.4	2.3	2.7	3.1	7.9	5.0	8.6	7.2	7.0	7.1	7.0	8.5	7.4
NO_3-N	mg/L	–	–	–	–	–	<0.04	<0.04	–	–	–	–	–	<0.04	<0.04
Turbidity	NTU	1.5	0.5	0.4	0.5	0.9	1.4	0.4	1.1	0.3	0.3	0.8	0.8	1.0	0.8
pH	–	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	8.2	7.9	8.5	8.0	7.9	7.9	7.9	8.0	7.9
Temperature	ºC	14.3	13.8	12.8	12.3	12.3	12.4	11.0	11.7	11.7	11.7	11.3	11.2	11.9	11.4
DO	mg/L	4.2[d]	4.4[d]	4.7[d]	1.8	1.7	1.7	0.7	1.0	1.6	1.2	0.7	1.3	1.8	1.9
ORP	mV	4	3	2	3	2	3	7	10	7	7	8	7	5	2
Total Hardness	mg/L[a]	–	–	–	–	–	110	93.1	–	–	–	–	–	65.0	92.1
Ca Hardness	mg/L[a]	–	–	–	–	–	77.7	63.5	–	–	–	–	–	39.4	62.9
Mg Hardness	mg/L[a]	–	–	–	–	–	32.1	29.6	–	–	–	–	–	25.6	29.2
As (total)	µg/L	28.7	1.1	0.5	2.3	2.5	15.6	2.1	15.1	0.6	1.0	3.2	2.9	14.3	0.8
As (total soluble)	µg/L	–	–	–	–	–	13.4	1.8	–	–	–	–	–	12.5	0.6
As (particulate)	µg/L	–	–	–	–	–	2.2	0.3	–	–	–	–	–	1.8	0.2
As (III)	µg/L	–	–	–	–	–	13.1	1.9	–	–	–	–	–	11.7	0.7
As (V)	µg/L	–	–	–	–	–	0.3	<0.1	–	–	–	–	–	0.8	<0.1
Fe (total)	µg/L	168	<25	<25	<25	<25	149	<25	101	<25	<25	<25	<25	113	<25
Fe (soluble)	µg/L	–	–	–	–	–	139	<25	–	–	–	–	–	99.0	<25
Mn (total)	µg/L	14.3	<0.5	<0.5	1.5	2.1	15.5	1.3	17	0.7	0.7	2.9	2.7	13.5	2.2
Mn (soluble)	µg/L	–	–	–	–	–	15.8	1.6	–	–	–	–	–	13.2	2.5

(a) As $CaCO_3$. (b) As PO_4. (c) pH probe was not operational. (d) Samples were potentially aerated by operator. (e) Field data (temp, pH, DO, ORP) were taken on 6/29/04 for this date.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		7/06/04					7/20/04		8/03/04					8/17/04	
Sampling Location Parameter	Unit	IN	TA	TB	TC	TD	IN	TT	IN	TA	TB	TC	TD	IN	TT
Bed Volume	10^3	–	3.8	3.8	3.5	3.6	–	4.6	–	5.7	5.7	5.2	5.2	–	6.4
Alkalinity	mg/L[(a)]	218	214	214	202	214	277	223	236 236	217 236	225 236	236 236	256 240	233	164
Fluoride	mg/L	–	–	–	–	–	1.3	1.4	–	–	–	–	–	1.4	1.8
Sulfate	mg/L	–	–	–	–	–	56	79	–	–	–	–	–	59	82
Orthophosphate	mg/L[(b)]	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10 <0.10	<0.10 <0.10	<0.10 <0.10	<0.10 <0.10	<0.10 <0.10	<0.10	<0.10
Silica (as SiO_2)	mg/L	9.5	7.5	8.1	7.5	7.8	14.3	7.2	8.3 8.7	8.0 7.8	8.1 7.8	7.7 7.7	7.6 7.6	8.7	7.9
NO_3-N	mg/L	–	–	–	–	–	NA[(c)]	NA[(c)]	–	–	–	–	–	<0.04	<0.04
Turbidity	NTU	2.3	0.4	0.6	0.6	0.4	0.8	0.6	0.2 1.2	0.3 0.2	0.3 0.5	0.3 0.2	0.1 0.2	0.5	0.1
pH	–	8.0	7.9	7.9	7.9	7.9	8.0	7.9	7.6	7.6	7.6	7.6	7.6	8.0	7.9
Temperature	ºC	11.9	11.7	11.6	11.6	11.7	11.7	13.4	11.6	11.7	11.7	11.8	11.7	11.8	11.6
DO	mg/L	2.5	1.4	1.6	2.7	2.2	2.4	1.5	2.3	2.0	1.9	1.4	2.3	1.7	1.4
ORP	mV	7	5	5	4	4	9	13	12	13	13	14	16	18	31
Total Hardness	mg/L[(a)]	–	–	–	–	–	111	131	–	–	–	–	–	82.9	99.2
Ca Hardness	mg/L[(a)]	–	–	–	–	–	66.4	91.1	–	–	–	–	–	55.0	71.4
Mg Hardness	mg/L[(a)]	–	–	–	–	–	44.8	40.0	–	–	–	–	–	27.9	27.8
As (total)	µg/L	21.5	0.7	0.7	0.8	0.4	15.6	0.7	14.5 14.3	1.2 1.6	2.0 2.1	0.8 1.2	1.6 1.8	13.1	2.8
As (total soluble)	µg/L	–	–	–	–	–	14.9	0.6	–	–	–	–	–	12.9	2.2
As (particulate)	µg/L	–	–	–	–	–	0.7	0.1	–	–	–	–	–	0.2	0.6
As (III)	µg/L	–	–	–	–	–	14.2	0.9	–	–	–	–	–	12.9	2.0
As (V)	µg/L	–	–	–	–	–	0.7	<0.1	–	–	–	–	–	<0.1	0.2
Fe (total)	µg/L	228	<25	<25	<25	<25	157	<25	164 167	<25 <25	<25 <25	<25 <25	<25 <25	108	<25
Fe (soluble)	µg/L	–	–	–	–	–	135	<25	–	–	–	–	–	105	<25
Mn (total)	µg/L	17.0	2.2	3.8	4.7	2.4	12.3	2.9	18.3 18.5	11.4 9.6	14.2 12.5	12.5 12.3	13.4 13.4	12.6	13.0
Mn (soluble)	µg/L	–	–	–	–	–	13.4	2.7	–	–	–	–	–	12.7	14.0

(a) As $CaCO_3$. (b) As PO_4. (c) Sample out of holding time for laboratory analysis.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		8/31/04					9/14/04		9/28/04					10/12/04	
Sampling Location Parameter	Unit	IN	TA	TB	TC	TD	IN	TT	IN	TA	TB	TC	TD	IN	TT
Bed Volume	10^3	–	8.0	8.0	7.1	7.2	–	8.5	–	10.1	10.1	9.0	9.0	–	10.4
Alkalinity	mg/L[a]	241	241	241	241	245	242	242	234	230	234	238	234	231	236
Fluoride	mg/L	–	–	–	–	–	1.8	1.8	–	–	–	–	–	3.3	1.6
Sulfate	mg/L	–	–	–	–	–	120	120	–	–	–	–	–	54	74
Orthophosphate	mg/L[b]	<0.10	<0.10	<0.10	<0.10	<0.10	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silica (as SiO_2)	mg/L	8.3	8.0	7.5	7.6	7.5	7.7	7.6	8.4	7.8	7.8	7.5	7.4	9.2	7.3
NO_3-N	mg/L	–	–	–	–	–	<0.04	<0.04	–	–	–	–	–	<0.04	<0.04
Turbidity	NTU	0.9	0.2	0.3	0.3	0.1	0.6	0.2	0.8	0.2	0.3	0.2	0.3	2.1	0.6
pH	–	8.0	7.9	7.9	7.9	7.9	7.9	7.9	8.0	7.9	7.8	7.9	7.8	7.9	7.9
Temperature	ºC	11.2	11.0	11.1	11.2	11.2	11.2	11.2	11.2	11.1	11.5	11.6	12.0	10.3	10.2
DO	mg/L	5.6[c]	2.0	2.0	1.7	2.3	2.2	1.6	1.9	1.6	1.6	1.9	1.6	1.4	1.8
ORP	mV	24	29	30	29	28	47	33	58	45	38	36	34	24	18
Total Hardness	mg/L[a]	–	–	–	–	–	98.4	100	–	–	–	–	–	104	87.5
Ca Hardness	mg/L[a]	–	–	–	–	–	75.9	77.0	–	–	–	–	–	62.9	61.4
Mg Hardness	mg/L[a]	–	–	–	–	–	22.5	23.3	–	–	–	–	–	41.2	26.1
As (total)	µg/L	14.9	1.4	2.1	1.8	2.2	9.5	3.6	12.6	2.4	2.8	2.2	3.0	15.6	2.6
As (total soluble)	µg/L	–	–	–	–	–	9.6	3.5	–	–	–	–	–	15.8	2.4
As (particulate)	µg/L	–	–	–	–	–	<0.1	0.1	–	–	–	–	–	<0.1	0.2
As (III)	µg/L	–	–	–	–	–	9.0	3.3	–	–	–	–	–	14.2	<1.0[d]
As (V)	µg/L	–	–	–	–	–	0.6	0.2	–	–	–	–	–	1.6	2.4
Fe (total)	µg/L	115	<25	<25	<25	<25	159	35.0	160	<25	<25	<25	<25	203	<25
Fe (soluble)	µg/L	–	–	–	–	–	127	<25	–	–	–	–	–	135	<25
Mn (total)	µg/L	13.7	13.2	15.5	15.6	17.1	17.0	19.7	15.0	20.5	21.8	19.2	22.0	16.6	22.4
Mn (soluble)	µg/L	–	–	–	–	–	16.5	19.1	–	–	–	–	–	14.8	19.3

(a) As $CaCO_3$. (b) As PO_4. (c) Sample was potentially aerated by operator. (d) Rerun sample was diluted 10 times due to insufficient quantity for analysis.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		11/02/04[c]					11/16/04		11/30/04					12/14/04	
Sampling Location Parameter	Unit	IN	TA	TB	TC	TD	IN	TT	IN	TA	TB	TC	TD	IN	TT
Bed Volume	10^3	–	12.5	12.5	11.0	11.0	–	12.5	–	14.1	13.7	12.2	12.4	–	13.8
Alkalinity	mg/L[a]	246 242	246 246	246 246	250 250	250 250	246	250	234	236	236	240	240	240	236
Fluoride	mg/L	–	–	–	–	–	1.4	1.5	–	–	–	–	–	1.6	1.6
Sulfate	mg/L	–	–	–	–	–	62	85	–	–	–	–	–	100	97
Orthophosphate	mg/L[b]	<0.06 <0.06	<0.06 <0.06	<0.06 <0.06	<0.06 <0.06	<0.06 <0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silica (as SiO_2)	mg/L	7.9 8.1	7.5 7.6	7.6 7.7	7.5 7.5	7.6 7.6	8.3	7.6	8.5	7.7	7.5	7.5	7.6	8.3	7.9
NO_3-N	mg/L	–	–	–	–	–	<0.04	<0.04	–	–	–	–	–	<0.04	<0.04
Turbidity	NTU	0.7 0.7	0.6 0.6	0.7 0.5	0.3 0.3	0.3 0.3	0.9	0.4	0.5	0.2	0.1	0.3	0.3	0.8	0.3
pH	–	8.0	7.9	7.8	7.8	7.8	7.9	7.7	7.9	7.8	7.8	7.7	7.7	NA[d]	NA[d]
Temperature	°C	10.9	10.8	10.9	10.9	10.9	11.0	11.4	11.0	10.9	10.9	10.8	10.7	NA[d]	NA[d]
DO	mg/L	2.1	1.3	1.4	1.4	1.2	1.7	1.5	2.1	1.5	1.8	1.4	1.9	NA[d]	NA[d]
ORP	mV	69	62	57	54	53	88	77	106	99	102	104	104	NA[d]	NA[d]
Total Hardness	mg/L[a]	–	–	–	–	–	71.2	92.1	–	–	–	–	–	113	111
Ca Hardness	mg/L[a]	–	–	–	–	–	41.8	60.1	–	–	–	–	–	81.1	78.6
Mg Hardness	mg/L[a]	–	–	–	–	–	29.4	32.0	–	–	–	–	–	31.7	32.7
As (total)	µg/L	12.4 12.9	4.3 5.2	7.8 8.7	7.8 7.6	8.0 7.9	12.1	7.1	11.6	2.4	3.6	3.8	4.1	16.4	7.9
As (total soluble)	µg/L	–	–	–	–	–	11.7	6.2	–	–	–	–	–	13.3	6.8
As (particulate)	µg/L	–	–	–	–	–	0.4	0.9	–	–	–	–	–	3.1	1.1
As (III)	µg/L	–	–	–	–	–	12.0	5.3	–	–	–	–	–	13.4	7.0
As (V)	µg/L	–	–	–	–	–	<0.1	0.9	–	–	–	–	–	<0.1	<0.1
Fe (total)	µg/L	165 152	<25 <25	<25 <25	<25 <25	<25 <25	142	<25	144	<25	<25	<25	<25	161	<25
Fe (soluble)	µg/L	–	–	–	–	–	108	<25	–	–	–	–	–	136	<25
Mn (total)	µg/L	13.8 13.3	16.5 17.3	17.3 17.2	21.7 22.8	23.7 25.0	13.7	20.5	13.1	18.1	16.1	19.5	20.5	15.0	20.4
Mn (soluble)	µg/L	–	–	–	–	–	13.0	19.9	–	–	–	–	–	14.5	19.9

(a) As $CaCO_3$. (b) As PO_4. (c) Vessel B did not fast rinse properly during 10/22/04 backwash, possibly affecting TB sample. (d) Field meter was not functional during this event.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		1/05/05[c]		1/18/05					2/01/05		2/15/05					3/07/05[d]	
Sampling Location Parameter	Unit	IN	TT	IN	TA	TB	TC	TD	IN	TT	IN	TA	TB	TC	TD	IN	TT
Bed Volume	10^3	–	15.2	–	17.3	16.7	15.0	15.1	–	17.0	–	19.4	18.8	16.8	16.9	–	19.2
Alkalinity	mg/L[(a)]	256	248	252 248	261 252	257 257	248 265	257 257	244	262	245	268	245	263	254	250	259
Fluoride	mg/L	1.7	1.7	–	–	–	–	–	1.6	1.7	–	–	–	–	–	1.0	1.1
Sulfate	mg/L	120	120	–	–	–	–	–	88	140	–	–	–	–	–	61	70
Orthophosphate	mg/L[(b)]	<0.06	<0.06	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	8.0	7.8	9.7 8.4	7.6 7.8	7.8 7.9	7.6 7.2	7.7 7.5	7.4	6.9	8.4	7.8	7.8	7.7	7.5	8.5	8.0
NO_3-N	mg/L	<0.04	<0.04	–	–	–	–	–	<0.05	<0.05	–	–	–	–	–	<0.05	0.1
Turbidity	NTU	0.5	0.2	0.8 0.5	<0.1 <0.1	0.9 <0.1	0.2 0.2	0.3 0.2	0.3	0.1	0.4	<0.1	<0.1	0.2	0.3	0.7	0.2
pH	–	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.1	8.0
Temperature	°C	10.9	12.2	11.1	11.1	11.0	11.0	11.0	11.9	11.0	11.0	10.9	10.9	10.8	10.9	11.0	12.2
DO	mg/L	2.3	1.7	2.4	1.4	1.6	1.9	1.5	2.0	1.7	1.5	1.3	1.4	1.7	2.3	2.8	1.5
ORP	mV	96	30	82	61	48	41	30	5	3	-30	-29	-29	-29	-30	-16	-20
Total Hardness	mg/L[(a)]	112	110	–	–	–	–	–	73.8	92.6	–	–	–	–	–	73.8	82.4
Ca Hardness	mg/L[(a)]	86.4	85.0	–	–	–	–	–	50.7	68.4	–	–	–	–	–	50.0	59.9
Mg Hardness	mg/L[(a)]	25.5	24.8	–	–	–	–	–	23.1	24.2	–	–	–	–	–	23.8	22.5
As (total)	µg/L	10.8	7.2	12.6 11.5	4.0 4.0	5.6 5.9	7.0 6.7	7.7 8.3	11.4	7.1	11.7	4.7	5.2	6.5	6.8	11.1	6.4
As (total	µg/L	10.4	6.5	–	–	–	–	–	11.4	7.1	–	–	–	–	–	11.7	6.4
As (particulate)	µg/L	0.4	0.7	–	–	–	–	–	<0.1	<0.1	–	–	–	–	–	<0.1	<0.1
As (III)	µg/L	10.0	6.3	–	–	–	–	–	11.4	7.5	–	–	–	–	–	11.2	6.3
As (V)	µg/L	0.4	0.2	–	–	–	–	–	<0.1	<0.1	–	–	–	–	–	0.5	0.1
Fe (total)	µg/L	142	<25	142 123	<25 <25	<25 <25	39.5 32.4	56.4 52.9	104	46.3	143	<25	<25	56.0	61.0	122	40.7
Fe (soluble)	µg/L	104	<25	–	–	–	–	–	100	<25	–	–	–	–	–	103	<25
Mn (total)	µg/L	17.1	20.5	14.8 13.3	18.1 17.4	19.0 18.3	22.4 20.9	24.4 24.4	25.9	21.9	23.1	21.2	19.1	18.3	18.8	12.9	19.1
Mn (soluble)	µg/L	15.8	19.3	–	–	–	–	–	13.9	22.6	–	–	–	–	–	13.5	18.3

(a) As $CaCO_3$. (b) As PO_4. (c) Water quality measurements were taken on 01/04/05. (d) Water quality measurements were taken on 03/08/05.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		3/15/05					3/29/05					4/13/05				
Sampling Location Parameter	Unit	IN	TA	TB	TC	TD	IN	TA	TB	TC	TD	IN	TA	TB	TC	TD
Bed Volume	10^3	–	21.4	20.5	18.5	18.6	–	22.3	21.5	19.4	19.4	–	23.3	22.6	20.3	20.3
Alkalinity	mg/L[(a)]	245	254	254	259	254	248	248	248	248	265	277 268	273 268	268 268	268 268	264 272
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05
Silica (as SiO_2)	mg/L	9.6	8.6	8.3	8.5	8.4	7.9	8.0	7.8	7.9	7.7	8.3 7.8	7.8 7.8	7.9 8.1	8.2 7.8	7.8 7.9
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	0.8	0.2	0.2	0.3	0.3	0.7	0.2	0.2	0.4	0.5	0.9 1.1	0.4 0.3	0.3 0.3	0.6 0.5	0.5 0.6
pH	–	8.1	8.1	8.0	8.0	8.0	8.0	7.9	8.0	8.0	8.0	8.1	7.9	8.0	8.0	8.0
Temperature	ºC	10.9	10.8	10.9	10.8	10.9	10.7	10.4	10.5	10.5	10.5	10.4	10.7	10.6	10.5	10.6
DO	mg/L	1.6	1.5	1.6	1.8	1.6	2.1	1.6	1.4	1.8	2.2	1.9	1.6	1.6	1.6	1.7
ORP	mV	-32	-27	-26	-29	-30	-51	-50	-47	-49	-49	-21	-19	-20	-21	-19
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	19.6	5.1	6.4	8.7	7.1	10.2	5.6	8.4	10.6	11.0	12.4 11.8	7.6 8.7	9.3 9.6	10.0 10.4	10.6 10.6
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	226	<25	33.1	124	92.1	110	31.6	26.7	82.3	130	153 153	<25 <25	37.2 32.0	98.0 111	119 112
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	17.1	20.5	21.6	27.4	18.9	12.8	17.0	17.4	17.4	18.7	18.1 18.8	21.0 22.7	22.2 21.8	20.9 22.8	23.2 22.7
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(a) As $CaCO_3$. (b) As PO_4.
IN = inlet; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		4/26/05		5/10/05					5/24/05[c]			6/07/05[e]					
Sampling Location Parameter	Unit	IN	TT	IN	TA	TB	TC	TD	IN	AC	TT	IN	AC	TA	TB	TC	TD
Bed Volume	10^3	–	22.3	–	25.0	24.2	21.7	21.8	–	–	24.0	–	–	27.0	26.2	23.5	23.4
Alkalinity	mg/L[a]	284	271	259	254	268	254	255	223	–	254	251	–	264	251	255	255
Fluoride	mg/L	1.5	1.5	–	–	–	–	–	1.3	–	1.4	–	–	–	–	–	–
Sulfate	mg/L	132	135	–	–	–	–	–	60	–	76	–	–	–	–	–	–
Orthophosphate	mg/L[b]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	–	<0.05	<0.05	–	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	7.9	7.8	9.4	8.2	8.2	7.8	7.7	14.6	–	7.8	7.7	–	8.0	7.6	7.7	7.5
NO_3-N	mg/L	<0.05	<0.05	–	–	–	–	–	<0.05	–	<0.05	–	–	–	–	–	–
Turbidity	NTU	0.6	0.4	0.9	0.2	0.2	1.1	0.6	0.9	–	6.1	0.6	–	0.1	<0.1	0.1	0.2
pH	–	8.0	8.0	8.0	8.0	8.0	8.0	8.0	NA[d]	–	NA[d]	8.1	–	8.0	8.0	8.0	8.0
Temperature	ºC	11.1	11.0	11.1	11.0	11.1	10.9	10.9	NA[d]	–	NA[d]	11.0	–	10.9	10.9	10.8	11.0
DO	mg/L	3.1	1.8	1.4	1.3	1.6	1.5	1.1	NA[d]	–	NA[d]	1.8	–	1.6	1.6	1.6	1.2
ORP	mV	46	43	-21	-21	-20	-20	-22	NA[d]	–	NA[d]	97	–	99	100	98	95
Free Chlorine	mg/L	–	–	–	–	–	–	–	–	0.4	NA[d]	–	0.8	0.4	0.0	0.0	0.0
Total Chlorine	mg/L	–	–	–	–	–	–	–	–	0.3	NA[d]	–	0.9	0.5	0.0	0.0	0.0
Total Hardness	mg/L[a]	119	123	–	–	–	–	–	90.0	–	90.0	–	–	–	–	–	–
Ca Hardness	mg/L[a]	91.5	93.1	–	–	–	–	–	57.8	–	62.6	–	–	–	–	–	–
Mg Hardness	mg/L[a]	27.6	29.8	–	–	–	–	–	32.2	–	27.4	–	–	–	–	–	–
As (total)	μg/L	12.5	12.8	14.7	6.9	7.8	9.3	7.7	15.6	–	7.5	10.2	–	1.5	2.7	7.8	8.5
As (total soluble)	μg/L	13.3	12.1	–	–	–	–	–	13.3	–	6.7	–	–	–	–	–	–
As (particulate)	μg/L	<0.1	0.7	–	–	–	–	–	2.2	–	0.9	–	–	–	–	–	–
As (III)	μg/L	11.2	10.2	–	–	–	–	–	12.8	–	6.3	–	–	–	–	–	–
As (V)	μg/L	2.1	1.9	–	–	–	–	–	0.5	–	0.3	–	–	–	–	–	–
Fe (total)	μg/L	163	79.0	164	149	139	235	134	135	–	39.4	129	–	<25	<25	<25	<25
Fe (soluble)	μg/L	149	54.3	–	–	–	–	–	119	–	<25	–	–	–	–	–	–
Mn (total)	μg/L	17.3	19.7	15.2	19.9	19.4	18.2	17.4	15.1	–	14.0	12.8	–	8.1	7.9	7.7	7.6
Mn (soluble)	μg/L	17.6	19.5	–	–	–	–	–	15.2	–	13.5	–	–	–	–	–	–

(a) As $CaCO_3$. (b) As PO_4. (c) Prechlorination began 05/16/05. (d) Operator was unable to take readings. (e) Water quality measurements taken on 6/02/05.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		6/22/05			7/05/05						7/19/05			8/02/05					
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	TD	IN	AC	TT	IN	AC	TA	TB	TC	TD
Bed Volume	10^3	–	–	26.0	–	–	29.2	28.6	25.3	25.3	–	–	28.2	–	–	31.3	31.3	27.5	27.2
Alkalinity	mg/L[(a)]	242	–	220	238	–	220	238	238	238	242	–	246	220	–	229	229	233	246
Fluoride	mg/L	1.4	–	1.4	–	–	–	–	–	–	1.6	–	1.5	–	–	–	–	–	–
Sulfate	mg/L	82	–	74	–	–	–	–	–	–	136	–	136	–	–	–	–	–	–
Orthophosphate	mg/L[(b)]	<0.05	–	<0.05	<0.05	–	<0.05	<0.05	<0.05	<0.05	<0.05	–	<0.05	<0.05	–	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	7.8	–	8.2	8.5	–	8.2	7.9	8.1	7.8	7.0	–	7.1	9.1	–	8.1	7.9	7.8	7.7
NO_3-N	mg/L	2.7	–	<0.05	–	–	–	–	–	–	<0.05	–	<0.05	–	–	–	–	–	–
Turbidity	NTU	1.1	–	1.3	0.6	–	<0.1	0.1	0.1	0.1	0.7	–	0.5	0.9	–	0.8	0.7	0.7	0.3
pH	–	NA[(c)]	NA[(c)]	NA[(c)]	8.0	–	8.1	8.0	8.0	8.0	NA[(c)]	NA[(c)]	NA[(c)]	8.1	–	8.0	8.1	8.0	8.0
Temperature	°C	NA[(c)]	NA[(c)]	NA[(c)]	12.1	–	11.8	11.8	11.9	11.8	NA[(c)]	NA[(c)]	NA[(c)]	12.9	–	13.0	13.5	13.5	13.9
DO	mg/L	NA[(c)]	NA[(c)]	NA[(c)]	1.5	–	1.4	1.3	1.4	1.4	NA[(c)]	NA[(c)]	NA[(c)]	NA[(d)]	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
ORP	mV	NA[(c)]	NA[(c)]	NA[(c)]	142	–	143	143	143	143	NA[(c)]	NA[(c)]	NA[(c)]	159	–	161	163	162	162
Free Chlorine	mg/L	–	NA[(c)]	NA[(c)]	–	0.4	0.7	0.4	0.4	0.4	–	NA[(c)]	NA[(c)]	–	0.4	0.4	0.4	0.4	0.4
Total Chlorine	mg/L	–	NA[(c)]	NA[(c)]	–	0.5	0.5	0.5	0.5	0.5	–	NA[(c)]	NA[(c)]	–	0.5	0.5	0.5	0.5	0.5
Total Hardness	mg/L[(a)]	92.7	–	103	–	–	–	–	–	–	99.6	–	99.2	–	–	–	–	–	–
Ca Hardness	mg/L[(a)]	66.2	–	72.3	–	–	–	–	–	–	73.5	–	73.7	–	–	–	–	–	–
Mg Hardness	mg/L[(a)]	26.5	–	30.8	–	–	–	–	–	–	26.1	–	25.5	–	–	–	–	–	–
As (total)	µg/L	11.1	–	0.9	11.5	–	0.6	0.7	1.0	1.2	13.5	–	4.9	24.3	–	1.2	0.6	0.7	0.8
As (total soluble)	µg/L	11.7	–	0.6	–	–	–	–	–	–	11.0	–	3.6	–	–	–	–	–	–
As (particulate)	µg/L	<0.1	–	0.3	–	–	–	–	–	–	2.5	–	1.3	–	–	–	–	–	–
As (III)	µg/L	11.5	–	1.1	–	–	–	–	–	–	10.1	–	2.8	–	–	–	–	–	–
As (V)	µg/L	0.2	–	<0.1	–	–	–	–	–	–	0.9	–	0.8	–	–	–	–	–	–
Fe (total)	µg/L	154	–	<25	139	–	<25	<25	<25	<25	160	–	<25	272	–	<25	<25	<25	<25
Fe (soluble)	µg/L	143	–	<25	–	–	–	–	–	–	128	–	<25	–	–	–	–	–	–
Mn (total)	µg/L	15.3	–	8.2	13.6	–	7.7	7.2	6.0	5.5	16.8	–	7.1	17.0	–	7.6	7.6	6.1	5.6
Mn (soluble)	µg/L	15.8	–	8.4	–	–	–	–	–	–	17.7	–	7.6	–	–	–	–	–	–

(a) As $CaCO_3$. (b) As PO_4. (c) Operator was unable to take water quality measurements. (d) DO Probe was not operational.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		8/16/05			9/06/05						9/13/05						9/28/05		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	TC	TD	IN	AC	TA	TB	TC	TD	IN	AC	TT
Bed Volume	10^3	–	–	30.7	–	–	34.3	34.8	30.0	29.7	–	–	35.0	35.6	30.6	30.3	–	–	34.0
Alkalinity	mg/L[(a)]	255	255	251	233	–	238	233	242	246	233	–	229	242	229	242	233	242	251
Fluoride	mg/L	1.4	1.5	1.4	–	–	–	–	–	–	–	–	–	–	–	–	1.4	1.4	1.4
Sulfate	mg/L	120	112	109	–	–	–	–	–	–	–	–	–	–	–	–	44	51	61
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05	–	<0.05	<0.05	<0.05	<0.05	<0.05	–	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	7.6	7.8	8.0	9.4	–	8.4	8.1	8.4	8.2	9.2	–	8.4	8.1	8.4	8.2	11.4	10.4	10.0
NO_3-N	mg/L	<0.05	<0.05	0.3	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Turbidity	NTU	0.6	0.1	<0.1	1.1	–	0.8	0.3	0.5	0.5	1.0	–	0.2	0.2	0.1	<0.1	0.9	0.1	<0.1
pH	–	8.1	–	8.0	8.1	–	8.0	8.0	8.0	8.0	NA[(d)]	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Temperature	ºC	12.1	–	12.2	12.1	–	12.1	12.1	12.1	12.1	NA[(d)]	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
DO	mg/L	NA[(c)]	–	NA[(c)]	NA[(c)]	–	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(d)]	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
ORP	mV	149	–	152	147	–	154	155	156	156	NA[(d)]	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Free Chlorine	mg/L	–	NA[(d)]	0.4	–	0.4	0.4	0.4	0.4	0.4	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	–	NA[(d)]	NA[(d)]
Total Chlorine	mg/L	–	0.5	0.5	–	0.5	0.5	0.5	0.5	0.5	–	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	–	NA[(d)]	NA[(d)]
Total Hardness	mg/L[(a)]	120	118	117	–	–	–	–	–	–	–	–	–	–	–	–	99.1	80.7	91.6
Ca Hardness	mg/L[(a)]	90.4	85.3	84.4	–	–	–	–	–	–	–	–	–	–	–	–	60.4	53.9	63.7
Mg Hardness	mg/L[(a)]	29.1	32.4	32.7	–	–	–	–	–	–	–	–	–	–	–	–	38.7	26.9	27.9
As (total)	µg/L	11.0	15.0	6.3	21.3	–	0.6	0.6	0.7	1.0	16.0	–	0.9	0.6	0.5	0.6	14.7	11.9	3.3
As (total soluble)	µg/L	11.5	10.7	5.7	–	–	–	–	–	–	–	–	–	–	–	–	14.8	11.2	3.2
As (particulate)	µg/L	<0.1	4.3	0.7	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	0.7	<0.1
As (III)	µg/L	10.3	3.2	3.3	–	–	–	–	–	–	–	–	–	–	–	–	14.3	1.5	2.4
As (V)	µg/L	1.1	7.5	2.4	–	–	–	–	–	–	–	–	–	–	–	–	0.5	9.7	0.8
Fe (total)	µg/L	163	164	<25	205	–	<25	<25	<25	<25	240	–	<25	68.2	<25	255	178	124	<25
Fe (soluble)	µg/L	152	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–	144	<25	<25
Mn (total)	µg/L	18.8	17.1	8.4	18.7	–	8.0	8.0	7.1	6.5	18.2	–	8.4	8.7	8.0	7.7	16.6	13.1	8.0
Mn (soluble)	µg/L	19.1	8.7	8.7	–	–	–	–	–	–	–	–	–	–	–	–	16.5	8.5	8.7

(a) As $CaCO_3$. (b) As PO_4. (c). DO Probe was not operational. (d) Water quality parameter not measured.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.
NA = data not available.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		10/18/05[c]						10/25/05			12/19/05[e]			1/17/06		
Sampling Location Parameter	Unit	IN	AC	TA	TB	TC	TD	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	–	–	37.9	38.6	33.0	32.4	–	–	35.9	–	–	37.1	–	–	39.0
Alkalinity	mg/L[a]	246	–	246	251	246	251	255	255	251	246	255	260	246	260	260
Fluoride	mg/L	–	–	–	–	–	–	1.1	1.2	1.2	1.1	1.3	1.2	1.1	1.2	1.2
Sulfate	mg/L	–	–	–	–	–	–	73	113	110	65	82	102	55	105	106
Orthophosphate	mg/L[b]	<0.05	–	<0.05	<0.05	<0.05	<0.05	–	–	–	–	–	–	–	–	–
Total P (as PO_4)	mg/L[b]	–	–	–	–	–	–	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Silica (as SiO_2)	mg/L	7.4	–	7.2	6.9	7.1	6.8	6.5	7.0	7.0	10.0	8.9	9.0	9.7	8.0	7.8
NO_3-N	mg/L	–	–	–	–	–	–	<0.05	<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Turbidity	NTU	0.5	–	<0.1	0.1	<0.1	0.1	0.3	0.2	<0.1	2.1	0.2	<0.1	1.2	0.4	0.2
pH	–	7.9	–	7.7	7.7	7.7	7.6	NA[d]	NA[d]	NA[d]	7.7	7.7	7.5	7.8	7.8	7.6
Temperature	ºC	10.8	–	10.6	10.6	10.5	10.6	NA[d]	NA[d]	NA[d]	11.8	11.8	11.3	11.8	11.8	11.6
DO	mg/L	1.8	–	2.3	1.9	1.5	1.8	NA[d]	NA[d]	NA[d]	2.0	1.8	1.3	1.3	1.4	1.5
ORP	mV	150	–	232	245	248	252	NA[d]	NA[d]	NA[d]	262	303	306	261	304	305
Free Chlorine	mg/L	–	0.5	0.3	0.3	0.3	0.3	–	NA[d]	NA[d]	–	0.4	0.3	–	0.4	0.3
Total Chlorine	mg/L	–	0.5	0.3	0.3	0.3	0.3	–	NA[d]	NA[d]	–	0.5	0.4	–	0.5	0.4
Total Hardness	mg/L[a]	–	–	–	–	–	–	94.1	116	109	107	107	151	88.8	116	115
Ca Hardness	mg/L[a]	–	–	–	–	–	–	66.4	87.9	82.2	64.3	73.2	103	49.8	80.5	78.9
Mg Hardness	mg/L[a]	–	–	–	–	–	–	27.8	28.4	27.1	43.0	34.0	48.0	39.0	35.2	35.9
As (total)	µg/L	12.8	–	1.2	1.4	2.3	3.1	12.3	12.4	3.3	16.9	13.6	3.1	15.2	16.0	5.2
As (total soluble)	µg/L	–	–	–	–	–	–	11.5	9.1	2.9	16.6	10.4	1.6	13.5	12.0	4.6
As (particulate)	µg/L	–	–	–	–	–	–	0.9	3.4	0.5	0.3	3.1	1.4	1.7	4.0	0.6
As (III)	µg/L	–	–	–	–	–	–	10.9	1.7	1.6	15.6	0.9	1.1	13.9	12.0	2.8
As (V)	µg/L	–	–	–	–	–	–	0.6	7.4	1.3	1.0	9.5	0.6	<0.1	<0.1	1.8
Fe (total)	µg/L	123	–	<25	<25	<25	<25	121	149	<25	298	205	<25	192	152	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	120	<25	<25	217	<25	<25	158	<25	<25
Mn (total)	µg/L	13.3	–	8.3	8.2	8.2	8.6	15.7	18.1	9.3	17.9	16.4	13.1	14.7	15.3	9.8
Mn (soluble)	µg/L	–	–	–	–	–	–	16.6	10.1	9.0	17.3	8.3	10.0	14.3	9.3	10.1

(a) As $CaCO_3$. (b) As PO_4. (c) Water quality measurements were taken on 10/20/05. (d) On-site water quality parameter not measured. (e) System off for well maintenance 11/09/05-12/11/05.

IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		3/01/06			3/21/06			4/18/06			5/16/06			6/14/06			7/11/06		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	–	–	41.5	–	–	42.7	–	–	44.2	–	–	45.9	–	–	48.2	–	–	50.4
Alkalinity	mg/L[(a)]	232	249	240	239	239	234	256	264	264	230	238	251	246	246	246	239	247	247
Fluoride	mg/L	1.4	1.5	1.5	1.3	1.4	1.3	1.9	<0.1	<0.1	1.2	1.4	1.3	0.9	0.8	1.3	1.5	1.6	1.9
Sulfate	mg/L	54	69	77	56	83	70	70	116[(c)]	111[(c)]	61	89	108	65	111	113	55	77	93
Sulfide	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<5	<5	<5
Total P (as PO_4)	mg/L[(b)]	<0.03	<0.03	<0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Silica (as SiO_2)	mg/L	10.3	8.2	7.8	9.8	7.7	8.2	8.0	7.7	7.6	9.5	8.9	8.0	9.0	8.3	7.7	8.8	7.6	8.1
NO_3-N	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	<0.05	<0.05
Turbidity	NTU	2.1	0.4	0.6	1.9	0.3	0.6	0.6	0.4	0.2	1	0.8	0.2	0.9	0.5	0.3	1.1	0.8	0.8
pH	–	7.7	7.8	7.7	7.9	7.8	7.8	7.7	7.6	7.6	7.8	7.7	7.7	7.9	7.8	7.8	7.6	7.7	7.7
Temperature	ºC	11.7	11.8	11.4	12.1	11.7	11.5	15.0	15.0	14.9	12.2	11.8	11.8	12.2	11.8	11.7	15.1	15.1	15.2
DO	mg/L	1.4	1.6	1.5	1.5	1.4	1.3	2.1	1.7	1.1	1.7	1.6	1.2	1.4	1.5	1.4	1.6	1.4	1.7
ORP	mV	259	303	307	314	319	316	331	357	353	312	342	342	314	340	341	365	370	370
Free Chlorine	mg/L	–	0.3	0.3	–	0.4	0.3	–	0.5	0.3	–	0.5	0.3	–	0.4	0.3	–	0.4	0.4
Total Chlorine	mg/L	–	0.4	0.4	–	0.4	0.4	–	0.5	0.4	–	0.5	0.4	–	0.4	0.4	–	0.4	0.4
Total Hardness	mg/L[(a)]	118	77.7	89.2	108	95.3	105	84.7	111	112	90.5	105	110	75.0	106	109	83.8	78.1	83.4
Ca Hardness	mg/L[(a)]	68.9	49.9	60.6	67.2	68.7	77.6	49.8	74.0	70.6	55.7	73.3	75.6	50.1	76.8	77.4	52.0	52.9	58.6
Mg Hardness	mg/L[(a)]	49.5	27.9	28.6	40.6	26.6	27.5	34.9	37.1	41.4	34.9	31.5	34.5	25.0	29.6	31.3	31.8	25.3	24.8
As (total)	µg/L	21.4	13.6	1.6	15.3	13.0	0.7	12.0	12.0	1.7	14.4	12.0	1.7	12.4	13.2	1.2	14.0	11.3	0.9
As (total soluble)	µg/L	15.7	9.8	1.2	13.2	10.8	0.6	11.3	9.3	1.4	13.0	10.0	1.3	12.5	9.9	1.0	10.9	8.4	0.5
As (particulate)	µg/L	5.8	3.8	0.3	2.0	2.2	0.1	0.7	2.7	0.3	1.4	2.1	0.4	<0.1	3.2	0.2	3.1	2.8	0.4
As (III)	µg/L	15.2	0.8	1.1	13.4	1.7	1.0	10.6	0.7	0.7	12.2	0.6	0.8	–	0.5	0.5	10.2	0.3	0.3
As (V)	µg/L	0.5	9.0	0.1	<0.1	9.1	<0.1	0.8	8.6	0.8	0.9	9.3	0.5	–	9.4	0.5	0.7	8.2	0.1
Fe (total)	µg/L	215	104	<25	165	108	<25	131	146	<25	164	136	<25	135	171	<25	157	97.2	<25
Fe (soluble)	µg/L	164	<25	<25	192	<25	<25	129	<25	<25	141	<25	<25	126	66.6	<25	120	<25	<25
Mn (total)	µg/L	18.6	12.6	8.4	15.8	13.6	8.5	13.9	17.4	10.1	15.3	14.5	10.8	12.4	16.0	14.2	16.2	13.4	9.9
Mn (soluble)	µg/L	17.6	7.5	8.6	15.7	8.2	8.5	14.0	10.6	9.9	14.0	10.3	10.6	12.4	15.5	13.8	14.1	6.5	9.3

(a) As $CaCO_3$. (b) As PO_4. (c) Samples reanalyzed outside of hold time.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		08/14/06			09/19/06			10/17/06			11/28/06			12/12/06			01/22/07		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	–	–	52.6	–	–	54.7	–	–	56.2	–	–	58.5	–	–	59.2	–	–	61.7
Alkalinity	mg/L[(a)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Fluoride	mg/L	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Sulfate	mg/L	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	63	87	110
Sulfide	mg/L	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Total P (as PO_4)	mg/L[(b)]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NA[(e)]	NA[(e)]	NA[(e)]	<0.01	<0.01	<0.01	NA[(e)]	NA[(e)]	NA[(e)]	NA[(e)]	NA[(e)]	NA[(e)]
Silica (as SiO_2)	mg/L	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
NO_3-N	mg/L	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
Turbidity	NTU	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]	NA[(d)]
pH	–	7.9	7.7	7.7	7.8	7.7	7.7	7.9	7.7	7.7	7.8	7.7	7.7	7.7	7.7	7.5	7.8	7.7	7.7
Temperature	°C	12.1	11.9	12.0	12.6	12.4	12.3	12.2	11.9	12.0	12.4	11.9	12.1	13.1	12.4	12.2	12.3	12.4	12.5
DO	mg/L	1.5	1.6	1.6	2.0	1.4	1.2	1.6	1.5	1.7	1.7	1.4	1.6	2.1	1.8	1.6	1.9	1.6	1.8
ORP	mV	315	342	342	357	362	370	314	368	370	358	364	365	389	419	421	360.1	380.1	381.1
Free Chlorine	mg/L	–	0.3	0.3	–	0.3	0.3	–	0.4	0.4	–	0.4	0.4	–	0.4	0.4	–	0.4	0.4
Total Chlorine	mg/L	–	0.4	0.4	–	0.3	0.3	–	0.4	0.4	–	0.4	0.4	–	0.4	0.4	–	0.4	0.4
Total Hardness	mg/L[(a)]	133	82.5	95.5	118	118	114	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]
Ca Hardness	mg/L[(a)]	77.7	55.9	69.5	87.7	87.7	83.3	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]
Mg Hardness	mg/L[(a)]	55.5	26.6	26.0	29.9	29.9	30.9	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]	NA[(f)]
As (total)	µg/L	24.4	12.4	0.6	12.3	11.9	1.8	19.9	14.0	1.4	20.8	11.4	0.8	29.6	13.5	0.8	16.9	13.1	1.9
As (total soluble)	µg/L	16.7	9.9	0.6	10.9	9.2	1.6	16.9	10.5	1.1	20.0	9.3	0.8	29.8	11.4	0.8	14.7	11.3	1.6
As (particulate)	µg/L	7.7	2.5	<0.1	1.4	2.8	0.2	3.0	3.5	0.2	0.8	2.1	<0.1	<0.1	2.1	<0.1	2.1	1.8	0.3
As (III)	µg/L	15.8	0.7	0.6	9.9	0.8	0.7	14.4	0.6	0.6	20.6	0.8	0.8	30.2	0.8	0.7	14.2	0.9	0.8
As (V)	µg/L	0.9	9.2	<0.1	1.0	8.4	1.0	2.5	9.9	0.5	<0.1	8.5	<0.1	<0.1	10.6	0.1	0.5	10.5	0.8
Fe (total)	µg/L	230	113	<25	166	151	<25	226	118	<25	260	158	<25	278	131	<25	245	169	<25
Fe (soluble)	µg/L	167	<25	<25	160	<25	<25	195	<25	<25	245	112	<25	285	<25	<25	197	62.2	<25
Mn (total)	µg/L	19.1	13.0	8.4	17.4	17.3	9.5	18.2	13.3	12.0	17.9	15.1	10.2	18.1	14.6	11.2	17.0	14.5	6.0
Mn (soluble)	µg/L	17.6	7.3	8.5	17.1	15.2	9.5	18.1	9.0	11.5	17.5	15.0	9.9	19.7	7.2	11.3	15.8	10.1	6.0

(a) As $CaCO_3$. (b) As PO_4. (c) Samples reanalyzed outside of hold time. (d) Alkaline samples not taken. (e) Total P samples not analyzed. (f) Hardness samples not analyzed.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.

Table B-1 Analytical Results from Long-Term Sampling, Brown City, MI (Continued)

Sampling Date		02/27/07			03/27/07			05/02/07		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	–	–	63.8	–	–	65.6	–	–	67.9
Alkalinity	mg/L[(a)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Fluoride	mg/L	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Sulfate	mg/L	57	65	80	NA[(c)]	NA[(c)]	NA[(c)]	85.4	146	139
Sulfide	mg/L	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Total P (as PO_4)	mg/L[(b)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Silica (as SiO_2)	mg/L	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
NO_3-N	mg/L	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Turbidity	NTU	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
pH	–	7.7	7.8	7.7	NA[(d)]	NA[(d)]	NA[(d)]	7.8	7.7	7.6
Temperature	ºC	12.3	12.2	12.2	NA[(d)]	NA[(d)]	NA[(d)]	15.8	15.4	15.2
DO	mg/L	1.8	1.5	1.8	NA[(d)]	NA[(d)]	NA[(d)]	1.6	1.9	1.7
ORP	mV	379	365	364	NA[(d)]	NA[(d)]	NA[(d)]	230	300	362
Free Chlorine	mg/L	–	0.3	0.3	–	NA[(d)]	NA[(d)]	–	0.5	0.5
Total Chlorine	mg/L	–	0.4	0.4	–	NA[(d)]	NA[(d)]	–	0.6	0.6
Total Hardness	mg/L[(a)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Ca Hardness	mg/L[(a)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
Mg Hardness	mg/L[(a)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]	NA[(c)]
As (total)	µg/L	21.6	15.4	1.0	11.4	12.0	1.7	12.9	11.8	3.1
As (total soluble)	µg/L	15.8	12.2	1.4	10.5	8.2	1.8	10.3	7.9	2.1
As (particulate)	µg/L	5.8	3.2	<0.1	0.9	3.8	<0.1	2.6	3.9	1.0
As (III)	µg/L	14.9	11.7	0.8	9.2	0.7	0.7	10.7	1.2	1.5
As (V)	µg/L	1.0	0.5	0.6	1.3	7.5	1.1	<0.1	6.6	0.5
Fe (total)	µg/L	312	181	<25	170	147	<25	179	157	<25
Fe (soluble)	µg/L	216	129	<25	164	<25	<25	146	<25	<25
Mn (total)	µg/L	20.0	15.9	11.5	16.8	16.1	13.5	16.2	17.8	14.8
Mn (soluble)	µg/L	18.6	13.9	12.7	17.1	3.3	13.5	14.6	11.1	14.7

(a) As $CaCO_3$. (b) As PO_4. (c) Alkaline samples not taken. (d) Water quality parameters not taken.
IN = inlet; AC = after prechlorination; TA = after tank A; TB = after tank B; TC = after tank C; TD = after tank D; TT = after tanks combined.