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Arsenic Removal from Drinking Water by Adsorptive Media U.S. EPA Demonstration Project at Webb Consolidated Independent School District in Bruni, TX Final Performance Evaluation Report

by

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from the arsenic removal treatment technology demonstration project at the Webb Consolidated Independent School District (Webb CISD) in Bruni, TX. The main objective of the project was to evaluate the effectiveness of AdEdge Technologies' AD-33 media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 μg/L. Additionally, this project evaluated 1) the reliability of the treatment system (Arsenic Package Unit [APU]-50LL-CS-S-2-AVH), 2) the required system operation and maintenance (O&M) and operator skills, and 3) the capital and O&M cost of the technology. The project also characterized the water in the distribution system and residuals produced by the treatment process. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost.

The treatment system consisted of two 42-in × 72-in carbon steel vessels in series configuration, each containing approximately 22 ft^3 of AD-33 pelletized media, which is an iron-based adsorptive media developed by Bayer AG and marketed under the name of AD-33 by AdEdge Technologies. The treatment system was designed for a peak flowrate of 40 gal/min (gpm) and an empty bed contact time (EBCT) of approximately 4.1 min per vessel. Over the performance evaluation period, the actual average flowrate was estimated at 40 gpm (although with quite a bit of fluctuation), based on readings of an hour meter interlocked to the well pump and the electromagnetic flow meter/totalizer installed on each adsorption vessel.

As part of the water treatment system, a pH adjustment/control system was used to adjust pH values of raw water from as high as 8.3 to a target value of 7.0. A prechlorination system also was used to oxidize As(III) to As(V) and maintain a target chlorine residual level of 1.2 mg/L (as Cl_2) in the distribution system. The pH adjustment/control system consisted of a carbon dioxide (CO_2) supply assembly, an automatic pH control panel, a CO_2 membrane module (that injected CO_2 into a CO_2 loop), and an inline pH probe. The prechlorination system, which was upgraded from the pre-existing system, included a chemical feed pump, a sodium hypochlorite (NaOCl) feed tank, and an inject port located downstream of the CO_2 loop and inline pH probe.

The treatment system began regular operation on December 8, 2005. The data collected included system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M cost. Between December 8, 2005, and June 29, 2007, the treatment system treated 5,658,728 gal of water. Since then, a system operator was not available and therefore system measurements were sporadic from June 30, 2007 through the end of the system performance evaluation on May 15, 2008. Based on an average daily operating time of 4.2 hr/day and total number of operational days (i.e., 889 days), the total amount of water treated was estimated at 8,841,000 gal. This estimated volume throughput was equivalent to 27,000 bed volumes (BV) based on the 44 ft^3 of media in both lead and lag vessels.

Since system startup, the treatment system has experienced component failures associated with the pH control system and flow meters/totalizers. Leaks were detected in the CO_2 supply line; the proportional flow control valve malfunctioned; and the inline pH probe failed. There were periods when the pH control system was switched from automatic to manual mode until replacement of certain system components were performed to address the problems encountered. In addition, errors were encountered with the system flow meters/totalizers. On two occasions, the system totalizers reset and began totalizing from zero, likely caused by a programming error. In the first few months of the performance evaluation study, the issues with the pH control system were resolved and programming updates were prepared to prevent future totalizer errors. On June 29, 2007, the licensed system operator working for Webb CISD

resigned, which impeded the data collection efforts for the remainder of the system performance evaluation. Operational and water quality data provided by Webb CISD after June 29, 2007, were collected by a temporary operator who was not formally trained on operating the system.

Total arsenic concentrations in raw water ranged from 46.0 to 68.7 μg/L. Soluble As(III) was the predominating species, ranging from 31.3 to 42.0 μg/L. Chlorine effectively oxidized soluble As(III) to soluble As(V), reducing soluble As(III) concentrations to an average value of 1.2 μg/L. At the end of the performance evaluation study on May 15, 2008, total arsenic levels in the treated water were 45.4 and 5.2 μg/L following the lead and lag adsorption vessels, respectively. Concentrations of phosphorus and silica, which could interfere with arsenic adsorption by competing with arsenate for adsorption sites, ranged from <10.0 to 13.7 mg/L (as P) and from 39.1 to 43.9 mg/L (as SiO_2), respectively, in raw water. Concentrations of iron, manganese, and other ions in raw water were not high enough to impact arsenic removal by the media.

Comparison of the distribution system sampling results before and after operation of the system showed a significant decrease in arsenic concentration (from an average of 68.7 μg/L to an average of 2.4 μg/L). The arsenic concentrations in the distribution system were similar to those in the system effluent. Lead and copper concentrations appeared to have been affected to some extent by the operation of the treatment system. However, the effects were not trendy, with the lead concentrations becoming mostly lower and the copper concentrations becoming mostly higher after system startup.

The capital investment cost of $138,642 included $94,662 for equipment, $24,300 for site engineering, and $19,680 for installation. Using the system's rated capacity of 40 gpm (or 57,600 gal/day [gpd]), the capital cost was $3,466/gpm (or $2.41/gpd) of design capacity. The capital cost also was converted to an annualized cost of $13,086/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-year return period. Assuming that the system operated 24 hours a day, 7 days a week at the system design flowrate of 40 gpm to produce 21,024,000 gal of water per year, the unit capital cost would be $0.62/1,000 gal. Because the system operated an average of 4.2 hr/day at 40 gpm, producing an estimated 3,679,200 gal of water annually, the unit capital cost increased to $3.56/1,000 gal at this reduced rate of use.

The O&M cost included only the cost associated with the adsorption system, such as media replacement and disposal, CO_2 and chlorine usage, electricity consumption, and labor. Although media replacement did not occur during the system performance evaluation, the media replacement cost would have represented the majority of the O&M cost and was estimated to be $11,190 to change out one vessel (including 22 ft^3 AD-33 media and associated labor for media changeout and disposal).

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FIGURES

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ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AAL	American Analytical Laboratories
AM	adsorptive media
APU	arsenic package unit
As	arsenic
ATS	Aquatic Treatment Systems
ATSI	Applied Technology Systems, Inc.
BET	Brunauer, Emmett, and Teller
BV	bed volume
Ca	calcium
C/F	coagulation/filtration process
CISD	Consolidated Independent School District
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluorine
Fe	iron
gpd	gallons per day
gph	gallons per hour
gpm	gallons per minute
HDPE	high-density polyethylene
HIX	hybrid ion exchanger
hp	horse power
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
ISFET	Ion Sensitive Field Effect Transistor
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MEI	Magnesium Elektron, Inc.
Mg	magnesium
Mn	manganese
mV	millivolts

ABBREVIATIONS AND ACRONYMS (Continued)

Na	sodium
NA	not analyzed
NaOCl	sodium hypochlorite
NRMRL	National Risk Management Research Laboratory
NSF	NSF International
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PID	Proportional Integral Derivative
PLC	programmable logic controller
PO_4	phosphate
POU	point of use
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RO	reverse osmosis
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SiO_2	silica
SMCL	secondary maximum contaminant level
SO_4^{2-}	sulfate
STS	Severn Trent Services
TCEQ	Texas Commission on Environmental Quality
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
U	uranium
V	vanadium
VOC	volatile organic compound

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1.0 INTRODUCTION

1.1 Background

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

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems 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, onsite demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in Round 1 of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 out of 115 sites to host the demonstration studies.

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

In 2003, EPA initiated Round 2 arsenic technology demonstration projects that were partially funded with Congressional add-on funding to the EPA budget. In June 2003, EPA selected 32 potential demonstration sites and the Webb Consolidated Independent School District (CISD) in Bruni, TX was one of those selected.

In September 2003, EPA again solicited proposals from engineering firms and vendors for arsenic removal technologies. EPA received 148 technical proposals for the 32 host sites, with each site receiving from two to eight proposals. In April 2004, another technical panel was convened by EPA to review the proposals and provide recommendations to EPA with the number of proposals per site ranging from none (for two sites) to a maximum of four. The final selection of the treatment technology at the sites that received at least one proposal was made, again through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. AdEdge Technologies (AdEdge), using the Bayoxide E33 (AD-33) media developed by Bayer AG, was selected for demonstration at the Webb CISD site in April 2004.

As of April 2010, 39 of the 40 systems were operational, and the performance evaluation of 36 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Round 1 and Round 2 demonstration host sites include 25 adsorptive media (AM) systems (the Oregon Institute of Technology [OIT] site has three AM systems), 13 coagulation/filtration (C/F) systems, two ion exchange (IX) systems, 17 point-of-use (POU) units (including nine under-the-sink reverse osmosis [RO] units at the Sunset Ranch Development site and eight AM units at the OIT site), and one process modification. Table 1-1 summarizes the locations, technologies, vendors, system flowrates, and key source water quality parameters (including arsenic, iron, and pH) at the 40 demonstration sites. An overview of the technology selection and system design for the 12 Round 1 demonstration sites and the associated capital cost is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Web site at http://www.epa.gov/ORD/NRMRL/wswrd/dw/arsenic/index.html.

1.3 Project Objectives

The objective of the Round 1 and Round 2 arsenic demonstration program is to conduct 40 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 AdEdge system at the Webb CISD in Bruni, from December 8, 2005, through May 15, 2008. The data collected included system operational data, water quality data (both across the treatment train and in the distribution system), and capital and preliminary O&M cost data.

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality

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

Table 1-1. Summary of Round 1 and Round 2 Arsenic Removal Demonstration Locations, Technologies, and Source Water Quality (Continued)

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

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

2.0 SUMMARY AND CONCLUSIONS

AdEdge's APU-50-LL-CS-S-AVH treatment system with AD-33 pelletized media was installed and has operated at the Webb CISD site in Bruni, TX since December 8, 2005. Based on the information collected during the system evaluation period, the following summary and conclusion statements are provided.

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

- Chlorine was effective in oxidizing soluble As(III) to soluble As(V). Analytical data confirmed that average soluble As(III) concentrations decreased from 37.5 μg/L in raw water to 1.2 μg/L after chlorination and that average As(V) concentrations increased correspondingly from 15.0 μg/L in raw water to 51.7 μg/L after chlorination. Because very little iron was present in raw water, little or no particulate arsenic was produced upon chlorination.
- AD-33 media effectively lowered arsenic concentrations to 5.2 μg/L at the end of the performance evaluation study. The volume throughput was estimated at 27,000 bed volumes (BV), based on 44 ft^3 of media in both lead and lag vessels.
- The operation of the treatment system significantly lowered arsenic concentrations in the distribution system (i.e., from 68.7 to 2.4 μg/L, on average). The treatment system did not appear to have impacted lead or copper concentrations in the distribution system.

Required system O&M and operator skill levels:

- The daily demand on the operator was typically 20 min to visually inspect the system and record operational parameters, although additional time and effort was required to troubleshoot the problems associated with the CO_2 system.
- Some operational problems related to the CO_2 gas flow control system were encountered during the system operation. Primary problems included a faulty proportioning valve and failure of the inline pH probe. A reoccurring problem unrelated to the pH adjustment system was associated with the electromagnetic water flow meters/totalizers, which randomly reset to zero.
- Operation of the system did not appear to require additional skills beyond those necessary to operate the existing water supply equipment, with the exception of the CO_2 and pH control portion of the system. The CO_2 system required additional operator training and safety awareness.

Process residuals produced by the technology:

- The pressure differential (Δp) measured across the media vessels during the system operation did not require a backwash. Therefore, no backwash residuals were produced. The average pressure drop was 13.9 psi through June 27, 2007.

Cost-effectiveness of the technology:

- Based on the system's rated capacity of 40 gpm (or 57,600 gal/day [gpd]), the capital cost was $3,466/gpm (or $2.41/gpd) of design capacity.
- Media replacement and disposal did not occur during system performance evaluation; however, the cost to change out one vessel (22 ft^3 AD-33 media) was estimated to be $11,190, which included the replacement media, spent media disposal, shipping, labor, and travel.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the predemonstration activities summarized in Table 3-1, the performance evaluation study of the AdEdge treatment system began on December 8, 2005 and ended on May 15, 2008. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall performance of the system was determined based on its ability to consistently remove arsenic to below the arsenic MCL of 10 µg/L through the collection of water samples across the treatment plant, as described in the Study Plan (Battelle, 2005). The reliability of the system was evaluated by tracking the unscheduled system downtime and the 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	November 15, 2004
Project Planning Meeting Held	February 17, 2005
Draft Letter of Understanding Issued	February 23, 2005
Final Letter of Understanding Issued	March 24, 2005
Request for Quotation Issued to Vendor	March 14, 2005
Vendor Quotation Received by Battelle	April 1, 2005
Purchase Order Completed and Signed	April 18, 2005
Engineering Plans Submitted to TCEQ	June 8, 2005
System Permit Issued by TCEQ	August 31, 2005
APU System Shipped and Arrived	October 13, 2005
System Installation Completed	November 19, 2005
System Shakedown Completed	November 19, 2005
Final Study Plan Issued	November 30, 2005
Performance Evaluation Begun	December 8, 2005

TECQ = Texas Commission on Environmental Quality

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

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This requires tracking of the capital cost for equipment, site engineering, and installation, as well as the O&M cost for media replacement and disposal, CO_2 and chlorine consumption, electrical power usage, and labor. Data on Webb CISD's O&M cost were limited to CO_2 and chlorine consumption, electricity usage, and labor because media replacement did not take place during the system performance evaluation.

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

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, biweekly, and monthly system O&M and data collection according to instructions provided by the vendor and Battelle. On a 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 and conducted visual inspections to ensure normal system operations. If any problem occurred, the plant operator would contact the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem encountered, course of action taken, materials and supplies used, and associated cost and labor incurred on the Repair and Maintenance Log Sheet. Every other week, the plant operator measured pH, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on an Onsite Water Quality Parameters Log Sheet. The Webb CISD operator resigned during the system performance evaluation; thus, there is no operational and water quality data after June 29, 2007.

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 chemical usage, electricity consumption, and labor. CO_2 and chlorine consumption was tracked through daily measurements and recorded on Daily System Operation Log Sheets. Electricity consumption was tracked through the onsite electric meter. Labor for various activities, such as routine system O&M, system 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 field logs, replenishing chemical solutions, ordering supplies, performing system inspections, 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 vendor, was recorded but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the performance of the system, samples were collected from the wellhead, across the treatment plant, from the backwash discharge line, and from the distribution system. Table 3-3 provides

Table 3-3. Sampling Schedules and Analytes

Sample Type	Sampling Locations[(a)]	No. of Sampling Locations	Frequency	Analytes	Sampling Date
Source Water	At Wellhead (IN)	1	Once during initial site visit	Onsite: pH, temperature, DO, and ORP Offsite: As (total and soluble), As(III), As(V), Fe (total and soluble), Mn (total and soluble), U (total and soluble), V (total and soluble), Na, Ca, Mg, Cl, F, NO_3, NO_2, NH_3, SO_4, SiO_2, PO_4, turbidity, alkalinity, TDS, and TOC	11/15/04
Treatment Plant Water	At Wellhead (IN), after pH Adjustment (AP), after Lead Vessel (TA), and after Lag Vessel (TB)	4	First week of each four-week cycle	Onsite: pH, temperature, DO, ORP, and Cl_2 (free and total)[(b)] Offsite: 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, P, turbidity, and alkalinity	12/08/05, 01/05/06, 02/01/06, 03/14/06, 04/11/06, 05/09/06, 06/06/06, 07/11/06, 08/02/06, 08/30/06, 09/28/06, 10/31/06, 11/28/06, 12/12/06, 01/22/07
		4	Third week of each four-week cycle	Onsite: pH, temperature, DO, ORP, and Cl_2 (free and total)[(b)] Offsite: As (total), Fe (total), Mn (total), SiO_2, P, turbidity, and alkalinity	12/13/05, 01/17/06, 02/15/06, 02/28/06, 03/28/06, 04/25/06, 05/23/06, 06/20/06, 07/19/06, 08/16/06, 09/15/06, 10/11/06, 11/08/06
		4	Monthly[(c)]	Onsite: NA Offsite: As (total and soluble)[d], As(III), As(V), SiO_2, and/or P	02/13/07, 03/13/07, 04/17/07, 05/09/07, 06/05/07, 09/20/07, 02/21/08, 04/16/08, 05/15/08
Distribution Water	Three LCR Locations Within School	3	Monthly[(d)]	pH, alkalinity, As, Fe, Mn, Pb, and Cu	Baseline and monthly sampling: See Table 4-10
Backwash Water	Backwash Discharge Line from Each Vessel	2	Monthly or as needed	pH, TDS, TSS, As (total and soluble), Fe (total and soluble), and Mn (total and soluble)	NA

(a) Abbreviations in parentheses corresponding to sample locations shown in Figure 4-5.
(b) Except at IN location.
(c) Only As (total) analyzed from 09/20/07 to 05/15/08.
(d) Four baseline sampling events performed from June to September 2005 before system became operational.
LCR = Lead and Copper Rule; NA = not applicable.

the sampling schedule and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2004).

3.3.1 Source Water Sample Collection. During the initial visit to the site on November 15, 2004, one set of source water samples was collected and speciated using an arsenic speciation kit (see Section 3.4.1). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Analytes for the source water samples are listed in Table 3-3.

3.3.2 Treatment Plant Water Sample Collection. During the system performance evaluation study, biweekly water samples were collected across the treatment train by the plant operator for onsite and offsite analyses. Except for a few exceptions, samples were collected during the first week of each four-week cycle at the wellhead (IN), after pH adjustment and chlorination (AP), after the lead adsorption vessel (TA), and after the lag adsorption vessel (TB) and analyzed for the analytes listed on Table 3-3. During the third week of the four-week cycle, samples were taken from the same four locations and analyzed for the analyte list shown on Table 3-3. Beginning on Feburary 13, 2007, samples were collected from the same four locations on a monthly basis and analyzed for the analytes shown on Table 3-3.

3.3.3 Backwash Wastewater/Solids and Spent Media Collection. Because the system did not require backwash during the system performance evaluation, no backwash residuals were produced. Further, because media replacement did not take place, there were no spent media samples collected.

3.3.4 Distribution System Water Sample Collection. Samples were collected from the distribution system by the plant operator to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically the arsenic, lead, and copper levels. From June to September 2005, prior to the startup of the treatment system, four baseline distribution sampling events were conducted at three locations within the distribution system. Following startup of the arsenic adsorption system, distribution system sampling continued on a monthly basis at the same three locations.

The three locations selected were sample taps within the Webb CISD that had been included in the Lead and Copper Rule (LCR) sampling in the past. The baseline and monthly distribution system samples were collected following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The date and time of last water use before sampling and the date and time of sample collection were recorded for calculation of the stagnation time. All samples were collected from a cold water faucet that had not been used for at least 6-hr to ensure that stagnant water was sampled. Analytes for the baseline samples coincided with the monthly distribution system water samples as described in Table 3-3. Arsenic speciation was not performed for the distribution system water samples.

3.4 Sampling Logistics

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

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

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, color-coded, and 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 for designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. For example, red, orange, yellow, and blue were used to designate sampling locations for IN, AP, TA, and TB, respectively. The prelabeled bottles for each sampling location were placed in separate zip-lock bags and packed in the cooler.

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

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

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

3.5 Analytical Procedures

The analytical procedures described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2004) were followed by Battelle ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assuarnce/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limits (MDLs), and completeness met the criteria established in the QAPP (i.e., relative percent difference [RPD] of 20%, percent recovery of 80% to 120%, and completeness of 80%). The QA data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Field measurements of pH, temperature, DO, and ORP were conducted by the plant operator using a VWR Symphony SP90M5 Handheld Multimeter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean, plastic beaker and placed the Symphony SP90M5 probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits following the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description and Pre-existing Treatment System Infrastructure

Located at 619 Avenue F in Bruni, Texas, the Webb CISD water system supplies water to approximately 230 students and staff members during the academic year. Figure 4-1 shows the pre-existing water treatment facility. The water system was served by a single well that is 7-in in diameter and approximately 345 ft deep. The supply well, shown in Figure 4-2, was equipped with a 5-horsepower (hp), 15-in submersible pump rated for 40 gpm at 300 ft H_2O or 130 lb/in^2 (psi). The pre-existing system typically operated for 6 to 8 hr/day, with an average daily demand of 10,000 gpd and an estimated peak daily demand of 15,000 gpd. The pre-existing treatment included only chlorination with a 10% sodium hypochlorite (NaOCl) solution to reach a target residual level of 1.2 mg/L (as Cl_2). Figure 4-3 shows the chlorine addition system at the site. Following chlorination, the treated water was stored in a 15,000-gal storage tank located in a fenced area in the immediate vicinity of the well and chlorine addition system.

Figure 4-1. Pre-existing Water Treatment Facility
(from Left to Right: Wellhead in front of White Storage Shed, Chlorine Addition System in Black Rectangular Box, and White Storage Tank for Treated Water)

4.1.1 Source Water Quality. Source water samples were collected and speciated on November 15, 2004, for onsite and offsite analyses. The results are presented in Table 4-1 and compared to those taken by the facility for the EPA demonstration site selection.

Arsenic**.** Total arsenic concentrations of source water ranged from 55.6 to 59 μg/L. Based on Battelle's speciation results, out of 55.2 μg/L of soluble arsenic, 19.6 μg/L existed as As(V) and 35.6 μg/L as As(III). Therefore, pre-oxidation of As(III) to As(V) prior to adsorption was required.

Figure 4-2. Wellhead at Webb CISD

Figure 4-3. Pre-existing Chlorine Addition System

Table 4-1. Water Quality Data for Webb CISD, Bruni, TX

Parameter	Unit	Raw Water		Treated Water
		Facility Data[a]	Battelle Data	TCEQ Data
Date		-	11/15/04	01/12/98–10/26/04
pH	S.U.	8.1	8.0	6.8–8.2
Temperature	°C	NA	25.3	NA
DO	mg/L	NA	1.5	NA
ORP	mV	NA	-122	NA
Total Alkalinity (as $CaCO_3$)	mg/L	323	325	232–297
Hardness (as $CaCO_3$)	mg/L	24.0	23.5	25.0–27.2
Turbidity	NTU	NA	0.7	NA
TDS	mg/L	NA	1,060	781–795
TOC	mg/L	NA	0.9	NA
Nitrate (as N)	mg/L	NA	<0.04	0.3–1.2
Nitrite (as N)	mg/L	NA	<0.01	0.01
Ammonia (as N)	mg/L	NA	<0.05	NA
Chloride	mg/L	188	130	180–229
Fluoride	mg/L	NA	1.0	0.7–0.8
Sulfate	mg/L	104	98.0	97.4–113
Silica (as SiO_2)	mg/L	NA	42.3	NA
Orthophosphate (as PO_4)	mg/L	NA	<0.06	NA
As(total)	μg/L	59.0	55.6	75.9–104
As (soluble)	μg/L	NA	55.2	NA
As (particulate)	μg/L	NA	0.4	NA
As(III)	μg/L	NA	35.6	NA
As(V)	μg/L	NA	19.6	NA
Fe (total)	μg/L	27	<25	10–51
Fe (soluble)	μg/L	NA	<25	NA
Mn (total)	μg/L	8	4.5	1–8
Mn (soluble)	μg/L	NA	4.3	NA
U (total)	pCi/L	NA	10.6	<25
U (soluble)	pCi/L	NA	10.2	NA
V (total)	μg/L	NA	4.4	NA
V (soluble)	μg/L	NA	4.4	NA
Na (total)	mg/L	301	333	272–293
Ca (total)	mg/L	7	6.1	7.1–8.0
Mg (total)	mg/L	2	2.0	1.0–2.3

(a) Provided by facility to EPA for demonstration site selection.
TCEQ = Texas Commission on Environmental Quality
NA = not analyzed

Iron. Iron concentrations in source water were low, typically less than its detection limit of 25 μg/L. In general, adsorptive media technologies are best suited to sites with relatively low iron levels (e.g., less than 300 μg/L of iron, which is the secondary maximum contaminant level [SMCL] for iron). With concentrations greater than 300 μg/L, taste, odor, and color problems can occur in the treated water, along with an increased potential for fouling of the adsorption system components with iron particulates.

pH. pH values of raw water were between 8.0 and 8.1. At pH values greater than 8.0 to 8.5, the AM vendor recommends that the pH values be lowered to enhance the adsorptive capacity of the media. The treatment process for the Webb CISD site included a CO_2 injection and pH monitoring and control module prior to arsenic adsorption. The target pH level after pH adjustment was 7.0.

Competing Anions. Arsenic adsorption can be influenced by the presence of competing anions such as silica and phosphate. Analysis of source water indicated silica levels at 42.3 mg/L and orthophosphate levels less than its detection limit (i.e., <0.06 mg/L). The effect of silica on arsenic adsorption was monitored closely during the demonstration study.

Other Water Quality Parameters. Other water quality parameters in source water were below their respective primary MCLs, including nitrate, nitrite, and ammonia. Also, chloride, fluoride, sulfate, and manganese were below their respective SMCLs. Total dissolved solids (TDS) were measured at 1,060 mg/L, which is above the SMCL of 500 mg/L.

4.1.2 Treated Water Quality. In addition to the source water quality data, Table 4-1 also presents historic treated water quality data collected by TCEQ from January 1998 through October 2004. These treated water quality data were similar to the source water quality data provided by the facility and collected by Battelle. Total arsenic concentrations of the treated water were slightly higher and ranged from 75.9 to 104 μg/L. No arsenic speciation data were available for the water following chlorination. pH values ranged from 6.8 to 8.2. Additional analytes including several metals and radionuclides are summarized in Table 4-2.

Table 4-2. TCEQ Treated Water Quality Data

Parameter	Unit	TCEQ Data
Date		01/12/98–10/26/04
Antimony	μg/L	1–4
Barium	μg/L	39.7–40
Beryllium	μg/L	<1
Cadmium	μg/L	0.2–1.2
Chromium	μg/L	<10
Copper	μg/L	2.2–7.7
Lead	μg/L	1–12
Mercury	μg/L	<0.4
Nickel	μg/L	1–20
Selenium	μg/L	8.5–12.7
Silver	μg/L	1–10
Thallium	μg/L	<1
Zinc	μg/L	<4–20
Gross Alpha	pCi/L	26.2–28.3[a]
Gross Beta	pCi/L	11.8–12.5
Radium 226	pCi/L	<1
Tritium	pCi/L	500

(a) over 15 pCi/L MCL

4.1.3 Distribution System. The distribution system was constructed primarily of polyvinyl chloride (PVC) piping and some galvanized piping. The piping within the building was copper. The distribution system was supplied directly from the 15,000-gal storage tank. The three locations selected for distribution sampling included one location each in the middle school, high school, and cafeteria. These locations represented the distribution system sampling and also were part of the school's historic

LCR sampling network. The school also sampled for coliform once a month and volatile organic compounds (VOCs), inorganics, nitrate, and radionuclides as directed by the TCEQ, typically once every two to three years.

4.2 Treatment Process Description

The AdEdge arsenic package unit (APU) is a fixed-bed, down-flow adsorption system used for small water systems in the flow range of 5 to 100 gpm. The system uses Bayoxide E33 media (branded as AD-33 by AdEdge), an iron-based adsorptive media developed by Bayer AG, for the removal of arsenic from drinking water supplies. Table 4-3 presents physical and chemical properties of the media. AD-33 media is delivered in a dry crystalline form and listed by NSF International (NSF) under Standard 61 for use in drinking water applications. The media exist in both granular and pelletized forms, which have similar physical and chemical properties, except that pellets are denser than granules (i.e., 35 lb/ft^3 vs. 28 lb/ft^3). For the Webb CISD site, pellets were selected for use.

Table 4-3. Physical and Chemical Properties of AD-33 Media[(a)]

Physical Properties	
Parameter	**Value**
Matrix	Iron oxide composite
Physical form	Dry pellets
Color	Amber
Bulk Density (lb/ft^3)	35
BET Area (m^2/g)	142
Attrition (%)	0.3
Moisture Content (%)	<15 (by weight)
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
MgO	1.00
MnO	0.11
SO_3	0.13
Na_2O	0.12
TiO_2	0.11
SiO_2	0.06
Al_2O_3	0.05
P_2O_5	0.02
Cl	0.01

(a) Provided by AdEdge
BET = Brunauer, Emmett, and Teller

For series operation, when the media in the lead vessel completely exhausts its capacity and/or when the effluent from the lag vessel reaches 10 µg/L of arsenic, the spent media in the lead vessel is removed and disposed of as a non-hazardous waste if it passes the Toxicity Characteristic Leaching Procedure (TCLP) test. The media life depends upon the arsenic concentration, the empty bed contact time (EBCT), the mode or variability of operation (on/off), pH, and concentrations of competing ions in source water.

After rebedding, the lead vessel is switched to the lag position and the lag vessel is switched to the lead position. In general, the series operation better utilizes the media capacity when compared to the parallel operation because the media in the lead vessel may be allowed to exhaust completely prior to change-out. During the system performance evaluation, the need for media replacement was never required. At the end of the performance evaluation study, the arsenic concentrations in the lead and lag vessels were 45.4 µg/L and 5.2 µg/L, respectively.

The arsenic treatment system at the Webb CISD site (specifically referred to as the APU-50LL-CS-S-2-AVH system) consisted of two vessels (i.e., A and B), operating in series. The piping and valve configuration of the pressure vessels allowed electrically actuated butterfly valves to divert raw water flow into either Vessel A or Vessel B depending on which was operating as the lead vessel. A simplified process flow diagram of the treatment system is shown in Figure 4-4. The system was located in the maintenance building, which provided sufficient space available to house the system. Figure 4-5 is a generalized process flow sampling diagram of the system that illustrates sampling locations and parameters analyzed during the demonstration study. Table 4-4 presents key system design parameters.

The key process steps and major components of the water treatment system include:

- **Intake**. Raw water was pumped from the supply well and fed to the treatment system.
- **pH adjustment**. pH values of raw water were lowered to a target pH value of 7.0 using CO_2, which was selected for pH adjustment because 1) CO_2 is less corrosive than mineral acids, such as H_2SO_4, and 2) when the treated water depressurized after exiting the adsorption vessels, some CO_2 may degas, thereby raising pH values of the treated water and reducing its corrosivity to the distribution piping.

  A Carbon Dioxide Gas Flow Control System manufactured by Applied Technology Systems, Inc. (ATSI) in Souderton, PA was used for pH adjustment. Figure 4-6 presents a process diagram of the system, which was designed to introduce gaseous CO_2 into water in a side-stream configuration, or a CO_2 loop. The system, illustrated in Figure 4-7 as a composite of photographs, consisted of a liquid CO_2 supply assembly, an automatic pH control panel, a CO_2 membrane assembly, and a pH probe located downstream of the membrane module:

  - Liquid CO_2 in two 50-lb cylinders vaporized into gaseous CO_2 via a feed vaporizer prior to entering the pH control panel.
  - As the CO_2 gas flowed to the pH control panel, the gas flowrate was automatically controlled and adjusted by a JUMO pH/Proportional Integral Derivative (PID) controller and an Alicat mass flowmeter (Figure 4-6) to reach a desired pH setpoint. As an alternative, manual regulation of the gas flowrate could also be achieved via the use of a three-way ball valve and a rotameter. Further, a solenoid valve interlocked with the well pump allowed gas to flow only when the well pump was turned on.
  - After flowing out of the control panel, CO_2 was injected into water through a Celgard® microporous hollow fiber membrane module housed in a 1.5-in stainless steel sanitary cross. Table 4-5 lists the properties and specifications of the hollow fiber membrane module. The sanitary cross was located in a side stream from the main water line to allow only a portion of water to flow through the membrane module to minimize the pressure drop. The membrane introduced CO_2 gas into the water at a near molecular level for rapid mixing/reaction with water to achieve a quick pH response/change.

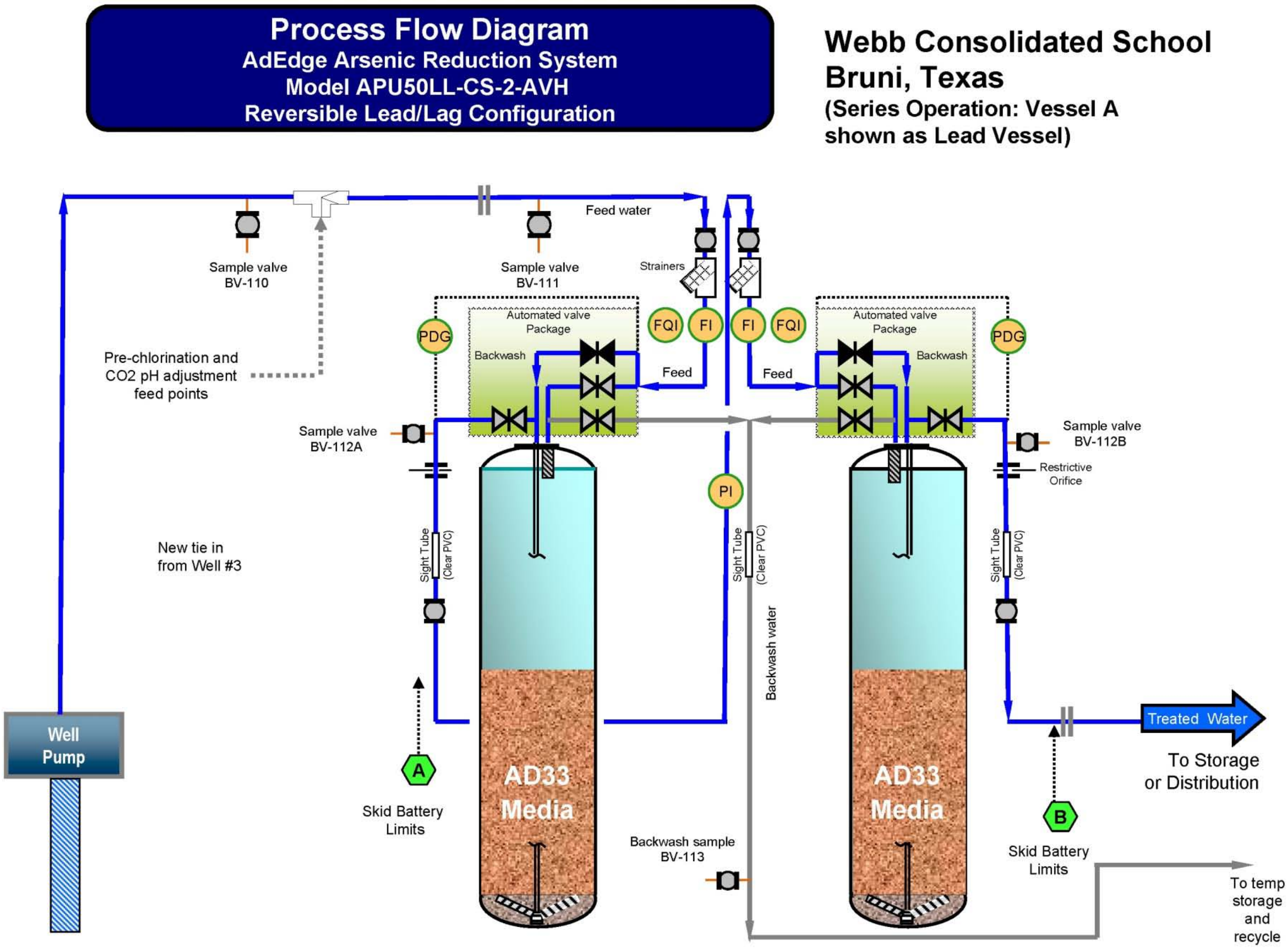


Figure 4-4. Process Flow Diagram for APU-50LL-CS-S-2-AVH System

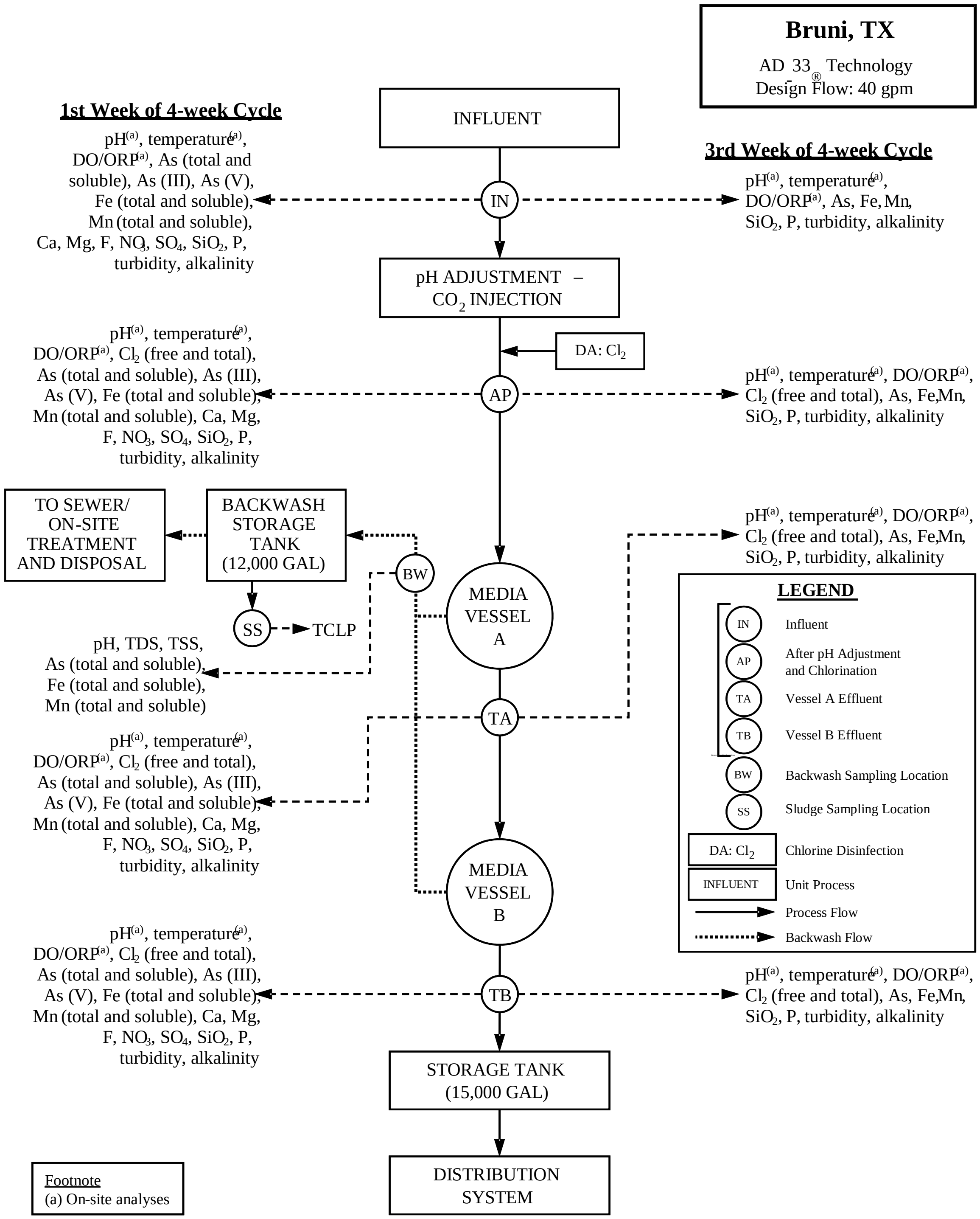


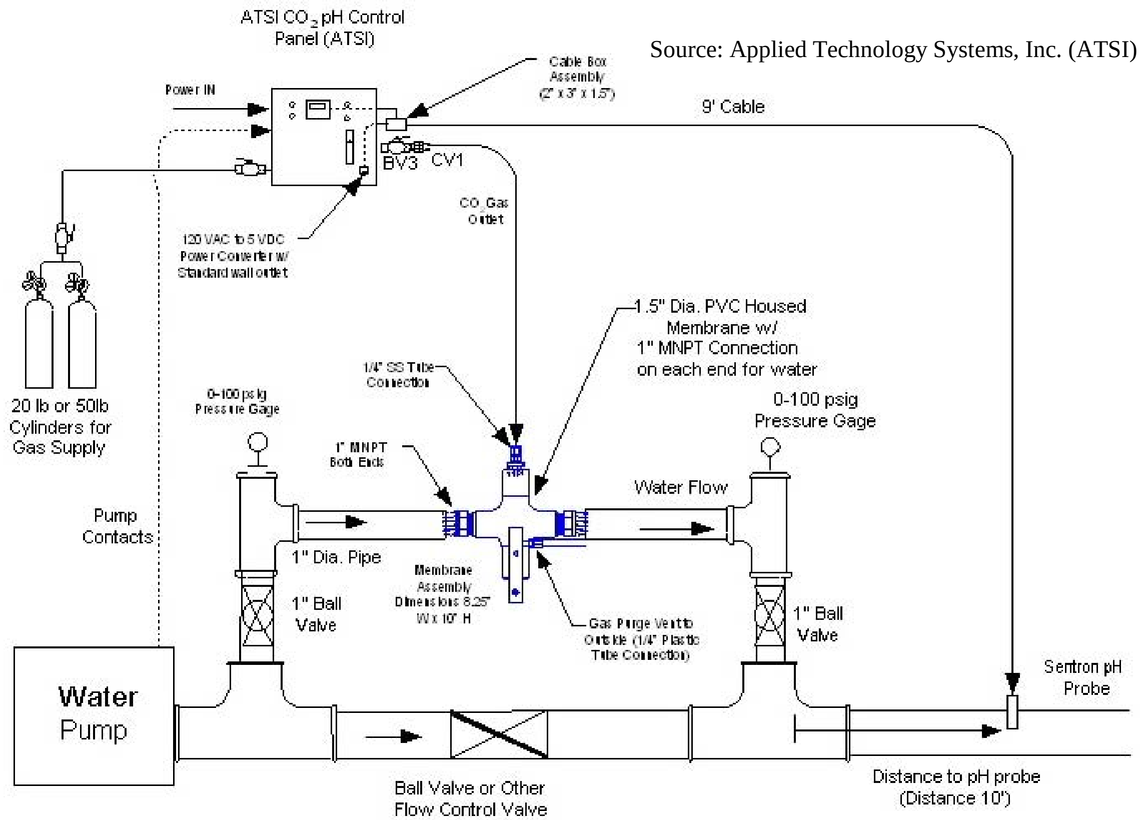
Figure 4-5. Process Flow Diagram and Sampling Schedules and Locations

Table 4-4. Design Specifications for AdEdge APU-50LL-CS-S-2-AVH System

Parameter	Value	Remarks
Pre-treatment		
Target pH Value after Adjustment (S.U.)	7.0	Using CO_2
Target Chlorine Residual (as Cl_2)	1.2	Using NaClO
Adsorption Vessels		
Vessel Size (in)	42 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	9.6	–
Number of Vessels	2	–
Configuration	Series	–
AD-33 Adsorption Media		
Media Bed Depth (in)	27.5	
Media Quantity (lb)	1,540	770 lb/vessel
Media Volume (ft^3)	44	22 ft^3/vessel
Media Type	AD-33	In pelletized form
Service		
Design Flowrate (gpm)	40	–
Hydraulic Loading Rate (gpm/ft^2)	4.2	–
EBCT (min/vessel)	4.1	Based on flowrate of 40 gpm per vessel (8.2 min total EBCT for both lead and lag vessels)
Estimated Working Capacity (BV)	46,900	Bed volumes to 10 µg/L total arsenic breakthrough from lag vessel based on vendor estimate
Throughput to Breakthrough (gal)	7,725,000	1 BV = 22 ft^3 = 164 gal
Average Use Rate (gal/day)	12,000	Based on 5 hr/day operation at 40 gpm
Estimated Media Life (months)	21.5	Estimated frequency of media change-out from lead vessel based on 12,000 gal/day use rate
Backwash		
Pressure Differential Set Point (psi)	10	–
Backwash Flowrate (gpm)	90	–
Hydraulic Loading Rate (gpm/ft^2)	9.4	–
Backwash Frequency (month/backwash)	3–4	Actual backwash frequency to be determined
Backwash Duration (min/vessel)	20	–
Service-to-Waste Fast Rinse Flowrate (gpm)	90	–
Fast Rinse Duration (min/vessel)	1–4	–
Wastewater Production (gal/vessel)	1,890–2,160	–

- Located downstream from the sanitary cross, a Sentron Ion Sensitive Field Effect Transistor (ISFET) type silicon chip sanitary pH probe with automatic temperature compensation continuously monitored pH levels of the treated water and sent signals back to the pH/PID controller for pH control.
- Throughout the study, the CO_2 pH control system supplied CO_2 at approximately 14.2 ft^3/hr, using about 6.6 lb/day (based on a gas density of 0.117 lb/ft^3 and an average operating time of 4.0 hr/day). The CO_2 gas supplied from two 50-lb cylinders provided CO_2 for about 7.5 days before requiring change-out.

Source: Applied Technology Systems, Inc. (ATSI)



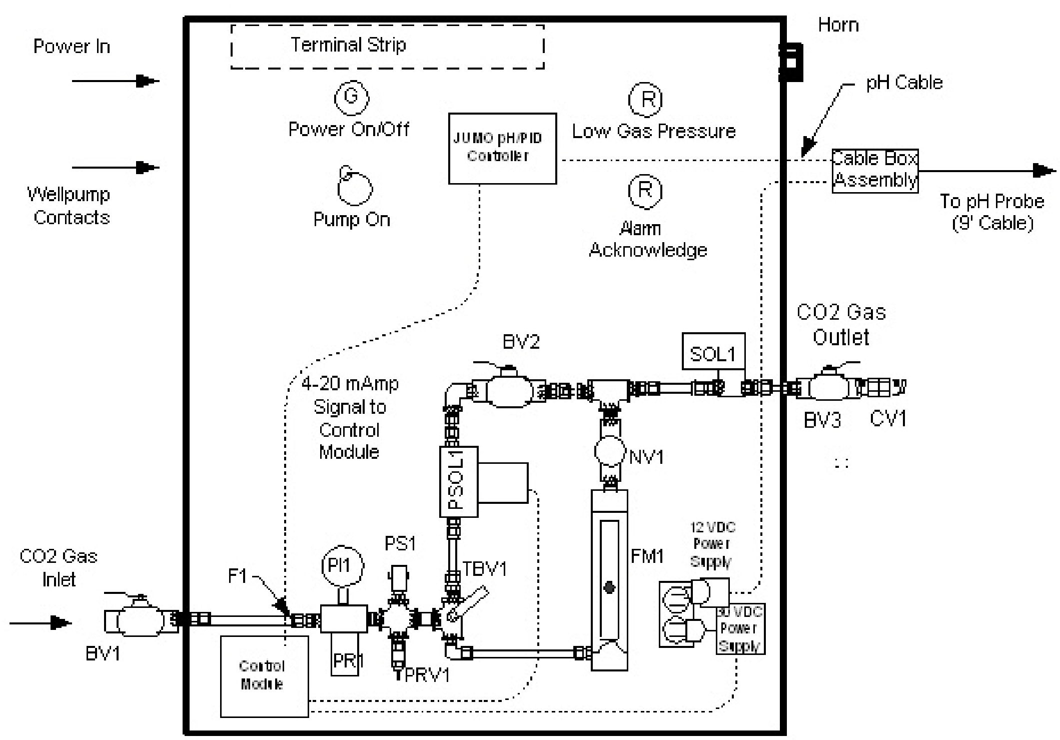


Figure 4-6. Process Diagram of CO_2 pH Adjustment System (top) and pH/PID Control Panel (bottom)

Figure 4-7. Carbon Dioxide Gas Flow Control System for pH Adjustment
(Clockwise from Top Left: Liquid CO_2 Supply Assembly;
Automatic pH Control Panel; CO_2 Membrane Module; Port for pH Probe)

Table 4-5. Properties of Celgard®, X50-215 Microporous Hollow Fiber Membrane

Parameter	Value
Porosity (%)	40
Pore Dimensions (µm)	0.04 × 0.10
Effective Pore Size (µm)	0.04
Minimum Burst Strength (psi)	400
Tensile Break Strength (g/filament)	≥300
Average Resistance to Air Flow (Gurley sec)	50
Axial Direction Shrinkage (%)	≤5
Fiber Internal Diameter, nominal (µm)	220
Fiber Wall Thickness, nominal (µm)	40
Fiber Outer Diameter, nominal (µm)	300
Module Dimensions (in)	1.5 × 3.0

Data Source: Celgard®

- **Prechlorination.** The existing chlorination system, as shown in Figure 4-3, was upgraded and installed inside the maintenance building along with the APU-50LL-CS-S-2-AVH system. Chlorine oxidizes As(III) to As(V) prior to the adsorption vessels and provides a target residual of 1.2 mg/L (as Cl_2) for disinfection in the distribution system. The chlorine feed system, illustrated in Figure 4-8, included a solenoid-driven, diaphragm-type metering pump with a capacity range of 0.19 to 8.4 gal/hr (gph), a 50-gal high-density polyethylene (HDPE) chemical feed tank to store the 10% NaClO solution, and a chlorine injection port. Chlorine was injected into the raw water line following the CO_2 injection and pH probe, but prior to the AP sampling location. Operation of the chlorine feed system was linked to the well pump so that chlorine was injected only when the well was on. Chlorine consumption was measured using volumetric markings on the outside of the feed tank.

Figure 4-8. Chlorination Feed System
(Clockwise from Top Left: Chlorine Metering Pump; HDPE Chemical Feed Tank with Secondary Containment; Chlorine Injection Port)

- **Adsorption**. The AdEdge APU-50LL-CS-S-2-AVH system consisted of two 42-in × 72-in pressure vessels configured in series, each containing 22 ft^3 of AD-33 media. The vessels were carbon steel construction, skid mounted, and rated for 100-psi working pressure. EBCT for the system was 4.1 min in each vessel. The hydraulic loading rate to each vessel was approximately 4.2 gpm/ft^2, based on the design flowrate of 40 gpm.

  Each pressure vessel was interconnected with schedule 80 PVC piping and five electrically actuated butterfly valves, which make up the valve tree shown in Figure 4-9. In addition to the 10 butterfly valves, the system had two manual diaphragm valves on the backwash line and six isolation ball valves to divert raw water flow into either vessel, which reversed the lead/lag vessel configuration. Each valve operated independently and the butterfly valves were controlled by a Square D Telemechanique programmable logic controller (PLC) with a Magelis G2220 color touch interface screen.

Figure 4-9. Adsorption System Valve Tree and Piping Configuration

- **Backwash**. The vendor recommended that the APU-50LL-CS-S-2-AVH system be backwashed, either manually or automatically, on a regular basis to remove particulates and media fines that accumulate in the media beds. Automatic backwash can be initiated by either timer or Δp across the vessels. During the backwash cycle, each vessel is backwashed individually, while the second vessel remains off-line. Backwash is performed upflow at a flowrate of 90 gpm to achieve a hydraulic loading rate of about 9.3 gpm/ft^2. Because the incoming flowrate from the supply well is insufficient to provide the necessary flow for backwash, supplemental water is supplied from the treated water storage tank to the head of the system. Each backwash cycle is set to last for about 20 min/vessel of backwash followed by 1 to 4 min/vessel of service-to-waste fast rinse, generating a combined total of approximately 1,890 to 2,160 gal/vessel of wastewater.

  The backwash water produced is pumped to a 12,000-gal fiberglass backwash storage tank located adjacent to the treated water storage tank (see Figure 4-1). Water from the backwash storage tank is sent to an onsite wastewater plant and then to a series of four stabilization ponds, which provide approximately 120 days of storage capacity. If the storage capacity of the stabilization ponds is exceeded, the discharge goes to a normally dry streambed, where it ultimately evaporates or percolates into the ground.

Due to minimal pressure drop across the vessels throughout the study, system backwash was not performed throughout the performance evaluation study. The pressure drop and the arsenic concentrations across the vessels were monitored regularly.

- **Media Replacement**. Based on the analytical results from the final sampling event, total arsenic concentrations in the treated water were 45.4 and 5.2 μg/L following Tanks A and B, respectively. The total arsenic concentration from the lag vessel did not exceed the MCL of 10 μg/L; therefore, the media in the lead vessel was not replaced during the study period. Based on the estimate provided by the vendor, breakthrough of arsenic was expected after about 46,900 BV of water treated or about 21.5 months of system operation, assuming an average use rate of 5 hr/day operation at 40 gpm.

4.3 System Installation

The installation of the APU system was completed by AdEdge on November 19, 2005. The following briefly summarizes some of the predemonstration activities, including permitting, building preparation, and system offloading, installation, shakedown, and startup.

4.3.1 Permitting. An exception submittal package was submitted to TCEQ by Webb CISD on April 18, 2005, requesting an exception to use data from an alternative site in lieu of conducting an onsite pilot study as required under Title 30 Texas Administrative Code (30 TAC) §290.42(g). The exception submittal included a written description of the treatment technology along with a schematic of the system and relevant pilot- and full-scale data. In addition, a permit application submittal package including a process flow diagram of the treatment system, mechanical drawings of the treatment equipment, and a schematic of the building footprint and equipment layout also was submitted to TCEQ for permit approval on April 18, 2005. TCEQ requested supplemental information, in a response letter dated June 3, 2005, to complete its review of the request. In response, supplementary data were provided by the vendor on July 14, 2005, Battelle on August 22, 2005, and Southwest Engineers, Inc. on August 29, 2005. Based on a review of the submitted data (which included revised engineering plans and specifications, dated August 19, 2005) and discussions with the vendor, Battelle, and EPA, TCEQ granted an exception request and approval to construct the arsenic removal treatment system on August 31, 2005.

4.3.2 Building Preparation. The existing maintenance shop building as shown in Figure 4-10 had adequate space to house the planned arsenic treatment system. The maintenance building is a single-story metal structure with concrete flooring. Additional preparation required the installation of a lockable wire cage enclosure around the treatment system.

4.3.3 Installation, Shakedown, and Startup. The treatment system arrived onsite on October 13, 2005. Figure 4-11 shows a photograph of the system arriving at the site. AdEdge and ATSI were onsite for the system installation during the week of November 14, 2005. ATSI performed the installation and shakedown of the carbon dioxide gas flow control system for pH adjustment. Meanwhile, AdEdge and the local operator performed the arsenic treatment system installation and shakedown work, which included hydraulic testing, media loading (by hand), and media backwash. The system officially went online and was put into regular service on December 7, 2005. Battelle was onsite on December 8 and 9, 2005, to inspect the system and provide training to the operator for sampling and data collection. As a result of the system inspections, a punch-list of items was identified, some of which were quickly resolved and did not affect system operations or data collection, although several problems related to the pH adjustment system and the media vessel flow meters surfaced throughout the system performance evaluation. Table 4-6 summarizes the items identified and corrective actions taken. In addition, these problems are discussed in detail in Section 4.4.3.

Figure 4-10. Maintenance Shop Building

Figure 4-11. System Delivery to Site

Table 4-6. System Punch-List/Operational Issues

Item No.	Punch-List/ Operational Issues	Corrective Action(s) Taken	Resolution Date
1	Well pump hour meter not provided	• Installed hour meter for well pump	01/09/06
2	Leak in CO_2 supply system	• Checked and tightened all connections and fittings	01/11/06
3	Flow totalizer for Vessels A and B reset to zero	• Vendor notified • No corrective action taken	01/12/06
4	Inline pH probe reporting pH >8	• Flushed pH probe by-pass line and increased flowrate through by-pass line	03/13/06
5	Malfunctioning proportioning valve restricted CO_2 injection	• Replaced proportioning valve	04/24/06
6	Inline pH probe not reporting pH reading	• Replaced pH probe	05/30/06 02/22/06
7	Flow totalizer for Vessels A and B reset to zero	• Vendor notified • Problem due to a programming error; a flash memory card with necessary programming updates provided by vendor	05/23/06 06/15/06

TBD = to be determined

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters for the system performance evaluation were tabulated and are attached as Appendix A. Key parameters are summarized in Table 4-7. From December 8, 2005, through May 15, 2008, the system operated for a total of 3,725 hr. Due to lack of a well pump hour meter from system startup through January 9, 2006 and due to the departure of the Webb CISD APU system operator from June 29, 2007 through the end of the performance evaluation study, no daily operating time was recorded during these time intervals. (Other operational data were not collected either since June 29, 2007.) Because the well and the system operated for 2,246 hr in 536 days from January 10, 2006, through June 29, 2007 (or 4.19 hr/day), the total operating time throughout the entire study period was estimated by multiplying the daily average of 4.19 hr/day by the total number of days, i.e., 889 days.

Due to the fact that the system supplied water to Webb CISD (a school), the daily operation times and throughput values during the weekends and summer breaks were anticipated to be low. However, investigation of time and throughput during these times did not reveal reductions. On the contrary, daily operating time and throughput measurements increased significantly during the summer months. Increased time and throughput during the summer months were caused by summer irrigation.

From December 8, 2005, through June 29, 2007, the amount of water treated by the system was 5,658,728 gal (or 9,945 gals/day). The system ran for 889 days during the performance evaluation study; the estimated throughput through May 15, 2008 was 8,841,000 gal, or 27,000 BV (1 BV = 44 ft^3 of media in both lead and lag vessels).

Table 4-7. Summary of APU-50LL-CS-S-2-AVH System Operation

Operational Parameter	Actual	Estimated
Duration	12/08/05–06/29/09	12/08/05–05/15/08
Cumulative Operating Time (hr)	2,246[a]	3,725
Average Daily Operating Time (hr)	4.19	4.19
Throughput (gal)	5,658,728	8,841,100
Throughput (BV)[b]	17,200	27,000
Average (Range) of Calculated Flowrate (gpm)	Vessel A 40.4 (5–92)[a,c] Vessel B 40.0 (6–88)[a,c]	–
Average (Range) of EBCT per Vessel (min)[d]	Vessel A 4.1 (1.8–32.9) Vessel B 4.1 (1.9–27.4)	–
Average (Range) of EBCT for System (min)	8.2	–
Average (Range) of System Inlet Pressure (psi)	42.0 (32–64)	NA
Average (Range) of System Outlet Pressure (psi)	28.6 (16–54)	NA
Average (Range) of Δp across System (psi)	13.9 (2–22)	NA
Average (Range) of Δp across Vessel A (psi)	5.7 (1–9)	NA
Average (Range) of Δp across Vessel B (psi)	5.3 (0–8)	NA

(a) From January 10, 2006, through June 29, 2007.
(b) Calculated based on 44 ft^3 of media in one vessel.
(c) Not including two outliers on January 29 and 30, 2007.
(d) Calculated based on 22 ft^3 of media in one vessel.

Flowrates of the system were tracked by instantaneous flowrate readings from the electromagnetic flow meter/totalizer on each adsorption vessel, and calculated flowrate values based on hour meter and flow totalizer readings from the same electromagnetic flow meters/totalizers and a pre-existing positive displacement type master totalizer installed at the wellhead. As shown in Figure 4-12, the instantaneous readings for Vessels A and B, denoted by "■" and "▲," respectively, were significantly higher than the corresponding calculated values, denoted by "□" and "△," respectively, with an average value of 51 gpm for the instantaneous readings and 42 gpm for the calculated values. In addition, the calculated values based on the electromagnetic flow meters/totalizers were significantly higher than those based on the master totalizer (denoted by "♦" in the figure). Although the results produced by the master totalizer were closer to the design flowrate of 40 gpm, the calculated values by the electromagnetic flow meters/totalizers were used as system flowrates. This was based on the belief that readings from the factory-calibrated electromagnetic flow meters/totalizers were more reliable than those from the master totalizer, for which little information was available regarding its accuracy and installation specifications. Therefore, for performance evaluation purposes, the data produced by the electromagnetic flow meter/totalizer on the lag vessel were used to determine system flowrates and total volume treated.

Figure 4-12 also identifies flowrate data that were not consistent with normal operations and caused by an unintentional resetting of the electromagnetic flow meters/totalizers on two separate occasions. Detailed discussions regarding the resetting of the totalizers are provided in Section 4.4.3.

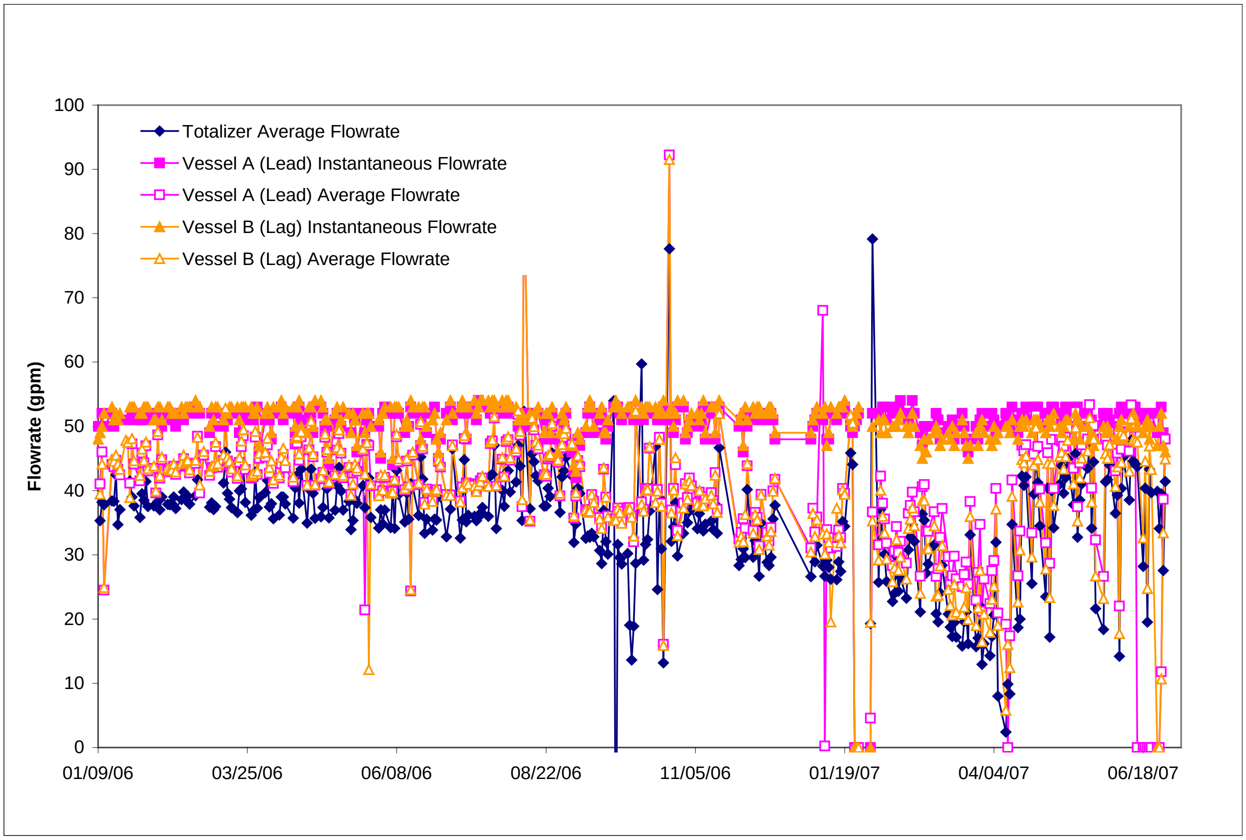


Figure 4-12. System Instantaneous and Calculated Flowrates

At the end of the study, the system treated approximately 8,841,000 gal of water. The amount of water treated was equivalent to approximately 27,000 BV based on the 44 ft^3 of media in both lead and lag vessels. Calculated flowrates through Vessels A and B averaged 40.4 and 40.0 gpm, respectively, which was very close to the design value (Table 4-4) derived from the 40-gpm supply well flowrate based on the pump curve provided by the facility. Based on the average calculated flowrate to the vessels, the EBCT was 4.1 min per vessel. Due to the fluctuating flowrates observed, the EBCTs varied for the lead and lag vessels from 1.8 and 32.9 min and from 1.9 to 27.4 min, respectively.

The APU system pressure readings were monitored at the system inlet and outlet and between the lead and lag vessels. Average Δp readings across the treatment train, lead vessel, and lag vessel for the first month of system operation were 10, 3, and 4 psi, respectively. On June 29, 2007, average Δp readings across the treatment train, lead vessel, and lag vessel were 12, 9, and 6 psi, respectively. As such, minimal pressure increase was observed after 2,384 hr of system operation or after treating 5,658,726 gal of water. As a result, no media backwash was performed during the system performance evaluation. Figure 4-13a presents the system operational pressures, inlet, outlet, and differential. Figure 4-13b presents Vessel A operational pressures, inlet, outlet, and differential. Figure 4-13c presents Vessel B operational pressures, inlet, outlet, and differential.

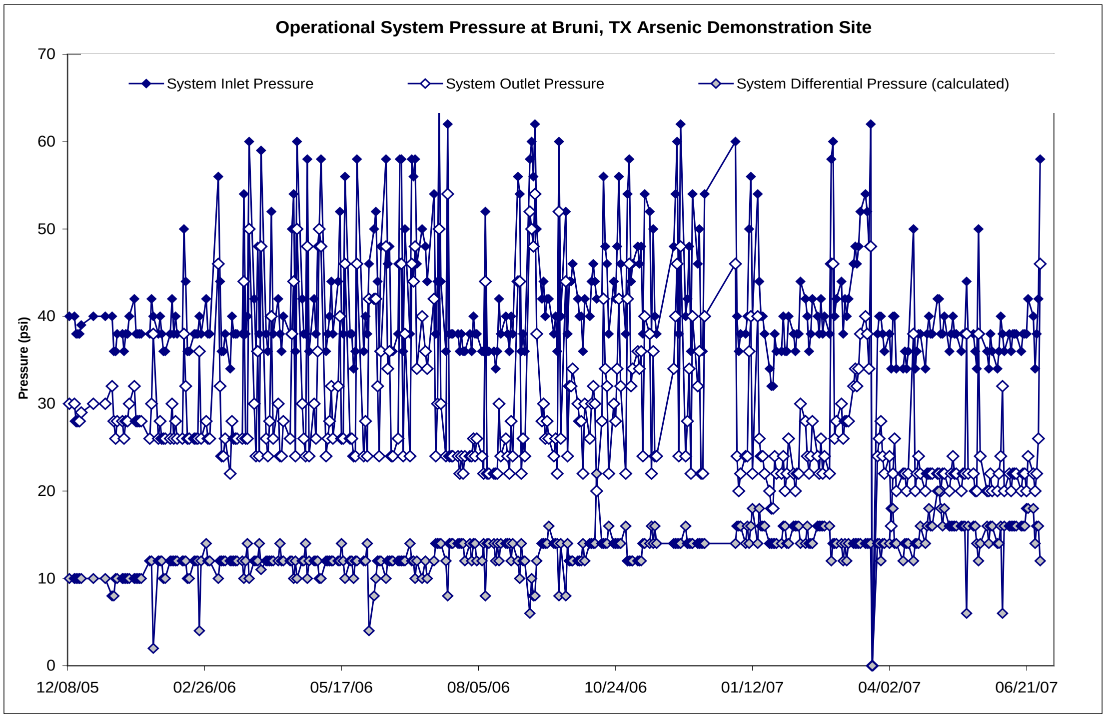


Figure 4-13a. System Operational Pressure Readings

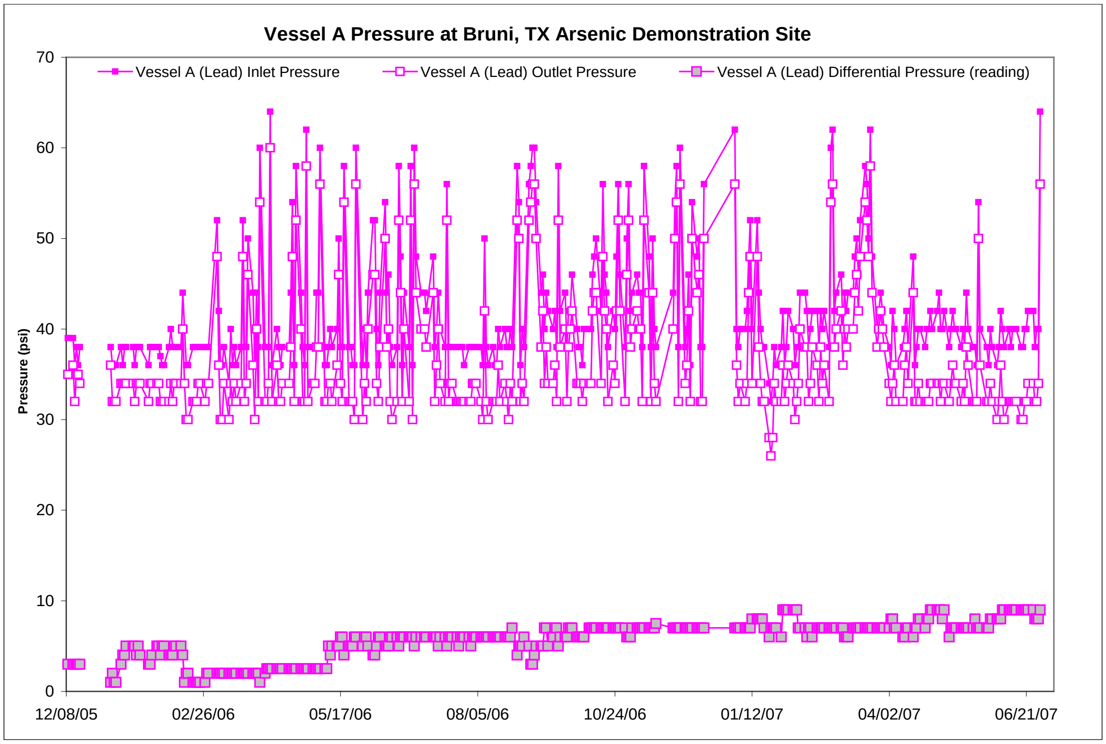


Figure 4-13b. Vessel A Operational Pressure Readings

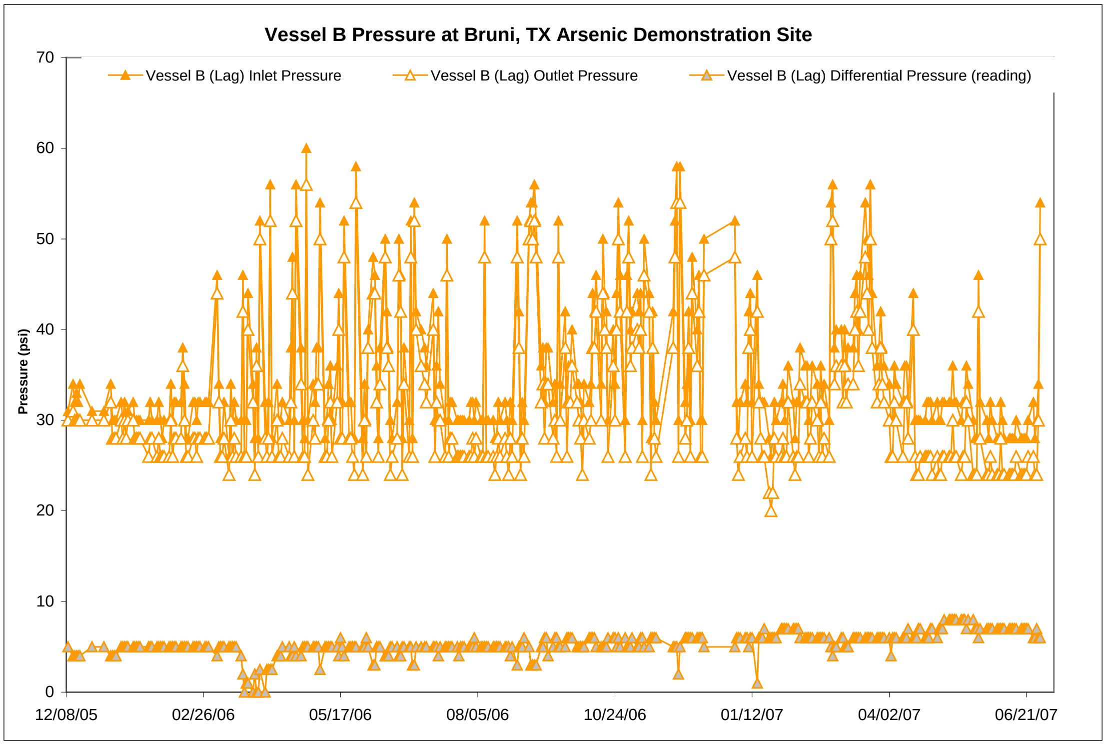


Figure 4-13c. Vessel B Operational Pressure Readings

4.4.2 Residual Management. No residuals were produced because neither backwash nor media replacement was required during the evaluation period.

4.4.3 System/Operation Reliability and Simplicity. Operational irregularities experienced during the demonstration study were related to the pH adjustment system and the adsorption vessel flow meters/totalizers.

As described in Section 4.2, pH adjustment using a CO_2 gas flow control system was a process component. On January 11, 2006, leaks were detected in the CO_2 system, resulting in an additional change-out of a CO_2 gas cylinder during the sixth week of system operations. The leaks were tracked to the supply line where loose fittings were discovered. During the week of March 13, 2006 (the 15th week of operation), the proportional flow control valve that regulated the CO_2 injection rate began operating improperly. The failure caused pH levels after pH adjustment to remain higher than desired, as indicated by the inline probe readings, which averaged 7.8 during that week of operation. The pH control system was switched from the automatic to manual mode until the control valve was replaced on April 24, 2006. On May 3, 2006, the digital screen on the JUMO pH/PID controller was not displaying the pH measurement. A replacement inline pH probe was installed on May 30, 2006, which restored the digital display on the JUMO pH/PID controller. The CO_2 system failed to consistently adjust pH values to the target value of 7.0, with the values varying between 6.5 and 8.2. Following the replacement of the faulty inline pH probe on May 30, 2006, the average pH was 7.2.

On two separate occasions on January 12, 2006, and May 23, 2006, both electromagnetic flow meters/totalizers malfunctioned, causing the meters to reset and begin totalizing from zero. The failure was thought to have been caused by a programming error. After being contacted, the vendor provided a flash memory card with the necessary programming updates, which was integrated by the operator on June 15, 2006, to prevent future reoccurrences of the problems.

The system O&M and operator skill requirements are discussed below in relation to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventive maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Two pre-treatment processes were required at the Webb CISD site, i.e., pH adjustment and prechlorination. CO_2 was used to lower pH values of raw water from as high as 8.2 (Table 4-1) to a target value of 7.0 in order to maintain effective adsorption by the AD-33 media. The CO_2 injection point and inline pH probe used to monitor and control the adjusted pH levels were installed upstream of the chlorine injection point. O&M of the pH adjustment system required routine system pressure checks and regular change-out of the CO_2 supply bottles as pressure was depleted. The operator also recorded daily pH readings from the inline probe and performed calibration of the pH probe, as needed. The use of CO_2 for pH adjustment also required safety training for and awareness by the operator, due to potential hazards.

For prechlorination, the existing chlorination system was upgraded and installed inside the maintenance building, which housed the APU-50LL-CS-S-2-AVH system. The upgraded chlorination system, as discussed in Section 4.2 and shown on Figure 4-8, utilized a 10% NaOCl solution to reach a target residual level of 1.2 mg/L (as Cl_2). The upgraded chlorination system did not require maintenance or skills other than those required by the previous system. The operator monitored chlorine tank levels, consumption rates, and residual chlorine levels.

System Automation. The system was fitted with automated controls that would allow for the backwash cycle to be controlled automatically. The system also was equipped with an automated carbon dioxide gas flow control system, which included a liquid CO_2 supply assembly, an automatic pH control panel, a CO_2 membrane module, and an inline pH probe located downstream of the membrane module. Each media vessel was equipped with five electrically actuated butterfly valves, which were controlled by a Square D Telemechanique PLC with a Magelis G2220 color touch interface screen. Although not automated, the system also was equipped with six isolation ball valves to allow for reversible lead/lag configuration.

The automated portion of the system did not require regular O&M; however operator awareness and an ability to detect unusual system measurements were necessary when troubleshooting system automation failures. The equipment vendor provided hands-on training and a supplemental operations manual to the operator.

Operator Skill Requirements. The skill requirements to operate the system demanded a higher level of awareness and attention than the previous system. The system offered increased operational flexibility, which, in turn, required increased monitoring of system parameters. The operator's knowledge of the system limitations and typical operational parameters were key to achieve system performance objectives. The operator was onsite typically five times a week and spent approximately 20 min each day to perform visual inspections and record the system operating parameters on the daily log sheets. The basis for the operator skills began with onsite training and a thorough review of the system operations manual; however, increased knowledge and invaluable system troubleshooting skills were gained through hands-on operational experience.

TCEQ requires that the operator of the treatment system hold at least a Class D TCEQ waterworks operator license. The TCEQ public water system operator certifications are classified by Class A through D. Licensing eligibility requirements are based on education, experience, and related training. The minimum requirements for a Class D license are high school graduate or GED and 20 hr of related training. Licensing requirements incrementally increase with each licensing level, with Class A being the highest requiring the most education, experience, and training.

Preventive Maintenance Activities. Preventive maintenance tasks included periodic checks of flow meters and pressure gauges and inspection of system piping and valves. Checking the CO_2 cylinders and supply lines for leaks and adequate pressure and calibrating the inline pH probe also were performed. Typically, the operator performed these duties while onsite for routine activities.

Chemical/Media Handling and Inventory Requirements. NaOCl was used for prechlorination; the operator ordered chemicals as done prior to the installation of the APU-50LL-CS-S-2-AVH system. CO_2 used for pH adjustment was ordered on an as needed basis. Typically, four 50-lb cylinders were used per month. As the CO_2 cylinders were delivered to the site by the CO_2 supplier, empty cylinders were returned for reuse.

4.5 System Performance

The performance of the system was evaluated based on analyses of water samples collected from raw and treated water and distribution system.

4.5.1 Treatment Plant Sampling. Table 4-8 summarizes the analytical results of arsenic, iron, and manganese concentrations measured at the four sampling locations across the treatment train. Table 4-9 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results through the system performance evaluation. The results of the water samples collected throughout the treatment plant are discussed below.

Arsenic. Treatment plant water samples were collected on 40 occasions (including three duplicate samples collected during three regular sampling events), with field speciation performed during 20 of the 40 occasions at IN, AP, TA, and TB sampling locations. Figure 4-14 contains four bar charts showing the concentrations of particulate arsenic, soluble As(III), and soluble As(V) for each speciation event.

Total arsenic concentrations in raw water ranged from 46.0 to 68.7 μg/L and averaged 57.6 μg/L. Soluble As(III) was the predominating species, ranging from 31.3 to 42.0 μg/L and averaging 37.5 μg/L. Soluble As(V) also was present in source water, ranging from 6.1 to 23.8 μg/L and averaging 15.0 μg/L. Particulate arsenic concentrations were lower, ranging from <0.1 to 12.3 μg/L and averaging 5.7 μg/L. The arsenic concentrations measured were consistent with those collected previously during source water sampling (Table 4-1).

Chlorine effectively oxidized As(III) to As(V) prior to the adsorption vessels. After chlorination the average soluble As(III) and soluble As(V) concentrations were 1.2 and 51.7 μg/L, respectively. Free and total chlorine residuals were monitored at the AP and TB sampling locations to ensure that the target chlorine residual levels were properly maintained for disinfection purposes. Free chlorine levels at the AP location ranged from 0.4 to 2.0 mg/L (as Cl_2) and averaged 0.9 mg/L (as Cl_2); total chlorine levels ranged from 0.6 to 2.1 mg/L (as Cl_2) and averaged 1.2 mg/L (as Cl_2) (Table 4-9). The residual chlorine levels measured at the TB location were similar to those measured at the AP location, indicating little or no chlorine demand through the AD-33 vessels.

Table 4-8. Summary of Analytical Results for Arsenic, Iron, and Manganese

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	µg/L	39	46.0	68.7	57.6	5.3
	AP	µg/L	40	47.4	88.4	59.2	7.1
	TA	µg/L	40	1.0	45.4	5.5	8.0
	TB	µg/L	40	0.2	16.9	2.0	2.7
As (soluble)	IN	µg/L	20	44.6	56.5	52.5	3.3
	AP	µg/L	20	44.5	61.0	52.9	3.7
	TA	µg/L	20	0.8	7.7	-[(a)]	-[(a)]
	TB	µg/L	20	0.1	2.9	-[(a)]	-[(a)]
As (particulate)	IN	µg/L	20	0.1	12.3	5.7	3.4
	AP	µg/L	20	1.2	14.6	6.5	3.5
	TA	µg/L	20	0.1	1.3	-[(a)]	-[(a)]
	TB	µg/L	20	0.1	1.8	-[(a)]	-[(a)]
As(III)	IN	µg/L	20	31.3	42.0	37.5	3.1
	AP	µg/L	20	0.4	3.3	1.2	0.8
	TA	µg/L	20	0.2	2.9	-[(a)]	-[(a)]
	TB	µg/L	20	0.1	2.4	-[(a)]	-[(a)]
As(V)	IN	µg/L	20	6.1	23.8	15.0	3.9
	AP	µg/L	20	43.3	57.7	51.7	3.5
	TA	µg/L	20	0.1	7.3	-[(a)]	-[(a)]
	TB	µg/L	20	0.1	1.6	-[(a)]	-[(a)]
Fe (total)	IN	µg/L	33	<25	163	31.8	35.1
	AP	µg/L	33	<25	190	<25	32.7
	TA	µg/L	33	<25	40.3	<25	7.6
	TB	µg/L	33	<25	44	<25	5.5
Fe (soluble)	IN	µg/L	17	<25	133.7	<25	30.7
	AP	µg/L	17	<25	62.2	<25	13.0
	TA	µg/L	17	<25	35.3	<25	6.9
	TB	µg/L	17	<25	28.2	<25	3.8
Mn (total)	IN	µg/L	33	2.6	14.7	5.1	2.8
	AP	µg/L	33	2.9	13.6	4.0	1.9
	TA	µg/L	33	<0.1	3.2	0.5	0.7
	TB	µg/L	33	<0.1	5.0	0.4	1.0
Mn (soluble)	IN	µg/L	17	2.6	14.5	4.9	2.8
	AP	µg/L	17	2.9	5.2	3.6	0.8
	TA	µg/L	17	<0.1	3.3	0.5	0.8
	TB	µg/L	17	<0.1	5.1	0.6	1.3

One-half of detection limit used for samples with concentrations less than detection limit for calculations.
(a) Statistics not provided; see Figure 4-15 for arsenic breakthrough curves.

Table 4-9. Summary of Water Quality Parameter Sampling Results

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Alkalinity (as $CaCO_3$)	IN	mg/L	33	305	357	327	14.1
	AP	mg/L	33	302	357	329	15.6
	TA	mg/L	33	275	368	326	17.6
	TB	mg/L	32	312	402	334	21.3
Fluoride	IN	mg/L	17	0.2	1.1	0.7	0.2
	AP	mg/L	17	0.5	1.8	0.9	0.3
	TA	mg/L	17	0.4	1.5	0.8	0.3
	TB	mg/L	17	0.1	1.3	0.8	0.3
Sulfate	IN	mg/L	17	91.0	137	110	11.2
	AP	mg/L	17	102	131	110	7.8
	TA	mg/L	17	98.0	142	114	12.5
	TB	mg/L	17	83.0	136	113	12.9
Nitrate (as N)	IN	mg/L	17	<0.05	<0.05	<0.05	-
	AP	mg/L	17	<0.05	<0.05	<0.05	-
	TA	mg/L	17	<0.05	<0.05	<0.05	-
	TB	mg/L	17	<0.05	<0.05	<0.05	-
P (as P)	IN	µg/L	32	<10	13.7	<10	2.3
	AP	µg/L	32	<10	20.4	<10	3.1
	TA	µg/L	32	<10	<10	<10	0.0
	TB	µg/L	32	<10	10.8	<10	1.0
Silica (as SiO_2)	IN	mg/L	33	39.1	43.9	41.5	1.2
	AP	mg/L	33	39.4	44.9	41.7	1.1
	TA	mg/L	33	13.5	50.6	40.3	6.2
	TB	mg/L	33	1.7	95.8	39.9	13.9
Turbidity	IN	NTU	33	0.1	1.2	0.6	0.3
	AP	NTU	33	0.1	1.5	0.5	0.3
	TA	NTU	33	0.1	1.9	0.5	0.4
	TB	NTU	32	0.1	2.0	0.5	0.4
pH	IN	S.U.	21	8.0	8.3	8.2	0.1
	AP	S.U.	21	7.1	8.1	7.4	0.3
	TA	S.U.	21	7.0	7.8	7.3	0.2
	TB	S.U.	21	7.0	7.7	7.3	0.2
Temperature	IN	°C	21	21.3	27.1	25.6	1.4
	AP	°C	20	21.2	27.2	25.9	1.5
	TA	°C	20	21.4	27.5	25.7	1.7
	TB	°C	19	21.2	27.4	25.5	2.0
Dissolved Oxygen	IN	mg/L	18	1.1	3.3	2.0	0.7
	AP	mg/L	18	1.4	4.1	2.1	0.6
	TA	mg/L	18	0.9	3.4	1.9	0.5
	TB	mg/L	18	1.3	3.5	2.0	0.5
ORP	IN	mV	18	234	378	278	38.5
	AP	mV	18	309	679	524	83.7
	TA	mV	18	337	690	578	98.0
	TB	mV	18	312	700	588	115
Free Chlorine (as CL_2)	IN	mg/L	0	-	-	-	-
	AP	mg/L	20	0.4	2.0	0.9	0.4
	TA	mg/L	0	-	-	-	-
	TB	mg/L	18	0.4	1.7	0.9	0.4

Table 4-9. Summary of Water Quality Parameter Sampling Results (Continued)

Parameter	Sample Location	Unit	Sample Count	Concentration Minimum	Maximum	Average	Standard Deviation
Total Chlorine (as CL_2)	IN	mg/L	0	-	-	-	-
	AP	mg/L	19	0.6	2.1	1.2	0.4
	TA	mg/L	0	-	-	-	-
	TB	mg/L	18	0.5	2.1	1.1	0.5
Total Hardness (as $CaCO_3$)	IN	mg/L	17	17.1	31.6	23.9	3.9
	AP	mg/L	17	19.1	30.1	23.8	3.6
	TA	mg/L	17	11.6	33.0	23.8	5.5
	TB	mg/L	17	14.3	64.4	28.9	14.0
Ca Hardness (as $CaCO_3$)	IN	mg/L	17	11.3	22.7	16.4	3.5
	AP	mg/L	17	11.9	22.8	16.4	3.3
	TA	mg/L	17	7.6	25.1	16.4	4.3
	TB	mg/L	17	9.9	48.3	19.9	9.9
Mg Hardness (as $CaCO_3$)	IN	mg/L	17	5.8	9.3	7.5	0.9
	AP	mg/L	17	5.3	9.1	7.4	0.9
	TA	mg/L	17	4.0	13.4	7.4	2.2
	TB	mg/L	17	3.3	23.3	9.0	5.2

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

The total arsenic breakthrough curves shown in Figure 4-15 indicate that the lead vessel removed the majority of arsenic existing predominately as As(V) following chlorination. Total arsenic concentrations following the lead vessel reached just below 10 µg/L (i.e., 9.6 µg/L) after treating approximately 41,000 BV of water (based on the 22 ft^3 of media in the lead vessel), which represents approximately 87% of the working capacity projected by the vendor (Table 4-4). Afterwards, total arsenic concentrations continued to ramp higher and reached 45.4 µg/L by the end of the performance evaluation study. By then, the system had treated an estimated 8,841,000 gal of water (see discussion in Section 4.4.1), equivalent to 27,000 BV based on the 44 ft^3 of media in both lead and lag vessel. At this point, arsenic breakthrough following the lag vessel, based on the laboratory analysis of water samples collected on May 15, 2008, was 5.2 µg/L, which was still below the 10-µg/L MCL.

Competing Anions. Phosphate and silica, which might influence arsenic adsorption, were measured at the four sampling locations across the treatment train through March 13, 2007. Phosphorus was not detected during almost all sampling events; however, on February 13, 2007, the phosphorus concentrations measured at IN, AP, TA and TB were 190, 214, 203, and 167 mg/, respectively. It was not clear why the phosphorus concentrations were significantly elevated during this sampling event and, therefore, were considered as outliers and removed from data analyses. Silica concentrations in raw water ranged from 39.1 to 43.9 mg/L and averaged 41.5 mg/L. Significant silica concentration reductions (96%, 85%, and 24%, respectively) were noted in TA and TB samples collected during the first three weeks of system operations, indicating removal by the media. Following the third week of operation the maximum silica concentration reduction was less than 10%. Figure 4-16 presents the silica breakthrough curves from the treatment train.

Figure 4-14. Concentrations of Various Arsenic Species at IN, AP, TA, and TB Sampling Locations

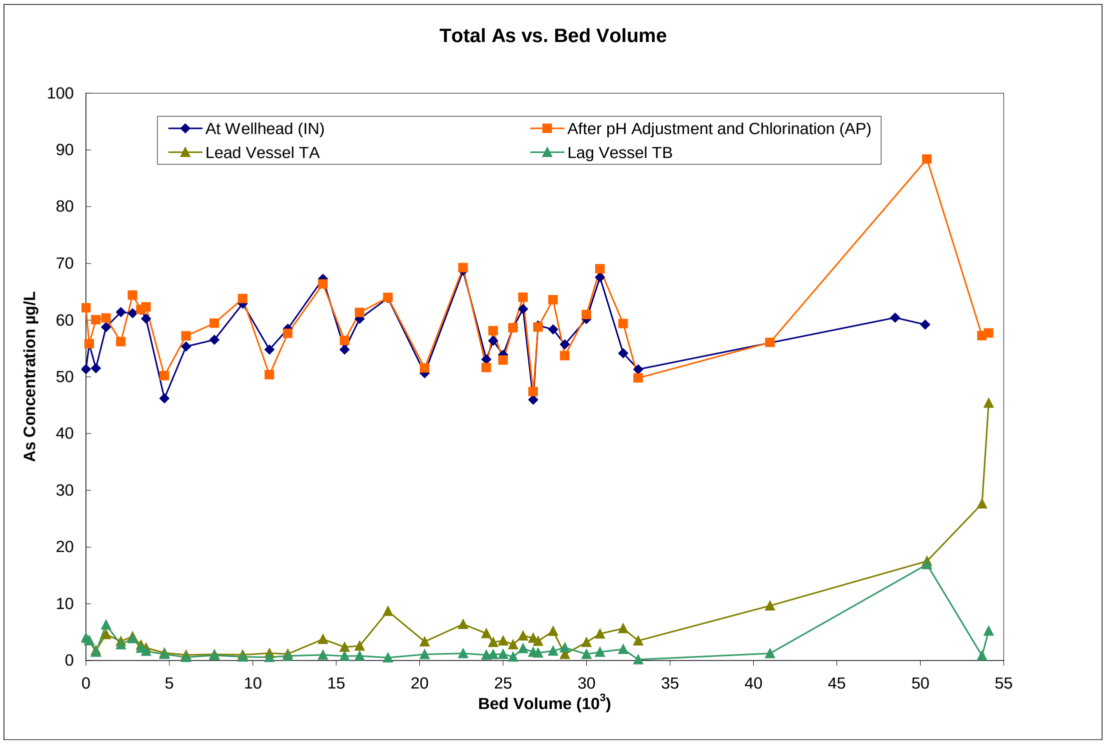


Figure 4-15. Total Arsenic Breakthrough Curves
(Based on 22 ft^3 of Media in One Vessel)

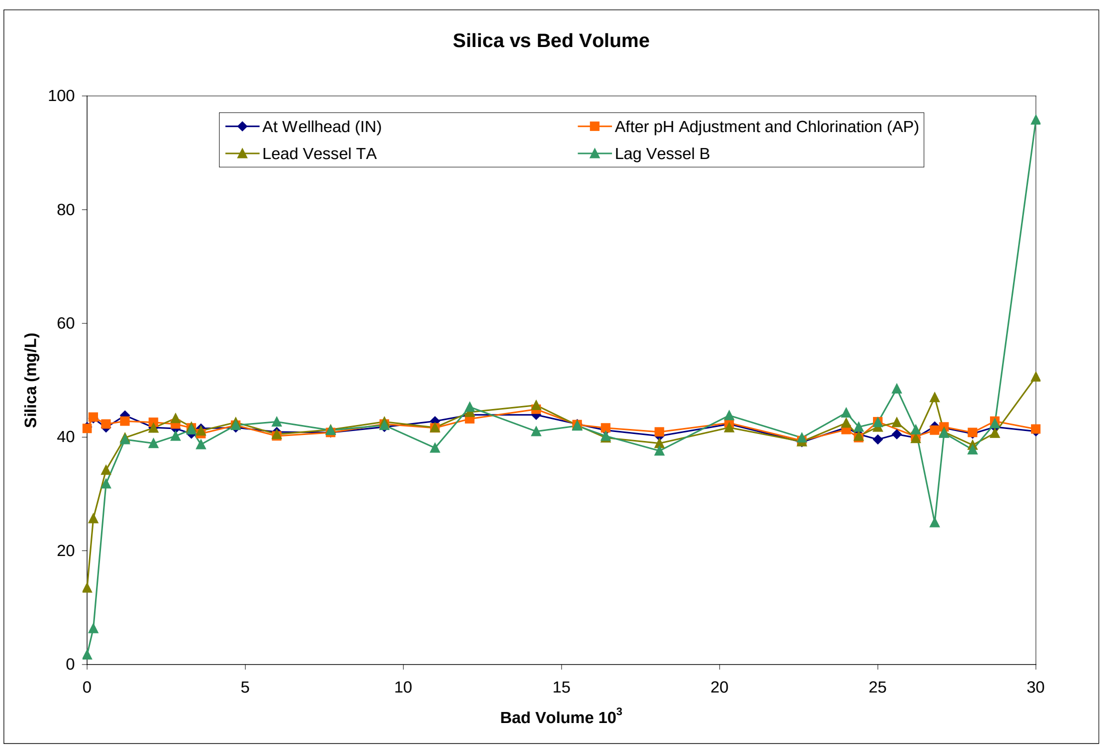


Figure 4-16. Silica (as SiO_2) Breakthrough Curves
(Based on 22 ft^3 of Media in Each Vessel)

Iron and Manganese. Iron and manganese were analyzed through January 22, 2007. The average total iron concentration in raw water was 31.8 µg/L (Table 4-8). Average total iron concentrations across the treatment train were below the detection limit of 25 µg/L. Total manganese levels in raw water also were low, ranging from 2.6 to 14.7 µg/L and averaging 5.1 µg/L. Manganese existed primarily in the soluble form even after chlorination. Total manganese levels were reduced to an average of 0.5 and 0.4 µg/L following the lead and lag vessels, respectively.

Other Water Quality Parameters. As shown in Table 4-9, pH values of raw water measured at the IN sample location varied from 8.0 to 8.3 and averaged 8.2. pH values, following CO_2 injection for pH adjustment, at the AP location, varied from 7.1 to 8.1 and averaged 7.4. A pH value of 7.0 at the AP location prior to the adsorption media was desirable, which, in general, would result in a greater arsenic removal capacity. Figure 4-17 presents the pH values measured throughout the treatment train.

On two separate occasions (January 5 and 17, 2006), the pH values as measured with a portable VWR Symphony handheld meter were not reduced following CO_2 injection, as indicated by the third and fourth sets of IN (denoted by "♦") and AP data points (denoted by "■") shown in Figure 4-17. In contrast, the pH values (denoted by "●") measured at the AP location by the inline pH probe were consistently over 1.0 unit less than those measured at the same location by the VWR meter. pH measurements prior to and following these two isolated events suggest that pH values measured by the VWR meter on January 5 and 17, 2006, most likely were the result of instrument or measurement errors.

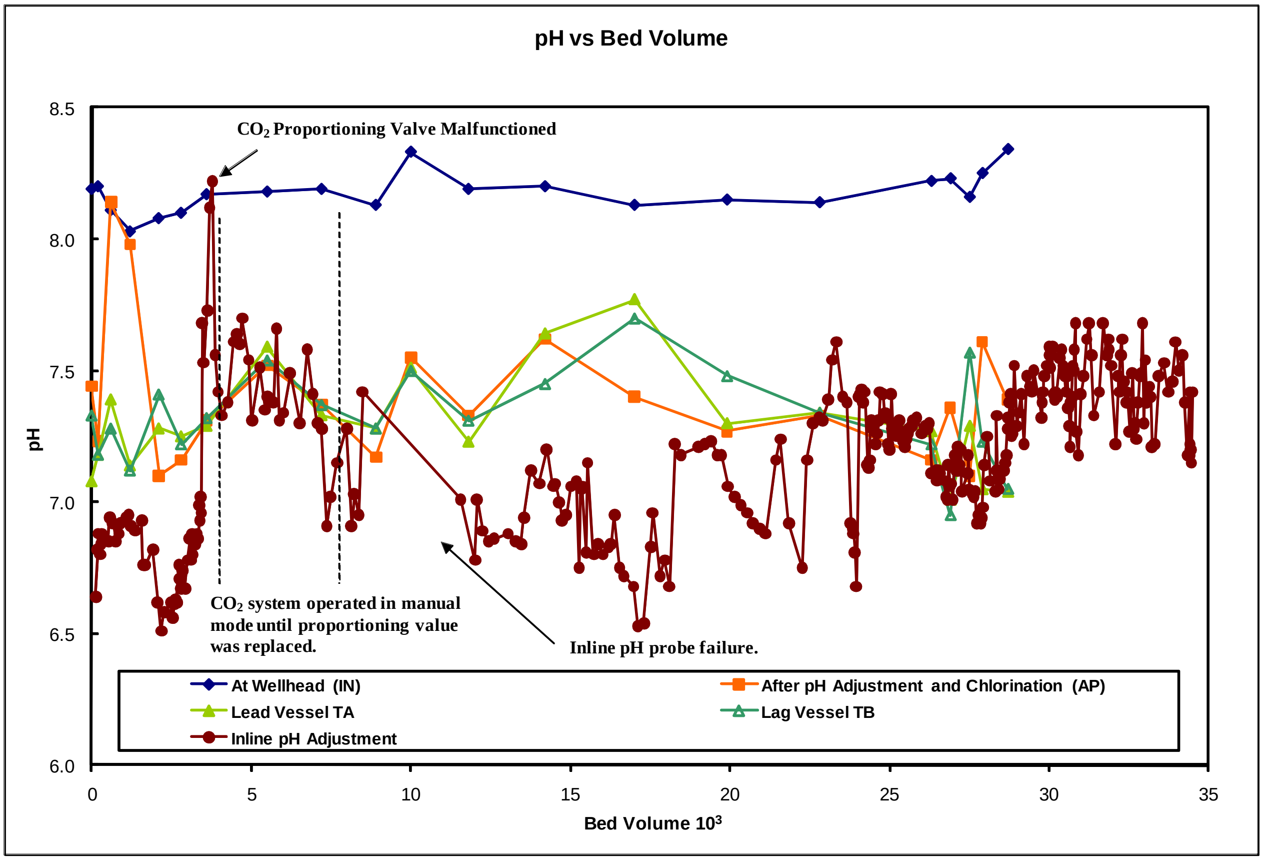


Figure 4-17. pH Values Across Treatment Train Versus Throughput
(Based on 22 ft³ of Media in Each Vessel)

Except for the two time periods when the CO_2 system was set in the manual mode prior to the replacement of the proportioning valve and after Vessel A had reached approximately 25,000 BV of throughput, pH values measured by the VWR meter were significantly lower than those measured by the inline pH probe, with the pH values varying from 7.2 to 7.6 and averaging 7.4 using the VWR probe, and varying from 6.5 to 7.6 and averaging 7.0 using the inline probe. The variations observed might be due to degassing of dissolved CO_2 when the water samples were collected from the AP location, thus resulting in elevated readings measured by the portable VWR meter. An inline pH probe failure occurred early May 2006 (Figure 4-17) and a replacement probe was installed on May 30, 2006, at approximately 12,000 BV. The replacement of the inline probe did not appear to have narrowed the differences between the two measurements.

Alkalinity, reported as $CaCO_3$, ranged from 305 to 357 mg/L and averaged 327 mg/L in raw water. As expected, alkalinity after pH adjustment and adsorption remained essentially unchanged at 326 to 334 mg/L (on average), since carbon dioxide, instead of mineral acids, was used for pH adjustment.

The treatment plant water samples were analyzed for hardness only on speciation weeks. Total hardness, reported as $CaCO_3$, ranged from 17.1 to 31.6 mg/L and averaged 23.9 mg/L in raw water. Total hardness existed primarily as calcium hardness. Total hardness remained unchanged at 23.8 to 28.9 mg/L, on average, following pH adjustment and adsorption.

Sulfate concentrations in raw water ranged from 91.0 to 137 mg/L and averaged 110 mg/L. After pH adjustment and adsorption, sulfate levels remained unchanged at 113 to 114 mg/L (on average). Fluoride results ranged from 0.1 to 1.5 mg/L following the treatment vessels. The results indicated that the adsorptive media did not affect the amount of fluoride in water after treatment.

Average DO levels ranged from 1.9 to 2.1 mg/L throughout the treatment train. ORP readings averaged 278 mV in raw water, but increased to an average of 524 mV after chlorination.

4.5.2 Backwash Wastewater Sampling. Backwash was not performed during the system performance evaluation.

4.5.3 Distribution System Water Sampling. Prior to the installation/operation of the treatment system, baseline distribution system water samples were collected from the middle school, high school, and cafeteria on June 15, July 21, August 24, and September 19, 2005. Following the installation of the treatment system, distribution system water sampling continued on a monthly basis at the same three locations, with samples collected from January through December 2006. The results of the distribution system sampling are summarized on Table 4-10.

The most noticeable change in the distribution system samples since the system began operation was a decrease in arsenic concentration. Baseline arsenic concentrations ranged from 49.6 to 99.9 µg/L and averaged 68.7 µg/L for all three sampling locations. After the performance evaluation began, arsenic concentrations were reduced to ≤5.0 µg/L (or 2.4 µg/L on average), which were similar to the arsenic concentrations in the system effluent.

Lead concentrations ranged from 0.3 to 4.0 µg/L, with none of the samples exceeding the action level of 15 µg/L. Copper concentrations ranged from 6.5 to 604 µg/L, with no samples exceeding the 1,300 µg/L action level. Measured pH values ranged from 7.4 to 8.1 and averaged 7.7, which were 0.4 units higher than the avearge pH value immediately after the adsorption vessels. Compared to an average value of 8.2 before the treatment sytem became operational, the lowered pH values appeared to have some effects on the lead and copper concentrations in the distribution system. However, the effects did not follow a trend, with the lead concentrations becoming mostly lower (decreasing from 1.3 to 0.8 µg/L [on average] at the

Table 4-10. Distribution System Sampling Results

Sampling Events	Location	Middle School								High School								Cafeteria							
	Sampling Date	Stagnation Time (hr)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time (hr)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time (hr)	pH	Alkalinity	As	Fe	Mn	Pb	Cu
BL1	06/15/05	14.5	8.3	334	52.0	<25	1.9	1.9	114	14.8	8.3	330	53.0	<25	1.2	2.3	115	15.0	8.3	330	77.7	<25	5.9	11.5	381
BL2	07/21/05	15.0	8.1	330	54.4	70.9	13.5	1.2	7.3	15.3	8.2	330	79.2	32.8	6.0	2.0	44.8	15.5	8.1	330	53.3	<25	6.8	2.9	106
BL3	08/24/05	15.6	8.2	317	83.1	<25	2.2	0.3	23.9	15.7	8.2	321	85.8	<25	1.2	0.9	72.5	15.8	8.2	321	84.7	<25	2.1	0.3	23.2
BL4	09/19/05	13.0	8.1	330	49.6	<25	3.3	1.9	40.1	13.3	8.1	330	51.4	<25	1.5	1.5	77.3	13.5	8.1	326	99.9	<25	2.4	1.9	44.4
1	01/05/06	14.8	7.7	343	2.1	<25	<0.1	0.8	209	14.5	7.7	348	3.5	<25	2.4	2.3	308	15.0	7.6	334	1.4	<25	<0.1	0.5	15.4
2	02/01/06	15.0	7.9	312	3.4	<25	0.4	0.3	119	15.2	8.1	312	4.4	<25	0.2	0.8	214	15.0	8.1	312	3.8	<25	0.6	0.6	250
3	03/14/06	15.0	7.6	310	1.4	<25	0.8	0.9	278	15.2	7.8	314	2.0	<25	0.8	1.8	259	15.3	7.8	318	1.3	<25	0.9	0.9	19.7
4	04/11/06	15.3	7.9	323	3.1	<25	0.3	1.0	113	15.0	7.9	311	5.0	<25	0.6	1.6	337	15.2	7.9	315	3.6	<25	0.3	0.8	16.0
5	05/09/06	10.8	7.6	326	1.3	<25	0.3	0.4	86.3	14.8	7.7	331	2.0	<25	0.7	0.7	164	14.7	7.7	322	1.2	<25	0.1	0.4	6.5
6	06/06/06	14.7	7.8	305	1.0	<25	0.1	1.0	234	14.8	7.7	309	2.0	<25	1.9	0.7	565	14.6	8.0	322	0.7	<25	0.2	0.6	14.9
7	07/19/06	NA[(a)]	7.9	319	1.2	<25	2.8	1.4	237	14.3	7.9	319	1.9	<25	4.8	2.0	316	15.3	8.0	315	0.9	<25	0.5	1.8	24.1
8	08/16/06	Operator did not take sample, building is not being used.								15.0	7.7	310	1.7	<25	0.6	2.0	96.6	16.3	7.7	306	1.5	<25	<0.1	0.8	16.0
9	09/15/06	Operator did not take sample, building is not being used.								15.8	7.7	328	1.5	<25	<0.1	3.3	322	15.5	7.8	337	0.8	<25	<0.1	1.0	26.2
10	10/11/06	Operator did not take sample, building is not being used.								15.5	7.5	344	1.5	<25	0.3	4.0	538	15.7	7.5	349	1.1	26.0	0.1	1.9	74.4
11	11/08/06	Operator did not take sample, building is not being used.								15.6	7.4	353	4.3	<25	0.4	1.8	604	14.5	7.3	343	3.8	<25	0.1	2.5	116
12	12/12/06	Operator did not take sample, building is not being used.								15.0	7.4	335	1.5	<25	0.4	2.5	427	16.3	7.4	341	1.4	<25	0.6	1.7	60.8

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

µg/L as unit for all analytes except for pH (S.U.) and alkalinity (mg/L [as $CaCO_3$]).

BL = Baseline Sampling; NA = Not Available middle school and from 4.2 to 1.1 µg/L [on average] at the cafeteria) and the copper concentrations becoming mostly higher (increasing from 46.3 to 182.3 µg/L [on average] at the middle school and from 77.4 to 345.9 µg/L [on average] at the high school).

Alkalinity levels ranged from 305 to 353 mg/L (as $CaCO_3$). Iron was detected in one of the samples; manganese concentrations ranged from <0.1 to 4.8 µg/L. The arsenic treatment system did not seem to affect these water quality parameters in the distribution system.

4.6 System Cost

System cost is evaluated based on the capital cost per gpm (or gpd) of the design capacity and the O&M cost per 1,000 gal of water treated. The capital cost includes the cost for equipment, site engineering, and installation. The O&M cost includes the cost for media replacement and disposal, electrical power use, and labor.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation of the treatment system was $138,642 (see Table 4-11). The equipment cost was $94,662 (or 68% of the total capital investment), which included $55,566 for the skid-mounted APU-50LL-CS-S-2-AVH unit, $21,516 for the CO_2 pH control system, $13,200 for the AD-33 media ($300/ft^3 or $8.57/lb to fill two vessels), $2,580 for shipping, and $1,800 for labor.

Table 4-11. Capital Investment Cost for APU-50LL-CS-S-2-AVH System

Description	Quantity	Cost	% of Capital Investment
Equipment Cost			
APU Skid-Mounted System (Unit)	1	$55,566	–
CO2 pH Control System	1	$21,516	–
AD-33 Media (ft^3)	44	$13,200	–
Shipping	–	$2,580	–
Vendor Labor	–	$1,800	–
Equipment Total	–	**$94,662**	**68**
Engineering Cost			
Vendor Labor/Travel	–	$11,800	–
Subcontractor Labor/Travel	–	$12,500	–
Engineering Total	–	**$24,300**	**18**
Installation Cost			
Subcontractor Labor	–	$12,574	–
Vendor Labor	–	$4,860	–
Vendor/ Subcontractor Travel	–	$2,246	–
Installation Total	–	**$19,680**	**14**
Total Capital Investment	–	**$138,642**	**100**

The engineering cost included the cost for preparing three submittal packages for the exception request, permit application, and supplemental information for the permit (see Section 4.3.1). The engineering cost was $24,300, or 18% of the total capital investment.

The installation cost included the equipment and labor to unload and install the skid-mounted unit, perform piping tie-ins and electrical work, load, and backwash the media, perform system shakedown and startup, and conduct operator training. The installation cost was $19,680, or 14% of the total capital investment.

The total capital cost of $138,642 was normalized to the system's rated capacity of 40 gpm (57,600 gpd), which resulted in $3,466/gpm of design capacity ($2.41/gpd). The capital cost also was converted to an annualized cost of $13,086/yr using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-year return period. Assuming that the system operated 24 hours a day, 7 days a week at the system design flowrate of 40 gpm to produce 21,024,000 gal of water per year, the unit capital cost would be $0.62/1,000 gal. Because the system operated an average of 4.2 hr/day at approximately 40 gpm (see Table 4-7), producing an estimated 8,841,100 gal of water during the performance evaluation study or 3,679,200 gal of water annually, the unit capital cost increased to $3.56/1,000 gal at this reduced rate of use.

4.6.2 Operation and Maintenance Cost. The O&M cost included the cost for such items as media replacement and disposal, CO_2 usage, electricity consumption, and labor (Table 4-12). Although media replacement did not occur during the system performance evaluation, the media replacement cost would have represented the majority of the O&M cost and was estimated to be $11,190 to change out the lead vessel. This media change-out cost would have included the cost for media, underbedding, freight, labor, travel, spent media analysis, and media disposal fee. This cost was used to estimate the media replacement cost per 1,000 gal of water treated as a function of the projected lead vessel media run length at the 10 μg/L arsenic breakthrough from the lag vessel (Figure 4-18).

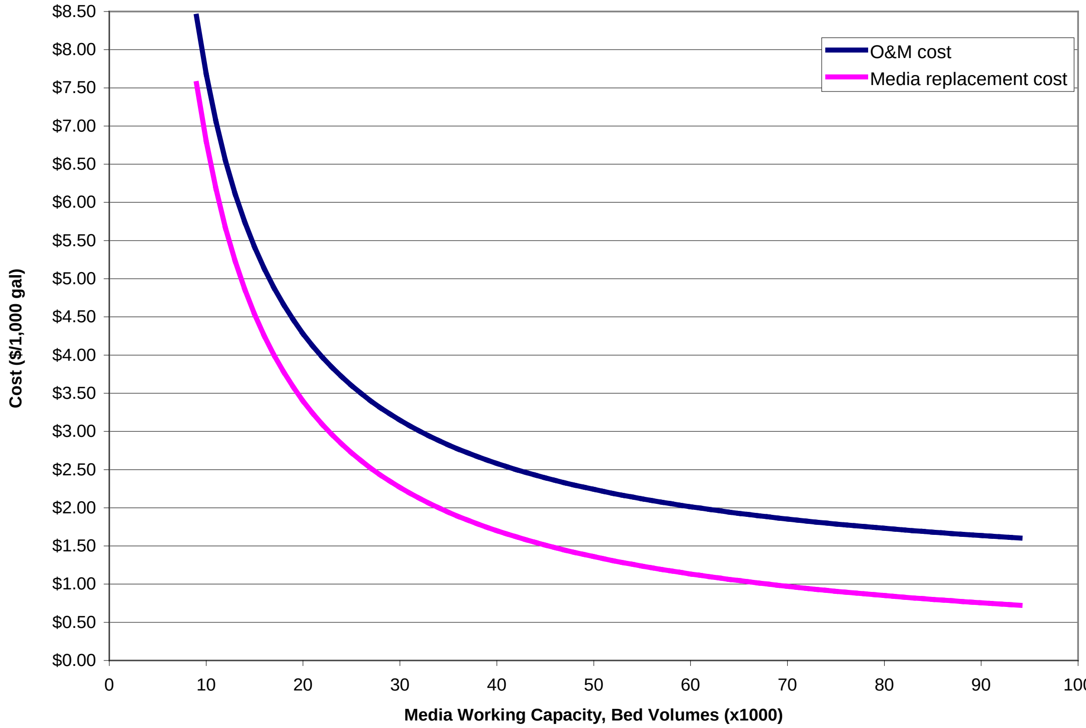
The chemical cost associated with system operation included the cost for NaClO for prechlorination and CO_2 gas for pH adjustment. NaClO had already been used at the site prior to the installation of the APU unit for disinfection purposes prior to distribution. The presence of the APU system did not affect the use rate of the NaClO solution. Therefore, the incremental chemical cost for chlorine was negligible. The 50-lb CO_2 cylinder was replaced four times a month during the system performance evaluation. Each change-out cost $31.52, which included the replacement and delivery charges. The CO_2 cost for the study period was $3,656 or $0.41/1,000 gal of water treated. The calculated annual CO_2 cost, including delivery, was $1,513.

Comparison of electrical bills supplied by the utility prior to system installation and since startup did not indicate a noticeable increase in power consumption. Therefore, electrical cost associated with operation of the system was assumed to be negligible.

Under normal operating conditions, routine labor activities to operate and maintain the system consumed 20 min per day, 5 days per week, as noted in Section 4.4.3. The labor cost for the performance evaluation study was $4,045 or $0.46/1,000 gal of water treated. The calculated annual labor cost was $1,690. Therefore, the estimated labor cost was $0.46/1,000 gal of water treated. This estimation assumed that maintenance and operational procedures were consistently performed through the completion of the system performance evaluation.

Table 4-12. Operation and Maintenance Cost for APU-50LL-CS-S-2-AVH System

Cost Category	Value	Assumptions
Estimated Volume Processed (gal)	8,841,000	889 total operational days
Media Replacement and Disposal Cost		
Media Replacement ($)	$6,600	$300/ft^3 for 22 ft^3 (one media vessel)
Underbedding and Freight for Media and Gravel Shipping ($)	$330	
Travel and per diem ($)	$1,000	
Vendor and Subcontractor Labor ($)	$2,160	
Media Disposal ($)	$1,100	Including spent media analysis
Subtotal	$11,190	
Media Replacement and Disposal ($/1,000 gal)	See Figure 4-18	Based upon lead vessel media run length at 10-μg/L arsenic breakthrough from lag vessel
CO_2 Usage		
Annual CO_2 cost ($)	$1,513	Based on CO_2 consumption (50-lb cylinders) and delivery
Unit CO_2 Cost ($/1,000 gal)	$0.41	
Electricity Cost		
Electricity ($/1,000 gal)	$0.001	Electrical cost assumed negligible
Labor Cost		
Average Weekly Labor (min)	100	20 min/day, 5 day/week
Annual Labor Cost ($)	$1,690	Labor rate = $19.50/hr
Unit Labor Cost ($/1,000 gal)	$0.46	
Total O&M Cost/1,000 gal	See Figure 4-18	Media replace cost (based upon lead vessel media run length at 10-μg/L arsenic breakthrough from lag vessel) + $0.41 ($CO_2$ cost) + $0.46 (labor cost)



Note: One bed volume equals 22 ft^3 (165 gal)

Figure 4-18. Media Replacement and Other Operation and Maintenance Cost

5.0 REFERENCES

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APPENDIX A

OPERATIONAL DATA

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

					Vessel A					Vessel B					System					
				Well Operational Hours	Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Inlet Pressure	Outlet Pressure	Pressure Differential	Cumulative Volume Treated	Bed Volumes Treated[a]	
Week No.	Day of Week	Date	Time	hr	gpm	gal	gal	gpm	psi	gpm	gal	gal	gpm	psi	psi	psi	psi	gal	BV	pH
1	Thu	12/08/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	12/09/05	08:25	NA	53	23,794	23,794	NA	3.0	51	19,174	19,174	NA	5.0	40	30	10	19,174	58	6.64
2	Mon	12/12/05	10:30	NA	50	35,319	11,525	NA	3.0	48	30,304	11,130	NA	4.0	40	30	10	30,304	92	6.82
	Tue	12/13/05	08:30	NA	50	38,069	2,750	NA	3.0	48	32,962	2,658	NA	4.0	38	28	10	32,962	100	6.88
	Wed	12/14/05	10:30	NA	50	48,075	10,006	NA	3.0	48	42,634	9,672	NA	4.0	38	28	10	42,634	130	6.80
	Thu	12/15/05	09:30	NA	50	51,866	3,791	NA	3.0	49	46,290	3,656	NA	4.0	38	28	10	46,290	141	6.84
	Fri	12/16/05	08:30	NA	49	57,415	5,549	NA	3.0	48	51,661	5,371	NA	4.0	39	29	10	51,661	158	6.88
3	Mon	12/19/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	12/20/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wed	12/21/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thu	12/22/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	12/23/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0	40	30	10	NA	NA	NA
4	Mon	12/26/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	12/27/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wed	12/28/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thu	12/29/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	12/30/05	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0	40	30	10	NA	NA	NA
5	Mon	01/02/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	01/03/06	10:00	NA	50	92,686	35,271	NA	1.0	48	85,630	33,969	NA	4.0	40	32	8	85,630	261	6.85
	Wed	01/04/06	09:00	NA	50	96,835	4,149	NA	2.0	49	89,621	3,991	NA	4.0	36	28	8	89,621	273	6.94
	Thu	01/05/06	09:30	NA	50	103,668	6,833	NA	1.0	48	96,210	6,589	NA	4.0	36	26	10	96,210	293	6.94
	Fri	01/06/06	09:00	NA	50	116,084	12,416	NA	1.0	48	108,229	12,019	NA	4.0	38	28	10	108,229	330	6.92
6	Mon	01/09/06	09:30	NA	50	131,789	15,705	NA	3.0	48	123,309	15,080	NA	5.0	38	28	10	123,309	376	6.85
	Tue	01/10/06	10:00	4.2	50	142,134	10,345	41	4.0	49	133,247	9,938	39	5.0	36	26	10	133,247	406	6.91
	Wed	01/11/06	09:00	2.4	52	148,763	6,629	46	4.0	50	139,601	6,354	44	5.0	38	28	10	139,601	426	6.88
	Thu	01/12/06[c][d]	09:00	4.5	50	6,614	6,614	24	5.0	52	6,727	6,727	25	5.0	38	28	10	146,328	446	6.92
	Fri	01/13/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.0	40	30	10	NA	NA	NA
7	Mon	01/16/06	09:30	10.9	52	35,434	28,820	44	5.0	53	36,043	29,316	45	5.0	42	32	10	175,644	536	6.94
	Tue	01/17/06	09:30	5.0	50	48,544	13,110	44	5.0	51	49,412	13,369	45	5.0	38	28	10	189,013	576	6.95
	Wed	01/18/06	09:30	4.4	51	60,350	11,806	45	4.0	52	61,429	12,017	46	5.0	38	28	10	201,030	613	6.91
	Thu	01/19/06	09:30	4.9	51	73,080	12,730	43	5.0	51	74,407	12,978	44	5.0	38	28	10	214,008	652	NM
	Fri	01/20/06	08:30	2.7	51	79,955	6,875	42	4.0	52	81,422	7,015	43	5.0	38	28	10	221,023	674	6.89
8	Mon	01/23/06		6.6	NA	98,481	18,526	NA	NA	NA	100,350	18,928	48	NA	NA	NA	NA	239,951	732	NA
	Tue	01/24/06		2.9	NA	106,034	7,553	NA	NA	NA	108,614	8,264	47	NA	NA	NA	NA	248,215	757	NA
	Wed	01/25/06	10:00	3.4	51	114,427	8,393	41	3.0	53	116,547	7,933	39	5.0	38	26	12	256,148	781	6.93
	Thu	01/26/06	09:30	2.4	52	121,235	6,808	47	3.0	53	123,472	6,925	48	5.0	42	30	12	263,073	802	6.76
	Fri	01/27/06	10:00	3.9	51	131,558	10,323	44	4.0	53	133,918	10,446	45	5.0	40	38	2	273,519	834	6.76
9	Mon	01/30/06	09:30	4.7	51	143,267	11,709	42	5.0	52	145,866	11,948	42	5.0	38	26	12	285,467	870	
	Tue	01/31/06	09:00	10.5	51	172,144	28,877	46	5.0	52	175,129	29,263	46	5.0	40	28	12	314,730	960	6.82
	Wed	02/01/06	09:00	8.4	52	194,479	22,335	44	4.0	53	197,638	22,509	45	5.0	38	26	12	337,239	1,028	6.62
	Thu	02/02/06	09:00	6.6	51	213,083	18,604	47	5.0	53	216,459	18,821	48	5.0	36	26	10	356,060	1,086	6.51
	Fri	02/03/06	09:00	5.6	52	227,540	14,457	43	5.0	53	231,048	14,589	43	5.0	36	26	10	370,649	1,130	6.58

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours	Vessel A					Vessel B					System						
					Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Inlet Pressure	Outlet Pressure	Pressure Differential	Cumulative Volume Treated	Bed Volumes Treated[a]	pH
				hr	gpm	gal	gal	gpm	psi	gpm	gal	gal	gpm	psi	psi	psi	psi	gal	BV	
10	Mon	02/06/06	09:00	13.6	51	262,989	35,449	43	4.0	51	266,801	35,753	44	5.0	38	26	12	406,402	1,239	6.62
	Tue	02/07/06	10:00	3.4	51	271,073	8,084	40	4.0	51	274,942	8,141	40	5.0	42	30	12	414,543	1,264	6.56
	Wed	02/08/06	10:00	3.0	52	279,832	8,759	49	4.0	53	283,796	8,854	49	5.0	38	26	12	423,397	1,291	6.61
	Thu	02/09/06	10:00	2.5	52	286,120	6,288	42	5.0	53	290,139	6,343	42	5.0	40	28	12	429,740	1,310	6.63
	Fri	02/10/06	09:30	2.2	50	292,035	5,915	45	5.0	51	296,107	5,968	45	5.0	38	26	12	435,708	1,328	6.62
11	Mon	02/13/06	09:00	4.8	52	304,459	12,424	43	5.0	53	308,620	12,513	43	5.0	38	26	12	448,221	1,367	6.76
	Tue	02/14/06	09:00	1.5	52	308,325	3,866	43	4.0	53	312,504	3,884	43	5.0	50	38	12	452,105	1,378	6.71
	Wed	02/15/06	09:30	2.0	51	313,473	5,148	43	1.0	52	317,684	5,180	43	5.0	44	32	12	457,285	1,394	6.67
	Thu	02/16/06	10:00	2.9	51	321,089	7,616	44	2.0	52	325,362	7,678	44	5.0	36	26	10	464,963	1,418	6.74
	Fri	02/17/06	09:00	5.6	50	335,365	14,276	42	2.0	52	339,775	14,413	43	5.0	36	26	10	479,376	1,462	6.67
12	Mon	02/20/06	09:30	5.4	52	349,543	14,178	44	1.0	53	354,107	14,332	44	5.0	38	26	12	493,708	1,505	6.78
	Tue	02/21/06	09:30	3.1	51	357,906	8,363	45	1.0	52	362,573	8,466	46	5.0	38	26	12	502,174	1,531	6.86
	Wed	02/22/06	09:30	2.2	52	363,712	5,806	44	1.0	53	368,442	5,869	44	5.0	38	26	12	508,043	1,549	6.78
	Thu	02/23/06	09:30	2.3	52	369,820	6,108	44	1.0	53	374,611	6,169	45	5.0	40	36	4	514,212	1,568	6.88
	Fri	02/24/06	09:30	2.2	52	375,462	5,642	43	1.0	53	380,319	5,708	43	5.0	38	26	12	519,920	1,585	6.80
13	Mon	02/27/06	09:30	5.1	53	388,999	13,537	44	1.0	54	393,999	13,680	45	5.0	42	28	14	533,600	1,627	6.84
	Tue	02/28/06	10:00	2.2	52	395,397	6,398	48	2.0	53	400,371	6,372	48	5.0	38	26	12	539,972	1,646	6.88
	Wed	03/01/06	09:30	2.1	52	400,388	4,991	40	2.0	53	405,522	5,151	41	5.0	38	26	12	545,123	1,662	6.86
	Thu	03/02/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	03/03/06	NA	1.3	NA	403,939	3,551	46	NA	NA	409,117	3,595	46	NA	NA	NA	NA	548,718	1,673	NA
14	Mon	03/06/06	10:00	1.9	49	408,768	4,829	42	2.0	50	413,981	4,864	43	4.0	56	46	10	553,582	1,688	6.99
	Tue	03/07/06	10:00	0.7	52	410,597	1,829	44	2.0	53	415,820	1,839	44	5.0	44	32	12	555,421	1,693	6.93
	Wed	03/08/06	10:00	0.9	50	412,952	2,355	44	2.0	51	418,191	2,371	44	5.0	36	24	12	557,792	1,701	7.02
	Thu	03/09/06	10:00	1.6	52	417,448	4,496	47	2.0	53	422,751	4,560	48	5.0	36	24	12	562,352	1,714	6.96
	Fri	03/10/06	10:00	1.9	52	422,421	4,973	44	2.0	53	427,788	5,037	44	5.0	38	26	12	567,389	1,730	7.68
15	Mon	03/13/06	09:00	3.0	50	430,465	8,044	45	2.0	51	435,993	8,205	46	5.0	34	22	12	575,594	1,755	7.53
	Tue	03/14/06	09:00	5.4	51	447,253	16,788	52	2.0	52	453,096	17,103	53	5.0	40	28	12	592,697	1,807	7.73
	Wed	03/15/06	09:00	4.8	51	460,094	12,841	45	2.0	52	466,107	13,011	45	5.0	38	26	12	605,708	1,847	8.12
	Thu	03/16/06	09:00	5.0	52	473,291	13,197	44	2.0	53	479,476	13,369	45	5.0	38	26	12	619,077	1,887	8.22
	Fri	03/17/06	09:00	5.4	52	487,179	13,888	43	2.0	53	493,527	14,051	43	5.0	38	26	12	633,128	1,930	7.56
16	Mon	03/20/06	09:00	5.7	52	501,498	14,319	42	2.0	53	507,994	14,467	42	4.0	38	26	12	647,595	1,974	7.42
	Tue	03/21/06	09:00	7.8	49	522,266	20,768	44	2.0	51	529,111	21,117	45	2.0	54	44	10	668,712	2,039	7.33
	Wed	03/22/06	09:00	10.1	52	550,641	28,375	47	2.0	53	558,031	28,920	48	0.0	38	26	12	697,632	2,127	7.38
	Thu	03/23/06	09:00	11.0	51	582,679	32,038	49	2.0	53	590,675	32,644	49	1.0	40	26	14	730,276	2,226	7.61
	Fri	03/24/06	09:00	5.2	52	596,177	13,498	43	2.0	53	604,398	13,723	44	1.0	60	50	10	743,999	2,268	7.64
17	Mon	03/27/06	09:00	6.5	52	612,520	16,343	42	2.0	53	620,897	16,499	42	0.0	42	30	12	760,498	2,319	7.60
	Tue	03/28/06	08:30	5.2	51	625,670	13,150	42	2.0	52	634,183	13,286	43	2.0	36	24	12	773,784	2,359	7.70
	Wed	03/29/06	09:00	7.7	52	647,997	22,327	48	2.0	52	656,918	22,735	49	0.0	48	36	12	796,519	2,428	NA
	Thu	03/30/06	09:00	3.8	53	657,686	9,689	42	2.0	53	666,722	9,804	43	0.0	38	24	14	806,323	2,458	7.54
	Fri	03/31/06	08:00	6.3	46	674,693	17,007	45	1.0	47	684,032	17,310	46	2.5	59	48	11	823,633	2,511	7.31

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours	Vessel A Flowrate	Vessel A Cumulative Totalizer	Vessel A Usage	Vessel A Average Flow	Vessel A Pressure Differential	Vessel B Flowrate	Vessel B Cumulative Totalizer	Vessel B Usage	Vessel B Average Flow	Vessel B Pressure Differential	System Inlet Pressure	System Outlet Pressure	System Pressure Differential	System Cumulative Volume Treated	System Bed Volumes Treated[a]	pH
				hr	gpm	gal	gal	gpm	psi	gpm	gal	gal	gpm	psi	psi	psi	psi	gal	BV	
18	Mon	04/03/06	09:00	14.7	51	714,575	39,882	45	2.0	52	724,554	40,522	46	0.0	38	26	12	864,155	2,635	7.51
	Tue	04/04/06	09:00	8.5	52	738,606	24,031	47	2.5	53	749,092	24,538	48	2.5	36	24	12	888,693	2,709	7.35
	Wed	04/05/06	09:00	6.1	51	754,237	15,631	43	2.5	52	765,045	15,953	44	2.5	40	28	12	904,646	2,758	7.40
	Thu	04/06/06	08:00	10.1	48	780,646	26,409	44	2.5	49	792,082	27,037	45	2.5	52	40	12	931,683	2,840	7.38
	Fri	04/07/06	09:00	7.3	52	798,657	18,011	41	2.5	53	810,333	18,251	42	2.5	38	26	12	949,934	2,896	7.66
19	Mon	04/10/06	08:30	5.8	52	813,257	14,600	42	2.5	53	825,086	14,753	42	4.0	42	30	12	964,687	2,941	7.31
	Tue	04/11/06	09:00	7.9	53	834,182	20,925	44	2.5	54	846,505	21,419	45	4.0	38	24	14	986,106	3,006	7.34
	Wed	04/12/06	08:30	12.0	51	867,024	32,842	46	2.5	52	880,032	33,527	47	4.0	36	24	12	1,019,633	3,109	7.49
	Thu	04/13/06	08:30	18.5	52	915,364	48,340	44	2.5	53	929,620	49,588	45	5.0	40	28	12	1,069,221	3,260	7.30
20	Mon	04/17/06	08:30	15.4	52	953,590	38,226	41	2.5	53	968,494	38,874	42	5.0	38	26	12	1,108,095	3,378	7.58
	Tue	04/18/06	08:30	9.4	49	980,223	26,633	47	2.5	50	995,672	27,178	48	4.0	50	38	12	1,135,273	3,461	7.41
	Wed	04/19/06	08:30	8.1	52	1,003,256	23,033	47	2.5	53	1,019,217	23,545	48	4.0	54	44	10	1,158,818	3,533	7.30
	Thu	04/20/06	08:30	8.5	53	1,026,074	22,818	45	2.5	54	1,042,523	23,306	46	5.0	36	24	12	1,182,124	3,604	7.28
	Fri	04/21/06	08:30	9.0	51	1,052,191	26,117	48	2.5	50	1,069,065	26,542	49	4.0	60	50	10	1,208,666	3,685	6.91
21	Mon	04/24/06	08:30	7.2	49	1,069,814	17,623	41	2.5	49	1,086,721	17,656	41	4.0	42	30	12	1,226,322	3,739	7.02
	Tue	04/25/06	08:30	12.4	52	1,104,268	34,454	46	2.5	53	1,121,440	34,719	47	5.0	38	26	12	1,261,041	3,845	7.15
	Wed	04/26/06	08:30	15.8	52	1,151,908	47,640	50	2.5	53	1,169,626	48,186	51	5.0	38	24	14	1,309,227	3,992	7.28
	Thu	04/27/06	08:00	8.8	49	1,175,787	23,879	45	2.5	50	1,193,750	24,124	46	5.0	58	48	10	1,333,351	4,065	6.91
	Fri	04/28/06	08:30	5.7	53	1,189,735	13,948	41	2.5	54	1,207,751	14,001	41	5.0	36	24	12	1,347,352	4,108	7.03
22	Mon	05/01/06	08:30	10.3	53	1,215,584	25,849	42	2.5	54	1,233,777	26,026	42	5.0	42	30	12	1,373,378	4,187	6.95
	Tue	05/02/06	08:30	7.4	52	1,234,603	19,019	43	2.5	53	1,252,930	19,153	43	5.0	38	26	12	1,392,531	4,246	7.42
	Wed	05/03/06	08:30	11.3	50	1,267,350	32,747	48	2.5	51	1,286,025	33,095	49	5.0	48	36	12	1,425,626	4,346	NA[e]
	Thu	05/04/06	08:00	9.6	50	1,293,809	26,459	46	2.5	51	1,312,756	26,731	46	5.0	60	50	10	1,452,357	4,428	NA[e]
	Fri	05/05/06	08:30	10.4	44	1,319,455	25,646	41	2.5	45	1,338,555	25,799	41	2.5	58	48	10	1,478,156	4,507	NA[e]
23	Mon	05/08/06	08:30	16.6	51	1,361,583	42,128	42	2.5	52	1,380,917	42,362	43	5.0	36	24	12	1,520,518	4,636	NA[e]
	Tue	05/09/06	08:30	9.4	52	1,387,691	26,108	46	2.5	53	1,407,248	26,331	47	5.0	38	26	12	1,546,849	4,716	NA[e]
	Wed	05/10/06	08:30	11.5	50	1,421,409	33,718	49	5.0	50	1,441,360	34,112	49	5.0	40	28	12	1,580,961	4,820	NA[e]
	Thu	05/11/06	08:30	10.1	50	1,449,175	27,766	46	4.0	51	1,469,389	28,029	46	5.0	44	32	12	1,608,990	4,905	NA[e]
	Fri	05/12/06	08:30	10.1	52	1,474,621	25,446	42	5.0	53	1,495,067	25,678	42	5.0	38	26	12	1,634,668	4,984	NA[e]
24	Mon	05/15/06	08:30	21.4	52	1,530,575	55,954	44	5.0	52	1,551,451	56,384	44	5.0	44	32	12	1,691,052	5,156	NA[e]
	Tue	05/16/06	08:30	2.8	49	1,537,194	6,619	39	5.0	49	1,558,049	6,598	39	4.0	52	40	12	1,697,650	5,176	NA[e]
	Wed	05/17/06	08:30	2.5	52	1,543,390	6,196	41	6.0	52	1,564,205	6,156	41	6.0	40	26	14	1,703,806	5,195	NA[e]
	Thu	05/18/06	08:30	7.6	51	1,563,262	19,872	44	6.0	51	1,584,309	20,104	44	5.0	38	26	12	1,723,910	5,256	NA[e]
	Fri	05/19/06	08:30	8.9	46	1,586,222	22,960	43	4.0	47	1,607,542	23,233	44	4.0	56	46	10	1,747,143	5,327	NA[e]
25	Mon	05/22/06	08:30	13.9	52	1,624,747	38,525	46	5.0	52	1,646,303	38,761	46	5.0	38	26	12	1,785,904	5,445	NA[e]
	Tue	05/23/06[c]	08:30	7.5	49	9,644	9,644	21	5.0	49	1,665,455	19,152	43	5.0	38	26	12	1,805,056	5,503	NA[e]
	Wed	05/24/06	08:30	9.3	51	35,965	26,321	47	5.0	52	1,691,932	26,477	47	5.0	34	24	10	1,831,533	5,584	NA[e]
	Thu	05/25/06	08:30	20.5	52	93,797	57,832	47	6.0	52	14,918	14,918	12	5.0	36	24	12	1,846,451	5,629	NA[e]
	Fri	05/26/06[d]	08:30	6.7	50	110,177	16,380	41	6.0	50	31,398	16,480	41	5.0	58	46	12	1,862,931	5,680	NA[e]

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Week No.	Day of Week	Date	Time	Well Operational Hours	Vessel A					Vessel B					System					
					Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Inlet Pressure	Outlet Pressure	Pressure Differential	Cumulative Volume Treated	Bed Volumes Treated[a]	
				hr	gpm	gal	gal	gpm	psi	gpm	gal	gal	gpm	psi	psi	psi	psi	gal	BV	pH
26	Tue	05/30/06	08:30	14.3	50	143,981	33,804	39	5.0	51	65,035	33,637	39	5.0	36	24	12	1,896,568	5,782	7.01
	Wed	05/31/06	08:30	10.9	45	171,468	27,487	42	6.0	46	92,786	27,751	42	5.0	40	28	12	1,924,319	5,867	NA[e]
	Thu	06/01/06	08:30	5.7	52	185,133	13,665	40	6.0	52	106,485	13,699	40	6.0	38	24	14	1,938,018	5,909	NA[e]
	Fri	06/02/06	08:30	7.3	53	203,556	18,423	42	5.0	53	125,055	18,570	42	5.0	46	42	4	1,956,588	5,965	NA[e]
27	Mon	06/05/06	08:30	5.7	52	217,127	13,571	40	4.0	53	138,591	13,536	40	3.0	50	42	8	1,970,124	6,006	6.78
	Tue	06/06/06	08:30	4.2	44	227,171	10,044	40	4.0	45	148,595	10,004	40	3.0	52	42	10	1,980,128	6,037	7.01
	Wed	06/07/06	08:30	10.6	52	253,528	26,357	41	5.0	53	175,113	26,518	42	5.0	44	32	12	2,006,646	6,118	6.89
	Thu	06/08/06	08:30	11.2	52	286,015	32,487	48	6.0	53	207,864	32,751	49	5.0	36	24	12	2,039,397	6,218	6.85
	Fri	06/09/06	08:30	10.2	52	313,234	27,219	44	6.0	53	235,373	27,509	45	5.0	48	36	12	2,066,906	6,302	6.86
28	Mon	06/12/06	08:00	30.3	49	386,155	72,921	40	5.0	50	308,616	73,243	40	4.0	58	48	10	2,140,149	6,525	6.88
	Tue	06/13/06	08:00	14.6	50	425,230	39,075	45	5.0	51	348,019	39,403	45	4.0	46	34	12	2,179,552	6,645	6.85
	Wed	06/14/06	08:00	10.5	50	450,793	25,563	41	5.0	50	373,791	25,772	41	4.0	48	36	12	2,205,324	6,724	6.84
	Thu	06/15/06[c][d]	08:00	9.7	53	14,179	14,179	24	6.0	54	14,293	14,293	25	5.0	36	24	12	2,219,617	6,767	6.94
	Fri	06/16/06	08:00	13.5	52	51,030	36,851	45	6.0	53	51,550	37,257	46	5.0	36	24	12	2,256,874	6,881	7.12
29	Mon	06/19/06	08:00	16.7	52	92,023	40,993	41	6.0	53	92,797	41,247	41	5.0	38	26	12	2,298,121	7,006	7.07
	Tue	06/20/06	08:00	12.6	47	130,048	38,025	50	5.0	48	131,155	38,358	51	4.0	58	46	12	2,336,479	7,123	7.20
	Wed	06/21/06	08:00	12.6	52	165,180	35,132	46	6.0	53	166,593	35,438	47	4.0	58	46	12	2,371,917	7,231	7.06
	Thu	06/22/06	08:00	3.8	52	173,880	8,700	38	6.0	53	175,234	8,641	38	5.0	36	24	12	2,380,558	7,258	7.07
	Fri	06/23/06	08:00	3.0	49	181,121	7,241	40	6.0	50	182,474	7,240	40	5.0	50	38	12	2,387,798	7,280	
30	Mon	06/26/06	08:00	6.5	52	196,136	15,015	39	6.0	51	197,425	14,951	38	5.0	38	24	14	2,402,749	7,325	7.00
	Tue	06/27/06	08:00	5.3	53	208,783	12,647	40	6.0	52	210,105	12,680	40	5.0	58	46	12	2,415,429	7,364	6.93
	Wed	06/28/06	08:00	8.8	48	229,962	21,179	40	6.0	48	231,308	21,203	40	3.0	56	44	12	2,436,632	7,429	6.95
	Thu	06/29/06	08:00	9.6	45	255,600	25,638	45	5.0	46	257,100	25,792	45	3.0	58	48	10	2,462,424	7,507	7.06
	Fri	06/30/06	08:00	10.3	48	282,568	26,968	44	6.0	49	284,287	27,187	44	5.0	46	34	12	2,489,611	7,590	7.08
31	Mon	07/03/06	08:00	6.4	52	297,683	15,115	39	6.0	51	299,369	15,082	39	5.0	50	40	10	2,504,693	7,636	6.75
	Wed	07/05/06	08:00	4.4	53	308,063	10,380	39	6.0	54	309,727	10,358	39	5.0	48	36	12	2,515,051	7,668	7.05
	Thu	07/06/06	08:00	1.9	51	313,431	5,368	47	6.0	52	315,086	5,359	47	5.0	44	34	10	2,520,410	7,684	7.06
32	Mon	07/10/06	08:00	9.0	52	334,145	20,714	38	6.0	53	335,726	20,640	38	5.0	54	42	12	2,541,050	7,747	6.81
	Tue	07/11/06	08:00	2.4	53	339,988	5,843	41	6.0	54	341,550	5,824	40	5.0	38	24	14	2,546,874	7,765	7.15
	Wed	07/12/06	08:00	10.6	52	370,563	30,575	48	6.0	53	372,433	30,883	49	5.0	44	30	14	2,577,757	7,859	6.80
	Thu	07/13/06	08:00	10.2	48	395,754	25,191	41	5.0	49	397,715	25,282	41	4.0	64	50	14	2,603,039	7,936	6.84
	Fri	07/14/06	08:00	9.5	52	419,172	23,418	41	6.0	53	421,058	23,343	41	5.0	44	30	14	2,626,382	8,007	6.80
33	Mon	07/17/06	08:00	11.3	53	446,844	27,672	41	6.0	54	448,627	27,569	41	5.0	36	24	12	2,653,951	8,091	6.83
	Tue	07/18/06	08:00	5.1	51	459,098	12,254	40	5.0	52	460,822	12,195	40	5.0	62	54	8	2,666,146	8,128	6.84
	Wed	07/19/06	08:00	7.9	54	478,549	19,451	41	6.0	53	480,161	19,339	41	5.0	38	24	14	2,685,485	8,187	6.95
	Thu	07/20/06	08:00	10.6	53	504,981	26,432	42	6.0	54	506,478	26,317	41	5.0	38	24	14	2,711,802	8,268	6.75
	Fri	07/21/06	08:00	9.1	53	527,891	22,910	42	6.0	54	529,538	23,060	42	5.0	38	24	14	2,734,862	8,338	6.72
34	Mon	07/24/06	08:00	20.0	53	576,653	48,762	41	6.0	54	578,328	48,790	41	5.0	38	24	14	2,783,652	8,487	6.68
	Tue	07/25/06	08:00	8.0	52	599,359	22,706	47	5.0	53	601,146	22,818	48	4.0	36	22	14	2,806,470	8,556	6.53
	Wed	07/26/06	08:00	10.7	53	629,984	30,625	48	6.0	54	631,879	30,733	48	5.0	38	24	14	2,837,203	8,650	6.54
	Thu	07/27/06	08:00	11.2	53	664,449	34,465	51	6.0	54	666,481	34,602	51	5.0	36	22	14	2,871,805	8,756	6.83
	Fri	07/28/06	08:00	4.5	52	675,432	10,983	41	6.0	53	677,500	11,019	41	5.0	36	24	12	2,882,824	8,789	6.96

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours	Vessel A					Vessel B					System					
				hr	Flowrate (gpm)	Cumulative Totalizer (gal)	Usage (gal)	Average Flow (gpm)	Pressure Differential (psi)	Flowrate (gpm)	Cumulative Totalizer (gal)	Usage (gal)	Average Flow (gpm)	Pressure Differential (psi)	Inlet Pressure (psi)	Outlet Pressure (psi)	Pressure Differential (psi)	Cumulative Volume Treated (gal)	Bed Volumes Treated[c] (BV)	pH
35	Mon	07/31/06	08:00	14.1	53	713,399	37,967	45	6.0	54	715,682	38,182	45	5.0	38	24	14	2,921,006	8,906	6.72
	Tue	08/01/06	08:00	8.7	52	735,385	21,986	42	5.0	53	737,748	22,066	42	5.0	36	24	12	2,943,072	8,973	6.78
	Wed	08/02/06	08:00	8.3	53	759,098	23,713	48	6.0	54	761,650	23,902	48	5.0	40	26	14	2,966,974	9,046	6.68
	Thu	08/03/06	08:00	10.4	53	788,997	29,899	48	6.0	54	791,831	30,181	48	6.0	38	24	14	2,997,155	9,138	7.22
	Fri	08/04/06	08:00	11.6	52	820,098	31,101	45	6.0	53	823,221	31,390	45	5.0	38	26	12	3,028,545	9,233	7.18
36	Mon	08/07/06	08:00	31.4	52	906,827	86,729	46	6.0	53	910,851	87,630	47	5.0	36	24	12	3,116,175	9,501	7.21
	Tue	08/08/06	08:00	10.7	50	940,110	33,283	52	6.0	51	944,497	33,646	52	5.0	36	22	14	3,149,821	9,603	7.22
	Wed	08/09/06	08:00	11.6	52	973,944	33,834	49	6.0	51	978,752	34,255	49	5.0	52	44	8	3,184,076	9,708	7.23
	Thu	08/10/06[e]	08:00	12.5	51	1,002,059	28,115	37	6.0	52	1,007,693	28,941	39	5.0	36	22	14	3,213,017	9,796	7.18
	Fri	08/11/06	08:00	4.3	50	1,024,852	22,793	88	6.0	51	1,030,319	22,626	88	5.0	36	22	14	3,235,643	9,865	7.18
37	Mon	08/14/06	08:00	15.2	52	1,056,965	32,113	35	6.0	52	1,062,635	32,316	35	5.0	36	22	14	3,267,959	9,963	7.06
	Tue	08/15/06	08:00	10.9	50	1,090,203	33,238	51	6.0	51	1,096,168	33,533	51	5.0	34	22	12	3,301,492	10,066	7.02
	Wed	08/16/06	08:00	11.8	52	1,125,207	35,004	49	6.0	52	1,131,532	35,364	50	5.0	36	22	14	3,336,856	10,173	6.99
	Thu	08/17/06	08:00	11.5	52	1,157,667	32,460	47	6.0	52	1,164,379	32,847	48	5.0	42	30	12	3,369,703	10,273	6.96
	Fri	08/18/06	08:00	10.2	52	1,186,123	28,456	46	6.0	53	1,193,181	28,802	47	5.0	38	24	14	3,398,505	10,361	6.92
38	Mon	08/21/06	08:00	13.0	48	1,219,233	33,110	42	6.0	49	1,226,433	33,252	43	5.0	40	26	14	3,431,757	10,463	6.90
	Tue	08/22/06	08:00	11.7	51	1,248,839	29,606	42	6.0	52	1,256,284	29,851	43	5.0	38	24	14	3,461,608	10,554	6.88
	Wed	08/23/06	08:00	19.2	51	1,300,577	51,738	45	6.0	52	1,308,656	52,372	45	5.0	36	22	14	3,513,980	10,713	7.16
	Thu	08/24/06	08:00	9.0	48	1,324,986	24,409	45	6.0	49	1,333,305	24,649	46	4.0	40	28	12	3,538,629	10,789	7.24
	Fri	08/25/06	08:00	14.5	52	1,368,493	43,507	50	7.0	53	1,377,159	43,854	50	5.0	38	24	14	3,582,483	10,922	6.92
39	Mon	08/28/06	08:30	25.9	45	1,437,485	68,992	44	4.0	46	1,446,743	69,584	45	3.0	56	44	12	3,652,067	11,134	6.75
	Tue	08/29/06	08:00	9.7	48	1,460,276	22,791	39	5.0	49	1,469,787	23,044	40	5.0	54	44	10	3,675,111	11,205	7.16
	Wed	08/30/06	08:00	11.2	51	1,491,622	31,346	47	5.0	52	1,501,477	31,690	47	5.0	36	22	14	3,706,801	11,301	7.30
	Thu	08/31/06	08:00	10.1	50	1,520,884	29,262	48	5.0	51	1,531,098	29,621	49	5.0	38	26	12	3,736,422	11,392	7.32
	Fri	09/01/06	08:00	6.2	52	1,539,070	18,186	49	6.0	53	1,549,582[f]	18,484	50	6.0	36	24	12	3,754,906	11,448	7.31
40	Mon	09/04/06	08:00	10.8	46	1,569,611	30,541	47	5.0	47	1,580,241	30,659	47	5.0	58	52	6	3,785,565	11,541	7.39
	Tue	09/05/06	08:00	8.3	43	1,587,401	17,790	36	3.0	44	1,598,219	17,978	36	3.0	60	50	10	3,803,543	11,596	7.54
	Wed	09/06/06	08:00	9.1	42	1,608,776	21,375	39	3.0	43	1,619,875	21,656	40	3.0	56	48	8	3,825,199	11,662	7.61
	Thu	09/07/06	08:00	12.5	48	1,642,284	33,508	45	4.0	49	1,653,926	34,051	45	3.0	62	54	8	3,859,250	11,766	7.40
	Fri	09/08/06	08:00	7.8	47	1,662,744	20,460	44	5.0	48	1,674,580[f]	20,654	44	3.0	50	38	12	3,879,904	11,829	7.38
41	Mon	09/11/06	08:00	8.8	49	1,682,302	19,558	37	5.0	50	1,694,118	19,538	37	5.0	42	28	14	3,899,442	11,889	6.92
	Tue	09/12/06[f]	08:00	4.2	52	1,691,589	9,287	37	5.0	53	1,703,344	9,226	37	5.0	44	30	14	3,908,668	11,917	6.90
	Wed	09/13/06[f]	08:00	2.8	53	1,697,803	6,214	37	7.0	54	1,709,522	6,178	37	6.0	40	26	14	3,914,846	11,936	6.88
	Thu	09/14/06[f]	08:00	2.9	52	1,704,654	6,851	39	7.0	53	1,716,366	6,844	39	6.0	42	28	14	3,921,690	11,956	6.81
	Fri	09/15/06	08:00	3.1	49	1,711,788	7,134	38	5.0	50	1,723,466	7,100	38	4.0	42	26	16	3,928,790	11,978	6.68
42	Mon	09/18/06	08:00	6.9	51	1,726,598	14,810	36	6.0	52	1,738,196	14,730	36	5.0	38	24	14	3,943,520	12,023	7.40
	Tue	09/19/06	08:00	3.2	52	1,733,172	6,574	34	7.0	53	1,744,744	6,548	34	6.0	40	26	14	3,950,068	12,043	7.41
	Wed	09/20/06	08:00	2.8	49	1,740,448	7,276	43	7.0	49	1,752,059	7,315	44	6.0	36	22	14	3,957,383	12,065	7.43
	Thu	09/21/06	08:00	2.6	48	1,746,526	6,078	39	5.0	49	1,758,138	6,079	39	5.0	60	52	8	3,963,462	12,084	7.38
	Fri	09/22/06	08:00	3.6	50	1,754,312	7,786	36	6.0	51	1,765,885	7,747	36	5.0	40	26	14	3,971,209	12,107	7.42

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours (hr)	Vessel A Flowrate (gpm)	Vessel A Cumulative Totalizer (gal)	Vessel A Usage (gal)	Vessel A Average Flow (gpm)	Vessel A Pressure Differential (psi)	Vessel B Flowrate (gpm)	Vessel B Cumulative Totalizer (gal)	Vessel B Usage (gal)	Vessel B Average Flow (gpm)	Vessel B Pressure Differential (psi)	System Inlet Pressure (psi)	System Outlet Pressure (psi)	System Pressure Differential (psi)	System Cumulative Volume Treated (gal)	System Bed Volumes Treated[a] (BV)	pH
43	Mon	09/25/06	08:00	6.7	53	1,768,626	14,314	36	6.0	53	1,780,090	14,205	35	5.0	52	44	8	3,985,414	12,151	7.14
	Tue	09/26/06	08:00	2.9	53	1,774,817	6,191	36	6.0	54	1,786,245	6,155	35	6.0	38	24	14	3,991,569	12,169	7.13
	Wed	09/27/06	08:00	2.9	53	1,781,304	6,487	37	7.0	53	1,792,713	6,468	37	6.0	44	32	12	3,998,037	12,189	7.16
	Thu	09/28/06	08:00	3.1	52	1,788,143	6,839	37	7.0	53	1,799,512	6,799	37	6.0	44	32	12	4,004,836	12,210	7.31
	Fri	09/29/06	08:00	4.2	51	1,796,987	8,844	35	7.0	52	1,808,309	8,797	35	6.0	46	34	12	4,013,633	12,237	7.28
44	Mon	10/02/06	08:00	6.9	52	1,812,453	15,466	37	6.0	53	1,823,662	15,353	37	5.0	42	30	12	4,028,986	12,283	7.22
	Tue	10/03/06	08:00	2.8	52	1,818,729	6,276	37	6.0	53	1,829,902	6,240	37	5.0	40	28	12	4,035,226	12,303	7.26
	Wed	10/04/06	08:00	3.3		1,825,877	7,148	36	6.0		1,837,004	7,102	36	5.0	40	28	12	4,042,328	12,324	7.31
	Thu	10/05/06	08:00	3.8	51	1,833,178	7,301	32	6.0	52	1,844,504	7,500	33	5.0	36	22	14	4,049,828	12,347	7.42
	Fri	10/06/06	08:00	4.3	53	1,846,727	13,549	53	6.0	54	1,858,024	13,520	52	5.0	42	30	12	4,063,348	12,388	7.41
45	Mon	10/09/06	08:00	6.0	52	1,860,487	13,760	38	7.0	53	1,871,657	13,633	38	6.0	40	26	14	4,076,981	12,430	7.34
	Tue	10/10/06	08:00	3.6	51	1,868,492	8,005	37	7.0	52	1,879,606	7,949	37	6.0	44	30	14	4,084,930	12,454	7.32
	Wed	10/11/06	08:00	2.9	52	1,875,509	7,017	40	7.0	53	1,886,569	6,963	40	6.0	46	32	14	4,091,893	12,475	7.22
	Thu	10/12/06	08:00	3.6	52	1,884,192	8,683	40	7.0	53	1,895,243	8,674	40	6.0	44	30	14	4,100,567	12,502	7.20
	Fri	10/13/06	08:00	2.4	52	1,890,900	6,708	47	7.0	53	1,901,980	6,737	47	5.0	42	20	22	4,107,304	12,522	7.41
46	Mon	10/16/06	08:00	3.2	52	1,898,383	7,483	39	7.0	53	1,909,301	7,321	38	5.0	42	28	14	4,114,625	12,545	7.28
	Tue	10/17/06	08:00	6.3	51	1,913,559	15,176	40	7.0	52	1,924,391	15,090	40	5.0	56	42	14	4,129,715	12,591	7.29
	Wed	10/18/06	08:00	1.8	52	1,918,776	5,217	48	7.0	53	1,929,569	5,178	48	5.0	48	34	14	4,134,893	12,606	7.25
	Thu	10/19/06	08:00	2.8	51	1,925,161	6,385	38	7.0	52	1,935,875	6,306	38	5.0	46	32	14	4,141,199	12,626	7.28
	Fri	10/20/06	08:00	8.1	53	1,932,964	7,803	16	7.0	54	1,943,594	7,719	16	6.0	38	22	16	4,148,918	12,649	7.31
47	Mon	10/23/06	08:00	3.8	51	1,953,998	21,034	92	7.0	52	1,964,464	20,870	92	6.0	44	30	14	4,169,788	12,713	7.23
	Tue	10/24/06	08:00	2.7	52	1,959,988	5,990	37	7.0	53	1,970,382	5,918	37	6.0	42	28	14	4,175,706	12,731	7.21
	Wed	10/25/06	08:00	1.6	49	1,963,860	3,872	40	7.0	50	1,974,232	3,850	40	5.0	48	34	14	4,179,556	12,743	7.23
	Thu	10/26/06	08:00	1.4	51	1,967,558	3,698	44	7.0	52	1,978,020	3,788	45	6.0	56	42	14	4,183,344	12,754	7.24
	Fri	10/27/06	08:00	1.9	53	1,971,409	3,851	34	7.0	54	1,981,780	3,760	33	5.0	46	32	14	4,187,104	12,766	7.25
48	Mon	10/30/06	08:00	3.5	53	1,979,404	7,995	38	7.0	54	1,989,611	7,831	37	6.0	38	22	16	4,194,935	12,789	7.26
	Tue	10/31/06	08:00	2.6	48	1,985,813	6,409	41	6.0	49	1,996,011	6,400	41	5.0	54	42	12	4,201,335	12,809	7.28
	Wed	11/01/06	08:00	5.0	49	1,997,485	11,672	39	6.0	50	2,007,603	11,592	39	5.0	58	46	12	4,212,927	12,844	7.29
	Thu	11/02/06	08:00	2.4	50	2,003,526	6,041	42	6.0	51	2,013,577	5,974	41	5.0	44	32	12	4,218,901	12,863	7.31
	Fri	11/03/06	08:00	7.7	51	2,022,337	18,811	41	7.0	52	2,032,433	18,856	41	6.0	46	34	12	4,237,757	12,920	7.32
49	Mon	11/06/06	08:00	11.7	51	2,049,083	26,746	38	7.0	52	2,058,966	26,533	38	5.0	48	36	12	4,264,290	13,001	7.26
	Tue	11/07/06	08:00	8.7	50	2,069,838	20,755	40	7.0	51	2,079,836	20,870	40	5.0	46	34	12	4,285,160	13,065	7.29
	Wed	11/08/06	08:00	4.0	51	2,078,954	9,116	38	7.0	52	2,088,865	9,029	38	6.0	48	36	12	4,294,189	13,092	7.28
	Thu	11/09/06	08:00	4.3	53	2,088,772	9,818	38	7.0	54	2,098,576	9,711	38	6.0	38	24	14	4,303,900	13,122	7.30
	Fri	11/10/06	08:00	4.6	48	2,099,542	10,770	39	7.0	49	2,109,269	10,693	39	5.0	54	40	14	4,314,593	13,154	7.11
50	Mon	11/13/06	08:00	7.8	52	2,118,110	18,568	40	7.0	53	2,127,647	18,378	39	5.0	52	38	14	4,332,971	13,210	7.11
	Tue	11/14/06	08:00	2.8	53	2,124,566	6,456	38	7.0	53	2,134,024	6,377	38	6.0	38	22	16	4,339,348	13,230	7.12
	Wed	11/15/06	08:00	2.2	48	2,130,214	5,648	43	7.0	49	2,139,620	5,596	42	6.0	50	36	14	4,344,944	13,247	7.08
	Thu	11/16/06	08:00	3.1	52	2,137,112	6,898	37	7.0	53	2,146,426	6,806	37	6.0	40	24	16	4,351,750	13,268	7.12
	Fri	11/17/06	08:00	2.0	53	2,143,360	6,248	52	7.5	54	2,152,662	6,236	52	6.0	38	24	14	4,357,986	13,287	7.11

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours (hr)	Vessel A Flowrate (gpm)	Vessel A Cumulative Totalizer (gal)	Vessel A Usage (gal)	Vessel A Average Flow (gpm)	Vessel A Pressure Differential (psi)	Vessel B Flowrate (gpm)	Vessel B Cumulative Totalizer (gal)	Vessel B Usage (gal)	Vessel B Average Flow (gpm)	Vessel B Pressure Differential (psi)	System Inlet Pressure (psi)	System Outlet Pressure (psi)	System Pressure Differential (psi)	System Cumulative Volume Treated (gal)	System Bed Volumes Treated[c] (BV)	pH
51[a]	Mon	11/20/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	11/21/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wed	11/22/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thu	11/23/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	11/24/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
52	Mon	11/27/06	08:00	13.3	50	2,169,226	25,866	32	7.0	51	2,178,162	25,500	32	5.0	48	34	14	4,383,486	13,364	7.08
	Tue	11/28/06	08:00	3.3	51	2,175,856	6,630	33	7.0	52	2,184,672	6,510	33	5.0	54	40	14	4,389,996	13,384	7.02
	Wed	11/29/06	08:00	2.8	46	2,181,841	5,985	36	7.0	47	2,190,056	5,384	32	5.0	60	46	14	4,395,380	13,401	7.01
	Thu	11/30/06	08:00	3.1	52	2,188,191	6,350	34	7.0	53	2,196,802	6,746	36	2.0	38	24	14	4,402,126	13,421	7.14
	Fri	12/01/06	08:00	2.2	50	2,193,980	5,789	44	7.0	51	2,202,633	5,831	44	5.0	62	48	14	4,407,957	13,439	7.06
53	Mon	12/04/06	08:00	5.4	52	2,204,927	10,947	34	7.0	53	2,213,433	10,800	33	6.0	40	24	16	4,418,757	13,472	7.07
	Tue	12/05/06	08:00	2.9	51	2,211,293	6,366	37	7.0	52	2,219,740	6,307	36	6.0	42	28	14	4,425,064	13,491	7.01
	Wed	12/06/06	08:00	3.2	52	2,218,173	6,880	36	7.0	53	2,226,548	6,808	35	6.0	48	34	14	4,431,872	13,512	7.15
	Thu	12/07/06	08:00	1.0	52	2,220,055	1,882	31	7.0	53	2,228,398	1,850	31	6.0	36	22	14	4,433,722	13,517	7.18
	Fri	12/08/06	08:00	3.1	51	2,227,385	7,330	39	7.0	52	2,235,707	7,309	39	6.0	54	40	14	4,441,031	13,540	7.12
54	Mon	12/11/06	08:00	3.7	51	2,234,821	7,436	33	7.0	52	2,243,015	7,308	33	6.0	46	32	14	4,448,339	13,562	7.12
	Tue	12/12/06	08:00	2.0	52	2,238,678	3,857	32	7.0	53	2,246,796	3,781	32	6.0	50	36	14	4,452,120	13,574	7.21
	Wed	12/13/06	08:00	1.8	52	2,242,373	3,695	34	7.0	53	2,250,430	3,634	34	6.0	36	22	14	4,455,754	13,585	7.14
	Thu	12/14/06	08:00	3.7	51	2,251,246	8,873	40	7.0	52	2,259,284	8,854	40	6.0	36	22	14	4,464,608	13,612	7.20
	Fri	12/15/06	08:00	1.9	48	2,256,004	4,758	42	7.0	49	2,264,059	4,775	42	5.0	54	40	14	4,469,383	13,626	7.04
55[b]	Mon	12/18/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	12/19/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wed	12/20/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thu	12/21/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	12/22/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
56[b]	Mon	12/25/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Tue	12/26/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Wed	12/27/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thu	12/28/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Fri	12/29/06	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
57	Tue	01/02/07	08:00	17.1	48	2,287,873	31,869	31	7.0	49	2,295,273	31,214	30	5.0	60	46	14	4,500,597	13,721	7.11
	Wed	01/03/07	08:00	1.3	50	2,290,778	2,905	37	7.0	51	2,298,114	2,841	36	6.0	40	24	16	4,503,438	13,730	7.18
	Thu	01/04/07	08:00	3.0	51	2,296,815	6,037	34	7.0	52	2,304,025	5,911	33	6.0	36	20	16	4,509,349	13,748	7.05
	Fri	01/05/07	08:00	3.6	52	2,304,563	7,748	36	7.0	53	2,311,682	7,657	35	6.0	38	22	16	4,517,006	13,771	7.04
58	Mon	01/08/07	08:00	3.6	51	2,319,259	14,696	68	7.0	52	2,318,866	7,184	33	6.0	38	24	14	4,524,190	13,793	7.03
	Tue	01/09/07	08:00	4.0	52	2,319,317	58	0	7.0	53	2,326,095	7,229	30	6.0	40	24	16	4,531,419	13,815	7.02
	Wed	01/10/07	08:00	4.0	48	2,327,461	8,144	34	7.0	47	2,334,075	7,980	33	5.0	50	36	14	4,539,399	13,840	7.04
	Thu	01/11/07	08:00	3.8	48	2,334,908	7,447	33	7.0	49	2,341,360	7,285	32	6.0	56	40	16	4,546,684	13,862	6.92
	Fri	01/12/07	08:00	2.8	52	2,340,121	5,213	31	8.0	53	2,344,644	3,284	20	6.0	40	22	18	4,549,968	13,872	NM

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours	Vessel A					Vessel B					System					
					Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Flowrate	Cumulative Totalizer	Usage	Average Flow	Pressure Differential	Inlet Pressure	Outlet Pressure	Pressure Differential	Cumulative Volume Treated	Bed Volumes Treated[a]	
				hr	gpm	gal	gal	gpm	psi	gpm	gal	gal	gpm	psi	psi	psi	psi	gal	BV	pH
59	Mon	01/15/07	08:00	4.4	51	2,348,377	8,256	31	8.0	52	2,354,478	9,834	37	1.0	54	40	14	4,559,802	13,902	6.95
	Tue	01/16/07	08:00	4.5	52	2,357,518	9,141	34	8.0	53	2,363,394	8,916	33	6.0	44	26	18	4,568,718	13,929	6.92
	Wed	01/17/07	08:00	3.1	52	2,363,595	6,077	33	8.0	53	2,369,319	5,925	32	6.0	40	24	16	4,574,643	13,947	6.94
	Thu	01/18/07	08:00	1.8	52	2,367,949	4,354	40	8.0	53	2,373,651	4,332	40	6.0	40	24	16	4,578,975	13,960	6.98
	Fri	01/19/07	08:00	1.5	53	2,371,509	3,560	40	7.0	54	2,377,198	3,547	39	7.0	38	22	16	4,582,522	13,971	NM
60	Mon	01/22/07	08:00	0.8	50	2,373,968	2,459	51	6.0	51	2,379,682	2,484	52	6.0	34	20	14	4,585,006	13,979	7.14
	Tue	01/23/07	08:00	1.4	49	2,378,168	4,200	50	7.0	50	2,383,926	4,244	51	6.0	32	18	14	4,589,250	13,992	NM
	Wed	01/24/07	08:00	NA	50	2,381,924	3,756	NA	7.0	51	2,387,770	3,844	NA	6.0	32	18	14	4,593,094	14,003	NM
	Thu	01/25/07	08:00	NA	51	2,389,746	7,822	NA	7.0	52	2,395,840	8,070	NA	6.0	38	24	14	4,601,164	14,028	7.25
	Fri	1/26/07[c][d]	08:00	NA	52	2,396,301	6,555	NA	7.0	53	2,402,338	6,498	NA	6.0	36	22	14	4,607,662	14,048	NM
61	Mon	01/29/07	08:00	0.9	NA	2,404,170	7,869	146	6.0	NA	2,409,779	7,441	138	7.0	36	22	14	4,615,103	14,070	7.08
	Tue	01/30/07	08:00	1.2	NA	2,435,656	31,486	437	9.0	NA	2,439,566	29,787	414	7.0	40	24	16	4,644,890	14,161	7.04
	Wed	01/31/07	08:00	0.9	NA	2,441,510	5,854	108	9.0	NA	2,444,805	5,239	97	7.0	36	20	16	4,650,129	14,177	7.33
	Thu	02/01/07	08:00	1.9	NA	2,442,030	520	5	9.0	NA	2,447,027	2,222	19	7.0	36	22	14	4,652,351	14,184	7.12
	Fri	2/02/07[c][d]	08:00	0.8	52	2,443,790	1,760	37	9.0	50	2,448,720	1,693	35	7.0	40	26	14	4,654,044	14,189	7.09
62	Mon	02/05/07	08:00	4.6	52	2,452,499	8,709	32	9.0	51	2,456,773	8,053	29	7.0	38	22	16	4,662,097	14,214	7.05
	Tue	02/06/07	08:00	1.8	51	2,457,063	4,564	42	9.0	49	2,461,100	4,327	40	7.0	36	20	16	4,666,424	14,227	7.09
	Wed	02/07/07	08:00	8.9	53	2,477,358	20,295	38	9.0	51	2,480,316	19,216	36	7.0	38	22	16	4,685,640	14,285	7.12
	Thu	02/08/07	08:00	4.1	53	2,486,111	8,753	36	7.0	51	2,488,539	8,223	33	7.0	38	22	16	4,693,863	14,311	7.15
	Fri	02/09/07	08:00	2.9	51	2,491,644	5,533	32	7.0	49	2,493,645	5,106	29	6.0	44	30	14	4,698,969	14,326	7.18
63	Mon	02/12/07	08:00	4.4	52	2,499,115	7,471	28	7.0	50	2,500,466	6,821	26	6.0	42	28	14	4,705,790	14,347	7.28
	Tue	02/13/07	08:00	2.5	53	2,503,703	4,588	31	6.0	50	2,504,662	4,196	28	6.0	40	24	16	4,709,986	14,360	7.32
	Wed	02/14/07	08:00	2.8	52	2,509,484	5,781	34	7.0	50	2,510,100	5,438	32	6.0	36	22	14	4,715,424	14,376	7.38
	Thu	02/15/07	08:00	3.7	53	2,516,224	6,740	30	7.0	51	2,516,221	6,121	28	6.0	38	24	14	4,721,545	14,395	7.41
	Fri	02/16/07	08:00	2.2	54	2,520,459	4,235	32	6.0	52	2,520,134	3,913	30	6.0	42	28	14	4,725,458	14,407	7.25
64	Mon	02/19/07	08:00	4.3	52	2,527,863	7,404	29	7.0	50	2,526,898	6,764	26	6.0	40	24	16	4,732,222	14,428	7.26
	Tue	02/20/07	08:00	3.9	51	2,536,398	8,535	36	7.0	49	2,534,873	7,975	34	6.0	38	22	16	4,740,197	14,452	7.52
	Wed	02/21/07	08:00	5.9	52	2,549,737	13,339	38	7.0	50	2,547,457	12,584	36	6.0	42	26	16	4,752,781	14,490	7.29
	Thu	02/22/07	08:00	5.0	54	2,561,657	11,920	40	7.0	52	2,558,641	11,184	37	6.0	38	22	16	4,763,965	14,524	7.34
	Fri	02/23/07	08:00	5.4	52	2,573,548	11,891	37	7.0	50	2,569,828	11,187	35	6.0	40	24	16	4,775,152	14,558	7.41
65	Mon	02/26/07	08:00	10.5	49	2,590,354	16,806	27	7.0	47	2,584,951	15,123	24	6.0	38	22	16	4,790,275	14,604	7.22
	Tue	02/27/07	08:00	6.7	47	2,606,677	16,323	41	7.0	45	2,600,415	15,464	38	5.0	58	46	12	4,805,739	14,652	7.48
	Wed	02/28/07	08:00	8.1	50	2,626,574	19,897	41	7.0	48	2,619,093	18,678	38	4.0	60	46	14	4,824,417	14,709	7.44
	Thu	03/01/07	08:00	3.5	48	2,633,642	7,068	34	7.0	46	2,625,582	6,489	31	5.0	40	26	14	4,830,906	14,728	7.42
	Fri	03/02/07	08:00	4.9	50	2,643,538	9,896	34	7.0	48	2,634,676	9,094	31	5.0	42	28	14	4,840,000	14,756	7.50
66	Mon	03/05/07	08:00	19.6	50	2,686,681	43,143	37	7.0	49	2,675,254	40,578	35	6.0	44	30	14	4,880,578	14,880	7.32
	Tue	03/06/07	08:00	2.4	52	2,690,518	3,837	27	7.0	50	2,678,646	3,392	24	6.0	38	26	12	4,883,970	14,890	7.38
	Wed	03/07/07	08:00	2.9	51	2,695,359	4,841	28	6.0	49	2,682,776	4,130	24	5.0	42	28	14	4,888,100	14,903	7.42
	Thu	03/08/07	08:00	3.6	48	2,702,425	7,066	33	6.0	47	2,688,882	6,106	28	5.0	40	28	12	4,894,206	14,921	7.48
	Fri	03/09/07	08:00	8.7	49	2,721,852	19,427	37	6.0	48	2,705,304	16,422	31	5.0	42	28	14	4,910,628	14,971	7.52

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours (hr)	Vessel A Flowrate (gpm)	Vessel A Cumulative Totalizer (gal)	Vessel A Usage (gal)	Vessel A Average Flow (gpm)	Vessel A Pressure Differential (psi)	Vessel B Flowrate (gpm)	Vessel B Cumulative Totalizer (gal)	Vessel B Usage (gal)	Vessel B Average Flow (gpm)	Vessel B Pressure Differential (psi)	System Inlet Pressure (psi)	System Outlet Pressure (psi)	System Pressure Differential (psi)	System Cumulative Volume Treated (gal)	System Bed Volumes Treated[a] (BV)	pH
	Mon	03/12/07	08:00	6.5	50	2,733,436	11,584	30	7.0	49	2,714,899	9,595	25	6.0	46	32	14	4,920,223	15,001	7.59
	Tue	03/13/07	08:00	3.2	49	2,738,396	4,960	26	7.0	48	2,719,150	4,251	22	6.0	48	34	14	4,924,474	15,014	7.56
67	Wed	03/14/07	08:00	2.7	51	2,742,726	4,330	27	7.0	50	2,722,493	3,343	21	6.0	46	32	14	4,927,817	15,024	7.51
	Thu	03/15/07	08:00	3.0	48	2,748,088	5,362	30	7.0	47	2,727,059	4,566	25	6.0	48	34	14	4,932,383	15,038	7.58
	Fri	03/16/07	08:00	3.2	50	2,753,132	5,044	26	7.0	49	2,731,100	4,041	21	6.0	52	38	14	4,936,424	15,050	7.59
	Mon	03/19/07	08:00	5.8	52	2,761,851	8,719	25	7.0	51	2,738,313	7,213	21	6.0	54	40	14	4,943,637	15,072	7.41
	Tue	03/20/07	08:00	4.0	50	2,768,319	6,468	27	7.0	49	2,743,557	5,244	22	6.0	52	38	14	4,948,881	15,088	7.39
68	Wed	03/21/07	08:00	3.4	48	2,774,210	5,891	29	7.0	47	2,748,632	5,075	25	6.0	48	34	14	4,953,956	15,104	7.42
	Thu	03/22/07	08:00	3.4	46	2,779,397	5,187	25	7.0	45	2,752,699	4,067	20	6.0	62	48	14	4,958,023	15,116	7.40
	Fri	03/23/07	08:00	7.7	48	2,797,088	17,691	38	7.0	47	2,769,312	16,613	36	6.0	NA	NA	NA	4,974,636	15,167	7.55
	Mon	03/26/07	08:00	8.5	50	2,808,791	11,703	23	7.0	49	2,778,986	9,674	19	6.0	38	24	14	4,984,310	15,196	7.58
	Tue	03/27/07	08:00	4.6	48	2,816,307	7,516	27	7.0	47	2,784,994	6,008	22	6.0	40	26	14	4,990,318	15,214	7.52
69	Wed	03/28/07	08:00	2.8	51	2,822,144	5,837	35	7.0	50	2,789,623	4,629	28	6.0	40	28	12	4,994,947	15,228	7.50
	Thu	03/29/07	08:00	5.8	52	2,829,525	7,381	21	7.0	51	2,795,355	5,732	16	6.0	38	24	14	5,000,679	15,246	7.48
	Fri	03/30/07	08:00	3.3	50	2,834,720	5,195	26	7.0	49	2,799,469	4,114	21	6.0	36	22	14	5,004,793	15,259	7.42
	Mon	04/02/07	08:00	7.8	50	2,845,195	10,475	22	7.0	48	2,807,852	8,383	18	6.0	38	24	14	5,013,176	15,284	7.48
	Tue	04/03/07	08:00	2.7	52	2,849,654	4,459	28	8.0	47	2,811,589	3,737	23	4.0	34	16	18	5,016,913	15,295	7.36
70	Wed	04/04/07	08:00	4.6	51	2,857,684	8,030	29	8.0	50	2,818,524	6,935	25	6.0	40	22	18	5,023,848	15,317	7.29
	Thu	04/05/07	08:00	1.2	49	2,860,587	2,903	40	7.0	48	2,821,196	2,672	37	6.0	40	26	14	5,026,520	15,325	7.21
	Fri	04/06/07	08:00	5.0	50	2,866,871	6,284	21	7.0	49	2,826,895	5,699	19	6.0	34	20	14	5,032,219	15,342	7.38
	Tue	04/10/07	08:00	12.4	52	2,881,150	14,279	19	6.0	50	2,831,194	4,299	6	6.0	34	22	12	5,036,518	15,355	7.40
71	Wed	04/11/07	08:00	4.4	51	2,881,150	-	-	6.0	50	2,835,427	4,233	16	6.0	36	22	14	5,040,751	15,368	7.52
	Thu	04/12/07	08:00	5.8	50	2,887,195	6,045	17	7.0	49	2,839,751	4,324	12	6.0	34	20	14	5,045,075	15,381	7.50
	Fri	04/13/07	08:00	1.2	53	2,890,194	2,999	42	7.0	51	2,842,566	2,815	39	7.0	36	22	14	5,047,890	15,390	7.58
	Mon	04/16/07	08:00	5.8	49	2,899,497	9,303	27	6.0	48	2,850,438	7,872	23	6.0	50	38	12	5,055,762	15,414	7.68
	Tue	04/17/07	08:00	1.0	51	2,901,519	2,022	34	7.0	50	2,852,282	1,844	31	6.0	34	20	14	5,057,606	15,420	7.27
72	Wed	04/18/07	08:00	4.3	52	2,913,653	12,134	47	7.0	51	2,863,852	11,570	45	6.0	36	22	14	5,069,176	15,455	7.18
	Thu	04/19/07	08:00	4.9	52	2,927,234	13,581	46	8.0	50	2,876,884	13,032	44	7.0	38	24	14	5,082,208	15,495	7.41
	Fri	04/20/07	08:00	5.5	53	2,942,789	15,555	47	8.0	51	2,891,863	14,979	45	7.0	38	22	16	5,097,187	15,540	7.48
	Mon	04/23/07	08:00	9.4	51	2,961,637	18,848	33	7.0	49	2,908,583	16,720	30	6.0	34	20	14	5,113,907	15,591	7.62
	Tue	04/24/07	08:00	4.1	53	2,972,877	11,240	46	8.0	51	2,919,396	10,813	44	6.0	38	22	16	5,124,720	15,624	7.68
73	Wed	04/25/07	08:00	4.3	53	2,986,215	13,338	52	8.0	51	2,932,242	12,846	50	6.0	40	22	18	5,137,566	15,663	7.56
	Thu	04/26/07	08:00	4.0	53	2,997,465	11,250	47	9.0	51	2,943,000	10,758	45	7.0	38	22	16	5,148,324	15,696	7.33
	Fri	04/27/07	08:00	13.0	52	3,028,847	31,382	40	9.0	50	2,972,763	29,763	38	7.0	38	22	16	5,178,087	15,787	7.42
	Mon	04/30/07	08:00	11.5	50	3,050,834	21,987	32	9.0	49	2,991,940	19,177	28	6.0	42	22	20	5,197,264	15,845	7.68
	Tue	05/01/07	08:00	6.6	52	3,069,000	18,166	46	9.0	51	3,009,455	17,515	44	7.0	42	22	20	5,214,779	15,899	7.56
74	Wed	05/02/07	08:00	6.5	52	3,080,183	11,183	29	9.0	50	3,018,560	9,105	23	7.0	38	20	18	5,223,884	15,926	7.62
	Thu	05/03/07	08:00	1.5	53	3,084,499	4,316	48	8.0	51	3,022,537	3,977	44	7.0	38	22	16	5,227,861	15,939	7.58
	Fri	05/04/07	08:00	3.9	53	3,093,939	9,440	40	9.0	52	3,031,355	8,818	38	8.0	40	22	18	5,236,679	15,965	7.52

Table A-1. EPA Arsenic Demonstration Project at Bruni, TX — Daily System Operation Log Sheet

Week No.	Day of Week	Date	Time	Well Operational Hours (hr)	Vessel A Flowrate (gpm)	Vessel A Cumulative Totalizer (gal)	Vessel A Usage (gal)	Vessel A Average Flow (gpm)	Vessel A Pressure Differential (psi)	Vessel B Flowrate (gpm)	Vessel B Cumulative Totalizer (gal)	Vessel B Usage (gal)	Vessel B Average Flow (gpm)	Vessel B Pressure Differential (psi)	System Inlet Pressure (psi)	System Outlet Pressure (psi)	System Pressure Differential (psi)	System Cumulative Volume Treated (gal)	System Bed Volumes Treated[a] (BV)	pH
76	Mon	05/14/07	08:00	3.0	50	3,162,310	7,824	43	7.0	48	3,096,046	7,385	41	8.0	36	20	16	5,301,370	16,163	7.46
	Tue	05/15/07	08:00	4.7	53	3,177,041	14,731	52	7.0	52	3,110,098	14,052	50	8.0	38	22	16	5,315,422	16,206	7.38
	Wed	05/16/07	08:00	2.8	53	3,183,335	6,294	37	7.0	51	3,116,021	5,923	35	8.0	38	22	16	5,321,345	16,224	7.42
	Thu	05/17/07	08:00	4.8	50	3,196,090	12,755	44	7.0	48	3,128,112	12,091	42	7.0	44	38	6	5,333,436	16,260	7.27
	Fri	05/18/07	08:00	5.4	52	3,211,352	15,262	47	7.0	50	3,142,700	14,588	45	8.0	38	22	16	5,348,024	16,305	7.49
77	Mon	05/21/07	08:00	2.3	52	3,217,979	6,627	48	7.0	50	3,149,071	6,371	46	8.0	38	22	16	5,354,395	16,324	7.28
	Tue	05/22/07	08:00	2.3	50	3,225,346	7,367	53	8.0	48	3,156,156	7,085	51	7.0	36	20	16	5,361,480	16,346	7.30
	Wed	05/23/07	08:00	2.1	51	3,230,435	5,089	40	7.0	49	3,160,968	4,812	38	7.0	34	20	14	5,366,292	16,361	7.24
	Thu	05/24/07	08:00	3.6	48	3,241,264	10,829	50	7.0	47	3,171,340	10,372	48	6.0	50	38	12	5,376,664	16,392	7.38
	Fri	05/25/07	08:00	4.7	50	3,250,383	9,119	32	7.0	48	3,178,874	7,534	27	7.0	38	24	14	5,384,198	16,415	7.48
78	Tue	05/29/07	08:00	5.9	52	3,259,807	9,424	27	7.0	50	3,187,081	8,207	23	7.0	36	20	16	5,392,405	16,440	7.49
	Wed	05/30/07	08:00	2.9	51	3,268,169	8,362	48	7.0	49	3,195,042	7,961	46	7.0	34	20	14	5,400,366	16,465	7.68
	Thu	05/31/07	08:00	2.0	52	3,273,816	5,647	47	8.0	50	3,200,441	5,399	45	7.0	38	22	16	5,405,765	16,481	7.30
	Fri	06/01/07	08:00	3.3	51	3,283,541	9,725	49	8.0	49	3,209,776	9,335	47	7.0	36	20	16	5,415,100	16,509	7.54
79	Mon	06/04/07	08:00	1.6	50	3,287,676	4,135	43	8.0	48	3,213,675	3,899	41	7.0	34	20	14	5,418,999	16,521	7.38
	Tue	06/05/07	08:00	5.9	50	3,303,898	16,222	46	8.0	48	3,229,139	15,464	44	7.0	36	22	14	5,434,463	16,568	7.44
	Wed	06/06/07	08:00	4.7	52	3,310,112	6,214	22	8.0	50	3,234,137	4,998	18	7.0	40	24	16	5,439,461	16,584	7.40
	Thu	06/07/07	08:00	3.1	53	3,318,744	8,632	46	9.0	51	3,242,389	8,252	44	7.0	38	32	6	5,447,713	16,609	7.21
	Fri	06/08/07	08:00	4.9	50	3,333,605	14,861	51	9.0	48	3,256,669	14,280	49	7.0	36	20	16	5,461,993	16,652	7.22
80	Mon	06/11/07	08:00	8.0	52	3,355,738	22,133	46	9.0	50	3,277,315	20,646	43	7.0	38	22	16	5,482,639	16,715	7.48
	Tue	06/12/07	08:00	8.5	52	3,382,932	27,194	53	9.0	51	3,303,424	26,109	51	7.0	36	20	16	5,508,748	16,795	7.53
	Wed	06/13/07	08:00	7.4	53	3,405,096	22,164	50	9.0	52	3,324,695	21,271	48	7.0	38	22	16	5,530,019	16,860	7.42
	Thu	06/14/07	08:00	7.7	53	3,428,119	23,023	50	9.0	51	3,346,757	22,062	48	7.0	38	22	16	5,552,081	16,927	7.46
	Fri	06/15/07	08:00	6.1	52	3,428,119	-	-	9.0	50	3,364,164	17,407	48	7.0	38	22	16	5,569,488	16,980	7.61
81	Mon	06/18/07	08:00	8.1	51	3,428,119	-	-	9.0	49	3,380,025	15,861	33	7.0	36	20	16	5,585,349	17,029	7.50
	Tue	06/19/07	08:00	7.6	52	3,428,119	-	-	9.0	50	3,400,347	20,322	45	7.0	38	22	16	5,605,671	17,090	7.56
	Wed	06/20/07	08:00	7.6	52	3,428,119	-	-	9.0	51	3,411,627	11,280	25	7.0	38	22	16	5,616,951	17,125	7.38
	Thu	06/21/07	08:00	5.0	50	3,428,119	-	-	9.0	48	3,425,705	14,078	47	7.0	38	20	18	5,631,029	17,168	7.18
	Fri	06/22/07	08:00	5.0	52	3,428,119	-	-	9.0	50	3,438,685	12,980	43	7.0	42	24	18	5,644,009	17,207	7.42
82	Mon	06/25/07	08:00	3.3	49	3,428,119	-	-	9.0	47	3,438,685	-	-	6.0	40	22	18	5,644,009	17,207	7.22
	Tue	06/26/07	08:00	2.2	52	3,428,119	-	-	8.0	50	3,438,685	-	-	6.0	34	20	14	5,644,009	17,207	7.18
	Wed	06/27/07	08:00	1.9	53	3,429,463	1,344	12	8.0	52	3,439,902	1,217	11	7.0	38	22	16	5,645,226	17,211	7.20
	Thu	06/28/07	08:00	2.3	49	3,434,795	5,332	39	8.0	47	3,444,512	4,610	33	6.0	42	26	16	5,649,836	17,225	7.15
	Fri	06/29/07	08:00	3.3	48	3,444,303	9,508	48	9.0	46	3,453,404	8,892	45	6.0	58	46	12	5,658,728	17,252	7.42

(a) Bed volume = 44 ft^3 or 328 gal (equivalent to volume of media in two vessels).
(b) Totalizer or Vessel A re-set on 01/12/06, 05/23/06, 06/15/06, 01/26/07, and 02/02/07.
(c) Totalizer for Vessel B re-set on 01/12/06, 05/26/06, 06/15/06, 01/26/07, and 02/02/07.
(d) Starting 08/10/06, totalizer readings for Vessels A and B are from gal since last backwash reading.
(e) Estimated master totalizer readings due to suspicious reported data.
(f) Operational data not collected week of November 20, 2006.
(h) Operational data not collected week of December 18th and 25th 2006 due to holidays.

NA = not available
Light green highlight indicates calculated value
Red highlight indicates system or well pump not operating
Orange highlight indicates parameter cannot be measured or is otherwise suspect

APPENDIX B

ANALYTICAL DATA

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX

Sampling Date		12/08/05[(a)]				12/13/05[(b)]				01/05/06				01/17/06				02/01/06			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	NA	NA	-	-	0.2	0.2	-	-	0.6	0.6	-	-	1.2	1.2	-	-	2.0	2.0
Alkalinity ($CaCO_3$)	mg/L	317 -	321 -	330 -	352 -	326 -	330 -	330 -	321 -	334 -	334 -	312 -	312 -	334 -	330 -	321 -	312 -	320 -	320 -	342 -	325 -
Fluoride	mg/L	0.5	0.6	0.5	0.4	-	-	-	-	0.5	0.6	0.6	0.7	-	-	-	-	0.5	0.6	0.5	0.6
Sulfate	mg/L	104	104	103	100	-	-	-	-	104	104	112	114	-	-	-	-	105	104	98	103
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L	0.03 -	0.1 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 -
Silica (as SiO_2)	mg/L	41.8 -	41.5 -	13.5 -	1.7 -	43.3 -	43.5 -	25.7 -	6.4 -	41.7 -	42.3 -	34.2 -	31.8 -	43.8 -	42.8 -	39.9 -	39.6 -	41.7 -	42.6 -	41.6 -	38.9 -
Turbidity	NTU	0.3 -	<0.1 -	<0.1 -	<0.1 -	<0.1 -	0.1 -	0.2 -	0.2 -	0.2 -	0.4 -	0.2 -	0.2 -	1.1 -	0.4 -	0.6 -	0.3 -	0.7 -	0.3 -	0.2 -	0.3 -
pH	S.U.	8.2	7.4	7.1	7.3	8.2	7.2	7.2	7.2	8.1	8.1	7.4	7.3	8.0	8.0	7.1	7.1	8.1	7.1	7.3	7.4
Temperature	^0C	26.6	26.7	24.8	24.7	24.1	24.0	24.0	23.0	23.5	23.5	23.2	23.1	25.7	25.9	25.1	24.2	26.7	26.5	26.2	26.2
DO	mg/L	1.8	2.3	0.9	1.3	1.5	1.5	1.8	2.0	2.1	2.2	2.1	2.0	2.4	1.6	1.5	1.4	1.3	1.4	1.5	1.3
ORP	mV	325	679	387	371	379	592	499	425	234	533	671	686	257	538	690	700	239	465	605	680
Free Chlorine (as Cl_2)	mg/L	-	1.0	0.1	-	-	0.6	-	-	-	2.0	-	1.5	-	1.5	-	1.7	-	1.6	-	1.7
Total Chlorine (as Cl_2)	mg/L	-	1.6	0.3	-	-	-	-	-	-	2.1	-	2.1	-	1.8	-	1.7	-	1.5	-	1.7
Total Hardness (as $CaCO_3$)	mg/L	17.1	19.3	27.9	47.2	-	-	-	-	19.4	19.1	11.6	15.8	-	-	-	-	23.7	22.2	33.0	17.1
Ca Hardness (as $CaCO_3$)	mg/L	11.3	13.4	17.2	29.4	-	-	-	-	12.0	11.9	7.6	9.9	-	-	-	-	17.0	16.9	25.1	13.8
Mg Hardness (as $CaCO_3$)	mg/L	5.8	5.9	10.7	17.9	-	-	-	-	7.4	7.2	4.0	5.9	-	-	-	-	6.7	5.3	7.9	3.3
As (total)	µg/L	51.4 -	62.2 -	3.9 -	4.0 -	55.7 -	55.8 -	3.6 -	3.5 -	51.5 -	60.1 -	1.8 -	1.5 -	58.8 -	60.4 -	4.6 -	6.3 -	61.4 -	56.2 -	3.4 -	2.8 -
As (soluble)	µg/L	53.1	61.0	3.4	2.2	-	-	-	-	56.5	51.3	1.3	1.3	-	-	-	-	54.3	50.8	3.0	2.9
As (particulate)	µg/L	<0.1	1.2	0.5	1.8	-	-	-	-	<0.1	8.7	0.4	0.2	-	-	-	-	7.1	5.4	0.4	<0.1
As (III)	µg/L	35.8	3.3	2.9	1.6	-	-	-	-	40.4	1.5	1.2	1.2	-	-	-	-	40.8	3.1	2.9	2.4
As (V)	µg/L	17.3	57.7	0.6	0.5	-	-	-	-	16.1	49.8	0.2	<0.1	-	-	-	-	13.5	47.7	0.1	0.5
Fe (total)	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	28.8 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	4.3 -	4.3 -	1.8 -	5.0 -	3.7 -	3.4 -	1.1 -	1.1 -	3.9 -	3.3 -	<0.1 -	<0.1 -	4.5 -	4.4 -	0.5 -	0.2 -	3.2 -	3.4 -	<0.1 -	<0.1 -
Mn (soluble)	µg/L	4.2	3.4	1.6	5.1	-	-	-	-	3.7	3.3	<0.1	0.2	-	-	-	-	3.6	3.5	<0.1	<0.1

(a) Chlorine measurements taken on 12/09/05.
(b) Water quality measurements taken on 12/15/05.
IN = at wellhead; AP = after pH adjustment; TA = after Tank A; TB = after Tank B.
NA = not available.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		02/15/06				02/28/06[a]				03/14/06				03/28/06[b]				04/11/06[c]			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	2.8	2.8	-	-	3.3	3.3	-	-	3.6	3.6	-	-	4.7	4.7	-	-	6.0	6.0
Alkalinity ($CaCO_3$)	mg/L	324 -	324 -	316 -	328 -	322 314	314 318	322 310	335 327	314 -	310 -	322 -	327 -	325 -	321 -	325 -	325 -	311 -	307 -	315 -	315 -
Fluoride	mg/L	-	-	-	-	-	-	-	-	0.7	0.8	0.8	0.8	-	-	-	-	0.7	0.8	0.8	0.8
Sulfate	mg/L	-	-	-	-	-	-	-	-	107	107	106	106	-	-	-	-	106	106	107	108
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L	<0.03 -	<0.03 -	<0.03 -	<0.03 -	<0.03 <0.03	<0.03 <0.03	<0.03 <0.03	<0.03 <0.03	<0.01 -	<0.01 -	<0.01 -	<0.01 -	- -	- -	- -	- -	<0.01 -	<0.01 -	<0.01 -	<0.01 -
Silica (as SiO_2)	mg/L	41.5 -	42.3 -	43.3 -	40.2 -	40.6 40.7	41.6 41.0	41.8 41.5	41.3 41.2	41.5 -	40.6 -	41.1 -	38.7 -	41.7 -	42.1 -	42.6 -	42.1 -	40.9 -	40.2 -	40.5 -	42.7 -
Turbidity	NTU	1.0 -	1.5 -	1.1 -	2.0 -	0.4 0.4	0.2 0.2	0.2 0.3	0.2 0.2	0.6 -	0.4 -	0.3 -	0.7 -	0.9 -	0.9 -	0.9 -	0.8 -	0.7 -	0.5 -	0.5 -	0.6 -
pH	S.U.	8.1	7.2	7.3	7.2	NA	NA	NA	NA	8.2	7.3	7.3	7.3	8.2	7.5	7.6	7.5	NA	NA	NA	NA
Temperature	^0C	26.7	26.9	27.0	27.1	NA	NA	NA	NA	26.3	26.7	26.5	26.6	26.5	27.2	27.4	27.4	NA	NA	NA	NA
DO	mg/L	1.1	1.6	1.5	2.1	NA	NA	NA	NA	1.6	1.7	1.3	2.3	1.5	1.8	1.8	1.9	NA	NA	NA	NA
ORP	mV	258	546	631	663	NA	NA	NA	NA	238	569	657	662	259	309	532	587	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	0.6	-	0.9	-	NA	-	NA	-	0.8	-	1.0	-	0.5	-	0.9	-	NA	-	NA
Total Chlorine (as Cl_2)	mg/L	-	0.7	-	1.0	-	NA	-	NA	-	1.1	-	1.2	-	1.2	-	1.0	-	NA	-	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	20.1	21.2	22.2	24.2	-	-	-	-	30.1	30.0	27.9	29.6
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	13.3	13.9	14.3	15.6	-	-	-	-	22.7	22.8	21.3	22.6
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	6.8	7.3	8.0	8.5	-	-	-	-	7.4	7.2	6.6	6.9
As (total)	µg/L	61.2 -	64.4 -	4.2 -	3.9 -	61.8 57.6	61.9 57.4	2.7 2.6	2.2 2.4	60.3 -	62.3 -	2.2 -	1.7 -	46.2 -	50.2 -	1.4 -	1.1 -	55.4 -	57.2 -	1.0 -	0.6 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-	51.9	53.5	1.5	1.5	-	-	-	-	51.5	51.6	0.8	0.6
As (particulate)	µg/L	-	-	-	-	-	-	-	-	8.3	8.9	0.7	0.2	-	-	-	-	3.8	5.6	0.2	<0.1
As (III)	µg/L	-	-	-	-	-	-	-	-	38.7	1.9	1.3	1.3	-	-	-	-	36.5	0.5	0.5	0.4
As (V)	µg/L	-	-	-	-	-	-	-	-	13.2	51.6	0.2	0.2	-	-	-	-	15.0	51.1	0.3	0.2
Fe (total)	µg/L	<25 -	<25 -	<25 -	<25 -	<25 <25	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	3.2 -	3.1 -	0.6 -	0.3 -	5.1 5.4	3.2 4.6	<0.1 <0.1	<0.1 <0.1	4.1 -	3.2 -	0.3 -	0.2 -	4.9 -	3.7 -	0.3 -	0.1 -	3.5 -	3.5 -	<0.1 -	<0.1 -
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	4.1	3.1	0.3	0.2	-	-	-	-	3.6	3.4	<0.1	<0.1

(a) Water quality parameters not measured.
(b) Water quality measurements taken on 04/05/06.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		04/25/06[c]				05/09/06[d]				05/23/06[e]				06/06/06[f]				06/20/06[g]			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	7.7	3.8	-	-	9.4	4.7	-	-	11.0	5.5	-	-	12.1	6.0	-	-	14.2	7.1
Alkalinity ($CaCO_3$)	mg/L	331 -	344 -	331 -	344 -	310 -	306 -	294 -	314 -	313 -	326 -	338 -	318 -	305 -	318 -	313 -	318 -	318 -	318 -	330 -	330 -
Fluoride	mg/L	-	-	-	-	0.9	1.2	1.5	1.0	-	-	-	-	0.7	0.8	0.8	0.8	-	-	-	-
Sulfate	mg/L	-	-	-	-	111	112	113	113	-	-	-	-	107	112	114	136	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-
Total P (as PO_4)	mg/L	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	40.8 -	40.8 -	41.3 -	41.2 -	41.8 -	42.3 -	42.7 -	42.1 -	42.8 -	41.6 -	41.7 -	38.1 -	43.9 -	43.2 -	44.4 -	45.3 -	43.9 -	44.9 -	45.6 -	41.0 -
Turbidity	NTU	0.2 -	0.2 -	0.7 -	0.1 -	0.2 -	0.2 -	0.2 -	0.3 -	0.3 -	0.5 -	0.3 -	0.2 -	0.6 -	0.5 -	0.7 -	0.8 -	0.7 -	0.7 -	0.6 -	0.6 -
pH	S.U.	8.2	7.4	7.3	7.4	8.1	7.2	7.3	7.3	8.3	7.6	7.5	7.5	8.2	7.3	7.2	7.3	8.2	7.6	7.6	7.5
Temperature	^0C	26.5	26.3	26.7	26.6	27.1	27.2	27.5	27.3	21.3	21.2	21.4	21.4	26.4	26.6	27.1	27.1	26.7	26.6	26.9	26.7
DO	mg/L	1.3	1.6	1.6	2.0	1.3	1.8	2.1	2.4	3.1	4.1	3.4	3.5	2.1	2.6	2.1	2.2	1.7	2.6	2.1	1.9
ORP	mV	327	603	650	623	279	499	610	643	271	546	597	636	299	537	594	620	234	476	516	533
Free Chlorine (as Cl_2)	mg/L	-	0.8	-	0.7	-	1.1	-	1.5	-	0.5	-	0.6	-	0.9	-	0.7	-	0.9	-	0.6
Total Chlorine (as Cl_2)	mg/L	-	1.1	-	0.8	-	1.2	-	1.5	-	0.8	-	0.7	-	0.9	-	0.8	-	1.0	-	0.6
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	28.6	29.3	26.8	29.8	-	-	-	-	20.2	19.8	21.0	20.5	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	19.7	20.2	18.3	21.1	-	-	-	-	12.4	12.2	13.0	12.7	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	9.0	9.1	8.5	8.8	-	-	-	-	7.8	7.6	8.0	7.8	-	-	-	-
As (total)	µg/L	56.5 -	59.5 -	1.1 -	0.9 -	62.9 -	63.8 -	1.0 -	0.6 -	54.8 -	50.4 -	1.3 -	0.6 -	58.5 -	57.6 -	1.1 -	0.8 -	67.3 -	66.4 -	3.8 -	1.0 -
As (soluble)	µg/L	-	-	-	-	54.3	55.4	0.8	0.6	-	-	-	-	52.3	51.6	1.1	0.8	-	-	-	-
As (particulate)	µg/L	-	-	-	-	8.6	8.4	0.2	<0.1	-	-	-	-	6.2	6.1	<0.1	<0.1	-	-	-	-
As (III)	µg/L	-	-	-	-	40.2	0.7	0.5	0.5	-	-	-	-	37.0	0.8	0.7	0.6	-	-	-	-
As (V)	µg/L	-	-	-	-	14.1	54.6	0.3	0.1	-	-	-	-	15.3	50.8	0.5	0.2	-	-	-	-
Fe (total)	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	28 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	3.1 -	2.9 -	<0.1 -	<0.1 -	3.3 -	3.1 -	<0.1 -	<0.1 -	3.9 -	2.9 -	<0.1 -	<0.1 -	2.6 -	3.0 -	<0.1 -	0.1 -	4.9 -	3.7 -	0.5 -	0.4 -
Mn (soluble)	µg/L	-	-	-	-	3.3	3.1	<0.1	<0.1	-	-	-	-	2.6	3.0	<0.1	<0.1	-	-	-	-

(c) Water quality measurements taken on 04/20/06.
(d) Water quality measurements taken on 05/04/06.
(e) Water quality measurements taken on 05/12/06.
(f) Water quality measurements taken on 06/01/06.
(g) Water quality measurements taken on 06/19/06.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		07/11/06				07/19/06[c]				08/02/06				08/16/06[d]				08/30/06[e]			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	15.5	7.8	-	-	16.4	8.2	-	-	18.1	9.0	-	-	20.3	10.2	-	-	22.6	11.3
Alkalinity ($CaCO_3$)	mg/L	320 -	324 -	328 -	NA -	319 315	315 315	319 319	315 315	316 -	320 -	312 -	312 -	310 -	302 -	298 -	314 -	342 -	353 -	340 -	351 -
Fluoride	mg/L	0.8	1.0	1.0	1.0	-	-	-	-	1.1	1.3	1.3	1.3	-	-	-	-	0.2	0.9	0.9	0.9
Sulfate	mg/L	137	108	106	110	-	-	-	-	91	107	110	112	-	-	-	-	129	131	140	132
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05
Total P (as PO_4)	mg/L	<10 -	<10 -	<10 -	<10 -	<10 <10	<10 <10	<10 <10	<10 <10	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	42.3 -	42.2 -	42.1 -	42.0 -	41.2 41.4	41.6 41.6	39.9 39.7	40.2 39.7	40.2 -	40.9 -	38.9 -	37.6 -	42.3 -	42.5 -	41.7 -	43.8 -	39.1 -	39.4 -	39.2 -	39.9 -
Turbidity	NTU	1.0 -	0.5 -	0.6 -	NA -	0.4 0.4	0.2 0.1	0.2 0.2	0.3 0.3	0.2 -	0.2 -	0.2 -	0.2 -	0.5 -	0.3 -	0.1 -	0.2 -	0.4 -	0.2 -	0.4 -	0.3 -
pH	S.U.	NA	NA	NA	NA	8.1	7.4	7.8	7.7	NA	NA	NA	NA	8.2	7.3	7.3	7.5	8.1	7.3	7.3	7.3
Temperature	^0C	NA	NA	NA	NA	26.3	26.8	27.0	27.0	NA	NA	NA	NA	26.3	27.0	26.9	27.1	25.8	26.3	26.4	26.4
DO	mg/L	NA	NA	NA	NA	2.3	2.5	2.2	2.4	NA	NA	NA	NA	2.4	2.2	2.3	2.2	3.3	2.4	2.3	2.3
ORP	mV	NA	NA	NA	NA	310	390	337	312	NA	NA	NA	NA	292	478	507	493	259	603	618	621
Free Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	0.6	-	0.4	-	NA	-	NA	-	0.8	-	0.4	-	0.8	-	0.6
Total Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	0.7	-	0.5	-	NA	-	NA	-	0.8	-	0.5	-	1.2	-	1.0
Total Hardness (as $CaCO_3$)	mg/L	20.0	20.4	19.7	18.7	-	-	-	-	25.3	23.9	16.9	17.9	-	-	-	-	24.5	24.9	21.9	25.1
Ca Hardness (as $CaCO_3$)	mg/L	12.6	12.8	12.6	12.1	-	-	-	-	18.1	16.4	11.9	12.2	-	-	-	-	17.1	17.6	15.4	16.9
Mg Hardness (as $CaCO_3$)	mg/L	7.4	7.6	7.1	6.6	-	-	-	-	7.2	7.5	5.0	5.8	-	-	-	-	7.4	7.3	6.5	8.2
As (total)	µg/L	54.8 -	56.4 -	2.4 -	0.8 -	60.2 61.8	61.3 60.2	2.6 2.4	0.8 0.8	63.9 -	64.0 -	8.7 -	0.5 -	50.6 -	51.6 -	3.3 -	1.1 -	68.7 -	69.3 -	6.4 -	1.3 -
As (soluble)	µg/L	50.4	52.0	2.0	0.7	-	-	-	-	54.4	56.9	7.7	0.4	-	-	-	-	56.4	56.5	5.3	1.3
As (particulate)	µg/L	4.4	4.4	0.4	<0.1	-	-	-	-	9.5	7.1	1.0	<0.1	-	-	-	-	12.3	12.7	1.1	<0.1
As (III)	µg/L	34.2	0.7	0.7	0.6	-	-	-	-	40.7	0.5	0.4	0.4	-	-	-	-	42.0	1.2	1.1	1.0
As (V)	µg/L	16.2	51.3	1.3	0.1	-	-	-	-	13.7	56.4	7.3	<0.1	-	-	-	-	14.4	55.4	4.2	0.3
Fe (total)	µg/L	49 -	<25 -	<25 -	<25 -	<25 <25	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	38	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-	<25	<25	<25	<25
Mn (total)	µg/L	6.0 -	4.0 -	0.7 -	0.6 -	3.7 3.7	3.2 3.0	0.2 0.2	0.1 0.1	3.5 -	3.4 -	0.1 -	0.1 -	3.4 -	3.1 -	0.2 -	0.1 -	3.4 -	3.4 -	0.2 -	<0.1 -
Mn (soluble)	µg/L	5.4	3.4	0.1	<0.1	-	-	-	-	3.5	3.2	0.2	0.2	-	-	-	-	3.5	3.4	0.2	<0.1

(c) Water quality measurements taken on 07/24/06.
(d) Water quality measurements taken on 08/14/06.
(e) Water quality measurements taken on 08/31/06.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		09/15/06				09/28/06				10/11/06				10/31/06				11/08/06[(c)]			
Sampling Location / Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	24.0	12.0	-	-	24.4	12.2	-	-	25.0	12.5	-	-	25.6	12.8	-	-	26.2	13.1
Alkalinity ($CaCO_3$)	mg/L	335	337	342	342	344	347	331	349	355	353	349	349	350	352	342	361	340	345	336	349
		-	-	-	-	-	-	-	-	349	349	331	344	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	0.5	0.5	0.5	0.5	-	-	-	-	0.7	0.7	0.9	0.7	-	-	-	-
Sulfate	mg/L	-	-	-	-	105	102	104	105	-	-	-	-	117	117	120	117	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-	<0.05	<0.05	<0.05	<0.05	-	-	-	-
Total P (as PO_4)	mg/L	<10	<10	<10	<10	<10	10.0	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
		-	-	-	-	-	-	-	-	<10	<10	<10	<10	-	-	-	-	-	-	-	-
Silica (as SiO_2)	mg/L	41.7	41.3	42.5	44.3	40.5	39.9	40.2	41.8	39.6	42.7	41.8	42.6	40.5	40.5	42.6	48.5	39.9	40.1	39.8	41.3
		-	-	-	-	-	-	-	-	42.2	42.0	41.1	41.7	-	-	-	-	-	-	-	-
Turbidity	NTU	0.4	0.9	0.5	0.4	0.3	0.3	0.4	0.4	1.2	0.6	0.5	0.4	1.1	0.7	0.6	0.7	0.8	0.8	1.3	1.2
		-	-	-	-	-	-	-	-	1.0	0.8	0.7	0.8	-	-	-	-	-	-	-	-
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8.2	7.2	7.3	7.2
Temperature	^0C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	26.3	26.9	26.8	26.8
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.0	1.9	2.3	1.8
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	284	507	646	646
Free Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	0.9	-	0.7
Total Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	1.8	-	1.1
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	25.7	26.8	26.9	30.1	-	-	-	-	23.9	24.0	27.3	41.2	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	18.7	19.3	19.4	21.8	-	-	-	-	16.7	16.7	20.6	32.5	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	7.0	7.5	7.6	8.3	-	-	-	-	7.2	7.3	6.7	8.7	-	-	-	-
As (total)	µg/L	53.1	51.6	4.8	1.0	56.4	58.1	3.2	1.1	53.9	53.0	3.5	1.1	58.7	58.6	2.8	0.6	62.0	64.0	4.4	2.1
		-	-	-	-	-	-	-	-	50.5	51.1	3.2	1.1	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	52.3	53.1	3.2	1.0	-	-	-	-	53.4	53.0	2.3	0.6	-	-	-	-
As (particulate)	µg/L	-	-	-	-	4.1	5.0	<0.1	<0.1	-	-	-	-	5.3	5.7	0.6	<0.1	-	-	-	-
As (III)	µg/L	-	-	-	-	37.9	0.9	0.7	0.5	-	-	-	-	36.9	0.7	0.4	0.3	-	-	-	-
As (V)	µg/L	-	-	-	-	14.4	52.3	2.5	0.5	-	-	-	-	16.5	52.3	1.9	0.2	-	-	-	-
Fe (total)	µg/L	76	190	29	<25	163	<25	29.6	<25	79	<25	<25	<25	<25	<25	<25	<25	46	<25	<25	<25
		-	-	-	-	-	-	-	-	113	<25	<25	<25	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	134	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	2.9	13.6	<0.1	<0.1	14.7	3.5	0.6	0.3	10.1	4.0	0.9	<0.1	6.3	3.3	0.8	0.3	8.6	4.7	0.5	0.2
		-	-	-	-	-	-	-	-	12.3	3.6	0.9	<0.1	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	14.5	3.5	0.5	0.2	-	-	-	-	6.1	3.1	0.5	0.2	-	-	-	-

(c)Water quality measurements taken on 11/10/06.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		11/28/06[c]				12/12/06				01/22/07[d]				02/13/07[e,f]				03/13/07			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	26.8	13.4	-	-	27.1	13.6	-	-	28.0	14.0	-	-	28.7	14.4	-	-	30.0	15.0
Alkalinity ($CaCO_3$)	mg/L	357 -	357 -	368 -	402 -	325 -	339 -	337 -	331 -	335 -	339 -	339 -	328 -	- -	- -	- -	- -	- -	- -	- -	- -
Fluoride	mg/L	0.8	0.8	0.8	0.7	0.6	0.8	0.8	0.8	0.8	1.0	0.9	0.9	-	-	-	-	-	-	-	-
Sulfate	mg/L	122	125	129	124	110	111	109	108	96	104	121	127	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	190 -	214 -	203 -	167 -	13.7 -	12.5 -	5 -	10.8 -
Silica (as SiO_2)	mg/L	41.9 -	41.2 -	47.0 -	25.0 -	41.6 -	41.8 -	40.9 -	40.7 -	40.6 -	40.8 -	38.6 -	37.8 -	41.8 -	42.8 -	40.7 -	42.4 -	41.0 -	41.4 -	50.6 -	95.8 -
Turbidity	NTU	0.8 -	0.8 -	0.7 -	0.6 -	0.2 -	0.1 -	0.2 -	0.2 -	0.5 -	0.6 -	0.5 -	0.4 -	- -	- -	- -	- -	- -	- -	- -	- -
pH	S.U.	8.2	7.4	7.0	7.0	NA	NA	NA	NA	8.3	7.6	7.1	7.2	8.3	7.4	7.0	7.1	NA	NA	NA	NA
Temperature	^0C	24.5	25.3	22.4	21.2	NA	NA	NA	NA	25.0	25.0	25.0	25.0	25.0	NM	NM	NM	NA	NA	NA	NA
DO	mg/L	2.2	1.7	2.1	2.0	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NM	NM	NA	NA	NA	NA
ORP	mV	264	563	666	678	NA	NA	NA	NA	NM	NM	NM	NM	NM	NM	NM	NM	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	0.4	-	0.5	-	NA	-	NA	-	NM	-	NM	-	0.8	-	1.0	-	NA	-	NA
Total Chlorine (as Cl_2)	mg/L	-	0.6	-	1.8	-	NA	-	NA	-	NM	-	NM	-	1.0	-	1.1	-	NA	-	NA
Total Hardness (as $CaCO_3$)	mg/L	24.8	21.9	31.1	49.9	23.7	23.0	25.1	22.3	21.9	22.0	17.0	14.3	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	15.8	13.8	17.7	26.6	16.0	15.7	17.2	15.3	14.6	14.7	11.7	10.0	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	9.0	8.1	13.4	23.3	7.7	7.2	8.0	7.0	7.4	7.3	5.2	4.3	-	-	-	-	-	-	-	-
As (total)	µg/L	46.0 -	47.4 -	4.0 -	1.5 -	59.0 -	58.8 -	3.4 -	1.3 -	58.4 -	63.6 -	5.2 -	1.7 -	55.7 -	53.7 -	1.1 -	2.3 -	60.2 -	61.0 -	3.2 -	1.1 -
As (soluble)	µg/L	44.6	44.5	3.8	0.7	55.2	56.3	3.1	1.3	55.1	56.3	4.7	1.8	51.6	51.2	0.8	2.0	53.7	52.2	1.9	1.0
As (particulate)	µg/L	1.4	2.9	0.2	0.8	3.8	2.5	0.3	<0.1	3.3	7.3	0.4	<0.1	4.1	2.5	0.3	0.2	6.5	8.7	1.3	<0.1
As (III)	µg/L	32.5	1.1	1.0	0.6	37.8	1.4	1.1	0.9	31.3	1.7	1.6	1.5	41.6	0.9	0.6	0.5	34.1	0.9	0.6	0.9
As (V)	µg/L	12.1	43.3	2.7	0.2	17.5	54.9	2.1	0.4	23.8	54.6	3.1	0.4	10.0	50.3	0.2	1.6	19.7	51.4	1.3	0.1
Fe (total)	µg/L	<25 -	67 -	40 -	<25 -	53 -	43 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	- -	- -	- -	- -	- -	- -	- -	- -
Fe (soluble)	µg/L	<25	62	31	<25	<25	33	<25	<25	<25	<25	<25	<25	-	-	-	-	-	-	-	-
Mn (total)	µg/L	3.8 -	5.2 -	1.3 -	0.3 -	4.9 -	4.7 -	0.8 -	0.3 -	4.4 -	3.0 -	0.2 -	<0.1 -	- -	- -	- -	- -	- -	- -	- -	- -
Mn (soluble)	µg/L	3.8	5.2	1.2	0.2	4.6	4.6	0.6	0.2	4.5	2.9	0.4	0.3	-	-	-	-	-	-	-	-

(c) Water quality measurements taken on 12/04/06.
(d) Water quality measurements taken on 01/17/07.
(e) Only As speciation samples collected starting 02/13/07.
(f) Water quality measurements taken on 02/09/07.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		04/17/07				05/09/07				06/05/07				09/20/07				02/21/08[d]			
Sampling Location Parameter	Unit	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB	IN	AP	TA	TB
Bed Volume	10^3	-	-	30.8	15.4	-	-	32.2	16.1	-	-	33.1	16.6	-	-	41.0[c]	20.5[c]	-	-	50.4[c]	25.2[c]
Alkalinity ($CaCO_3$)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Silica (as SiO_2)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Turbidity	NTU	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	^{0}C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (total)	µg/L	67.5 -	69.1 -	4.7 -	1.5 -	54.2 -	59.4 -	5.7 -	2.0 -	51.3 -	49.8 -	3.5 -	0.2 -	NA -	56.1 -	9.6 -	1.2 -	60.4 -	88.4 -	17.5 -	16.9 -
As (soluble)	µg/L	55.8	54.4	3.8	1.3	46.4	49.7	5.2	2.4	46.4	46.7	3.2	0.1	-	-	-	-	-	-	-	-
As (particulate)	µg/L	11.8	14.6	0.9	0.2	7.8	9.7	0.5	<0.1	4.9	3.0	0.3	<0.1	-	-	-	-	-	-	-	-
As (III)	µg/L	35.3	1.2	0.9	0.9	35.4	1.2	1.3	1.8	40.4	0.4	0.2	<0.1	-	-	-	-	-	-	-	-
As (V)	µg/L	20.5	53.2	2.8	0.4	11.0	48.5	3.9	0.6	6.1	46.4	3.0	<0.1	-	-	-	-	-	-	-	-
Fe (total)	µg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(c) Operational data no longer available from operator. Bed volumes estimated based on historical measurements.
(d) IN sample taken on 02/24/08.

Table B-1. Analytical Results from Treatment Plant Sampling at Bruni, TX (Continued)

Sampling Date		04/16/08				05/15/08			
Sampling Location		IN	AP	TA	TB	IN	AP	TA	TB
Parameter	Unit								
Bed Volume	10^3	-	-	53.7[(c)]	26.7[(c)]	-	-	54.7[(c)]	27.4[(c)]
Alkalinity ($CaCO_3$)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -
Fluoride	mg/L	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-
Total P (as PO_4)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -
Silica (as SiO_2)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -
Turbidity	NTU	- -	- -	- -	- -	- -	- -	- -	- -
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	^0C	NA	NA	NA	NA	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	-	NA	-	NA	-	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	-	-	-	-
As (total)	µg/L	59.2 -	57.2 -	27.6 -	0.8 -	59.9 -	57.7 -	45.4 -	5.2 -
As (soluble)	µg/L	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-
Fe (total)	µg/L	- -	- -	- -	- -	- -	- -	- -	- -
Fe (soluble)	µg/L	-	-	-	-	-	-	-	-
Mn (total)	µg/L	- -	- -	- -	- -	- -	- -	- -	- -
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-

(c) Operational data no longer available from operator. Bed volumes estimated based on historical measurements.