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

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Sally Gutierrez, Director
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ABSTRACT

This report documents the activities performed and the results obtained from the arsenic removal treatment technology demonstration project in the City of Wellman, 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. This project also evaluated (1) the reliability of the treatment system (Arsenic Package Unit [APU]-100CS-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 any residuals produced by the treatment process. The types of data collected included system operation, water quality parameters (both across the treatment train and in the distribution system), and capital and O&M cost.

The Wellman water system is supplied by five groundwater wells. Four are located in close proximity to a 110,000-gal water tank and an underground well-manifold vault, and the fifth is located approximately 3 miles southwest. The combined flowrate from the first four wells is 50 gal/min (gpm), and the flowrate from the fifth is 40 gpm. Therefore, the total flowrate is approximately 90 gpm. Operating simultaneously 4 to 6 hr at a time, the wells are used to meet the average daily demand of approximately 26,000 gal in the winter and 50,000 gal in the summer.

The newly constructed treatment building is located adjacent to the water tank and underground vault. The treatment system consisted of two 48-in-diameter, 72-in-tall carbon steel vessels in parallel configuration, each containing approximately 38 ft^3 of E33 pelletized media – an iron-based adsorptive media developed by Bayer AG and marketed by AdEdge Technologies under the name of AD-33. The treatment system was designed for a maximum flowrate of 100 gpm and an empty bed contact time (EBCT) of approximately 5.7 min.

Over the performance evaluation period, the average calculated flowrate was 118 gpm, based on readings of two electromagnetic flow meters/totalizers installed on the adsorption vessels and an hour meter interconnected to the flow meters/totalizers. This average calculated flowrate (118 gpm) was significantly greater than that of a master totalizer (91 gpm) installed at the common well manifold and the design flowrate value of 100 gpm. Based on a one-day flowrate test using a portable ultrasonic flow meter and statistical analysis, it was determined that the electromagnetic flow meters/totalizers were the least accurate of the available meters. Therefore, the master totalizer was used to track the amount of water treated during the performance evaluation study.

The AdEdge treatment system began regular operation on August 10, 2006. Between August 10, 2006, and April 17, 2008, the system operated an average of 5.9 hr/day, treating approximately 14,744,962 gal of water or 25,938 bed volumes (BV) based on the 76 ft^3 of media in both adsorption vessels.

Total arsenic concentrations measured at the common well manifold (IN) varied significantly, ranging from 6.0 to 50.6 μg/L. Soluble As(V) was the predominating species, ranging from 6.1 to 43.8 μg/L; soluble As(III) concentrations ranged from less than the method detection limit (MDL) to 6.0 μg/L. A review of the significant variations measured in the IN samples indicated that system operations and sampling techniques were likely contributing to the variations in concentration. In fact, the after chlorination (AC) sample results provided concentrations in a more representative range of the true water quality based on historical sampling events. The total arsenic concentrations in the AC samples ranged from 37.5 to 50.0 μg/L. Soluble As(V) in the AC samples remained predominant, ranging from 35.2 to 42.9 μg/L; soluble As(III) concentrations ranged from less than the MDL to 11.4 μg/L. At the end of this

performance evaluation study on April 17, 2008, total arsenic concentrations in the treated water were 6.8 and 2.3 µg/L from Vessels A and B, respectively, – less than the target 10-µg/L MCL.

Concentrations of vanadium, phosphate, and silica, which could adversely affect arsenic adsorption by competing with arsenate for adsorption sites, averaged 136 µg/L, <10 µg/L (as P), and 46.2 mg/L (as SiO_2), respectively, in the AC samples. Vanadium existed entirely in the soluble form, some of which was removed during the first 10,000 BV. Concentrations of iron, manganese, and other ions in raw water were not considered significant enough to impact arsenic removal by the adsorptive 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 38.9 µg/L to an average of 3.2 µg/L). The arsenic concentrations in the distribution system were similar to those in the system effluent. Lead and copper concentrations in the distribution system remained below their respective action levels of 15 and 1,300 µg/L. Overall, their concentrations were not adversely affected by system operation.

The capital investment cost of $149,221 included $103,897 for equipment, $25,310 for site engineering, and $20,014 for installation. Using the system's rated capacity of 100 gpm (or 144,000 gal/day [gpd]), the capital cost was $1,492/gpm (or $1.04/gpd) of design capacity. The capital cost also was converted to an annualized cost of $14,085/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 hr a day, 7 days a week at the system design flowrate of 100 gpm to produce 52,560,000 gal of water per year, the unit capital cost would be $0.27/1,000 gal. Because the system actually operated an average of 5.9 hr/day at an average flowrate of approximately 91 gpm, the approximate annual water production was 11,758,000 gal, and the actual unit capital cost was $1.20/1,000 gal of water.

The O&M cost included only incremental cost associated with the adsorption system, such as media replacement and disposal, chlorine usage, electricity consumption, and labor. Although media replacement did not occur during the evaluation period, the media replacement cost would represent the majority of the O&M cost and was estimated to be $30,010 to change out both vessels (including 76 ft^3 AD-33 media and associated labor for media changeout and disposal).

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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 System
BET	Brunauer, Emmett, and Teller
BV	bed volume
Ca	calcium
C/F	coagulation/filtration process
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
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HCl	hydrochloric acid
HDPE	high-density polyethylene
HIX	hybrid ion exchange
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	Lead and Copper Rule
LOU	Letter of Understanding
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
ND	not detectable
NRMRL	National Risk Management Research Laboratory
NTU	Nephelometric Turbidity Units
O&M	operation and maintenance
OIT	Oregon Institute of Technology
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PLC	programmable logic controller
psi	pounds per square inch
PO_4	orthophosphate
POE	point of entry
POU	point of use
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA	quality assurance
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
TOC	total organic carbon
U	uranium
V	vanadium
VOC	volatile organic compounds
WTW	Wissenschaftlich-Technische-Werkstätten

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1.0 INTRODUCTION

1.1 Background

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

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance cost. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, 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 of the 115 candidate sites to host the demonstration studies.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic-removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving one to six proposals. In April 2003, an independent technical panel reviewed the proposals and 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 City of Wellman, 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 two to eight proposals. In April 2004, EPA convened another technical panel to review the proposals and provide recommendations to EPA; the number of proposals per site ranged from none (for two sites) to a maximum of four. Final selection of the treatment technology at sites receiving at least one proposal was made through a joint effort by EPA, the state regulators, and the host site. Since then, four sites have withdrawn from the demonstration program, reducing the number of sites to 28. AdEdge Technologies' (AdEdge) Bayoxide E33 granular media (developed by Bayer AG) was selected for demonstration at the Wellman site.

As of December 2009, 39 of the 40 systems were operational, and the performance evaluation of 34 systems was completed.

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the Rounds 1 and 2 demonstration host sites included 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 Rounds 1 and 2 arsenic demonstration program is to conduct full-scale arsenic treatment technology demonstration studies on the removal of arsenic from drinking-water supplies. The specific objectives are to:

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

This report summarizes the performance of the AdEdge system at the City of Wellman, TX, from August 10, 2006, through April 17, 2008. The types of data collected included system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and preliminary O&M cost.

Table 1-1. Summary of Rounds 1 and 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 Rounds 1 and 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) 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.
(f) Including nine residential units.
(g) Including eight under-the-sink units.

2.0 SUMMARY AND CONCLUSIONS

AdEdge's Arsenic Package Unit [APU]-100CS-S-2-AVH treatment system with AD-33 pelletized media was installed and has operated in the City of Wellman, TX, since August 10, 2006. 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:

- The AD-33 media was effective at removing soluble As(V), the predominating arsenic species in raw water. During the evaluation period from August 10, 2006, through April 17, 2008, it was estimated that the system treated 14,744,962 gal or 25,938 bed volumes (BV) of water, leaving <3.3 µg/L (on average) of total arsenic in the treated water.
- The arsenic treatment system significantly reduced arsenic concentrations (from 38.9 to 3.2 µg/L, on average) in the distribution system. Impact of the treatment on lead and copper concentrations, however, was less significant, with lead concentrations remaining relatively unchanged from 0.2 to 0.4 µg/L (on average) and copper concentrations decreasing from 115 to 81.7 µg/L (on average).

Required system O&M and operator skill levels:

- The system was easy to operate and maintain. The daily demand on the operator was 15 min after system startup, but progressively decreased to only 3 min by the end of the evaluation period.
- Operation of the system did not require additional skills beyond those necessary to operate the existing water supply equipment, with the exception of the pH adjustment system. The pH adjustment system required additional operator training and safety awareness.
- The pre-existing master turbine flow meter/totalizer was used for flow measurements, because the electromagnetic flow meter/totalizer installed on the treatment system was determined to be inaccurate due to out-of-spec piping configuration.

Process residuals produced by the technology:

- The treatment system did not require backwash (because differential pressure [Δp] measured across the media vessels did not reach 10 pounds per square inch [psi], the Δp set point) and therefore did not produce any backwash residuals. Also, the system did not require a media changeout during the evaluation period because the effluent arsenic concentration did not reach 10 µg/L.

Cost-effectiveness of the technology:

- Based on the system's rated capacity of 100 gal/min (gpm) (or 144,000 gal/day [gpd]), the capital cost was $1,492/gpm (or $1.04/gpd) of design capacity. Assuming that the system operated 24 hr/day, 7 day/week at its rated capacity, the unit capital cost would be $0.27/1,000 gal. However, because the system actually operated an average of 5.9 hr/day at an average flowrate of approximately 91 gpm, the actual unit capital cost was $1.20/1,000 gal of water.

- Media replacement and subsequent disposal did not occur during the system evaluation period. The cost to change out two vessels (76 ft^3 AD-33 media) was estimated to be $30,010, which included the replacement media, spent media disposal, shipping, labor, and travel.
- The O&M cost did not include chemical cost for pH adjustment because acid was not used during the demonstration study.

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 August 10, 2006, and ended on April 17, 2008. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall performance of the system was 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 train, as described in a Performance Evaluation Study Plan (Battelle, 2005). The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The plant operator recorded unscheduled downtime and repair information on a Repair and Maintenance Log Sheet.

Table 3-1. Predemonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting Held	November 18, 2004
Project Planning Meeting Held	March 22, 2005
Draft LOU Issued	March 29, 2005
Final LOU Issued	April 12, 2005
Request for Quotation Issued to Vendor	April 20, 2005
Vendor Quotation Received by Battelle	May 30, 2005
Purchase Order Completed and Signed	June 28, 2005
Exception Request Submitted to TECQ	July 11, 2005
Engineering Plans Submitted to TCEQ	August 25, 2005
APU System Shipped and Arrived	October 14, 2005
Exception Request Granted by TCEQ	October 31, 2005
System Permit Issued by TCEQ	February 2, 2006
System Installation Completed	June 20, 2006
System Shakedown Completed	August 9, 2006
Final Study Plan Issued	December 28, 2005
Performance Evaluation Begun	August 10, 2006

LOU = letter of understanding; TCEQ = Texas Commission on Environmental Quality

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

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This task required tracking the capital cost for equipment, site engineering, and installation, as well as the O&M cost for media replacement and disposal, chlorine consumption, electrical power usage, and labor. Data on Wellman O&M cost were limited to electricity usage and labor because media replacement did not take place during the evaluation period and chlorine injection was part of the pre-existing treatment process.

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

Evaluation Objective	Data Collection
Performance	Ability to consistently meet 10 μg/L of arsenic in treated water
Reliability	Unscheduled system downtime Frequency and extent of repairs, including a description of problems, materials and supplies needed, and associated labor and cost
System O&M and Operator Skill Requirements	Pre- and post-treatment requirements Level of automation for system operation and data collection Staffing requirements, including number of operators and laborers Task analysis of preventive maintenance, including number, frequency, and complexity of tasks Chemical handling and inventory requirements General knowledge needed for relevant chemical processes and health and safety practices
Residual Management	Quantity and characteristics of aqueous and solid residuals generated by system operation
System Cost	Capital cost for equipment, site engineering, and installation O&M cost for chemical usage, electricity consumption, 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. The plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet; checked the sodium hypochlorite (NaOCl) tank level; and conducted visual inspections to ensure normal system operations. In the event of problems, the plant operator contacted the Battelle Study Lead, who determined if the vendor should be contacted for troubleshooting. The plant operator recorded all relevant information, including the 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 a Bi-Weekly Onsite Water Quality Parameters Log Sheet.

The capital cost for the arsenic-removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for media replacement and spent-media disposal, chemical and electricity consumption, and labor. The NaOCl consumption was tracked on the Daily System Operation Log Sheet. Because the chemical addition system was pre-existing, chlorine consumption was not counted toward the O&M cost. Electricity consumption was tracked through the onsite electric meter. Labor for various activities, such as routine system O&M, troubleshooting and repairs, and demonstration-related work, was 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 labor, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the system's performance, samples were collected from a common manifold containing raw water from five wells, across the treatment train, and from the distribution system. Table 3-3

Table 3-3. Sampling Schedule and Analytes

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Collection Date(s)
Source Water	Well 1 and IN[b]	2	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), Sb (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	11/18/04
Treatment Plant Water	IN, AC, TA, and TB	4	Regular Sampling Events: Monthly	Onsite[c]: pH, temperature, DO, ORP, and Cl_2 (free and total) Offsite: total As, Fe, Mn, P, and V, SiO_2, turbidity, and alkalinity	08/30/06, 09/20/06, 10/19/06, 11/15/06, 01/03/07, 02/06/07, 03/01/07, 03/28/07, 04/25/07, 05/24/07, 06/28/07, 07/23/07, 08/21/07, 09/27/07, 11/08/07[d], 12/05/07, 01/13/08, 02/20/08, 03/12/08, 04/17/08
	IN, AC, and TT	3	Speciation Sampling Events: Monthly	Same as above plus the following: Offsite: As(III) and As(V), Fe (soluble), Mn (soluble), V (soluble), Ca, Mg, F, NO_3, SO_4, and TOC	08/10/06, 09/06/06, 10/02/06, 11/02/06, 11/28/06, 12/14/06, 01/18/07, 02/13/07, 03/14/07, 04/18/07, 05/08/07, 06/14/07, 07/09/07, 08/14/07, 09/11/07, 10/10/07
Distribution Water	Three residences (including two Lead and Copper Rule [LCR] residences)	3	Monthly	Total As, Fe, Mn, Cu, V (total and soluble) and Pb, pH, and alkalinity	Baseline sampling[e]: 06/22/05, 07/14/05, 08/18/05, 09/14/05 Monthly sampling: 09/06/06, 10/10/06, 11/15/06, 12/14/06, 01/18/07, 02/21/07, 03/20/07, 04/18/07, 05/24/07, 06/14/07, 07/12/07, 08/22/07, 09/11/07

(a) Abbreviation (IN = at common well manifold; AC = after chlorination; TA = after Vessel A; TB = after Vessel B; TT = after Vessels A and B combined) corresponding to sample location in Figure 3-1.
(b) Speciation not performed at IN.
(c) Onsite measurements of chlorine not collected at IN.
(d) Starting November 8, 2007, treatment plant samples were analyzed only for total phosphate, arsenic, iron, manganese, and vanadium at locations IN, AC, TA, and TB.
(e) Sampling events performed before system startup.

provides the sampling schedule and analytes measured during each sampling event. In addition, Figure 3-1 presents a flow diagram of the treatment system, along with the analytes and schedules at each sampling location. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of an EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2004). The procedure for arsenic speciation is described in Appendix A of the QAPP.

3.3.1 Source Water. During the site visit on November 18, 2004, source-water samples were collected from Well 1 and a common well manifold (IN) containing water from all five wells and analyzed for the analytes listed in Table 3-3. Speciation was performed for Well 1 water using an arsenic speciation kit described in Section 3.4.1. The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation.

3.3.2 Treatment Plant Water. During the system performance evaluation study, treatment plant water samples were collected every other week for the onsite and offsite analyses shown in Table 3-3. For the speciation sampling events, samples were taken at IN, after chlorination (AC), and after Vessels A and B combined (TT); speciation was performed onsite during these events. For the regular sampling events, samples were collected at IN, AC, after Vessel A (TA), and after Vessel B (TB) without onsite speciation. Starting from November 8, 2007, only regular sampling was performed and the samples collected were analyzed only for total arsenic, iron, manganese, vanadium, and phosphorus.

3.3.3 Backwash Wastewater/Solids and Spent Media Samples. Because the system did not require backwash during the evaluation period, no backwash residuals were produced. Furthermore, no spent-media samples were collected, because media replacement was not necessary durng the performance evaluation study.

3.3.4 Distribution System Water. The plant operator collected samples from the distribution system to determine the impact of the arsenic treatment system on the water chemistry in the distribution system, specifically, the arsenic, lead, and copper levels. 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, monthly distribution system sampling continued at the same three locations.

The three locations selected were sample taps within the City of Wellman. Two of the locations had been included in the 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 homeowners recorded the dates and times of last water usage before sampling and the dates and times of sample collection for calculation of 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. Table 3-3 lists analytes for the baseline and monthly sampling. Arsenic speciation was not performed for the distribution system water samples.

3.4 Sampling Logistics

All sampling logistics are discussed below, including preparation of arsenic speciation kits and sample coolers, as well as sample shipping and handling.

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).

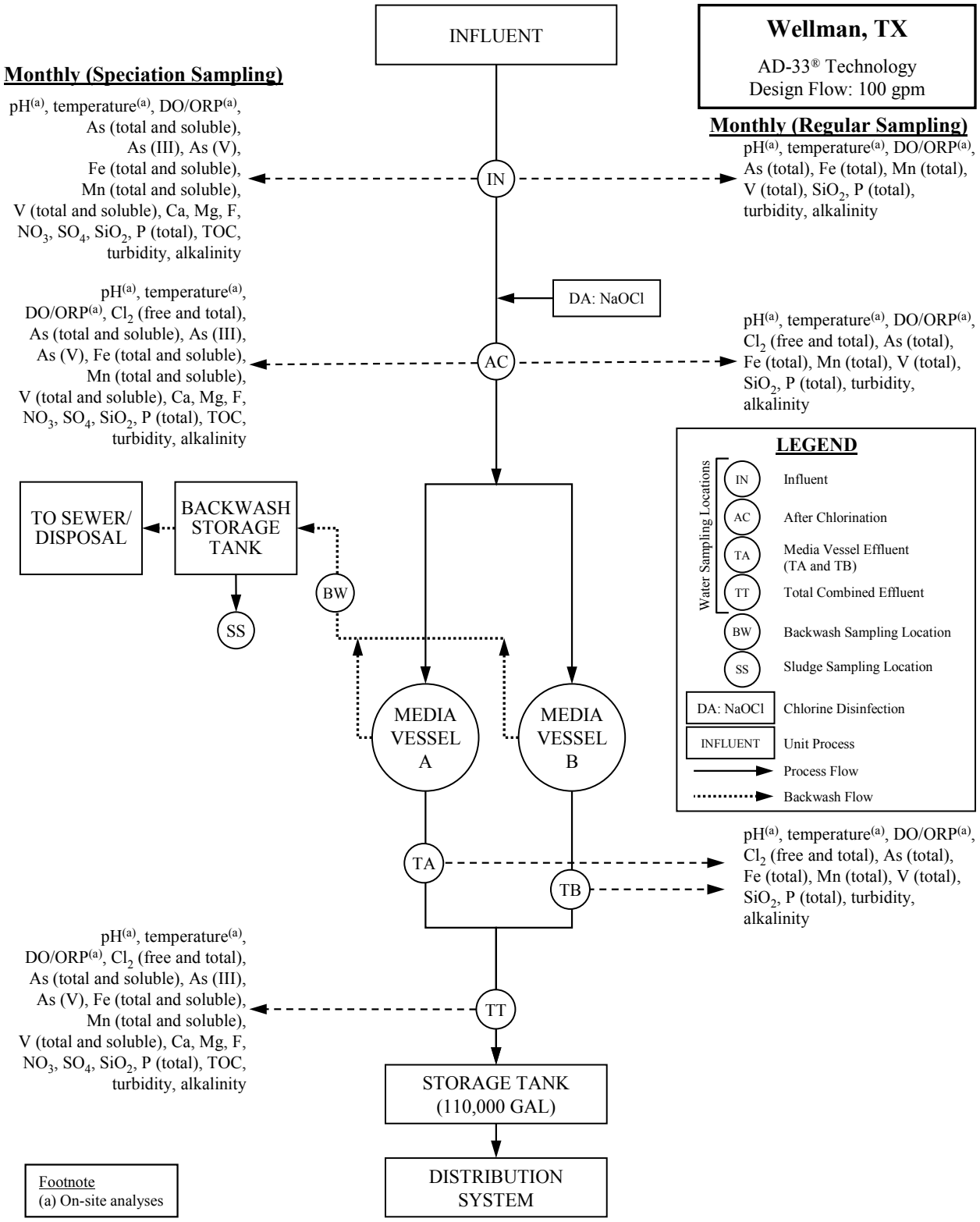

Figure 3-1. Process Flow Diagram and Sampling Schedule and Locations

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 waterproof label, consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. For example, red, orange, yellow, and blue were used to designate sampling locations for IN, AC, TA, and TB, respectively. The pre-labeled bottles for each sampling location were placed in separate Ziploc® bags and packed in the cooler. When needed, the sample cooler also included bottles for the distribution system water sampling.

In addition, all sampling and shipping-related materials, such as latex gloves, sampling instructions, chain-of-custody forms, prepaid/pre-addressed FedEx air bills, and bubble wrap, were placed in each cooler. The chain-of-custody forms and FedEx air bills were completed except for the operator's signature and the sample dates and times. After preparation, the sample coolers were sent to the facility via FedEx approximately 1 week prior to the scheduled sampling date.

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

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

3.5 Analytical Procedures

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

The plant operator conducted field measurements of pH, temperature, DO, and ORP using a Wissenschaftlich-Technische-Werkstätten (WTW) Multi 340i handheld meter, which was calibrated for pH and DO prior to use following the procedures provided in the user's manual. The ORP probe also was checked for accuracy by measuring the ORP of a standard solution and comparing it to the expected value. The plant operator collected a water sample in a clean 400-mL plastic beaker and placed the Multi 340i probe in the beaker until a stable value was obtained. The plant operator also performed free and total chlorine measurements using Hach™ chlorine test kits, following procedures in the user's manual.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description and Pre-existing Treatment System Infrastructure

Supplied by five groundwater wells located along U.S. Highway 385, the community water system in the City of Wellman distributes water to approximately 225 community members via 95 service connections. Of the five supply wells, Wells 1, 2, 3, and 4 are located in relatively close proximity to the 110,000-gal water tank (Figure 4-1) and underground vault that houses the well manifold (Figure 4-2). Well 5 is located approximately 3 miles southwest. The five supply wells range in size from 6 to 8 in, each equipped with a submersible pump of 7 to 15 horsepower (hp). The combined flowrate from the first four wells is estimated to be 40 gpm, and the flowrate from the fifth is 50 gpm. Therefore, the total flowrate is approximately 90 gpm. Operating simultaneously 4 to 6 hr at a time, the well pumps are typically on twice per day in the summer and once per day in the winter to meet the average daily demand of approximately 50,000 and 26,000 gal, respectively. The on/off of the well pumps is controlled by pressure switches located on the manifold piping at each wellhead, set at 40/54 psi. After chlorination with a 12.5% NaOCl solution (injected at the Well 1 manifold as shown in Figure 4-3), water is sent to the water tank for storage and distribution. The target free-chlorine residual level in the distribution system is 1.0 mg/L (as Cl_2).

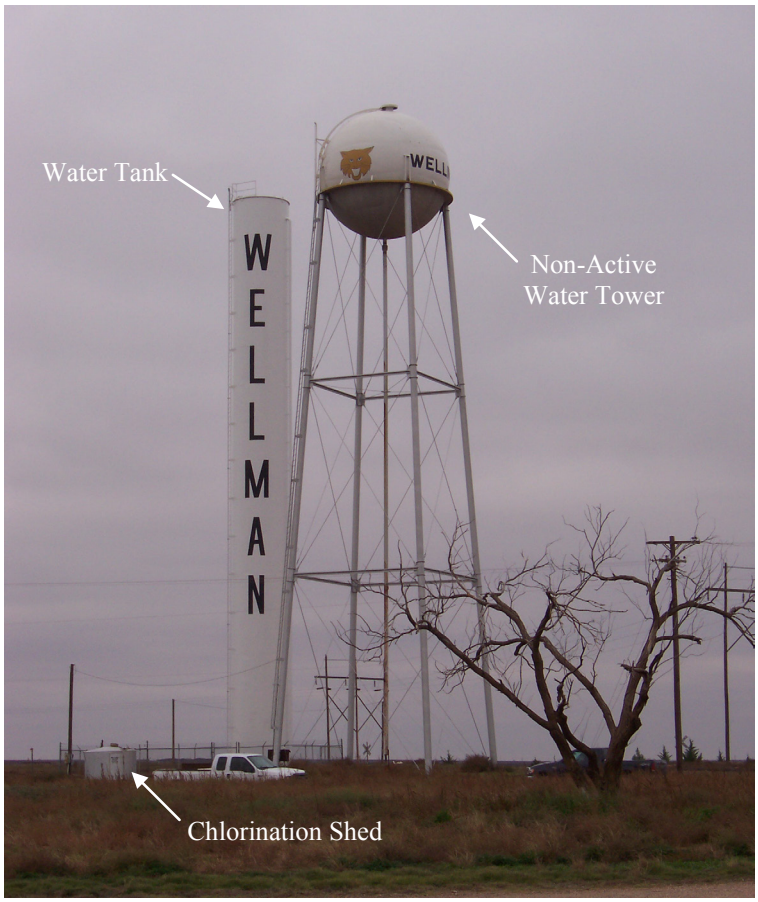

Figure 4-1. Water Tank and Chlorination Shed (Small Grey Structure Left of Truck)

Figure 4-2. Vault Containing Supply Well Manifold, Sampling Tap, and Master Totalizer

Figure 4-3. Pre-existing Chlorine Addition System

4.1.1 Source Water Quality. Two sets of source-water samples were collected on November 18, 2004, for on- and offsite analyses by Battelle. One set was collected from Well 1 and the other set from the common manifold containing water from all five wells after chlorination. Well 1 water was speciated. The results are presented in Table 4-1 and compared to those taken by the facility for the EPA demonstration site selection.

Table 4-1. Water Quality Data for Wellman, TX

Parameter	Unit	Facility Source Water Data[(a)]	Battelle Data		TCEQ Treated Water Data
			Well 1 Source Water	Five Wells Combined, Chlorinated	
Date	-	NA	11/18/04		04/27/98–11/10/04
pH	S.U.	7.8	8.2	7.7	7.5
Temperature	°C	NA	15.6	NA	NA
DO	mg/L	NA	6.6	NA	NA
ORP	mV	NA	741	NA	NA
Total Alkalinity (as $CaCO_3$)	mg/L	246; 302*	369	250	246–248
Hardness (as $CaCO_3$)	mg/L	406	442	446	686
Turbidity	NTU	NA	0.6	0.9	NA
TDS	mg/L	NA	1,690	806	823
TOC	mg/L	NA	5.2	3.4	NA
Nitrate (as N)	mg/L	NA	0.6	5.4	5.3–5.6
Nitrite (as N)	mg/L	NA	0.04	<0.01	NA
Ammonia (as N)	mg/L	NA	<0.05	<0.05	NA
Chloride	mg/L	102; 131*	590	75	103–108
Fluoride	mg/L	NA	5.0	5.3	0.6–6.1
Sulfate	mg/L	217; 224*	240	240	241–256
Silica (as SiO_2)	mg/L	19.5*	45.5	45.9	NA
Orthophosphate (as P)	mg/L	0.096*	<0.06	<0.06	NA
As (total)	µg/L	39; 33*	62.0	45.4	16.5–39.3
As (soluble)	µg/L	NA	50.2	NA	NA
As (particulate)	µg/L	NA	11.8	NA	NA
As(III) (soluble)	µg/L	NA	2.8	NA	NA
As(V) (soluble)	µg/L	NA	38.4	NA	NA
Fe (total)	µg/L	24; 55*	<25	<25	<10
Fe (soluble)	µg/L	NA	<25	NA	NA
Mn (total)	µg/L	6; <0.4	1.6	2.0	<2
Mn (soluble)	µg/L	NA	0.4	NA	NA
U (total)	µg/L	NA	10.0	10.1	NA
U (soluble)	µg/L	NA	10.1	NA	NA
V (total)	µg/L	NA	165	145	NA
V (soluble)	µg/L	NA	151	NA	NA
Sb (total)	µg/L	NA	<0.1	<0.1	NA
Sb (soluble)	µg/L	NA	<0.1	NA	NA
Na (total)	mg/L	107; 172*	403	112	140
Ca (total)	mg/L	64; 58*	47.5	50.6	73.7
Mg (total)	mg/L	60; 61*	78.5	77.6	122

(a) Provided by facility to EPA for demonstration site selection.
NA = not analyzed; NTU = Nephelometric Turbidity Units; TCEQ = Texas Commission of Environmental Quality; TDS = total dissolved solids; TOC = total organic carbon.
* EPA data.

Arsenic. Total arsenic concentrations of source water ranged from 33 to 62 μg/L. Based on the November 18, 2004, sampling results of Well 1, out of 62 μg/L of total arsenic, 50.2 μg/L existed as soluble arsenic and 11.8 μg/L as particulate arsenic. Of the 50.2 μg/L of soluble arsenic, 38.4 μg/L existed as As(V) and 2.8 μg/L as As(III). The existence of As(V) as the predominant species is consistent with the relatively oxidizing condition at the wellhead as reflected by the high DO (i.e., 6.6 mg/L) and ORP (i.e., 741 mV) levels measured during sampling.

Iron and Manganese. Iron concentrations were generally low, ranging from its MDL of 25 μg/L to 55 μg/L. In general, AM technologies are best suited for sites with relatively low iron levels in source water (i.e., less than 300 μg/L, the secondary maximum contaminant level [SMCL] for iron). Above 300 μg/L, taste, odor, and color problems can occur in treated water, along with an increased potential for fouling of the adsorption system components with iron particulates. Manganese concentrations also were low, ranging from <0.4 to 6 μg/L.

pH. The pH range of 7.7 to 8.2 was at the upper end of the target range of 6.0 to 8.5 for optimal arsenic adsorption onto the AD-33 media. At pH values greater than 8.0 to 8.5, the vendor recommended that pH adjustment be implemented to maintain the capacity of the adsorption media. Although pH adjustment was not included in the original system design, a pH adjustment system was later required by TCEQ (see Section 4.2). However, the facility chose not to use the system because of safety concerns. Disinfection byproducts were not measured under the arsenic demonstration program.

Competing Anions. Silica, phosphate, and vanadium may compete with arsenic for available adsorptive sites on the AD-33 media. The silica level in the source water sample collected by Battelle was 45.5 mg/L, and the orthophosphate level was below detection (<0.06 mg/L). High levels of silica could adversely affect the adsorptive capacity of the AD-33 media. Vanadium concentrations were high, ranging from 145 to 165 μg/L in the source water samples collected by Battelle.

Other Water-Quality Parameters. The majority of water-quality parameters analyzed in source water were below their respective primary MCLs. Fluoride levels were measured as high as 5.3 mg/L, exceeding the MCL of 4 mg/L. Total dissolved solids (TDS) and chloride also were observed to exceed their respective SMCLs of 500 mg/L and 250 mg/L, respectively, in at least one source-water sample. Total organic carbon (TOC) concentrations also were high, ranging from 3.4 to 5.2 mg/L.

4.1.2 Treated Water Quality. In addition to the source water data, Table 4-1 also presents historic treated-water quality data taken by the TCEQ from April 1998 through November 2004. The treated-water quality data obtained from TCEQ were similar to the City of Wellman and Battelle test results. Total arsenic concentrations of the treated water ranged from 16.5 to 39.3 μg/L. Although no arsenic speciation data were available for the water following chlorination, it was assumed that arsenic was present as As(V) because of the addition of chlorine. The average pH value of the treated water was 7.5, slightly lower than that of raw water. Additional analytes (including several metals and radionuclides) were included in the historical data provided by TCEQ. These data are summarized in Table 4-2.

4.1.3 Distribution System. Based on the information provided by the facility, the mains for the water distribution system in the City of Wellman are constructed of 6-in cast iron. Connections within the distribution system include 3- to 6-in polyvinyl chloride (PVC). Piping within the homes is PVC and copper; neither lead pipe nor lead solder are thought to be present.

The three locations selected for distribution-system water sampling before and after system startup were representative of the distribution system overall. Two of the locations were also part of the city's historic

Table 4-2. TCEQ Treated Water Quality Data

Parameter	Unit	TCEQ Treated Water Data
Aluminum	µg/L	<20
Antimony	µg/L	<3
Barium	µg/L	28.8
Beryllium	µg/L	<1
Cadmium	µg/L	<1
Chromium	µg/L	<10
Copper	µg/L	6.6
Iron	µg/L	<10
Lead	µg/L	<1
Mercury	µg/L	<0.4
Nickel	µg/L	1.1
Selenium	µg/L	43.2
Silver	µg/L	<10
Thallium	µg/L	<1
Zinc	µg/L	7.1
Gross Alpha	pCi/L	8.8
Gross Beta	pCi/L	15.2
Radium 226/228	pCi/L	0.3/<1

sampling network for the LCR. The facility also samples water for volatile organic compounds (VOCs), inorganics, nitrate, and radionuclides as directed by the TCEQ, typically once every 2 to 3 years.

4.2 Treatment Process Description

The APU marketed by AdEdge is a fixed-bed, downflow adsorptive media system used for small water systems in the flow range of up to 100 gpm. The system uses Bayoxide E33 media (branded as AD-33 by AdEdge) – an iron-based adsorptive media developed by Lanxess (formerly Bayer AG) for removing arsenic from drinking-water supplies. Table 4-3 presents physical and chemical properties of the AD-33 media. The media, available in both granular and pelletized forms, is delivered in a dry crystalline form and listed by NSF International (NSF) under Standard 61 for use in drinking-water applications. The pelletized media, which is 25% denser than its granular counterpart (i.e., 35 vs. 28 lb/ft^3), was used for the demonstration at Wellman.

As groundwater is pumped through the fixed-bed pressure vessels, dissolved arsenic is adsorbed onto the media, thus reducing the dissolved arsenic concentration in the treated water. When the media reaches its capacity (effluent water ≥10 µg/L total arsenic), the spent media is removed and disposed of as a non-hazardous waste after passing the EPA's Toxicity Characteristic Leaching Procedure (TCLP) test. The media life depends on the arsenic concentration, empty bed contact time (EBCT), mode or variability of operation (on-off), pH, and concentrations of competing ions in source water.

Both chlorination and pH adjustment equipment were included at the Wellman demonstration site. Chlorination had already been used prior to the demonstration study. Because As(V) was the predominant species and the As(III) concentration was low (i.e., 2.8 µg/L based on November 18, 2004, data), chlorination was used primarily to maintain a chlorine residual in the distribution system. As described in Section 4.1, source water pH ranged from 7.7 to 8.2. A pH adjustment system required by TCEQ was installed to lower source-water pH values to a target value of 7.2. Although installed, the pH adjustment system was not used because of the operator's safety concerns.

Table 4-3. **Physical and Chemical Properties of Bayoxide E33 (or AD-33) Pelletized Media**

Physical Properties	
Parameter	**Values**
Matrix	Iron oxide composite
Physical Form	Dry pelletized media
Color	Amber
Bulk Density (lb/ft^3; g/cm^3)	35; 0.56
BET Surface Area (m^2/g)	142
Attrition (%)	0.3
Moisture Content (%, by wt.)	~5
Particle Size Distribution (mm)	1.0–1.4 (14×18 mesh)
Crystal Size (Å)	70
Crystal Phase	α – FeOOH
Chemical Analysis	
Constituents	**Weight %**
FeOOH	90.1
CaO	0.27
SiO_2	0.06
MgO	1.00
Na_2O	0.12
SO_3	0.13
Al_2O_3	0.05
MnO	0.23
TiO_2	0.11
P_2O_5	0.02
Cl	0.01

Data Source: Bayer AG.
BET = Brunauer, Emmett, and Teller.

The arsenic treatment system (specifically referred to as the APU-100CS-S-2-AVH system) consisted of two pressure vessels (Vessels A and B) operating in parallel. The system was in a newly constructed treatment building located next to the pre-existing water tank and underground vault along U.S. Highway 385 (Figure 4-4). Table 4-4 presents key system design parameters.

The major process components of the arsenic treatment system are:

- **Intake**. Raw water was pumped from the five supply wells and fed to the treatment system. Wells 1, 2, 3, and 4 were triggered to operate by a single pressure switch, and Well 5, which provided nearly half the water supply, was triggered by a separate pressure switch. The two pressure switches were configured to allow for simultaneous operation of all five wells. The raw water from each of the supply wells was piped through a common PVC manifold that combined raw water from all five wells just prior to entering the underground vault that housed a master totalizer and raw water sample tap (IN).

- **Prechlorination.** The pre-existing chlorination system, shown in Figure 4-3, injected a 12.5% NaOCl solution directly into Well 1. During installation of the arsenic treatment system, the prechlorination equipment was relocated inside the new treatment building, and a new chlorination injection point was installed on the raw water influent line, downstream of the common well manifold (IN) and prior to the AC sampling location.

Figure 4-4. Water Treatment Facility in Wellman, TX

The chlorination system was used primarily to provide a target free-chlorine residual level of 1.0 mg/L (as Cl_2) for disinfection purposes. The added benefit was to oxidize any As(III) to As(V) prior to the adsorption vessels. Operation of the chlorine feed system was linked to the well pumps such that chlorine was injected only when the wells were operating. The system operator monitored chlorine consumption weekly by recording the chlorine levels in the chlorine supply tank and by measuring the volume of chlorine added to the tank.

- **pH Adjustment.** A pH adjustment system was installed (but not used) inside the new treatment building, along with the arsenic treatment system. The pH adjustment system consisted of a solenoid-driven diaphragm metering chemical feed pump (ProMinent®, beta/4®), a 50-gal, high-density polyethylene (HDPE) chemical feed tank (to store a 31% hydrochloric acid [HCl] solution), tubing to transfer the acid from the tank to injection valve, an in-line mixer, and a pH probe and monitor (Figure 4-5). The acid injection point was just after the chlorine injection point. Figure 4-5 identified the chemical injection points (chlorine and acid), and Figure 4-6 identified the treatment train sample collection points, with the exception of the IN sample location, which is in the vault outside the new treatment building.

- **Adsorption**. The arsenic treatment system consisted of two 48-in × 72-in pressure vessels configured in parallel, each containing 38 ft^3 of pelletized AD-33 media. The skid-mounted vessels were of carbon steel construction and rated for 100-psi working pressure (Figure 4-6). At a design flowrate of 50 gpm for each vessel (or 100 gpm for the whole system), the EBCT was 5.7 min. The hydraulic loading rate to each vessel was approximately 4.0 gpm/ft^2.

  Each pressure vessel was interconnected with schedule 80 PVC piping and five electrically actuated butterfly valves, which made up the valve tree as shown in Figure 4-6. In addition, the system had two manual diaphragm valves on the backwash line and two manual lug-style butterfly valves to divert raw water flow into each vessel. Each valve operated

Table 4-4. Design Specifications of AdEdge Arsenic Removal System

Parameter	Value	Remarks
Adsorption Vessels		
Vessel Size (in)	48 D × 72 H	–
Cross-Sectional Area (ft^2/vessel)	12.6	–
No. of Vessels	2	–
Configuration	Parallel	–
AD-33 Adsorptive Media		
Media Type	AD-33 (pelletized)	–
Media Volume (ft^3/vessel)	38	–
Media Bed Depth (in)	36	–
Media Weight (lb/vessel)	1,330	2,660 lb for both vessels
Pretreatment		
Free Chlorine Residual (mg/L [as Cl_2])	1.0	Using 12.5% NaOCl
Target pH Value (S.U.)	7.2	pH adjustment not implemented during performance evaluation study
Service		
Design Flowrate (gpm/vessel)	50	100 gpm for both vessels
Hydraulic Loading (gpm/ft^2)	4.0	–
EBCT (min)	5.7	–
Estimated Working Capacity (BV)	17,240	Bed volumes to 10 µg/L total As breakthrough from each vessel based on vendor estimate
Estimated Throughput to Breakthrough (gal)	9,800,000	1 BV = 568 gal
Average Use Rate (gal/day)	31,860	Based on 5.9 hr of daily operation at 90 gpm
Estimated Media Life (day)	308 (10.1 months)	Estimated frequency of media changeout based on average throughput to system
Backwash		
Pressure Differential Setpoint	10 psi	–
Backwash Hydraulic Loading (gpm/ft^2)	9	–
Backwash Frequency (per month)	Once	System not backwashed during performance evaluation study
Backwash Flowrate (gpm)	113	–
Backwash Duration (min/vessel)	20	–
Fast Rinse Flowrate (gpm)	113	–
Fast Rinse Duration (min/vessel)	1 to 4	–
Wastewater Production (gal/vessel)	2,710	Assuming 4-min fast rinse

independently, and the butterfly valves were controlled by a Square D Telemechanique programmable logic controller (PLC) with a Magelis XBT G2220 color touch-interface screen.

- **Backwash.** The vendor recommended that the adsorption vessels be backwashed regularly to remove particulates and media fines that accumulated in the media beds. The system can be backwashed automatically based on Δp across the individual pressure vessels, time of operation, or volume of water treated. The vendor recommended a backwash flowrate of 113 gpm to achieve a backwash hydraulic loading rate of approximately 9 gpm/ft^2. Because the incoming flowrate from the supply well is insufficient to provide the

Figure 4-5. pH Adjustment System and Chemical Injection Valves

necessary flow for backwash, supplemental water would be supplied from the treated-water storage tank to the head of the system. Each backwash cycle is set to last about 21 to 24 min per vessel (including rinse to waste for up to 4 min) and would generate a total of 5,420 gal for the two vessels. The backwash wastewater produced would be pumped to a 5,000-gal polyethylene storage tank located next to the treatment system. From the backwash storage tank, the backwash wastewater would be either discharged to a local sewer or collected and used for irrigation purposes. However, due to the minimal pressure drop across the vessels throughout the performance evaluation study, system backwash was never performed.

- **Media Replacement.** Based on the final sampling event at Wellman, total arsenic concentrations in the treated water were 6.8 and 2.3 µg/L from TA and TB, respectively. The total arsenic concentration did not exceed the MCL of 10 µg/L; therefore, media replacement did not occur during the study period. Based on the estimate provided by the vendor, breakthrough of arsenic was expected after about 17,240 BV of water treated or about 12 months of system operation.

- **Water Storage.** Treated water from the APU system was sent to the 110,000-gal water tank located at the site and used to supply treated water to the distribution system.

4.3 System Installation

The vendor and its subcontractor completed installation of the APU system on July 20, 2006. The following sections summarize some of the pre-demonstration activities, including permitting, building preparation, and system installation, shakedown, and startup.

Figure 4-6. Adsorption System Valve Tree and Piping Configuration

4.3.1 Permitting. A pre-permit package submitted to TCEQ by the City of Wellman on July 11, 2005, requested an exception to use data from an alternative site in lieu of conducting an onsite pilot study as required under 30 TAC §290.42(g). The exception request included a written description of the treatment technology, along with a schematic of the system and relevant pilot- and full-scale data. On August 25, 2005, a permit application 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, was submitted to TCEQ for permit approval. TCEQ granted the exception request on October 31, 2005, and granted a conditional approval for construction on February 2, 2006. The conditional approval required that the loading rate, media depth, and pH adjustment comply with the requirements outlined in the TCEQ exception request response letter dated October 31, 2005. A final response to the TCEQ conditional approval was submitted by Oller Engineering, Inc. (the engineer of record) on June 26, 2006, ensuring that the system installation would be in accordance to the guidance provided by the TCEQ.

4.3.2 Building Preparation. Construction of a new building to house the planned arsenic treatment system began on January 20, 2006, and was completed on February 6, 2006. The building is a single-story metal structure with concrete flooring, as shown in Figure 4-4. Additional preparation required reconfiguration of the chlorination system from the previous treatment facility to the new building.

4.3.3 Installation, Shakedown, and Startup. The treatment system arrived onsite on October 14, 2005. The electrical and plumbing hookups were completed by the vendor's subcontractor during the week of March 6, 2006. During the week of August 9, 2006, the vendor completed the arsenic treatment system installation and shakedown work, which included hydraulic testing, media loading, and media backwash. Two Battelle staff members were onsite on August 9, 2006, to inspect the system and to train the operator for sampling and data collection. The system officially went online and was put into regular service on August 10, 2006. 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 problems related to the media vessel flow meters could not be resolved immediately and resurfaced throughout the evaluation. The issues associated with the flow meters are further discussed in Section 4.4.3. Table 4-5 summarizes the items identified and corrective actions taken.

Table 4-5. System Punch-List/Operational Issues and Corrective Action

Item No.	Punch-List/ Operational Issues	Corrective Action(s) Taken	Resolution Date
1	No backwash flow for Vessel A	Malfunctioning actuator on valve BV-014A replaced	8/11/2006
2	Relocate acid and chlorine injection points	Acid and chlorine injection points moved to inside of treatment building prior to treatment system	8/14/2006
3	Install inline mixer after acid and chlorine injection points	Vendor notified but no action taken to date	8/14/2006
4	Install second chlorine injection point after treatment	Vendor supplied two additional 4-in PVC saddles to site; no additional action taken to date	8/14/2006
5	Install "IN" sampling point on raw water line in vault	Sample tap installed on combined well manifold in vault	8/14/2006
6	Calibrate and evaluate pressure gauges on system for accuracy	Gauges functioning properly after malfunctioning actuator was replaced on valve BV-014A	8/14/2006
7	Replace backwash line sampling port with larger port	Larger sampling port provided to facility	8/14/2006
8	Confirm Vessels A and B flow meters for proper calibration and measurements	Flow coefficients in software checked and correct setting confirmed per factory specifications; Battelle sent portable flow meter to site to verify flow meter reading	8/15/2006 10/9/2006

4.4 System Operation

4.4.1 Operational Parameters. System operational parameters recorded during the performance evaluation study are tabulated and attached as Appendix A; key parameters are summarized in Table 4-6. From August 10, 2006, through April 17, 2008, the system operated for 3,615 hr, equivalent to 5.9 hr/day and a utilization rate of 24%. The operating hours were tracked by the hour meter interlocked with the electromagnetic flow totalizers installed on the adsorption vessels.

The system treated 14,744,962 gal (or 25,938 BV) of water based on true readings of the turbine master totalizer from August 10, 2006, through November 30, 2007, and on estimated values from November 30, 2007, through the remainder of the performance evaluation study. Because the master totalizer began to malfunction on November 30, 2007, amounts of water produced by the wells were estimated using historically measured values. In comparison, the two electromagnetic flow meters/totalizers installed as

Table 4-6. Summary of APU-100CS-S-2-AVH System Operation

Operational Parameter	Value/Condition	
Duration	08/10/06–04/17/08	
Cumulative Operating Time (hr)	3,615	
Average Daily Operating Time (hr)	5.9	
Flow Meter/Totalizer	Electromagnetic[a]	Turbine[b]
Throughput (gal)	18,498,848[e]	14,744,962
Throughput (BV)[c]	32,541[e]	25,938
Average (Range of) Calculated Flowrate (gpm)[d]	118 (18–323)	91 (21–372)
Average (Range of) EBCT for System (min)[c]	4.8 (1.8–31.1)	6.2 (1.5–27.4)
Average (Range of) Inlet Pressure (psi)	46.4 (36–54)	
Average (Range of) Outlet Pressure (psi)	45.9 (33–54)	
Average (Range of) Δp across System (psi)	1.1 (0–4)	
Average (Range of) Δp across Vessel A (psi)	0.6 (0–2)	
Average (Range of) Δp across Vessel B (psi)	0.6 (0–13)	

(a) Flow meter installed on each adsorption vessel.
(b) Master flow meter installed at combined manifold of five supply wells.
(c) Calculated based on 76 ft^3 of media in both vessels.
(d) Rosner's outliers test used to determine flowrate average and range from data collected between 08/10/06 and 11/30/07.
(e) Value based on true measurements from 08/10/06 through 11/30/07 and estimated values, based on historical data from 11/30/07 through 04/17/08.

part of the treatment system on the two adsorption vessels reported 18,498,848 gal of water treated. Bed volumes were calculated based on the 76 ft^3 of media in both vessels.

System flowrates were tracked by instantaneous flowrate readings from the electromagnetic flow meter/totalizer on each adsorption vessel, and on calculated flowrate values based on readings of the hour meter and the same electromagnetic meters/totalizers. Over the system evaluation period, the calculated system flowrates varied from 18 to 323 gpm and averaged 118 gpm (not including the data collected after November 30, 2007, when the Well 5 pump was shut down due to pump- and piping-related issues). This calculated average flowrate is significantly greater than that of the pre-existing turbine master totalizer (i.e., 91 gpm) and the system design value of 100 gpm. Figure 4-7 compares calculated system flowrates of the electromagnetic flow meter/totalizer and the master totalizer throughout the performance evaluation study.

To determine a more representative average and range of flowrate values, the Rosner's outlier test was used for statistical analysis and elimination of erroneous values collected from both the electromagnetic flow meter/totalizer and turbine master totalizer. Based on the test results, the average electromagnetic totalizer flowrate through the adsorption vessels was consistently greater than the average master totalizer flowrate by approximately 30%.

Because of this large discrepancy, a one-day flowrate test was performed on October 9, 2006, using a portable ultrasonic flow meter to establish an alternate reference for evaluating the accuracy of the electromagnetic flow meters/totalizers and turbine master totalizer. Table 4-7 summarizes the results of the one-day flowrate test. In general, the one-day flowrate test results were more comparable with the master totalizer; therefore, the master totalizer values (provided in Table 4-6) were used for the purposes of this performance evaluation study and reported throughout this document. Section 4.4.3 further examines inconsistent flowrates among the treatment system flow meters/totalizers, master totalizer, and portable flow meter.

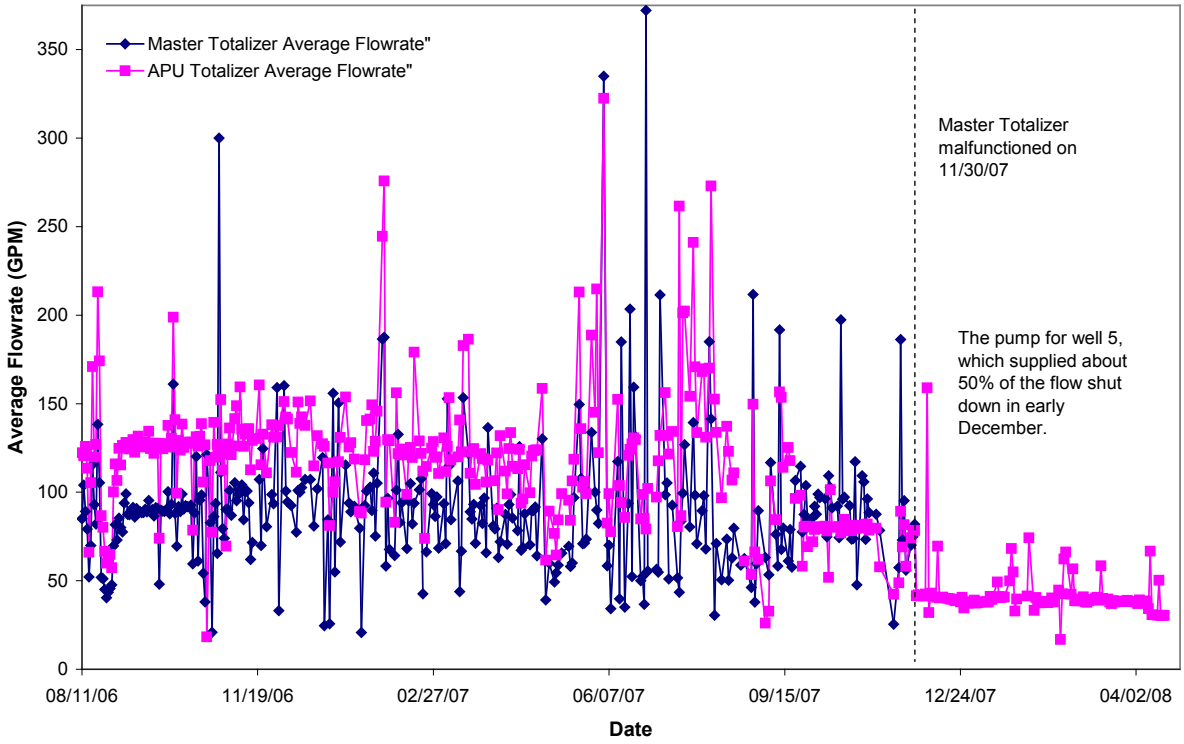

Figure 4-7. Calculated Flowrate Values from Electromagnetic Flow Meter/Totalizer and Master Totalizer

Table 4-7. Flowrates Measured by Various Flow Meters/Totalizers on October 9, 2006

Flow Meter/Totalizer	Type of Flow Meter/Totalizer	Average Flowrate (gpm)	Difference (%)
Master Totalizer	Turbine	92	0
Portable Flow Meter	Ultrasonic	101	+10
APU System Totalizer	Electromagnetic	128	+39

As noted in Table 4-6, a statistical analysis was used to eliminate erroneous flowrate values collected from both the electromagnetic flow meter/totalizer and the turbine master totalizer to determine a more representative average and range of values. Specifically, Rosner's outlier test was employed because there were more than 25 independent observations and because it was believed that there were multiple outliers in both datasets (Rosner, 1975). Overall, there were two outliers from the turbine master totalizer (on February 22 and July 12, 2007) and five outliers from the electromagnetic flow meter/totalizer (on October 2, 2006, and on July 12, August 30, September 4, and September 6, 2007). Following removal of the outliers, based on Rosner's outlier test, the turbine master totalizer average flowrate was 91 gpm and the electromagnetic flow meter/totalizer average flowrate was 118 gpm, a 30% variance in flowrate averages.

It is also possible that there was serial correlation between the almost daily observations; therefore, autocorrelation (i.e., correlation between consecutive observations) was calculated for both totalizers. It was found that the master turbine totalizer values were not autocorrelated but that the electromagnetic flow meter/totalizer values were autocorrelated. This observation was confirmed by performing a Durbin-Watson test for autocorrelation (Durbin and Watson, 1950). Overall, the methods and results for the master turbine totalizer are statistically acceptable, while the presence of autocorrelation affects the results for the electromagnetic flow meter/totalizer.

The treatment system pressure readings were monitored at the system inlet and outlet and between both Vessels A and B. Figure 4-8 is a histogram of inlet, outlet, and differential pressures for the system and each vessel over the system evaluation period. The average Δp across the system, Vessel A, and Vessels B was 1.1, 0.6, and 0.6 psi, respectively, and remained relatively low. As such, no significant pressure increases were observed after 3,615 hr of system operation. Several pressure spikes were observed; however, none of these spikes caused a significant increase across the system or adsorption vessels that would have required backwashing of the media during the evaluation period.

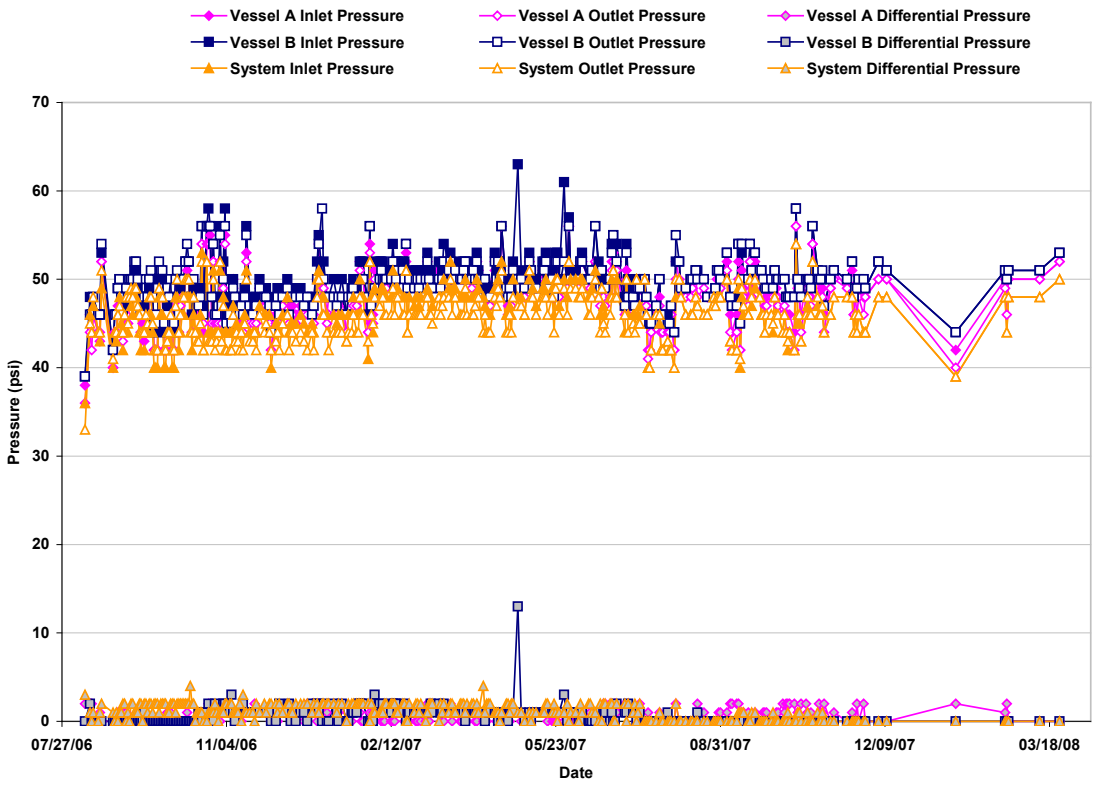

Figure 4-8. Treatment System Operational Pressure Readings

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. The only operational irregularity experienced during the evaluation period was related to the electromagnetic flow meters/totalizers on the arsenic treatment system. Over the system evaluation period, the electromagnetic flow meters/totalizers

installed with the treatment system had been reporting flowrates significantly greater than the design value and master totalizer values. Because of this, a one-day flowrate test was performed on October 9, 2006, using a portable ultrasonic flow meter to determine the accuracy of the electromagnetic flow meters/totalizers and turbine master totalizer.

Each type of totalizer operates differently; hence, several different variables could influence the actual flow measurement. The master totalizer is a turbine flow meter, which is most often used for water distribution systems. Turbine meters are less accurate than positive displacement and jet meters, although turbine meters allow for higher flow rates and less pressure loss than displacement-type meters. The portable flow meter is ultrasonic, which requires known values to be preset prior to use. The portable flow meter reports an accuracy of ±1% to 3% within a velocity range of ±0.1 m/sec under ideal flow conditions in 4-in PVC piping. The treatment system flow meter/totalizer is an electromagnetic flow meter, which requires a minimum of 10 straight pipe diameters upstream and a minimum of five straight pipe diameters downstream of the flow meters/totalizers. At Wellman, neither upstream nor downstream specifications were met. Upstream from the flow meters/totalizers there should have been a minimum of 30 in of straight pipe, and downstream there should have been a minimum of 15 in of straight pipe. For both flow meters/totalizers installed, there were only 21 in upstream and 6 in downstream, a difference of 30% and 60%, respectively, and less than the minimum requirements.

Based on the one-day flow rate test, it was concluded that the APU system flow meters are the least accurate of the meters due to the current piping configuration and that results from the master totalizer and portable flow meter are within an acceptable margin of error (Battelle, 2008). As such, the master turbine totalizer was used for demonstration purposes and the use of the electromagnetic flow meters/totalizers was discontinued until the factory-set K-factors were adjusted to compensate for the inaccuracy (i.e., piping configuration). Unfortunately, the vendor was unable to recalibrate the K-factor during the evaluation period; therefore, the master turbine totalizer was used for the demonstration study until it began to malfunction on November 30, 2007. Following the malfunction of the master totalizer on November 30, 2007, flowrate values were estimated, based on historically measured values, through the completion of the performance evaluation study on April 17, 2008.

Once the master totalizer readings were no longer reliable, subsequent flowrate values were calculated using adjusted historical APU system flowrates (i.e., values from August 10, 2006 through November 27, 2007). These historical values were adjusted based on the percentage of water flowing through each vessel and then the adjusted historical values were used to calculate subsequent flowrate values through April 17, 2008 (see Appendix A).

Pre- and Post-Treatment Requirements. Two pretreatments were required at the Wellman site: chlorination and pH adjustment. A chlorination step was required to provide a chlorine residual in the distribution system and to oxidize As(III) to As(V). The existing chlorination system was relocated from the pre-existing chlorination shed into the new treatment building and reconfigured to inject solution after the combined raw-water sampling location (IN) (as opposed to directly into Well 1) but prior to the AC sampling location. The chlorination system, as discussed in Section 4.2 and shown in Figure 4-3, used a 12.5% NaOCl solution to reach a target free-residual level of 1.0 mg/L (as Cl_2). The reconfigured chlorination system did not require additional maintenance or skills, other than those required by the previous system. The operator monitored chlorine solution consumption rates (gal/week) and residual chlorine levels.

A pH adjustment system was installed to reduce the pH to 7.2 (TCEQ permit requirement); however, it was never used because of the operator's safety concerns. Throughout the evaluation period, pH values ranged from 7.6 to 8.0 for the IN samples (i.e., raw water); 7.4 to 7.8 for the AC samples; and 7.4 to 7.7 for the TT samples (i.e., treated water).

***System Automation*.** The system was fitted with automated controls for automatic backwash. 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. 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 the operator with hands-on training and a supplemental operations manual.

Operator Skill Requirements. The operation of the adsorption system demanded a higher level of awareness and attention than the previous system. The system required increased monitoring of system parameters. The operator's knowledge of the system limitations and typical operational parameters was critical in achieving system performance objectives. The operator was onsite typically three times per week and spent approximately 3 to 15 min each time performing visual inspections and recording the system operating parameters on the daily log sheets. Operator training began with onsite training and a thorough review of the system operations manual. However, over the system evaluation period, the operator found that invaluable system troubleshooting skills were gained through hands-on operational experience.

TCEQ requires that treatment-system operator hold at least a Class D TCEQ waterworks operator license. The TCEQ public water system operator certifications are classified as A through D. Licensing eligibility requirements are based on education, experience, and related training. The minimum requirements for a Class D license are a high school diploma or GED, as well as 20 hr of related training. Licensing requirements incrementally increase with each licensing level, with Class A being the highest and 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. The prechlorination tank and supply lines also were checked for leaks and adequate pressure. Typically, the operator performed these duties when onsite for routine activities.

Chemical/Media Handling and Inventory Requirements. NaOCl was used for prechlorination. The operator ordered chemicals as had been done prior to treatment-system's installation. HCl was intended to be used for pH adjustment, but it was not incorporated into the water treatment system and therefore not handled by the operator.

4.5 System Performance

The performance of the arsenic treatment system was evaluated based on analyses of water samples collected from the treatment facility and distribution system.

4.5.1 Treatment Plant Sampling. The treatment plant water was sampled on 41 occasions, including five duplicate and 16 speciation sampling events. Appendix B provides a complete set of tabulated results. Table 4-8 summarizes the results for arsenic, iron, manganese, and vanadium across the treatment train. Table 4-9 summarizes the results of other water quality parameters. The results of the water samples collected throughout the treatment train are discussed below.

Arsenic. As shown in Table 4-8, total arsenic concentrations at the combined manifold (IN) varied considerably, ranging from 6.0 to 50.6 µg/L and averaging 36.0 µg/L. The predominant soluble species was As(V), ranging from 6.1 to 43.8 µg/L and averaging 29.0 µg/L. Low levels of soluble As(III) and particulate arsenic also were present, averaging 1.3 and 4.2 µg/L, respectively. A review of the significant concentration variations at the IN sampling location identified that system operations and sampling techniques most likely were contributing to these variations. In fact, samples collected after

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

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
As (total)	IN	µg/L	41	6.0	50.6	36.0	11.4
	AC	µg/L	41	37.5	50.0	42.9	3.4
	TA	µg/L	25	0.1	7.5	-[(a)]	-[(a)]
	TB	µg/L	25	0.7	7.6	-[(a)]	-[(a)]
	TT	µg/L	16	0.4	7.9	-[(a)]	-[(a)]
As (soluble)	IN	µg/L	16	8.8	44.2	30.3	13.2
	AC	µg/L	16	35.9	48.6	41.3	2.8
	TT	µg/L	16	0.4	7.8	-[(a)]	-[(a)]
As (particulate)	IN	µg/L	16	<0.1	18.5	4.2	4.9
	AC	µg/L	16	<0.1	9.2	3.2	2.6
	TT	µg/L	16	<0.1	0.6	-[(a)]	-[(a)]
As (III)	IN	µg/L	16	<0.1	6.0	1.3	1.4
	AC	µg/L	16	<0.1	11.4	1.8	2.7
	TT	µg/L	16	<0.1	8.7	-[(a)]	-[(a)]
As (V)	IN	µg/L	16	6.1	43.8	29.0	13.8
	AC	µg/L	16	35.2	42.9	39.6	2.0
	TT	µg/L	16	<0.1	5.5	-[(a)]	-[(a)]
Fe (total)	IN	µg/L	41	<25	131	<25	21.4
	AC[(b)]	µg/L	40	<25	51.9	<25	9.3
	TA	µg/L	25	<25	<25	<25	
	TB	µg/L	25	<25	<25	<25	
	TT	µg/L	16	<25	<25	<25	
Fe (soluble)	IN	µg/L	16	<25	<25	<25	
	AC	µg/L	16	<25	<25	<25	
	TT	µg/L	16	<25	<25	<25	
Mn (total)	IN	µg/L	41	<0.1	2.2	0.6	0.4
	AC	µg/L	41	<0.1	2.0	0.4	0.4
	TA	µg/L	25	<0.1	0.4	<0.1	0.1
	TB	µg/L	25	<0.1	0.5	<0.1	0.1
	TT	µg/L	16	<0.1	0.5	0.1	0.1
Mn (soluble)	IN	µg/L	16	0.3	1.3	0.7	0.3
	AC	µg/L	16	<0.1	0.9	0.4	0.2
	TT	µg/L	16	<0.1	0.5	0.1	0.1
V (total)	IN	µg/L	41	17.5	167	112	36.5
	AC	µg/L	41	105	174	136	15.8
	TA	µg/L	25	0.7	133	-[(a)]	-[(a)]
	TB	µg/L	25	0.7	136	-[(a)]	-[(a)]
	TT	µg/L	16	0.6	132	-[(a)]	-[(a)]
V (soluble)	IN	µg/L	16	28.7	156	100	46.9
	AC	µg/L	16	112	169	143	15.2
	TT	µg/L	16	0.5	139	-[(a)]	-[(a)]

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

(a) Average and standard deviation calculations were not meaningful due to breakthrough of respective contaminants from adsorption vessels; see breakthrough curves in Figure 4-10 for total arsenic; Figure 4-9 for particulate arsenic, As(III), and As(V); and Figure 4-12 for vanadium.

(b) Analytical results from April 17, 2008, were not used in statistical calculations due to abnormally high results (1,516 µg/L) and were considered erroneous.

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	34	232	301	262	11.2
	AC	mg/L	34	239	273	255	9.6
	TA	mg/L	18	252	275	261	6.8
	TB	mg/L	18	246	276	260	7.0
	TT	mg/L	16	243	272	259	7.9
Fluoride[(a)]	IN	mg/L	15	0.4	7.6	5.5	1.6
	AC	mg/L	15	3.6	6.8	5.3	0.9
	TT	mg/L	15	4.5	7.8	5.8	0.9
Sulfate	IN	mg/L	16	70.0	318	240	57.1
	AC	mg/L	16	218	470	299	77.6
	TT	mg/L	16	230	380	272	45.1
Nitrate (as N)	IN	mg/L	16	3.5	7.2	5.1	1.0
	AC	mg/L	16	3.5	7.2	5.1	1.1
	TT	mg/L	16	3.9	7.3	5.1	1.0
Total P (as P)	IN	µg/L	41	<10	33.6	<10	6.8
	AC	µg/L	41	<10	34.9	<10	7.1
	TA	µg/L	25	<10	17.4	<10	2.5
	TB	µg/L	25	<10	25.4	<10	4.1
	TT	µg/L	16	<10	27.7	<10	6.3
Silica (as SiO_2)	IN	mg/L	34	42.1	62.1	46.8	4.0
	AC	mg/L	34	42.6	60.8	46.2	3.3
	TA	mg/L	18	41.3	61.5	47.3	4.5
	TB	mg/L	18	42.8	64.2	47.9	4.8
	TT	mg/L	16	24.4	50.6	45.2	6.0
Turbidity	IN	NTU	34	0.2	2.6	0.6	0.5
	AC	NTU	34	0.1	2.4	0.7	0.6
	TA	NTU	18	0.1	2.7	0.5	0.6
	TB	NTU	18	0.1	3.4	0.5	0.7
	TT	NTU	16	0.2	0.8	0.4	0.2
Total Organic Carbon	IN	mg/L	15	1.0	1.9	1.3	0.2
	AC	mg/L	15	1.1	1.7	1.3	0.2
	TT	mg/L	15	1.1	1.6	1.3	0.1
pH	IN	S.U.	13	7.6	8.0	7.8	0.1
	AC	S.U.	13	7.4	7.8	7.6	0.1
	TT	S.U.	12	7.4	7.7	7.5	0.1
Temperature	IN	°C	13	8.1	22.3	15.9	4.8
	AC	°C	13	9.7	23.8	16.3	4.5
	TT	°C	12	10.1	23.8	16.4	4.3
DO	IN	mg/L	11	4.7	7.1	5.7	0.7
	AC	mg/L	11	4.1	7.0	5.5	0.8
	TT	mg/L	9	4.6	6.3	5.5	0.6
ORP	IN	mV	12	178	612	477	112
	AC	mV	12	185	676	503	129
	TT	mV	11	271	726	557	133
Free Cl_2 (as Cl_2)	TT	mg/L	3	0.8	1.4	1.0	0.3
Total Cl_2 (as Cl_2)	TT	mg/L	5	0.2	2.2	0.9	0.8

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

Parameter	Sample Location	Unit	Sample Count	Concentration			Standard Deviation
				Minimum	Maximum	Average	
Total Hardness (as $CaCO_3$)	IN	mg/L	15	333	604	410	78.3
	AC	mg/L	15	349	668	458	99.7
	TT	mg/L	15	351	557	417	59.6
Ca Hardness (as $CaCO_3$)	IN	mg/L	16	101	187	133	21.1
	AC	mg/L	16	100	187	136	20.3
	TT	mg/L	16	105	182	142	20.7
Mg Hardness (as $CaCO_3$)	IN	mg/L	15	195	474	276	71.4
	AC	mg/L	15	227	507	322	91.6
	TT	mg/L	15	212	401	275	50.6

One-half of detection limit used for samples with concentrations less than detection limit for calculations.
(a) Analytical results from June 14, 2007 at IN and July 9, 2007 at AC and TT were not used in statistical calculations because they were determined to be outliers.

chlorination (AC) provided concentrations in a more reasonable range and are believed to be more representative of the true water quality. Total arsenic concentrations in the AC samples ranged from 37.5 to 50.0 μg/L and averaged 42.9 μg/L. In the AC samples, soluble As(V) remained predominant, ranging from 35.2 to 42.9 μg/L and averaging 39.6 μg/L. Soluble As(III) concentrations averaged 1.8 μg/L, and particulate arsenic concentrations averaged 3.2 μg/L.

The presence of As(V) as the predominant species in raw water was consistent with the high DO and ORP levels/readings, which averaged 5.7 mg/L and 477 mV, respectively (Table 4-9). After prechlorination, DO levels remained rather unchanged, averaging 5.5 mg/L at both AC and TT sampling locations. However, ORP readings increased significantly to levels averaging 503 and 557 mV at the AC and TT locations, respectively. The increase in ORP was caused by the presence of up to 1.0 mg/L (as Cl_2) of free-chlorine residuals in the chlorinated water.

Figure 4-9 presents the results of the 16 arsenic speciation events measured at the IN, AC, and TT locations. Beginning March 14, 2007, As(V) concentrations from the combined effluent began to increase gradually along with the volume of water treated, indicating that the media was becoming exhausted (however, breakthrough at 10 μg/L was never reached during the evaluation period). As(III) levels at the IN, AC, and TT locations were similar, averaging 1.3, 1.8, and 1.5 μg/L, respectively. The measurements of As(III) at AC and TT are most likely due to the limitation of the speciation method, since as much as 1.0 mg/L (as Cl_2) of free-chlorine residuals were measured in the combined effluent.

Figure 4-10 illustrates total arsenic concentrations measured across the treatment train as a function of throughput in bed volumes. The total arsenic breakthrough curves indicate that the AD-33 media removed arsenic to levels well below the MCL of 10 μg/L. The final sampling event, April 17, 2008, measured the total arsenic concentration at the TA and TB sampling locations at 6.8 and 2.3 μg/L, respectively. Throughout the evaluation period, the system treated an estimated 25,938 BV (14,744,962 gal) of water with treated water containing <6.8 μg/L of arsenic. This volume of treated water surpassed the vendor's estimate of 17,240 BV (9,800,000 gal) by 50%.

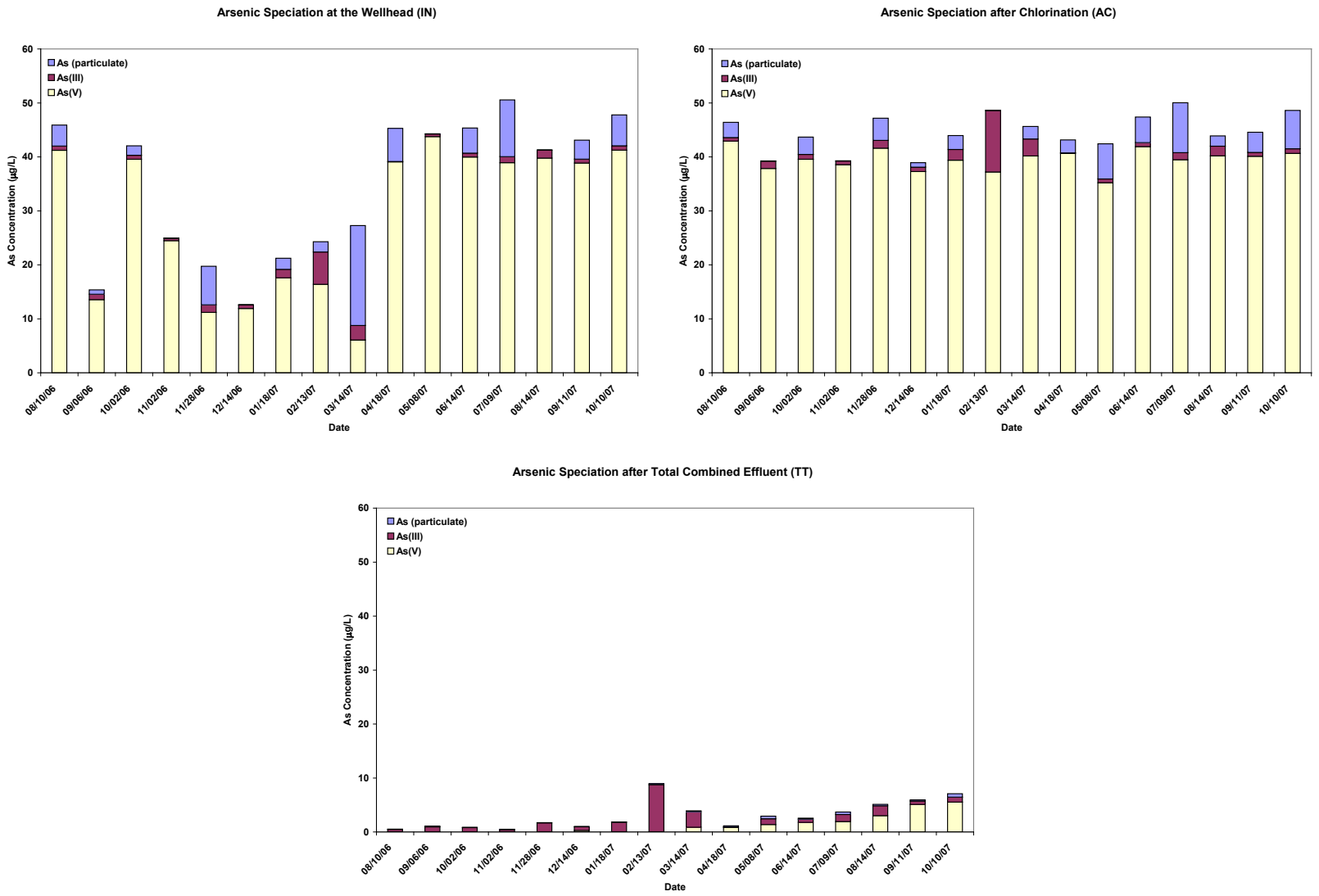

Figure 4-9. Concentrations of Arsenic Species at IN, AC, and TT Sampling Locations

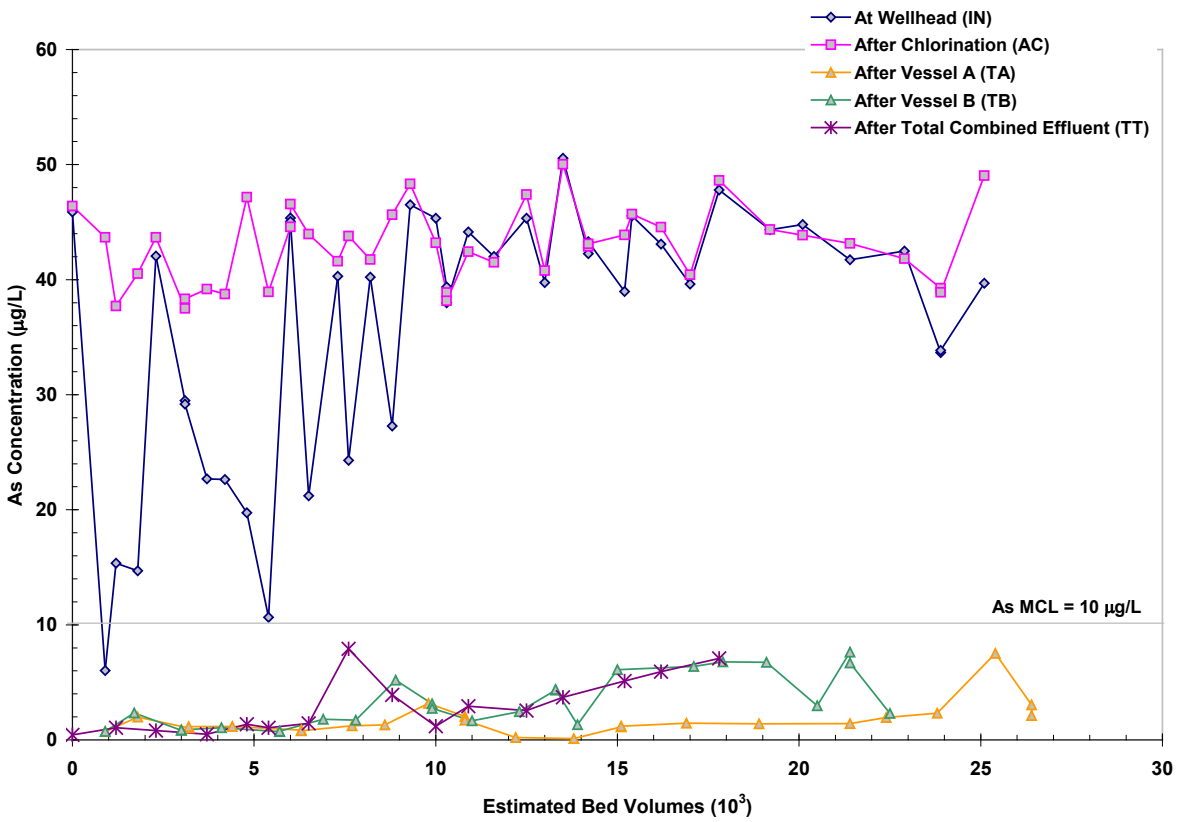

Figure 4-10. Total Arsenic Breakthrough Curves

As indicated earlier, total arsenic concentrations (along with concentrations of various other analytical parameters, including total vanadium) unexpectedly increased from the IN to the AC sampling location on 12 occasions (see Figure 4-11). During these sampling events, the average total arsenic concentration at the IN and AC sampling locations was 19.8 and 40.9 µg/L, respectively. Repeat analysis of these samples and discussions with the operator did not reveal an explanation. One factor that was most likely the cause of this inconsistency was the intermittent operation of the wells and the possibility of samples being collected while the system was not operating. The system treats water based on demand, and the water is supplied by five wells. Wells 1, 2, 3, and 4 are operated by a single pressure switch and Well 5, which produces nearly half the treated water, is operated by a separate pressure switch. This type of pressure switch configuration might have allowed some wells to operate somewhat longer than others, thereby producing inconsistencies in water quality and analytical results. In fact, in some cases, if one of the pressure switches was delayed, pressure could build in the pipeline and prevent the delayed well pump or pumps from being switched on.

In an effort to evaluate this possibility, the operator was instructed to collect samples only while the system was operating and producing the average flow expected from all five supply wells. Since that time, the average total arsenic concentrations at the IN and AC sampling locations were 42.3 and 43.5 µg/L, respectively. Overall, the analytical results indicate that once the operator began collecting samples while the system was operating, the total arsenic concentrations (along with various other analytical parameters) became more consistent between the IN and AC sampling locations.

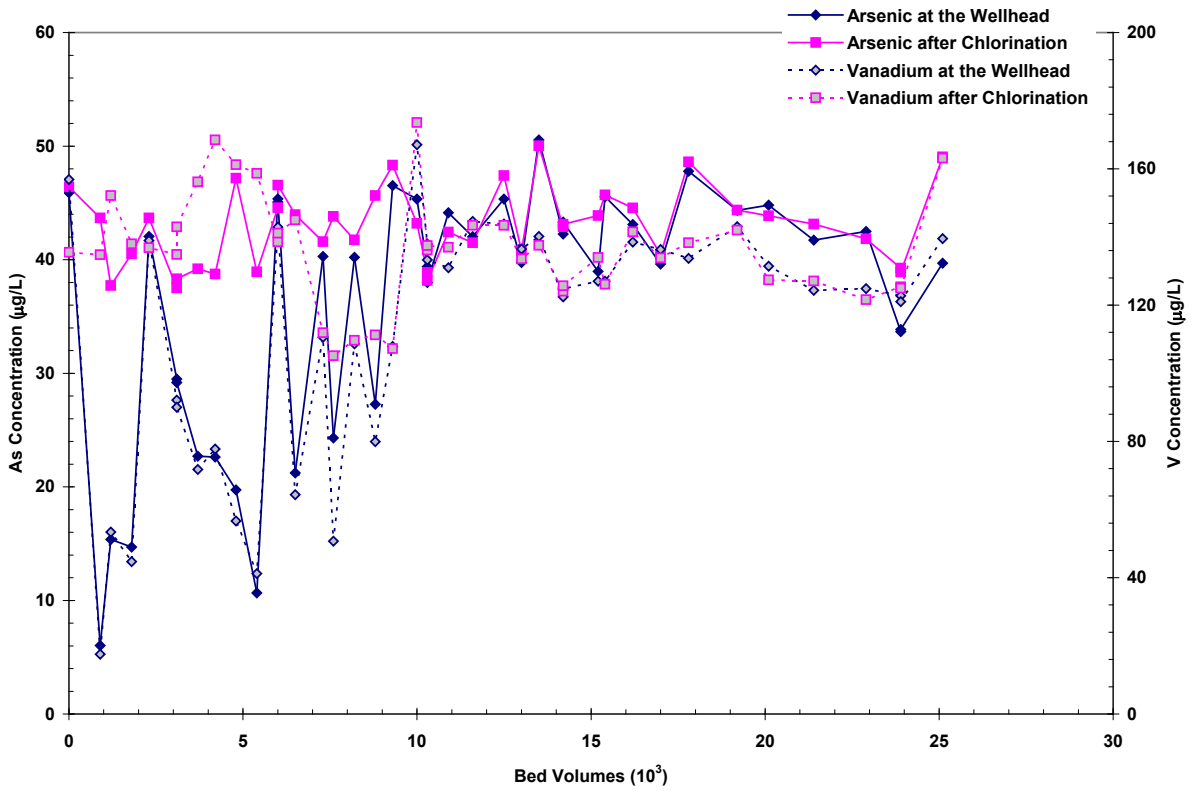

Figure 4-11. Total Arsenic and Vanadium Concentrations at IN and AC Sampling Locations

Iron, Manganese, and Vanadium. Total iron levels at the wellhead averaged below the MDL of 25 µg/L (Table 4-8). However, iron was detected during the first three sampling events, on July 23, 2007 and on April 17, 2008. Total iron concentrations after chlorination were below the MDL, except on October 19, 2006, February 13, 2007, July 23, 2007, and April 17, 2008. Iron levels consistently remained below the detection limit in the treatment system effluent.

Total manganese levels at the wellhead averaged 0.6 µg/L (Table 4-8). Total manganese in the system effluent decreased to levels below the detection limit of 0.1 µg/L at the TA and TB sampling locations and averaged 0.1 µg/L from the total combined effluent (TT). Soluble manganese concentrations were similar to total concentrations, averaging 0.7, 0.4, and 0.1 µg/L at the IN, AC, and TT locations, respectively.

Total vanadium levels varied significantly in the IN samples, ranging from 17.5 to 167 µg/L, with 89% existing in the soluble form (Table 4-8). Figure 4-12 illustrates the vanadium breakthrough curves at sampling locations across the treatment train. Over the evaluation period, total vanadium concentrations were reduced to <133 µg/L in the treatment system effluent.

As discussed previously, total vanadium concentrations unexpectedly increased from the wellhead to the after-chlorination sampling location – similar to total arsenic levels – on 12 occasions. Figure 4-11 illustrates the similarities at the IN and AC sampling locations between total arsenic and total vanadium concentrations. During these sampling events, the average total vanadium concentration at the IN and AC sampling locations was 61.7 and 142 µg/L, respectively. As indicated previously, this variation was most

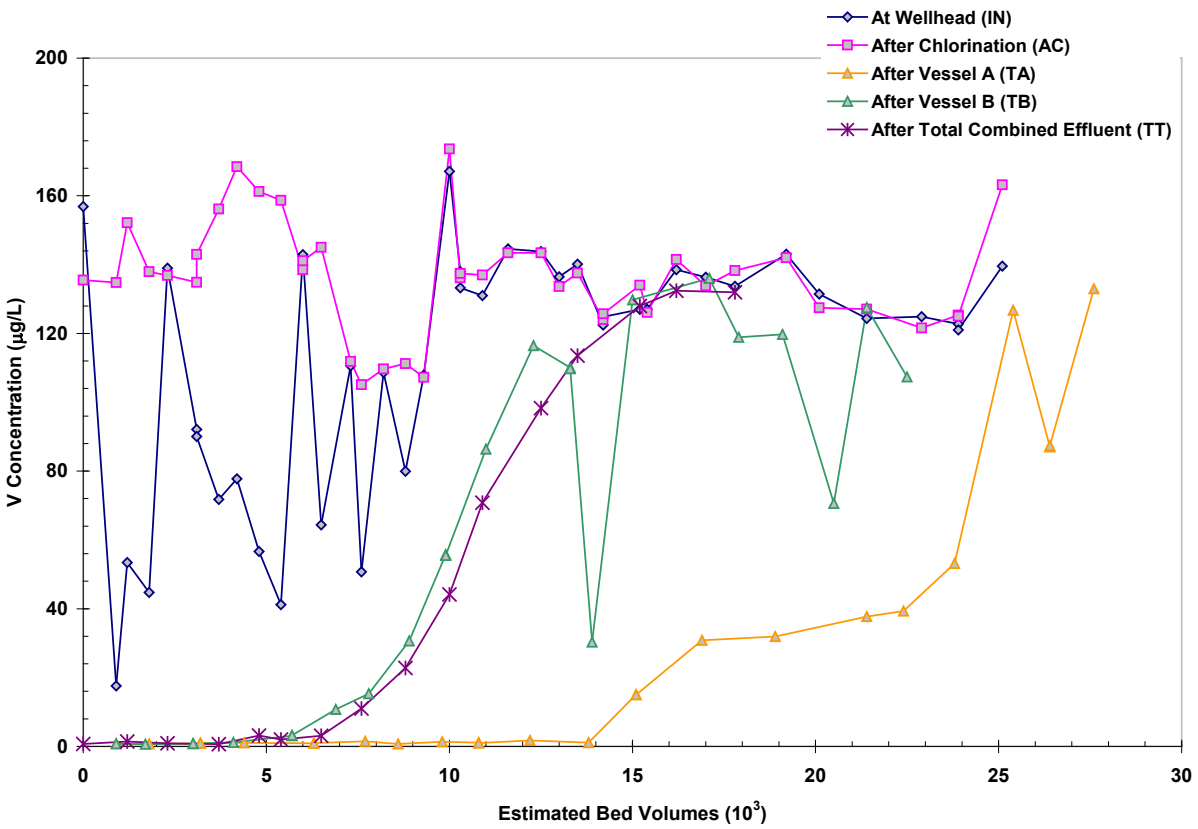

Figure 4-12. Total Vanadium Breakthrough Curves

likely caused by inconsistent operations of pressure switches and well pumps used to supply water to the treatment system. Once the operator began collecting samples while the treatment system was operating, the analytical results were more consistent, as demonstrated by the average total vanadium concentrations of 133 and 135 µg/L at the IN and AC sampling locations, repectively.

Total vanadium concentrations at the TB sampling location were consistently higher than those at the TA sampling location, at corresponding sampling intervals. This noticeable trend also was present with total arsenic concentrations at the TA and TB sampling locations. It is not clear what caused the differences observed. Figures 4-10 and 4-12 illustrate these trends.

Competing Anions. Phosphate and silica, which can adversely affect arsenic adsorption onto the AD-33 media, were measured at sampling locations across the treatment train. Total phosphorous concentrations remained low throughout the treatment train, averaging <10 µg/L (as P); therefore, it was not expected to affect system performance. Silica concentrations remained relatively constant across the treatment train, averaging from 45.2 mg/L at the TT location to 47.9 mg/L at the TB location (Table 4-9). Some silica was removed during the first 2,000 BV; similar removal by AD-33 media was observed elsewhere during the arsenic demonstration studies (McCall, et al., 2007; Williams, et al., 2007).

Other Water Quality Parameters. As shown in Table 4-9, pH values of raw water ranged from 7.6 to 8.0 and averaged 7.8. After chlorination, pH values ranged from 7.4 to 7.8 and averaged 7.6. This pH range of 7.4 to 7.8 after chlorination, but prior to the adsorption vessels, is lower than that for which pH

adjustment should be implemented. As discussed previously, pH adjustment was required by TCEQ, but was not implemented because of the operator's safety concerns.

Alkalinity levels averaged 262 mg/L (as $CaCO_3$) in raw water and 260 mg/L (as $CaCO_3$) in system effluent. Total hardness levels ranged from 333 to 604 mg/L (as $CaCO_3$) in raw water and from 351 to 557 mg/L (as $CaCO_3$) in the treated water. Average fluoride results ranged from 5.3 to 5.8 mg/L at all sampling locations. The fluoride levels were higher than the fluoride MCL of 4 mg/L. Average nitrate concentrations were 5.1 mg/L at all sampling locations. Average sulfate concentrations ranged from 240 to 299 mg/L at all sampling locations. The results indicated that the AD-33 media did not affect the amount of alkalinity, total hardness, fluoride, nitrate, and sulfate in the treated water.

4.5.2 Backwash Wastewater Sampling. The arsenic treatment system was not backwashed during the evaluation period due to the minimal pressure drop across the vessels.

4.5.3 Distribution System Water Sampling. Prior to the installation and operation of the arsenic treatment system, baseline distribution system water samples were collected on June 22, July 14, August 18, and September 14, 2005, at three residences, including two that had been included for the city's LCR sampling in the past. Following installation of the treatment system, distribution water sampling continued on a monthly basis at the same three locations, with samples collected on 13 occasions from September 6, 2006, through September 11, 2007. Table 4-10 summarizes the results of the distribution system sampling.

The most significant change in the distribution system water since the system began operation was a decrease in arsenic concentration. Baseline arsenic concentrations ranged from 33.2 to 44.7 µg/L and averaged 38.9 µg/L for all three locations. After treatment began, arsenic concentrations decreased at all three locations, averaging 3.2 µg/L. Distribution system samples collected on September 6, 2006, and February 21, 2007 contained relatively high arsenic concentrations ranging from 7.0 to 11.4 and 6.0 to 14.1 µg/L, respectively. The remaining samples contained lower arsenic concentrations ranging from <0.1 to 3.9 µg/L and averaging 2.0 µg/L for all three locations.

After treatment began, average lead concentrations remained relatively constant, ranging from 0.3 to 0.4 µg/L at the three locations, with no samples exceeding the action level of 15 µg/L. Average copper concentrations varied significantly, ranging from 17.0 to 115 µg/L at the three locations, with no samples exceeding the 1,300 µg/L action level. Overall, operation of the arsenic treatment system did not adversely affect the lead or copper concentrations in the distribution system.

After treatment began, measured pH values averaged 7.7, which is consistent with the values measured before the system became operational (pH was 7.6) and with the average values measured after the adsorption vessels (pH was 7.5). Average alkalinity levels ranged from 261 to 271 mg/L (as $CaCO_3$), iron was not detected in any of the samples, and average manganese concentrations ranged from 0.3 to 0.4 µg/L at all three locations. Overall, the arsenic treatment system did not appear to affect these water quality parameters in the distribution system.

4.6 System Cost

The system cost is presented 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 media replacement and disposal, chemical usage, electrical power use, and labor.

Table 4-10. Distribution System Sampling Results

Event No.	Location	DS1								DS2								DS3							
	Sample Type	LCR								LCR								Residence							
	Sampling Date	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu	Stagnation Time	pH	Alkalinity	As	Fe	Mn	Pb	Cu
No.	Date	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	hr	S.U.	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L
BL1	06/22/05	11.3	7.6	242	40.6	<25	0.3	0.2	62.3	8.8	7.6	242	42.3	<25	0.2	<0.1	73.0	6.5	8.2	242	40.5	<25	0.5	0.3	275
BL2	07/14/05	10.5	7.5	246	39.4	<25	0.9	0.4	67.0	6.4	7.6	251	39.7	<25	0.2	0.4	65.8	7.1	7.6	251	38.5	<25	0.3	0.2	139
BL3	08/18/05	6.5	7.5	242	38.3	<25	0.3	0.3	51.1	8.4	7.5	246	37.9	<25	0.1	0.1	97.2	8.3	7.6	NA[a]	44.7	<25	0.3	0.2	197
BL4	09/14/05	8.5	7.5	264	33.2	<25	<0.1	0.3	67.5	7.8	7.6	264	36.2	<25	0.3	0.1	126	7.4	7.5	264	35.1	<25	<0.1	0.2	153
1	09/06/06	6.5	7.7	263	7.0	<25	<0.1	<0.1	3.0	7.5	7.6	367	11.4	<25	<0.1	<0.1	74.4	7.9	7.8	272	11.4	<25	<0.1	<0.1	72.9
2	10/10/06	9.3	7.6	258	1.4	<25	<0.1	0.4	10.1	6.5	7.6	260	2.4	<25	<0.1	<0.1	78.0	7.5	7.7	271	1.8	<25	<0.1	0.3	190
3	11/15/06	6.5	7.5	254	1.1	<25	<0.1	0.5	7.8	8.5	7.5	258	2.1	<25	<0.1	0.2	129	7.3	7.5	258	1.4	<25	0.1	0.3	182
4	12/14/06	6.5	7.6	268	1.1	<25	<0.1	<0.1	5.2	11.0	7.5	262	2.5	<25	0.3	0.5	141	8.1	7.7	266	1.3	<25	0.2	0.2	94.8
5	01/18/07	6.5	7.8	265	2.1	<25	<0.1	<0.1	134	7.8	7.6	272	1.4	<25	0.1	0.2	139	8.2	7.7	272	1.1	<25	<0.1	0.3	13.4
6	02/21/07	6.5	7.8	264	6.0	<25	0.7	1.0	9.5	9.0	7.7	267	7.3	<25	0.8	1.2	141	6.6	7.8	269	14.1	<25	1.7	1.8	120
7	03/20/07	7.5	7.9	271	0.9	<25	0.3	0.6	7.8	7.5	7.7	273	1.7	<25	0.3	0.5	112	7.5	7.9	276	<0.1	<25	<0.1	0.2	196
8	04/18/07	6.5	7.8	276	0.4	<25	0.1	0.3	6.3	8.0	7.7	260	1.1	<25	0.2	0.3	99.0	7.3	7.7	264	0.6	<25	0.2	0.2	111
9	05/24/07	6.5	7.8	261	1.2	<25	<0.1	0.2	5.8	7.0	7.7	257	1.8	<25	<0.1	0.2	139	7.0	7.7	257	1.3	<25	<0.1	0.2	28.7
10	06/14/07	6.5	7.8	247	2.0	<25	<0.1	0.2	7.7	8.8	8.0	262	2.5	<25	<0.1	0.1	113	7.6	8.0	274	2.4	<25	<0.1	0.1	124
11	07/12/07	7.5	8.0	252	3.5	<25	<0.1	<0.1	6.3	8.8	7.8	256	3.7	<25	<0.1	<0.1	70.7	6.8	7.7	249	3.9	<25	0.4	<0.1	167
12	08/22/07	6.5	7.8	259	2.9	<25	<0.1	0.2	8.4	7.5	7.7	265	3.2	<25	<0.1	0.1	117	7.0	7.7	263	3.9	<25	0.1	0.2	157
13	09/11/07	6.5	7.9	260	3.2	<25	<0.1	0.3	8.3	8.3	7.8	264	3.5	<25	0.4	0.3	118	7.0	7.7	262	3.3	<25	<0.1	0.3	37.9

(a) Insufficient sample for analysis due to loss during shipment.
BL = Baseline Sampling; NA = not analyzed; NS = not sampled.
Lead action level = 15 µg/L; copper action level = 1,300 µg/L.

4.6.1 Capital Cost. The capital investment for equipment, site engineering, and installation of the arsenic treatment system was $149,221 (see Table 4-11). The equipment cost was $103,897 (or 70% of the total capital investment), which included $76,254 for the skid-mounted APU-100CS-S-2-AVH unit, $21,280 for the AD-33 media (i.e., $280/ft^3 to fill two vessels with 76 ft^3 of media), $2,851 for the pH adjustment system, and $3,512 for shipping.

Table 4-11. Capital Investment Cost for APU System

Description	Quantity	Cost	% of Capital Investment
Equipment Cost			
APU Skid-Mounted System (Unit)	1	$76,254	–
AD-33 Media (ft^3)	76	$21,280	–
pH Adjustment System	–	$2,851	–
Shipping	–	$3,512	–
Equipment Total	–	**$103,897**	**70%**
Engineering Cost			
Vendor Material/Labor/Travel	–	$11,660	–
Subcontractor Labor/Travel	–	$13,650	–
Engineering Total	–	**$25,310**	**17%**
Installation Cost			
Vendor Labor/Travel	–	$6,374	–
Subcontractor Labor/Travel	–	$13,640	–
Installation Total	–	**$20,014**	**13%**
Total Capital Investment	–	**$149,221**	**100%**

The engineering cost included the cost for preparing one submittal package for the exception request and permit application and for obtaining the required permit in addition to labor and travel (see Section 4.3.1). The engineering cost was $25,310, or 17% 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 $20,014, or 13% of the total capital investment.

The total capital cost of $149,221 was normalized to the system's rated capacity of 100 gpm (144,000 gpd), which resulted in $1,492/gpm ($1.04/gpd) of design capacity. The capital cost also was converted to an annualized cost of $14,085/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 hr/day, 7 day/week at the system design flowrate of 100 gpm to produce 52,560,000 gal of water per year, the unit capital cost would be $0.27/1,000 gal. Because the system only operated an average of 5.9 hr/day at 91 gpm (see Table 4-6), producing approximately 11,758,000 gal of water over a 1 year period, the unit capital cost increased to $1.20/1,000 gal of water at this reduced rate of use.

4.6.2 Operation and Maintenance Cost. The O&M cost includes the cost for items such as media replacement and disposal, chemical usage, electricity consumption, and labor. Although media replacement did not occur during the evaluation period, the media replacement cost would represent the majority of the O&M cost and is estimated to be $30,010 to change out both vessels (Table 4-12). This media changeout cost would include the cost for media, 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

Table 4-12. Operation and Maintenance Cost for APU System

Cost Category	Value	Assumptions
Volume Processed (gal)	14,744,962	Through April 17, 2008
Media Replacement and Disposal Cost		
Media and Underbedding Replacement	$22,420	Vendor quote; $295/ft^3 for 76 ft^3 (two media vessel)
Shipping	$983	Vendor quote
Vendor Labor/Travel	$3,717	Vendor quote
Subcontractor Labor	$1,890	Vendor quote
Media Analysis and Disposal	$1,000	Vendor quote
Subtotal	$30,010	Vendor quote plus spent-media analysis
Media Replacement and Disposal ($/1,000 gal)	See Figure 4-13	Based upon both vessels' media run length at 10 μg/L arsenic breakthrough
Electricity Cost		
Electricity ($/1,000 gal)	$0.001	Electrical costs assumed negligible
Labor Cost		
Average Weekly Labor (min)	45	15 min/day, 3 day/week
Annual Labor Cost ($/yr(	$234	Labor rate = $6.00/hr; 52 week/yr
Labor ($/1,000 gal)	$0.02	Annual system throughput = 11,758,000 gal
Total O&M Cost/1,000 gal	See Figure 4-13	Based on both vessels' media run length at 10 μg/L arsenic breakthrough

treated as a function of the projected media run length in bed volumes to 10 μg/L arsenic breakthrough (Figure 4-13).

The chemical cost associated with the treatment system's operation included the use of hydrochloric acid for pH adjustment and sodium hypochlorite for chlorination. The pH adjustment system was not operated; therefore, no cost accrued for acid consumption. Sodium hypochlorite was already being used at the site prior to installation of the APU system for disinfection purposes. The operation of the APU system did not affect the use of sodium hypochlorite; therefore, the incremental chemical cost for chlorine was negligible and not included in O&M costs.

Electrical bills prior to and after installation showed no indication of an 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 up to 15 min/day, 3 day/week, as noted in Section 4.4.3. Based on this time commitment, a labor rate of $6.00/hr, and an annual system throughput of 11,758,000 gal, the estimated labor cost was $0.02/1,000 gal of water treated.

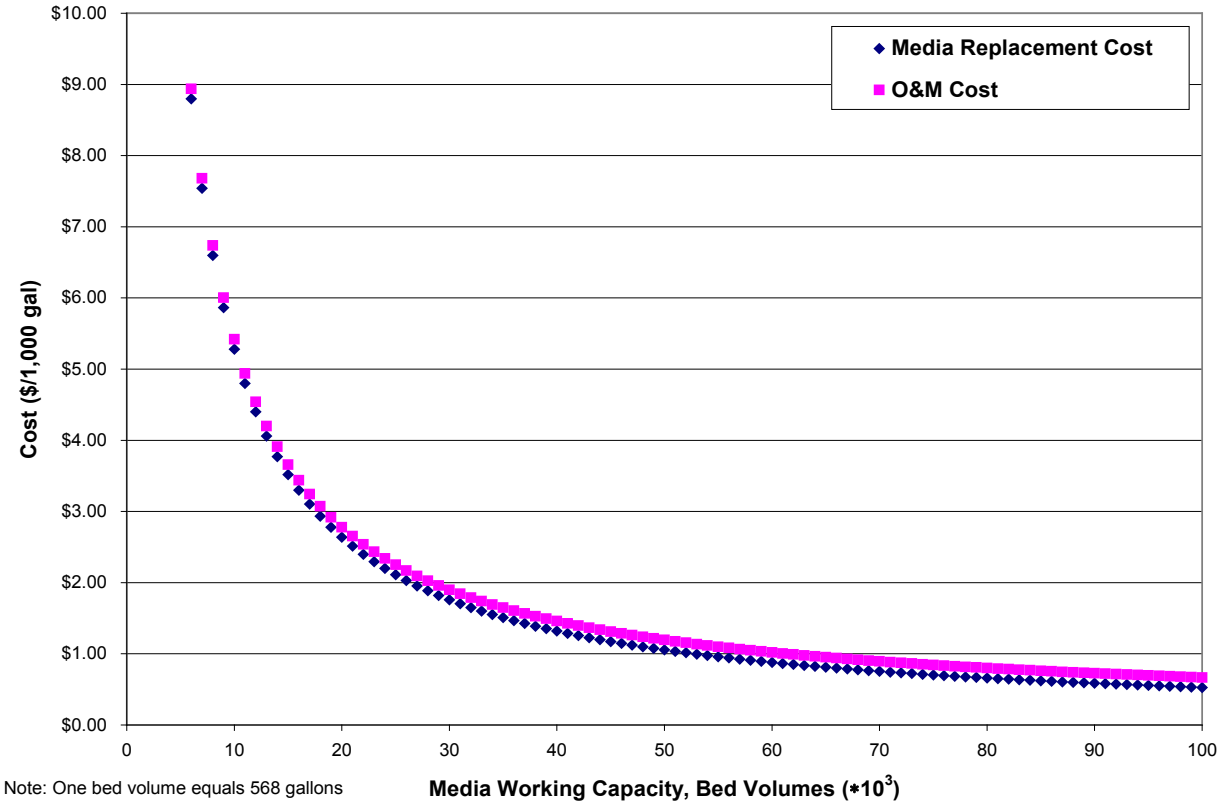

Figure 4-13. Media Replacement and Operation and Maintenance Cost

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APPENDIX A

OPERATIONAL DATA

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

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
1	Thu	08/10/06	0.0	33,039,400	0	0	NA	23,951	0	0	0	NA	NA	NA	36	33	3
	Fri	08/11/06	14.9	33,115,400	76,000	76,000	85	133,239	109,288	109,288	192	122	65.4	59.0	NA	NA	NA
	Sat	08/12/06	3.3	33,136,000	20,600	96,600	104	157,120	23,881	133,169	234	121	60.5	60.1	NA	NA	NA
	Sun	08/13/06	4.6	33,160,600	24,600	121,200	89	191,863	34,743	167,912	295	126	67.6	59.4	46	45	1
2	Mon	08/14/06	5.6	33,187,200	26,600	147,800	79	229,992	38,129	206,041	362	113	48.2	64.4	44	44	0
	Tue	08/15/06	8.7	33,214,400	27,200	175,000	52	264,499	34,507	240,548	423	66	25.0	41.1	47	48	1
	Wed	08/16/06	4.6	33,233,700	19,300	194,300	70	293,575	29,076	269,624	474	105	53.4	51.9	NA	NA	NA
	Thu	08/17/06	3.3	33,256,600	22,900	217,200	116	327,434	33,859	303,483	534	171	90.5	80.5	NA	NA	NA
	Fri	08/18/06	2.4	33,270,000	13,400	230,600	93	344,691	17,257	320,740	564	120	59.1	59.1	44	44	0
	Sat	08/19/06	6.3	33,301,000	31,000	261,600	82	392,696	48,005	368,745	649	127	67.6	60.8	43	44	1
	Sun	08/20/06	3.0	33,325,900	24,900	286,500	138	431,068	38,372	407,117	716	213	119.9	90.7	49	51	2
3	Mon	08/21/06[a]	3.4	33,347,400	21,500	308,000	105	466,586	35,518	442,635	779	174	105.0	70.4	NA	NA	0
	Tue	08/22/06	6.9	33,368,900	21,500	329,500	52	502,488	35,902	478,537	842	87	51.8	34.7	NA	NA	0
	Wed	08/23/06	7.7	33,392,500	23,600	353,100	51	539,511	37,023	515,560	907	80	47.3	33.0	NA	NA	0
	Thu	08/24/06	9.4	33,417,900	25,400	378,500	45	577,067	37,556	553,116	973	67	33.4	33.1	NA	NA	0
	Fri	08/25/06	9.7	33,441,400	23,500	402,000	40	611,907	34,840	587,956	1,034	60	30.2	29.7	NA	NA	0
	Sat	08/26/06	7.9	33,462,000	20,600	422,600	43	641,610	29,703	617,659	1,087	63	31.6	31.1	NA	NA	0
	Sun	08/27/06	1.5	33,466,100	4,100	426,700	46	647,446	5,836	623,495	1,097	65	32.3	32.5	40	41	1
4	Mon	08/28/06	12.3	33,501,300	35,200	461,900	48	689,782	42,336	665,831	1,171	57	29.3	28.0	44	44	0
	Tue	08/29/06	5.0	33,522,200	20,900	482,800	70	719,819	30,037	695,868	1,224	100	49.8	33.6	43	44	1
	Wed	08/30/06	5.9	33,551,100	28,900	511,700	82	760,881	41,062	736,930	1,296	116	59.7	69.8	46	46	0
	Thu	08/31/06	6.3	33,578,700	27,600	539,300	73	801,170	40,289	777,219	1,367	107	55.7	78.2	48	47	1
	Fri	09/01/06	3.3	33,595,600	16,900	556,200	85	825,870	24,700	801,919	1,411	125	61.7	10.7	45	44	1
	Sat	09/02/06	5.5	33,622,000	26,400	582,600	80	863,921	38,051	839,970	1,478	115	59.7	56.4	42	44	2
	Sun	09/03/06	4.6	33,643,400	21,400	604,000	78	898,784	34,863	874,833	1,539	126	64.0	62.3	44	46	2
5	Mon	09/04/06	3.8	33,664,800	21,400	625,400	94	927,588	28,804	903,637	1,590	126	64.1	62.2	48	48	0
	Tue	09/05/06	3.6	33,686,200	21,400	646,800	99	955,246	27,658	931,295	1,638	128	65.4	62.6	44	45	1
	Wed	09/06/06	4.8	33,711,400	25,200	672,000	87	991,279	36,033	967,328	1,702	125	64.0	61.1	48	48	0
	Thu	09/07/06	4.6	33,735,500	24,100	696,100	87	1,025,595	34,316	1,001,644	1,762	124	63.4	61.0	47	49	2
	Fri	09/08/06	3.8	33,756,000	20,500	716,600	90	1,054,775	29,180	1,030,824	1,813	128	65.4	62.6	46	48	2
	Sat	09/09/06	3.9	33,777,400	21,400	738,000	91	1,085,135	30,360	1,061,184	1,867	130	65.9	63.8	48	49	1
	Sun	09/10/06	3.8	33,797,000	19,600	757,600	86	1,113,081	27,946	1,089,130	1,916	123	62.3	60.3	48	49	1
6	Mon	09/11/06	4.9	33,823,700	26,700	784,300	91	1,150,871	37,790	1,126,920	1,982	129	65.1	63.4	46	47	1
	Tue	09/12/06	5.0	33,850,300	26,600	810,900	89	1,190,365	39,494	1,166,414	2,052	132	70.1	61.5	44	46	2
	Wed	09/13/06	4.4	33,873,800	23,500	834,400	89	1,223,797	33,432	1,199,846	2,111	127	64.7	62.0	42	44	2
	Thu	09/14/06	4.2	33,896,100	22,300	856,700	88	1,255,406	31,609	1,231,455	2,166	125	63.9	61.5	44	44	0
	Fri	09/15/06	4.1	33,917,900	21,800	878,500	89	1,286,453	31,047	1,262,502	2,221	126	64.6	61.6	42	44	2
	Sat	09/16/06	4.5	33,942,300	24,400	902,900	90	1,321,101	34,648	1,297,150	2,282	128	65.5	62.8	44	46	2
	Sun	09/17/06	4.2	33,964,700	22,400	925,300	89	1,352,826	31,725	1,328,875	2,338	126	64.5	61.4	44	45	1
7	Mon	09/18/06	4.7	33,991,600	26,900	952,200	95	1,390,716	37,890	1,366,765	2,404	134	69.1	65.3	46	48	2
	Tue	09/19/06	3.8	34,011,900	20,300	972,500	89	1,419,142	28,426	1,395,191	2,454	125	64.0	60.7	46	48	2
	Wed	09/20/06	4.4	34,035,700	23,800	996,300	90	1,452,145	33,003	1,428,194	2,512	125	63.3	61.7	44	45	1
	Thu	09/21/06	3.6	34,054,400	18,700	1,015,000	87	1,478,474	26,329	1,454,523	2,559	122	62.4	59.4	40	42	2
	Fri	09/22/06	4.8	34,080,700	26,300	1,041,300	91	1,515,255	36,781	1,491,304	2,623	128	65.2	62.5	40	42	2
	Sat	09/23/06	4.9	34,107,400	26,700	1,068,000	91	1,552,716	37,461	1,528,765	2,689	127	65.4	62.0	40	42	2
	Sun	09/24/06	13.5	34,146,300	38,900	1,106,900	48	1,612,618	59,902	1,588,667	2,795	74	42.7	31.2	48	49	1

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
8	Mon	09/25/06	5.3	34,174,900	28,600	1,135,500	90	1,653,161	40,543	1,629,210	2,866	127	65.4	62.1	46	48	2
	Tue	09/26/06	4.2	34,197,400	22,500	1,158,000	89	1,684,529	31,368	1,660,578	2,921	124	63.1	61.3	46	48	2
	Wed	09/27/06	2.3	34,209,700	12,300	1,170,300	89	1,701,942	17,413	1,677,991	2,952	126	64.9	61.3	40	42	2
	Thu	09/28/06	4.9	34,236,200	26,500	1,196,800	90	1,738,868	36,926	1,714,917	3,017	126	63.3	62.3	40	42	2
	Fri	09/29/06	4.7	34,264,500	28,300	1,225,100	100	1,777,720	38,852	1,753,769	3,085	138	69.5	67.5	44	43	1
	Sat	09/30/06	5.6	34,294,000	29,500	1,254,600	88	1,819,883	42,163	1,795,932	3,159	125	63.5	62.6	43	44	1
	Sun	10/01/06	5.6	34,325,300	31,300	1,285,900	93	1,863,726	43,843	1,839,775	3,236	130	66.2	64.3	44	46	2
9	Mon	10/02/06	2.4	34,348,500	23,200	1,309,100	161	1,892,368	28,642	1,868,417	3,287	199	111.2	87.7	40	42	2
	Tue	10/03/06	5.3	34,376,500	28,000	1,337,100	88	1,937,203	44,835	1,913,252	3,366	141	72.5	68.5	40	42	2
	Wed	10/04/06	10.9	34,422,000	45,500	1,382,600	70	2,002,215	65,012	1,978,264	3,480	99	52.7	46.4	48	47	1
	Thu	10/05/06	8.2	34,467,200	45,200	1,427,800	92	2,065,789	63,574	2,041,838	3,592	129	66.0	63.6	48	50	2
	Fri	10/06/06	3.8	34,487,500	20,300	1,448,100	89	2,094,019	28,230	2,070,068	3,641	124	63.0	60.8	42	44	2
	Sat	10/07/06	4.5	34,514,200	26,700	1,474,800	99	2,131,415	37,396	2,107,464	3,707	139	71.1	67.4	44	46	2
	Sun	10/08/06	4.6	34,539,200	25,000	1,499,800	91	2,165,969	34,554	2,142,018	3,768	125	63.6	61.6	46	48	2
10	Mon	10/09/06	4.8	34,565,800	26,600	1,526,400	92	2,202,812	36,843	2,178,861	3,833	128	65.0	62.9	46	48	2
	Tue	10/10/06	4.7	34,591,700	25,900	1,552,300	92	2,238,965	36,153	2,215,014	3,896	128	64.9	63.3	48	50	2
	Wed	10/11/06	4.6	34,617,000	25,300	1,577,600	92	2,274,199	35,234	2,250,248	3,958	128	64.7	62.9	48	50	2
	Thu	10/12/06	4.1	34,639,800	22,800	1,600,400	93	2,305,780	31,581	2,281,829	4,014	128	65.1	63.2	48	50	2
	Fri	10/13/06	2.1	34,647,300	7,500	1,607,900	60	2,315,671	9,891	2,291,720	4,031	79	44.2	35.3	48	44	4
	Sat	10/14/06	4.4	34,670,600	23,300	1,631,200	88	2,349,386	33,715	2,325,435	4,091	128	64.9	62.4	42	44	2
	Sun	10/15/06	5.3	34,708,800	38,200	1,669,400	120	2,391,138	41,752	2,367,187	4,164	131	67.0	64.3	46	48	2
11	Mon	10/16/06	4.8	34,726,400	17,600	1,687,000	61	2,427,468	36,330	2,403,517	4,228	126	63.8	61.4	44	44	0
	Tue	10/17/06	4.4	34,751,600	25,200	1,712,200	95	2,462,190	34,722	2,438,239	4,289	132	67.7	64.6	44	43	1
	Wed	10/18/06	4.2	34,776,400	24,800	1,737,000	98	2,497,148	34,958	2,473,197	4,351	139	72.2	67.6	44	43	1
	Thu	10/19/06	7.1	34,799,500	23,100	1,760,100	54	2,542,188	45,040	2,518,237	4,430	106	54.9	33.3	46	45	1
	Fri	10/20/06	3.9	34,808,400	8,900	1,769,000	38	2,571,835	29,647	2,547,884	4,482	127	65.1	92.1	53	52	1
	Sat	10/21/06	3.2	34,831,700	23,300	1,792,300	121	2,575,347	3,512	2,551,396	4,488	18	10.1	8.0	42	42	0
12	Mon	10/23/06	11.5	34,888,800	57,100	1,849,400	83	2,656,647	81,300	2,632,696	4,631	118	64.8	53.0	52	52	0
	Tue	10/24/06	1.6	34,890,800	2,000	1,851,400	21	2,664,075	7,428	2,640,124	4,644	77	44.7	32.3	44	43	1
	Wed	10/25/06	5.8	34,920,800	30,000	1,881,400	86	2,712,601	48,526	2,688,650	4,730	139	72.9	66.5	44	43	1
	Thu	10/26/06	6.3	34,956,200	35,400	1,916,800	94	2,757,824	45,223	2,733,873	4,809	120	61.2	58.5	44	43	1
	Fri	10/27/06	8.0	34,987,600	31,400	1,948,200	65	2,818,802	60,978	2,794,851	4,916	127	63.9	63.1	51	50	1
	Sat	10/28/06	1.4	35,012,800	25,200	1,973,400	300	2,829,299	10,497	2,805,348	4,935	125	64.2	60.6	44	42	2
	Sun	10/29/06	3.9	35,038,800	26,000	1,999,400	111	2,864,949	35,650	2,840,998	4,998	152	77.6	76.3	44	43	1
13	Mon	10/30/06	5.1	35,063,100	24,300	2,023,700	79	2,899,391	34,442	2,875,440	5,058	113	58.6	54.8	44	44	0
	Tue	10/31/06	5.7	35,088,400	25,300	2,049,000	74	2,941,041	41,650	2,917,090	5,131	122	61.6	58.8	51	52	1
	Wed	11/01/06	1.9	35,098,700	10,300	2,059,300	90	2,948,962	7,921	2,925,011	5,145	69	41.3	28.2	44	43	1
	Thu	11/02/06	5.0	35,125,800	27,100	2,086,400	90	2,987,116	38,154	2,963,165	5,212	127	65.4	63.2	48	47	1
	Fri	11/03/06	3.1	35,144,600	18,800	2,105,200	101	3,012,449	25,333	2,988,498	5,257	136	69.6	64.4	44	42	2
	Sat	11/04/06	6.0	35,175,900	31,300	2,136,500	87	3,056,088	43,639	3,032,137	5,334	121	62.0	59.0	44	42	2
14	Mon	11/06/06	4.7	35,205,600	29,700	2,166,200	105	3,095,999	39,911	3,072,048	5,404	142	73.0	68.2	44	42	2
	Tue	11/07/06	5.2	35,235,300	29,700	2,195,900	95	3,142,454	46,455	3,118,503	5,486	149	78.7	70.3	44	42	2
	Wed	11/08/06	5.2	35,266,100	30,800	2,226,700	99	3,181,806	39,352	3,157,855	5,555	126	65.4	61.1	47	46	1
	Thu	11/09/06	3.0	35,284,400	18,300	2,245,000	102	3,210,514	28,708	3,186,563	5,605	159	86.7	72.6	44	43	1
	Fri	11/10/06	4.4	35,311,900	27,500	2,272,500	104	3,246,301	35,787	3,222,350	5,668	136	70.8	64.1	45	44	1
	Sat	11/11/06	5.5	35,339,800	27,900	2,300,400	85	3,287,855	41,554	3,263,904	5,741	126	66.1	60.3	44	43	1
	Sun	11/12/06	4.8	35,368,600	28,800	2,329,200	100	3,326,104	38,249	3,302,153	5,809	133	68.9	63.6	44	42	2

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
15	Mon	11/13/06	4.6	35,396,400	27,800	2,357,000	101	3,363,546	37,442	3,339,595	5,875	136	70.6	64.9	44	44	0
	Tue	11/14/06	4.4	35,421,200	24,800	2,381,800	94	3,399,411	35,865	3,375,460	5,938	136	70.9	64.6	45	42	3
	Wed	11/15/06	8.5	35,452,800	31,600	2,413,400	62	3,456,845	57,434	3,432,894	6,039	113	59.9	53.2	46	45	1
	Thu	11/16/06	7.1	35,483,300	30,500	2,443,900	72	3,511,902	55,057	3,487,951	6,136	129	65.4	62.9	51	50	1
	Sat	11/18/06	1.4	35,511,900	28,600	2,472,500	340	3,522,844	10,942	3,498,893	6,155	130	69.5	64.0	44	43	1
16	Mon	11/20/06	9.5	35,573,000	61,100	2,533,600	107	3,614,399	91,555	3,590,448	6,316	161	86.8	73.9	44	43	1
	Tue	11/21/06	7.2	35,603,200	30,200	2,563,800	70	3,664,271	49,872	3,640,320	6,404	115	60.4	54.6	44	44	0
	Wed	11/22/06	4.2	35,634,600	31,400	2,595,200	125	3,697,728	33,457	3,673,777	6,462	133	68.8	64.7	44	42	2
	Fri	11/24/06	7.7	35,671,800	37,200	2,632,400	81	3,748,951	51,223	3,725,000	6,553	111	59.0	51.7	47	46	1
17	Mon	11/27/06	13.3	35,750,600	78,800	2,711,200	99	3,859,197	110,246	3,835,246	6,746	138	72.2	66.0	46	44	2
	Tue	11/28/06	3.6	35,770,800	20,200	2,731,400	94	3,887,493	28,296	3,863,542	6,796	131	68.6	62.8	46	45	1
	Thu	11/30/06	3.5	35,804,200	33,400	2,764,800	159	3,915,038	27,545	3,891,087	6,845	131	69.9	63.6	46	44	2
	Fri	12/01/06	7.4	35,818,900	14,700	2,779,500	33	3,976,151	61,113	3,952,200	6,952	138	44.4	40.2	40	42	2
18	Mon	12/04/06	5.4	35,870,800	51,900	2,831,400	160	4,025,129	48,978	4,001,178	7,038	151	118.2	104.2	45	43	2
	Tue	12/05/06	4.9	35,900,400	29,600	2,861,000	101	4,066,994	41,865	4,043,043	7,112	142	76.0	67.7	45	44	1
	Wed	12/06/06	4.5	35,925,900	25,500	2,886,500	94	4,105,140	38,146	4,081,189	7,179	141	75.4	64.3	44	42	2
	Fri	12/08/06	6.7	35,963,100	37,200	2,923,700	93	4,154,331	49,191	4,130,380	7,266	122	65.5	56.9	46	45	1
19	Mon	12/11/06	13.5	36,025,800	62,700	2,986,400	77	4,244,457	90,126	4,220,506	7,424	111	61.4	49.8	48	46	2
	Tue	12/12/06	3.3	36,045,800	20,000	3,006,400	101	4,274,353	29,896	4,250,402	7,477	151	83.8	69.0	44	42	2
	Wed	12/13/06	4.8	36,074,600	28,800	3,035,200	100	4,314,337	39,984	4,290,386	7,547	139	74.1	63.6	45	44	1
	Thu	12/14/06	3.8	36,098,000	23,400	3,058,600	103	4,346,846	32,509	4,322,895	7,604	143	74.5	68.0	45	44	1
	Sat	12/16/06	3.9	36,123,100	25,100	3,083,700	107	4,379,073	32,227	4,355,122	7,661	138	71.9	65.6	45	43	2
20	Tue	12/19/06	10.0	36,187,400	64,300	3,148,000	107	4,470,042	90,969	4,446,091	7,821	152	83.6	68.1	46	44	2
	Thu	12/21/06	5.4	36,213,600	26,200	3,174,200	81	4,507,251	37,209	4,483,300	7,886	115	61.9	53.0	45	43	2
	Sat	12/23/06	5.1	36,244,800	31,200	3,205,400	102	4,547,606	40,355	4,523,655	7,957	132	70.4	61.1	44	42	2
21	Tue	12/26/06	11.0	36,323,700	78,900	3,284,300	120	4,631,629	84,023	4,607,678	8,105	127	67.3	60.2	45	44	1
	Wed	12/27/06	5.3	36,331,500	7,800	3,292,100	25	4,671,645	40,016	4,647,694	8,176	126	65.8	60.0	44	42	2
	Fri	12/29/06	8.4	36,374,000	42,500	3,334,600	84	4,730,331	58,686	4,706,380	8,279	116	61.7	54.5	50	48	2
	Sat	12/30/06	9.8	36,389,100	15,100	3,349,700	26	4,778,028	47,697	4,754,077	8,363	81	44.4	37.0	51	50	1
22	Mon	01/01/07	3.7	36,423,700	34,600	3,384,300	156	4,800,221	22,193	4,776,270	8,402	100	53.3	46.6	48	46	2
	Tue	01/02/07	7.3	36,447,800	24,100	3,408,400	55	4,846,560	46,339	4,822,609	8,483	106	55.6	50.3	48	46	2
	Thu	01/04/07	3.8	36,482,100	34,300	3,442,700	150	4,873,274	26,714	4,849,323	8,530	117	59.7	56.3	46	44	2
	Fri	01/05/07	5.1	36,504,100	22,000	3,464,700	72	4,913,339	40,065	4,889,388	8,601	131	67.9	63.7	44	42	2
23	Mon	01/08/07	8.7	36,564,300	60,200	3,524,900	115	4,993,595	80,256	4,969,644	8,742	154	83.1	70.6	46	44	2
	Wed	01/10/07	4.9	36,591,900	27,600	3,552,500	94	5,030,477	36,882	5,006,526	8,807	125	64.8	61.3	45	44	1
	Thu	01/11/07	5.3	36,620,200	28,300	3,580,800	89	5,071,184	40,707	5,047,233	8,878	128	65.3	62.2	46	44	2
	Sat	01/13/07	6.3	36,655,000	34,800	3,615,600	92	5,116,058	44,874	5,092,107	8,957	119	61.2	57.0	46	44	2
24	Tue	01/16/07	15.2	36,727,700	72,700	3,688,300	80	5,197,238	81,180	5,173,287	9,100	89	49.4	39.8	43	43	0
	Wed	01/17/07	8.6	36,738,400	10,700	3,699,000	21	5,242,721	45,483	5,218,770	9,180	88	49.4	38.6	46	44	2
	Fri	01/19/07	6.2	36,772,800	34,400	3,733,400	92	5,286,751	44,030	5,262,800	9,258	118	61.2	56.9	46	44	2
	Sat	01/20/07	5.0	36,803,000	30,200	3,763,600	101	5,328,881	42,130	5,304,930	9,332	140	75.1	65.8	48	46	2
25	Mon	01/22/07	11.4	36,873,400	70,400	3,834,000	103	5,425,537	96,656	5,401,586	9,502	141	75.6	65.6	46	44	2
	Tue	01/23/07	6.3	36,907,300	33,900	3,867,900	90	5,481,966	56,429	5,458,015	9,601	149	81.4	69.0	46	44	2
	Wed	01/24/07	4.5	36,937,200	29,900	3,897,800	111	5,515,194	33,228	5,491,243	9,660	123	63.2	58.2	50	48	2
	Thu	01/25/07	3.7	36,953,900	16,700	3,914,500	75	5,543,756	28,562	5,519,805	9,710	129	72.7	56.1	48	46	2
	Fri	01/26/07	3.9	36,978,500	24,600	3,939,100	105	5,577,869	34,113	5,553,918	9,770	146	79.2	66.3	48	46	2

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
26	Mon	01/29/07	6.3	37,049,000	70,500	4,009,600	187	5,670,301	92,432	5,646,350	9,932	245	134.3	110.8	41	43	2
	Tue	01/30/07	2.0	37,071,500	22,500	4,032,100	188	5,703,399	33,098	5,679,448	9,991	276	183.5	89.4	52	52	0
	Wed	01/31/07	1.6	37,077,100	5,600	4,037,700	58	5,712,463	9,064	5,688,512	10,007	94	66.5	37.0	48	46	2
	Thu	02/01/07	3.4	37,096,800	19,700	4,057,400	97	5,738,921	26,458	5,714,970	10,053	130	61.6	63.7	44	45	1
	Fri	02/02/07	5.2	37,117,900	21,100	4,078,500	68	5,779,209	40,288	5,755,258	10,124	129	72.8	57.0	49	48	1
27	Mon	02/05/07	16.7	37,182,300	64,400	4,142,900	64	5,862,438	83,229	5,838,487	10,270	83	41.7	41.3	48	47	1
	Tue	02/06/07	3.0	37,200,500	18,200	4,161,100	101	5,890,537	28,099	5,866,586	10,320	156	78.5	77.6	49	48	1
	Wed	02/07/07	2.5	37,220,400	19,900	4,181,000	133	5,908,806	18,269	5,884,855	10,352	122	62.7	66.3	49	48	1
	Thu	02/08/07	3.4	37,237,300	16,900	4,197,900	83	5,933,510	24,704	5,909,559	10,395	121	62.0	54.0	48	46	2
	Fri	02/09/07	3.6	37,257,600	20,300	4,218,200	94	5,960,370	26,860	5,936,419	10,443	124	63.8	60.6	48	46	2
28	Mon	02/12/07	15.9	37,322,600	65,000	4,283,200	68	6,054,614	94,244	6,030,663	10,608	99	53.3	45.5	48	46	2
	Tue	02/13/07	3.1	37,340,300	17,700	4,300,900	95	6,077,131	22,517	6,053,180	10,648	121	61.5	59.4	51	49	2
	Wed	02/14/07	2.4	37,355,400	15,100	4,316,000	105	6,095,165	18,034	6,071,214	10,680	125	63.5	61.6	48	46	2
	Thu	02/15/07	4.2	37,376,100	20,700	4,336,700	82	6,125,292	30,127	6,101,341	10,733	120	60.1	59.6	49	48	1
	Fri	02/16/07	3.5	37,395,800	19,700	4,356,400	94	6,162,913	37,621	6,138,962	10,799	179	100.0	84.3	49	48	1
29	Mon	02/19/07	11.7	37,467,000	71,200	4,427,600	101	6,253,448	90,535	6,229,497	10,958	129	66.7	60.6	48	46	2
	Tue	02/20/07	3.5	37,489,600	22,600	4,450,200	108	6,279,052	25,604	6,255,101	11,003	122	62.2	60.2	48	46	2
	Wed	02/21/07	7.5	37,508,800	19,200	4,469,400	43	6,329,432	50,380	6,305,481	11,092	112	58.7	53.3	51	51	0
	Thu	02/22/07	0.8	37,529,100	20,300	4,489,700	423	6,332,975	3,543	6,309,024	11,098	74	42.5	29.8	44	44	0
	Fri	02/23/07	4.8	37,548,200	19,100	4,508,800	66	6,365,959	32,984	6,342,008	11,156	115	58.5	56.2	48	46	2
30	Mon	02/26/07	11.7	37,617,800	69,600	4,578,400	99	6,453,664	87,705	6,429,713	11,310	125	78.0	61.2	47	46	1
	Tue	02/27/07	7.4	37,659,100	41,300	4,619,700	93	6,510,736	57,072	6,486,785	11,411	129	44.0	62.0	48	46	2
	Wed	02/28/07	3.3	37,676,200	17,100	4,636,800	86	6,534,480	23,744	6,510,529	11,453	120	61.8	58.3	48	46	2
	Thu	03/01/07	3.1	37,694,300	18,100	4,654,900	97	6,556,748	22,268	6,532,797	11,492	120	61.4	58.1	47	46	1
	Fri	03/02/07	5.7	37,717,700	23,400	4,678,300	68	6,594,552	37,804	6,570,601	11,558	111	57.3	35.8	48	46	2
31	Mon	03/05/07	13.0	37,790,600	72,900	4,751,200	93	6,696,478	101,926	6,672,527	11,737	131	67.8	70.4	48	48	0
	Tue	03/06/07	5.7	37,814,900	24,300	4,775,500	71	6,734,674	38,196	6,710,723	11,805	112	57.8	54.3	49	48	1
	Wed	03/07/07	3.0	37,842,400	27,500	4,803,000	153	6,757,321	22,647	6,733,370	11,845	126	64.1	61.2	48	46	2
	Thu	03/08/07	4.6	37,874,100	31,700	4,834,700	115	6,799,645	42,324	6,775,694	11,919	153	81.8	71.6	48	46	2
	Fri	03/09/07	8.6	37,917,700	43,600	4,878,300	84	6,860,708	61,063	6,836,757	12,026	118	60.2	58.1	47	45	2
32	Tue	03/13/07	16.9	38,025,500	107,800	4,986,100	106	6,982,330	121,622	6,958,379	12,240	120	61.3	58.6	48	48	0
	Wed	03/14/07	3.0	38,033,400	7,900	4,994,000	44	7,007,674	25,344	6,983,723	12,285	141	74.1	67.2	48	46	2
	Thu	03/15/07	4.1	38,049,800	16,400	5,010,400	67	7,037,865	30,191	7,013,914	12,338	123	62.3	60.1	48	47	1
	Fri	03/16/07	3.4	38,081,100	31,300	5,041,700	153	7,075,164	37,299	7,051,213	12,404	183	77.7	80.6	50	48	2
33	Mon	03/19/07	8.9	38,146,200	65,100	5,106,800	122	7,174,690	99,526	7,150,739	12,579	186	114.3	81.5	49	48	1
	Tue	03/20/07	4.5	38,170,200	24,000	5,130,800	89	7,204,586	29,896	7,180,635	12,631	111	57.5	53.0	52	50	2
	Wed	03/21/07	5.6	38,198,700	28,500	5,159,300	85	7,245,866	41,280	7,221,915	12,704	123	62.7	60.3	48	46	2
	Thu	03/22/07	3.4	38,217,700	19,000	5,178,300	93	7,271,300	25,434	7,247,349	12,749	125	63.6	60.8	49	48	1
	Fri	03/23/07	7.4	38,249,300	31,600	5,209,900	71	7,317,652	46,352	7,293,701	12,830	104	54.8	49.7	49	48	1
34	Mon	03/26/07	11.8	38,314,800	65,500	5,275,400	93	7,403,921	86,269	7,379,970	12,982	122	61.8	60.0	48	46	2
	Tue	03/27/07	3.7	38,333,100	18,300	5,293,700	82	7,430,352	26,431	7,406,401	13,028	119	60.4	58.8	48	46	2
	Wed	03/28/07	3.6	38,354,000	20,900	5,314,600	97	7,455,993	25,641	7,432,042	13,074	119	60.6	58.0	48	46	2
	Thu	03/29/07	8.0	38,385,600	31,600	5,346,200	66	7,506,768	50,775	7,482,817	13,163	106	55.0	50.5	50	49	1
	Fri	03/30/07	2.1	38,402,800	17,200	5,363,400	137	7,521,643	14,875	7,497,692	13,189	118	60.0	56.7	48	46	2

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
35	Mon	04/02/07[b)]	15.2	38,476,700	73,900	5,437,300	81	4,031,120	NA	NA	NA		59.2	NA	48	46	2
	Tue	04/03/07	7.8	38,513,800	37,100	5,474,400	79	4,080,951	49,831	7,547,523	13,277	106	55.8	NA	48	46	2
	Wed	04/04/07	3.1	38,530,700	16,900	5,491,300	91	4,103,668	22,717	7,570,240	13,317	122	62.7	NA	48	47	1
	Thu	04/05/07	9.8	38,567,800	37,100	5,528,400	63	4,156,665	52,997	7,623,237	13,410	90	49.1	39.1	50	48	2
	Fri	04/06/07	2.8	38,579,900	12,100	5,540,500	72	4,178,824	22,159	7,645,396	13,449	132	69.1	62.5	49	48	1
36	Mon	04/09/07	13.0	38,648,100	68,200	5,608,700	87	4,266,121	87,297	7,732,693	13,602	112	56.6	55.3	48	44	4
	Tue	04/10/07	5.4	38,671,000	22,900	5,631,600	71	4,298,233	32,112	7,764,805	13,659	99	52.7	46.4	47	46	1
	Wed	04/11/07	3.6	38,691,100	20,100	5,651,700	93	4,325,160	26,927	7,791,732	13,706	125	61.8	61.3	46	44	2
	Thu	04/12/07	4.0	38,714,800	23,700	5,675,400	99	4,357,225	32,065	7,823,797	13,763	134	68.6	66.5	46	44	2
	Fri	04/13/07	4.6	38,738,400	23,600	5,699,000	86	4,388,850	31,625	7,855,422	13,818	115	57.9	57.0	46	44	2
37	Mon	04/16/07	16.0	38,813,600	75,200	5,774,200	78	4,497,635	108,785	7,964,207	14,010	113	57.8	55.5	49	48	1
	Tue	04/17/07	2.4	38,831,700	18,100	5,792,300	126	4,515,502	17,867	7,982,074	14,041	124	62.1	61.8	48	47	1
	Wed	04/18/07	6.5	38,857,900	26,200	5,818,500	67	4,552,062	36,560	8,018,634	14,105	94	49.5	44.1	50	49	1
	Thu	04/19/07	6.5	38,884,700	26,800	5,845,300	69	4,589,559	37,497	8,056,131	14,171	96	50.8	45.6	48	48	0
	Fri	04/20/07	7.9	38,926,300	41,600	5,886,900	88	4,644,287	54,728	8,110,859	14,268	115	58.4	56.9	52	51	1
38	Mon	04/23/07	17.6	39,000,500	74,200	5,961,100	70	4,749,592	105,305	8,216,164	14,453	100	52.2	47.5	46	44	2
	Tue	04/24/07	4.6	39,025,200	24,700	5,985,800	89	4,782,828	33,236	8,249,400	14,511	120	60.6	60.2	46	44	2
	Wed	04/25/07	4.7	39,050,500	25,300	6,011,100	90	4,817,612	34,784	8,284,184	14,573	123	63.4	59.7	47	46	1
	Thu	04/26/07	3.8	39,071,400	20,900	6,032,000	92	4,845,817	28,205	8,312,389	14,622	124	63.1	60.8	46	44	2
	Fri	04/27/07	7.1	39,098,700	27,300	6,059,300	64	4,898,579	52,762	8,365,151	14,715	124	64.1	60.8	50	48	2
39	Mon	04/30/07	14.7	39,213,500	114,800	6,174,100	130	5,038,468	139,889	8,505,040	14,961	159	80.2	77.8	48	47	1
	Wed	05/02/07	18.8	39,257,600	44,100	6,218,200	39	5,107,936	69,468	8,574,508	15,083	62	35.2	26.3	48	47	1
	Fri	05/04/07	7.6	39,284,900	27,300	6,245,500	60	5,148,686	40,750	8,615,258	15,155	89	49.5	40.0	46	46	0
40	Mon	05/07/07	30.2	39,374,300	89,400	6,334,900	49	5,287,649	138,963	8,754,221	15,399	77	44.3	32.4	50	51	1
	Tue	05/08/07	5.2	39,391,300	17,000	6,351,900	54	5,307,747	20,098	8,774,319	15,435	64	37.6	20.4	48	48	0
	Wed	05/09/07	5.9	39,412,100	20,800	6,372,700	59	5,337,630	29,883	8,804,202	15,487	84	46.7	43.0	49	48	1
	Fri	05/11/07	8.9	39,447,100	35,000	6,407,700	66	5,390,625	52,995	8,857,197	15,580	99	54.1	45.0	47	46	1
41	Tue	05/15/07	24.9	39,550,800	103,700	6,511,400	69	5,533,329	142,704	8,999,901	15,832	96	51.1	44.4	49	48	1
	Wed	05/16/07	8.9	39,581,800	31,000	6,542,400	58	5,578,267	44,938	9,044,839	15,911	84	47.0	37.2	49	48	1
	Thu	05/17/07	3.8	39,595,500	13,700	6,556,100	60	5,602,522	24,255	9,069,094	15,953	106	56.3	49.8	50	48	2
	Fri	05/18/07	2.7	39,611,200	15,700	6,571,800	97	5,621,739	19,217	9,088,311	15,987	119	61.4	57.5	48	46	2
42	Mon	05/21/07	8.1	39,683,900	72,700	6,644,500	150	5,725,319	103,580	9,191,891	16,169	213	120.7	92.5	49	48	1
	Tue	05/22/07	2.6	39,700,700	16,800	6,661,300	108	5,746,512	21,193	9,213,084	16,207	136	70.1	66.0	46	44	2
	Wed	05/23/07	8.2	39,735,600	34,900	6,696,200	71	5,797,053	50,541	9,263,625	16,295	103	54.6	48.1	50	49	1
	Thu	05/24/07	5.4	39,758,700	23,100	6,719,300	71	5,831,388	34,335	9,297,960	16,356	106	56.8	49.1	50	50	0
	Fri	05/25/07	4.4	39,778,100	19,400	6,738,700	73	5,857,569	26,181	9,324,141	16,402	99	53.0	46.1	47	46	1
43	Mon	05/28/07	8.8	39,848,700	70,600	6,809,300	134	5,957,190	99,621	9,423,762	16,577	189	107.0	82.2	50	49	1
	Wed	05/30/07	7.3	39,892,500	43,800	6,853,100	100	6,020,735	63,545	9,487,307	16,689	145	82.9	61.6	48	46	2
	Thu	05/31/07	6.3	39,926,500	34,000	6,887,100	90	6,101,927	81,192	9,568,499	16,832	215	119.7	95.1	52	52	0
	Fri	06/01/07	5.0	39,951,200	24,700	6,911,800	82	6,138,614	36,687	9,605,186	16,896	122	58.8	36.5	50	49	1
44	Mon	06/04/07	3.0	40,011,500	60,300	6,972,100	335	6,196,656	58,042	9,663,228	16,998	322	207.2	160.4	50	49	1
	Wed	06/06/07	11.1	40,050,400	38,900	7,011,000	58	6,251,586	54,930	9,718,158	17,095	82	45.8	36.7	48	48	0
	Thu	06/07/07	6.4	40,077,300	26,900	7,037,900	70	6,289,666	38,080	9,756,238	17,162	99	52.7	46.3	50	48	2
	Fri	06/08/07	15.7	40,109,500	32,200	7,070,100	34	6,362,863	73,197	9,829,435	17,291	78	44.0	33.7	50	49	1

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
45	Tue	06/12/07	12.0	40,194,000	84,500	7,154,600	117	6,472,617	109,754	9,939,189	17,484	152	88.8	63.7	48	46	2
	Wed	06/13/07	7.2	40,211,200	17,200	7,171,800	40	6,517,444	44,827	9,984,016	17,563	104	50.2	42.0	48	46	2
	Thu	06/14/07	3.1	40,245,600	34,400	7,206,200	185	6,534,939	17,495	10,001,511	17,593	94	61.3	59.7	49	48	1
	Sat	06/16/07	17.9	40,283,300	37,700	7,243,900	35	6,626,969	92,030	10,093,541	17,755	86	46.9	38.8	51	50	1
46	Mon	06/18/07	7.6	40,326,000	42,700	7,286,600	94	6,682,072	55,103	10,148,644	17,852	121	63.5	57.3	48	48	0
	Tue	06/19/07	2.4	40,355,300	29,300	7,315,900	203	6,699,946	17,874	10,166,518	17,884	124	64.0	60.6	46	44	2
	Wed	06/20/07	6.3	40,375,100	19,800	7,335,700	52	6,748,092	48,146	10,214,664	17,968	127	66.3	60.8	49	49	0
	Thu	06/21/07	2.5	40,399,000	23,900	7,359,600	159	6,767,686	19,594	10,234,258	18,003	131	66.5	63.6	47	45	2
	Fri	06/22/07	4.2	40,432,100	33,100	7,392,700	131	6,800,362	32,676	10,266,934	18,060	130	68.4	63.9	46	44	2
47	Mon	06/25/07	30.4	40,523,400	91,300	7,484,000	50	6,955,058	154,696	10,421,630	18,332	85	46.6	37.9	48	46	2
	Tue	06/26/07	7.6	40,547,300	23,900	7,507,900	52	7,000,056	44,998	10,466,628	18,412	99	51.8	46.9	50	48	2
	Wed	06/27/07	8.0	40,564,900	17,600	7,525,500	37	7,040,980	40,924	10,507,552	18,484	85	45.9	37.9	51	51	0
	Thu	06/28/07	0.9	40,585,000	20,100	7,545,600	372	7,045,255	4,275	10,511,827	18,491	79	42.1	48.5	48	48	0
	Fri	06/29/07	6.4	40,606,300	21,300	7,566,900	55	7,084,477	39,222	10,551,049	18,560	102	53.0	49.0	50	48	2
48	Wed	07/04/07	31.9	40,714,300	108,000	7,674,900	56	7,270,545	186,068	10,737,117	18,887	97	51.1	46.0	44	46	2
	Thu	07/05/07	9.4	40,745,200	30,900	7,705,800	55	7,336,900	66,355	10,803,472	19,004	118	58.8	59.1	50	50	0
	Fri	07/06/07	1.9	40,769,300	24,100	7,729,900	211	7,351,950	15,050	10,818,522	19,031	132	65.8	66.7	46	44	2
49	Mon	07/09/07	13.4	40,848,500	79,200	7,809,100	99	7,477,586	125,636	10,944,158	19,252	156	82.9	73.3	46	45	1
	Tue	07/10/07	3.5	40,870,600	22,100	7,831,200	105	7,505,307	27,721	10,971,879	19,300	132	64.3	62.6	46	44	2
	Wed	07/11/07	6.4	40,890,200	19,600	7,850,800	51	7,551,977	46,670	11,018,549	19,382	122	63.0	61.8	50	50	0
	Thu	07/12/07	0.3	40,907,800	17,600	7,868,400	978	7,563,843	11,866	11,030,415	19,403	659	369.7	290.5	46	45	1
	Fri	07/13/07	3.6	40,927,800	20,000	7,888,400	93	7,592,841	28,998	11,059,413	19,454	134	67.8	65.7	47	45	2
50	Mon	07/16/07	28.6	41,016,500	88,700	7,977,100	52	7,730,965	138,124	11,197,537	19,697	80	44.3	37.5	50	50	0
	Tue	07/17/07	12.6	41,049,400	32,900	8,010,000	44	7,928,743	197,778	11,395,315	20,045	262	44.8	213.9	46	46	0
	Wed	07/18/07	5.9	41,079,000	29,600	8,039,600	84	7,959,422	30,679	11,425,994	20,099	87	66.2	20.0	40	40	0
	Thu	07/19/07	5.3	41,110,600	31,600	8,071,200	99	8,023,433	64,011	11,490,005	20,212	201	148.8	53.9	40	40	0
	Fri	07/20/07	5.1	41,149,400	38,800	8,110,000	127	8,085,332	61,899	11,551,904	20,321	202	145.2	54.4	42	42	0
51	Mon	07/23/07	18.6	41,239,200	89,800	8,199,800	80	8,257,360	172,028	11,723,932	20,623	154	113.2	41.2	46	46	0
	Wed	07/25/07	6.7	41,295,200	56,000	8,255,800	139	8,354,307	96,947	11,820,879	20,794	241	182.1	58.7	45	46	1
	Thu	07/26/07	2.9	41,312,300	17,100	8,272,900	98	8,384,030	29,723	11,850,602	20,846	171	124.6	58.1	42	42	0
	Fri	07/27/07	6.3	41,339,100	26,800	8,299,700	71	8,434,567	50,537	11,901,139	20,935	134	99.8	28.9	42	42	0
52	Mon	07/30/07	17.4	41,432,600	93,500	8,393,200	90	8,610,066	175,499	12,076,638	21,244	168	125.2	42.9	43	43	0
	Tue	07/31/07	4.3	41,457,900	25,300	8,418,500	98	8,653,865	43,799	12,120,437	21,321	170	125.7	45.7	42	42	0
	Wed	08/01/07	5.1	41,478,700	20,800	8,439,300	68	8,693,951	40,086	12,160,523	21,391	131	97.2	33.1	42	42	0
	Fri	08/03/07	3.8	41,520,900	42,200	8,481,500	185	8,732,725	38,774	12,199,297	21,460	170	125.0	45.2	40	40	0
	Sat	08/04/07	5.8	41,570,100	49,200	8,530,700	141	8,827,734	95,009	12,294,306	21,627	273	206.3	64.5	48	50	2
53	Mon	08/06/07	7.0	41,582,900	12,800	8,543,500	30	8,891,822	64,088	12,358,394	21,739	153	115.5	38.5	50	50	0
	Tue	08/07/07	5.7	41,607,200	24,300	8,567,800	71	8,937,554	45,732	12,404,126	21,820	134	100.6	33.3	48	48	0
	Fri	08/10/07	23.8	41,679,400	72,200	8,640,000	51	9,075,760	138,206	12,542,332	22,063	97	74.9	21.9	46	46	0
54	Mon	08/13/07	17.5	41,756,600	77,200	8,717,200	74	9,219,905	144,145	12,686,477	22,316	137	103.4	33.8	46	46	0
	Tue	08/14/07	10.9	41,789,500	32,900	8,750,100	50	9,300,323	80,418	12,766,895	22,458	123	92.3	30.6	46	46	0
	Thu	08/16/07	14.3	41,843,400	53,900	8,804,000	63	9,392,032	91,709	12,858,604	22,619	107	81.9	25.1	48	48	0
	Fri	08/17/07	7.7	41,880,200	36,800	8,840,800	80	9,443,305	51,273	12,909,877	22,709	111	84.2	26.7	47	47	0
55	Tue	08/21/07	25.7	41,970,800	90,600	8,931,400	59	5,831,516	NA	NA	NA		NA	210.7	46	46	0
	Thu	08/23/07	12.4	42,017,300	46,500	8,977,900	62	5,877,045	45,529	12,955,406	22,790	61	36.8	24.5	46	46	0

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
56	Mon	08/27/07	41.4	42,132,200	114,900	9,092,800	46	6,009,953	132,908	13,088,314	23,023	54	33.4	20.1	48	48	0
	Tue	08/28/07	2.7	42,166,500	34,300	9,127,100	212	6,034,202	24,249	13,112,563	23,066	150	92.0	58.2	47	47	0
	Wed	08/29/07	7.2	42,182,900	16,400	9,143,500	38	6,062,797	28,595	13,141,158	23,116	66	39.8	26.2	48	48	0
	Thu	08/30/07	5.7	42,203,300	20,400	9,163,900	60	6,336,382	273,585	13,414,743	23,598	800	NA	1302.0	48	48	0
	Fri	08/31/07	4.6	42,228,000	24,700	9,188,600	89	6,353,505	17,123	13,431,866	23,628	62	34.2	26.7	48	48	0
57	Tue	09/04/07	36.3	42,365,600	137,600	9,326,200	63	6,410,234	56,729	13,488,595	23,727	26	129.4	34.4	50	50	0
	Thu	09/06/07	18.6	42,425,100	59,500	9,385,700	53	6,446,716	36,482	13,525,077	23,792	33	NA	27.0	43	43	0
	Fri	09/07/07	4.0	42,453,100	28,000	9,413,700	117	6,472,253	25,537	13,550,614	23,837	106	51.8	53.5	42	42	0
58	Mon	09/10/07	17.3	42,532,200	79,100	9,492,800	76	6,559,927	87,674	13,638,288	23,991	84	42.2	42.3	42	42	0
	Tue	09/11/07	7.4	42,558,100	25,900	9,518,700	58	19,248	NA	NA	NA		NA	NA	49	50	1
	Wed	09/12/07	1.4	42,574,200	16,100	9,534,800	192	32,409	13,161	13,651,449	24,014	157	122.4	47.9	40	41	1
	Thu	09/13/07	8.3	42,607,900	33,700	9,568,500	68	108,857	76,448	13,727,897	24,148	154	111.0	42.2	48	49	1
	Fri	09/14/07	6.6	42,639,500	31,600	9,600,100	80	154,028	45,171	13,773,068	24,228	114	85.0	29.0	46	47	1
59	Mon	09/17/07	26.4	42,736,300	96,800	9,696,900	61	352,352	198,324	13,971,392	24,577	125	92.3	32.7	46	46	0
	Tue	09/18/07	10.3	42,785,100	48,800	9,745,700	79	425,199	72,847	14,044,239	24,705	118	88.0	30.8	50	50	0
	Wed	09/19/07	11.7	42,825,600	40,500	9,786,200	58	36,994	NA	NA	NA		NA	NA	47	48	1
	Fri	09/21/07	10.3	42,891,500	65,900	9,852,100	107	96,579	59,585	14,103,824	24,810	96	57.7	38.7	49	50	1
60	Mon	09/24/07	14.1	42,988,500	97,000	9,949,100	115	179,649	83,070	14,186,894	24,956	98	57.4	40.8	48	48	0
	Tue	09/25/07	4.9	43,011,300	22,800	9,971,900	78	196,768	17,119	14,204,013	24,986	58	32.0	26.2	46	46	0
	Wed	09/26/07	4.1	43,032,800	21,500	9,993,400	87	216,525	19,757	14,223,770	25,021	80	42.5	37.9	46	46	0
	Thu	09/27/07	3.6	43,055,200	22,400	10,015,800	104	233,973	17,448	14,241,218	25,051	81	42.7	38.0	44	44	0
	Fri	09/28/07	6.9	43,089,800	34,600	10,050,400	84	262,589	28,616	14,269,834	25,102	69	37.2	31.8	46	46	0
61	Mon	10/01/07	22.3	43,204,700	114,900	10,165,300	86	359,002	96,413	14,366,247	25,271	72	38.8	33.3	46	46	0
	Tue	10/02/07	7.5	43,246,100	41,400	10,206,700	92	394,520	35,518	14,401,765	25,334	79	41.9	37.0	44	45	1
	Wed	10/03/07	7.1	43,283,400	37,300	10,244,000	88	428,846	34,326	14,436,091	25,394	81	42.8	37.7	48	48	0
	Thu	10/04/07	8.2	43,332,100	48,700	10,292,700	99	467,950	39,104	14,475,195	25,463	79	42.2	37.3	46	46	0
	Fri	10/05/07	3.8	43,354,200	22,100	10,314,800	97	486,174	18,224	14,493,419	25,495	80	42.4	37.6	46	46	0
62	Mon	10/08/07	17.8	43,457,100	102,900	10,417,700	96	572,404	86,230	14,579,649	25,647	81	42.9	37.9	44	44	0
	Tue	10/09/07	5.5	43,481,800	24,700	10,442,400	75	598,156	25,752	14,605,401	25,692	78	41.6	36.4	46	46	0
	Wed	10/10/07	4.1	43,508,700	26,900	10,469,300	109	610,911	12,755	14,618,156	25,714	52	40.7	35.5	44	44	0
	Thu	10/11/07	5.0	43,539,500	30,800	10,500,100	103	641,334	30,423	14,648,579	25,768	101	43.1	38.1	42	43	1
	Fri	10/12/07	5.5	43,569,600	30,100	10,530,200	91	667,874	26,540	14,675,119	25,815	80	42.9	38.1	44	44	0
63	Mon	10/15/07	15.8	43,656,900	87,300	10,617,500	92	743,924	76,050	14,751,169	25,948	80	42.7	37.5	42	42	0
	Tue	10/16/07	10.4	43,703,300	46,400	10,663,900	74	794,175	50,251	14,801,420	26,037	81	42.9	37.6	54	54	0
	Wed	10/17/07	2.6	43,734,100	30,800	10,694,700	197	806,173	11,998	14,813,418	26,058	77	40.8	35.5	45	46	1
	Thu	10/18/07	3.9	43,756,600	22,500	10,717,200	96	824,693	18,520	14,831,938	26,091	79	43.8	36.9	45	46	1
	Fri	10/19/07	4.2	43,781,100	24,500	10,741,700	97	846,004	21,311	14,853,249	26,128	85	44.0	37.8	43	43	0
64	Mon	10/22/07	17.8	43,879,800	98,700	10,840,400	92	930,089	84,085	14,937,334	26,276	79	42.1	37.0	46	46	0
	Tue	10/23/07	5.1	43,902,300	22,500	10,862,900	74	954,029	23,940	14,961,274	26,318	78	41.9	36.3	47	48	1
	Wed	10/24/07	6.7	43,932,000	29,700	10,892,600	74	986,687	32,658	14,993,932	26,375	81	43.6	37.6	46	46	0
	Thu	10/25/07	3.2	43,954,500	22,500	10,915,100	117	1,001,957	15,270	15,009,202	26,402	80	42.8	37.1	46	46	0
	Fri	10/26/07	8.8	43,979,700	25,200	10,940,300	48	1,044,053	42,096	15,051,298	26,476	80	43.0	74.5	52	52	0
65	Mon	10/29/07	14.4	44,074,100	94,400	11,034,700	109	1,114,318	70,265	15,121,563	26,600	81	43.2	15.0	47	48	1
	Tue	10/30/07	3.1	44,093,800	19,700	11,054,400	106	1,129,166	14,848	15,136,411	26,626	80	42.0	37.4	46	46	0
	Wed	10/31/07	4.5	44,113,600	19,800	11,074,200	73	1,151,249	22,083	15,158,494	26,665	82	43.4	38.5	46	46	0
	Thu	11/01/07	5.8	44,147,100	33,500	11,107,700	96	1,179,797	28,548	15,187,042	26,715	82	43.5	38.6	46	47	1
	Fri	11/02/07	3.9	44,167,800	20,700	11,128,400	88	1,198,187	18,390	15,205,432	26,748	79	41.8	36.7	44	44	0

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
66	Tue	11/06/07	18.6	44,265,600	97,800	11,226,200	88	1,287,053	88,866	15,294,298	26,904	80	43.1	36.5	46	46	0
	Thu	11/08/07	14.8	44,335,300	69,700	11,295,900	78	1,338,409	51,356	15,345,654	26,994	58	32.2	25.7	48	48	0
67	Fri	11/16/07	76.2	44,451,700	116,400	11,412,300	25	1,531,972	193,563	15,539,217	27,335	42	25.1	17.3	48	48	0
68	Mon	11/19/07	20.3	44,521,700	70,000	11,482,300	57	1,591,390	59,418	15,598,635	27,439	49	28.1	20.7	48	48	0
	Tue	11/20/07	2.3	44,547,400	25,700	11,508,000	186	1,603,691	12,301	15,610,936	27,461	89	47.7	41.2	44	44	0
	Wed	11/21/07	6.1	44,574,100	26,700	11,534,700	73	1,628,959	25,268	15,636,204	27,505	69	37.8	31.2	46	46	0
	Thu	11/22/07	4.2	44,598,100	24,000	11,558,700	95	1,649,534	20,575	15,656,779	27,541	82	43.9	37.8	44	44	0
	Fri	11/23/07	6.7	44,620,600	22,500	11,581,200	56	1,672,945	23,411	15,680,190	27,583	58	32.9	25.4	46	46	0
69	Mon	11/26/07	14.6	44,682,100	61,500	11,642,700	70	1,737,932	64,987	15,745,177	27,697	74	40.4	33.8	44	44	0
	Tue	11/27/07	4.7	44,703,200	21,100	11,663,800	75	1,760,058	22,126	15,767,303	27,736	78	42.3	36.1	44	44	0
	Wed	11/28/07	4.5	44,725,300	22,100	11,685,900	82	1,781,196	21,138	15,788,441	27,773	78	NA	NA	NA	NA	NA
	Thu	11/29/07	9.2	44,748,200	22,900	11,708,800	41	1,804,104	22,908	15,811,349	27,813	41	NA	NA	NA	NA	NA
	Fri	11/30/07	11.0	44,775,900	27,700	11,736,500	42	1,831,855	27,751	15,839,100	27,862	42	NA	NA	NA	NA	NA
70	Mon	12/03/07	21.9	NA	NA	NA	NA	1,886,130	54,275	15,893,375	27,958	41	NA	NA	NA	NA	NA
	Tue	12/04/07	8.7	NA	NA	NA	NA	1,908,290	22,160	15,915,535	27,997	42	NA	NA	NA	NA	NA
	Wed	12/05/07	2.1	NA	NA	NA	NA	1,928,318	20,028	15,935,563	28,032	159	NA	NA	48	48	0
	Thu	12/06/07	17.1	NA	NA	NA	NA	1,961,079	32,761	15,968,324	28,090	32	NA	NA	NA	NA	NA
	Fri	12/07/07	8.5	NA	NA	NA	NA	1,982,991	21,912	15,990,236	28,128	43	NA	NA	NA	NA	NA
71	Mon	12/10/07	17.3	NA	NA	NA	NA	2,025,224	42,233	16,032,469	28,202	41	NA	NA	48	48	0
	Tue	12/11/07	4.5	NA	NA	NA	NA	2,044,007	18,783	16,051,252	28,235	70	NA	NA	NA	NA	NA
	Wed	12/12/07	7.2	NA	NA	NA	NA	2,061,378	17,371	16,068,623	28,266	40	NA	NA	NA	NA	NA
	Thu	12/13/07	8.1	NA	NA	NA	NA	2,081,010	19,632	16,088,255	28,300	40	NA	NA	NA	NA	NA
	Fri	12/14/07	8.4	NA	NA	NA	NA	2,101,524	20,514	16,108,769	28,337	41	NA	NA	NA	NA	NA
72	Mon	12/17/07	26.2	NA	NA	NA	NA	2,164,438	62,914	16,171,683	28,447	40	NA	NA	NA	NA	NA
	Tue	12/18/07	8.4	NA	NA	NA	NA	2,184,396	19,958	16,191,641	28,482	40	NA	NA	NA	NA	NA
	Wed	12/19/07	11.1	NA	NA	NA	NA	2,210,724	26,328	16,217,969	28,529	40	NA	NA	NA	NA	NA
	Thu	12/20/07	8.6	NA	NA	NA	NA	2,231,130	20,406	16,238,375	28,565	40	NA	NA	NA	NA	NA
	Fri	12/21/07	9.5	NA	NA	NA	NA	2,253,165	22,035	16,260,410	28,603	39	NA	NA	NA	NA	NA
73	Mon	12/24/07	22.6	NA	NA	NA	NA	2,304,675	51,510	16,311,920	28,694	38	NA	NA	NA	NA	NA
	Tue	12/25/07	6.3	NA	NA	NA	NA	2,320,041	15,366	16,327,286	28,721	41	NA	NA	NA	NA	NA
	Wed	12/26/07	6.1	NA	NA	NA	NA	2,332,684	12,643	16,339,929	28,743	35	NA	NA	NA	NA	NA
	Thu	12/27/07	6.1	NA	NA	NA	NA	2,346,562	13,878	16,353,807	28,768	38	NA	NA	NA	NA	NA
	Fri	12/28/07	6.1	NA	NA	NA	NA	2,360,192	13,630	16,367,437	28,792	37	NA	NA	NA	NA	NA
74	Mon	12/31/07	23.4	NA	NA	NA	NA	2,413,573	53,381	16,420,818	28,885	38	NA	NA	NA	NA	NA
	Tue	01/01/08	7.2	NA	NA	NA	NA	2,430,415	16,842	16,437,660	28,915	39	NA	NA	NA	NA	NA
	Wed	01/02/08	10.0	NA	NA	NA	NA	2,452,760	22,345	16,460,005	28,954	37	NA	NA	NA	NA	NA
	Thu	01/03/08	8.7	NA	NA	NA	NA	2,472,346	19,586	16,479,591	28,989	38	NA	NA	NA	NA	NA
	Fri	01/04/08	9.1	NA	NA	NA	NA	2,493,040	20,694	16,500,285	29,025	38	NA	NA	NA	NA	NA
75	Mon	01/07/08	27.1	NA	NA	NA	NA	2,555,078	62,038	16,562,323	29,134	38	NA	NA	NA	NA	NA
	Tue	01/08/08	9.5	NA	NA	NA	NA	2,576,676	21,598	16,583,921	29,172	38	NA	NA	NA	NA	NA
	Wed	01/09/08	7.8	NA	NA	NA	NA	2,594,411	17,735	16,601,656	29,204	38	NA	NA	NA	NA	NA
	Thu	01/10/08	6.5	NA	NA	NA	NA	2,610,441	16,030	16,617,686	29,232	41	NA	NA	NA	NA	NA
	Fri	01/11/08	4.4	NA	NA	NA	NA	2,620,828	10,387	16,628,073	29,250	39	NA	NA	NA	NA	NA

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
76	Mon	01/14/08	18.4	NA	NA	NA	NA	2,675,289	54,461	16,682,534	29,346	49	NA	NA	NA	NA	NA
	Tue	01/15/08	6.3	NA	NA	NA	NA	2,690,810	15,521	16,698,055	29,373	41	NA	NA	NA	NA	NA
	Wed	01/16/08	6.8	NA	NA	NA	NA	2,707,272	16,462	16,714,517	29,402	40	NA	NA	NA	NA	NA
	Thu	01/17/08	5.8	NA	NA	NA	NA	2,721,504	14,232	16,728,749	29,427	41	NA	NA	NA	NA	NA
	Fri	01/18/08	7.3	NA	NA	NA	NA	2,739,384	17,880	16,746,629	29,459	41	NA	NA	NA	NA	NA
77	Mon	01/21/08	18.0	NA	NA	NA	NA	2,793,315	53,931	16,800,560	29,553	50	NA	NA	39	39	0
	Tue	01/22/08	3.6	NA	NA	NA	NA	2,808,029	14,714	16,815,274	29,579	68	NA	NA	NA	NA	NA
	Wed	01/23/08	5.4	NA	NA	NA	NA	2,825,824	17,795	16,833,069	29,611	55	NA	NA	NA	NA	NA
	Thu	01/24/08	10.8	NA	NA	NA	NA	2,847,083	21,259	16,854,328	29,648	33	NA	NA	NA	NA	NA
	Fri	01/25/08	7.4	NA	NA	NA	NA	2,864,695	17,612	16,871,940	29,679	40	NA	NA	NA	NA	NA
78	Mon	01/28/08	NA	NA	NA	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
	Tue	01/29/08	28.9	NA	NA	NA	NA	2,936,868	NA	NA	NA		NA	NA	NA	NA	NA
	Wed	01/30/08	NA	NA	NA	NA	NA	2,954,467	17,599	16,889,539	29,710		NA	NA	NA	NA	NA
	Thu	01/31/08	6.1	NA	NA	NA	NA	2,969,613	15,146	16,904,685	29,737	41	NA	NA	NA	NA	NA
	Fri	02/01/08	4.8	NA	NA	NA	NA	2,990,986	21,373	16,926,058	29,774	74	NA	NA	NA	NA	NA
79	Mon	02/04/08	20.8	NA	NA	NA	NA	3,032,424	41,438	16,967,496	29,847	33	NA	NA	NA	NA	NA
	Tue	02/05/08	7.5	NA	NA	NA	NA	3,050,640	18,216	16,985,712	29,879	40	NA	NA	NA	NA	NA
	Wed	02/06/08	8.8	NA	NA	NA	NA	3,070,877	20,237	17,005,949	29,915	38	NA	NA	NA	NA	NA
	Thu	02/07/08	8.3	NA	NA	NA	NA	3,089,540	18,663	17,024,612	29,948	37	NA	NA	NA	NA	NA
	Fri	02/08/08	9.0	NA	NA	NA	NA	3,110,038	20,498	17,045,110	29,984	38	NA	NA	NA	NA	NA
80	Mon	02/11/08	36.8	NA	NA	NA	NA	3,194,542	84,504	17,129,614	30,132	38	NA	NA	NA	NA	NA
	Tue	02/12/08	8.5	NA	NA	NA	NA	3,213,684	19,142	17,148,756	30,166	38	NA	NA	NA	NA	NA
	Wed	02/13/08	8.7	NA	NA	NA	NA	3,233,566	19,882	17,168,638	30,201	38	NA	NA	NA	NA	NA
	Thu	02/14/08	8.6	NA	NA	NA	NA	3,254,327	20,761	17,189,399	30,237	40	NA	NA	NA	NA	NA
	Fri	02/15/08	6.4	NA	NA	NA	NA	3,268,936	14,609	17,204,008	30,263	38	NA	NA	NA	NA	NA
81	Mon	02/18/08	24.9	NA	NA	NA	NA	3,335,826	66,890	17,270,898	30,381	45	NA	NA	NA	NA	NA
	Tue	02/19/08	7.6	NA	NA	NA	NA	3,343,513	7,687	17,278,585	30,394	17	NA	NA	NA	NA	NA
	Wed	02/20/08	4.2	NA	NA	NA	NA	3,354,246	10,733	17,289,318	30,413	43	NA	NA	48	48	0
	Thu	02/21/08	5.0	NA	NA	NA	NA	3,372,912	18,666	17,307,984	30,446	62	36.2	25.9	44	44	0
	Fri	02/22/08	5.8	NA	NA	NA	NA	3,395,943	23,031	17,331,015	30,487	66	39.8	27.1	48	48	0
82	Mon	02/25/08	20.8	NA	NA	NA	NA	3,448,877	52,934	17,383,949	30,580	42	NA	NA	NA	NA	NA
	Tue	02/26/08	3.9	NA	NA	NA	NA	3,462,146	13,269	17,397,218	30,603	57	NA	NA	NA	NA	NA
	Wed	02/27/08	8.6	NA	NA	NA	NA	3,482,090	19,944	17,417,162	30,638	39	NA	NA	NA	NA	NA
	Thu	02/28/08	10.9	NA	NA	NA	NA	3,508,018	25,928	17,443,090	30,684	40	NA	NA	NA	NA	NA
	Fri	02/29/08	9.8	NA	NA	NA	NA	3,530,657	22,639	17,465,729	30,724	39	NA	NA	NA	NA	NA
83	Mon	03/03/08	31.0	NA	NA	NA	NA	3,606,782	76,125	17,541,854	30,857	41	NA	NA	NA	NA	NA
	Tue	03/04/08	7.7	NA	NA	NA	NA	3,624,381	17,599	17,559,453	30,888	38	NA	NA	NA	NA	NA
	Wed	03/05/08	8.1	NA	NA	NA	NA	3,642,778	18,397	17,577,850	30,921	38	NA	NA	NA	NA	NA
	Thu	03/06/08	7.7	NA	NA	NA	NA	3,660,633	17,855	17,595,705	30,952	39	NA	NA	NA	NA	NA
	Fri	03/07/08	7.2	NA	NA	NA	NA	3,677,657	17,024	17,612,729	30,982	39	NA	NA	NA	NA	NA
84	Mon	03/10/08	26.5	NA	NA	NA	NA	3,741,712	64,055	17,676,784	31,095	40	NA	NA	NA	NA	NA
	Tue	03/11/08	11.3	NA	NA	NA	NA	3,769,237	27,525	17,704,309	31,143	41	NA	NA	NA	NA	NA
	Wed	03/12/08	8.2	NA	NA	NA	NA	3,788,403	19,166	17,723,475	31,177	39	NA	NA	48	48	0
	Thu	03/13/08	5.2	NA	NA	NA	NA	3,806,635	18,232	17,741,707	31,209	58	NA	NA	NA	NA	NA
	Fri	03/14/08	9.9	NA	NA	NA	NA	3,830,441	23,806	17,765,513	31,251	40	NA	NA	NA	NA	NA

Table A-1. EPA Arsenic Demonstration Project at Wellman, TX - Daily System Operation Log Sheet (Continued)

				Master Totalizer Measurements				APU Instrument Panel Measurements									
Week No.	Day of Week	Date	Operational Hours	Master Totalizer Meter	Volume Produced Daily	Cumulative Volume Produced	Calculated Flowrate	APU Totalizer Meter	Daily Treated Volume	Cumulative Treated Volume	Total Bed Volumes	Calculated System Flowrate	Calculated Vessel A Flowrate	Calculated Vessel B Flowrate	Inlet Pressure	Outlet Pressure	Pressure Differential
			hr	gal	gal	gal	gpm	gal	gal	gal	BV	gpm	gpm	gpm	psi	psi	psi
85	Mon	03/17/08	25.5	NA	NA	NA	NA	3,891,081	60,640	17,826,153	31,358	40	NA	NA	NA	NA	NA
	Tue	03/18/08	9.3	NA	NA	NA	NA	3,912,225	21,144	17,847,297	31,395	38	NA	NA	NA	NA	NA
	Wed	03/19/08	7.7	NA	NA	NA	NA	3,929,347	17,122	17,864,419	31,425	37	NA	NA	NA	NA	NA
	Thu	03/20/08	7.9	NA	NA	NA	NA	3,947,706	18,359	17,882,778	31,457	39	NA	NA	NA	NA	NA
	Fri	03/21/08	8.1	NA	NA	NA	NA	3,966,145	18,439	17,901,217	31,490	38	NA	NA	NA	NA	NA
86	Mon	03/24/08	28.3	NA	NA	NA	NA	4,030,940	64,795	17,966,012	31,604	38	NA	NA	50	50	0
	Tue	03/25/08	8.8	NA	NA	NA	NA	4,051,198	20,258	17,986,270	31,639	38	NA	NA	NA	NA	NA
	Wed	03/26/08	10.5	NA	NA	NA	NA	4,075,435	24,237	18,010,507	31,682	38	NA	NA	NA	NA	NA
	Thu	03/27/08	11.8	NA	NA	NA	NA	4,102,416	26,981	18,037,488	31,729	38	NA	NA	NA	NA	NA
	Fri	03/28/08	14.6	NA	NA	NA	NA	4,136,507	34,091	18,071,579	31,789	39	NA	NA	NA	NA	NA
87	Mon	03/31/08	34.4	NA	NA	NA	NA	4,215,374	78,867	18,150,446	31,928	38	NA	NA	NA	NA	NA
	Tue	04/01/08	11.3	NA	NA	NA	NA	4,241,434	26,060	18,176,506	31,974	38	NA	NA	NA	NA	NA
	Wed	04/02/08	7.9	NA	NA	NA	NA	4,259,398	17,964	18,194,470	32,005	38	NA	NA	NA	NA	NA
	Thu	04/03/08	9.3	NA	NA	NA	NA	4,280,051	20,653	18,215,123	32,042	37	NA	NA	NA	NA	NA
	Fri	04/04/08	12.6	NA	NA	NA	NA	4,309,615	29,564	18,244,687	32,094	39	NA	NA	NA	NA	NA
88	Mon	04/07/08	33.0	NA	NA	NA	NA	4,385,994	76,379	18,321,066	32,228	39	NA	NA	NA	NA	NA
	Tue	04/08/08	11.4	NA	NA	NA	NA	4,412,228	26,234	18,347,300	32,274	38	NA	NA	NA	NA	NA
	Wed	04/09/08	10.0	NA	NA	NA	NA	4,432,746	20,518	18,367,818	32,310	34	NA	NA	NA	NA	NA
	Thu	04/10/08	3.9	NA	NA	NA	NA	4,448,359	15,613	18,383,431	32,338	67	NA	NA	NA	NA	NA
	Fri	04/11/08	7.3	NA	NA	NA	NA	4,461,848	13,489	18,396,920	32,362	31	NA	NA	NA	NA	NA
89	Mon	04/14/08	27.2	NA	NA	NA	NA	4,511,650	49,802	18,446,722	32,449	31	NA	NA	NA	NA	NA
	Tue	04/15/08	5.5	NA	NA	NA	NA	4,528,238	16,588	18,463,310	32,478	50	NA	NA	NA	NA	NA
	Wed	04/16/08	9.3	NA	NA	NA	NA	4,545,094	16,856	18,480,166	32,508	30	NA	NA	NA	NA	NA
	Thu	04/17/08	10.2	NA	NA	14,744,962	NA	4,563,776	18,682	18,498,848	32,541	31	NA	NA	NA	NA	NA
	Fri	04/18/08	8.5	NA	NA	NA	NA	4,579,298	15,522	18,514,370	32,568	30	NA	NA	NA	NA	NA

NA = not available (in most cases, system not in operation when operator was on-ite; therefore, data not available).
1 BV = 38 ft^3/vessel = 284 gal/vessel (or 568 gal for whole system)
System is in parallel configuration.
Master totalizer down on 11/30/07; cumulative volume treated during remainder of performance evaluation estimated from historical data on 12/05/07, 01/14/08, 02/20/08, 02/12/08, and 04/17/08.

APPENDIX B

ANALYTICAL DATA

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

Sampling Date		08/10/06			08/30/06				09/06/06			09/20/06[b]				10/02/06[c]		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10^3	-	-	NA	-	-	0.9	0.9	-	-	1.2	-	-	1.8	1.7	-	-	2.3
Alkalinity (as $CaCO_3$)	mg/L	232 -	248 -	248 -	266 -	255 -	255 -	266 -	265 -	254 -	265 -	255 -	239 -	255 -	261 -	301 -	258 -	258 -
Fluoride	mg/L	5.0[a]	6.8	7.0	-	-	-	-	6.0	4.9	6.0	-	-	-	-	0.4	5.8	5.6
Sulfate	mg/L	245	305[a]	302[a]	-	-	-	-	244	218	249	-	-	-	-	70	260	265
Nitrate (as N)	mg/L	5.2	4.3	4.1	-	-	-	-	4.0	3.5	3.9	-	-	-	-	3.5	4.3	4.6
Total P (as P)	µg/L	25.4 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	43.5 -	43.8 -	24.4 -	42.1 -	43.6 -	41.3 -	42.8 -	42.1 -	42.6 -	42.0 -	48.2 -	46.6 -	45.4 -	48.5 -	57.6 -	47.5 -	45.8 -
Turbidity	NTU	1.1 -	0.3 -	0.2 -	0.4 -	0.2 -	0.2 -	0.1 -	0.3 -	0.2 -	0.4 -	0.3 -	0.3 -	0.1 -	0.1 -	0.7 -	0.1 -	0.5 -
TOC	mg/L	-	-	-	-	-	-	-	1.3	1.3	1.2	-	-	-	-	1.3	1.3	1.3
pH	S.U.	7.7	7.7	7.5	NA	NA	NA	NA	NA	NA	NA	7.7	7.7	7.6	7.7	7.9	7.6	7.6
Temperature	°C	22.3	23.8	23.8	NA	NA	NA	NA	NA	NA	NA	20.0	20.0	21.3	21.0	18.9	17.0	17.0
DO	mg/L	5.4	5.8	NA	NA	NA	NA	NA	NA	NA	NA	4.7	5.0	4.6	5.0	6.2	5.6	5.5
ORP	mV	178	352	271	NA	NA	NA	NA	NA	NA	NA	483	569	475	524	500	574	585
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	-	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	-	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	604	422	415	-	-	-	-	387	521	395	-	-	-	-	410	418	434
Ca Hardness (as $CaCO_3$)	mg/L	130	131	133	-	-	-	-	128	136	130	-	-	-	-	134	137	140
Mg Hardness (as $CaCO_3$)	mg/L	474	291	282	-	-	-	-	258	385	265	-	-	-	-	277	281	295
As (total)	µg/L	45.9 -	46.4 -	0.4 -	6.0 -	43.7 -	0.7 -	0.7 -	15.4 -	37.7 -	1.1 -	14.7 -	40.5 -	2.0 -	2.3 -	42.1 -	43.7 -	0.8 -
As (soluble)	µg/L	42.0	43.6	0.4	-	-	-	-	14.6	39.2	0.9	-	-	-	-	40.3	40.5	0.7
As (particulate)	µg/L	3.9	2.8	<0.1	-	-	-	-	0.8	<0.1	0.1	-	-	-	-	1.7	3.2	<0.1
As (III)	µg/L	0.8	0.7	0.4	-	-	-	-	1.0	1.4	0.9	-	-	-	-	0.7	0.9	0.8
As (V)	µg/L	41.2	42.9	<0.1	-	-	-	-	13.6	37.9	<0.1	-	-	-	-	39.6	39.6	<0.1
Fe (total)	µg/L	131 -	<25 -	<25 -	52 -	<25 -	<25 -	<25 -	39 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	<25	<25	<25	-	-	-	-	<25	<25	<25
Mn (total)	µg/L	1.8 -	0.2 -	0.1 -	0.6 -	0.5 -	<0.1 -	<0.1 -	0.6 -	0.3 -	0.2 -	0.8 -	0.3 -	0.1 -	0.1 -	0.3 -	0.2 -	<0.1 -
Mn (soluble)	µg/L	0.8	0.3	0.2	-	-	-	-	0.4	0.3	0.2	-	-	-	-	0.3	0.2	<0.1
V (total)	µg/L	157 -	136 -	0.7 -	17.5 -	135 -	0.8 -	0.8 -	53.4 -	152 -	1.4 -	44.7 -	138 -	0.7 -	0.7 -	139 -	137 -	0.9 -
V (soluble)	µg/L	154	134	0.5	-	-	-	-	51.8	154	1.1	-	-	-	-	138	143	1.0

(a) Parameter analyzed outside of hold time. (b) Water quality measurements taken on 09/27/06. (c) Water quality measurements taken on 10/10/06.

NOTE:Varying arsenic and vanadium concentrations at the wellhead (IN), occationally lower than after chlorination (AC), have been investigated by Battelle.

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

Sampling Date		10/19/06				11/02/06			11/15/06				11/28/06			12/14/06		
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TT
Bed Volume	10^3	-	-	3.2	3.0	-	-	3.7	-	-	4.4	4.1	-	-	4.8	-	-	5.4
Alkalinity (as $CaCO_3$)	mg/L	256	240	260	260	267	246	261	258	246	254	246	259	245	259	258	243	252
		258	244	260	258	-	-	-	-	-	-	-	-	-	-	-	-	-
Fluoride	mg/L	-	-	-	-	4.6	3.6	4.6	-	-	-	-	7.6	4.4	6.2	5.1	3.8	4.8
Sulfate	mg/L	-	-	-	-	221	427	272	-	-	-	-	308	470	379	318	400	380
Nitrate (as N)	mg/L	-	-	-	-	4.2	5.3	4.6	-	-	-	-	5.6	6.1	6.1	4.8	5.2	4.4
Total P (as P)	µg/L	<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	46.3	45.8	47.1	47.6	45.7	43.0	44.4	44.7	42.7	44.2	46.6	45.5	43.3	45.4	43.3	42.8	43.3
		46.7	46.7	47.2	48.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.4	0.3	0.2	0.2	0.8	0.2	0.3	0.5	1.0	0.6	3.4	0.9	0.9	0.2	0.5	1.6	0.4
		0.2	0.3	0.2	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
TOC	mg/L	-	-	-	-	1.1	1.5	1.2	-	-	-	-	1.1	1.5	1.4	1.3	1.5	1.4
pH	S.U.	NA	NA	NA	NA	7.9	7.7	7.7	NA	NA	NA	NA	7.8	7.7	7.6	7.9	7.8	7.6
Temperature	°C	NA	NA	NA	NA	13.1	11.5	11.2	NA	NA	NA	NA	15.2	15.6	15.9	12.4	13.1	13.4
DO	mg/L	NA	NA	NA	NA	5.7	6.0	6.3	NA	NA	NA	NA	6.5	5.8	5.9	5.7	5.6	5.2
ORP	mV	NA	NA	NA	NA	477	522	603	NA	NA	NA	NA	479	481	492	529	514	529
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	NA	0.4	-	NA	NA	NA	-	NA	0.2	-	NA	1.4
Total Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	NA	-	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	350	668	395	-	-	-	-	423	608	527	489	593	557
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	155	161	159	-	-	-	-	147	148	164	136	143	155
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	195	507	236	-	-	-	-	276	460	364	353	450	401
As (total)	µg/L	29.5	37.5	1.0	0.8	22.7	39.2	0.5	22.6	38.7	1.2	1.1	19.7	47.2	1.4	10.7	38.9	1.1
		29.2	38.3	1.2	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-
As (soluble)	µg/L	-	-	-	-	24.9	39.2	0.4	-	-	-	-	12.6	43.1	1.4	12.6	38.1	1.0
As (particulate)	µg/L	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	7.2	4.1	<0.1	<0.1	0.8	<0.1
As (III)	µg/L	-	-	-	-	0.4	0.7	0.4	-	-	-	-	1.4	1.4	1.6	0.7	0.8	0.7
As (V)	µg/L	-	-	-	-	24.5	38.6	<0.1	-	-	-	-	11.2	41.6	<0.1	11.9	37.3	0.3
Fe (total)	µg/L	<25	52	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25	<25
		<25	46	<25	<25	-	-	-	-	-	-	-	-	-	-	-	-	-
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	<25	<25	<25	<25	<25	<25
Mn (total)	µg/L	0.7	0.2	<0.1	<0.1	0.6	0.3	<0.1	1.0	0.2	<0.1	<0.1	0.8	0.1	<0.1	0.5	0.4	<0.1
		0.6	0.2	<0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (soluble)	µg/L	-	-	-	-	0.5	0.3	<0.1	-	-	-	-	1.2	0.1	<0.1	0.5	0.4	<0.1
V (total)	µg/L	92.1	135	0.9	0.8	71.8	156	0.6	77.7	168	1.0	1.1	56.7	161	3.2	41.2	159	2.0
		90.0	143	1.0	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-
V (soluble)	µg/L	-	-	-	-	82.1	161	0.5	-	-	-	-	41.7	160	3.7	47.7	160	1.9

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

Sampling Date		01/03/07				01/18/07			02/06/07				02/13/07			03/01/07			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Bed Volume	10^3	-	-	NA[a]	NA[a]	-	-	NA[a]	-	-	7.7	6.9	-	-	7.6	-	-	8.6	7.8
Alkalinity (as $CaCO_3$)	mg/L	268 268	272 270	270 258	262 276	263 -	248 -	263 -	281 -	256 -	263 -	268 -	263 -	256 -	265 -	262 -	262 -	267 -	262 -
Fluoride	mg/L	-	-	-	-	5.7	4.7	5.5	-	-	-	-	6.3	5.8	7.8	-	-	-	-
Sulfate	mg/L	-	-	-	-	272	381	273	-	-	-	-	223	305	257	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	4.8	5.5	4.9	-	-	-	-	4.4	4.7	4.6	-	-	-	-
Total P (as P)	µg/L	<10 <10	<10 <10	<10 <10	<10 <10	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	29.0 -	33.2 -	27.7 -	<10 -	10.0 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	45.6 44.8	45.1 45.7	45.2 44.7	45.4 45.5	45.4 -	45.3 -	47.6 -	42.5 -	42.7 -	44.6 -	43.8 -	49.7 -	50.0 -	50.6 -	46.8 -	47.8 -	47.6 -	46.7 -
Turbidity	NTU	0.5 0.5	2.3 2.4	1.1 1.2	0.3 0.3	0.4 -	0.6 -	0.6 -	0.2 -	0.1 -	0.3 -	0.2 -	0.4 -	1.0 -	0.6 -	0.8 -	0.3 -	0.2 -	0.3 -
TOC	mg/L	-	-	-	-	1.2	1.5	1.2	-	-	-	-	1.0	1.3	1.2	-	-	-	-
pH	S.U.	NA	NA	NA	NA	8.0	7.8	7.7	NA	NA	NA	NA	7.9	7.6	7.6	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA	8.1	9.8	10.1	NA	NA	NA	NA	8.6	9.7	12.5	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA	NA[b]	NA[b]	NA[b]	NA	NA	NA	NA	NA[b]	NA[b]	NA[b]	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	535	512	659	NA	NA	NA	NA	468	502	726	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	1.0	NA	-	NA	NA	NA	-	NA	2.2	-	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	372	503	371	-	-	-	-	406	422	435	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	113	118	114	-	-	-	-	162	153	162	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	259	385	257	-	-	-	-	244	270	273	-	-	-	-
As (total)	µg/L	45.4 45.1	44.6 46.6	0.8 0.8	0.7 0.8	21.2 -	44.0 -	1.4 -	40.3 -	41.6 -	1.2 -	1.8 -	24.3 -	43.8 -	7.9 -	40.2 -	41.7 -	1.3 -	1.7 -
As (soluble)	µg/L	-	-	-	-	19.2	41.4	1.4	-	-	-	-	22.4	48.6	7.8	-	-	-	-
As (particulate)	µg/L	-	-	-	-	2.1	2.6	<0.1	-	-	-	-	1.9	<0.1	0.2	-	-	-	-
As (III)	µg/L	-	-	-	-	1.6	2.0	1.8	-	-	-	-	6.0	11.4	8.7	-	-	-	-
As (V)	µg/L	-	-	-	-	17.6	39.4	<0.1	-	-	-	-	16.4	37.2	<0.1	-	-	-	-
Fe (total)	µg/L	<25 <25	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	35 -	<25 -	<25 -	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	0.3 0.2	0.2 0.2	<0.1 <0.1	<0.1 <0.1	0.4 -	0.5 -	<0.1 -	0.3 -	0.3 -	<0.1 -	<0.1 -	0.9 -	2.0 -	0.5 -	0.2 -	0.1 -	<0.1 -	<0.1 -
Mn (soluble)	µg/L	-	-	-	-	0.6	0.7	<0.1	-	-	-	-	1.0	0.7	0.5	-	-	-	-
V (total)	µg/L	142 143	139 141	0.9 0.9	3.1 3.2	64.3 -	145 -	3.1 -	111 -	112 -	1.5 -	10.8 -	50.7 -	105 -	11.0 -	109 -	110 -	0.7 -	15.3 -
V (soluble)	µg/L	-	-	-	-	62.2	142	3.8	-	-	-	-	42.7	121	10.3	-	-	-	-

(a) Operational data not taken. (b) DO probe not operational.

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

Sampling Date		03/14/07			03/28/07				04/18/07			04/25/07				05/08/07		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10^3	-	-	8.8	-	-	9.8	8.9	-	-	10.2	-	-	10.9	9.9	-	-	11.2
Alkalinity (as $CaCO_3$)	mg/L	273 -	273 -	268 -	266 -	261 -	268 -	259 -	260 -	260 -	262 -	270 270	268 268	275 268	262 265	270 -	258 -	265 -
Fluoride	mg/L	5.2	5.2	5.8	-	-	-	-	5.4	5.5	5.5	-	-	-	-	5.3	5.4	4.5
Sulfate	mg/L	251	245	252	-	-	-	-	251	258	261	-	-	-	-	165	239	241
Nitrate (as N)	mg/L	4.0	3.7	4.3	-	-	-	-	5.0	4.9	5.0	-	-	-	-	4.4	4.5	4.6
Total P (as P)	µg/L	16.0 -	24.8 -	16.8 -	33.6 -	34.9 -	17.4 -	25.4 -	17.8 -	16.1 -	11.5 -	<10 <10	<10 <10	<10 <10	<10 <10	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	46.2 -	45.6 -	46.9 -	44.5 -	45.6 -	45.4 -	46.1 -	48.5 -	47.3 -	49.1 -	47.0 46.9	46.9 47.1	46.8 47.0	47.7 47.3	48.2 -	46.4 -	49.3 -
Turbidity	NTU	1.3 -	0.7 -	0.7 -	0.3 -	0.3 -	0.2 -	0.7 -	0.8 -	0.5 -	0.7 -	0.4 0.5	0.3 0.5	0.3 0.3	0.4 0.3	0.3 -	0.4 -	0.2 -
TOC	mg/L	1.9	1.7	1.6	-	-	-	-	1.3[a]	1.3[a]	1.3[a]	-	-	-	-	1.5	1.2	1.3
pH	S.U.	7.9	7.6	7.6	NA	NA	NA	NA	8.0	7.7	7.6	NA	NA	NA	NA	7.8	7.5	7.5
Temperature	°C	12.9	14.7	15.4	NA	NA	NA	NA	14.4	15.5	16.1	NA	NA	NA	NA	17.5	17.8	18.2
DO	mg/L	7.1	7.0	6.2	NA	NA	NA	NA	5.9	5.8	5.6	NA	NA	NA	NA	5.0	4.6	4.6
ORP	mV	413	504	563	NA	NA	NA	NA	443	185	404	NA	NA	NA	NA	NA[b]	NA[b]	NA[b]
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	-	NA	NA	NA	-	NA	0.8	-	NA	NA	NA	-	NA	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	1.1	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	547	474	471	-	-	-	-	386	399	385	-	-	-	-	333	359	351
Ca Hardness (as $CaCO_3$)	mg/L	187	187	182	-	-	-	-	101	99.5	105	-	-	-	-	124	126	139
Mg Hardness (as $CaCO_3$)	mg/L	361	287	289	-	-	-	-	285	300	281	-	-	-	-	209	233	212
As (total)	µg/L	27.3 -	45.6 -	3.9 -	46.5 -	48.3 -	3.2 -	5.2 -	45.3 -	43.2 -	1.2 -	39.4 38.0	38.9 38.2	2.0 1.7	3.1 2.7	44.1 -	42.4 -	2.9 -
As (soluble)	µg/L	8.8	43.3	3.8	-	-	-	-	39.2	40.8	1.0	-	-	-	-	44.2	35.9	2.5
As (particulate)	µg/L	18.5	2.3	0.2	-	-	-	-	6.2	2.4	0.2	-	-	-	-	<0.1	6.5	0.5
As (III)	µg/L	2.7	3.1	2.9	-	-	-	-	<0.1	<0.1	<0.1	-	-	-	-	0.5	0.7	1.1
As (V)	µg/L	6.1	40.2	0.9	-	-	-	-	39.1	40.7	0.9	-	-	-	-	43.8	35.2	1.4
Fe (total)	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 <25	<25 <25	<25 <25	<25 <25	<25 -	<25 -	<25 -
Fe (soluble)	µg/L	<25	<25	<25	-	-	-	-	<25	<25	<25	-	-	-	-	<25	<25	<25
Mn (total)	µg/L	0.3 -	<0.1 -	<0.1 -	0.7 -	0.6 -	0.4 -	0.5 -	0.6 -	0.3 -	0.2 -	0.4 0.4	0.3 0.4	<0.1 <0.1	<0.1 <0.1	0.2 -	0.4 -	<0.1 -
Mn (soluble)	µg/L	0.5	0.1	<0.1	-	-	-	-	0.8	0.4	0.2	-	-	-	-	0.3	0.4	<0.1
V (total)	µg/L	79.9 -	111 -	22.8 -	108 -	107 -	1.3 -	30.7 -	167 -	174 -	44.2 -	138 133	136 137	1.1 1.0	55.7 55.5	131 -	137 -	70.8 -
V (soluble)	µg/L	28.7	112	23.1	-	-	-	-	156	169	44.0	-	-	-	-	120	135	69.3

(a) TOC samples were analyzed outside of hold time. (b) ORP probe not operational.

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

Sampling Date		05/24/07				06/14/07			06/28/07				07/09/07			07/23/07			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Bed Volume	10^3	-	-	12.1	11.0	-	-	12.7	-	-	13.8	12.3	-	-	13.7	-	-	15.1	13.3
Alkalinity (as $CaCO_3$)	mg/L	252 -	254 -	259 -	254 -	257 -	259 -	259 -	264 -	264 -	267 -	262 -	256 -	249 -	252 -	260 255	260 252	255 252	255 252
Fluoride	mg/L	-	-	-	-	29.2	6.0	6.5	-	-	-	-	6.5	30.5	14.2	-	-	-	-
Sulfate	mg/L	-	-	-	-	268	287	250	-	-	-	-	261	254	259	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	4.9	4.2	4.4	-	-	-	-	6.4	6.0	5.5	-	-	-	-
Total P (as P)	µg/L	<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	45.9 -	46.4 -	47.0 -	47.6 -	47.3 -	47.0 -	48.1 -	62.1 -	60.8 -	61.5 -	64.2 -	47.1 -	47.1 -	46.2 -	45.8 46.4	45.6 45.5	47.3 46.7	46.4 46.3
Turbidity	NTU	0.4 -	0.3 -	0.1 -	0.5 -	0.5 -	0.3 -	0.3 -	0.2 -	0.5 -	0.2 -	0.6 -	0.5 -	1.0 -	0.3 -	1.5 2.6	1.5 1.3	2.7 0.6	0.8 0.3
TOC	mg/L	-	-	-	-	1.4	1.3	1.4	-	-	-	-	1.3	1.3	1.3	-	-	-	-
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	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
ORP	mV	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	-	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA
Total Hardness (as $CaCO_3$)	mg/L	-	-	-	-	337	349	362	-	-	-	-	360	369	385	-	-	-	-
Ca Hardness (as $CaCO_3$)	mg/L	-	-	-	-	116	122	132	-	-	-	-	126	126	119	-	-	-	-
Mg Hardness (as $CaCO_3$)	mg/L	-	-	-	-	222	227	230	-	-	-	-	234	244	266	-	-	-	-
As (total)	µg/L	42.0 -	41.5 -	0.2 -	1.7 -	45.3 -	47.4 -	2.5 -	39.8 -	40.8 -	0.1 -	2.5 -	50.6 -	50.0 -	3.7 -	42.3 43.3	42.9 43.1	1.1 1.2	4.3 4.4
As (soluble)	µg/L	-	-	-	-	40.7	42.6	2.4	-	-	-	-	40.1	40.8	3.2	-	-	-	-
As (particulate)	µg/L	-	-	-	-	4.6	4.7	0.2	-	-	-	-	10.5	9.2	0.5	-	-	-	-
As (III)	µg/L	-	-	-	-	0.7	0.7	0.6	-	-	-	-	1.1	1.3	1.3	-	-	-	-
As (V)	µg/L	-	-	-	-	40.0	41.9	1.8	-	-	-	-	38.9	39.5	1.9	-	-	-	-
Fe (total)	µg/L	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	<25 -	28 25	29 29	<25 <25	<25 <25
Fe (soluble)	µg/L	-	-	-	-	<25	<25	<25	-	-	-	-	<25	<25	<25	-	-	-	-
Mn (total)	µg/L	0.3 -	0.2 -	<0.1 -	<0.1 -	0.3 -	<0.1 -	<0.1 -	2.2 -	1.8 -	<0.1 -	<0.1 -	1.1 -	1.0 -	0.1 -	1.1 1.0	0.9 0.9	<0.1 <0.1	<0.1 <0.1
Mn (soluble)	µg/L	-	-	-	-	0.5	0.1	<0.1	-	-	-	-	1.3	0.9	0.4	-	-	-	-
V (total)	µg/L	145 -	143 -	1.8 -	86.4 -	144 -	143 -	98.3 -	136 -	134 -	1.1 -	116 -	140 -	138 -	114 -	122 125	124 126	15.1 15.0	110 110
V (soluble)	µg/L	-	-	-	-	138	144	101	-	-	-	-	137	138	112	-	-	-	-

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

Sampling Date		08/14/07			08/21/07				09/11/07			09/27/07				10/10/07		
Sampling Location / Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Bed Volume	10^3	-	-	15.4	-	-	NA[a]	13.9	-	-	NA[a]	-	-	18.9	15.0	-	-	18.4
Alkalinity (as $CaCO_3$)	mg/L	267 -	272 -	272 -	250 -	248 -	252 -	250 -	255 -	251 -	251 -	262 -	258 -	260 -	258 -	245 -	245 -	243 -
Fluoride	mg/L	5.2	5.3	5.4	-	-	-	-	6.1	6.1	6.2	-	-	-	-	7.4	6.3	6.0
Sulfate	mg/L	240	230	230	-	-	-	-	250	250	240	-	-	-	-	258	253	245
Nitrate (as N)	mg/L	6.0	5.9	6.0	-	-	-	-	7.2	7.2	7.3	-	-	-	-	6.6	7.0	6.9
Total P (as P)	µg/L	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	45.4 -	45.2 -	48.4 -	52.5 -	52.4 -	55.3 -	55.2 -	44.7 -	45.0 -	45.9 -	47.6 -	47.7 -	47.1 -	47.1 -	45.3 -	45.4 -	46.3 -
Turbidity	NTU	1.0 -	0.7 -	0.6 -	0.7 -	0.8 -	0.2 -	0.5 -	1.4 -	1.0 -	0.8 -	0.5 -	0.3 -	0.7 -	0.6 -	0.4 -	0.2 -	0.3 -
TOC	mg/L	1.2	1.2	1.3	-	-	-	-	1.1	1.1	1.1	-	-	-	-	1.1	1.1	1.1
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	7.8	7.6	7.4	NA	NA	NA	NA	7.6	7.4	7.4
Temperature	°C	NA	NA	NA	NA	NA	NA	NA	21.6	21.5	21.8	NA	NA	NA	NA	21.1	21.3	21.4
DO	mg/L	NA	NA	NA	NA	NA	NA	NA	6.1	5.1	5.4	NA	NA	NA	NA	4.8	4.1	4.6
ORP	mV	NA	NA	NA	NA	NA	NA	NA	612	645	584	NA	NA	NA	NA	610	676	714
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	0.9
Total Chlorine (as Cl_2)	mg/L	-	NA	NA	-	NA	NA	NA	-	NA	NA	-	NA	NA	NA	-	NA	0.7
Total Hardness (as $CaCO_3$)	mg/L	365	380	375	-	-	-	-	377	390	402	-	-	-	-	NA	NA	NA
Ca Hardness (as $CaCO_3$)	mg/L	117	118	148	-	-	-	-	131	144	161	-	-	-	-	122	130	138
Mg Hardness (as $CaCO_3$)	mg/L	248	261	227	-	-	-	-	246	246	241	-	-	-	-	NA	NA	NA
As (total)	µg/L	39.0 -	43.9 -	5.1 -	45.6 -	45.7 -	1.5 -	1.3 -	43.1 -	44.6 -	5.9 -	39.6 -	40.4 -	1.4 -	6.1 -	47.8 -	48.6 -	7.1 -
As (soluble)	µg/L	41.2	42.0	4.9	-	-	-	-	39.6	40.8	5.7	-	-	-	-	42.1	41.5	6.5
As (particulate)	µg/L	<0.1	1.9	0.3	-	-	-	-	3.5	3.7	0.2	-	-	-	-	5.7	7.1	0.6
As (III)	µg/L	1.5	1.8	1.8	-	-	-	-	0.7	0.7	0.6	-	-	-	-	0.8	0.8	0.9
As (V)	µg/L	39.8	40.2	3.0	-	-	-	-	38.9	40.1	5.1	-	-	-	-	41.3	40.7	5.5
Fe (total)	µg/L	<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	<25
Mn (total)	µg/L	0.6 -	0.5 -	<0.1 -	0.9 -	0.8 -	<0.1 -	<0.1 -	0.8 -	0.6 -	<0.1 -	<0.1 -	<0.1 -	<0.1 -	<0.1 -	0.4 -	0.3 -	<0.1 -
Mn (soluble)	µg/L	0.9	0.4	<0.1	-	-	-	-	0.9	0.6	<0.1	-	-	-	-	0.9	0.3	0.3
V (total)	µg/L	127 -	134 -	128 -	127 -	126 -	30.8 -	30.3 -	139 -	141 -	132 -	136 -	134 -	31.9 -	130 -	134 -	138 -	132 -
V (soluble)	µg/L	132	133	126	-	-	-	-	140	142	139	-	-	-	-	134	136	135

(a) Bed volume calculations not accurate due to malfunctioning totalizer.

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

Sampling Date		11/08/07				12/05/07				01/13/08				02/20/08				03/12/08			
Sampling Location / Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Bed Volume	10^3	-	-	21.8	17.2	-	-	22.4[(a)]	17.9[(a)]	-	-	23.8[(a)]	19.1[(a)]	-	-	25.4[(a)]	20.5[(a)]	-	-	26.4[(a)]	21.4[(a)]
Alkalinity (as $CaCO_3$)	mg/L	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Fluoride	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sulfate	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total P (as P)	µg/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	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Turbidity	NTU	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TOC	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	S.U.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°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	NA	NA	-	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	-	NA	NA	NA	-	NA	NA	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	44.3 -	44.4 -	1.4 -	6.4 -	44.8 -	43.9 -	2.0 -	6.8 -	41.7 -	43.1 -	2.3 -	6.8 -	42.5 -	41.8 -	7.5 -	3.0 -	33.7 33.9	39.3 38.9	3.1 2.1	7.6 6.7
As (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (particulate)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (III)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
As (V)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn (total)	µg/L	0.4 -	0.3 -	<0.1 -	<0.1 -	0.2 -	0.2 -	<0.1 -	<0.1 -	0.3 -	0.3 -	<0.1 -	<0.1 -	0.2 -	0.2 -	<0.1 -	<0.1 -	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1
Mn (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
V (total)	µg/L	143 -	142 -	37.7 -	136 -	131 -	127 -	39.3 -	119 -	124 -	127 -	53.2 -	120 -	125 -	122 -	127 -	70.6 -	123 121	125 125	87.0 87.4	127 128
V (soluble)	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(a) Bed volumes estimated by taking bed volumes calculated from the Master Totalizer readings from the previous year and adding onto the last available data (11/27/08).

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

Sampling Date		04/17/08			
Sampling Location / Parameter	Unit	IN	AC	TA	TB
Bed Volume	10^3	-	-	27.6[(a)]	22.5[(a)]
Alkalinity (as $CaCO_3$)	mg/L	- -	- -	- -	- -
Fluoride	mg/L	-	-	-	-
Sulfate	mg/L	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-
Total P (as P)	µg/L	<10 -	<10 -	<10 -	<10 -
Silica (as SiO_2)	mg/L	- -	- -	- -	- -
Turbidity	NTU	- -	- -	- -	- -
TOC	mg/L	-	-	-	-
pH	S.U.	NA	NA	NA	NA
Temperature	°C	NA	NA	NA	NA
DO	mg/L	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA
Free Chlorine (as Cl_2)	mg/L	-	NA	NA	NA
Total Chlorine (as Cl_2)	mg/L	-	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	39.7 -	49.0 -	6.8 -	2.3 -
As (soluble)	µg/L	-	-	-	-
As (particulate)	µg/L	-	-	-	-
As (III)	µg/L	-	-	-	-
As (V)	µg/L	-	-	-	-
Fe (total)	µg/L	69	1,516	<25	<25
Fe (soluble)	µg/L	-	-	-	-
Mn (total)	µg/L	0.2 -	0.9 -	<0.1 -	<0.1 -
Mn (soluble)	µg/L	-	-	-	-
V (total)	µg/L	140 -	163 -	133 -	107 -
V (soluble)	µg/L	-	-	-	-

(a) Bed volumes estimated by taking bed volumes calculated from the Master Totalizer readings from the previous year and adding onto the last available data (11/27/08).