

**Arsenic Removal from Drinking Water by Adsorptive Media
USEPA Demonstration Project at Desert Sands MDWCA, NM
Six-Month Evaluation Report**

by

**Chris T. Coonfare
Abraham S.C. Chen
Lili Wang
Julia M. Valigore**

**Battelle
Columbus, OH 43201-2693**

**Contract No. 68-C-00-185
Task Order No. 0019**

for

**Thomas J. Sorg
Task Order Manager**

**Water Supply and Water Resources Division
National Risk Management Research Laboratory
Cincinnati, OH 45268**

**National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268**

DISCLAIMER

The work reported in this document is funded by the United States Environmental Protection Agency (EPA) under Task Order 0019 of Contract 68-C-00-185 to Battelle. It has been subjected to the Agency's peer and administrative reviews and has been approved for publication as an EPA document. Any opinions expressed in this paper are those of the author(s) and do not, necessarily, reflect the official positions and policies of the EPA. Any mention of products or trade names does not constitute recommendation for use by the EPA.

FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed during and the results obtained from the first six months of the arsenic removal treatment technology demonstration project at the Desert Sands Mutual Domestic Water Consumers Association (MDWCA) facility in Anthony, NM. The objectives of the project are to evaluate the effectiveness of Severn Trent Services (STS) Arsenic Package Unit-300 (APU-300) SORB 33TM media in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 µg/L, the reliability of the treatment system, the simplicity of required system operation and maintenance (O&M) and operator's skills, and the cost-effectiveness of the technology. The project is also characterizing water in the distribution system and process residuals produced by the treatment system.

The STS treatment system became operational on January 16, 2004. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), process residuals, and capital and O&M costs. After treating approximately 14,647,000 gallons, or 12,200 bed volumes, of water, which was approximately 9% of the vendor estimated working capacity for the adsorptive media, total arsenic concentrations were reduced from 20.7-30.1 µg/L in raw water to 2.8 µg/L in the treated water. As(III) was the predominating species in raw water, averaging 21.1 µg/L. Prechlorination was effective in oxidizing As(III) to As(V), as evident by the low As(III) concentrations (i.e., 0.5 to 1.1 µg/L) in water sampled immediately after prechlorination. Total and free chlorine residuals measured before and after the adsorption vessels were nearly identical at 0.3-0.5 mg/L (as Cl₂) and 0.4-0.6 mg/L (as Cl₂), respectively, indicating little or no chlorine consumption by the SORB 33TM media. Concentrations of iron, manganese, silica, orthophosphate, and other ions in raw water were not high enough to impact arsenic removal by the media.

Comparison of the distribution system sampling results before and after the operation of the STS system showed a decrease in arsenic concentration (from 22.4-28.2 µg/L to 1.8-10.4 µg/L) at all three sampling locations. However, the concentrations measured after system operation were higher than those in the plant effluent. This likely was due to the blending with untreated water produced by a separate well in the distribution system. Neither lead nor copper concentrations at the sample sites appeared to have been affected by the operation of the system.

Two sets of backwash water samples were collected during the first six months of system operation. Dissolved arsenic concentrations in the backwash water ranged from 3.5-12.1 µg/L, which were significantly lower than those measured in raw water, indicating removal of arsenic by the media during backwash. Dissolved iron and manganese concentrations in backwash water correlated more closely with the influent concentrations.

The capital investment cost of \$153,000 includes \$112,000 for equipment, \$23,000 for site engineering, and \$18,000 for installation. Using the system's rated capacity of 320 gpm, the capital cost was \$476 per gallon of design capacity and the equipment-only cost was \$350 per gallon of design capacity. These calculations do not include the cost of a building addition to house the treatment system.

O&M costs for the STS system included only incremental costs associated with the APU-300 system, such as media replacement and disposal, chemical supply, electricity, and labor. Because the incremental costs for chemical supply and electricity were negligible, only media replacement and disposal and O&M labor would impact the O&M costs. O&M costs for media replacement were estimated based upon media replacement cost and projected breakthrough and will be determined once the actual throughput and cost at the time of the media replacement become available.

The STS system experienced excessive flow restriction, imbalanced flow, and/or elevated pressure differential across the adsorption vessels and the entire system during the first four months of system operation. After extensive on-site and off-site investigations and hydraulic testing, the system was retrofitted in May 2004 and, thus, able to operate according to the original design specifications thereafter. After the retrofit, the only O&M issue encountered was the temporary failure of the digital flow meters on the vessels on two separate occasions for one to two days at a time.

CONTENTS

FOREWORD	iii
ABSTRACT	iv
FIGURES	vii
TABLES	vii
ABBREVIATIONS AND ACRONYMS	ix
ACKNOWLEDGMENTS	xi
1.0 INTRODUCTION	1
1.1 Background.....	1
1.2 Treatment Technologies for Arsenic Removal.....	1
1.3 Project Objectives.....	2
2.0 CONCLUSIONS.....	3
3.0 MATERIALS AND METHODS.....	4
3.1 General Project Approach.....	4
3.2 System O&M and Cost Data Collection.....	5
3.3 Sample Collection Procedures and Schedules	6
3.3.1 Source Water Sample Collection.....	6
3.3.2 Treatment Plant Water Sample Collection	6
3.3.3 Backwash Water Sample Collection	6
3.3.4 Backwash Solid Sample Collection.....	6
3.3.5 Distribution System Water Sample Collection.....	6
3.4 Sampling Logistics	8
3.4.1 Preparation of Arsenic Speciation Kits.....	8
3.4.2 Preparation of Sampling Coolers.....	8
3.4.3 Sample Shipping and Handling	9
3.5 Analytical Procedures.....	9
4.0 RESULTS AND DISCUSSION	10
4.1 Facility Description	10
4.1.1 Existing System	10
4.1.2 Source Water Quality	10
4.1.3 Distribution System	14
4.2 Treatment Process Description	15
4.3 System Installation	15
4.3.1 Permitting	15
4.3.2 Building Construction.....	18
4.3.3 Installation, Shakedown, and Startup	19
4.4 System Operation	19
4.4.1 Operational Parameters.....	19
4.4.2 System Retrofit.....	21
4.4.3 Backwash.....	25
4.4.4 Residual Management	25
4.4.5 System Operation Reliability and Simplicity	25
4.5 System Performance	27
4.5.1 Treatment Plant Sampling	27
4.5.2 Backwash Water Sampling.....	34
4.5.3 Distribution System Water Sampling	34

4.6 System Costs.....	36
4.6.1 Capital Costs.....	38
4.6.2 Operation and Maintenance Costs.....	39
5.0 REFERENCES	41
APPENDIX A: OPERATIONAL DATA	
APPENDIX B: ANALYTICAL RESULTS	

FIGURES

Figure 4-1. Map of the Desert Sands MDWCA Service Area.....	11
Figure 4-2. Well No. 3 (Left) and In-Line Sand Separator (Center) Adjacent to the Pump House (Right) at the Desert Sands MDWCA Site	12
Figure 4-3. Piping Inside the Pump House at the Desert Sands MDWCA Site.....	12
Figure 4-4. Process Flow Diagram and Sampling Locations.....	17
Figure 4-5. Photograph of APU-300 System at the Desert Sands MDWCA Site	18
Figure 4-6. Pump House (on the right) and System Enclosure.....	19
Figure 4-7. Vessels A and B Flowrates Before and After System Retrofitting	21
Figure 4-8. Pressure Losses (Δp) across Each Vessel and the System over Time.....	22
Figure 4-9. Schematic Diagram of STS APU-300 System as Installed at Desert Sands MDWCA in December 2003	24
Figure 4-10. Schematic Diagram of STS APU-300 System after System Retrofitting in May 2004	26
Figure 4-11. Concentration of Arsenic Species in the Influent, After Prechlorination, and in the Combined System Effluent	32
Figure 4-12. Total Arsenic Breakthrough Curve	33
Figure 4-13. Total Manganese Concentrations over Time	33
Figure 4-14. Concentrations of Manganese Species.....	35
Figure 4-15. Media Replacement and O&M Cost for the Desert Sands MDWCA APU-300 System.....	39

TABLES

Table 1-1. Summary of Arsenic Removal Demonstration Technologies and Source Water Quality Parameters.....	2
Table 3-1. Pre-Demonstration Study Activities and Completion Dates.....	4
Table 3-2. Evaluation Objectives and Supporting Data Collection Activities	5
Table 3-3. Sample Collection Schedule and Analyses.....	7
Table 4-1. Desert Sands MDWCA Well No. 3 Water Quality Data.....	13
Table 4-2. Desert Sands MDWCA Distribution System Water Quality Data	14
Table 4-3. Physical and Chemical Properties of SORB 33 TM Media.....	16
Table 4-4. Design Features for the APU-300 System.....	16
Table 4-5. Summary of APU-300 System Operation	20
Table 4-6. Results of Hydraulic Testing of STS APU-300 Systems.....	23
Table 4-7. Summary of Arsenic, Iron, and Manganese Analytical Results	28
Table 4-8. Summary of Water Quality Parameter Measurements	29
Table 4-9. Backwash Water Sampling Results	36

Table 4-10. Distribution System Sampling Results	37
Table 4-11. Capital Investment for the APU-300 System at the Desert Sands MDWCA Site	38
Table 4-12. O&M Costs for the APU-300 System at the Desert Sands MDWCA Site.....	40

ABBREVIATIONS AND ACRONYMS

Δp	differential pressure
AA	activated alumina
AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
APU	arsenic package unit
As	arsenic
bgs	below ground surface
BV	bed volume(s)
c/f	coagulation/filtration
Ca	calcium
Cl ₂	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EBCT	empty bed contact time
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FRP	fiberglass reinforced plastic
GFH	granular ferric hydroxide
GFO	granular ferric oxide
gpd	gallons per day
gpm	gallons per minute
HDPE	high-density polyethylene
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	(EPA) Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDWCA	Mutual Domestic Water Consumers Association
Mg	magnesium
mg/L	milligrams per liter
$\mu\text{g/L}$	micrograms per liter
Mn	manganese
Mo	molybdenum
mV	millivolts

N/A	not applicable
Na	sodium
NA	not available
NaOCl	sodium hypochlorite
NMED	New Mexico Environmental Department
NTU	nephelometric turbidity unit
O&M	operation and maintenance
ORD	Office of Research and Development
ORP	oxidation-reduction potential
Pb	lead
psi	pounds per square inch
PO ₄	orthophosphate
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SiO ₂	silica
SO ₄	sulfate
SOC	synthetic organic compound
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
V	vanadium
VOC	volatile organic compound

ACKNOWLEDGMENTS

The authors wish to extend their sincere appreciation to the staff of the Desert Sands Mutual Domestic Water Consumers Association in Anthony, New Mexico. The Desert Sands staff monitored the treatment system daily, and collected samples from the treatment system and distribution system on a regular schedule throughout this reporting period. This performance evaluation would not have been possible without their efforts.

1.0 INTRODUCTION

1.1 Background

The Safe Drinking Water Act (SDWA) mandates that 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 an maximum contaminant level (MCL) for arsenic at 0.05 mg/L. Amended in 1996, the SDWA required that EPA develop an arsenic research strategy and publish a proposal to revise the arsenic MCL by January 2000. On January 18, 2001, EPA finalized the arsenic MCL at 0.01 mg/L (EPA, 2001). In order to clarify the implementation of the original rule, EPA revised the rule text on March 25, 2003 to express the MCL as 0.010 mg/L (10 µg/L) (EPA, 2003). The final rule requires all community and non-transient, non-community water systems to comply with the new standard by January 23, 2006.

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in the first round of this EPA-sponsored demonstration program to provide information on their water systems. In June 2002, EPA selected 17 sites from a list of 115 sites to be the host sites for the demonstration studies. The Desert Sands Mutual Domestic Water Consumers Association (MDWCA) water system in Anthony, NM was selected as one of the 17 Round 1 host sites for the demonstration program.

In September 2002, EPA solicited proposals from engineering firms and vendors for cost-effective arsenic removal treatment technologies for the 17 host sites. EPA received 70 technical proposals for the 17 host sites, with each site receiving from one to six proposals. In April 2003, an independent technical review panel reviewed the proposals and provided its recommendations to EPA on the technologies that it determined were acceptable for the demonstration at each site. Because of funding limitations and other technical reasons, only 12 of the 17 sites were selected for the demonstration project. Using the information provided by the review panel, EPA in cooperation with the host sites and the drinking water programs of the respective states selected one technical proposal for each site. Severn Trent Services, (STS) using the Bayoxide E33 media developed by Bayer AG, was selected for the Desert Sands MDWCA facility. STS has given the E33 media the designation "SORB 33™."

1.2 Treatment Technologies for Arsenic Removal

The technologies selected for the 12 Round 1 EPA arsenic removal demonstration host sites include nine adsorptive media systems, one anion exchange system, one coagulation/filtration system, and one process modification with iron addition. Table 1-1 summarizes the locations, technologies, vendors, and key source water quality parameters (including arsenic, iron, and pH) of the 12 demonstration sites. The technology selection and system design for the 12 demonstration sites have been reported in an EPA report (Wang et al., 2004) posted on an EPA web site (<http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm>).

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

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

AM = adsorptive media process; C/F = coagulation/filtration process; IX = ion exchange process; SM = system modification;

STMGID = South Truckee Meadows General Improvement District.

(a) Due to system reconfiguration from parallel to series operation, the design flowrate is reduced by 50%.

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

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

1.3 Project Objectives

The objective of the Round 1 arsenic demonstration program is to conduct 12 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 simplicity of required system operation and maintenance (O&M) and operator's skill levels.
- Determine the cost-effectiveness of the technologies.
- Characterize process residuals produced by the technologies.

This report summarizes the results gathered during the first six months of the STS system operation from January 16 through July 16, 2004. The types of data collected include system operational data, water quality data (both across the treatment train and in the distribution system), residuals characterization data, and capital and preliminary O&M cost data.

2.0 CONCLUSIONS

The STS APU-300 system became operational on January 16, 2004. After treating approximately 14,647,000 gallons, or 12,200 bed volumes (BV), of water, which was approximately 9% of the vendor estimated working capacity for SORB 33™, the media reduced total arsenic concentrations from 20.7-30.1 µg/L in raw water to 2.8 µg/L in the treated water. As(III) was the predominating species in raw water, and was effectively oxidized to As(V) with sodium hypochlorite before entering the adsorption vessels. Little or no chlorine was consumed by the SORB 33™ media. Concentrations of iron, manganese, silica, orthophosphate, and other ions in raw water were not high enough to cause adverse effects on arsenic removal.

Arsenic concentrations in the distribution system were reduced from the pre-demonstration levels of 22.4-28.2 µg/L to 1.8-10.4 µg/L after the system became operational. However, the reduced concentrations were still higher than those in the plant effluent, probably due to the blending of the treated water with untreated water produced by a separate well in the distribution system. Neither lead nor copper concentrations appear to have been affected by operation of the system.

Dissolved arsenic concentrations in the backwash water ranged from 3.5-12.1 µg/L, which were significantly lower than those measured in raw water, indicating removal of arsenic by the media during backwash. Dissolved iron and manganese concentrations correlated more closely with the influent concentrations.

The capital investment costs for equipment, site engineering, and installation were \$153,000. Using the system's rated capacity of 320 gpm, the capital cost was \$476 per gallon of design capacity and the equipment-only cost was \$350 per gallon of design capacity. These calculations do not include the cost of a building addition to house the treatment system.

O&M costs included only incremental costs, such as media replacement and disposal, chemical supply, electricity, and labor. Because the incremental costs for chemical supply and electricity were negligible, only media replacement and disposal and O&M labor would impact the O&M costs. O&M costs for media replacement will be determined once the actual throughput and cost data at the time of the media replacement become available.

The APU-300 system has experienced excessive flow restriction, imbalanced flow, and elevated pressure differential across the adsorption vessels and entire system since the inception of the study in January 2004. After a series of on-site and off-site investigations and hydraulic testing, the system was retrofitted in May 2004. Since then, the system has been operated as originally specified by the vendor.

3.0 MATERIALS AND METHODS

3.1 General Project Approach

Following the pre-demonstration activities summarized in Table 3-1, the performance evaluation study of the STS treatment system began on January 16, 2004. Table 3-2 summarizes the types of data collected and/or considered as part of the technology evaluation process. The overall performance of the system was determined based on its ability to consistently remove arsenic to the target MCL of 10 µg/L; this was monitored through the collection of weekly and monthly water samples across the treatment train. The reliability of the system was evaluated by tracking the unscheduled system downtime and frequency and extent of repair and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

Simplicity of the system operation and the level of operator skill required were evaluated based on a combination of quantitative data and qualitative considerations, including any pre-treatment and/or post-treatment requirements, level of system automation, operator skill requirements, task analysis of the preventive maintenance activities, frequency of chemical and/or media handling and inventory requirements, and general knowledge needed for safety requirements and chemical processes. The staffing requirements on the system operation were recorded on a Field Log Sheet.

The cost-effectiveness of the system is evaluated based on the cost per 1,000 gallons (\$/1,000 gallons) of water treated. This requires the tracking of capital costs such as equipment, engineering, and installation costs, as well as O&M costs for media replacement and disposal, chemical supply, electrical power use, and labor hours. The capital costs have been reported in an EPA report (Chen et al., 2004) posted on an EPA web site (<http://www.epa.gov/ORD/NRMRL/arsenic/resource.htm>). Data on O&M costs were limited to chemicals, electricity, and labor hours because media replacement did not take place during the six months of operation.

Table 3-1. Pre-Demonstration Study Activities and Completion Dates

Activity	Date
Introductory Meeting	August 20, 2003
Request for Quotation Issued to Vendor	August 26, 2003
Vendor Quotation Submitted to Battelle	September 17, 2003
Purchase Order Completed and Signed	October 3, 2003
Letter Report Issued	October 16, 2003
Concrete Pad Poured	October 30, 2003
Engineering Package Submitted to NMED	November 18, 2003
APU-300 Unit Shipped by STS	November 18, 2003
Draft Study Plan Issued	November 26, 2003
APU-300 Unit Delivered to Desert Sands MDWCA	December 1, 2003
System Installation Completed	December 11, 2003
Permit Issued by NMED	December 22, 2003
Building Construction Begun	December 23, 2003
System Shakedown Completed	January 15, 2004
Performance Evaluation Begun	January 16, 2004
Final Study Plan Issued	January 19, 2004
Building Construction Completed	January 23, 2004

NMED = New Mexico Environmental Department.

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

Evaluation Objectives	Data Collection
Performance	-Ability to consistently meet 10 µg/L of arsenic in effluent
Reliability	-Unscheduled downtime for system -Frequency and extent of repairs to include labor hours, problem description, description of materials, and cost of materials
Simplicity of Operation and Operator Skill	-Pre- and post-treatment requirements -Level of system automation for data collection and system operation -Staffing requirements including number of operators and labor hours -Task analysis of preventative maintenance to include labor hours per month and number and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed of safety requirements and chemical processes
Cost-Effectiveness	-Capital costs including equipment, engineering, and installation -O&M costs including chemical and/or media usage, electricity, and labor
Residual Management	-Quantity of the residuals generated by the process -Characteristics of the aqueous and solid residuals

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

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection following the instructions provided by STS and Battelle. On a daily basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Battelle-provided Daily Field Log Sheet; checked the sodium hypochlorite drum level; and conducted visual inspections to ensure normal system operations. In the event of problems, the plant operator would contact the Battelle Study Lead, who then would determine if STS should be contacted for troubleshooting. The plant operator recorded all relevant information on the Repair and Maintenance Log Sheet. Weekly or bi-weekly, the plant operator measured water quality parameters, including temperature, pH, dissolved oxygen (DO)/oxidation-reduction potential (ORP), and residual chlorine, and recorded the data on a Weekly Water Quality Parameters Log Sheet. Monthly, the plant operator inspected the system control panel to ensure that moisture had not penetrated into the panel (STS, 2004). A monthly backwash of the media was originally recommended by STS; however, since it had been retrofitted in May 2004, the system was backwashed automatically when triggered by an increase in differential pressure across each adsorption vessel.

Capital costs for the STS system consisted of costs for equipment, site engineering, and system installation. The O&M costs consisted primarily of costs for the media replacement and spent media disposal, chemical and electricity consumption, and labor. The sodium hypochlorite and electricity consumption was tracked using the Daily Field Log Sheet. Labor hours for various activities, such as the routine system O&M, system troubleshooting and repair, and demonstration-related work, were tracked using an Operator Labor Hour Record. The routine O&M included activities such as filling field logs, replenishing the sodium hypochlorite solution, ordering inventories, performing system inspection, and others as recommended by STS. The demonstration-related work included activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead. The demonstration-related activities were recorded but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the performance of the system, samples were collected from the source, treatment plant, distribution system, and adsorptive vessel backwash. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Specific sampling requirements for analytical methods, sample volumes, containers, preservation, and holding times are presented in Table 4-1 of the EPA-endorsed Quality Assurance Project Plan (QAPP) (Battelle, 2003).

3.3.1 Source Water Sample Collection. During the initial visit to the site, Battelle collected one set of source water samples for detailed water quality analyses. The source water also was speciated for particulate and soluble As, iron (Fe), manganese (Mn), aluminum (Al), and As(III) and As(V). The sample tap was flushed for several minutes before sampling; special care was taken to avoid agitation, which might cause unwanted oxidation. Arsenic speciation kits and containers for water quality samples were prepared as described in Section 3.4. Additionally, Battelle arranged for the plant operator to collect one set of source water samples for sulfide analysis.

3.3.2 Treatment Plant Water Sample Collection. During the system performance evaluation study, water samples were collected across the treatment train by the plant operator. After receiving training, the plant operator also performed on-site arsenic speciation once every four weeks. For the first three months of the demonstration, samples were collected weekly, on a four-week cycle. For the first week of each four-week cycle, treatment plant samples were collected at three locations (i.e. the wellhead [IN], after chlorination but before splitting to the two vessels [AC], and from the combined effluent of the two vessels [TT] (as designated in Table 3-3) and analyzed for the analytes listed under the monthly treatment plant analyte list (see Table 3-3). For the second, third, and fourth week, treatment plant samples were collected at four locations (i.e. IN, AC, after the first vessel [TA], and after the second vessel [TB]) and analyzed for the analytes listed under the weekly treatment plant analyte list. Since April 14, 2004, the sampling frequency was reduced from weekly to biweekly due to the low water demand and the resulting low volume throughput to the system. Under this revised schedule, the “monthly” speciation and sampling remained unchanged; however, the “weekly” sampling at IN, AC, TA, and TB was reduced from three weeks of each four-week cycle to one week.

3.3.3 Backwash Water Sample Collection. Two backwash water samples were collected on May 23 and July 13, 2004 from the sample taps located at the backwash water effluent line from each vessel. Unfiltered samples were measured on site for pH using a field pH meter and a one-gallon sample was sent to American Analytical Laboratories (AAL) for total dissolved solids (TDS) and turbidity measurements. Filtered samples using 0.45- μm filters were sent to Battelle’s inductively coupled plasma-mass spectrometry (ICP-MS) laboratory for soluble As, Fe, and Mn analyses. Arsenic speciation was not performed for the backwash water samples.

3.3.4 Backwash Solid Sample Collection. Backwash solid samples were not collected in the initial six months of this demonstration. Two to three solid/sludge samples will be collected from the overflow discharge pond at the site. A dipper (EPA III-1) or a scoop (EPA II-3) will be used for solid sample collection. The solid/sludge samples will be collected in glass jars and submitted to TCCI Laboratories for Toxicity Characteristic Leaching Procedure (TCLP) tests.

3.3.5 Distribution System Water Sample Collection. Samples were collected from the distribution system to determine what impact the addition of the arsenic treatment system would have on the water chemistry in the distribution system, and specifically on the lead and copper level. In December 2003, prior to the startup of the treatment system, three baseline distribution system sampling events were conducted at three locations per sampling event within the distribution system. Following the installation

Table 3-3. Sample Collection Schedule and Analyses

Sample Type	Sample Locations ^(a)	No. of Samples	Frequency	Analytes	Date(s) Samples Collected
Source Water	Wellhead (IN)	1	Once during the initial site visit	As(total), particulate and soluble As, As(III), As(V), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), Na, Ca, Mg, V, Mo, Sb, Cl, SO ₄ , sulfide, F, SiO ₂ , PO ₄ , TOC, and alkalinity.	08/20/03
Treatment Plant Water (three of every four weeks)	Wellhead (IN), after chlorination (AC), after first vessel (TA), and after second vessel (TB)	4	Weekly ^(b)	On-site: pH, temperature, DO/ORP, Cl ₂ (free and total) (except at wellhead). Off-site: As (total), Fe (total), Mn (total), SiO ₂ , PO ₄ , turbidity, and alkalinity.	01/28/04, 02/04/04, 02/11/04, 02/25/04, 03/03/04, 03/10/04, 03/24/04, 03/31/04, 04/07/04, 04/30/04, 05/26/04, 06/23/04, 07/07/04
Treatment Plant Water (once every four weeks)	Wellhead (IN), after chlorination (AC), and combined effluent (TT)	3	Monthly	On-site: pH, temperature, DO/ORP, and Cl ₂ (free and total) (except at wellhead). Off-site: As(total), particulate and soluble As, As(III), As(V), Fe (total and soluble), Mn (total and soluble), sulfide, SiO ₂ , PO ₄ , turbidity, alkalinity, SO ₄ , F, NO ₃ , Ca, and Mg.	01/23/04, 02/18/04, 03/17/04, 04/14/04, 05/12/04, 06/09/04
Distribution Water	One home (an LCR sampling site) and two sample taps within the area served by Well No. 3, according to MDWCA models	3	Monthly	As, pH, alkalinity, Cu, Pb, Fe, and Mn.	Baseline sampling ^(d) : 12/08/03, 12/11/03, 12/30/03 Monthly sampling: 02/11/04, 03/10/04, 04/07/04, 05/12/04, 06/23/04
Backwash Water	Sample ports on backwash discharge line from each vessel	2	Monthly ^(c)	TDS, turbidity, pH, As (soluble), Fe (soluble), and Mn (soluble)	05/23/04 07/13/04
Residual Sludge	Overflow discharge pond	2-3	TBD	TCLP Metals	TBD

- (a) The abbreviation in each parenthesis corresponds to the sample location in Figure 4-4.
 (b) Reduced to once per every four-week cycle after April 14, 2004.
 (c) Though scheduled for monthly sampling, the frequency has been reduced to quarterly.
 (d) Three baseline sampling events were performed before the system became operational.
 TBD = to be determined.

of the arsenic adsorption system, distribution system sampling continued on a monthly basis at the same three locations.

Baseline and monthly distribution system samples were collected by the plant operator. Samples were collected at one home, which were included in the current Desert Sands MDWCA Lead and Copper Rule (LCR) sampling schedule (the home of the operator), as well as two non-LCR sampling taps, with all three locations served by the water produced from Well No. 3, as indicated by the Desert Sands MDWCA distribution system model. Analytes for the baseline samples coincided with the monthly distribution system water samples as described in Table 3-3. Arsenic speciation was not performed for the distribution water samples. The samples collected at the LCR location were taken following an instruction sheet developed according to the *Lead and Copper Rule Reporting Guidance for Public Water Systems* (EPA, 2002). Sampling at the two non-LCR locations was performed with the first sample taken at the first draw and the second sample after flushing the sample tap for several minutes. The first draw sample was collected from a cold-water faucet that had not been used for at least six hours to ensure that stagnant water was sampled. The sampler recorded the date and time of last water use before sampling and the date and time of sample collection for calculation of the stagnation time.

3.4 Sampling Logistics

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

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

3.4.2 Preparation of Sampling Coolers. All sample bottles were new and contained appropriate preservatives. Each sample bottle was taped with a pre-printed, colored-coded, and water proof label. The sample label consisted of sample identification (ID), date and time of sample collection, sampler initials, location, sent to, analysis required, and preservative. The sample ID consisted of a two-letter code for a specific water facility, the sampling date, a two-letter code for a specific sampling location, and a one-letter code for the specific analysis to be performed. The sampling locations were color-coded for easy identification. For example, red, orange, yellow, and green were used to designate sampling locations for IN, TA, TB, and TT, respectively. Pre-labeled bottles were placed in one of the plastic bags (each corresponding to a specific sampling location) in a sample cooler. When arsenic speciation samples were to be collected, an appropriate number of arsenic speciation kits also were included in the cooler.

When appropriate, the sample cooler was packed with bottles for the three distribution system sampling locations and/or the two backwash sampling locations (one for each vessel). For the distribution system sampling, each set of bottles consisted of one 1-L high-density polyethylene (HDPE) wide-mouth bottle with no preservative for pH and alkalinity analyses, and one 250-mL plastic bottle for metals analysis (As, Fe, Mn, Pb, and Cu), which was preserved with nitric acid upon receipt at the laboratory. For the backwash sampling, each set of bottles consisted of one 1-gal wide-mouth HDPE jar with no preservative used for analysis of pH, TDS, and turbidity, and one 125-mL HDPE bottle preserved with 0.625 mL of 40% ultrapure nitric acid, which was to be filled with 60 mL of a filtered sample for analysis of soluble As, Fe, and Mn.

In addition, a packet containing all sampling and shipping-related supplies, such as latex gloves, sampling instructions, chain-of-custody forms, prepaid Federal Express air bills, ice packs, and bubble wrap, also was placed in the cooler. Except for the operator's signature, the chain-of-custody forms and prepaid

Federal Express air bills had already been completed with the required information. The sample coolers were shipped via Federal Express to the facility approximately one week prior to the scheduled sampling date.

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

Samples for water quality analyses by Battelle's subcontract laboratories were packed in coolers at Battelle and picked up by a courier from either AAL (Columbus, OH) or TCCI Laboratories (New Lexington, OH). The samples for arsenic speciation analyses were stored at Battelle's ICP-MS Laboratory. 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 are described in detail in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003). Field measurements of pH, temperature, and DO/ORP were conducted by the plant operator using a WTW Multi 340i handheld meter, which was calibrated prior to use following the procedures provided in the user's manual. The plant operator collected a water sample in a 400-mL, plastic beaker and placed the Multi 340i probe in the beaker until a stable measured value was reached. The plant operator also performed free and total chlorine measurements using Hach chlorine test kits.

Laboratory quality assurance/quality control (QA/QC) of all methods followed the guidelines provided in the QAPP (Battelle, 2003). 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 80-120%, 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 and to be shared with the other 11 demonstration sites included in the Round 1 arsenic study.

4.0 RESULTS AND DISCUSSION

4.1 Facility Description

Desert Sands MDWCA has been in operation as a non-profit association under the Sanitary Projects Act since December 1978. The governing board consists of five members, and the staff members consist of an office manager (Secretary of the Association), a full-time operator, a part-time customer service clerk, and a part-time contracted operator intern. Desert Sands MDWCA serves its customers through an existing supply, storage, and distribution network that covers an area of approximately four square miles of unincorporated area in Southern Dona Ana County. The water treatment facility is located approximately 2 miles north of Anthony, NM and serves an area generally situated between Interstate 10 on the east, NM 478 on the west, O'Hara Road on the south, and Ernesto Road on the north.

According to the *40 Year Water Plan* (Desert Sands MDWCA, 2002a) prepared for the water utility, Desert Sands MDWCA currently serves 1,886 community members. It is projected that population in the Desert Sands MDWCA service area will increase by approximately 5,600 over a 40-year planning period, assuming a median growth rate of 3.5%. The water production and use have fluctuated over the past several years with the peak production occurring in 1998 at 63.5 million gallons. In 2002, total water production and use were approximately 56.1 and 51.4 million gallons, respectively. Water loss percentages ranged from 6.3 to 14.1% during 1998 through 2002, with the lowest and highest loss occurring in 2002 and 1998, respectively.

4.1.1 Existing System. The existing system consists of two production wells (Wells No. 2 and 3) with a combined capacity of 420 gpm, one 99,000-gallon and one 240,000-gallon storage tank, and approximately 30 miles of distribution piping. Figure 4-1 presents a map of the Desert Sands MDWCA delivery service area.

Prior to the installation of the STS arsenic removal system, the treatment plant consisted of Well No. 3 (located about 20 ft from the pump house), a pump house, and a drainage pond. Well No. 3 is screened from 690 to 740 ft below ground surface (bgs) with the static groundwater table is at 45 ± 1 ft bgs. The well water was filtered through an in-line sand separator (shown along with Well No. 3 on Figure 4-2) and then fed into the pump house (see piping in the pump house on Figure 4-3). A pressure of 75 pounds per square inch (psi) was maintained through the system. The maximum daily production was approximately 259,000 gallons per day (gpd) and the average daily production was 158,000 gpd.

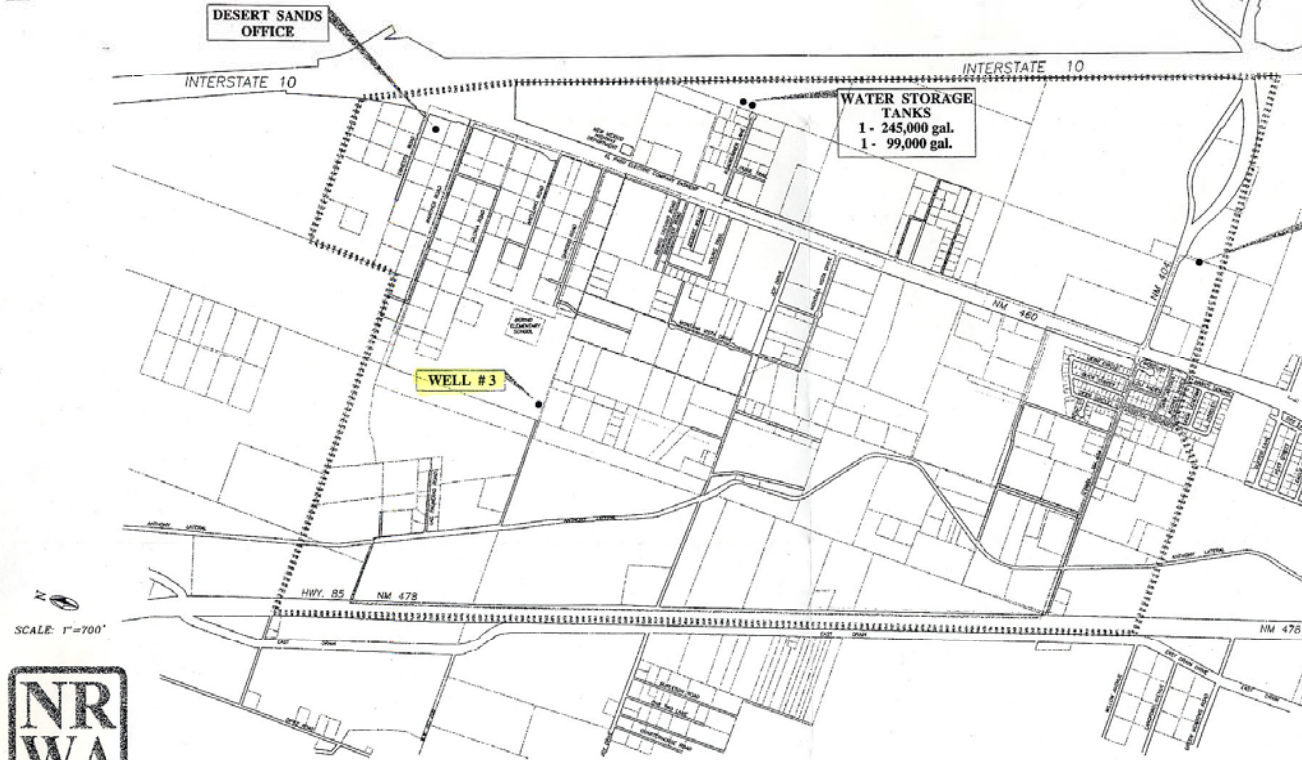
Before entering the distribution system, 0.4 to 0.5 mg/L of sodium hypochlorite (NaOCl) was added to the water using a peristaltic pump for a target chlorine residual level of 0.3 mg/L (as Cl₂). The two storage tanks are filled with excess water from the distribution system.

4.1.2 Source Water Quality. Source water samples were collected from Well No. 3 on August 20, 2003 and subsequently analyzed for the analytes shown in Table 3-3. The results of the source water analyses, along with those provided by the facility to EPA for the demonstration site selection and those independently collected and analyzed by EPA, are presented in Table 4-1.

DESERT SANDS MUTUAL DOMESTIC WATER CONSUMERS ASSOCIATION DOÑA ANA COUNTY, NEW MEXICO



PROJECT LOCATION



PROJECT COST ESTIMATES

PHASE I COST ESTIMATES	
• NEW WELL	\$ 600,000
• WATER RIGHTS ACQUISITION	\$ 000,000
• DISTRIBUTION LINES	\$ 000,000
• EQUIPMENT	\$ 000,000
TOTAL PROJECT COST:	\$ 0,000,000

PHASE II COST ESTIMATES	
• WATER STORAGE	\$ 000,000
• WATER RIGHTS ACQUISITION	\$ 000,000
• DISTRIBUTION LINES	\$ 000,000
TOTAL PROJECT COST:	\$ 0,000,000

LEGEND													
---	EXISTING 2" WATER LINE	---	EXISTING 3" WATER LINE	---	EXISTING 4" WATER LINE	---	EXISTING 6" WATER LINE	---	PROPOSED 6" WATER LINE	---	DECLARED SERVICE DELIVERY AREA	---	UNSERVED AREAS



Figure 4-1. Map of the Desert Sands MDWCA Service Area



Figure 4-2. Well No. 3 (Left) and In-Line Sand Separator (Center) Adjacent to the Pump House (Right) at the Desert Sands MDWCA Site



Figure 4-3. Piping Inside the Pump House at the Desert Sands MDWCA Site

Table 4-1. Desert Sands MDWCA Well No. 3 Water Quality Data

Parameter	Units	Utility Data	EPA Data	Battelle Data
<i>Sample Date</i>		NA	09/24/02	08/20/03
pH	–	7.6	NA	7.7
Total Alkalinity	mg/L (as CaCO ₃)	240	185	188
Hardness	mg/L (as CaCO ₃)	152	NA	84.0
Chloride	mg/L	253	161	180
Fluoride	mg/L	NA	0.5	1.0
Sulfide	mg/L	NA	NA	<0.05
Sulfate	mg/L	158	180	190
Silica	mg/L (as SiO ₂)	NA	34.6	35.1
Orthophosphate	mg/L	<0.065	0.1	<0.10
TOC	mg/L	NA	NA	1.6
As(total)	µg/L	22.0	17.0	22.7
As (total soluble)	µg/L	NA	NA	22.3
As (particulate)	µg/L	NA	NS	0.4
As(III)	µg/L	NA	NA	21.6
As(V)	µg/L	NA	NA	0.7
Total Fe	µg/L	NA	73.0	38.9
Soluble Fe	µg/L	NA	NA	<30
Total Al	µg/L	NA	<25	27.2
Soluble Al	µg/L	NA	NA	<10
Total Mn	µg/L	NA	8.9	10.0
Soluble Mn	µg/L	NA	NA	9.0
Total V	µg/L	NA	NA	0.5
Soluble V	µg/L	NA	NA	0.5
Total Mo	µg/L	NA	NA	11.6
Soluble Mo	µg/L	NA	NA	11.9
Total Sb	µg/L	NA	<25	<0.1
Soluble Sb	µg/L	NA	NA	<0.1
Total Na	mg/L	266	225	189
Total Ca	mg/L	43.0	26.3	27.2
Total Mg	mg/L	11.0	3.4	3.9

NA = not available.

Total arsenic concentrations in raw water ranged from 17.0 to 22.7 µg/L. Based on the August 20, 2003 sampling results, arsenic existed primarily as As(III) (i.e., 96.9% at 21.6 µg/L), with a small amount also present as As(V) (i.e., 0.7 µg/L) and particulate As (i.e., 0.4 µg/L). Because As(V) adsorbs better with the SORB 33™ media, it was desirable to oxidize As(III) to As(V) before adsorption.

Raw water pH values ranged from 7.6 to 7.7, which was within the STS-recommended range. Therefore, pH adjustment was not recommended.

The concentrations of iron (38.9 to 73.0 µg/L) and other ions in the raw water were sufficiently low that pretreatment prior to the adsorption process was not required. The concentrations of orthophosphate and

silica also were sufficiently low (i.e., <0.1 mg/L and <35.1 mg/L, respectively) and, therefore, were not expected to affect the As adsorption on the SORB 33™ media.

Although sulfide odor has been observed by the operator and by sampling personnel, sulfide was not detected at a detection limit of 0.05 mg/L. Additional samples were collected monthly during the demonstration study and analyzed for sulfide using a detection limit of 0.005 mg/L. The results are discussed in Section 4.5.1.

4.1.3 Distribution System. The Desert Sands MDWCA distribution system consists of a looped distribution line supplied by Wells No. 2 and No. 3. After chlorination, water from the two wells is pumped into the distribution system at two different locations, separated by approximately 2 miles. When the water production from the two wells exceeds the consumer demand, the excess flows under pressure into the two storage tanks (i.e., Tank No. 2 at 75 ft tall by 15 ft in diameter, and Tank No. 3 at 86 ft tall by 22 ft in diameter), that are connected to the distribution system by 6- and 10-inch-diameter polyvinyl chloride (PVC) pipe, respectively. The distribution system is constructed of PVC pipe, measuring approximately 30 miles in total length and varying from 2 to 10 inches in diameter. The well pumps are activated by level sensors in the storage tanks, which signal the pumps to turn on and off when the tank level reaches a pre-set low and high level, respectively.

Water from Wells No. 2 and No. 3 blends within the distribution system and the storage tanks. Desert Sands MDWCA has completed a modeling effort to examine the portions of the system served by the individual wells. The results of this modeling study were used to select distribution system sampling locations from areas that appear to be served by Well No. 3.

Desert Sands MDWCA samples water periodically from the distribution system for several analytes: once a month for bacteria; once every three years for inorganics (such as heavy metals, cyanide, and F), volatile organic compounds (VOCs), and synthetic organic compounds (SOCs); and once every four years for radionuclides. Under the LCR, samples have been collected from customer taps at 20 locations every three years, with samples most recently collected in 2000. The monitoring results for 2002 (except for the LCR results that were reported in 2000) are summarized in Table 4-2.

Table 4-2. Desert Sands MDWCA Distribution System Water Quality Data^(a)

Parameter	Units	Detected Level (range)
Arsenic (total)	µg/L	19 (10.4 to 19.3)
Barium	µg/L	52 (34.1 to 55.2)
Cadmium	µg/L	0.2 (0 to 0.2)
Chromium	µg/L	6 (3.3 to 5.5)
Copper ^(b)	µg/L	93 (2.8 to 103.5)
Nickel	µg/L	1 (0.54 to 1.2)
Lead ^(b)	µg/L	6 (0 to 6.9)
Selenium	µg/L	2 (1.1 to 1.6)
Thallium	µg/L	0.12 (0 to 0.12)

(a) Desert Sands MDWCA's Consumer Confidence Report (2002b) also includes results for the contaminants that are monitored every three years for inorganics, VOCs, and SOCs, or four years for radionuclides.

(b) Lead and copper data reported based on the result of 20 samples collected on August 29, 2000.

4.2 Treatment Process Description

The STS APU is designed for arsenic removal for small systems with flowrates greater than 100 gpm. It uses Bayoxide® E33 (branded as SORB 33™ by STS), an iron-based adsorptive media developed by Bayer AG, for the removal of arsenic from drinking water supplies. Table 4-3 presents physical and chemical properties of the media. Unlike some other iron-based media, the SORB 33™ media is delivered in a dry crystalline form and has NSF 61 approval for use in drinking water.

The STS APU system is a fixed-bed down-flow adsorption system using SORB 33™ granular ferric oxide (GFO) media for the adsorption of dissolved arsenic. When the media reaches its capacity, the spent media is removed and disposed of after being subjected to the EPA TCLP test.

STS provided an APU-300 system for the Desert Sands MDWCA site. The APU-300 system consists of two pressure vessels operating in parallel. The design features of the APU-300 system are summarized in Table 4-4, and a flow diagram along with the sampling/analysis schedule are presented in Figure 4-4. Four key process components are discussed as follows:

- **Intake and In-Line Sand Separation.** Raw water supplied from Well No. 3 passes through the in-line sand separator before it is chlorinated and fed into the APU-300 system.
- **Prechlorination.** The previously existing chlorination system, i.e., sodium hypochlorite (NaOCl) fed with a metering pump, is used for prechlorination to oxidize As(III) and hydrogen sulfide.
- **Adsorption.** The APU-300 system consists of two 63-inch-diameter, 86-inch-tall vessels configured in parallel, each containing 80 ft³ of SORB 33™ media supported by a gravel underbed. The tanks are fiberglass reinforced plastic (FRP) construction, rated for 75 psi working pressure, skid mounted, and piped to a valve rack mounted on a polyurethane coated, welded frame. Empty bed contact time (EBCT) for the system is 3.7 minutes in each vessel. Hydraulic loading to each vessel based on a design flowrate of 320 gpm is approximately 7.3 gpm/ft². Figure 4-5 shows the APU-300 system before the building enclosure was completed around it.
- **Backwash.** STS recommends that the SORB 33™ media be backwashed approximately once per month to loosen up the media bed. Automatic backwash may be initiated either by timer or by differential pressure in the vessels. Controllers for the backwash system include actuated valves for the adsorption, backwash and forward flush (fast rinse) cycles, timers, and pressure sensors. The backwash water is directly discharged into a drainage pond adjacent to the treatment facility.

4.3 System Installation

The installation of the STS APU-300 system at the site was completed in December 2003, with shakedown and startup activities continuing into January 2004. The system installation and building construction activities were carried out by the plant operator as a subcontractor to STS.

4.3.1 Permitting. Engineering plans for the system permit application were prepared by Bohannon Huston, an STS subcontractor located in Las Cruces, NM. The plans included diagrams and specifications of the APU-300 system, as well as drawings detailing the connections of the new unit to the

Table 4-3. Physical and Chemical Properties of SORB 33™ Media

<i>Physical Properties</i>	
Parameter	Values
Matrix	Iron oxide composite
Physical form	Dry granular media
Color	Amber
Bulk density (g/cm ³)	0.45
Bulk density (lb/ft ³)	28.1
BET surface area (m ² /g)	142
Attrition (%)	0.3
Moisture content (%)	<15% by weight
Particle size distribution	10 x 35 mesh
Crystal size (Å)	70
Crystal phase	α – FeOOH
<i>Chemical Analysis</i>	
Constituents	Weight %
FeOOH	90.1
CaO	0.27
SiO ₂	0.06
MgO	1.00
Na ₂ O	0.12
SO ₃	0.13
Al ₂ O ₃	0.05
MnO	0.23
TiO ₂	0.11
P ₂ O ₅	0.02
Cl	0.01

Source: STS.

Table 4-4. Design Features for the APU-300 System

Parameter	Value	Remarks
Number of adsorbers	2	–
Configuration	Parallel	–
Vessel size (inches)	63 x 86	–
Type of media	Bayoxide E33	–
Quantity of media (ft ³ /vessel)	80	Media loss has been observed
Pretreatment	NaOCl	Prechlorination
Backwash hydraulic loading (gpm/ft ²)	5-6	9-11 gpm/ft ² recommended and used by STS on site
Backwash frequency (per month)	1	Or based on a set pressure differential
Backwash duration (min/vessel)	20-25	–
Peak flow rate (gal/min)	320	–
EBCT (min)	3.7	Based on the peak flow of 320 gpm
Average use rate (gal/day)	345,600	Based on 18 hours of daily operation at 320 gpm
Estimated working capacity (BV)	132,000	Bed volumes to 10 µg/L As breakthrough
Est. gallons to breakthrough (gal)	158,400,000	1 BV = 1,200 gal (both vessels)
Estimated media life (months)	15	Based on 18 hours of daily operation (i.e., 75% utilization) at 320 gpm

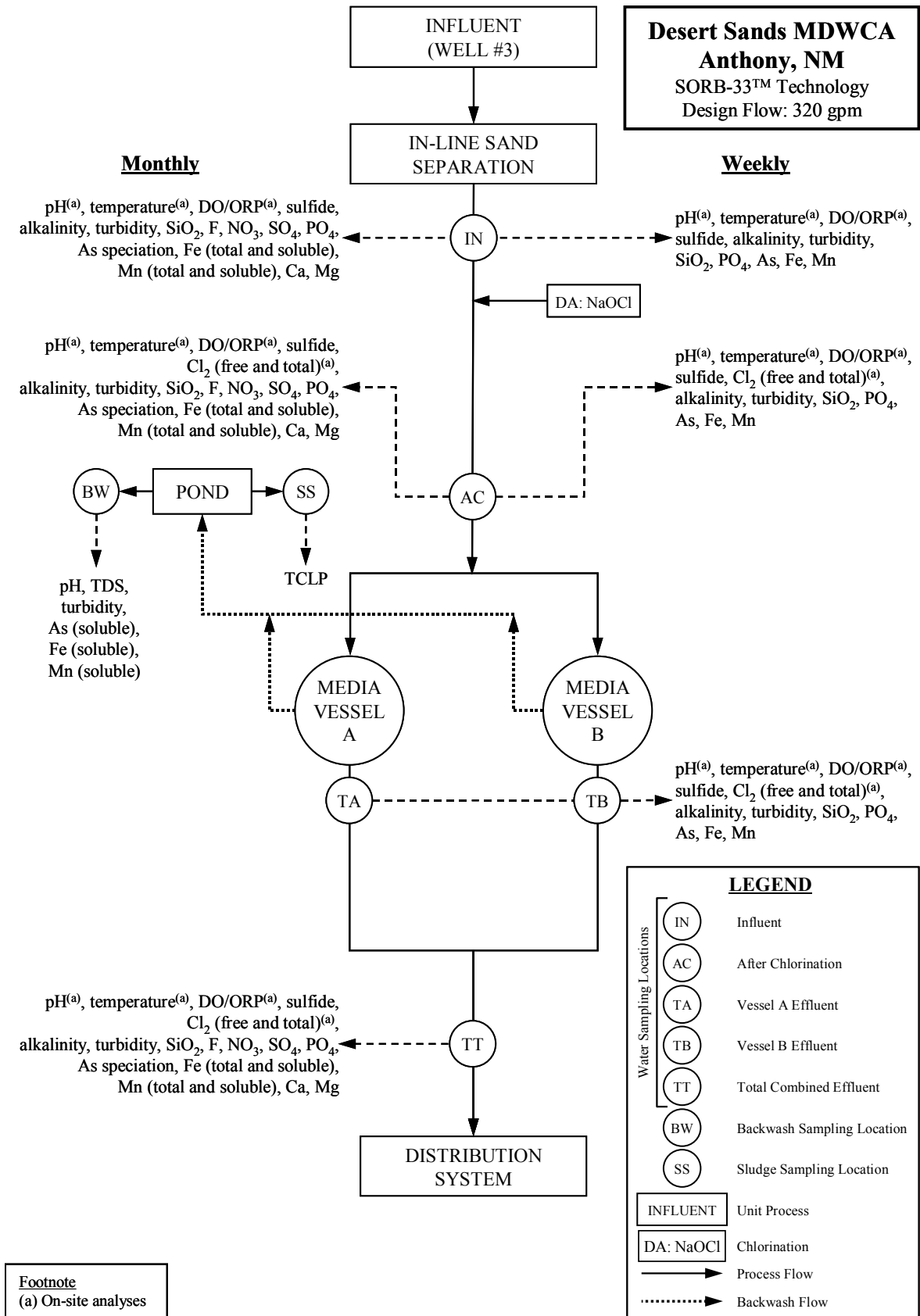


Figure 4-4. Process Flow Diagram and Sampling Locations

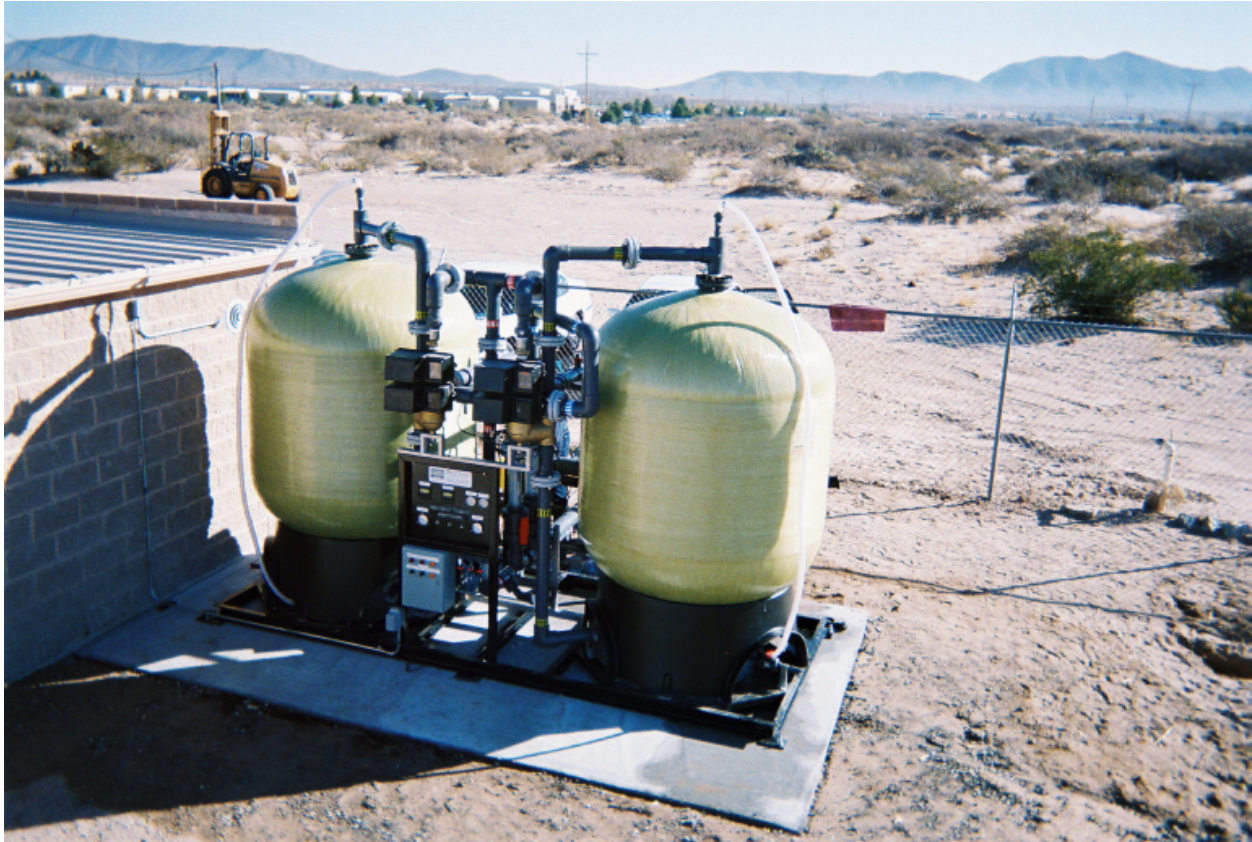


Figure 4-5. Photograph of APU-300 System at the Desert Sands MDWCA Site

existing facility. After incorporating comments from Desert Sands MDWCA and Battelle, the plans were submitted by Desert Sands MDWCA to the NMED Drinking Water Bureau for review and approval on November 18, 2003. The NMED issued a letter of approval on December 22, 2003, requiring that Desert Sands MDWCA flush and disinfect the system and associated plumbing, and retain negative results from bacteriological sampling prior to sending treated water to the distribution system.

4.3.2 Building Construction. Desert Sands MDWCA constructed an addition to its existing pump house at Well No. 3 to house the APU-300 system. The structure measures 15 ft by 15.5 ft at the base (232.5 ft²) with a total height of 12 ft, and consists of a concrete floor, a steel frame, insulated steel sidings and roofing, and a walk-through door. The structure is just large enough to house the APU-300 system and the inlet and outlet plumbing. A photograph of the new structure, adjacent to the existing block pump house, is shown in Figure 4-6.

The building construction began on October 30, 2003, as the concrete pad was poured. After the APU-300 system had been placed on the pad, the work on frame and roof began on December 23, 2003 and was completed on January 5, 2004. Installation of the siding and insulation was completed by January 23, 2004.



Figure 4-6. Pump House (on the right) and System Enclosure

4.3.3 Installation, Shakedown, and Startup. The APU-300 system was delivered to the site on December 1, 2003. The plant operator, subcontracted to STS, performed the off-loading and installation of the system, including connections to the existing entry and distribution piping. The system installation and media loading were completed and the system shakedown and startup commenced on December 11, 2003.

During system shakedown and startup, it was noticed that the system could produce no more than 40 gpm of flow in either the service or backwash mode, and that under-sized orifice plates had caused the unwanted flow restriction. The opening of the orifice plates had to be enlarged in an STS shop and repeatedly tested on-site from 0.5 to 1.5 inch (by January 8, 2004) and then to 1.875 inch (by January 15, 2004) in order to achieve the 150-gpm/vessel target flowrate in the service mode and 160 gpm/vessel in the backwash mode. Moreover, while operating at 320 gpm, the system experienced a pressure loss of 18 psi across the system, which was significantly higher than the STS specified value of <8 psi. The pressure loss across the adsorption vessels and the associated valve controllers also was elevated, exceeding the maximum valued of the differential pressure gauge readouts (i.e., 15 psi). Because of this elevated pressure loss (which was higher than the would-be set point of about 15 psi for triggering the automatic backwash), the pressure-actuated automatic backwash feature at the control panel had to be disabled to avoid the system operating in an constant backwash mode.

Under the conditions described above, the performance evaluation study officially began on January 16, 2004. Battelle provided operator training on data and sample collection and collected the first set of samples from the APU-300 system.

4.4 System Operation

4.4.1 Operational Parameters. The operational parameters of the system are tabulated and attached as Appendix A. Key parameters are summarized in Table 4-5. From January 16 through July 16, 2004, the APU-300 system operated for approximately 909 hours based on the well pump hour meter readings collected daily at the well head. The operational time represented a utilization rate of approximately 21%, or 5 hours/day, over the 26-week period. The low utilization rate experienced at

Table 4-5. Summary of APU-300 System Operation

Duration	Before System Retrofitting			After System Retrofitting		
	01/16/04 – 05/16/04 (Week 1 – Week 17)			05/24/04 – 07/16/04 (Week 19 – Week 26)		
Operating Time (hr)	493			416		
Average Daily Operating Time (hr) ^(a)	4.0 for January; 4.2 for February; 4.5 for March; 3.5 for April; 5.9 for May			5.9 for May; 7.8 for June; 8.3 for July		
	Vessel A	Vessel B	Total	Vessel A	Vessel B	Total
Throughput (kgal)	3,442	4,433	7,875	3,284	3,488	6,772
Average Flowrate (gpm)	116	150	266	132	140	271
Range of Flowrate Readings (gpm)	110–150	140–180	250–330	135–150	140–180	175–330
Average EBCT (min) ^(b)	5.2	4.0	N/A	4.5	4.3	N/A
Range of EBCTs (min) ^(b)	5.4–4.0	4.3–3.3	N/A	4.4–4.0	4.3–3.3	N/A
Pressure Loss (psi)	>20	>20	~30 ^(c)	2.75–10.0	2.5–10.0	6–12 ^(c)
Time between Two Backwash Events (hr)	22-63 (33)	22-63 (33)	N/A	48-119 (79)	48-119 (79)	N/A

(a) Overall average daily operating time was 5 hours/day.

(b) Calculated based on 80 ft³ of media per vessel. The underbedding in each vessel was 14 ft³ and the free board in Vessels A and B was 16.5 and 16.3 inches, respectively, as measured after the system retrofit.

(c) Pressure loss across the entire system.

N/A = not applicable.

Well No. 3 was due primarily to a relatively low consumer demand and the concurrent use of Well No. 2 to supply water to the distribution system. The average daily operating time for Well No. 3 increased steadily (except for April) from 4.0 hours in January to 8.3 hours in July, as it would be expected to have more water demand in the summer than in the winter.

The total system throughput during this 26-week period was approximately 14,055,000 gallons, according to the flow totalizer located in the pump house. Based on the flow totalizers installed on the adsorption vessels, however, the combined system throughput totaled 14,647,000 gallons, including 6,726,000 and 7,921,000 gallons through Vessels A and B, respectively. The imbalanced flow observed between the two vessels occurred mainly before Week 18, when the system was shut down for repair and retrofitting (see Section 4.4.2). For example, the cumulative throughputs for Vessels A and B were 3,442,000 and 4,433,000 gallons, respectively, from Weeks 1 through 17, but were 3,284,000 and 3,488,000 gallons, respectively, from Weeks 19 through 26. The increased throughput after system retrofitting was due mainly to the increased system operating time, as the system flowrate remained relatively constant throughout the six-month duration (i.e., at 266 and 271 gpm before and after retrofitting, respectively, which were 83.1 and 84.7% of the peak flowrate [see Table 4-5]). Before retrofitting, however, Vessel B received preferential flow at 150 gpm (vs. 116 gpm through Vessel A). The problems associated with the imbalanced flow were resolved with system retrofitting. Figure 4-7 presents the flowrates through Vessels A and B both before and after retrofitting.

Because of the imbalanced flow problem, the EBCT varied significantly from 3.3 to 5.4 min between the two adsorption vessels before system retrofitting. After retrofitting, EBCT varied in a much tighter range from 3.3 to 4.4 min and averaged 4.3 min for Vessel A and 4.5 min for Vessel B. (Note that EBCT was calculated based on instant flowmeter readings and that averaged EBCT was calculated based on total throughput and operating hours).

Other problems encountered during the first four months of the system operation related to pressure losses across both the adsorption vessels and the entire system. As observed during the system shakedown and startup, the differential pressure (Δp) across each vessel consistently exceeded the upper range of the factory-installed gauges (i.e., 15 psi) and that of the replacement gauges (i.e., 20 psi) (see Figure 4-8). The Δp across the entire system based on the difference between the pressure readings at the system inlet and outlet typically increased from the low- to mid-20s to more than 30 psi between two consecutive backwash events. After system retrofitting, the Δp across each vessel and the entire system was restored to as low as 2.5 and 6 psi, respectively, immediately after backwash. Similar to the imbalanced flow problems, the problems associated with the pressure losses appeared to have been resolved with system retrofitting.

As part of the effort to reduce Δp , more frequent backwash was performed during the first four months of system operation. For example, the time elapsed between two consecutive backwash events increased significantly from 22-63 hours before retrofitting to 48-119 hours after retrofitting. Note that, before retrofitting, the backwash was initiated manually (see Section 4.4.3); after retrofitting, the backwash was set at 10 psi Δp across each vessel.

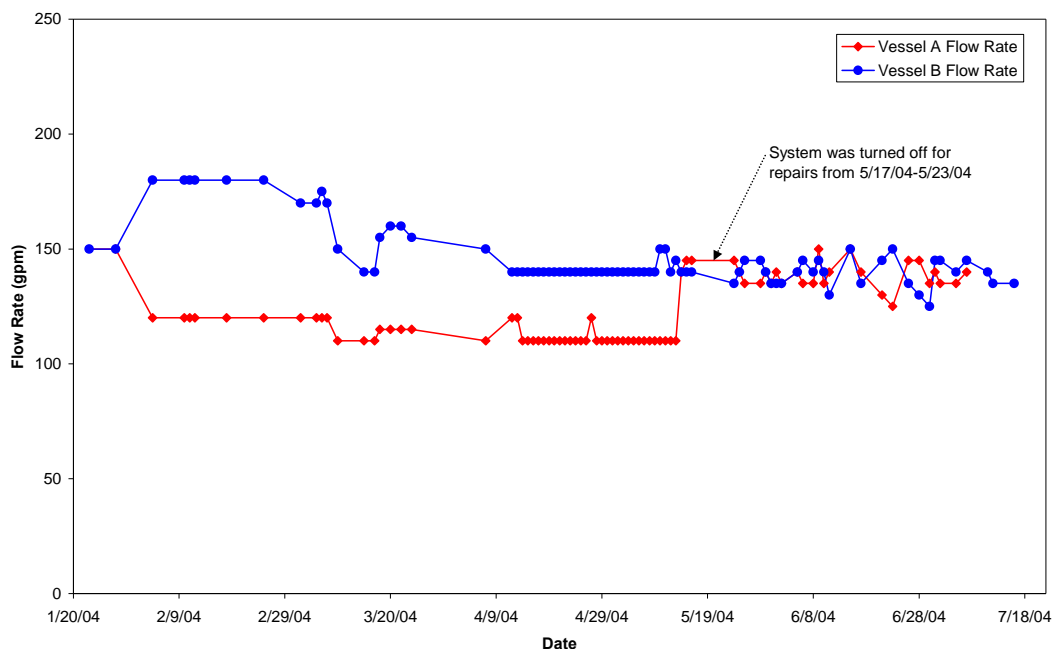


Figure 4-7. Vessels A and B Flowrates Before and After System Retrofitting

4.4.2 System Retrofit. Difficulties encountered during the first two months of system operation (including an incident that occurred on February 3, 2004 when the flow through Vessel A dropped to 40 gpm with a system inlet pressure reaching 100 psi) prompted STS to perform a series of systematic hydraulic testing at STS' Torrance, CA shop and at the Round 1 study site in Brown City, MI, where two similar APU-300 systems installed also had experienced problems related to flow restriction, imbalanced flow, and elevated pressure losses. Before reaching the decision to perform the hydraulic testing, STS initially suggested that the problems encountered might have been caused by damaged media (media crushed by zero to 300 gpm flow swings after flow restrictors had been temporarily removed from the system to troubleshoot the flow restriction problem during the initial startup), insufficient backwash

flowrates (due to the presence of restrictor plates in the valve controllers), and clogged top distributors and/or bottom laterals. As part of its investigative work, STS performed a more aggressive backwash and collected media samples for a sieve analysis on February 19 and 26, 2004, and, on March 8, 2004, installed a 3-inch-diameter bypass line around the valve controller on each vessel with the intent to decrease the pressure loss and increase backwash flowrate. These efforts, however, did not help resolve the problems, and the results of the particle size distribution analysis did not appear to support the speculation regarding the media damage. These results led STS to focus its investigative work on the system plumbing design and construction thereafter.

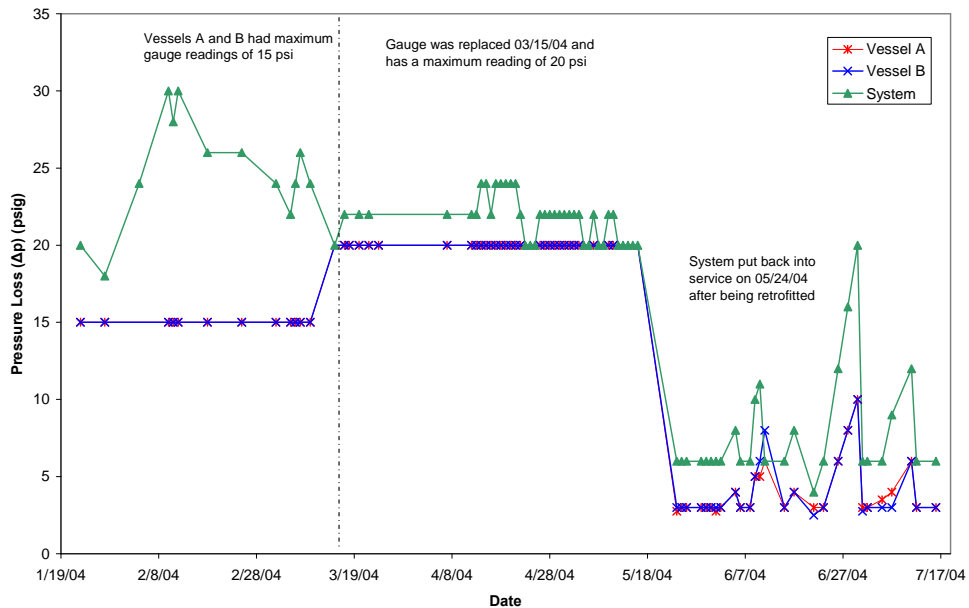


Figure 4-8. Pressure Losses (Δp) across Each Vessel and the System over Time

Systematic hydraulic testing on the two APU-300 systems installed at Brown City, MI, was conducted on March 19, 2004 with no media loaded in the vessels. While operating the system at 103 to 115 gpm (vs. a design flowrate of 160 gpm/vessel), a pressure loss of 7 to 8 psi was observed across each empty vessel, and 24 to 26 psi across the entire system. These results suggested that the system plumbing most likely was the source of the high pressure losses, and that the media mostly likely was not responsible for the difficulties encountered at the Desert Sands MDWCA site. Replacement of the restrictive orifices from 1.25 to 1.875 inch (as was used for the Desert Sands MDWCA system) did not solve the elevated pressure loss problems. Additional hydraulic testing was conducted at Brown City, MI and STS' Torrance, CA facility in mid-April 2004. Table 4-6 summarizes the hydraulic test results collected at Brown City, MI, Torrance, CA, and Anthony, NM.

Pressure profile data were collected across major components of the system at Brown City, MI and a similar APU-300 system at STS' Torrance, CA facility. As listed in Table 4-6 and shown in Figure 4-9, the major system components across each treatment train included a piping inlet, an automatic variable diaphragm valve (to control flow), a strainer, a programmable Fleck valve controller (to control flow from a service to backwash mode), an FRP vessel with top diffuser and bottom laterals, a restrictive orifice, and an outlet. Pressure gauges were across the treatment train so that a complete pressure profile might be established.

Table 4-6. Results of Hydraulic Testing of STS APU-300 Systems

Site	Date	Vessel	Flowrate (gpm)	Pressure (psi)						ΔP (psi)		System Components								
				P1	P2	P3	P4	P5	P6	Vessel ^(a)	System	Variable Diaphragm Valve	Valve Controller	Strainer	Vessel				Restrictive Orifice	
															Top Diffuser	Media	Underbedding	Bottom Laterals		
<i>Before System Retrofitting</i>																				
Desert Sands MDWCA, NM	02/10/04	A	120	84					54	>15	30	✓	✓	✓	✓	✓	✓	✓	✓	
		B	180	84					54	>15	30	✓	✓	✓	✓	✓	✓	✓	✓	✓
Brown City, MI	03/19/04	A (unit 1)	115	82					58	7	24	✓	✓	✓	✓			✓	✓	
		B (unit 1)	113	82					58	8	24	✓	✓	✓	✓			✓	✓	
		A (unit 2)	105	84					58	8	26	✓	✓	✓	✓			✓	✓	
		B (unit 2)	113	84					58	8	26	✓	✓	✓	✓			✓	✓	
	04/06/04	A	160	80	71	61			58	58	13	22	✓	✓					✓	
		B	160	80	71				58	58	13	22	✓	✓					✓	
Torrance, CA	04/08/04	A	150	44	43	34	33	30	30	13	14	✓	✓	✓	✓			✓		
		B	150	44							13	14	✓	✓	✓	✓			✓	
	04/14/04	A	158	64	64	54	53	50		14	NA	✓	✓	✓	✓			✓	✓	
<i>After System Retrofitting</i>																				
Torrance, CA	04/20/04	A	165	23		22	19		19	3	4								✓	
		B	165	52		51	50		50	1	2								✓	
		A	170	34		33	30		30	3	4								✓	
		B	155	34		34	33		30	1	4								✓	
Brown City, MI	04/29/04	A	190	62					58	0	4								✓	
		B	190	62					58	0	4								✓	
Desert Sands MDWCA, NM	05/24/04	A	140	66					60	3	6			✓	✓	✓	✓	✓	✓	
		B	135	66					60	3	6			✓	✓	✓	✓	✓	✓	

P1 = at system inlet.
 P2 = after variable diaphragm valve and before entering strainer, valve controller, and vessel.
 P3 = at top of vessel.
 P4 = at bottom of vessel.
 P5 = after vessel and valve controller and before entering restrictive orifice (if present).
 P6 = at system outlet.

ΔP across vessel (including valve controller) = P2 – P5.
 ΔP across vessel = P3 – P4 (after retrofitting).
 ΔP across system (treatment train) = P1 – P6.
 (a) Including valve controller before system retrofitting.

Note that Δp across the vessel as measured at Desert Sands MDWCA included the pressure loss across the strainer, valve controller, and vessel, which was equipped with a top diffuser and bottom laterals and loaded with 14 ft³ of underbedding and 80 ft³ of media.

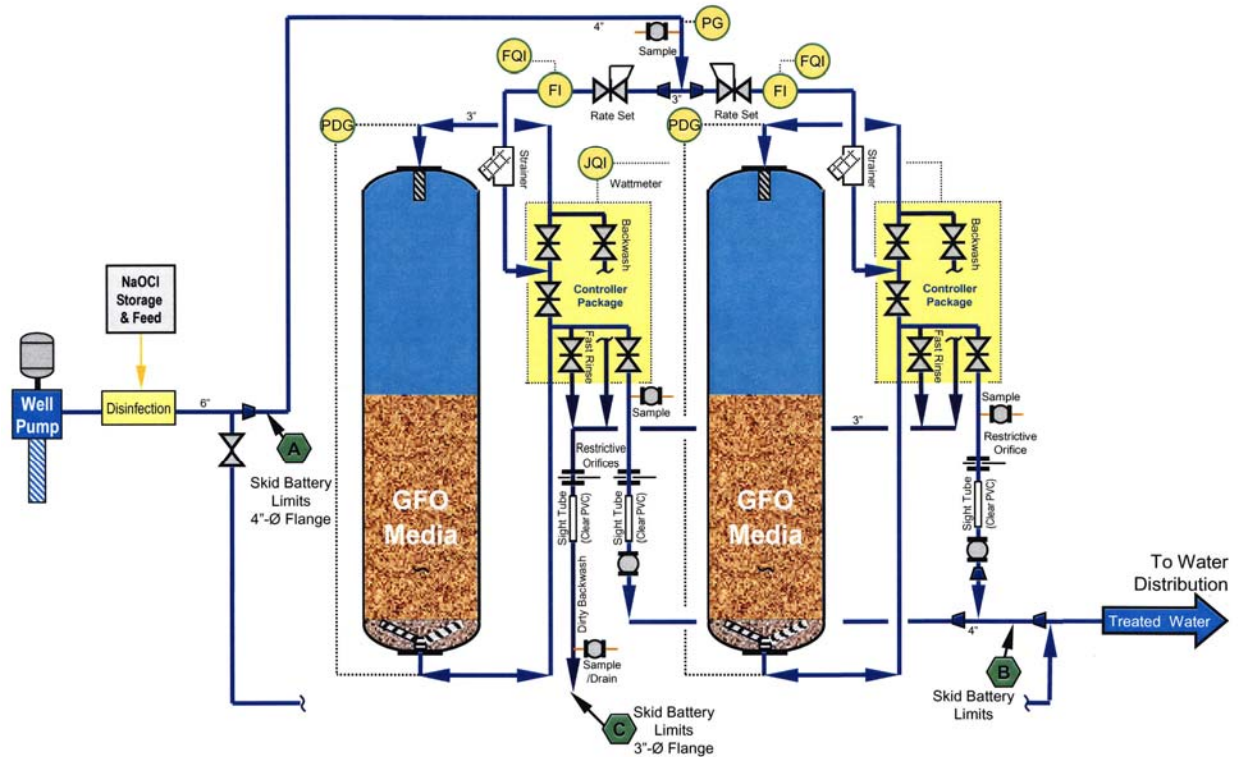


Figure 4-9. Schematic Diagram of STS APU-300 System as Installed at Desert Sands MDWCA in December 2003

The results of the Brown City testing on April 6, 2004 showed that, after removing the restrictive orifice, strainer, and top diffuser, pressure losses were observed across the variable diaphragm valve (from 80 to 71 psi) and valve controller and bottom laterals (from 61 to 58 psi). These results were consistent with those observed during the April 8, 2004 testing at Torrance, CA, except for the 1-psi loss (from 44 to 43 psi) across the variable diaphragm valve. It was not clear what had caused the 11 psi loss across the variable diaphragm valve at Brown City; one possible explanation was that the valve was partially throttled during the testing. The pressure loss across the valve controller, strainer, top diffuser, and bottom laterals at Torrance, CA was 13 psi (from 43 to 30 psi), identical to that found at Brown City, MI. Furthermore, the pressure loss across top diffuser and bottom laterals was 1 psi (from 34 to 33 psi), indicating little or no loss across these system components.

The test results at Brown City, MI and Torrance, CA were further confirmed during a separate test in Torrance, CA on April 14, 2004, which showed no loss across the variable diaphragm valve, 1 psi loss (from 54 to 53 psi) across top diffuser and bottom lateral, 13 psi loss (from 64 to 50 psi and less 1 psi across the top diffuser and bottom laterals) across the valve controller, and possibly 20 psi across the restrictive orifice (see the 20 psi increase at the inlet after restrictive orifice was restored to the system in Table 4-6). It was therefore evident that the main sources of the pressure loss came from the valve controller and restrictive orifice.

Upon completion of the hydraulic testing, STS recommended four options to address the problems at Desert Sands MDWCA (and Brown City):

1. Replace the submersible pump by the host site,
2. Install a booster pump,
3. Run the existing submersible pump for longer periods each day, or
4. Retrofit the STS system.

After reviewing the merits of each option, STS decided to retrofit the STS systems at both the Desert Sands MDWCA, NM and Brown City, MI sites. The changes included replacement of the 3-inch-diameter pipe with 4-inch-diameter pipe; removal of the diaphragm valves, restrictive orifices, and valve controllers; and installation of a nested system of fully-ported actuated butterfly valves and a new control panel. A schematic diagram of the new system design is presented in Figure 4-10.

The test results collected at Torrance, CA, Brown City, MI, and Desert Sands MDWCA, NM after the system retrofit are presented in Table 4-6. With the Torrance, CA and Brown City, MI systems operating at 155 to 190 gpm without media or underbedding loaded in the vessels, the pressure losses across the vessel (along with bottom laterals) and the system were 0-3 and 2-4 psi, respectively. The system was returned to service on May 24, 2004 with the modified pipe design, a new upper distributor, and new control panel in place. STS measured the freeboard as the new upper distributors were being installed, observing between 16.25 and 16.5 inches of freeboard in each vessel. Startup testing of the retrofitted unit showed a pressure loss across the media-filled vessels of 3 psi, and a total pressure loss across the system of 6 psi.

4.4.3 Backwash. STS recommended the SORB 33™ media be backwashed manually or automatically approximately once per month to loosen up the media bed. Automatic backwash could be initiated either by timer or by differential pressure in the vessels. The system was backwashed 15 times during the first 17 weeks of operation leading up to the mid-May retrofit. The backwash was performed automatically five times from May 24 through the end of the first six months of system operation. Before retrofitting, the time elapsed between two backwash events ranged from 22 to 63 hours, averaging 33 hours. The interval between backwash events was much longer after retrofitting, ranging from 48 to 119 hours of operating time, with an average of 79 hours.

The backwash was performed at approximately 200 gpm, or 9 gpm/ft², as set by STS on May 24 using the manual valve on the backwash discharge line. Each backwash event lasted for 20 minutes, followed by a four-minute rinse, producing approximately 4,800 gallons of water per vessel during each backwash event. Due to the cycles of consumer demand, automated backwash events typically occurred overnight, when the operator was not present. The vessels will be backwashed manually for selected events during the remaining six months of the demonstration to facilitate backwash water sampling and improved observation of the backwash events.

4.4.4 Residual Management. Residuals produced by the operation of the APU-300 system include spent media and backwash water. The media was not exhausted during the first six months of system operation; therefore, the only residual produced was backwash wastewater. Above ground piping for backwash water from both vessels is combined before extending outside the building below the base of the wall. Backwash water flows from the pipe into the pond, where it either evaporates or infiltrates. Any particulates carried in the backwash water remain in the pond.

4.4.5 System Operation Reliability and Simplicity. The overall system reliability and simplicity was examined both before and after retrofitting of the system in May 2004. Aside from the excessive pressure losses and imbalance flow prior to the system retrofit, the only other O&M issue encountered

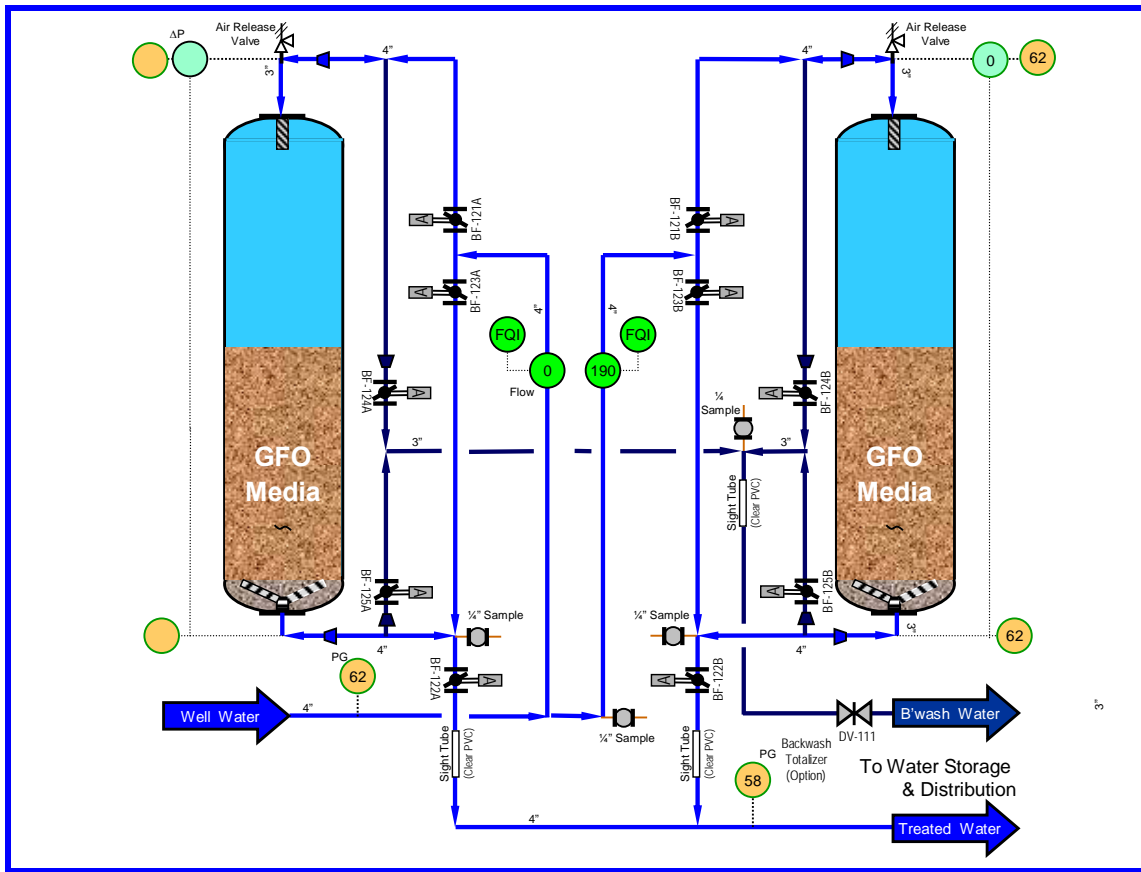


Figure 4-10. Schematic Diagram of STS APU-300 System after System Retrofitting in May 2004

was the temporary failure of the digital flow meters on the vessels on two separate occasions for one to two days at a time.

Unscheduled downtime during the first six months of system operation was caused by the need to address elevated pressure losses and imbalanced flows, as discussed above. The system was shut down on February 19 for a system inspection, February 26 for media sampling, March 8 for the installation of a bypass line around the valve controller, and May 16 through 24 for system retrofitting. Neither scheduled nor unscheduled downtime has been required since the completion of the system retrofit.

The simplicity of system operation and operator skill requirements are discussed according pre- and post treatment requirements, levels of system automation, operator skill requirements, preventative maintenance activities, and frequency of chemical/media handling and inventory requirements.

Pre- and Post-Treatment Requirements. Pre-treatment at the site consisted of the injection of sodium hypochlorite upstream of the system for oxidation of sulfide and As(III) to As(V). The prechlorination system was already in place to provide chlorine residuals in water before entering the distribution system. Vigilant oversight of the prechlorination system was necessary to ensure that the residual chlorine levels were maintained properly. Post-treatment was not required at this site.

System Automation. The backwash cycle was controlled automatically, triggered by the differential pressure across each vessel. Since the retrofit, the system was backwashed automatically on five

occasions, with the interval between backwash events reaching approximately 14 days and the amount of water treated reaching approximately 2,000,000 gallons.

Although backwash of the vessels was triggered automatically, on some occasions only one vessel reached the trigger level. In this situation, the one vessel that was backwashed subsequently was able to receive water at a higher flowrate, producing an imbalanced flow. When this occurred, the operator initiated a manual backwash on the second vessel, returning the system to a balanced flow. All other functions of the APU-300 system were automated.

Operator Skill Requirements. Under normal operating conditions, the skill requirements to operate the APU-300 system were minimal. The daily demand on the operator was 15 minutes to allow the operator to visually inspect the system and record the operating parameters on the log sheets. The operation of the system did not appear to require additional skills beyond those necessary to operate the existing production equipment. Based on the size of the population served and the treatment technology, the State of New Mexico requires Level 2 Certification for system operation.

Preventative Maintenance Activities. Preventative maintenance tasks recommended by STS included monthly inspection of the control panel, quarterly checking and calibration of the flow meters, biannual inspection of the actuator housings, fuses, relays, and pressure gauges, and annual inspection of the butterfly valves. STS recommended checking the actuators at each backwash event to ensure that the valves were opening and closing in the proper sequence. Further, inspection of the adsorber laterals and replacement of the underbedding gravel was recommended to be performed concurrent with the media replacement. During this reporting period, the operator inspected the valves and wiring monthly, which consumed approximately 15 minutes/month. The operator also compared the flow meter and totalizer data from the STS system to his existing meters on a consistent basis, which did not require any appreciable time expenditure.

Chemical/Media Handling and Inventory Requirements. Chemical use was not required beyond the prechlorination system already in place. At the current water production rate, Desert Sands MDWCA orders one 53-gallon drum of sodium hypochlorite per month. The plant operator switched the metering pump inlet tube from the empty drum to the new drum when necessary.

4.5 System Performance

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

4.5.1 Treatment Plant Sampling. Water samples were collected at five locations through the treatment train: the inlet (IN), after prechlorination (AC), at the effluent of Vessels A and B (TA and TB, respectively), and at the combined effluent (TT). Field-speciated samples at IN, AC, and TT were collected once every four weeks throughout this reporting period. Table 4-7 summarizes the arsenic, iron, and manganese analytical results. Table 4-8 summarizes the results of other water quality parameters. Appendix B contains a complete set of analytical results through the first six months of system operation. The results of the water samples collected throughout the treatment plant are discussed below.

Arsenic. The key parameter for evaluating the effectiveness of the APU-300 system was the concentration of arsenic in the treated water. The treatment plant water was sampled on 19 occasions during the first six months of system operation, with field speciation performed on seven of the 19 occasions. Samples were collected at the IN and AC sample ports at each of the 19 sampling events. TA and TB were sampled 12 times, and TT was sampled seven times.

Table 4-7. Summary of Arsenic, Iron, and Manganese Analytical Results

Parameter	Sampling Location	Units	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
As (total)	IN	µg/L	20	20.7	30.1	25.3	2.7
	AC	µg/L	20	21.2	30.1	25.6	2.7
	TA	µg/L	13	1.4	2.4	1.9	0.3
	TB	µg/L	13	1.4	2.8	1.9	0.4
	TT	µg/L	7	0.9	3.0	1.8	0.8
As(total soluble)	IN	µg/L	7	21.9	24.8	23.1	1.0
	AC	µg/L	7	20.3	24.7	22.8	1.4
	TT	µg/L	7	0.8	2.8	1.7	0.7
As (particulate)	IN	µg/L	7	0.1	4.7	2.7	1.5
	AC	µg/L	7	0.2	5.1	3.2	2.0
	TT	µg/L	7	0.1	0.2	0.2	0.1
As(III)	IN	µg/L	7	17.6	22.8	21.1	1.7
	AC	µg/L	6	0.5	1.1	0.9	0.2
	TT	µg/L	7	0.3	1.8	1.0	0.5
As(V)	IN	µg/L	7	0.5	5.6	1.9	1.8
	AC	µg/L	6	19.4	23.6	21.8	1.4
	TT	µg/L	7	0.3	1.6	0.8	0.5
Total Fe	IN	µg/L	20	<25	106	49	25
	AC	µg/L	20	<25	112	43	26
	TA	µg/L	13	<25	46	18	12
	TB	µg/L	13	<25	41	16	10
	TT	µg/L	7	<25	<25	<25	0.0
Dissolved Fe	IN	µg/L	7	<25	43	17	11.5
	AC	µg/L	7	<25	<25	<25	0.0
	TT	µg/L	7	<25	<25	<25	0.0
Total Mn	IN	µg/L	20	7.0	11.0	9.0	0.9
	AC	µg/L	20	7.1	10.3	8.6	0.9
	TA	µg/L	13	<0.1	0.5	0.2	0.1
	TB	µg/L	13	<0.1	0.5	0.2	0.1
	TT	µg/L	7	<0.1	0.8	0.3	0.3
Dissolved Mn	IN	µg/L	7	7.1	10.5	8.6	1.1
	AC	µg/L	7	5.3	9.2	6.6	1.5
	TT	µg/L	7	<0.1	0.50	0.2	0.2

One-half of the detection limit was used for nondetect samples for calculations.

Duplicate samples were included in the calculations.

Table 4-8. Summary of Water Quality Parameter Measurements

Parameter	Sampling Location	Units	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
Alkalinity	IN	mg/L	20	164	226	187	13
	AC	mg/L	20	170	197	183	8
	TA	mg/L	13	169	199	184	8
	TB	mg/L	13	169	194	182	7
	TT	mg/L	7	173	189	182	6
Fluoride	IN	mg/L	7	0.5	0.7	0.6	0.1
	AC	mg/L	7	0.5	0.7	0.6	0.1
	TT	mg/L	7	0.5	0.7	0.6	0.1
Sulfate	IN	mg/L	7	170	190	184	8
	AC	mg/L	7	170	190	181	9
	TT	mg/L	7	180	190	184	5
Orthophosphate (as PO ₄)	IN	mg/L	19	<0.10	0.20	0.06	0.03
	AC	mg/L	19	<0.10	0.18	0.06	0.03
	TA	mg/L	12	<0.10	<0.10	<0.10	0.00
	TB	mg/L	12	<0.10	<0.10	<0.10	0.00
	TT	mg/L	7	<0.10	0.15	0.06	0.04
Silica	IN	mg/L	20	36.4	41.8	38.3	1.3
	AC	mg/L	20	36.4	41.7	38.2	1.3
	TA	mg/L	13	35.3	39.9	37.7	1.3
	TB	mg/L	13	36.3	40.0	38.0	1.1
	TT	mg/L	7	37.2	38.6	37.8	0.5
Sulfide	IN	µg/L	12	<5.0	5.7	3.2	1.3
Nitrate (as N)	IN	mg/L	7	<0.05	0.1	0.04	0.03
	AC	mg/L	7	<0.05	0.1	0.04	0.03
	TT	mg/L	7	<0.05	0.1	0.04	0.03
Turbidity	IN	NTU	19	0.2	3.5	1.0	1.0
	AC	NTU	19	0.1	1.5	0.5	0.4
	TA	NTU	12	0.1	0.7	0.3	0.2
	TB	NTU	12	0.1	0.8	0.3	0.2
	TT	NTU	7	<0.1	0.7	0.3	0.2
pH	IN	S.U.	18	7.6	8.1	7.9	0.1
	AC	S.U.	18	7.7	8.0	7.9	0.1
	TA	S.U.	10	7.7	8.0	7.9	0.1
	TB	S.U.	10	7.7	7.9	7.8	0.1
	TT	S.U.	7	7.6	8.0	7.8	0.1
Temperature	IN	°C	18	28.4	31.6	30.2	0.8
	AC	°C	18	28.8	31.5	30.3	0.8
	TA	°C	10	28.9	31.2	30.3	0.8
	TB	°C	10	29.0	31.1	30.3	0.7
	TT	°C	7	29.5	31.6	30.5	0.8
Dissolved Oxygen	IN	mg/L	18	1.0	1.9	1.3	0.3
	AC	mg/L	18	1.1	2.0	1.4	0.3
	TA	mg/L	10	1.1	2.0	1.4	0.3

Table 4-8. Summary of Water Quality Parameter Measurements (Continued)

Parameter	Sampling Location	Units	Number of Samples	Minimum Concentration	Maximum Concentration	Average Concentration	Standard Deviation
Dissolved Oxygen (Cont.)	TB	mg/L	10	1.1	1.9	1.4	0.3
	TT	mg/L	7	1.3	2.3	1.5	0.4
ORP	IN	mV	7	42	81	57	13
	AC	mV	7	486	550	518	26
	TA	mV	3	503	531	518	14
	TB	mV	3	510	528	521	10
	TT	mV	4	495	561	525	31
Free Cl ₂	AC	mg/L	15	0.3	0.5	0.4	0.1
	TA	mg/L	9	0.3	0.5	0.4	0.1
	TB	mg/L	8	0.3	0.5	0.4	0.1
	TT	mg/L	7	0.3	0.5	0.4	0.1
Total Cl ₂	AC	mg/L	13	0.4	0.6	0.5	0.1
	TA	mg/L	7	0.5	0.6	0.5	0.1
	TB	mg/L	6	0.5	0.6	0.5	0.0
	TT	mg/L	6	0.5	0.6	0.5	0.0
Total Hardness (as CaCO ₃)	IN	mg/L	7	78.4	101.1	86.5	7.8
	AC	mg/L	7	79.2	111.1	88.0	10.9
	TT	mg/L	7	74.5	110.1	86.8	11.3

One-half of the detection limit was used for nondetect samples for calculations.

Duplicate samples are included the calculations.

Figure 4-11 contains three bar charts showing the concentrations of total As, particulate As, As(III), and As(V) at the IN, AC, and TT locations for each sampling event. Total arsenic concentrations in raw water ranged from 20.7 to 30.1 µg/L and averaged 25.3 µg/L (Table 4-7). As(III) was the predominating species, ranging from 17.7 to 22.8 µg/L and averaging 21.1 µg/L. Only trace amounts of particulate As and As(V) existed, with concentrations averaged 2.7 and 1.9 µg/L, respectively. The arsenic concentrations measured during this six-month period were consistent with those in the raw water sample collected on August 20, 2003 (Table 4-1).

The prechlorination step oxidized As(III) to As(V) and provided required chlorine residuals to the distribution system. Samples collected downstream of the chlorine addition point (AC) had average As(III) and As(V) concentrations of 0.9 and 21.8 µg/L, respectively. As (III) concentrations after prechlorination remained consistently low (ranging from 0.5 to 1.1 µg/L), indicating complete oxidation. Analytical results for As(III) and As(V) were not available for the June 9, 2004 sample, so the data from that date showed only the soluble and particulate concentrations (Figure 4-11).

Free and total chlorine was monitored at the AC, TA, TB, and TT sampling locations to ensure that the target chlorine residual level was properly maintained. Typically, free chlorine was measured at 0.3 to 0.5 mg/L at the AC location, with total chlorine levels ranging from 0.4 to 0.6 mg/L (Table 4-7). The residual chlorine measured at the TA, TB, and TT locations was nearly identical to that measured at the AC location, indicating little or no chlorine consumption through the SORB 33™ vessels.

Total As concentrations in the combined effluent (TT) ranged from 0.9 to 3.0 µg/L and averaged 1.8 µg/L (Table 4-7). The average particulate As, As(III), and As(V) concentrations in the combined effluent were 0.2, 1.0, and 0.8 µg/L, respectively. The average As(III) concentration of 1.0 µg/L at the TT location

indicated that little or no As(III) removal by the SORB 33™ media (Figure 4-11). The total As and As(V) concentrations in the treated water increased slightly during the two most recent sampling events, after remaining at or below 1.6 µg/L for the first five sampling events. The total As concentrations at the TT location will be monitored throughout the next reporting period to determine if the recent increase was the beginning of a trend or simply a temporary spike. By the end of the first six months of system operation, the APU-300 system treated approximately 14,647,000 gallons of water, equivalent to 12,206 bed volumes during this reporting period, approximately 9% of the STS estimated working capacity for this media (132,000 bed volumes), as shown in Table 4-4.

The results of the total arsenic analyses at each sampling location throughout the first six months of system operation are plotted against the bed volumes of treated water in Figure 4-12. The plots clearly demonstrated the similarity in total arsenic concentrations at the IN and AC ports, and significant decreases in concentrations at the outlet of each vessel (TA and TB) and the combined outlet (TT). The plot also showed that the samples at the effluent of each vessel were very similar, even though the imbalanced flow problems had caused some variation in EBCT before system retrofitting. The difference in the TA and TB plots could be explained by the imbalanced flow and the difference in the number of bed volumes treated by each vessel. Thus far, the STS APU-300 has removed arsenic from the influent water to levels well below the 10 µg/L MCL.

Iron. Total iron concentrations varied from <25 to 112 µg/L (Table 4-7) with nearly all of the concentrations at the TA, TB, and TT locations being <25 µg/L. Dissolved iron concentrations were <25 µg/L for all samples with the exception of the IN sample on July 7, 2004 at 43 µg/L. These data indicate that the majority of the total iron entering the system was in particulate form, and that the iron particles were captured by the media beds.

Manganese. The treatment plant water samples were analyzed for total Mn for all sampling events, but also for soluble Mn during speciation week sampling. The total Mn concentrations at the various sampling locations are plotted over time in Figure 4-13. The total and soluble Mn concentrations are shown in Figure 4-14. Influent total Mn levels ranged from 7.0 to 11.0 µg/L (Table 4-7), with the majority being soluble Mn(II). After prechlorination, about 27% (in average) of the Mn(II) was oxidized to form particulate Mn and the rest remained in the soluble form, indicating incomplete oxidation of Mn(II). This was consistent with previous findings that free chlorine was relatively ineffective to oxidize Mn(II) unless the solution pH value was above 8.0 to 8.5 (Knocke et al., 1987 and 1990). However, total Mn concentrations at the TA, TB, and TT locations were reduced to <0.1 to 0.8 µg/L, indicating removal of Mn by the SORB 33™ media. Knocke et al. (1990) reported that the presence of free chlorine in the filter promoted Mn(II) removal on MnO_x-coated media; and that in the absence of free chlorine, Mn(II) removal was by adsorption only. Unlike the MnO_x-coated media, SORB 33™ media could not remove Mn(II) via adsorption in the absence of free chlorine, based on the data collected from the Rollinsford demonstration site. Therefore, Mn(II) was likely removed via an oxidation/filtration mechanism on the SORB 33™ media surface where free chlorine existed.

Other Water Quality Parameters. In addition to arsenic analyses, other water quality parameters were analyzed to provide insight into the chemical processes occurring within the treatment system. The results of the water quality parameters are included in Appendix B, and are summarized in Table 4-8.

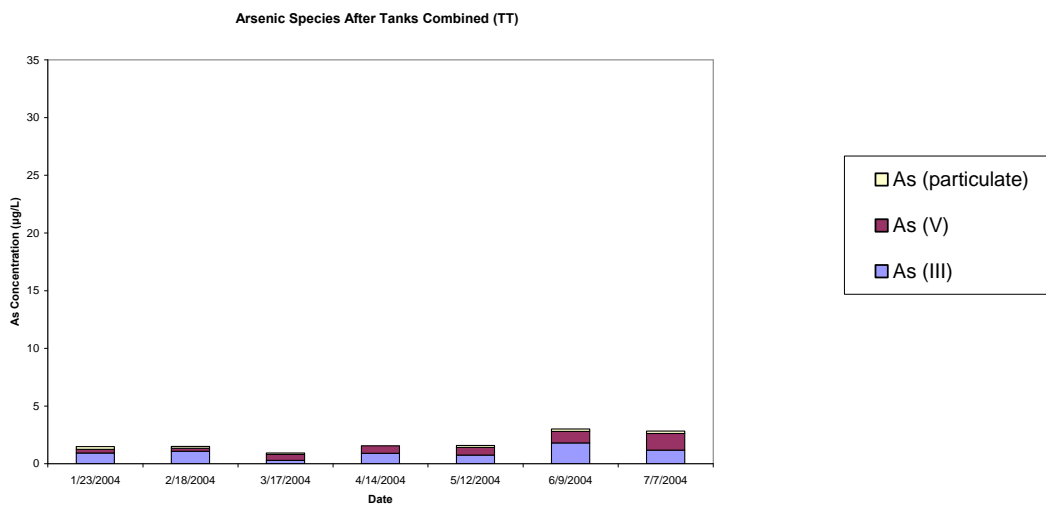
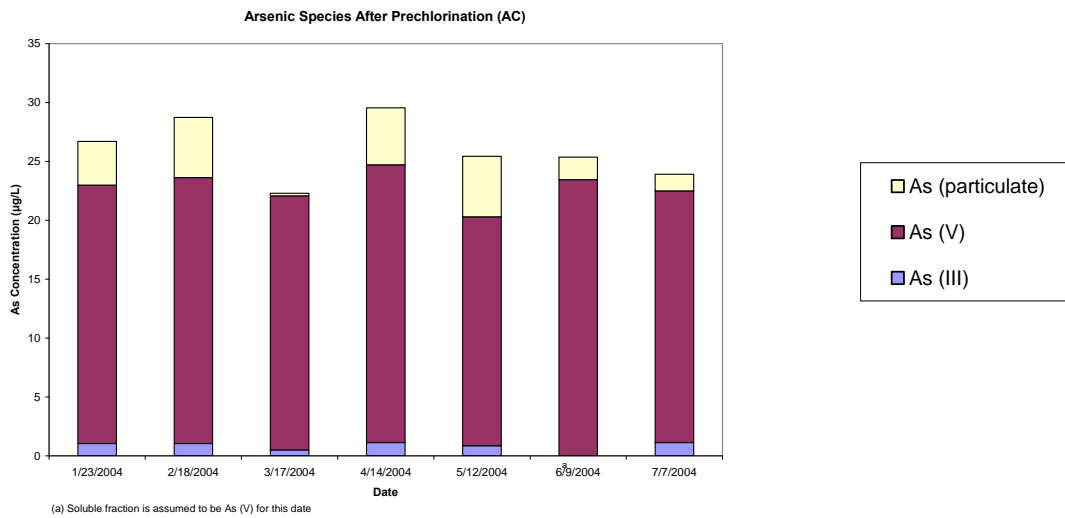
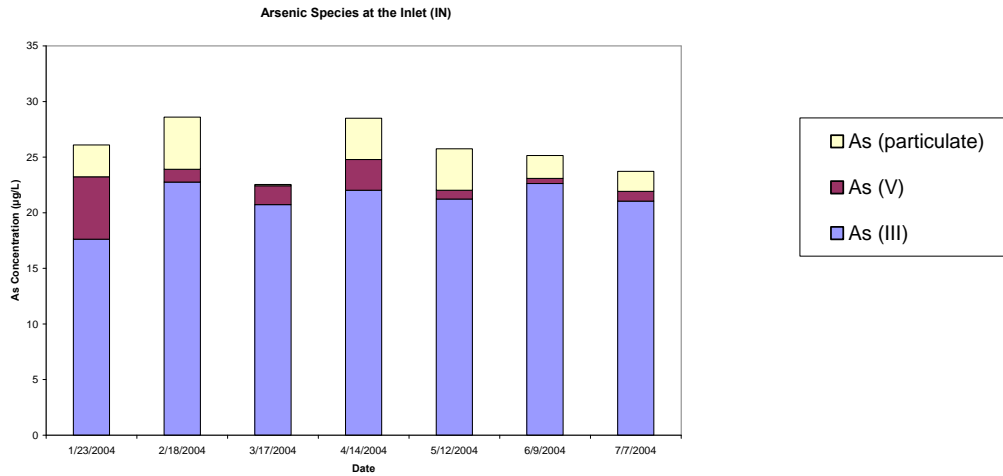


Figure 4-11. Concentration of Arsenic Species in the Influent, After Prechlorination, and in the Combined System Effluent

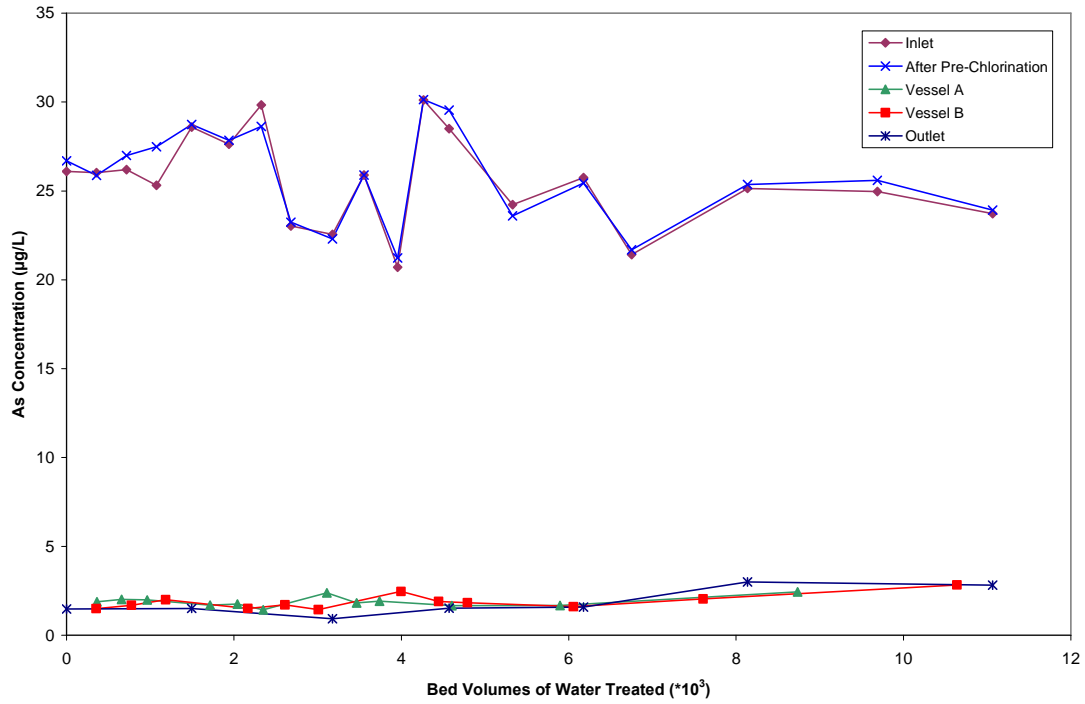


Figure 4-12. Total Arsenic Breakthrough Curve

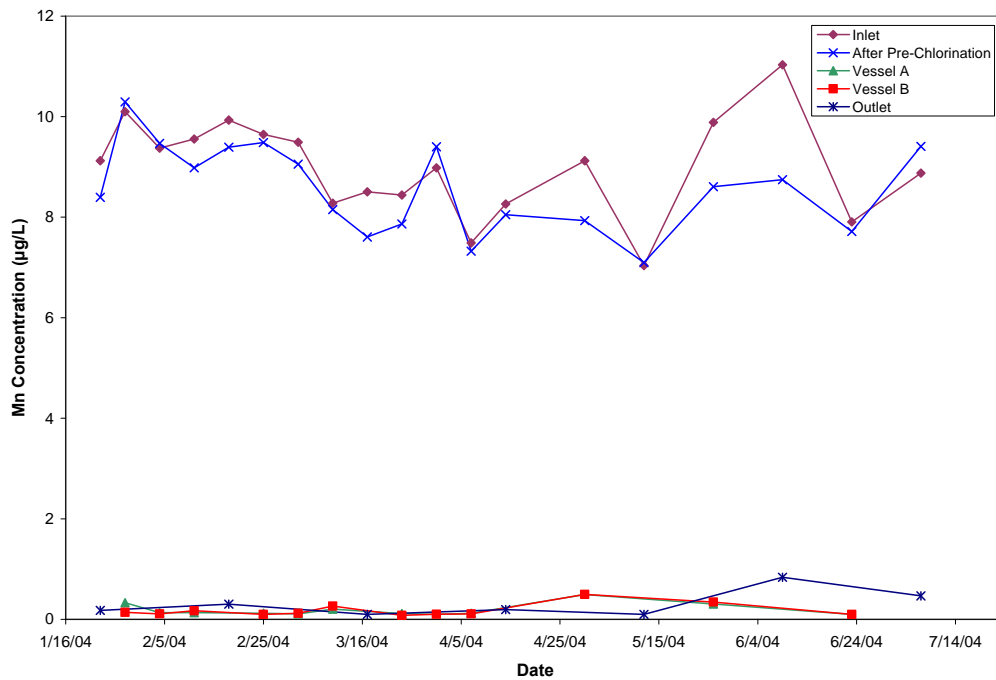


Figure 4-13. Total Manganese Concentrations over Time

On-site measurements of pH remained consistent at all sampling locations, ranging from 7.8 to 8.1. Sulfate concentrations ranged from 170 to 190 mg/L, and remained constant throughout the treatment train. Alkalinity results ranged from 164 to 199 mg/L, measured as CaCO₃. The results indicated that the alkalinity was not affected by the prechlorination or the media. Historically, sulfide odor in the raw water had been detected by the system operator. Samples for sulfide were collected at the IN sampling location on six occasions. Sulfide was detected in two samples, at 5.2 µg/L on March 3, 2004 and 5.7 µg/L on March 31, 2004. All other sulfide samples were below the detection limit of 5 µg/L. The treatment plant samples were analyzed for hardness only during speciation weeks. The total hardness results ranged from 74.5 to 90.1 mg/L as CaCO₃. The samples had predominantly calcium hardness (approximately 75-80%). Hardness was not affected by either the prechlorination or the media.

Fluoride results ranged from 0.5 to 0.7 mg/L. Fluoride concentrations, measured only during speciation weeks, were not affected by the treatment unit. Orthophosphate was below the detection limit of 0.10 mg/L at all sampling points in every sampling event, with the exception of the first event on January 23, 2004, when the orthophosphate results were 0.2 mg/L at each sampling point. The silica (as SiO₂) concentration ranged from 36.0 to 41.8 mg/L, and was not removed by the treatment media.

Sodium hypochlorite was added upstream of the treatment system. In addition to the original purpose of disinfecting water, chlorine also oxidized As(III) to As(V) to increase the arsenic removal capacity of the media. Free and total chlorine measurements were performed and recorded at each sampling event along with the pH, DO, ORP, and temperature readings. Free and total chlorine was monitored at the AC, TA, TB, and TT sampling locations. Free chlorine typically was measured at 0.3 to 0.5 mg/L at the AC location with total chlorine levels ranging from 0.4 to 0.6 mg/L. The total chlorine remained about 0.1 mg/L higher than the free chlorine. The residual chlorine measured at the TA, TB, and TT locations was nearly identical to that measured at the AC port indicating little or no loss of chlorine through the APU-300.

DO levels ranged from 1.0 to 2.3 mg/L with most measurements being less than 1.6 mg/L. The DO levels were not affected by the prechlorination or the media. ORP readings were collected using a dedicated ORP probe since April 14, 2004. In the seven subsequent events, the ORP readings at the IN location varied from 42 to 81 mV, indicating a reducing environment. After prechlorination, the ORP readings at the AC, TA, TB, and TT locations increased significantly, ranging from 486 to 561 mV.

4.5.2 Backwash Water Sampling. Backwash water was sampled on May 23 and July 13, 2004. Samples were collected from the sample ports located in the backwash effluent discharge lines from each vessel. Unfiltered samples were analyzed for pH, turbidity, and TDS/TSS. Filtered samples (using 0.45-µm disc filters) were analyzed for soluble As, Fe, and Mn. Turbidity and soluble Fe and Mn results from the May 23, 2004 sample were significantly higher than the concentrations in raw water measured during the study. This was caused by a sampling error with unfiltered water being inadvertently added to the sample bottles. Soluble Fe and Mn concentrations measured in the July 13, 2004 sample correlated more closely with the influent concentrations for these parameters. Soluble As concentrations in the backwash water ranged from 3.5 to 12.1 µg/L and were significantly lower than those measured in raw water, indicating that arsenic was removed as it passed through the media during backwash. The analytical results from the two backwash water sampling events are summarized in Table 4-9.

4.5.3 Distribution System Water Sampling. Distribution system samples were collected to investigate if the water treated by the arsenic removal system would impact the lead and copper level and water chemistry in the distribution system. Prior to the installation and operation of the system, baseline distribution water samples were collected on December 8, 11, and 30, 2003. Following the installation of the system, distribution water sampling continued on a monthly basis at the same three locations, with

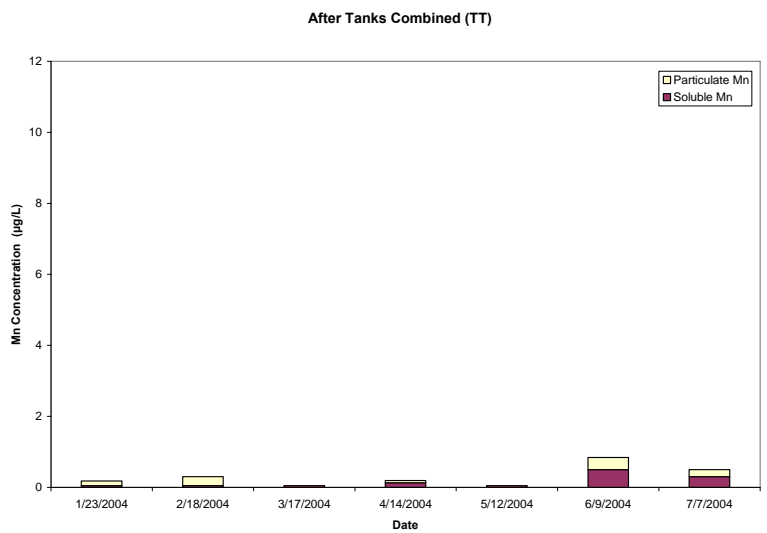
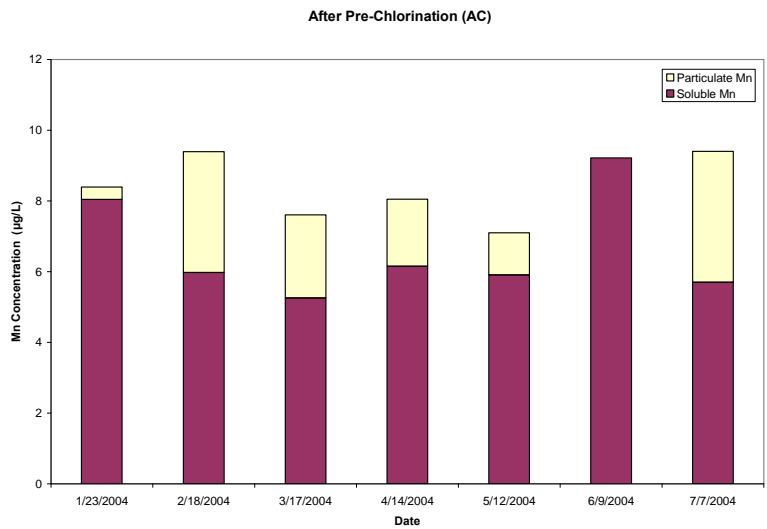
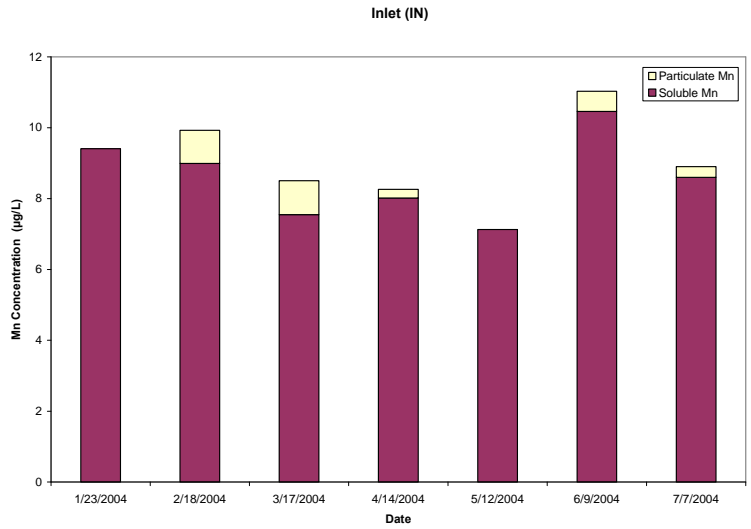


Figure 4-14. Concentrations of Manganese Species

Table 4-9. Backwash Water Sampling Results

Units	Vessel A						Vessel B					
	pH	Turbidity	TDS	Soluble As ^(b)	Soluble Fe ^(b)	Soluble Mn ^(b)	pH	Turbidity	TDS	Soluble As ^(b)	Soluble Fe ^(b)	Soluble Mn ^(b)
	–	NTU	mg/L	µg/L	µg/L	µg/L	–	NTU	mg/L	µg/L	µg/L	µg/L
5/23/2004 ^(a)	7.45	180	203	3.5	825	89.0	7.9	99	202	5.6	2,166	131.0
7/13/2004	7.88	220	766	12.1	69.8	7.6	7.88	160	756	9.6	83	8.21

- (a) Samples were mistakenly analyzed for TSS rather than TDS.
- (b) Filtered (0.45 µm) samples.

samples collected on February 11, March 10, April 7, May 12, and June 23, 2004. The samples were analyzed for pH, alkalinity, arsenic, iron, manganese, lead, and copper.

Samples at the DS1 location were collected according to the procedures in the LCR (first draw samples). Both first draw and flushed samples were collected at the DS2 and DS3 non-LCR locations. The main difference observed from the baseline samples to the present was a decrease in the arsenic concentrations at each of the sampling locations. Arsenic concentrations in the baseline samples ranged from 22.4 to 28.2 µg/L, whereas the concentrations measured since the treatment system was started ranged from 1.8 to 10.4 µg/L. The arsenic concentrations measured during system operation were lower than the baseline values, but higher than the system effluent results. This was due probably to the blending of water produced by Well No. 3 in the distribution system with untreated water from Well No. 2. A sample collected from Well No. 2 on June 2, 2004 exhibited a 14.9 µg/L concentration of total arsenic.

Measured pH values ranged from 7.5 to 8.0, with one outlier of 7.1 at DS1 during the first baseline sampling event. Alkalinity levels ranged from 168 to 265 mg/L as CaCO₃. Iron concentrations in the first draw samples ranged from <25 to 931 µg/L, with the majority of the samples <25 µg/L. Iron concentrations in the flushed samples from DS1 and DS2 ranged from <25 to 55 µg/L. In general, the iron concentrations in the distribution system samples decreased since the system began operating. The concentrations of manganese in the distribution system samples ranged from <0.1 to 94.1 µg/L, but the only results greater than 7.7 µg/L were first draw samples at DS2. Manganese levels appear slightly lower since the system began to operate.

Lead levels ranged from 0.2 to 71.7 µg/L, with 7 of the 34 samples exceeding the action level of 15 µg/L. Five of the action level exceedances for lead were from first draw samples at DS2, with the remaining two exceedances in first draw samples from DS3. Copper concentrations ranged from 1.6 to 393 µg/L, with no samples exceeding the 1,300 µg/L action level. Neither lead nor copper concentrations in the distribution system appeared to have been affected by the operation of the arsenic treatment unit. The results of the distribution system sampling are summarized in Table 4-10.

4.6 System Costs

The cost-effectiveness of the system is evaluated based on the dollar cost per 1,000 gallons of water treated. This includes the tracking of capital costs such as equipment, engineering, and installation costs and O&M costs such as media replacement and disposal, chemical supply, electrical power use, and labor.

Table 4-10. Distribution System Sampling Results

No. of Sampling Events	Address	DS1								DS2								DS3																				
	Sample Type	12 Warthen								Crossroads								Guillermo																				
	Flushed/1st Draw	1st Draw								1st Draw				Flushed				1st Draw				Flushed																
	Sampling Date*	Stagnation Time (hrs)	pH	Alkalinity	As	Fe	Mn	Pb	Cu	pH	Alkalinity	As	Fe	Mn	Pb	Cu	pH	Alkalinity	As	Fe	Mn	Pb	Cu	pH	Alkalinity	As	Fe	Mn	Pb	Cu								
	BL1	12/8/2003	8	7.1	200	23.3	48	5.0	0.9	9.1	7.7	187	26.3	37	6.4	22.5	99.5	NS	NS	NS	NS	NS	NS	NS	7.8	181	26.3	74	7.5	8.2	33.6	NS	NS	NS	NS	NS	NS	
BL2	12/11/2003	8.5	7.8	178	26.0	40	4.0	0.6	7.1	7.8	196	28.2	931	94.1	16.8	206	NS	NS	NS	NS	NS	NS	NS	7.9	200	23.7	40	7.7	1.0	10.1	NS	NS	NS	NS	NS	NS		
BL3	12/30/2003	7.7	7.7	197	22.4	<25	2.0	1.1	17.0	NS	NS	NS	NS	NS	NS	NS	7.8	201	23.4	<25	2.3	1.2	8.6	NS	NS	NS	NS	NS	NS	NS	NS	7.8	207	23.6	<25	2.1	1.1	9.1
1	2/11/2004	8.5	7.6	207	10.4	49	1.9	0.4	NA	7.8	182	7.4	783	34.1	60.2	393	7.8	186	2.5	55	0.6	2.9	25.7	7.7	198	5.3	47	1.7	8.7	30.0	7.7	215	6.7	48	2.3	1.0	17.0	
2	3/10/2004	7.8	7.8	230.0	8.1	<25	1.9	0.7	12.5	7.8	235.0	8.8	97.7	10.8	71.7	159	7.8	230.0	8.3	<25	2.7	1.5	9.3	7.9	197.0	2.4	22.5	5.6	41.3	315	8.0	185.0	1.8	<25	0.1	6.2	14.5	
3	4/7/2004	8.5	7.7	249	9.3	<25	3.5	0.2	7.5	7.8	257	10.2	27	23.8	15.9	105	7.8	265	9.5	<25	1.3	0.8	6.6	8.0	168	2.8	<25	4.1	3.3	42.5	7.9	180	2.5	<25	0.1	0.9	10.8	
4	5/12/2004	8.1	7.8	223	9.5	<25	1.7	1.7	156	7.8	237	7.2	<25	1.8	1.7	15.5	7.8	241	7.6	<25	2.2	2.3	11.4	7.8	229	5.1	<25	1.9	3.4	19.6	7.8	233	5.6	<25	1.0	2.1	11.0	
5	6/23/2004	8.1	8.0	183	1.8	<25	1.0	2.0	33.7	7.9	195	3.1	<25	1.4	6.0	84.7	7.9	195	4.3	<25	1.2	9.3	1.6	8.0	195	2.5	<25	0.6	22.9	121	7.9	175	4.5	<25	1.2	3.8	19.2	

* System operation started on January 16, 2004.

The unit for analytical parameters is µg/L, except for pH (no unit) and alkalinity (mg/L as CaCO₃).

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

NS = not sampled; NA = not available; BL = baseline sampling.

4.6.1 Capital Costs. The capital investment costs for equipment, site engineering, and installation were \$153,000 (see Table 4-11). The equipment costs were \$112,000 (or 73% of the total capital investment), which included \$72,200 for the APU-300 skid-mounted unit, \$24,000 for the SORB 33™ media (i.e., \$150/ft³ or \$5.34/lb to fill two vessels), and vendor’s labor and travel for the system shakedown and startup.

Table 4-11. Capital Investment for the APU-300 System at the Desert Sands MDWCA Site

Description	Quantity	Cost	% of Capital Investment Cost
<i>Equipment Costs</i>			
APU-300 Skid-Mounted System	1 unit	\$72,200	–
SORB 33™ Media	160 ft ³	\$24,000	–
Miscellaneous Equipment and Materials	–	\$2,500	–
Vendor Labor	–	\$9,500	–
Vendor Travel	–	\$3,800	–
Equipment Total	–	\$112,000	73%
<i>Engineering Costs</i>			
Subcontractor	–	\$16,300	–
Vendor Labor	–	\$6,700	–
Engineering Total	–	\$23,000	15%
<i>Installation Cost</i>			
Subcontractor	–	\$9,000	–
Vendor Labor	–	\$5,600	–
Vendor Travel	–	\$3,400	–
Installation Total	–	\$18,000	12%
Total Capital Investment	–	\$153,000	100%

The engineering costs included the costs for the preparation of the system layout and footprint, design of the piping connections up to the distribution tie-in points, design of the electrical connections, and assembling and submission of the engineering plans for the permit application (Section 4.3.1). The engineering costs were \$23,000, which was 15% of the total capital investment.

The installation costs included the costs for the equipment and labor to unload and install the APU-300 system, perform the piping tie-ins and electrical work, and load and backwash the media (Section 4.3.3). The installation was performed by STS and the Desert Sands MDWCA plant operator subcontracted to STS. A variety of elevated pressure and flow restriction issues caused the actual system startup date to be delayed, eventually prompting STS to redesign the system’s piping, valving, and instruments and controls. The costs for the system retrofitting were not included in this cost analysis. The installation costs were \$18,000, or 12% of the total capital investment.

Desert Sands MDWCA constructed an addition to its existing pump house at Well No. 3 to house the APU-300 system (Section 4.3.2). The structure was built by the Desert Sands MDWCA plant operator with the exception of the electrical tie-in. The total cost for the building was \$3,700, with \$2,700 for materials and \$1,000 for labor. Approximately 80 hours of labor were required to complete the construction effort.

The total capital cost of \$153,000 and equipment cost of \$112,000 were converted to a unit cost of \$0.06/1,000 gallon and \$0.04/1,000 gallon, respectively, using a capital recovery factor (CRF) of 0.06722

based on a 3% interest rate and a 20-year return period (Chen et al., 2004). These calculations assumed that the system operated 24 hours a day, 7 days a week at the system design flowrate of 320 gpm. The system operated only 4 to 8.3 hours a day (see Table 4-5), producing 14,647,000 gallons of water during the 6-month period, so the total unit cost and equipment-only unit cost were increased to \$0.35/1,000 gallon and \$0.26/1,000 gallon, respectively, at this reduced rate of usage. Using the system's rated capacity of 320 gpm, the capital cost was \$476 per gallon of design capacity and equipment-only cost was \$350 per gallon of design capacity. These calculations did not include the building construction cost.

4.6.2 Operation and Maintenance Costs. O&M costs for the Desert Sands MDWCA system includes only incremental costs associated with the APU-300 system, such as media replacement and disposal, chemical supply, electricity, and labor. These costs are summarized in Table 4-12. Because media replacement and disposal did not take place during the first six-months of operation, its cost per 1,000 gallons of water treated was calculated based upon a projected breakthrough and an estimated media changeout cost (i.e., \$26,800 to change out both vessels) (Figure 4-15). This media changeout cost included costs for media, freight, labor, travel expenses, and media profiling and disposal fee. At the vendor-estimated media capacity of 132,000 BV (Table 4-4), the media replacement cost is projected to be \$0.17/1,000 gallons (Figure 4-15). This cost, however, will be determined once the actual breakthrough occurs and the cost of media replacement becomes available.

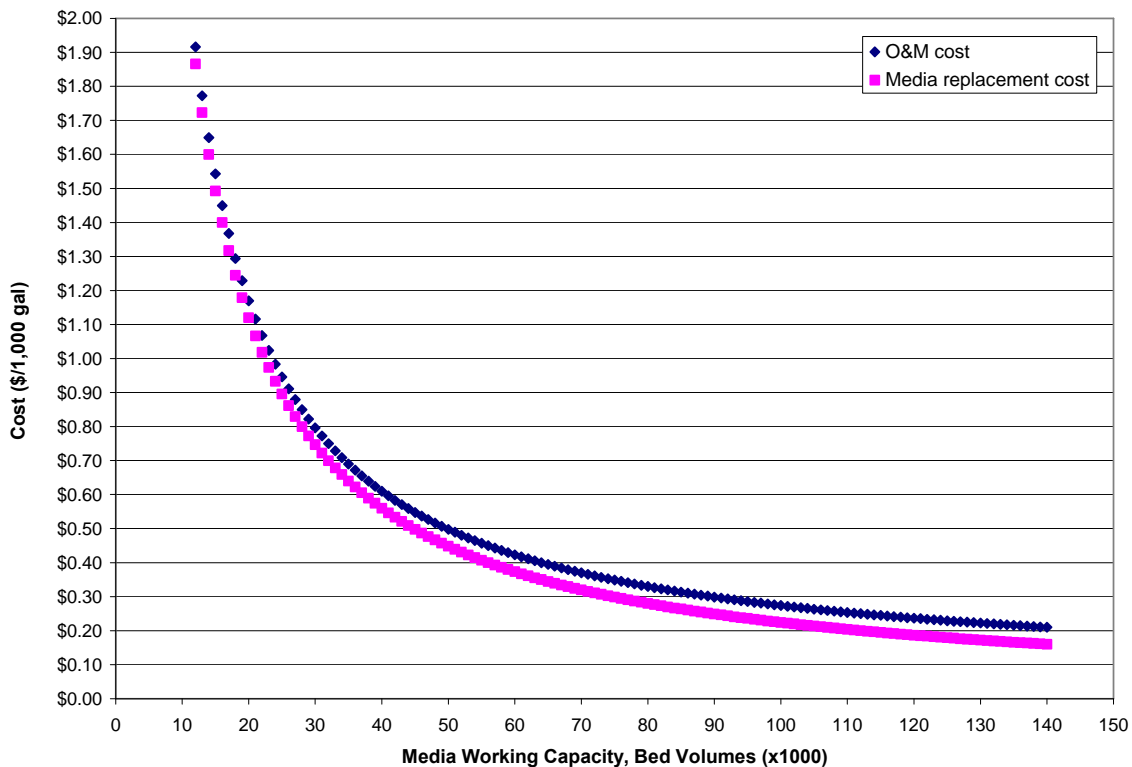


Figure 4-15. Media Replacement and O&M Cost for the Desert Sands MDWCA APU-300 System

Table 4-12. O&M Costs for the APU-300 System at the Desert Sands MDWCA Site

Cost Category	Value	Assumptions
Volume processed (kgal)	14,647	Through July 16, 2004
<i>Media Replacement and Disposal</i>		
Media cost (\$/ft ³)	\$150	Vendor quote
Total media volume (ft ³)	160	Both vessels
Media replacement cost (\$)	\$24,000	Vendor quote
Labor cost (\$)	\$2,120	Vendor quote
Media disposal fee (\$)	\$680	Vendor quote
Subtotal	\$26,800	Vendor quote
Media replacement and disposal cost (\$/1,000 gal)	See Figure 4-15	Based upon media run length at 10-μg/L arsenic breakthrough
<i>Chemical Usage</i>		
Chemical cost (\$)	\$0.000	No additional chemicals required.
<i>Electricity</i>		
Electric utility charge (\$/kWh)	\$0.14	Rate provided by DSMDWCA
Usage (kWh)	108	All prior to retrofit on May 16, 2004
Total electricity cost (\$)	\$15.12	–
Electricity cost (\$/1,000 gal)	\$0.001	\$0.01/1,000 gal prior to retrofit
<i>Labor</i>		
Average weekly labor (hrs)	1.75	15 minutes/day
Labor cost (\$/1,000 gal)	\$0.053	Labor rate = \$17/hr
Total O&M cost (\$/1,000 gal)	See Figure 4-15	Based upon media run length at 10-μg/L arsenic breakthrough

The only chemical cost was the use sodium hypochlorite for prechlorination, which was in place prior to the installation of the APU-300 system for the purpose of providing chlorine residual prior to distribution. The APU-300 system did not change the use rate of the sodium hypochlorite solution. Therefore, the chemical cost was negligible.

Electrical power consumption also was negligible, particularly since the system retrofit in May 2004. After retrofitting, the electric meter stopped registering power consumption. The operator assumed that the meter was faulty, and replaced it with a new and factory-tested meter, which also did not register any power consumption. The APU-300 system did not consume enough electricity to register on the meter.

The routine, non-demonstration related labor activities consume only 15 minutes per day, as noted in Section 4.4.5. Therefore, the labor cost is \$0.053/1,000 gallons of water treated.

5.0 REFERENCES

- Battelle. 2003. *Revised Quality Assurance Project Plan for Evaluation of Arsenic Removal Technology*. Prepared under Contract No. 68-C-00-185, Task Order No. 0019, for U.S. EPA NRMRL. November 17.
- Battelle. 2004. *Final System Performance Evaluation Study Plan: U.S. EPA Demonstration of Arsenic Removal Technology at Desert Sands MDWCA in Anthony, New Mexico*. Prepared under Contract No. 68-C-00-185, Task Order No. 0019 for U.S. EPA NRMRL. January 19.
- Chen, A.S.C., L. Wang, J. Oxenham, and W. Condit. 2004. *Capital Costs of Arsenic Removal Technologies: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1*. EPA/600/R-04/201. U.S. EPA NRMRL, Cincinnati, OH.
- Desert Sands MDWCA. 2002a. *40 Year Water Plan 2003-2004*. July 18.
- Desert Sands MDWCA. 2002b. *Consumer Confidence Report for 2002*.
- Edwards, M., S. Patel, L. McNeill, H. Chen, M. Frey, A.D. Eaton, R.C. Antweiler, and H.E. Taylor. 1998. "Considerations in As Analysis and Speciation." *J. AWWA* (March): 103-113.
- Knocke, W.R., et al. 1987. "Using Alternative Oxidants to Remove Dissolved Manganese from Waters Laden with Organics." *J. AWWA*(March), 79:3:75.
- Knocke, W.R., et al. 1990. *Alternative Oxidants for the Remove of Soluble Iron and Manganese*. Final report prepared for the AWWA Research Foundation, AWWARF, Denver, Colorado (March).
- Severn Trent Services. 2004. *Operation and Maintenance Manual, Model APU-300, Desert Sands MDWCA (Anthony), NM*. June 30.
- U.S. Environmental Protection Agency. 2003. Minor Clarification of the National Primary Drinking Water Regulation for Arsenic. *Federal Register*, 40 CFR Part 141. March 25.
- U.S. Environmental Protection Agency. 2002. *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems*. Prepared by EPA's Office of Water. EPA/816/R-02/009. February.
- U.S. Environmental Protection Agency. 2001. National Primary Drinking Water Regulations: Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring. *Fed. Register.*, 66:14:6975. January 22.
- Wang, L., W. Condit, and A. Chen. 2004. *Technology Selection and System Design: U.S. EPA Arsenic Removal Technology Demonstration Program Round 1*. EPA/600/R-05/001. U.S. EPA NRMRL, Cincinnati, OH.

APPENDIX A

OPERATIONAL DATA

EPA Arsenic Demonstration Project at Desert Sands MDWCA, NM - Daily System Operation Log Sheet

Week No.	Date	Pump House					Instrument Panel											
		Pump Hour Meter	Opt Hours	Master Flow Meter	Avg Flowrate	APU Electric Meter	Flow Totalizer 1		Cum. Bed Volume Totalizer 1	Flow Totalizer 2		Cum. Bed Volume Totalizer 2	Head Loss (psi)		Pressure (psig)		ΔP	System Back-washed
		hr	hr	Kgal	gpm	KWH	gpm	Kgal	# of BV	gpm	Kgal	# of BV	Tank A	Tank B	Influent	Effluent	psig	Yes/No
1	01/23/04	15128.0	0.0	234,081	NA	14	150	221		150	216		>15	>15	76	56	20	Yes
	01/24/04	15132.9	4.9	234,153	245	15	off	266	75	off	259	72	off	off	52	52	NA	
	01/25/04	15141.0	8.1	234,282	265	16	off	335	190	off	327	185	off	off	56	56	NA	
2	01/26/04	15146.0	5.0	234,359	257	17	off	375	257	off	367	252	off	off	58	58	NA	
	01/27/04	15148.0	2.0	234,403	367	18	off	399	297	off	391	292	off	off	54	54	NA	
	01/28/04	15153.0	5.0	234,476	243	19	150	438	362	150	428	353	>15	>15	78	60	18	Yes
	01/29/04	15157.0	4.0	234,540	267	NR	off	471	417	off	461	408	off	off	54	54	NA	
	01/30/04	15161.0	4.0	234,597	238	33	off	501	467	off	491	458	off	off	60	60	NA	
	01/31/04	15164.0	3.0	234,658	339	34	off	538	528	off	526	517	off	off	60	60	NA	
3	02/01/04	15168.0	4.0	234,713	227	35	off	568	578	off	558	570	off	off	60	60	NA	
	02/02/04	15172.0	4.0	234,771	244	35	off	584	605	off	603	645	off	off	55	55	NA	
	02/03/04	15177.6	5.6	234,845	221	38	off	600	632	off	663	745	off	off	60	60	NA	
	02/04/04	15178.9	1.3	234,866	264	40	120	615	657	180	681	775	24	24	80	56	24	Yes
4	02/05/04	15186.9	8.0	234,989	256	NR	off	620	665	off	757	902	off	off	52	52	NA	
	02/09/04	15198.4	11.5	235,167	258	44	off	753	887	off	868	1087	off	off	NR	NR	NA	
	02/10/04	15198.8	0.4	235,174	292	44	120	756	892	180	872	1093	>15	>15	84	54	30	
	02/11/04	15204.5	5.7	235,225	150	45	120	799	963	180	926	1183	>15	>15	84	56	28	Yes
	02/12/04	15209.2	4.7	235,333	382	46	120	830	1015	180	969	1255	>15	>15	86	56	30	
5	02/13/04	15214.1	4.9	235,408	256	47	off	863	1070	off	1,015	1332	off	off	56	56	NA	
	02/16/04	15228.2	14.1	235,623	254	48	off	956	1225	off	1,111	1492	off	off	54	54	NA	
	02/17/04	15233.4	5.2	235,701	250	49	off	990	1282	off	1,158	1570	off	off	50	50	NA	
	02/18/04	15238.4	5.0	235,777	253	50	120	1,025	1340	180	1,207	1652	>15	>15	82	56	26	Yes
	02/19/04	15245.9	7.5	235,891	253	51	off	1,074	1422	off	1,277	1768	off	off	54	54	NA	
6	02/20/04	15251.4	5.5	235,976	258	51	off	1,112	1485	off	1,328	1853	off	off	50	50	NA	
	02/23/04	15262.8	11.4	236,151	256	53	off	1,192	1618	off	1,436	2033	off	off	50	50	NA	
	02/24/04	15267.1	4.3	236,216	252	54	off	1,221	1667	off	1,476	2100	off	off	50	50	NA	
	02/25/04	15271.4	4.3	236,282	256	55	120	1,250	1715	180	1,516	2167	>15	>15	82	56	26	Yes
	02/26/04	15275.3	3.9	236,342	256	55	off	1,279	1763	off	1,555	2232	off	off	52	52	NA	
	02/27/04	15278.2	2.9	236,387	259	56	off	1,298	1795	off	1,582	2277	off	off	50	50	NA	
7	02/28/04	15282.2	4.0	236,448	254	56	off	1,327	1843	off	1,623	2345	off	off	50	50	NA	
	02/29/04	15286.4	4.2	236,511	250	57	off	1,356	1892	off	1,660	2407	off	off	50	50	NA	
	03/01/04	15290.5	4.1	236,575	260	57	off	1,384	1938	off	1,698	2470	off	off	50	50	NA	
	03/02/04	15295.1	4.6	236,644	250	58	off	1,415	1990	off	1,740	2540	off	off	52	52	NA	
	03/03/04	15299.1	4.0	236,715	296	58	120	1,446	2042	170	1,782	2610	>15	>15	82	58	24	Yes
	03/04/04	15303.7	4.6	236,775	217	59	off	1,475	2090	off	1,820	2673	off	off	54	54	NA	
	03/05/04	15310.6	6.9	236,801	63	60	off	1,480	2098	off	1,836	2700	off	off	59	54	NA	
8	03/06/04	15315.6	5.0	236,876	250	60	120	1,521	2167	170	1,883	2778	>15	>15	82	60	22	
	03/07/04	15321.5	5.9	236,966	254	61	120	1,563	2237	175	1,936	2867	>15	>15	84	60	24	
	03/08/04	15323.2	1.7	236,994	275	61	120	1,563	2237	170	1,936	2867	>15	>15	82	56	26	
	03/09/04	15326.0	2.8	237,035	244	61	off	1,594	2288	off	1,977	2935	off	off	off	off	NA	
	03/10/04	15331.0	5.0	237,112	257	62	110	1,631	2350	150	2,022	3010	>15	>15	80	56	24	Yes
	03/11/04	15336.8	5.8	237,201	256	62	off	1,671	2417	off	2,083	3112	off	off	off	off	NA	
03/12/04	15340.1	3.3	237,253	263	63	off	1,694	2455	off	2,105	3148	off	off	off	off	NA		
03/13/04	15343.5	3.4	237,305	255	63	off	1,717	2493	off	2,137	3202	off	off	off	off	NA		
03/14/04	15349.7	6.2	237,377	194	64	off	1,749	2547	off	2,180	3273	off	off	off	off	NA		

EPA Arsenic Demonstration Project at Desert Sands MDWCA, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Pump House					Instrument Panel											System Back-washed Yes/No
		Pump Hour Meter hr	Opt Hours hr	Master Flow Meter Kgal	Avg Flowrate gpm	APU Electric Meter KWH	Flow Totalizer 1		Cum. Bed Volume Totalizer 1 # of BV	Flow Totalizer 2		Cum. Bed Volume Totalizer 2 # of BV	Head Loss (psi)		Pressure (psig)		ΔP psig	
							gpm	Kgal		gpm	Kgal		Tank A	Tank B	Influent	Effluent		
9	03/15/04	15352.7	3.0	237,455	433	65	110	1,784	2605	140	2,227	3352	>20	>20	80	60	20	
	03/16/04	15360.3	7.6	237,564	239	65	off	1,839	2697	off	2,299	3472	off	off	off	off	NA	
	03/17/04	15367.2	6.9	237,671	258	66	110	1,889	2780	140	2,360	3573	>20	>20	82	60	22	Yes
	03/18/04	15369.1	1.9	237,698	237	67	115	1,902	2802	155	2,377	3602	>20	>20	off	off	NA	
	03/19/04	15377.5	8.4	237,799	200	67	off	1,949	2880	off	2,434	3697	off	off	off	off	NA	
	03/20/04	15379.7	2.2	237,864	492	68	115	1,979	2930	160	2,472	3760	>20	>20	84	62	22	
03/21/04	15383.0	3.3	237,924	303	70	off	2,003	2970	off	2,502	3810	off	off	54	off	NA		
10	03/22/04	15386.2	3.2	237,963	203	70	115	2,025	3007	160	2,531	3858	>20	>20	84	62	22	
	03/23/04	15390.2	4.0	238,025	258	71	off	2,053	3053	off	2,567	3918	off	off	off	off	NA	
	03/24/04	15395.3	5.1	238,103	255	71	115	2,088	3112	155	2,613	3995	>20	>20	84	off	NA	Yes
	03/25/04	15401.1	5.8	238,199	276	72	off	2,138	3195	off	2,676	4100	off	off	off	off	NA	
	03/26/04	15405.4	4.3	238,258	229	72	off	2,166	3242	off	2,710	4157	off	off	off	off	NA	
	03/27/04	15409.0	3.6	238,315	264	73	off	2,192	3285	off	2,743	4212	off	off	off	off	NA	
03/28/04	15412.5	3.5	238,369	257	74	off	2,217	3327	off	2,775	4265	off	off	off	off	NA		
11	03/29/04	15416.8	4.3	238,434	252	75	off	2,246	3375	off	2,813	4328	off	off	NR	60	NA	
	03/30/04	15420.3	3.5	238,494	286	75	off	2,273	3420	off	2,848	4387	off	off	NR	60	NA	
	03/31/04	15424.6	4.3	238,554	233	76	off	2,301	3467	off	2,884	4447	off	off	NR	58	NA	Yes
	04/01/04	15429.4	4.8	238,628	257	76	off	2,341	3533	off	2,934	4530	off	off	NR	60	NA	
	04/02/04	15432.3	2.9	238,674	264	77	off	2,363	3570	off	2,960	4573	off	off	NR	58	NA	
	04/03/04	15435.3	3.0	238,719	250	78	off	2,384	3605	off	2,987	4618	off	off	NR	58	NA	
04/04/04	NR	NA	238,772	NA	79	off	2,408	3645	off	3,018	4670	off	off	NR	60	NA		
12	04/05/04	15441.6	6.3	238,816	116	80	off	2,428	3678	off	3,043	4712	off	off	NR	60	NA	
	04/06/04	15444.5	2.9	238,868	299	81	off	2,449	3713	off	3,071	4758	off	off	NR	60	NA	
	04/07/04	15446.5	2.0	238,893	208	81	110	2,464	3738	150	3,090	4790	>20	>20	60	82	22	Yes
	04/08/04	15450.4	3.9	238,952	252	82	off	2,497	3793	off	3,130	4857	off	off	NR	62	NA	
	04/09/04	15453.2	2.8	238,995	256	83	off	2,517	3827	off	3,155	4898	off	off	NR	58	NA	
	04/10/04	15456.7	3.5	239,049	257	83	off	2,542	3868	off	3,186	4950	off	off	NR	60	NA	
04/11/04	15459.6	2.9	239,093	253	84	off	2,562	3902	off	3,212	4993	off	off	NR	60	NA		
13	04/12/04	15462.8	3.2	239,135	219	84	120	2,582	3935	140	3,237	5035	>20	>20	82	60	22	
	04/13/04	15465.7	2.9	239,188	305	85	120	2,606	3975	140	3,268	5087	>20	>20	82	60	22	
	04/14/04	15468.9	3.2	239,235	245	85	110	2,627	4010	140	3,296	5133	>20	>20	84	60	24	Yes
	04/15/04	15473.2	4.3	239,301	256	86	110	2,664	4072	140	3,341	5208	>20	>20	84	60	24	
	04/16/04	15476.6	3.4	239,353	255	87	110	2,688	4112	140	3,372	5260	>20	>20	82	60	22	
	04/17/04	15480.6	4.0	239,413	250	87	110	2,715	4157	140	3,407	5318	>20	>20	84	60	24	
04/18/04	15484.0	3.4	239,465	255	88	110	2,739	4197	140	3,438	5370	>20	>20	84	60	24		
14	04/19/04	15488.0	4.0	239,525	250	89	110	2,767	4243	140	3,473	5428	>20	>20	84	60	24	
	04/20/04	15491.6	3.6	239,580	255	90	110	2,791	4283	140	3,505	5482	>20	>20	84	60	24	
	04/21/04	15495.7	4.1	239,634	220	91	110	2,816	4325	140	3,537	5535	>20	>20	82	58	24	
	04/22/04	15498.6	2.9	239,687	305	91	110	2,846	4375	140	3,575	5598	>20	>20	82	60	22	
	04/23/04	15501.9	3.3	239,737	253	92	110	2,870	4415	140	3,604	5647	>20	>20	80	60	20	
	04/24/04	15505.7	3.8	239,795	254	92	110	2,896	4458	140	3,638	5703	>20	>20	80	60	20	
04/25/04	15510.1	4.4	239,860	246	93	110	2,926	4508	140	3,676	5767	>20	>20	80	60	20		
15	04/26/04	15513.9	3.8	239,919	259	94	110	2,953	4553	140	3,711	5825	>20	>20	82	60	22	
	04/27/04	15517.9	4.0	239,980	254	94	off	2,955	4557	140	3,746	5883	>20	>20	82	60	22	
	04/28/04	15521.9	4.0	240,023	179	95	off	2,955	4557	140	3,779	5938	>20	>20	82	60	22	
	04/29/04	15525.0	3.1	240,101	419	96	off	2,955	4557	140	3,817	6002	>20	>20	82	60	22	
	04/30/04	15528.8	3.8	240,147	202	97	120	2,983	4603	140	3,850	6057	>20	>20	82	60	22	Yes
	05/01/04	15534.2	5.4	240,230	256	98	110	3,022	4668	140	3,895	6132	>20	>20	82	60	22	
05/02/04	15539.3	5.1	240,291	199	98	110	3,030	4682	140	3,953	6228	>20	>20	82	60	22		

A-2

EPA Arsenic Demonstration Project at Desert Sands MDWCA, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Pump House					Instrument Panel												System Back-washed Yes/No
		Pump Hour Meter hr	Opt Hours hr	Master Flow Meter Kgal	Avg Flowrate gpm	APU Electric Meter KWH	Flow Totalizer 1		Cum. Bed Volume Totalizer 1 # of BV	Flow Totalizer 2		Cum. Bed Volume Totalizer 2 # of BV	Head Loss (psi)		Pressure (psig)		ΔP psig		
							gpm	Kgal		gpm	Kgal		Tank A	Tank B	Influent	Effluent			
16	05/03/04	15542.1	2.8	240,360	411	99	110	3,077	4760	140	3,968	6253	>20	>20	82	60	22		
	05/04/04	15546.0	3.9	240,400	171	100	110	3,104	4805	140	4,002	6310	>20	>20	82	60	22		
	05/05/04	15550.5	4.5	240,478	289	101	110	3,136	4858	140	4,042	6377	>20	>20	80	60	20		
	05/06/04	15557.1	6.6	240,577	250	101	110	3,188	4945	140	4,107	6485	>20	>20	80	60	20		
	05/07/04	15562.8	5.7	240,664	254	102	110	3,229	5013	140	4,157	6568	>20	>20	82	60	22		
	05/08/04	15569.0	6.2	240,759	255	102	110	3,274	5088	140	4,210	6657	>20	>20	80	60	20		
05/09/04	15575.0	6.0	240,849	250	103	110	3,315	5157	140	4,262	6743	>20	>20	80	60	20			
17	05/10/04	15580.7	5.7	240,936	254	103	110	3,356	5225	150	4,312	6827	>20	>20	82	60	22		
	05/11/04	15588.2	7.5	241,034	218	104	110	3,402	5302	150	4,368	6920	>20	>20	80	58	22		
	05/12/04	15592.2	4.0	241,110	317	105	110	3,436	5358	140	4,412	6993	>20	>20	80	60	20	Yes	
	05/13/04	15599.1	6.9	241,215	254	106	110	3,493	5453	145	4,478	7103	>20	>20	80	60	20		
	05/14/04	15602.4	3.3	241,266	258	106	110	3,517	5493	140	4,507	7152	>20	>20	80	60	20		
	05/15/04	15608.1	5.7	241,353	254	107	110	3,557	5560	140	4,557	7235	>20	>20	80	60	20		
05/16/04	15621.0	12.9	241,554	260	108	110	3,663	5737	140	4,649	7388	>20	>20	80	60	20			
18	05/17/04																		
	05/18/04																		
	05/19/04																		
	05/20/04																		
	05/21/04																		
	05/22/04																		
05/23/04																			
19	05/24/04	15625.6	4.6	241,646	333	112	140	3,663	5737	135	4,649	7388	3	3	66	60	6		
	05/25/04	15632.6	7.0	241,746	238	112	145	3,705	5807	140	4,752	7560	3	3	68	62	6		
	05/26/04	15638.8	6.2	241,846	269	112	145	3,759	5897	145	4,779	7605	3	3	64	58	6	Yes	
	05/27/04	15644.6	5.8	241,940	270	112	off	3,809	5980	off	4,820	7673	off	off	52	52	NA		
	05/28/04	15648.4	3.8	242,002	272	112	off	3,842	6035	off	4,852	7727	off	off	52	52	NA		
	05/29/04	15657.3	8.9	242,146	270	112	145	3,919	6163	145	4,929	7855	3	3	56	50	6		
	05/30/04	15663.7	6.4	242,248	266	112	140	3,972	6252	140	4,983	7945	3	3	62	56	6		
20	05/31/04	15670.2	6.5	242,353	269	112	135	4,029	6347	135	5,040	8040	3	3	66	60	6		
	06/01/04	15679.0	8.8	242,498	275	112	135	4,104	6472	135	5,116	8167	3	3	68	62	6		
	06/02/04	15686.8	7.8	242,617	254	112	140	4,166	6575	135	5,179	8272	3	3	60	54	6	Yes	
	06/03/04	15693.7	6.9	242,725	261	112	off	4,223	6670	off	5,231	8358	off	off	off	52	NA		
	06/04/04	15699.0	5.3	242,810	267	112	off	4,266	6742	off	5,283	8445	off	off	off	50	NA		
	06/05/04	15705.8	6.8	242,917	262	112	135	4,321	6833	140	5,341	8542	4	4	60	52	8		
	06/06/04	15712.2	6.4	243,018	263	112	140	4,373	6920	145	5,396	8633	3	3	56	50	6		
21	06/07/04	15721.4	9.2	243,164	264	112	off	4,446	7042	off	5,476	8767	off	off	off	58	NA		
	06/08/04	15728.1	6.7	243,270	264	112	135	4,499	7130	140	5,534	8863	3	3	56	50	6		
	06/09/04	15738.5	10.4	243,432	260	112	140	4,580	7265	145	5,621	9008	5	5	62	52	10	Yes	
	06/10/04	15747.7	9.2	243,576	261	112	135	4,652	7385	140	5,700	9140	5	6	67	56	11		
	06/11/04	15752.1	4.4	243,645	261	112	135	4,680	7432	130	5,739	9205	6	8	64	58	6		
	06/12/04	15761.6	9.5	243,795	263	112	off	4,761	7567	off	5,821	9342	off	off	off	52	NA		
	06/13/04	15767.7	6.1	243,891	262	112	off	4,808	7645	off	5,872	9427	off	off	off	58	NA		
22	06/14/04	15778.0	10.3	244,054	264	112	off	4,837	7693	off	5,970	9590	off	off	off	58	NA		
	06/15/04	15787.2	9.2	244,203	270	112	150	4,910	7815	150	6,054	9730	3	3	66	60	6		
	06/16/04	15794.7	7.5	244,321	262	112	off	4,972	7918	off	6,116	9833	off	off	off	62	NA		
	06/17/04	15804.4	9.7	244,477	268	112	135	5,055	8057	135	6,197	9968	4	4	70	62	8		
	06/18/04	15812.5	8.1	244,606	265	112	off	5,123	8170	off	6,263	10078	off	off	off	58	NA		
	06/19/04	15821.4	8.9	244,747	264	112	off	5,198	8295	off	6,337	10202	off	off	off	60	NA		
06/20/04	15827.4	6.0	244,843	267	112	off	5,248	8378	off	6,387	10285	off	off	off	52	NA			

System was turned off for repairing

EPA Arsenic Demonstration Project at Desert Sands MDWCA, NM - Daily System Operation Log Sheet (Continued)

Week No.	Date	Pump House					Instrument Panel											
		Pump Hour Meter	Opt Hours	Master Flow Meter	Avg Flowrate	APU Electric Meter	Flow Totalizer 1		Cum. Bed Volume Totalizer 1	Flow Totalizer 2		Cum. Bed Volume Totalizer 2	Head Loss (psi)		Pressure (psig)		ΔP	System Back-washed
		hr	hr	Kgal	gpm	KWH	gpm	Kgal	# of BV	gpm	Kgal	# of BV	Tank A	Tank B	Influent	Effluent	psig	Yes/No
23	06/21/04	15842.4	15.0	245,019	196	112	140	5,349	8547	145	6,479	10438	3	3	60	56	4	
	06/22/04	15851.5	9.1	245,164	266	112	off	5,415	8657	off	6,555	10565	off	off	off	off	NA	
	06/23/04	15857.0	5.5	245,251	264	112	150	5,461	8733	150	6,600	10640	3	3	58	52	6	Yes
	06/24/04	15866.8	9.8	245,407	265	112	off	5,542	8868	off	6,683	10778	off	off	off	58	NA	
	06/25/04	15872.6	5.8	245,509	293	112	off	5,589	8947	off	6,732	10860	off	off	off	60	NA	
	06/26/04	15879.0	6.4	245,602	242	112	140	5,643	9037	135	6,786	10950	6	6	72	60	12	
	06/27/04	15885.0	6.0	245,706	289	112	off	5,697	9127	off	6,841	11042	off	off	off	58	NA	
24	06/28/04	15891.4	6.4	245,794	229	112	130	5,742	9202	130	6,887	11118	8	8	76	60	16	
	06/29/04	15898.7	7.3	245,911	267	112	off	5,803	9303	off	6,948	11220	off	off	off	62	NA	
	06/30/04	15904.2	5.5	245,999	267	112	125	5,849	9380	125	6,994	11297	10	10	80	60	20	
	07/01/04	15911.0	6.8	246,109	270	112	145	5,907	9477	145	7,051	11392	3	3	62	56	6	
	07/02/04	15916.9	5.9	246,205	271	112	145	5,958	9562	145	7,101	11475	3	3	58	52	6	
	07/03/04	15927.1	10.2	246,368	266	112	off	6,045	9707	off	7,189	11622	off	off	off	60	NA	
	07/04/04	15932.4	5.3	246,455	274	112	off	6,090	9782	off	7,230	11690	off	off	off	58	NA	
25	07/05/04	15940.7	8.3	246,588	267	112	135	6,158	9895	140	7,301	11808	4	3	62	56	6	
	07/06/04	15949.8	9.1	246,735	269	112	off	6,227	10010	off	7,385	11948	off	off	off	52	NA	
	07/07/04	15955.9	6.1	246,832	265	112	140	6,277	10093	145	7,437	12035	4	3	63	54	9	Yes
	07/08/04	15969.3	13.4	247,046	266	102	off	6,384	10272	off	7,554	12230	off	off	off	58	NA	
	07/09/04	15977.3	8.0	247,175	269	0	off	6,453	10387	off	7,621	12342	off	off	off	60	NA	
	07/10/04	15987.2	9.9	247,333	266	0	off	6,535	10523	off	7,705	12482	off	off	off	62	NA	
	07/11/04	15995.2	8.0	247,468	281	0	135	6,603	10637	140	7,777	12602	6	6	68	56	12	
26	07/12/04	16003.5	8.3	247,597	259	down	135	6,667	10743	135	7,848	12720	3	3	62	56	6	
	07/13/04	16008.2	4.7	247,672	266	down	off	6,703	10803	off	7,891	12792	off	off	off	54	NA	
	07/14/04	16021.6	13.4	247,886	266	down	off	6,815	10990	off	8,006	12983	off	off	off	56	NA	
	07/15/04	16029.9	8.3	248,022	273	down	off	6,886	11108	off	8,076	13100	off	off	off	56	NA	
	07/16/04	16036.9	7.0	248,136	271	down	140	6,947	11210	135	8,137	13202	3	3	62	56	6	

Note: 4/27/04 - 4/29/04 Unit A Flow meter quit working and worked again on 4/29/04
 Green highlight indicates a calculated value
 NR = No reading; NA = Not available

APPENDIX B
ANALYTICAL DATA

Analytical Results from Long-Term Sampling, Desert Sands MDWCA

Sampling Date		1/23/04 ^(b)			1/28/04				2/4/04				2/11/04			
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity	mg/L ^(a)	173	173	173	173	173	169	169	180	176	180	178	186	190	186	182
Fluoride	mg/L	0.5	0.5	0.5												
Sulfate	mg/L	180	170	180												
orthophosphate	mg/L	0.2	0.2	0.2	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silica (as SiO ₂)	mg/L	41.8	41.7	37.2	40.5	40.8	38.5	39.2	36.4	37.3	35.3	36.4	36.6	37.4	36.2	37.0
Sulfide	µg/L	<5	NA	NA						NA	NA	NA				
NO ₃ -(N)	mg/L	<0.05	<0.05	<0.05												
Turbidity	NTU	3.5	1.2	0.1	0.2	0.2	0.1	<0.1	0.5	0.8	0.2	0.2	0.4	0.5	0.2	0.2
pH	-	7.8	7.9	7.9	8.1	8.0	8.0	7.9	8.1	8.0	7.9	7.9	7.9	7.9	7.9	7.9
Temperature	°C	28.7	29.4	29.7	28.4	28.8	28.9	29.0	30.2	29.5	29.9	29.8	29.9	30.0	30.2	29.9
DO	mg/L	1.0	1.4	2.3	1.9	2.0	2.0	1.9	1.1	1.8	1.5	1.5	1.0	1.6	1.5	1.4
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine	mg/L	NA	0.5	0.3	NA	0.3	0.3	0.3	NA	NA	0.4	0.4	NA	NA	NA	NA
Total Hardness	mg/L ^(a)	81.1	80.7	81.5												
Ca Hardness	mg/L ^(a)	65.5	67.5	67.6												
Mg Hardness	mg/L ^(a)	15.6	13.2	13.9												
As (total)	µg/L	26.1	26.7	1.5	26.0	25.9	1.9	1.5	26.2	27.0	2.0	1.7	25.3	27.5	2.0	2.0
As (total soluble)	µg/L	23.2	23.0	1.2												
As (particulate)	µg/L	2.9	3.7	0.2												
As (III)	µg/L	17.6	1.1	0.9												
As (V)	µg/L	5.6	21.9	0.3												
Total Fe	µg/L	45	43	<25	73	70	<25	<25	106	112	45	35	98	97	46	42
Dissolved Fe	µg/L	<25	<25	<25												
Total Mn	µg/L	9.1	8.4	0.2	10.1	10.3	0.3	0.1	9.4	9.5	0.1	0.1	9.6	9.0	0.1	0.2
Dissolved Mn	µg/L	9.4	8.1	0.1												

(a) Measured as CaCO₃.

(b) Water quality parameters sampled on January 27, 2004.

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

NA = not analyzed.

Analytical Results from Long Term Sampling, Desert Sands MDWCA

Sampling Date		2/18/04			2/25/04				3/3/04				3/10/04			
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity	mg/L ^(a)	193	191	189	185	185	185	185	177	179	179	181	181	189	185	181
Fluoride	mg/L	0.6	0.6	0.6												
Sulfate	mg/L	190	190	190												
orthophosphate	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silica	mg/L	38.4	39.0	38.2	39.3	38.9	39.0	38.5	37.9	37.3	37.9	38.3	36.4	36.4	36.0	36.3
Sulfide	µg/L									NA	NA	NA				
NO ₃ -(N)	mg/L	<0.08	<0.08	<0.08												
Turbidity	NTU	2.4	0.2	0.7	0.3	0.3	0.1	0.1	0.3	0.1	0.2	<0.1	0.4	0.3	0.2	0.2
pH	-	7.8	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	NA	NA	8.0	7.9	7.8	7.8
Temperature	°C	29.8	30.1	30.2	29.7	28.9	29.0	29.4	29.9	29.7	NA	NA	30.4	30.8	30.6	30.6
DO	mg/L	1.2	1.3	1.4	1.2	1.2	5.2 1.1	1.6	1.3	1.3	NA	NA	1.3	1.2	1.2	1.2
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine	mg/L	NA	0.4	0.4	NA	0.4	0.4	0.4	NA	NA	NA	NA	NA	0.4	0.4	0.4
Total Chlorine	mg/L	NA	0.5	0.5	NA	0.5	0.5	0.5	NA	NA	NA	NA	NA	0.5	0.5	0.5
Total Hardness	mg/L ^(a)	89.4	87.4	89.2												
Ca Hardness	mg/L ^(a)	71.9	70.7	71.1												
Mg Hardness	mg/L ^(a)	17.5	16.7	18.1												
As (total)	µg/L	28.6	28.7	1.5	27.6	27.9	1.7	1.5	29.8	28.6	1.8	1.7	23.0	23.2	1.4	1.4
As (total soluble)	µg/L	23.9	23.6	1.4												
As (particulate)	µg/L	4.7	5.1	0.1												
As (III)	µg/L	22.8	1.1	1.1												
As (V)	µg/L	1.1	22.6	0.3												
Total Fe	µg/L	55	36	<25	35	31	<25	<25	39	30	<25	<25	53	47	<25	<25
Dissolved Fe	µg/L	<25	<25	<25												
Total Mn	µg/L	9.9	9.4	0.3	9.7	9.5	0.1	0.1	9.5	9.1	0.1	0.1	8.3	8.2	0.2	0.3
Dissolved Mn	µg/L	9.0	6.0	0.1												

(a) Measured as CaCO₃.
 IN = inlet; AC = after chlorination; TA = after tank A; TB = after the tank B; TT = after tanks combined.

Analytical Results from Long Term Sampling, Desert Sands MDWCA

Sampling Date		3/17/04			3/24/04				3/31/04				4/7/04			
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity	mg/L ^(a)	182	182	178	189	189	185	193	183	181	185	181	180	180	184	180
Fluoride	mg/L	0.5	0.5	0.5												
Sulfate	mg/L	190	180	190												
orthophosphate	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silica	mg/L	38.7	38.4	38.6	38.5	38.3	38.0	38.4	37.9	37.2	37.6	37.8	39.4	40.2	39.9	40.0
Sulfide	µg/L									NA	NA	NA				
NO ₃ -(N)	mg/L	<0.05	<0.05	<0.05												
Turbidity	NTU	0.5	0.2	0.2	0.4	0.3	0.1	0.1	1.0	1.5	0.5	0.2	0.9	1.0	0.2	0.4
pH	-	7.9	7.9	7.9	7.9	7.9	7.9	7.8	7.8	7.9	7.9	7.9	NA	NA	NA	NA
Temperature	°C	30.4	30.4	30.6	30.4	31.0	30.9	31.1	30.2	30.6	31.0	31.0	NA	NA	NA	NA
DO	mg/L	1.3	1.2	1.3	1.5	1.2	5.7 1.1	1.1	1.2	1.2	1.3	1.1	NA	NA	NA	NA
ORP	mV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Free Chlorine	mg/L	NA	0.4	0.4	NA	0.4	0.5	0.4	NA	0.5	0.5	NA	NA	NA	NA	NA
Total Chlorine	mg/L	NA	0.5	0.5	NA	0.5	0.5	0.5	NA	0.6	0.6	NA	NA	NA	NA	NA
Total Hardness	mg/L ^(a)	78.4	82.1	81.9												
Ca Hardness	mg/L ^(a)	63.9	67.4	66.6												
Mg Hardness	mg/L ^(a)	14.5	14.7	15.3												
As (total)	µg/L	22.6	22.3	0.9	25.9	25.9	2.4	2.5	20.7	21.2	1.8	1.9	30.1	30.1	1.9	1.8
As (total soluble)	µg/L	22.4	22.1	0.8												
As (particulate)	µg/L	0.2	0.2	0.1												
As (III)	µg/L	20.7	0.5	0.3												
As (V)	µg/L	1.7	21.6	0.5												
Total Fe	µg/L	49	32	<25	33	30	<25	<25	71	69	<25	<25	<25	<25	<25	<25
Dissolved Fe	µg/L	<25	<25	<25												
Total Mn	µg/L	8.5	7.6	<0.1	8.4	7.9	0.1	0.1	9.0	9.4	<0.1	0.1	7.5	7.3	0.1	0.1
Dissolved Mn	µg/L	7.5	5.3	<0.1												

(a) Measured as CaCO₃.

IN = inlet; AC = after chlorination; TA = after tank A; TB = after the tank B; TT = after tanks combined.

Analytical Results from Long Term Sampling, Desert Sands MDWCA

Sampling Date		4/14/04			4/30/04				5/12/04			5/26/04				
Sampling Location	Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Alkalinity	mg/L ^(a)		164	170	178	199	175	199	179	194	194	188	226 194	190 186	194 190	194 194
Fluoride	mg/L		0.7	0.7	0.7					0.6	0.6	0.6				
Sulfate	mg/L		190	190	180						180	180				
orthophosphate	mg/L		<0.10	<0.10	<0.10					<0.10	<0.10	<0.10	<0.10 <0.10	<0.10 <0.10	<0.10 <0.10	<0.10 <0.10
Silica	mg/L		38.2	38.1	37.6	38.1	38.0	38.0	37.9	37.4	37.5	37.7	38.3 38.1	37.3 37.1	37.9 37.1	37.6 37.2
Sulfide	µg/L									<5	NA	NA				
NO ₃ -(N)	mg/L		0.05	0.05	0.05			180		<0.05	<0.05	<0.05				
Turbidity	NTU		0.6	0.3	0.3					0.7	0.6	0.5	2.8 1.5	0.8 0.5	0.4 0.7	0.5 0.8
pH	-		7.9	7.9	8.0	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.9	7.8	7.8	7.7
Temperature	°C		29.6	29.5	29.5	30.3	30.6	30.1	30.5	30.7	30.9	31.2	31.0	31.3	31.2	31.1
DO	mg/L		1.3	1.3	1.3	1.2	1.2	1.1	1.2	1.2	1.1	1.3	1.2	1.1	1.6	1.5
ORP	mV		42	550	561	48	542	521	525	52	537	541	62	525	503	510
Free Chlorine	mg/L		NA	0.4	0.5	NA	0.4	0.4	0.4	NA	0.4	0.4	NA	0.5	0.5	0.5
Total Chlorine	mg/L		NA	0.5	0.6	NA	0.5	0.5	0.5	NA	0.5	0.5	NA	0.6	0.6	0.6
Total Hardness	mg/L ^(a)		85.7	85.3	84.0					101.1	111.1	110.1				
Ca Hardness	mg/L ^(a)		71.1	70.9	69.4					83.7	91.9	86.6				
Mg Hardness	mg/L ^(a)		14.6	14.4	14.6					17.4	19.2	23.5				
As (total)	µg/L		28.5	29.6	1.5	24.2	23.6	1.7	1.6	25.8	25.4	1.6	21.4 21.2	21.7 21.7	1.7 2.0	2.1 2.4
As (total soluble)	µg/L		24.8	24.7	1.6					22.0	20.3	1.4				
As (particulate)	µg/L		3.7	4.9	<0.1					3.8	5.1	0.2				
As (III)	µg/L		22.0	1.1	0.9					21.2	0.9	0.8				
As (V)	µg/L		2.8	23.6	0.7					0.8	19.4	0.6				
Total Fe	µg/L		<25	<25	<25	32	27	<25	<25	<25	<25	<25	64 51	40 38	<25 <25	<25 <25
Dissolved Fe	µg/L		<25	<25	<25						<25	<25				
Total Mn	µg/L		8.3	8.1	0.2	9.1	7.9	0.5	0.5	7.0	7.1	<0.1	9.9 9.1	8.6 8.4	0.3 0.3	0.3 0.3
Dissolved Mn	µg/L		8.0	6.2	0.1					7.1	5.9	<0.1				

(a) Measured as CaCO₃.

IN = inlet; AC = after chlorination; TA = after tank A; TB = after the tank B; TT = after tanks combined.

Analytical Results from Long Term Sampling, Desert Sands MDWCA

Sampling Date		06/09/04			06/23/04				07/07/04		
Sampling Location	Parameter	IN	AC	TT	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L ^(a)	187	187	182	195	179	171	175	197	197	189
Fluoride	mg/L	0.6	0.6	0.6					0.6	0.6	0.6
Sulfate	mg/L	170	170	180						190	190
orthophosphate	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Silica	mg/L	37.8	37.8	37.2	38.7	38.3	38.1	38.9	38.0	37.9	38.2
Sulfide	µg/L				<5	NA	NA	NA			
NO ₃ -(N)	mg/L	<0.04	<0.04	<0.04						<0.2	<0.2
Turbidity	NTU	2.7	0.6	0.3	0.8	0.7	0.4	0.5	0.2	0.2	0.1
pH	-	7.8	7.8	7.7	7.7	7.7	7.7	7.7	7.6	7.7	7.6
Temperature	°C	31.6	31.5	31.6	31.1	31.3	30.9	30.8	30.6	31.2	31.0
DO	mg/L	1.8	1.4	1.7	1.7	1.5	1.5	1.4	1.3	1.2	1.5
ORP	mV	55	488	495	490	501	631	528	81	486	502
Free Chlorine	mg/L	NA	0.4	0.5	NA	0.5	0.5	0.4	NA	0.4	0.4
Total Chlorine	mg/L	NA	0.5	0.5	NA	0.5	0.5	0.5	NA	0.4	0.5
Total Hardness	mg/L ^(a)	89.8	90.1	86.6					80.2	79.2	74.5
Ca Hardness	mg/L ^(a)	72.5	73.0	70.1					64.1	63.1	60.6
Mg Hardness	mg/L ^(a)	17.3	17.1	16.5	<0.2				16.1	16.1	13.9
As (total)	µg/L	25.1	25.4	3.0	25.0	25.6	2.4	2.8	23.7	23.9	2.8
As (total soluble)	µg/L	23.1	23.5	2.8					21.9	22.5	2.6
As (particulate)	µg/L	2.0	1.9	0.2					1.8	1.4	0.2
As (III)	µg/L	22.6	NA	1.8					21.0	1.1	1.2
As (V)	µg/L	0.5	NA	1.0					0.9	21.4	1.4
Total Fe	µg/L	50	28	<25	36	34	<25	<25	58	50	<25
Dissolved Fe	µg/L	<25	<25	<25						<25	<25
Total Mn	µg/L	11.0	8.8	0.8	7.9	7.7	<0.1	<0.1	8.9	9.4	0.5
Dissolved Mn	µg/L	10.5	9.2	0.5					8.6	5.7	0.3

(a) Measured as CaCO₃.

IN = inlet; AC = after chlorination; TA = after tank A; TB = after the tank B; TT = after tanks combined.

NA = not available.