EPA/600/R-06/152
December 2006

Arsenic Removal from Drinking Water by Iron Removal
U.S. EPA Demonstration Project at Climax, MN
Final Performance Evaluation Report

by

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

for

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FOREWORD

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Sally Gutierrez, Director
National Risk Management Research Laboratory

ABSTRACT

This report documents the activities performed and the results obtained for the arsenic removal treatment technology demonstration project at the Climax, Minnesota, site. The objectives of the project were to evaluate: (1) the effectiveness of Kinetico's Macrolite® pressure filtration process in removing arsenic to meet the new arsenic maximum contaminant level (MCL) of 10 μg/L; (2) the reliability of the treatment system; (3) the required system operation and maintenance (O&M) and operator's skills; and 4) the capital and O&M costs of the technology. The project also characterized water in the distribution system and process residuals produced by the treatment system.

The Macrolite® FM-236-AS arsenic removal system consisted of two 42-in-diameter by 72-in-tall contact tanks (345 gal), and two 36-in-diameter by 72-in-tall filtration vessels (264 gal), each containing 14 ft^3 of Macrolite® media. The system also included two chemical addition assemblies, one each for prechlorination and supplemental iron addition. Prechlorination was used to oxidize As(III) to As(V) and form As(V)-laden iron solids prior to the Macrolite® pressure filtration. The design flowrate was 140 gal/min (gpm), which yielded 5 min of contact time prior to pressure filtration and 10 gpm/ft^2 of hydraulic loading rate to the filters. From August 11, 2004, through August 12, 2005, the system operated for a total of 2,086 hr at approximately 5.6 hr/day. Based on the totalizer to treatment readings, the system treated approximately 13,829,000 gal of water with an average daily water demand of 38,560 gal during this time period. The system operated in the service mode within the flow and pressure specifications. Operational issues related to the automated backwash process led to a number of backwash failures, but were later resolved.

Total arsenic concentrations in source water ranged from 31.2 to 51.4 μg/L with As(III) being the predominating species at an average concentration of 35.8 μg/L. Iron in raw water existed primarily in the soluble form with an average value of 485 μg/L. This amount of soluble iron corresponded to an iron:arsenic ratio of 13:1 given the average soluble iron and soluble arsenic levels in raw water. From August 11, 2004, to January 3, 2005, total arsenic levels in the treated water averaged 14.1 μg/L, indicating the need for supplemental iron addition to improve arsenic removal.

Supplemental iron addition using ferric chloride was initiated on January 3, 2005, with an average iron dosage of approximately 0.85 mg/L (as Fe). Total arsenic levels in the treated water were reduced to 6.0 to 9.3 μg/L with no exceedances of arsenic above the 10-μg/L MCL. A slight increase in particulate iron was observed in the Macrolite® filter effluent with concentrations increasing from <25 to 36.8 μg/L before iron addition to <25 to 104 μg/L after iron addition. However, filtration of arsenic-laden particles at a hydraulic loading rate of up to 10.7 gpm/ft^2 (compared to 2 gpm/ft^2 for conventional gravity filters) and a median filter run time of 11 hr did not appear to have caused significant penetration of particles through the Macrolite® filters. The filters were set for backwash at 20 lb/in^2 increase in differential pressure across the filters, 24 hr of run time, or 48 hr of standby time.

After adjustments were made to the backwash control settings, the rate of backwash water generation was reduced to approximately 1.6% of the amount of treated water produced. The backwash water contained relatively low levels of soluble arsenic (i.e., 8.7 μg/L on average) and soluble iron (i.e., 86.4 μg/L on average); total arsenic levels ranged from 1,420 to 1,850 μg/L and total iron levels from 74.2 to 97.6 mg/L. The iron levels in the solids ranged from 2.46×10^5 to 3.12×10^5 μg/g and the arsenic levels from 3,830 to 4,540 μg/g. Given an average total suspended solid (TSS) loading of 233 mg/L and 1,000 gal per backwash event, approximately 1.9 lb of solids were generated per backwash event. The backwash solids passed the Toxicity Characteristic Leaching Procedure (TCLP) test for all analytes with only barium showing detectable concentrations ranging from 0.189 to 0.231 mg/L. The TCLP regulatory

limit set by EPA is 5 mg/L for arsenic and 100 mg/L for barium. As such, the backwash solids were non-hazardous.

Arsenic levels in the distribution system water samples averaged 10.3 μg/L after iron addition, which was higher than the average arsenic level in the treated water at 7.4 μg/L. The higher arsenic levels in the distribution system are an indication of potential solubilization, destablization, and/or desorption of arsenic-laden particles/scales in the distribution system. Total iron levels in the distribution system at an average of 74.7 μg/L were also higher in the distribution system, compared to the average value of 41.8 μg/L in the treated water. Manganese levels were generally lower in the distribution system samples at 33.8 μg/L, compared to 83.4 μg/L in the treated water. Lead levels in the distribution system were not affected by the treatment system. Copper concentrations appeared to have increased with concentrations ranging from 53 to 1,027 μg/L after system startup, but the teatment system did not appear to have impacted the pH, temperature, and/or hardness of the water in the distribution system.

The capital investment cost was $270,530, which included $159,419 for equipment, $39,344 for engineering, and $71,767 for installation. The equipment cost can vary based on the level of preassembly, automation, and instrumentation included on the system. Using the system's rated capacity of 140 gpm (201,600 gal/day [gpd]), the capital cost was $1,932 per gpm ($1.34 per gpd). These calculations did not include the cost of a building addition to house the treatment system. The total capital cost of $270,530 was converted to a unit cost of $0.35/1,000 gal, using a capital recovery factor (CRF) of 0.09439 based on a 7% interest rate and a 20-year return period. These calculations assumed that the system operated 24 hours a day, 7 days a week, at the system design flowrate of 140 gpm. The system operated only 5.6 hr/day and produced 13,829,000 gal of water during the study period. At this reduced usage rate, the total unit cost was increased to $1.85/1,000 gal.

The O&M cost for the system included only incremental expenses associated with the chemical supply, electricity consumption, and labor. The total O&M cost was estimated at $0.29/1,000 gal. The total cost for arsenic removal was estimated at $2.14/1,000 gal based on the actual water usage rate and capital and O&M cost incurred during the one-year demonstration study period.

CONTENTS

APPENDICES

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

AAL	American Analytical Laboratories
Al	aluminum
AM	adsorptive media
As	arsenic
BL	baseline
BTU-hr	British Thermal Units per hour
Ca	calcium
C/F	coagulation/filtration
Cl	chlorine
CRF	capital recovery factor
Cu	copper
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
FRP	fiberglass reinforced plastic
GFH	granular ferric hydroxide
gpd	gallons per day
gpm	gallons per minute
HDPE	high-density polyethylene
hp	horsepower
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
IX	ion exchange
LCR	Lead and Copper Rule
MCL	maximum contaminant level
MDL	method detection limit
MDH	Minnesota Department of Health
MDWCA	Mutual Domestic Water Consumer's Association
Mg	magnesium
Mn	manganese
Mo	molybolenum
mV	millivolts
Na	sodium
NA	not applicable
NaOCl	sodium hypochlorite

ABBREVIATIONS AND ACRONYMS (Continued)

NRMRL	National Risk Management Research Laboratory
NS	not sampled
NSF	NSF International
NTU	nephelometric turbidity units
O&M	operation and maintenance
OIP	operator-interface-panel
ORD	Office of Research and Development
ORP	oxidation-reduction potential
PE	professional engineer
P&ID	piping and instrumentation diagrams
PLC	programmable logic controller
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
Sb	antimony
SDWA	Safe Drinking Water Act
SM	system modification
STMGID	South Truckee Meadows General Improvement District
STS	Severn Trent Services
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
WRWC	White Rock Water Company
UPS	uninterruptible power supply
V	vanadium

ACKNOWLEDGMENTS

The authors wish to extend their sincere appreciation to the staff of the Water Department in Climax, Minnesota. The staff monitored the treatment system daily and collected samples from the treatment system and distribution system on a regular schedule throughout this study. This performance evaluation would not have been possible without their efforts.

Section 1.0: INTRODUCTION

1.1 Background

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

In October 2001, EPA announced an initiative for additional research and development of cost-effective technologies to help small community water systems (<10,000 customers) meet the new arsenic standard, and to provide technical assistance to operators of small systems in order to reduce compliance costs. As part of this Arsenic Rule Implementation Research Program, EPA's Office of Research and Development (ORD) proposed a project to conduct a series of full-scale, on-site demonstrations of arsenic removal technologies, process modifications, and engineering approaches applicable to small systems. Shortly thereafter, an announcement was published in the *Federal Register* requesting water utilities interested in participating in 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 water system in Climax, Minnesota, 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 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. Kinetico's Macrolite® pressure filtration process was selected for the Climax, Minnesota, facility.

Following a series of pre-demonstration activities including engineering design, permitting, and system installation, startup, and shakedown, the performance evaluation of the system began on August 11, 2004, and was completed on August 12, 2005.

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. An overview of the technology selection and system design for the 12 demonstration sites and the associated capital cost is provided in two EPA reports (Wang et al., 2004; Chen et al., 2004), which are posted on the EPA Web site at http://www.epa.gov/ORD/NRMRL/arsenic/ resource.htm.

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 required system operation and maintenance (O&M) and operator skill levels
- Determine the capital and O&M cost of the technologies
- Characterize process residuals produced by the technologies.

This report summarizes the performance of the Kinetico system in Climax, Minnesota, from August 11, 2004, through August 12, 2005. The types of data collected include system operation, water quality (both across the treatment train and in the distribution system), residuals, and capital and O&M cost.

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

Demonstration Site	Technology (Media)	Vendor	Design Flowrate (gpm)	Source Water Quality		
				As (µg/L)	Fe (µg/L)	pH
WRWC Public Water System, 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; GFH = granular ferric hydroxide; IX = ion exchange; SM = system modification; MDWCA = Mutual Domestic Water Consumer's Association; STMGID = South Truckee Meadows General Improvement District; STS = Severn Trent Services; WRWC = White Rock Water Company

(a) System reconfigured from parallel to series operation due to a reduced flowrate of 40 gpm.
(b) Arsenic existing mostly as As(III).
(c) Iron existing mostly as soluble Fe(II).

Section 2.0 SUMMARY AND CONCLUSIONS

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

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

- With proper pre-chlorination and supplemental iron addition, the Macrolite® pressure filtration system can consistently remove arsenic to < 10 µg/L. The addition of ferric chloride was needed to supplement the natural iron in raw water that had an average soluble iron to average soluble arsenic ratio of 13:1.
- Natural iron solids appear to have a greater As(V) adsorptive capacity than iron solids formed from supplemental iron addition. Analyses of backwash solids yield an Fe:As ratio of 67:1, which is much higher than the 20:1 ratio as a rule of thumb for effective arsenic removal (EPA, 2001; Sorg, 2002).
- Chlorine was effective in oxidizing As(III) to As(V), reducing As(III) concentrations from 35.8 µg/L (on average) in raw water to 2.0 µg/L (on average) after the contact tank.
- The pressure filters can be operated at filtration rates as high as 10.7 gpm/ft^2; no significant particulate arsenic leakage was observed under these high filtration rates. After iron addition, a slight increase in particulate iron (from < 25 to 42.8 µg/L [on average]) in the treated water was observed, however.
- Pre-chlorination oxidized and precipitated approximately 42% of soluble manganese; only particulate manganese was removed by the Macrolite® filters.

Simplicity of required system O&M and operator skill levels:

- The daily demand for operator labor was approximately 30 min; however, it was necessary for the operator to closely monitor backwash operational issues and work closely with the vendor to troubleshoot and perform on-site repairs throughout the study period.
- Backwash problems encountered were caused by improper field settings, turbidimeter malfunctioning, and power interruptions. The turbidimeter photo cell required frequent cleaning to maintain normal operations. Programming and hardware changes also were made to address backwash issues.

Process residuals produced by the technology:

- The rate of backwash water generation can be as low as 1.6%. The amount of solids produced per backwash event was 1.9 lb, which was composed of approximately 0.54 lb of iron and 0.008 lb of arsenic.

Cost-effectiveness of the technology:

- The unit capital cost is \$0.35/1,000 gal if the system operates at 100% utilization rate. The system's real unit cost is \$1.85/1,000 gal, based on 5.6 hr/day of system operation and 13,829,000 gal of water production. The O&M cost is \$0.29/1,000 gal, based on labor, chemical usage, and electricity consumption.

Section 3.0: MATERIALS AND METHODS

3.1 General Project Approach

Following the pre-demonstration activities summarized in Table 3-1, the performance evaluation of the Macrolite® treatment system began on August 11, 2004, and ended on August 12, 2005. Table 3-2 summarizes the types of data collected and considered as part of the technology evaluation process. The overall system performance was evaluated based on its ability to consistently remove arsenic to the target MCL of 10 μg/L 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 equipment repair and replacement. The unscheduled downtime and repair information were recorded by the plant operator on a Repair and Maintenance Log Sheet.

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

Activity	Date
Introductory Meeting Held	07/30/03
Request for Quotation Issued to Vendor	07/30/03
Vendor Quotation Received by Battelle	10/02/03
Purchase Order Completed and Signed	10/16/03
Letter of Understanding Issued	09/09/03
Letter Report Issued	10/20/03
Engineering Package Submitted to MDH	02/09/04
Permit Issued by MDH	06/22/04
Building Construction Begun	05/19/04
Final Study Plan Issued	07/12/04
Building Construction Completed	07/30/04
Macrolite® System Shipped by Kinetico	06/17/04
Macrolite® System Delivered to Climax, MN	06/21/04
System Installation Completed	07/30/04
System Shakedown Completed	08/11/04

MDH = Minnesota Department of Health

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

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

The quantity of aqueous and solid residuals generated was estimated by tracking the amount of backwash water produced during each backwash cycle. Backwash water was sampled and analyzed for chemical characteristics.

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 treated water
Reliability	-Unscheduled system downtime -Frequency and extent of repairs including a description of problems, materials and supplies needed and associated labor and cost
System O&M and Operator Skill Requirements	-Pre- and post-treatment requirements -Level of automation for system operation and data collection -Staffing requirements including number of operators and laborers -Task analysis of preventive maintenance including number, frequency, and complexity of tasks -Chemical handling and inventory requirements -General knowledge needed of relevant chemical processes and health and safety practices
Cost-Effectiveness	-Capital cost for equipment, engineering, and installation -O&M cost for chemical usage, electricity consumption, and labor
Residual Management	-Quantity of the residuals generated by the process -Characteristics of the aqueous and solid residuals

3.2 System O&M and Cost Data Collection

The plant operator performed daily, weekly, and monthly system O&M and data collection according to instruction provided by the vendor and Battelle. On a daily basis, the plant operator recorded system operational data, such as pressure, flowrate, totalizer, and hour meter readings on a Daily System Operation Log Sheet and conducted visual inspections to ensure normal system operations. In the event of problems, the plant operator would contact the Battelle Study Lead, who then would determine if Kinetico should be contacted for troubleshooting. The plant operator recorded all relevant information, including the problem, course of action taken, materials and supplies used, and associated cost and labor, on the Repair and Maintenance Log Sheet. On a weekly basis, the plant operator measured pH, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP), and recorded the data on a Weekly Water Quality Parameters Log Sheet. During the one year study period, the system was backwashed automatically, except during the monthly backwash sampling events when the system was backwashed manually to capture the required backwash samples.

The capital cost for the arsenic removal system consisted of the cost for equipment, site engineering, and system installation. The O&M cost consisted of the cost for chemical usage, electricity consumption, and labor. Ferric chloride consumption was tracked on the Daily Field Log Sheet. Electricity consumption was tracked through a comparison of utility bills before and after the system became operational. Labor 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 completing field logs, replenishing chemical solutions, ordering supplies, performing system inspections, and others as recommended by the vendor. The demonstration-related work, including activities such as performing field measurements, collecting and shipping samples, and communicating with the Battelle Study Lead and the vendor, was recorded, but not used for the cost analysis.

3.3 Sample Collection Procedures and Schedules

To evaluate the performance of the system, samples were collected at the wellhead, across treatment plant, during pressure filter backwash, and from the distribution system. Table 3-3 provides the sampling schedules and analytes measured during each sampling event. Specific requirements for the analytical

Table 3-3. Sample Collection Schedule and Analyses

Sample Type	Sample Locations[a]	No. of Samples	Frequency	Analytes	Date(s) Samples Collected
Source Water	At Wellhead (IN)	1	Once during initial site visit	As(total), particulate As, As(III), As(V), Fe (total and soluble), Mn (total and soluble), Al (total and soluble), Na, Ca, Mg, V, Mo, Sb, Cl, F, SO_4, SiO_2, PO_4, TOC, turbidity, and alkalinity	07/30/03
Treatment Plant Water	At Wellhead (IN), After Contact Tanks (AC), After Tank A (TA), After Tank B (TB)	4	Weekly	On-site: pH, temperature, DO/ORP, and Cl_2 (free and total) (except at wellhead) Off-site: As (total), Fe (total), Mn (total), SiO_2, PO_4, turbidity, and alkalinity	08/18/04, 08/24/04, 08/31/04, 09/14/04, 09/21/04, 09/28/04, 10/12/04, 10/19/04, 10/26/04, 11/09/04, 11/16/04, 12/07/04, 12/14/04, 01/11/05, 01/18/05, 01/25/05, 02/01/05, 02/16/05, 02/22/05, 03/01/05, 03/15/05, 03/22/05 03/29/05, 04/12/05 04/19/05, 04/26/05 05/10/05, 05/17/05 05/24/05, 06/07/05 06/14/05, 06/21/05 07/05/05, 07/12/05 07/19/05, 08/02/05
	At Wellhead (IN), After Contact Tanks (AC), After Tanks A and B Combined (TT)	3	Monthly	On-site: pH, temperature, DO/ORP, and Cl_2 (free and total) (except at wellhead). Off-site: As(total), particulate As, As(III), As(V), Fe (total and soluble), Mn (total and soluble), Ca, Mg, F, NO_3, SO_4, SiO_2, PO_4, turbidity, and alkalinity	08/11/04, 09/07/04, 10/05/04, 11/02/04, 11/30/04, 01/04/05, 02/08/05, 03/08/05, 04/05/05, 05/03/05, 05/31/05, 06/28/05, 07/26/05
Distribution Water	Three LCR Residences	3	Monthly	pH, alkalinity, As (total), Fe (total), Mn (total), Pb (total), and Cu (total)	Baseline Sampling[b] 01/28/04, 02/23/04 03/22/04, 04/27/04 Monthly Sampling: 08/31/04, 09/28/04 10/26/04, 11/30/04 12/14/04, 01/11/05 02/08/05, 03/08/05, 04/08/05, 05/03/05, 06/14/05, 07/12/05
Backwash Water	At Backwash Discharge Line from Tanks A and B	2	Monthly	TDS, TSS, turbidity, pH, As (total and soluble), Fe (total and soluble), and Mn (total and soluble)	09/24/04, 10/20/04, 11/16/04, 12/13/04, 01/12/05, 02/16/05, 03/22/05, 04/20/05, 05/24/05, 06/21/05, 07/27/05, 11/15/05[c]
Residual Sludge	At Backwash Discharge Point	2	Once	TCLP Metals As(Total)	08/09/05

(a) Abbreviation corresponding to the sample location in Figure 4-6.
(b) Four baseline sampling events performed before system became operational.
(c) Total/soluble metals and total suspended solids (TSS) collected during backwash event on November 15, 2005.

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

3.3.2 Treatment Plant Water Sample Collection. During the system performance evaluation study, the plant operator collected samples weekly, on a four-week cycle, for on- and off-site analyses. For the first three weekly events, samples were collected at four locations (i.e., at the wellhead [IN], after the contact tanks [AC], after Tank A [TA], and after Tank B [TB]) and analyzed for the analytes listed under the weekly treatment plant analyte list in Table 3-3. For the fourth weekly event, samples taken at IN, AC, and after Tanks A and B combined [TT] were speciated on-site and analyzed for the analytes listed under the monthly treatment plant analyte list in Table 3-3.

In addition, two separate studies (one each before and after iron addition) were carried out to assess fitler performance over the course of five filter runs. A series of filtered (using 0.45-µm disc fitlers) and unfiltered samples were collected at regular intervals throughout the entire duration of these filter runs. The samples were analyzed for As, Fe, and Mn to determine penetration of any particles through the Macrolite® filters.

3.3.3 Backwash Water Sample Collection. One backwash water sample was collected from each vessel during each of the first 11 sampling events from the sample tap located on the backwash water discharge line. Unfiltered samples were measured on-site for pH and off-site for total dissolved solids (TDS) and turbidity. Filtered samples using 0.45-µm disc filters were analyzed for soluble As, Fe, and Mn. During the final sampling event on November 15, 2005, the sampling procedure was modified to include the collection of composite samples for total As, Fe, and Mn as well as TSS. This modified procedure involved diverting a portion of backwash water from the backwash discharge line to a 32-gal plastic container over the duration of the backwash for each vessel and collecting a composite sample from the container after the content had been well mixed. The composite samples also were filtered using 0.45-µm disc filters and analyzed for soluble As, Fe, and Mn.

3.3.4 Backwash Solid Sample Collection. Backwash solid samples were collected from 1-gal plastic jars containing backwash water/solids collected during a backwash event on August 9, 2005. After solids in the jar were settled and the supernatant was carefully decanted, one aliquot of the solids/water mixture was taken for TCLP testing. The remaining solid/water mixture was air-dried, acid-digested, and analyzed for Mg, Al, Si, P, Ca, Fe, Mn, Ni, Cu, Zn, As, Cd, and Pb.

3.3.5 Distribution System Water Sample Collection. Samples were collected from the distribution system by the plant operator to determine the impact of the arsenic treatment system on the water chemistry in the distribution system: specifically, lead and copper levels. From January to April 2004, prior to the startup of the treatment system, four monthly baseline distribution system sampling events were conducted at three locations within the distribution system. Following the start-up of the arsenic adsorption system, distribution system sampling continued on a monthly basis at the same three locations.

The three homes selected for the sampling had been included in the City's Lead and Copper Rule (LCR) sampling. The samples collected at the LCR locations were taken following an instruction sheet developed according to the *Lead and Copper Monitoring and Reporting Guidance for Public Water Systems* (EPA, 2002). The first draw sample was collected from a cold-water faucet that had not been used for at least 6 hr 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. Analytes for the baseline samples coincided with the monthly distribution system water samples as described in Table 3-3. Arsenic speciation was not performed for the distribution system water samples.

3.4 Sampling Logistics

All sampling logistics including 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). Resin columns were prepared in batches at Battelle laboratories according to the procedures detailed in Appendix A of the EPA-endorsed QAPP (Battelle, 2003).

3.4.2 Preparation of Sampling Coolers. For each sampling event, a sample cooler was prepared with the appropriate number and type of sample bottles, disc filters, and/or speciation kits. All sample bottles were new and contained appropriate preservatives. Each sample bottle was affixed with a pre-printed, colored-coded, and waterproof label, consisting of the sample identification (ID), date and time of sample collection, collector's name, site location, sample destination, analysis required, and preservative. The sample ID consisted of a two-letter code for the specific water facility, sampling date, a two-letter code for a specific sampling location, and a one-letter code designating the arsenic speciation bottle (if necessary). The sampling locations at the treatment plant were color-coded for easy identification. For example, red, orange, yellow, green, and blue were used for IN, AC, TA, TB, and TT sampling locations. The pre-labeled bottles for each sampling location were placed in separate ziplock bags and packed 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). 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 FedEx air bills had already been completed with the required information. The sample coolers were shipped via FedEx 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 IDs were checked against the chain-of-custody forms and the samples were logged into the laboratory sample receipt log. Discrepancies noted by the sample custodian were addressed with the plant operator by the Battelle Study Lead.

Samples for water quality analyses were packed in separate coolers and picked up by couriers from American Analytical Laboratories (AAL) in Columbus, Ohio, and TCCI Laboratories in New Lexington, Ohio, both of which were under contract with Battelle for this demonstration study. Samples for metal analyses were stored at Battelle's Inductively Coupled Plasma-Mass Spectrometry (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

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

The analytical procedures described in Section 4.0 of the EPA-endorsed QAPP (Battelle, 2003) were followed by Battelle's ICP-MS, AAL, and TCCI Laboratories. Laboratory quality assurance/quality control (QA/QC) of all methods followed the prescribed guidelines. Data quality in terms of precision, accuracy, method detection limit (MDL), and completeness met the criteria established in the QAPP, i.e., relative percent difference (RPD) of 20%, percent recovery of 80% to 120%, and completeness of 80%. The quality assurance (QA) data associated with each analyte will be presented and evaluated in a QA/QC Summary Report to be prepared under separate cover upon completion of the Arsenic Demonstration Project.

Section 4.0: RESULTS AND DISCUSSION

4.1 Facility Description and Pre-Existing Treatment System Infrastructure

The water treatment system located on West Broadway in Climax, Minnesota, supplies drinking water to 264 community members. Figure 4-1 shows the pre-existing pump house at the facility. The water source is groundwater from two wells screened in a Quaternary Buried Artesian aquifer. Each well is 141 ft deep with 15 ft of slotted screen. Well No. 1 is 6-in diameter and has a 7.5 horsepower (hp) submersible pump with a capacity of 140 gpm. Well No. 2 is 8-in diameter and has a 10 hp submersible pump with a capacity of 160 gpm. These two wells are alternated every month to meet the peak daily demand of 105,000 gpd based on historic records. Both pumps are used during fire emergencies with a full capacity of 300 gpm. The treatment system originally consisted of a gas chlorine feed to reach a target chlorine residual level of 0.6 mg/L. The water also is fluoridated to a target level of 1.0 mg/L. Figure 4-2 shows the pre-existing wellhead and associated piping. The treated water is stored in a nearby water tower as shown in Figure 4-3.

4.1.1 Source Water Quality. Source water samples were collected on July 30, 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, MDH, and the vendor are presented in Table 4-1.

As shown in Table 4-1, total arsenic concentrations in source water ranged from 31.0 to 41.0 µg/L. Based on Battelle's July 30, 2003, sampling results, as much as 90% of the total arsenic, or 34.8 µg/L, was found to exist as As(III) and 10% existed as particulate As.

Figure 4-1. Pre-Existing Pump House at Climax, MN, Site

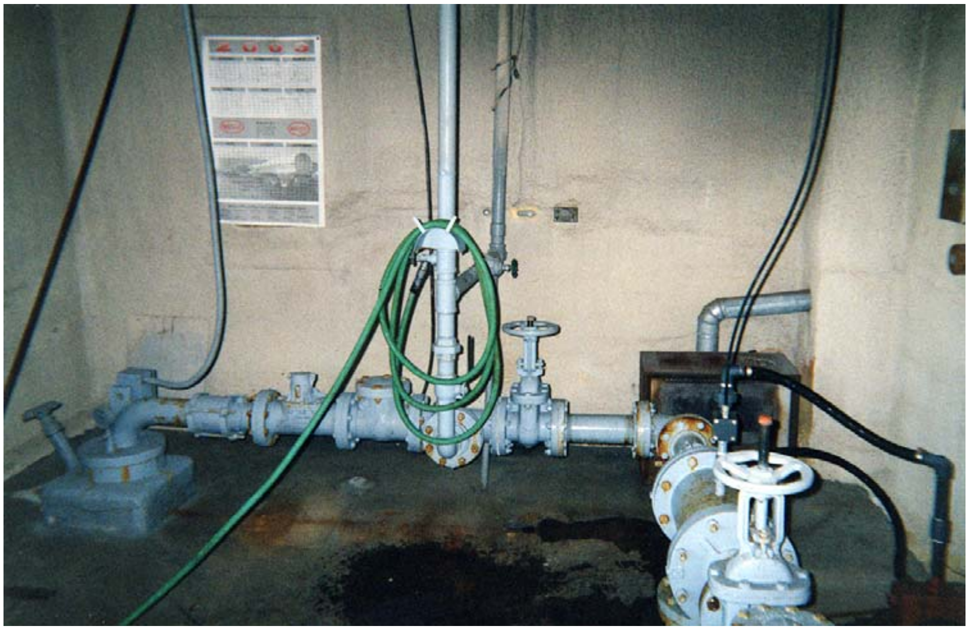

Figure 4-2. Pre-Existing Wellhead and Associated Piping

Figure 4-3. Climax, MN, Water Tower

Table 4-1. Climax, MN, Raw and Treated Water Quality Data

Parameter	Unit	Raw Water					Treated Water
		Utility Data	Vendor Data	EPA Data	Battelle Data	MDH Data	MDH Data
Date		-	-	10/16/02	07/30/03	2000-2003	2000-2003
pH	S.U.	7.6	7.9	NS	7.4	NS	NS
Alkalinity (as $CaCO_3$)	mg/L	325	332	328	304	NS	NS
Hardness (as $CaCO_3$)	mg/L	256	288	NS	228	NS	NS
Chloride	mg/L	180	180	183	190	NS	NS
Fluoride	mg/L	NS	0.5	NS	1.7	NS	0.5 to 1.6
Sulfate	mg/L	114	100	107	120	NS	110 to 120
Silica (as SiO_2)	mg/L	27.8[(a)]	29.9	28.0	27.3	NS	NS
Orthophosphate (as PO_4)	mg/L	<0.065[(a)]	<0.1	NS	<0.10	NS	NS
TOC	mg/L	NS	NS	NS	<1.0	NS	NS
As (total)	μg/L	38.0	31.0	33.0	38.7	33.0 to 41.0	<1.0 to 36.0
As (soluble)	μg/L	NS	NS	NS	34.6	NS	NS
As (particulate)	μg/L	NS	NS	NS	4.2	NS	NS
As(III)	μg/L	NS	NS	NS	34.8	NS	NS
As(V)	μg/L	NS	NS	NS	<0.1	NS	NS
Fe (total)	μg/L	850[(a)]	820	850	546	NS	NS
Fe (soluble)	μg/L	NS	NS	NS	540	NS	NS
Al (total)	μg/L	NS	NS	NS	<10	NS	NS
Al (soluble)	μg/L	NS	NS	NS	<10	NS	NS
Mn (total)	μg/L	145[(a)]	170	149	128	NS	NS
Mn (soluble)	μg/L	NS	NS	NS	130	NS	NS
V (total)	μg/L	NS	NS	NS	0.4	NS	NS
V (soluble)	μg/L	NS	NS	NS	0.4	NS	NS
Mo (total)	μg/L	NS	NS	NS	8.9	NS	NS
Mo (soluble)	μg/L	NS	NS	NS	8.7	NS	NS
Sb (total)	μg/L	NS	NS	NS	<0.1	NS	<0.6
Sb (soluble)	μg/L	NS	NS	NS	<0.1	NS	NS
Na (total)	mg/L	170	175	181	177	NS	180 to 190
Ca (total)	mg/L	74.0[(a)]	76.0	74.3	60.6	NS	NS
Mg (total)	mg/L	25.0[(a)]	24.0	24.5	18.5	NS	NS

(a) Data provided by EPA.
NS = not sampled

Iron concentrations in source water ranged from 546 to 850 μg/L with almost all existing as soluble iron based on Battelle's July 30, 2003, results. A rule of thumb is that the soluble iron concentration should be at least 20 times the soluble arsenic concentration for effective removal of arsenic onto iron solids (EPA, 2001; Sorg, 2002). The results from the July 30, 2003, sampling event indicated that the soluble iron level was approximately 16 times the soluble arsenic level. Because the natural iron content in the source water was close to the target Fe/As ratio of 20:1, the initial plan was to operate the system without supplemental iron addition. The manganese levels were elevated, ranging from 128 to 170 μg/L. The pH values ranged from 7.4 to 7.9. Hardness ranged from 228 to 288 mg/L, silica from 27.3 to 29.9 mg/L, and sulfate from 100 to 120 mg/L.

4.1.2 Distribution System and Treated Water Quality. The distribution system for Climax, Minnesota, is supplied by two wells, alternating on a monthly basis. The distribution system materials are primarily 6-in polyvinyl chloride (PVC) pipe with ¾-in PVC or copper pipe used at individual homes. The city conducts quarterly compliance sampling for coliform and fluoride and annual compliance sampling for arsenic. Prior to this demonstration project, the treatment system consisted of only a gas chlorine feed to reach a target chlorine residual level of 0.6 mg/L. The water also was fluoridated to a target level of approximately 1.0 mg/L with fluoride levels in the distribution system ranging from 0.5 to 1.6 mg/L (see Table 4-1). The historic As levels detected within the distribution system at several different sampling points, including residences, businesses, and at the treatment plant effluent, ranged from less than the detection limit to 36 µg/L based on MDH's treated water sampling data (see Table 4-1).

4.2 Treatment Process Description

The treatment train for the Climax system includes oxidation, co-precipitation/adsorption, and Macrolite® pressure filtration. Macrolite® is a low-density, spherical, and chemically inert ceramic media that is designed for a high-rate filtration up to 10 gpm/ft^2. The media, manufactured by Kinetico, is approved for use in drinking water applications under NSF International Standard 61. The physical properties of Macrolite® are summarized in Table 4-2.

Table 4-2. Physical Properties of 40/60 Mesh Macrolite® Media

Property	Value
Color	Taupe, Brown to Gray
Thermal Stability (°F)	2,000
Sphere Size Range (mm)	0.25 – 0.35
Sphere Size Range (in)	0.009 – 0.014
Bulk Density (g/cm^3)	0.86
Bulk Density (lb/ft^3)	54
Particle Density (g/cm^3)	2.05
Particle Density (lb/ft^3)	129

Figure 4-4 is a schematic and Figure 4-5 a photograph of the Macrolite® FM-236-AS Arsenic Removal System. The primary components consisted of one each chemical feed system for prechlorination and iron, two contact tanks, two pressure filtration vessels, and associated instrumentation to monitor pressure, flowrate, and turbidity (continuous turbidity monitoring was performed only during backwash). The system also was equipped with a central control panel that housed a touch screen operator-interface-panel (OIP), a programmable logic controller (PLC), a modem, and an uninterruptible power supply (UPS). The PLC automatically controlled the system by actuating PVC pneumatic valves using a 5-hp, 60-gal vertical air compressor. The system also featured Schedule 80 PVC solvent bonded plumbing and all of the necessary isolation valves, check valves, and sampling ports. Table 4-3 summarizes the system's design specifications. Figure 4-6 presents a process flowchart, along with the sampling/analysis schedule for the system. The major process steps and system components are presented as follows.

- **Oxidation -** The existing gas chlorine system was initially used for the oxidation of As(III) and Fe(II) in source water. Because it malfunctioned, the gas chlorine system was replaced on January 14, 2005 with a sodium hypochlorite (NaOCl) feed system, which consisted of a

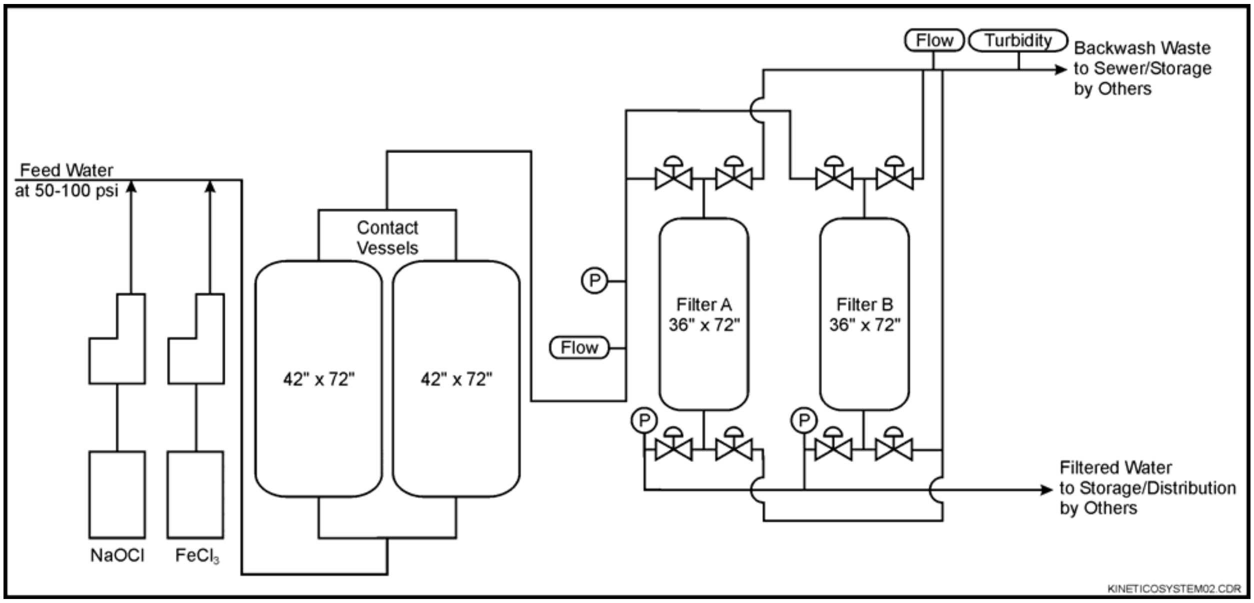

Figure 4-4. Process Schematic of Macrolite® Pressure Filtration System

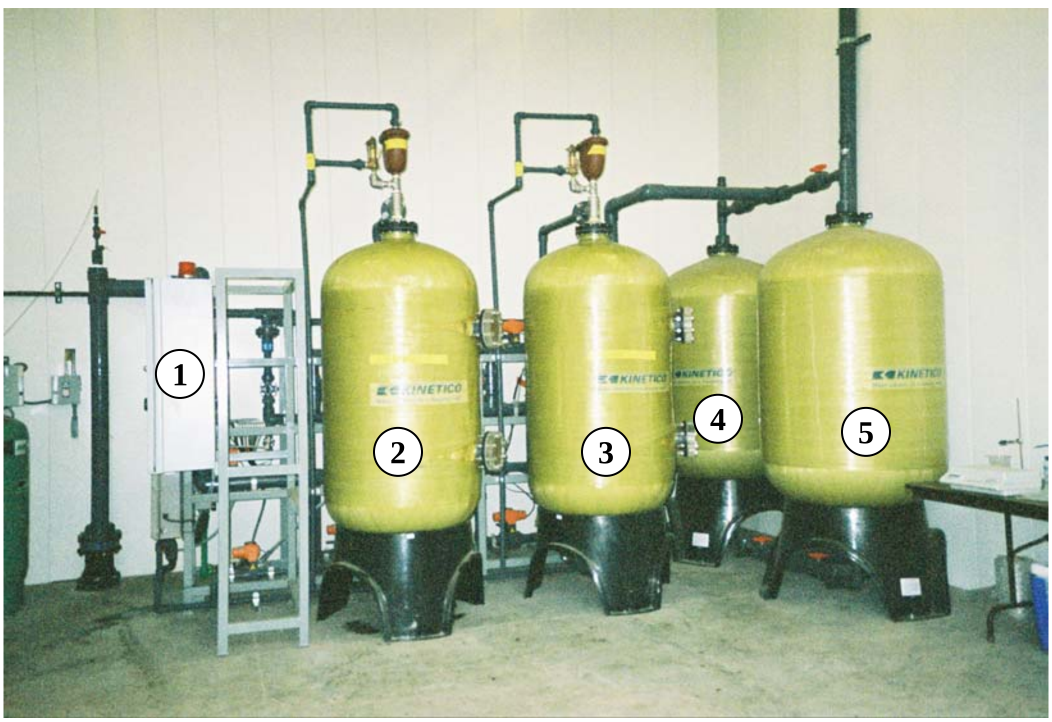

Figure 4-5. Photograph of Macrolite® Pressure Filtration System (Control Panel [#1], Macrolite® Filters [#2 and #3], and Contact Tanks [#4 and #5])

Table 4-3. Design Specifications for Macrolite® FM-236-AS Pressure Filtration System

Parameter	Value	Remarks
Pretreatment		
Prechlorination Dosage (mg/L [as Cl_2])	1.2	Sodium hypochlorite system installed on 01/14/05. Prior to that date chlorine gas was used. Calculated chlorine demand based on arsenic, iron, and manganese in source water was 0.6 mg/L. Actual demand was higher due to presence of ammonia in source water. Target free chlorine residual was 0.6 mg/L to distribution system.
Iron Dosage (mg/L [as Fe])	0.5	Implemented on 01/03/05
Contact		
Vessel Size (in)	42 D × 72 H	345 gal each tank
Number of Vessels	2	—
Configuration	Parallel	
Contact Time (min/vessel)	5	—
Filtration		
Vessel Size (in)	36 D × 72 H	264 gal each tank
Number of Vessels	2	—
Configuration	Parallel	—
Media Quantity (ft^3/vessel)	14	24-in bed depth of 40/60 mesh Macrolite® in each vessel
Media Type	Macrolite®	—
Design Flowrate (gpm)	140	70 gpm per vessel
Filtration Rate (gpm/ft^2)	10	—
Δp across Clean Bed (psi)	15	—
Maximum Daily Production (gpd)	201,600	Based on peak flow, 24 hr per day
Hydraulic Utilization (%)	52	Estimated based on peak daily demand[(a)]
Backwash		
Backwash Initiating Δp (psi)	20	Across bed at end of filter run
Throughput before Backwash (gal)	Variable	Based on PLC settings for pressure differential, run time, and standby time
Backwash Hydraulic Loading Rate (gpm/ft^2)	8 to 10	—
Backwash Duration (min)	Variable	Based on PLC settings for minimum and maximum backwash time (e.g. 7 and 15 min, respectively, factory set points)
Wastewater Generation (gal)	Variable	Based on PLC settings for minimum and maximum backwash time (e.g. 7 and 15 min, respectively, factory set points)

(a) Based on a historic peak daily demand of 105,000 gpd.

55-gal day tank and a 6-gal/hr chemical feed pump. The proper operation of the NaOCl system was tracked by the measurements of free and total chlorine residuals across the treatment train.

- **Supplemental Iron Addition -** The system was operated without supplemental iron addition from August 11, 2004, to January 2, 2005. Beginning on January 3, 2005, an iron addition system using a ferric chloride solution was used to inject a target dose of 0.5 mg/L of iron after the prechlorination tap. The iron addition system included one 55-gal polyethylene

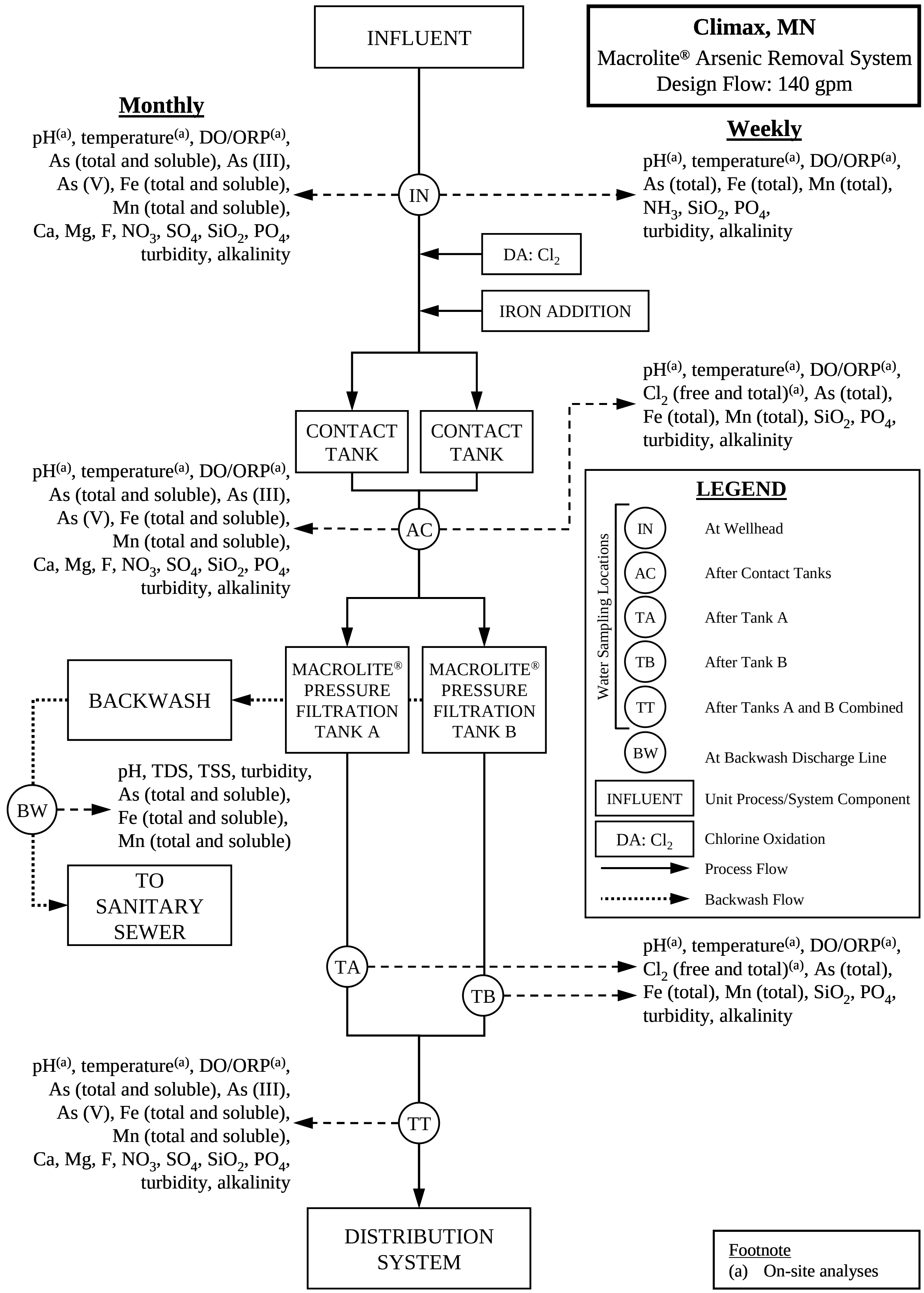

Figure 4-6. Process Flow Diagram and Sampling Locations

tank with containment, an overhead mixer, a 2.5-gal/hr chemical metering pump, and a 600-lb capacity drum scale. The working solution was prepared by adding 3 gal of a 35% ferric chloride stock solution into 47 gal of water. The consumption of the ferric chloride solution was measured based on the daily readings by the operator of the weight of the day tank.

- **Contact Time -** Two 345-gal contact tanks arranged in parallel were used to provide 5 min of contact time to facilitate the formation of iron flocs prior to filtration. The 42-in-diameter by 72-in-height contact tanks were constructed of fiberglass reinforced plastic (FRP) and had 6-in top and bottom flanges. The water passed through the contact tanks in an upflow configuration.

- **Pressure Filtration -** Pressure filtration involved downflow filtration through two pressure vessels arranged in parallel. The 36-in-diameter and 72-in-height FRP vessels, equipped with 6-in top and bottom flanges, were mounted on a polyurethane-coated steel frame. Each vessel was filled with approximately 24 in (14 ft^3) of 40/60 mesh Macrolite® media, which was underlain by a fine garnet fill layered 1 in above the 0.006-in slotted stainless steel wedge-wire underdrain. The flow through each vessel was regulated to less than 70 gpm using a flow-limiting device to prevent filter overrun or damage to the system. The normal system operation with both tanks would produce a total system flowrate of 140 gpm.

- **Backwash -** At a 10 gpm/ft^2 hydraulic loading rate and 24-in bed depth, the anticipated pressure drop was 15 pounds per square inch (psi) across a clean bed in service mode. As the pressure drop across the bed had reached 20 psi, the filter was automatically backwashed in an upflow configuration. The backwash might also be triggered by the length of time the system had been in service and/or in stand-by mode (see Section 4.4.2). During backwash, the water in one of the filtration vessels was first drained from the vessel and the filter was then sparged with air at 100 psig for 2 min. After a 5-min settling period, the filtration vessel was backwashed with treated water at approximately 55 gpm (or 8 gpm/ft^2) until the turbidity of the backwash water had reached a target threshold level of 6 nephelometric turbidity units (NTU) based on the factory setting. The backwash was conducted one vessel at a time and the resulting wastewater was sent to a sump before being discharged to the sanitary sewer. After backwash, the filtration vessel underwent a filter-to-waste cycle for 5-min before returning to the service mode.

4.3 System Installation

This section provides a summary of system installation activities including permitting, building construction, and system shakedown.

4.3.1 Permitting. Engineering plans for the system permit application were prepared by Kinetico and Widseth, Smith, and Nolting. The plans included diagrams and specifications for the Macrolite® FM-236-AS Arsenic Removal System, as well as drawings detailing the connections of the new system to the pre-existing facility infrastructure. The plans were submitted to the MDH on February 9, 2004. After changes were incorporated related to MDH comments from March 22 and May 24, 2004, MDH granted its approval of the application on June 22, 2004. On November 23, 2004, an approval also was granted for the installation and startup of a supplemental ferric chloride chemical feed system.

4.3.2 Building Construction. On May 19, 2004, the city began to build a building to house the treatment system. The 22-ft × 24-ft structure was built as an addition onto the existing concrete block well house. The building walls were constructed with a wood stud frame and 24-gauge pre-fabricated metal wall panels and set on a 6-in-thick concrete slab floor with footings. The building also was equipped with an insulated, 10-ft-wide overhead door. Because of a shortage of the interior metal wall panels, the treatment system was delivered and installed prior to completing the building interior walls. By July 30, 2004, the city had completed the building along with the sump installation and sanitary sewer connection, and obtained the duplex sump pumps as required by MDH. Figure 4-7 shows the new building adjacent to the pre-existing pump house and water tower.

Figure 4-7. New Building Constructed Adjacent to the Pre-Existing Pump House and Water Tower

4.3.3 System Installation, Shakedown, and Startup. The Macrolite® system was shipped on June 17, 2004, and delivered to the site on June 21, 2004. The vendor, through its subcontractor, performed the off-loading and installation of the system, including connections to the entry and distribution piping and electrical interlocking. The system mechanical equipment installation was completed by July 30, 2004, when the city completed the backwash sump installation. The system shakedown was conducted from August 4 to August 7, 2004.

Prior to system startup, the contact tanks and filtration vessels were sanitized using chlorine from the existing chlorine gas feed system. The Macrolite® filtration media was backwashed at 50 gpm (or 7 gpm/ft^2) for 2 to 3 hr to remove fines. During this initial backwash, adjustments were made to the sump pump to ensure proper drainage of backwash water to the sanitary sewer.

After it was turned to the service mode, the system experienced higher-than-normal system inlet pressure and lower-than-normal system flowrates. (Note that the system was specified for 140 gpm at a maximum system inlet pressure of 100 psi.) Careful examination of the operation of the well pumps and the system revealed that the system encountered an elevated inlet pressure (over 125 psi) with the 10-hp pump in

Well No. 2 operating at 126 to 130 gpm. This elevated pressure caused leakage of the seals in the flange assemblies at the top of the filtration vessels. With the 7.5-hp pump in Well No. 1 operating, the corresponding inlet pressure was 75 psi at 105 to 115 gpm. It was determined that the factory-installed flow restrictors had overly restricted the water flow through the system and that removal of some rubber inserts in the restrictors should resolve the problems. After removal of three inserts from each flow restrictor, the system inlet pressure was reduced to 59 to 74 psi with flowrates ranging from approximately 120 gpm for the 7.5 hp pump and 140 gpm for the 10-hp pump.

Other issues noted and corrective actions taken during the system shakedown included the installation of a bubble trap to reduce entrained air in backwash water as an attempt to alleviate high NTU readings on the backwash turbidimeter, installation of an hour meter to record cumulative hours of operation, and connection of the PLC to the pump motor starters to coordinate system operation.

During the August 5 to August 7, 2004 startup trip, the vendor conducted operator training for system operations and Battelle conducted a system inspection and operator training for system sampling and data collection. The treated water was sent to the distribution system on August 11, 2004. A Battelle staff member returned to the site on September 1, 2004, to review system operations and re-train the operator on proper use of the field handheld meter for pH, temperature, DO, and ORP measurements.

4.4 System Operation

4.4.1 Operational Parameters. Table 4-4 summarizes the operational parameters including operational time, throughput, flowrate, and pressure. Detailed daily operational data are attached as Appendix A. The plant operational data were recorded from August 16, 2004, through August 12, 2005.

Table 4-4. Summary of System Operation at Climax, MN

Parameter	Values	
Operational Period	August 16, 2004 – August 12, 2005	
Total Operating Time (hr)	2,086	
Average Daily Operating Time (hr)	5.6	
Throughput to Distribution (gal)	13,829,000	
Average Daily Demand (gpd)	38,560	
Peak Daily Demand (gpd)	107,100	
Number of Backwash Cycles[(a)]	189	
Run Time between Backwash Cycles (hr)	3 – 20	
Throughput between Backwash Cycles (gal)	20,540 – 131,600	
	Well No. 1 (7.5 HP)	**Well No. 2 (10 HP)**
Average Flowrate (gpm)	122	142
Range of Flowrates (gpm)	104 – 134	121 – 151
Contact Time (min)	5.1 – 6.6	4.6 – 5.7
Hydraulic Loading Rate to Macrolite® Filters (gpm/ft^2)	7.4 – 9.5	8.6 – 10.7
Δp across Filtration Vessels A and B (psi)	5 – 18	7 – 21
Δp across Entire System (psi)	19 – 30	21 – 34

(a) Backwash triggered by 48-hr standby time, 24-hr run time, or 20 psi pressure loss. Count not including backwash malfunctions on March 14, 2005, and March 30, 2005, which resulted in multiple successive backwash cycles.

Between August 16, 2004, and August 12, 2005, the treatment system operated for approximately 2,086 hr, based on the PLC hour meter readings, with an average daily operating time of 5.6 hr/day. The total system throughput was approximately 13,829,000 gal based on the flow totalizer readings. The average daily demand was approximately 38,560 gal and the peak daily demand occurred on July 28, 2005, at 107,100 gal. During this time period, a total number of 189 backwash cycles took place. The run time between backwash cycles ranged from approximately 3 to 20 hr and the throughput between backwash cycles from 20,540 to 131,600 gal. The median value of run time was 11 hr and the median throughput was 73,050 gal between two consecutive backwash cycles. The throughput varied based on the amount of run time required to meet demand and the corresponding amount of time that the system was in standby mode. The filter run ended when the system had been in service mode for 24 hr or in standby mode for 48 hr, unless a pressure-initiated backwash was triggered.

The flowrate through the system varied slightly based on which well pump was operational. When the Well No. 1 pump (7.5 hp) was operational, the flowrate readings ranged from 104 to 134 gpm with an average value of 122 gpm. This corresponded to a contact time of 5.1 to 6.6 min, compared to a design value of 5 min. At these flowrates, the hydraulic loading rates to the filter ranged from 7.4 to 9.5 gpm/ft^2, compared to the design value of 10 gpm/ft^2. When the Well No. 2 pump (10 hp) was operational, the flowrate readings ranged from 121 to 151 gpm with an average value of 142 gpm. This corresponded to a contact time of 4.6 to 5.7 min and a hydraulic loading rate of 8.6 to 10.7 gpm/ft^2, which were closer to the respective design values.

Figure 4-8 illustrates differential pressure (Δp) readings across the system and filtration Vessels A and B. With Well No. 1 operating and before iron addition, the Δp readings ranged from 19 to 30 psi across the system and from 5 to 14 psi across Vessels A and B. With Well No. 2 operating and before iron addition, the Δp readings ranged from 26 to 33 psi across the system and from 8 to 16 psi across Vessels A and B.

After the start of iron addition, the Δp readings across the system ranged from 19 to 26 psi for Well 1 and 21 to 34 psi for Well 2. There was a slight increase in the Δp readings across Vessels A and B after iron addition, ranging from 5 to 18 psi for Well 1 and 7 to 21 psi for Well 2. This represents a 4 to 5 psi increase in the pressure drop across the filters after the start of iron addition. The majority of backwash cycles during the one year study period occurred as a result of the elapse of the 48-hr standby time. After each backwash event, a filter-to-waste cycle occurred for 5 min to flush water through the filter bed in the downflow mode before returning to service.

4.4.2 **Backwash**. The system PLC was set to initiate a backwash based on four potential triggers: (1) high differential pressure, (2) standby time, (3) run time, or (4) manual initiation. Table 4-5 summarizes the programming set points associated with these automatic backwash triggers (20 psi Δp, 48 hr of standby time, or 24 hr system run time) and the backwash duration. The backwash duration was controlled by the minimum and maximum backwash time per vessel and the backwash water turbidity measured by a Hach™ turbidimeter. Under the factory settings, if the turbidity threshold of 6 NTU was reached before the minimum backwash time set point, backwash would end at the minimum backwash time of 7 min. Otherwise, it would continue until the target turbidity threshold was reached. If the turbidity threshold was not reached at the end of the maximum backwash time of 15 min, then a backwash failure would be indicated and the operator had to acknowledge the alarm. This would result in a repeat backwash before the pressure filter could resume service. The use of turbidity as one of the backwash set points was designed as a potential water-saving measure. Table 4-5 provides a comparison of the factory settings to the initial field settings at startup of the treatment system on August 11, 2004, and the modified field settings which were set on January 14, 2005.

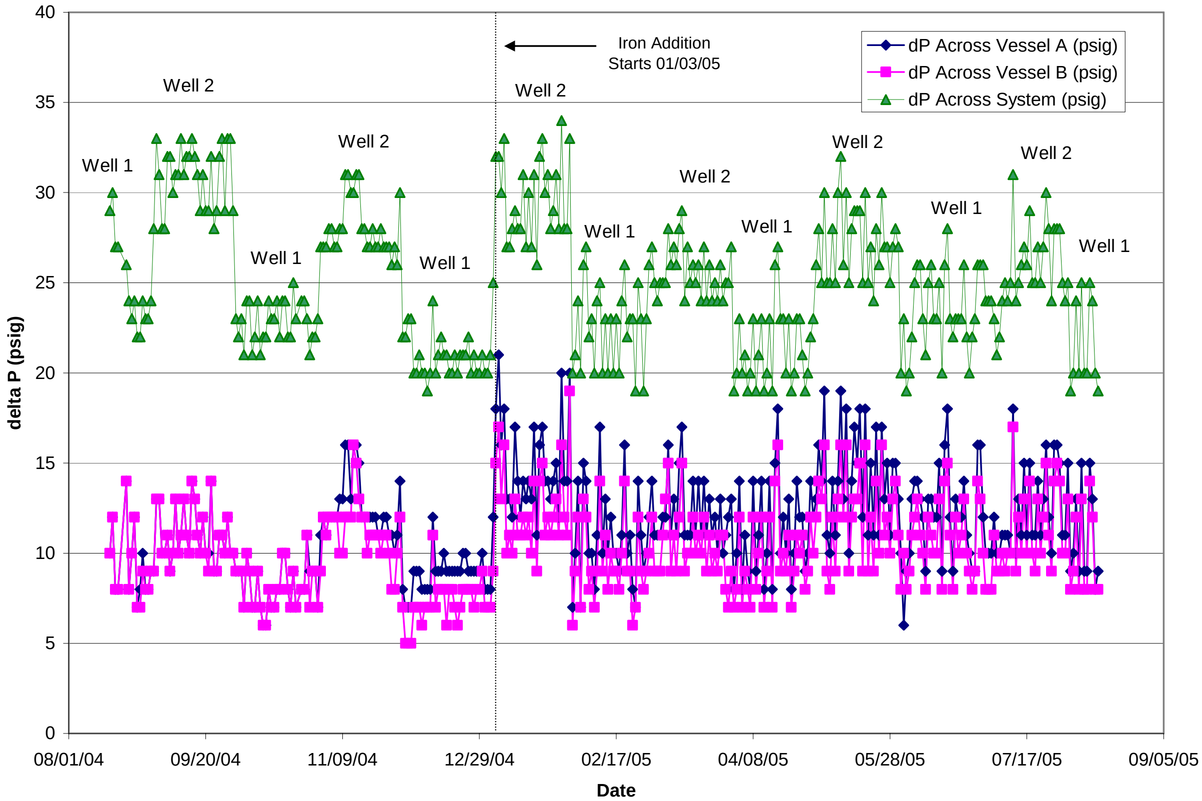

Figure 4-8. Δp Readings across Macrolite® System and Filtration Vessels A and B

Table 4-5. Summary of PLC Settings for Automated Backwash Operations at Climax, MN

Parameter	Factory Setting	Initial Field Settings (From 08/11/04 through 01/14/05)	Modified Field Settings (From 01/14/05 through 08/12/05)
Δp Trigger (psi)	20	20	20
Standby Time Trigger (hr)	48	48	48
Run Time Trigger (hr)	24	24	24
Minimum Backwash Time Per Vessel (min)	7	18[(a)]	5
Maximum Backwash Time Per Vessel (min)	15	15	15
Turbidity Threshold (NTU)	6	45	20
Low Backwash Flow Set Point (gpm)	75	75	75

(a) Minimum backwash time longer than maximum backwash time, which was corrected on January 14, 2005, when field settings were modified.

Several issues associated with the automated backwash process arose during the one year duration of system operations, including correction of initial field set points and operational issues associated with the Hach™ turbidimeter, fuse replacement, and backwash control malfunctions related to electrical power outages. These issues are discussed as follows.

4.4.2.1 Backwash Settings. Table 4-6 summarizes data related to the backwash duration and backwash water quantity produced under the initial and modified field settings from August 11, 2004, through January 14, 2005, and from January 14, 2005, through August 12, 2005, respectively. The backwash flowrate for both time periods was approximately 50 gpm or 7 gpm/ft^2, which is lower than the 8 to 10 gpm/ft^2 design value. The backwash flowrate was lowered during the system startup to avoid media loss that was observed when a higher flowrate, such as the factory set point of 75 gpm, was used.

Between August 11, 2004, and January 14, 2005, each backwash cycle lasted for at least 18 min per vessel with one cycle that lasted for up to 53 min per vessel. The median backwash time was 18 min per vessel. The wastewater generated from backwash was 800 to 2,650 gal per vessel. The median value was 900 gal corresponding to a 50-gpm backwash flowrate for an 18 min duration. From January 14, 2005, to August 12, 2005, each backwash cycle lasted for 5 to 306 min per vessel with a median value at 10 min per vessel. The quantities of backwash water generated ranged from 250 to 15,300 gal per vessel with a median value of 500 gal per vessel. The maximum value of 15,300 gal was the result of a backwash control malfunction on March 14, 2005, which will be discussed below.

Since the startup through January 14, 2005, the system produced 126,900 gal of backwash water (including the initial backwash cycles after media loading). This amount was equivalent to 2.4% of the total amount of water treated (i.e., 5,275,950 gal) during this time period. The time to backwash each vessel was at least 18 min, which was the minimum backwash time set by the vendor at the system startup. This 18-min backwash time was 3 min longer than the factory-set maximum backwash time or 2.6 times longer than the factory-set minimum backwash time (see Table 4-5). In addition, because of entrained air in the backwash water, the turbidity threshold was reset at an elevated level of 45 NTU at the system startup (instead of the 6 NTU factory setting).

Table 4-6. Summary of Backwash Parameters

Backwash Parameters	Minimum	Median	Maximum
Initial Field Settings (From 08/11/04 through 01/14/05) (a)			
Backwash Duration Per Vessel (min)	18	18	53(c)
Backwash Water Quantity Generated Per Vessel (gal)	800	900	2,650(c)
Modified Field Setting (From 01/14/05 through 08/12/05) (b)			
Backwash Duration Per Vessel (min)	5	10	306(c)
Backwash Water Quantity Generated Per Vessel (gal)	250	500	15,300(c)

(a) Seventy-one backwash cycles recorded during this time period (70 for Vessel A; 71 for Vessel B).
(b) One-hundred and nineteen backwash cycles recorded during this time period (119 for Vessel A; 115 for Vessel B). Count not including backwash malfunctions on March 14, 2005, and March 30, 2005, which resulted in multiple successive backwash cycles.
(c) Repeat backwash cycles occurred on same day due to failure to reach turbidity threshold or other backwash control malfunction.

Figure 4-9 includes six backwash water turbidity profiles. Four of the profiles were collected prior to the start of iron addition on January 3, 2005. These four profiles included two (one for each vessel) recorded manually by the plant operator over one backwash cycle and two recorded remotely by the vendor using a dial-in modem over a separate backwash cycle, all with the minimum backwash time set at 18 min and the turbidity threshold set at 45 NTU. As shown in the figure, the data collected manually by the operator were comparable to those collected remotely by the vendor and the turbidity values of the backwash water were reduced to below 40 NTU in the first 7 min, and to below 20 NTU after approximately 9 min of backwashing. For the remaining 9 min of the 18 min minimum set time, the turbidity values leveled off at 8 to 16 NTU. These results indicate that the 18 min minimum backwash time and the 45 NTU turbidity threshold settings were overly conservative and could be significantly reduced to save water. (Note that approximately 900 gal of wastewater was produced per vessel under these field settings.)

On January 14, 2005, the backwash settings were modified to more closely match the factory settings. The minimum backwash time was changed from 18 to 5 min and the turbidity threshold was lowered from 45 to 20 NTU. Also presented in Figure 4-9 are two backwash water turbidity profiles with the modified PLC settings. Even after iron addition that resulted in turbidity readings much higher than 100 NTU, the time to reach 20 NTU remained at approximately 9 to 10 min for both vessels.

Under these modified settings, the treatment system produced 163,500 gal of backwash water from January 14, 2005, through August 12, 2005. This is equivalent to 1.9% of the total amount of water treated and represents 0.5% (i.e., reduced from 2.4 to 1.9%) of water savings compared to that under the initial field settings from August 11, 2004, to January 14, 2005. The water savings potentially could have been higher, but backwash control problems discussed below in Section 4.4.2.2 significantly increased the quantity of backwash water generated.

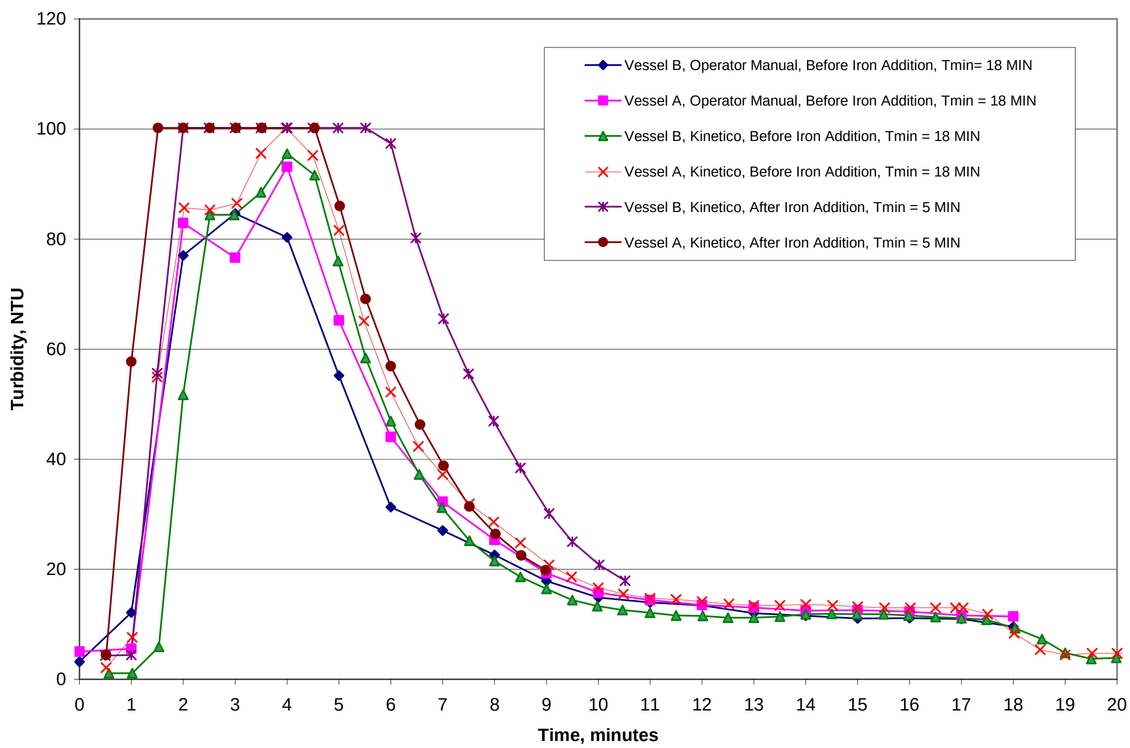

Figure 4-9. Backwash Water Turbidity Profiles

4.4.2.2 ***Other Backwash Problems.*** In addition to the backwash settings, other backwash problems were encountered throughout the study period. Table 4-7 summarizes the problems encountered, volume of backwash water produced as a result of the problems, and corrective actions taken.

Table 4-7. Summary of Backwash Issues Reported During Study Period

Date	Volume of Backwash Water Generated from Vessels A and B Combined (gal)	Problem Encountered/Action Taken
10/22/04	3,200	Backwash failed to reach turbidity threshold of 45 NTU. Alarm acknowledged. Manual backwash initiated by operator.
11/18/04	5,300	Backwash failed to reach turbidity threshold of 45 NTU. Alarm acknowledged. Manual backwash initiated by operator.
11/26/04	3,300	Backwash failed to reach turbidity threshold of 45 NTU on Vessel A. Alarm acknowledged. Manual backwash initiated by operator.
12/18/04	1,700	Backwash failure noted by operator. Backwash volume within normal limits. Cause not identified by operator.
01/09/05	3,300	Backwash failure due to low flowrate at 35 gpm. Operator initiated a manual backwash and opened valve to achieve more flow at 50 gpm.
02/02/05	4,600	Backwash failed to reach turbidity threshold of 20 NTU. Alarm acknowledged. Manual backwash initiated by operator.
02/12/05	6,700	Backwash failed to reach turbidity threshold of 20 NTU. Alarm acknowledged. Manual backwash initiated by operator. Operator subsequently noted deposit on turbidimeter lense and cleaned to restore operation.
02/27/05	2,400	Backwash failed to reach turbidity threshold of 20 NTU on Vessel B. Alarm acknowledged. Manual backwash initiated by operator.
03/14/05	15,900	Backwash failure due to loss of control by PLC after power outage. Vessel B in backwash mode for at least 5 hr, generating 15,300 gal of wastewater. Issue addressed by operator by re-booting PLC.
03/30/05	14,000	Backwash failure due to loss of control by PLC after power outage. Vessel B in backwash mode for at least 4.5 hr, generating 13,500 gal of wastewater. Issue addressed by operator by re-booting PLC and replacing a fuse in control panel.
04/10/05	2,600	Backwash failed to reach turbidity threshold of 20 NTU. Alarm acknowledged. Operator cleaned deposit on turbidimeter lense. After cleaning, manual backwash was initiated by operator.
06/18/05	2,400	Backwash failed to reach turbidity threshold of 20 NTU due to deposit on turbidimeter lense.
06/19/05	3,400	Backwash failed to reach turbidity threshold of 20 NTU due to deposit on turbidimeter lense.
06/20/05	2,400	Backwash failed to reach turbidity threshold of 20 NTU due to deposit on turbidimeter lense. Operator subsequently cleaned lense on turbidimeter.
07/06/05	900	Backwash failure noted by operator. Backwash volume within normal limits. Cause not identified by operator.

As described above, the duration of each backwash cycle was controlled by the backwash water turbidity reaching a pre-set threshold. Operational issues with the Hach™ turbidimeter resulted in backwash malfunctions that extended the duration of several backwash cycles over the one year study period. The first operational issue was related to entrained air in the backwash water and the second related to the build-up of deposits on the photocell of the Hach™ turbidimeter.

After system startup on August 11, 2004, several steps were taken by the vendor to troubleshoot elevated turbidity readings in the backwash water. It was noted during system shakedown that the turbidity readings of backwash water remained significantly higher than the factory setpoint of 6 NTU at the end of each backwash cycle. The turbidity threshold was therefore re-set to 45 NTU in the PLC at system startup on August 11, 2004. The elevated NTU readings were first addressed through the installation of a bubble trap on the turbidimeter line (on August 11, 2004), followed by the repair of a leaky air-actuated valve (on September 15, 2004), and testing of the compressed air supply in November 2004 to ensure that it did not contribute to entrained air in the backwash water.

On January 14, 2005, the PLC settings were changed to more closely match the factory-defined settings with the turbidity threshold of 20 NTU, the minimum backwash time of 5 min, and the maximum backwash time of 15 min. After January 14 to August 12, 2005, the NTU readings at the end of the backwash cycles ranged from 5.9 to 19.2 with the exception of seven backwash cycles when the backwash did not meet the turbidity threshold of 20 NTU. Five of these seven cycles were related to the build-up of deposits on the photocell of the Hach™ turbidimeter. The operator reported that the backwash malfunction on February 12, 2005, produced 6,700 gal of backwash water and was apparently caused by calcium deposits on the photocell. To minimize this problem, the glass lens was periodically inspected and cleaned as part of the routine maintenance. Nevertheless, similar problems reoccurred on April 10, June 18, June 19, and June 20, 2005.

Two backwash malfunctions occurred relating to electrical problems with the treatment plant. These two backwash malfunctions produced over 29,900 gal backwash water. Without these two backwash malfunctions, the backwash water generated would have been reduced to only 1.6% (instead of 1.9%) of the treated water during the time period from January 14, 2005, to August 12, 2005. These backwash malfunctions were initially reported to be related to a bad fuse in the control panel. However, it was later determined that the uncontrolled backwash cycles were likely related to temporary power outages and the PLC programming logic sequence that controlled the opening and closing of the backwash valves. On March 14, 2005, approximately 15,300 gal of backwash water was discharged to the sanitary sewer during the backwash of Tank B (15,900 gallons total from both vessels). At a flowrate of 50 gpm, this would equate to at least 5 hr of continuous backwash during this cycle. Troubleshooting activities performed by the operator included turning the system on and off to re-set the PLC and valve settings and replacing the modem to allow the vendor to dial-in to the PLC. On March 30, 2005, the system experienced another backwash problem with Tank B operating in a continuous backwash mode for approximately 4.5 hr generating 13,500 gal of wastewater (14,000 from both vessels). After examination of the PLC panel, a 5-amp fuse was determined to be bad and subsequently replaced by the operator. No additional backwash malfunctions of this magnitude were experienced after the fuse replacement through the end of the study in August 2005. However, the vendor later determined that the uncontrolled backwash cycles might have been caused by a temporary loss in power to the PLC, which interrupted the sequence of valve operations. This power interruption subsequently caused the backwash valves to remain open until manually reset by an operator. This issue was addressed through programming changes in the PLC logic and the installation of an uninterruptible power supply (UPS) unit on December 15, 2005, to provide back-up power to the PLC. With these repairs taken into account, the rate of backwash water generation was reduced to approximately 1.6% of the amount of treated water produced.

4.4.3 Residual Management. Residuals produced by the operation of the system included only backwash water, which was discharged to an underground sump and then pumped to a nearby sanitary sewer line for disposal.

4.4.4 System/Operation Reliability and Simplicity. No major operational problems were encountered in the service mode. The only major operational issues encountered were related to the filter backwash as described in Section 4.4.2. Neither scheduled nor unscheduled downtime had been required since the start of system operations. The required system operation and operator skills are discussed according to pre- and post-treatment requirements, levels of system automation, operator skill requirements, preventive maintenance activities, and frequency of chemical/media handling and inventory requirements.

4.4.4.1 Pre- and Post-Treatment Requirements. Pre-treatment at the site included prechlorination for the oxidation of arsenic and iron and supplemental iron addition to enhance the arsenic removal from raw water. Specific chemical handling requirements are further discussed under chemical handling and inventory requirements.

4.4.4.2 System Automation. All major functions of the treatment system are automated and would require only minimal operator oversight and intervention if all functions are operating as intended. Automated processes include system startup in the forward feed mode when the well energizes, backwash cycling based on time or pressure triggers, fast rinse cycling, and system shutdown when the well pump shuts down. However, as noted in Section 4.4.2, a number of operational issues did arise with the automated system backwash and associated equipment.

4.4.4.3 Operator Skill Requirements. Under normal operating conditions, the skill set required to operate the Macrolite® system was limited to observation of the process equipment integrity and operating parameters such as pressure, flow, and system alarms. The PLC interface was intuitive and all major system operations were automated as described above. The daily demand on the operator was about 30 min to visually inspect the system and record the operating parameters on the log sheets. Other skills needed included performing O&M activities such as cleaning the turbidimeter photo cell, monitoring backwash operational issues, and working with the vendor to troubleshoot and perform minor on-site repairs.

4.4.4.4 Preventive Maintenance Activities. Preventive maintenance tasks recommended by the vendor included daily to monthly visual inspection of the piping, valves, tanks, flowmeters, and other system components. Routine maintenance also may be required on an as-needed basis for the air compressor motor and the replacement of o-ring seals or gaskets on automated or manual valves (Kinetico, 2004). Maintenance activities performed by the operator included the repair of a leaky fitting and removal of rubber inserts in the flow restrictors for each filtration vessel during system startup. On September 15, 2004, the operator repaired an air leak associated with an air-actuated valve on the bottom of Tank B. It also was found that cleaning of the turbidimeter photocell was required to prevent the buildup of deposits. On December 15, 2005, a UPS was installed to address the backwash malfunctions that occurred during power outages (see Section 4.4.2.2). Other maintenance and troubleshooting activities were conducted as described in Section 4.4.2 related to the malfunction of automated backwash operations.

4.4.4.5 Chemical/Media Handling and Inventory Requirements. Prechlorination was implemented since the system startup and supplemental iron addition was initiated on January 3, 2005. The iron addition required only minimal effort (10 min as reported by the operator) to prepare the iron solution approximately once every two weeks. The sodium hypochlorite and ferric chloride chemical consumption was checked each day as part of the routine operational data collection.

4.5 System Performance

The performance of the Macrolite® FM-236-AS Arsenic Removal System was evaluated based on analyses of water samples collected from the treatment plant, backwash lines, and distribution system.

Table 4-8. Summary of Arsenic, Iron, and Manganese Analytical Results before and after Supplemental Iron Addition[(a)]

Parameter	Sampling Location	Unit	Number of Samples	Concentration			
				Minimum	Maximum	Average	Standard Deviation
As (total)	IN	μg/L	53	31.2	51.4	36.5	4.2
	AC	μg/L	19 [34]	33.4 [18.5]	72.0 [42.1]	39.4 [35.1]	9.0 [3.9]
	TA	μg/L	14 [26]	9.3 [5.2]	17.9 [9.0]	11.3 [6.6]	2.3 [0.9]
	TB	μg/L	14 [26]	9.9 [5.6]	18.3 [9.7]	12.1 [6.9]	2.5 [1.0]
	TT	μg/L	5 [8]	9.7 [6.0]	19.0 [9.3]	14.1 [7.4]	4.1 [1.2]
As (soluble)	IN	μg/L	13	33.3	51.3	37.8	4.4
	AC	μg/L	5 [8]	11.0 [4.5]	19.5 [18.3]	14.7 [11.7]	3.8 [3.8]
	TT	μg/L	5 [8]	9.7 [4.8]	16.1 [8.8]	12.6 [6.5]	3.0 [1.3]
As (particulate)	IN	μg/L	13	<0.1	6.8	0.7	1.9
	AC	μg/L	5 [8]	20.9 [15.3]	28.4 [28.4]	24.1 [23.4]	3.1 [3.9]
	TT	μg/L	5 [8]	<0.1 [<0.1]	3.3 [2.4]	1.5 [0.9]	1.5 [0.8]
As(III)	IN	μg/L	13	32.6	39.8	35.8	2.3
	AC	μg/L	5 [8]	1.0 [0.9]	6.2 [3.1]	2.6 [2.0]	2.2 [0.7]
	TT	μg/L	5 [8]	1.0 [1.2]	5.1 [3.2]	2.5 [2.0]	1.7 [0.7]
As(V)	IN	μg/L	13	<0.1	11.5	2.1	3.0
	AC	μg/L	5 [8]	9.9 [3.5]	14.8 [16.9]	12.2 [9.7]	2.1 [3.8]
	TT	μg/L	5 [8]	8.1 [3.1]	11.8 [6.5]	10.1 [4.5]	1.6 [1.2]
Fe (total)	IN	μg/L	53	361	1,209	540	117
	AC	μg/L	19 [34]	363 [515]	1,002[1,985]	563 [1,359]	145 [234]
	TA	μg/L	14 [26]	<25 [<25]	66.4 [107]	<25 [46.7]	20.2 [27.1]
	TB	μg/L	14 [26]	<25 [<25]	66.0 [122]	<25 [56.3]	16.3 [27.7]
	TT	μg/L	5 [8]	<25 [<25]	36.8 [104]	<25 [41.8]	12.2 [38.0]
Fe (soluble)	IN	μg/L	13	342	649	485	78.7
	AC	μg/L	5 [8]	<25 [<25]	<25 [32.1]	<25 [<25]	0.0 [8.0]
	TT	μg/L	5 [8]	<25 [<25]	<25 [<25]	<25 [<25]	0.0 [0.0]
Mn (total)	IN	μg/L	53	112	505	136	53.9
	AC	μg/L	19 [34]	109 [110]	156 [149]	126 [132]	11.9 [8.6]
	TA	μg/L	14 [26]	65.6 [65.1]	85.7 [128]	74.3 [92.7]	5.9 [15.1]
	TB	μg/L	14 [26]	66.0 [62.9]	82.6 [126]	73.3 [93.1]	5.3 [14.5]
	TT	μg/L	5 [8]	62.6 [57.2]	86.8 [126]	70.6 [91.9]	9.4 [25.9]
Mn (soluble)	IN	μg/L	13	112	145	126	10.5
	AC	μg/L	5 [8]	61.7 [59.0]	78.9 [89.1]	69.1 [76.6]	7.4 [10.1]
	TT	μg/L	5 [8]	61.8 [55.5]	80.9 [91.5]	69.1 [76.4]	7.1 [11.5]

(a) Number in parentheses representing data compiled after start of iron addition on January 3, 2005.
One-half of detection limit used for non-detect samples for calculations.
Duplicate samples included in calculations.

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

Parameter	Sampling Location	Unit	Number of Samples	Concentration Minimum	Concentration Maximum	Concentration Average	Concentration Standard Deviation
Alkalinity (as $CaCO_3$)	IN	mg/L	53	294	540	326	35
	AC	mg/L	53	284	535	323	33
	TA	mg/L	40	288	562	324	41
	TB	mg/L	40	292	544	324	38
	TT	mg/L	13	284	336	313	19
Ammonia (as N)	IN	mg/L	31	0.6	0.8	0.7	0.1
Fluoride	IN	mg/L	13	0.2	0.7	0.4	0.1
	AC	mg/L	13	0.2	1.0	0.5	0.2
	TT	mg/L	13	0.4	1.5	1.0	0.3
Sulfate	IN	mg/L	13	105	154	123	15
	AC	mg/L	13	100	155	121	15
	TT	mg/L	13	107	155	122	14
Orthophosphate (as PO_4)	IN	mg/L	53	<0.05	<0.1	<0.1	0.01
	AC	mg/L	53	<0.05	<0.1	<0.1	0.01
	TA	mg/L	40	<0.05	<0.1	<0.1	0.01
	TB	mg/L	40	<0.05	<0.1	<0.1	0.01
	TT	mg/L	13	<0.05	0.6	0.07	0.16
Silica (as SiO_2)	IN	mg/L	53	16.8	39.2	28.7	2.3
	AC	mg/L	53	26.8	30.5	28.7	0.8
	TA	mg/L	40	27.0	30.4	28.5	0.7
	TB	mg/L	40	27.0	30.6	28.5	0.8
	TT	mg/L	13	27.5	29.8	28.8	0.7
Nitrate (as N)	IN	mg/L	13	<0.04	0.07	<0.04	0.02
	AC	mg/L	13	<0.04	0.05	<0.04	0.01
	TT	mg/L	13	<0.04	0.11	<0.04	0.03
Turbidity	IN	NTU	53	0.1	18.0	6.3	2.3
	AC	NTU	53	0.2	15.0	1.5	2.2
	TA	NTU	40	<0.1	1.0	0.3	0.2
	TB	NTU	40	<0.1	1.2	0.4	0.3
	TT	NTU	13	<0.1	1.0	0.3	0.3
pH	IN	S.U.	48	7.4	7.7	7.5	0.1
	AC	S.U.	48	7.3	7.6	7.4	0.1
	TA	S.U.	36	7.3	7.6	7.4	0.1
	TB	S.U.	36	7.3	7.6	7.4	0.1
	TT	S.U.	12	7.3	7.5	7.4	0.0
Temperature	IN	ºC	48	8.1	12.4	9.1	0.8
	AC	ºC	48	8.1	10.8	9.0	0.6
	TA	ºC	36	8.1	10.7	8.9	0.6
	TB	ºC	36	8.1	11.0	8.9	0.6
	TT	ºC	12	8.3	10.4	8.9	0.7
Dissolved Oxygen	IN	mg/L	48	0.4	4.1	1.7	0.7
	AC	mg/L	48	0.6	2.6	1.5	0.5
	TA	mg/L	36	0.4	2.2	1.3	0.4
	TB	mg/L	36	0.5	4.9	1.6	0.7
	TT	mg/L	12	0.9	2.5	1.5	0.4

Table 4-9. Summary of Other Water Quality Parameter Sampling Results (Cont'd)

Parameter	Sampling Location	Unit	Number of Samples	Concentration Minimum	Maximum	Average	Standard Deviation
ORP	IN	mV	42	-128	-63	-77	10
	AC	mV	42	121	382	247	50
	TA	mV	30	218	379	257	42
	TB	mV	30	222	364	259	39
	TT	mV	11	223	347	268	48
Free Chlorine (as Cl_2)	AC	mg/L	48	0.2	3.0	0.9	0.4
	TA	mg/L	36	0.2	3.0	0.9	0.5
	TB	mg/L	36	0.2	3.0	0.9	0.5
	TT	mg/L	12	0.6	1.6	0.9	0.3
Total Chlorine (as Cl_2)	AC	mg/L	48	0.9	3.0	1.9	0.7
	TA	mg/L	36	0.9	3.0	2.0	0.7
	TB	mg/L	36	0.9	3.0	2.0	0.7
	TT	mg/L	12	1.2	3.0	1.9	0.6
Total Hardness (as $CaCO_3$)	IN	mg/L	13	202	283	231	25
	AC	mg/L	13	201	279	229	22
	TT	mg/L	13	196	278	232	24
Ca Hardness (as $CaCO_3$)	IN	mg/L	13	130	188	151	16
	AC	mg/L	13	130	185	151	15
	TT	mg/L	13	128	185	153	16
Mg Hardness (as $CaCO_3$)	IN	mg/L	13	67.9	94.4	79.8	9.4
	AC	mg/L	13	61.3	93.7	77.9	9.0
	TT	mg/L	13	58.9	93.0	78.8	9.6

One-half of the detection limit was used for non-detect samples for calculations.
Duplicate samples are included in the calculations.

4.5.1 Treatment Plant Sampling. The treatment plant water was sampled on 53 occasions (including four duplicate sampling events) during the one year period of system operations. Field speciation also was performed for 13 of the 53 occasions. Table 4-8 summarizes the arsenic, iron, and manganese analytical results. Table 4-9 summarizes the results of the other water quality parameters. Appendix B contains a complete set of analytical results for the one year duration of system operations. The results of the water samples collected throughout the treatment plant are discussed below.

4.5.1.1 Arsenic and Iron Removal. Figure 4-10 shows total arsenic levels across the treatment train over the duration of the one-year study period. Total arsenic levels in raw water ranged from 31.2 to 51.4 μg/L. From August 11, 2004, to January 2, 2005, total arsenic levels in the treated water ranged from 9.7 to 19.0 μg/L. As noted below, it was determined that there was insufficient natural iron in raw water to achieve effective arsenic removal to below the 10 μg/L MCL. After supplemental iron addition was implemented on January 3, 2005, total arsenic levels in the treated water were reduced to 6.0 to 9.3 μg/L with no exceedances of arsenic above the 10 μg/L level throughout the one-year study period.

Figure 4-11 shows the total iron levels across the treatment train over the duration of the one-year study period. Total iron levels in raw water ranged from 361 to 1,209 μg/L and averaged 540 μg/L. As shown in Table 4-8, iron in raw water existed primarily in the soluble form with an average value of 485 μg/L. Given the average soluble iron and soluble arsenic levels in source water, this corresponded to an

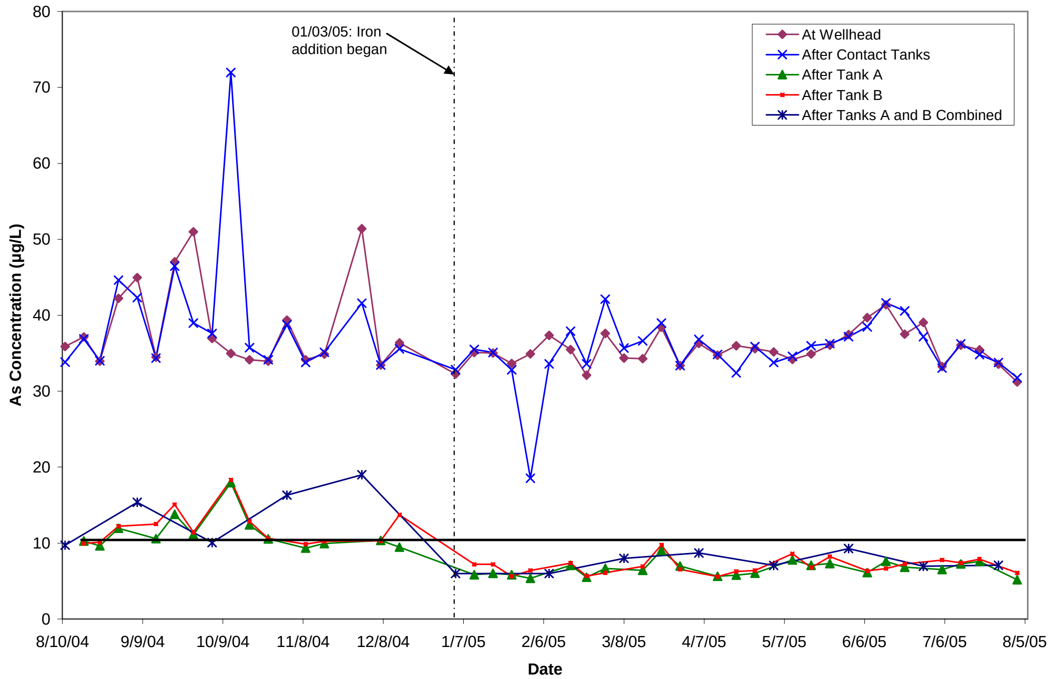

Figure 4-10. Total Arsenic Concentrations across Treatment Train

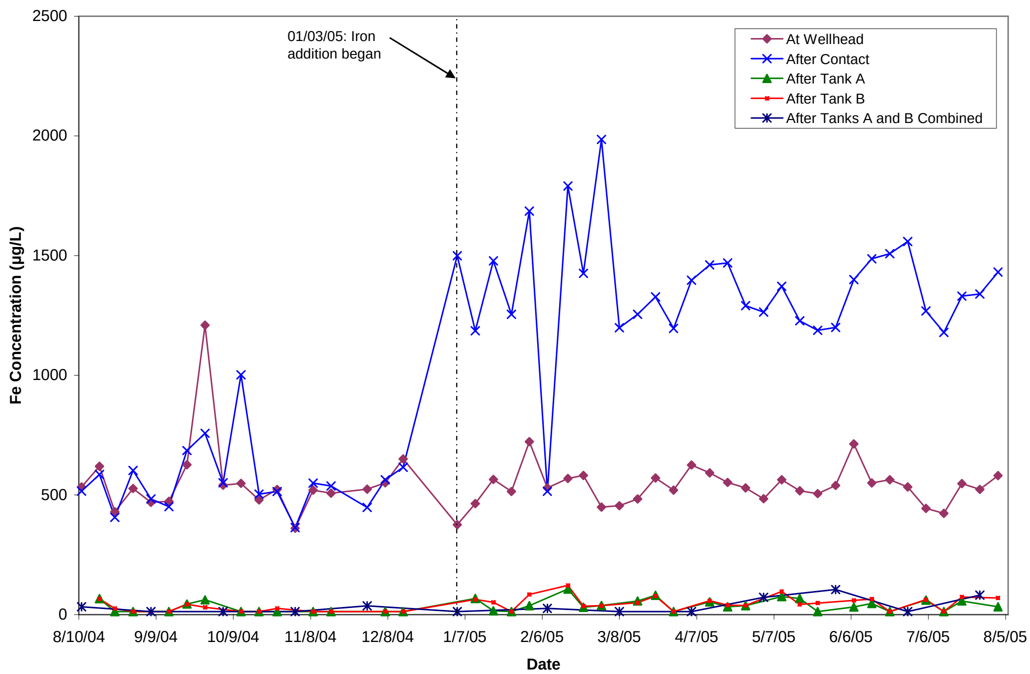

Figure 4-11. Total Iron Concentrations across Treatment Train

iron:arsenic ratio of 13:1, which was below the target ratio of 20:1 for effective arsenic removal (EPA, 2001; Sorg, 2002).

On January 3, 2005, supplemental iron addition was started at a target dosage of 0.5 mg/L of iron using a ferric chloride solution. Figure 4-11 shows the increase in iron concentrations after the contact tanks following the initiation of iron addition, which was equivalent to an average iron dose of 0.85 mg/L (as Fe). Figure 4-11 also shows a slight increase in iron concentrations in the treated water, with total iron levels (existing solely as particulates) ranging from <25 to 122 μg/L, indicating iron leakage from the Macrolite® filters after the start of supplemental iron addition. However, no apparent correlation was observed between the corresponding particulate iron and particulate arsenic levels (to be discussed under Arsenic Speciation).

Arsenic Speciation. Figure 4-12 shows the arsenic speciation results. Total arsenic concentrations in raw water averaged 36.5 μg/L with As(III) existing as the predominant species with concentrations ranging from 32.6 to 39.8 μg/L and averaging 35.8 μg/L. Only trace amounts of particulate As and As(V) existed in raw water with concentrations averaging 0.7 and 2.1 μg/L, respectively. These results compared well with those of the July 30, 2003, source water sampling.

After prechlorination and the contact tanks, As(III) concentrations ranged from 0.9 to 3.1 μg/L (except one data point at 6.2 μg/L), suggesting effective oxidation of As(III) to As(V) with chlorine. Particulate arsenic concentrations after the contact tanks ranged from 15.3 to 28.4 μg/L. As expected, after prechlorination and the contact tanks, iron existed solely in the particulate form. The corresponding free and total chlorine concentrations after the contact tanks averaged 0.9 and 1.9 mg/L, respectively (see Table 4-9). The chlorine demand was elevated due to the presence of ammonia in the raw water at 0.6 to 0.8 mg/L, which led to the formation of combined chlorine.

Prior to the start of supplemental iron addition, total arsenic concentrations in the combined effluent (TT) ranged from 9.7 to 19.0 μg/L and averaged 14.1 μg/L, of which 8.1 to 11.8 μg/L existed as As(V). Particulate arsenic levels in the treated water were low, ranging from 0.1 to 3.3 μg/L. After the start of supplemental iron addition on January 3, 2005, total arsenic concentrations at the TT location averaged 7.4 μg/L. As(V) concentrations in the combined effluent ranged from 3.1 to 6.5 μg/L and averaged 4.5 μg/L. It should be noted that further As(V) removal via adsorption was observed across the filters with As(V) levels averaging 9.7 μg/L before and 4.5 μg/L after the pressure filters, respectively. This seems to suggest that the iron particles accumulated within the filters had some additional adsorptive capacity for As(V). Particulate As levels in the treated water were low, ranging from <0.1 to 2.4 μg/L and averaging 0.9 μg/L.

Arsenic and Iron Leakage. Because the treatment plant samples discussed above were collected on a weekly basis at varying filter run lengths, additional treatment plant sampling was performed to further establish the performance of the filters throughout the duration of several filter runs. A series of filtered and unfiltered samples were collected after the filters during five filter runs before and after the start of supplemental iron addition.

Figure 4-13(a) shows the particulate and soluble arsenic concentration in the treated water over an 8-hr filtration run before the start of supplemental iron addition. Arsenic concentrations in the treated water existed primarily in the soluble form (at 11.2 to 14.6 μg/L) and there was very little particulate arsenic (at <1 to 1.1 μg/L) in the treated water, indicating little As leakage through the Macrolite® filters. This observation was further supported by low levels of particulate iron in the treated water (<25 to 136 μg/L) over the 8-hr run length. The presence of soluble arsenic over the 10 μg/L level in the treated water

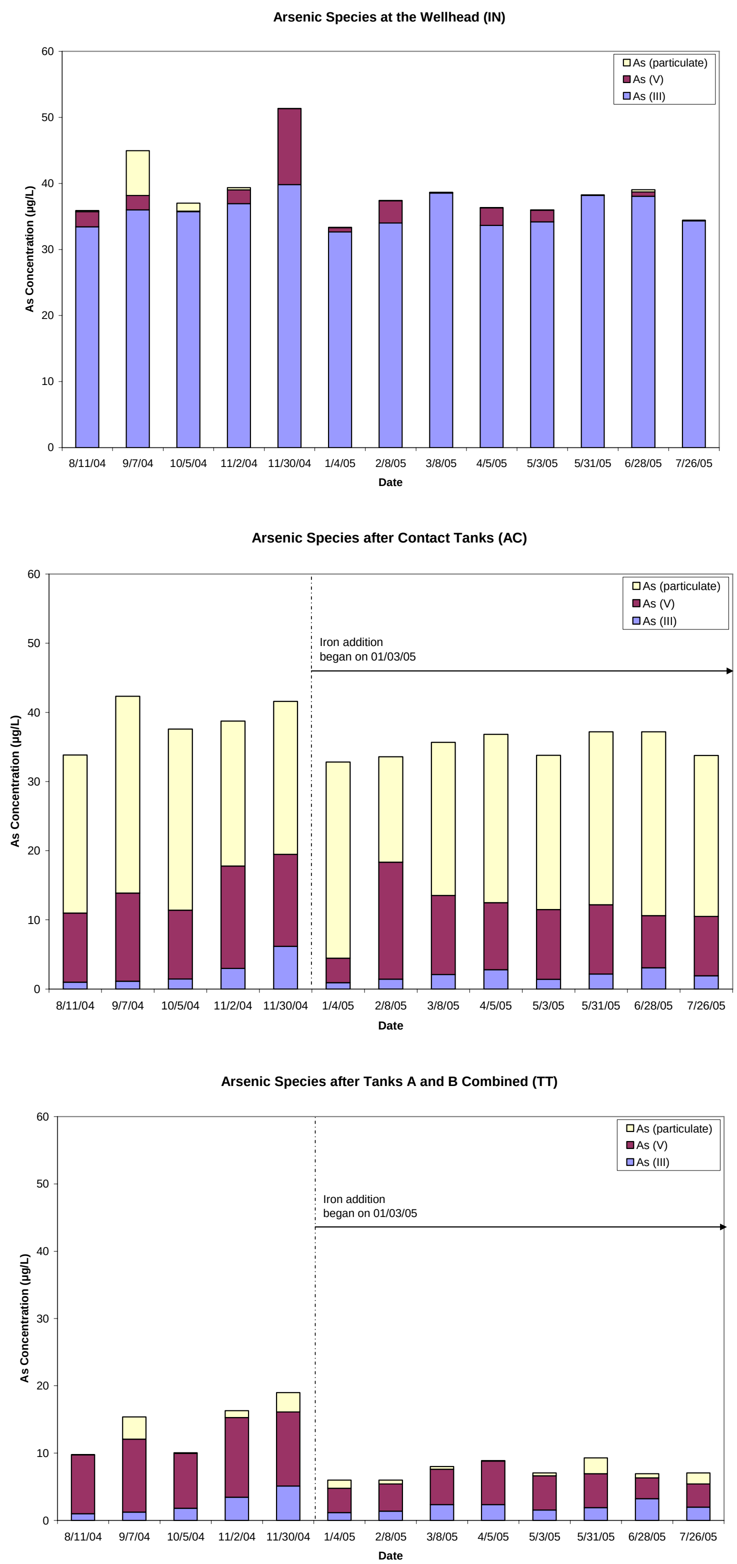

Figure 4-12. Concentrations of Arsenic Species at Wellhead (IN), after Contact Tanks (AC), and after Tanks A and B Combined (TT)

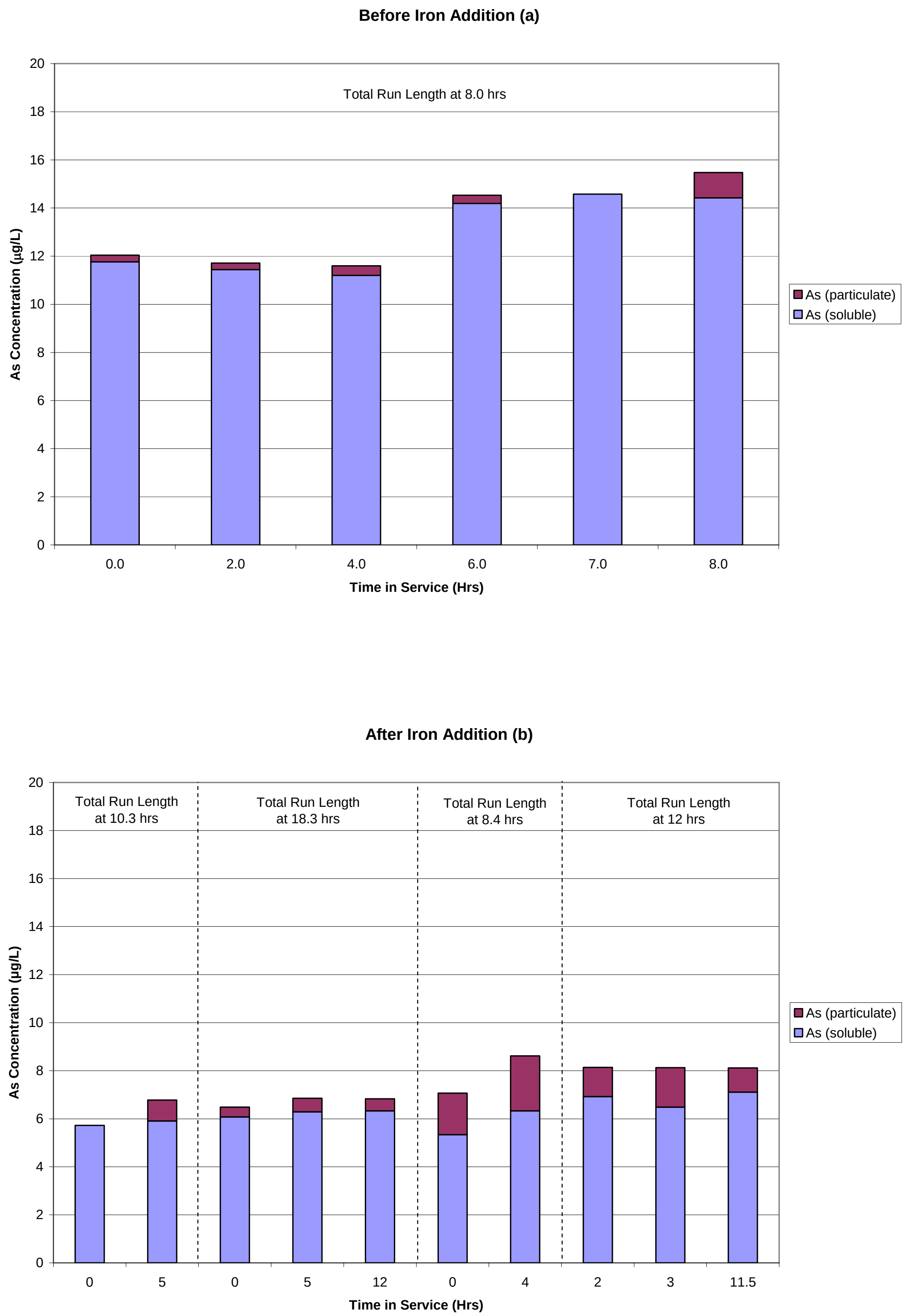

Figure 4-13. Results of Arsenic/Iron Leakage Studies

throughout the 8-hr filtration run confirmed the need for supplemental iron addition for further As(V) removal.

Figure 4-13(b) shows the particulate and soluble arsenic concentrations in the treated water over the span of four filtration runs following the start of iron addition on January 3, 2005. The filter run time between consecutive backwash events ranged from 8.4 to 18.3 hr. Again, arsenic in the treated water existed primarily in the soluble form (at 5.3 to 7.1 μg/L) with very low particulate arsenic concentrations at <1 to 2.3 μg/L. The particulate iron levels ranged from <25 to 121 μg/L in the treated water; no significant increasing trend in particulate As or Fe concentrations was observed over the span of the four filter runs. The results indicate that the Macrolite® filters performed well with minimal particulate arsenic and iron leakage at high loading rates (i.e. 7.4 to 10.7 gpm/ft^2) compared to 2 gpm/ft^2 for conventional sand filters as specified in the *Recommended Standards for Water Works or Ten State Standards* (Great Lakes-Upper Mississippi River Board of State Sanitary Engineers, 2003).

4.5.1.2 Manganese Removal. Total manganese levels in raw water ranged from 112 to 218 μg/L with an outlier at 505 μg/L (see Table 4-8). Manganese in raw water existed primarily in the soluble form at levels ranging from 112 to 145 μg/L. After prechlorination and the contact tanks, soluble manganese concentrations decreased to 59.0 to 89.1 μg/L. An average of 42% of the soluble manganese was precipitated to become particulate manganese. This incomplete oxidation of Mn(II) is consistent with previous findings that the oxidation of Mn(II) by free chlorine has slow kinetics for pH values below 8.5. (Knocke et al., 1987; 1990). Unlike MnO_x-coated media, Macrolite® does not promote Mn(II) removal via adsorption with the presence of chlorine. Only particulate manganese was filtered out by the Macrolite® filters, leaving soluble manganese in the treated water at levels ranging from 55.5 to 91.5 μg/L.

4.5.1.3 Other Water Quality Parameters. As shown in Table 4-9, DO levels remained low across the treatment train, with average values ranging from 1.3 to 1.7 mg/L, but ORP values significantly increased after chlorine addition ranging from -63 to -128 mV before chlorination to 121 to 382 mV after chlorination. The pH values of the raw water had an average value of 7.5 and pH values of the treated water had an average value of 7.4. Average alkalinity results ranged from 313 to 326 mg/L (as $CaCO_3$) across the treatment train. Average total hardness results ranged from 229 to 232 mg/L (as $CaCO_3$) across the treatment train (the total hardness is the sum of calcium hardness and magnesium hardness). The water had predominantly calcium hardness. Fluoride concentrations ranged from 0.2 to 1.0 mg/L in raw water and after contact tanks and were not affected by the Macrolite® filtration. Fluoride averaged 1.0 mg/L in the combined effluent samples after the fluoridation step. No significant levels of nitrate or orthophosphate were detected in raw water. Average sulfate concentrations ranged from 121 to 123 mg/L across the treatment train. The silica (as SiO_2) concentration remained at approximately 28 mg/L across the treatment train.

4.5.2 Backwash Water Sampling. The source of the backwash water is treated water. Table 4-10 summarizes the analytical results from the twelve backwash water sampling events. For the first 11 sampling events, only pH, turbidity, TDS, and soluble As, Fe, and Mn were analyzed for the grab samples collected at the backwash water discharge line. Prior to iron addition (from Events 1 to 4), soluble arsenic and iron concentrations in the backwash water averaged 16.0 μg/L and 21.0 μg/L, respectively. After iron addition (from Events 5 to 11), soluble arsenic concentrations decreased and averaged 8.7 μg/L, while soluble iron concentrations increased and averaged 86.4 μg/L (excluding the July 27, 2005, data that had uncharacteristically high soluble As, Fe, and Mn). After iron addition, the soluble iron levels in the backwash water increased due to equilibrium with the higher total iron levels (e.g., iron particulates) in the backwash water. However, the soluble arsenic levels decreased, due to increased adsorption onto the iron particulates in the backwash water.

Table 4-10. Backwash Water Sampling Results

Sampling Event		Vessel A											Vessels B										
		pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn	pH	Turbidity	TDS	TSS	Total As	Soluble As	Particulate As	Total Fe	Soluble Fe	Total Mn	Soluble Mn
No.	Date	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	S.U.	NTU	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1	09/24/04	7.1	45	908	NA	NA	14.8	NA	NA	<25	NA	37.4	7.2	52	990	NA	NA	17.9	NA	NA	<25	NA	24.9
2	10/20/04(a)	7.6	54	824	NA	NA	21.6	NA	NA	<25	NA	413	7.5	29	774	NA	NA	19.5	NA	NA	30.7	NA	235
3	11/16/04	7.9	60	826	NA	NA	15.6	NA	NA	<25	NA	49.6	7.9	48	840	NA	NA	14.1	NA	NA	<25	NA	54.8
4	12/13/04	7.7	38	798	NA	NA	12.3	NA	NA	34.6	NA	69.8	7.6	6.7	758	NA	NA	12.5	NA	NA	39.9	NA	72.7
5	01/12/05	7.5	140	648	NA	NA	9.2	NA	NA	148	NA	86.7	7.5	120	646	NA	NA	7.8	NA	NA	87.1	NA	81.8
6	02/16/05	7.5	14	808	NA	NA	7.2	NA	NA	83.4	NA	73.1	7.5	14	798	NA	NA	6.4	NA	NA	27.3	NA	68.7
7	03/22/05	7.5	120	848	NA	NA	9.9	NA	NA	132	NA	73.7	7.5	100	806	NA	NA	7.6	NA	NA	40.7	NA	72.9
8	04/20/05	7.3	120	778	NA	NA	8.4	NA	NA	127	NA	73.2	7.5	110	786	NA	NA	8.8	NA	NA	98.5	NA	66.8
9	05/24/05	7.5	100	940	NA	NA	10.0	NA	NA	33.3	NA	69.4	7.5	96	726	NA	NA	10.7	NA	NA	65.7	NA	65.6
10	06/21/05	7.4	113(b)	804	NA	NA	7.6	NA	NA	42.8	NA	68.1	7.4	82(b)	838	NA	NA	7.5	NA	NA	25.7	NA	69.5
11	07/27/05	NA(c)	NA(c)	NA(c)	NA	NA	12.6	NA	NA	212	NA	91.1	NA(c)	NA(c)	NA(c)	NA	NA	25.6	NA	NA	771	NA	118
12	11/15/05	7.5	NA	780	278	1,850	13.2	1,837	97,594	340	4,541	95.6	7.6	NA	794	188	1,415	15.1	1,399	74,196	395	3,454	99.2

TDS = total dissolved solids; TSS = total suspended solids; NA = data not available

(a) Soluble Mn reanalyzed with similar results for both samples for this date.

(b) Analyzed outside of hold time.

(c) Not analyzed due to loss of sample during shipment.

For the last sampling event on November 15, 2005, TSS and total As, Fe, and Mn also were analyzed for the composite samples collected using the modified backwash procedure discussed in Section 3.3.3. The results showed total iron levels in the backwash water at 74.2 to 97.6 mg/L and total arsenic levels at 1.42 to 1.85 mg/L. TSS levels in the backwash water ranged from 188 to 278 mg/L.

Table 4-11 presents the results of total metals analysis for two backwash water solid samples collected on August 9, 2006. The iron levels in the solids ranged from 2.46×10^5 to 3.12×10^5 µg/g and the arsenic levels from 3,830 to 4,540 µg/g. This yields an Fe:As ratio of 67:1, which is much higher than the 20:1 ratio as a rule of thumb for effective arsenic removal (EPA, 2001; Sorg, 2002). These data suggest that natural iron solids may have a greater As(V) adsorptive capacity than iron solids formed from supplemental iron addition. According to jar tests performed by Lytle (2005), the adsorption process would be more favorable when the oxidation of As(III) to As(V) occurs prior to the addition of supplemented iron. Table 4-11 also provides an estimate of the amount of solids generated during the backwash event. This estimate assumes an average TSS of 233 mg/L and a backwash volume of 1,000 gallons for two vessels. Approximately 1.9 lb of solids would be generated per backwash event including 0.54 lb of iron and 0.008 lb of arsenic.

Table 4-12 shows the TCLP results of the backwash water solids. The samp les were filtered through 0.7 µm glass fiber filters. The solid-liquid compositions were 5.6% solid and 94.4% liquid for Sample BW1 and 8.57% solid and 91.4% liquid for Sample BW2. The filtrates were preserved with HNO_3 until they could be digested for metal analyses. Both samples were found to require Extraction Fluid No. 1 (EF1), which contains 5.7 mL of acetic acid and 64.3 mL of NaOH with a pH of 4.93. Two 10-gram solid portions of each sample were extracted with EF1 on a rotary agitation device for 18 hr. The solids were filtered off and discarded. The extracts were digested along with the initial filtrates for metal analyses according to EPA Methods 200.7 for Ag, As, Ba, Cd, Cr, Pb, and Se and 245.1 for Hg. The results for each sample were obtained by adding the filtrate and extract results based on their percentage of the sample. The TCLP results of the backwash solids showed no detectable arsenic concentrations in the leachate. Only barium showed detectable concentrations ranging from 0.189 to 0.231 mg/L. The TCLP regulatory limit set by EPA is 5 mg/L for arsenic and 100 mg/L for barium.

Table 4-11. Backwash Solid Sample Total Metal Results

Sample ID	Vessel A-Solids A	Vessel A -Solids B	Vessel A -Solids C	Average	Vessel B -Solids A	Vessel B -Solids B	Vessel B -Solids C	Average	Solids
Units	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**mg/g**	**lbs**
Al	5.95E+03	6.15E+03	4.62E+03	**5.57E+03**	2.76E+03	2.97E+03	2.72E+03	**2.82E+03**	8.20E-03
As	5.03E+03	5.21E+03	3.38E+03	**4.54E+03**	3.81E+03	3.78E+03	3.90E+03	**3.83E+03**	8.10E-03
Ca	3.60E+04	3.69E+04	2.21E+04	**3.17E+04**	2.44E+04	3.93E+04	2.45E+04	**2.94E+04**	5.90E-02
Cd	5.00E-02	5.00E-02	2.00E-02	**4.00E-02**	8.00E-02	8.00E-02	8.00E-02	**8.00E-02**	1.20E-07
Cu	2.92E+01	2.97E+01	2.23E+01	**2.71E+01**	2.58E+01	2.75E+01	2.51E+01	**2.61E+01**	5.20E-05
Fe	3.56E+05	3.53E+05	2.28E+05	**3.12E+05**	2.51E+05	2.53E+05	2.35E+05	**2.46E+05**	5.40E-01
Mg	2.89E+03	2.97E+03	2.26E+03	**2.71E+03**	3.02E+03	3.26E+03	3.01E+03	**3.09E+03**	5.60E-03
Mn	1.21E+04	1.24E+04	7.99E+03	**1.08E+04**	8.95E+03	8.84E+03	9.15E+03	**8.98E+03**	1.90E-02
P	8.92E+03	9.02E+03	5.50E+03	**7.81E+03**	6.21E+03	6.44E+03	5.94E+03	**6.19E+03**	1.40E-02
Pb	2.25E+00	2.12E+00	1.73E+00	**2.03E+00**	2.51E+00	2.69E+00	2.55E+00	**2.59E+00**	4.50E-06
Ni	4.24E+00	4.04E+00	2.90E+00	**3.73E+00**	8.85E+00	9.54E+00	8.53E+00	**8.97E+00**	1.20E-05
Si	5.70E+01	7.06E+01	4.82E+01	**5.86E+01**	3.84E+01	6.83E+01	6.24E+01	**5.64E+01**	1.10E-04
Zn	2.92E+01	3.00E+01	2.23E+01	**2.72E+01**	7.21E+01	7.58E+01	6.94E+01	**7.24E+01**	9.70E-05

Table 4-12. Backwash Solid Sample TCLP Results

Parameter	Unit	Vessel A 08/09/05	Vessel B 08/09/05
As	mg/L	<0.05	<0.5
Ba	mg/L	0.189	0.231
Cd	mg/L	<0.05	<0.05
Cr	mg/L	<0.05	<0.05
Pb	mg/L	<0.1	<0.1
Hg	mg/L	<0.003	<0.003
Se	mg/L	<0.3	<0.3
Si	mg/L	<0.05	<0.05

4.5.3 Distribution System Water Sampling. The results of the distribution system sampling are summarized in Table 4-13. The stagnation times for the samples ranged from 5.8 to 24 hr with an average stagnation time of 10.3 hr.

There was no major change in pH values, which ranged from 7.4 to 7.6 before the system became operational and 7.3 to 7.9 (with one outlier at 8.0 for DS1 Event 11) after the system became operational. Alkalinity levels ranged from 198 to 331 and from 294 to 339 mg/L (as $CaCO_3$) before and after treatment system startup, respectively.

Arsenic concentrations in the baseline samples ranged from 21.8 to 52.3 μg/L and averaged 37.0 μg/L. These values were consistent with those in the raw water (i.e. 31.2 to 51.4 μg/L and averaged 36.5 μg/L) as shown in Table 4-8. Arsenic concentrations decreased at each of the three sampling locations after system startup.

Arsenic levels in the distribution system ranged from 11.3 to 17.0 μg/L (averaged 14.1 μg/L) before iron addition (from Events 1 to 5 [except for DS1 in Event 1]), and from 5.9 to 14.1 μg/L (averaged 10.3 μg/L) after iron addition (from Events 6 to 12). However, arsenic levels in the treated water decreased to 9.3 to 18.3 μg/L (averaged 11.7 μg/L) before iron addition and 5.2 to 9.7 μg/L (averaged 6.97 μg/L) after iron addition (Table 4-8). Arsenic levels in the distribution system were higher than those in the treated water, indicating solubilization, destablization, and/or desorption of arsenic-laden particles/scales in the distribution system (Lytle, 2005). One outlier event occurred on August 31, 2004, when the operator reported a "red water" slug from the DS1 tap, which contained signficiant solids and elevated levels of arsenic, iron, manganese, lead, and copper.

Iron concentrations in the baseline samples were high ranging from 36.6 to 580 μg/L and averaging 286 μg/L. Since system startup, iron levels in the distribution system decreased significantly with an average of 43.2 μg/L before iron addition and 74.7 μg/L after iron addition. These values were still higher than the corresponding average iron levels of <25 μg/L before iron addition and 41.8 μg/L after iron addition in the treated water. These data again may suggest some solublization, destabilization, and/or desoprtion of iron particles within the distribution system (Lytle, 2005).

The manganese levels in the distribution system samples averaged 65.6 μg/L in the baseline samples and decreased to an average of 33.8 μg/L after the system startup. In general, total managanese levels in the distribution samples were lower than those in the treated water (averaged 83.4 μg/L). This may be due to further oxidation of Mn(II) and adsorption and/or coating onto metal oxide scales in the distribution

Table 4-13. Distribution Sampling Results

No. of Sampling Events	Location ID	DS1									DS2									DS3								
	Sampling Date	Stagnation Time (hr)	pH (S.U.)	Alkalinity (mg/L as $CaCO_3$)	Fluoride (mg/L)	As (µg/L)	Fe (µg/L)	Mn (µg/L)	Pb (µg/L)	Cu (µg/L)	Stagnation Time (hr)	pH (S.U.)	Alkalinity (mg/L as $CaCO_3$)	Fluoride (mg/L)	As (µg/L)	Fe (µg/L)	Mn (µg/L)	Pb (µg/L)	Cu (µg/L)	Stagnation Time (hr)	pH (S.U.)	Alkalinity (mg/L as $CaCO_3$)	Fluoride (mg/L)	As (µg/L)	Fe (µg/L)	Mn (µg/L)	Pb (µg/L)	Cu (µg/L)
BL1	01/28/04	7.5	7.4	292	1.2	37.2	372	89.1	2.5	61.9	8.9	7.5	282	NA	39.2	371	65.8	4.1	208	6.0	7.4	286	1.1	52.3	580	111	4.7	402
BL2	02/23/04	6.3	7.5	198	1.1	34.1	212	86.5	0.3	26.0	8.8	7.6	298	1.2	49.0	417	45.4	3.9	195	15.5	7.6	300	1.1	41.7	321	82.4	0.9	230
BL3	03/22/04	6.3	7.5	331	0.9	40.4	276	81.6	0.3	28.8	10.0	7.6	307	1.0	35.0	260	42.3	4.6	215	6.9	7.5	323	1.0	45.8	472	89.0	3.0	335
BL4	04/27/04	6.7	7.6	307	1.0	21.8	39.5	37.3	0.6	19.7	8.0	7.6	299	1.0	22.9	36.6	17.0	0.5	55.8	6.8	7.6	299	1.1	25.1	71.0	40.8	0.7	86.6
1	08/31/04[(a)]	6.8	7.4	314	0.5	483	13,903	1,291	142	6,605	12.0	7.5	314	0.6	15.9	<25	12.7	1.9	122	7.5	7.5	306	0.6	13.9	<25	25.0	1.0	110
2	09/28/04	8.3	7.3	304	0.9	14.6	70.7	76.6	2.2	62.5	12.0	7.4	304	0.9	15.0	74.6	47.4	3.3	145	18.0	7.4	308	0.9	12.9	<25	51.5	2.2	119
3	10/26/04	5.8	7.5	316	0.6	14.9	58.3	29.7	1.7	53.4	6.4	7.6	316	0.5	13.5	35.4	12.6	1.2	110	18.5	7.7	316	0.5	12.0	31.7	25.1	1.2	213
4	11/30/04[(b)]	7.0	7.5	309	1.4	15.6	54.5	37.1	3.4	281	12.0	7.5	317	1.3	17.0	81.0	49.9	4.2	187	7.2	7.6	309	1.4	16.0	61.6	27.9	3.3	593
5	12/14/04	6.8	7.6	305	0.7	12.1	<25	26.2	2.8	297	8.0	7.6	301	1.0	13.1	52.6	23.4	1.6	121	17.0	7.6	301	0.6	11.3	35.0	23.0	3.5	1,027
6	01/11/05[(c)]	7.0	7.6	298	1.2	10.7	71.5	45.4	2.0	233	24.0	7.6	294	1.2	11.8	109	25.1	2.4	106	16.3	7.6	328	1.0	7.4	180	33.0	2.9	407
7	02/08/05	7.0	7.5	334	1.0	8.0	69.4	26.2	2.3	241	12.0	7.6	326	1.0	9.3	69.6	13.9	1.6	112	16.3	7.7	339	1.0	5.9	46.1	46.9	3.3	108
8	03/08/05	6.5	7.8	317	0.8	10.1	60.9	35.3	1.4	230	9.8	7.7	312	0.8	11.5	70.6	14.4	1.7	139	18.0	7.8	326	0.8	10.3	88.7	58.0	1.8	247
9	04/05/05	6.6	7.3	330	1.3	9.1	70.3	46.1	1.8	205	11.0	7.4	330	1.4	12.2	73.1	10.0	3.1	141	12.0	7.5	330	1.3	10.9	92.5	56.6	2.8	367
10	05/03/05	7.3	7.5	329	1.0	10.5	84.8	36.2	2.1	189	9.8	7.6	337	1.0	13.0	188.2	51.3	6.0	142	16.0	7.6	329	1.0	9.4	67.9	36.9	2.2	375
11	06/14/05	7.3	8.0	326	0.8	9.4	<25	34.3	1.5	190	8.0	7.6	330	0.8	9.9	29.9	21.3	1.2	63	14.3	7.9	326	0.8	9.3	<25	40.3	1.7	370
12	07/12/05	7.3	7.3	317	0.9	11.8	46.4	31.9	1.6	102	13.5	7.5	317	0.9	14.1	78.8	16.0	2.1	61	16.3	7.5	330	0.9	11.9	46.7	34.1	1.6	223

(a) Homeowner at DS1 noticed a flush of red water during sample collection.
(b) DS2 taken on 12/07/04 for this sampling event.
(c) DS3 taken on 01/12/05 for this sampling event.
NA = not analyzed; BL = baseline sampling
Lead action level = 15 µg/L; copper action level = 1.3 mg/L
µg/L as unit for all analytical parameters except for pH (S.U.) and alkalinity (mg/L [as $CaCO_3$])

system. Note that an average of 0.9 mg/L as Cl_2 of free chlorine residuals were maintained in the distribution system.

Lead levels in the distribution system ranged from 0.3 to 6.0 μg/L with no samples exceeding the action level of 15 μg/L (with the excpetion of the August 31, 2004, sample collected at the DS1 location). Lead levels in the distribution system did not appear to have been affected by the operation of the arsenic treatment unit. Copper concentrations in the distribution system ranged from 19.7 to 401.8 μg/L and averaged 155 mg/L in the baseline samples and ranged from 53.4 to 1,027 μg/L and averaged 266 mg/L after the system startup. The copper levels appeared to have increased overall after system startup, but no samples exceeded the 1,300 μg/L action level with the exception of the August 31, 2004, event noted above. Several factors can increase the solubility of copper in drinking water in contact with plumbing fixtures including low pH, high temerature, and soft water with fewer dissolved minerals. However, the treatment system did not appear to have any impact on these factors.

4.6 System Cost

The cost of the system was evaluated based on the capital cost per gpm (or gpd) of design capacity and the O&M cost per 1,000 gal of water treated. This included the tracking of capital cost for equipment, engineering, and installation and O&M cost for chemical supply, electrical power consumption, and labor. However, the cost associated with the building, sanitary sewer connections, and other discharge-related infrastructure was not included in the treatment system cost, because it was not included in the scope of the demonstration project, and was funded separately by the demonstration site.

4.6.1 Capital Cost. The capital investment for the Climax system was $270,530 (Table 4-14), which included $159,419 for equipment, $39,344 for engineering, and $71,767 for installation. The equipment cost included the Macrolite® media, contact tanks, filtration skid, instrumentation and controls, labor (including activities for the system shakedown), system warranty, and freight and sales tax. The system warranty included repair and/or replacement of any equipment or installation workmanship for a period of twelve months after system startup. The iron addition system purchased and installed by January 3, 2005, included one 55-gal polyethylene tank with secondary containment, a tank mixer, a 2.5-gal/hr chemical metering pump, and a 600-lb capacity drum scale. The equipment cost was 59% of the total capital investment.

The engineering cost included preparing a process design report and the required engineering plans, including a general arrangement drawing, piping and instrumentation diagrams (P&IDs), interconnecting piping layouts, tank fill details, a schematic of the PLC panel, an electrical on-line diagram, and other associated drawings, as well as obtaining required permit from MDH. After certified by a Minnesota-registered professional engineer (PE), the plans were submitted to the MDH for permit review and approval. The engineering cost was 15% of the total capital investment.

The installation cost included the labor and materials for system unloading and anchoring, plumbing, and mechanical and electrical connections. The installation cost was 26% of the total capital investment.

The total capital cost of $270,530 was normalized to the system's rated capacity of 140 gpm (201,600 gpd), which resulted in $1,932 per gpm ($1.34 per gpd). The total capital cost of $270,530 was converted to a unit cost of $0.35/1,000 gal, using a CRF of 0.09439 based on a 7% interest rate and a 20-year return period. These calculations assumed that the system operated 24 hour a day, seven days a week, at the system design flowrate of 140 gpm. The system operated only 5.6 hr/day and produced 13,829,000 gal of water during the study period. At this reduced usage rate, the total unit cost was increased to $1.85/1,000 gal.

Table 4-14. Summary of Capital Investment for the Climax, MN, Treatment System

Description	Quantity	Cost	% of Capital Investment Cost
Equipment Cost			
Media, Filter Skid, and Tanks	1	$66,210	–
Air Compressor	1	$2,346	–
Control Panel	1	$11,837	–
Labor	–	$43,005	–
Warranty	–	$11,950	–
Additional Flowmeter/Totalizers	1	$2,622	–
Iron Addition Equipment	1	$5,259	–
Freight and Sales Tax	1	$16,190	–
Equipment Total	–	**$159,419**	**59%**
Engineering Cost			
Labor	–	$38,094	–
Subcontractor	–	$1,250	–
Engineering Total	–	**$39,344**	**15%**
Installation Cost			
Labor	–	$12,914	–
Travel	–	$6,163	–
Subcontractor	–	$52,690	–
Installation Total	–	**$71,767**	**26%**
Total Capital Investment	–	**$270,530**	**100%**

A 22-ft × 24-ft building was built as an addition onto the existing concrete block well house for $88,256. The building walls were constructed with a wood stud frame and 24-gauge pre-fabricated metal wall panels and set on a 6-in-thick concrete slab floor with footings. The building also was equipped with an insulated, 10-ft-wide overhead door. The building construction cost includes all of the required insulation, mechanical, and electrical work. The building was heated with a 60,000 British Thermal Units per hour (BTU-hr) heater. The connection to the existing water main required 16 linear ft of 6-in-diameter C900 pipe and cost $4,650. The initial budget called for $6,730 for connection to the sanitary sewer with 145 ft of 6-in-diameter PVC pipe. However, after plan review by the MDH, a code requirement was identified to complete the sanitary sewer connection at a distance greater than 50 ft from the wellhead. An underground storage tank was placed at a distance of 50 ft from the well house to hold the backwash water prior to pumping to the sewer. The cost for this change was approximately $12,000.

4.6.2 Operation and Maintenance Cost. The O&M cost included primarily chemical supply, electricity consumption, and labor. Because the system was under warranty during the one-year study period, no expenses were incurred for repairs to the system. These expenses are summarized in Table 4-15. Since chlorination was performed prior to this demonstration study, the incremental cost for the sodium hypochlorite (NaOCl) solution was assumed to be negligible. The usage rate for the ferric chloride stock solution was approximately 80 gal or 900 pounds on an annual basis. The incremental power cost was estimated based on the change in electric utility bills for a one year timeframe before and after the treatment plant installation. The routine, non-demonstration related labor activities consumed about 30 min per day, as noted in Section 4.4.4. Based on this time commitment and a labor rate of $21/hr, the labor cost was $0.22/1,000 gal of water treated. The total O&M cost was approximately $0.29/1,000 gal based on labor, chemical usage, and electricity consumption.

Table 4-15. O&M Cost for the Climax, MN, Treatment System

Cost Category	Value	Assumptions
Volume processed (kgal)	13,829	From 08/16/04 through 08/12/05 (see Table 4-4)
Chemical Usage		
Ferric Chloride Unit Price ($/lb)	$0.40	35% ferric chloride in a 600 lb drum
Ferric Chloride Consumption Rate (lb/1,000 gall)	0.065	80 gal or 900 pounds on an annual basis
Chemical cost ($/1,000 gal)	$0.03	
Electricity		
Power use ($/1,000 gal)	$0.04	Based on additional electrical cost after treatment plant startup; not including propane cost to heat building
Labor		
Average weekly labor (hr)	2.5	30 min/day; five days a week
Labor cost ($/1,000 gal)	$0.22	Labor rate = $21/hr
Total O&M Cost/1,000 gal	**$0.29**	—

Section 5.0: REFERENCES

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APPENDIX A

OPERATIONAL DATA

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 1 of 13)

Sampling Date		08/11/04			08/18/04[d]				08/24/04[f]				08/31/04[h]			
Sampling Location Parameter	**Unit**	**IN**	**AC**	**TT**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**
Alkalinity	mg/L[a]	323	311	295	303	299	295	299	316	308	304	312	314	310	310	310
Fluoride	mg/L	0.5	0.5	1.4	–	–	–	–	–	–	–	–	–	–	–	–
NO_3-N	mg/L	<0.04	<0.04	<0.04	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate	mg/L[b]	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silica (as SiO_2)	mg/L	28.6	28.2	28.8	29.1	29.1	29.1	28.9	28.5	28.1	28.5	28.4	28.7	28.5	29.1	28.4
Sulfate	mg/L	110	110	110	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	6.1	0.6	0.2	6.7	0.8	0.4	0.4	4.9	0.5	0.2	0.3	6.5	1.1	0.6	0.5
pH	–	NA[c]	NA[c]	NA[c]	7.6	7.5	7.6	7.6	7.6	7.5	7.5	7.5	7.6	7.5	7.4	7.4
Temperature	ºC	NA[c]	NA[c]	NA[c]	10.1	10.0	10.0	10.1	9.1	10.7	8.8	8.8	8.6	8.9	10.7	11.0
DO	mg/L	NA[c]	NA[c]	NA[c]	2.6	2.6	2.2	2.2	4.1[g]	1.0	1.8	1.8	2.2	2.3	2.1	1.3
ORP	mV	NA[c]	NA[c]	NA[c]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]	NA[e]
Free Chlorine	mg/L	–	NA[c]	NA[c]	–	0.6	0.6	0.6	–	0.6	0.6	0.6	–	0.6	0.6	0.6
Total Chlorine	mg/L	–	NA[c]	NA[c]	–	3.0	3.0	3.0	–	3.0	3.0	3.0	–	3.0	3.0	3.0
Total Hardness	mg/L[a]	262	259	260	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[a]	170	168	168	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[a]	91.5	91.1	91.1	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	35.9	33.8	9.7	37.2	36.9	10.3	10.0	34.0	34.0	9.6	10.1	42.2	44.6	12.0	12.2
As (total soluble)	µg/L	35.7	11.0	9.7	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	0.2	22.8	<0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	33.4	1.0	1.0	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	2.3	10.0	8.7	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	533	516	32.6	620	585	66.4	66.0	430	406	<25	25.5	527	602	<25	<25
Fe (soluble)	µg/L	469	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	117	114	66.2	131	127	75.5	73.0	128	126	68.1	71.9	130	129	77.7	74.0
Mn (soluble)	µg/L	123	65.1	67.1	–	–	–	–	–	–	–	–	–	–	–	–

(a) as $CaCO_3$ (b) as PO_4 (c) On-site measurements were not collected. (d) On-site measurements were taken on August 20, 2004. (e) On-site measurement was not recorded correctly. (f) On-site measurements for TA and TB were taken on August 23, 2004. (g) Sample was potentially aerated during sample collection. (h) On-site WQ measurements were taken on September 3, 2004.
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined. NA = data not available

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 2 of 13)

Sampling Date		09/07/04			09/14/04[c]				09/21/04				09/28/04			
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB
Alkalinity	mg/L[a]	314	302	302	323	303	307	307	304	304	304	304	316	308	308	308
Fluoride	mg/L	0.3	0.3	1.1	–	–	–	–	–	–	–	–	–	–	–	–
NO_3-N	mg/L	<0.04	<0.04	<0.04	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate	mg/L[b]	<0.1	<0.1	<0.1	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silica (as SiO_2)	mg/L	28.5	29.0	29.1	29.0	29.3	29.1	28.8	16.8	28.7	28.6	28.4	28.8	28.7	28.4	28.8
Sulfate	mg/L	120	120	120	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	4.8	0.6	0.6	6.1	0.9	0.4	0.1	6.5	1.0	0.3	0.6	5.6	0.7	0.3	0.3
pH	–	7.6	7.5	7.4	7.7	7.4	7.4	7.6	7.6	7.5	7.4	7.5	7.5	7.4	7.4	7.4
Temperature	°C	9.8	9.7	8.6	12.4	10.7	10.6	10.8	9.3	9.3	9.3	9.3	8.4	8.4	8.3	8.3
DO	mg/L	2.8	2.6	1.6	2.5	0.9	0.8	4.9	2.1	1.1	0.7	1.0	1.9	1.1	1.2	1.9
ORP	mV	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	NA[d]	-76	121	NA[d]	NA[d]
Free Chlorine	mg/L	–	0.6	0.6	–	0.8	0.8	0.8	–	1.0	1.0	1.0	–	1.0	1.0	1.0
Total Chlorine	mg/L	–	3.0	3.0	–	3.0+	3.0+	3.0+	–	3.0	3.0	3.0	–	3.0	3.0	3.0
Total Hardness	mg/L[a]	210	208	204	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[a]	130	130	128	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[a]	79.6	78.2	75.8	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	44.9	42.3	15.4	34.5	34.3	10.6	12.5	47.0	46.5	13.8	15.1	51.0	39.0	11.1	11.4
As (total soluble)	µg/L	38.2	13.9	12.1	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	6.7	28.4	3.3	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	36.0	1.1	1.2	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	2.2	12.8	10.9	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	469	483	<25	473	450	<25	<25	626	686	44.3	43.3	1,209	758	61.6	30.8
Fe (soluble)	µg/L	492	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	146	138	86.8	127	126	73.8	72.2	135	139	81.9	82.6	505	156	85.7	82.6
Mn (soluble)	µg/L	145	78.9	80.9	–	–	–	–	–	–	–	–	–	–	–	–

(a) as $CaCO_3$ (b) as PO_4 (c) On-site measurements were taken on September 15, 2004 for locations IN and AC. (d) On-site measurement not recorded correctly.
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 3 of 13)

Sampling Date		10/05/04			10/12/04				10/19/04				10/26/04			
Sampling Location **Parameter**	**Unit**	**IN**	**AC**	**TT**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**
Alkalinity	mg/L[a]	313	317	313	305	305	301	313	294	290	288	292	312 312	308 308	308 308	308 312
Ammonia	mg/L	–	–	–	–	–	–	–	–	–	–	–	0.8 0.7	–	–	–
Fluoride	mg/L	0.2	0.2	1.0	–	–	–	–	–	–	–	–	–	–	–	–
NO_3-N	mg/L	<0.04	<0.04	<0.04	–	–	–	–	–	–	–	–	–	–	–	–
Orthophosphate	mg/L[b]	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06 <0.06	<0.06 <0.06	<0.06 <0.06	<0.06 <0.06
Silica (as SiO_2)	mg/L	28.5	28.5	28.8	28.7	28.2	28.3	27.8	28.4	28.2	28.2	27.9	28.3 28.0	28.2 28.4	28.1 28.3	28.2 28.4
Sulfate	mg/L	110	110	110	–	–	–	–	–	–	–	–	–	–	–	–
Turbidity	NTU	8.6	0.6	0.1	7.7	1.0	0.6	1.1	6.9	0.7	0.5	0.3	6.5 6.5	0.5 0.5	<0.1 0.1	0.1 0.1
pH	–	7.5	7.4	7.3	7.5	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.5	7.4	7.4	7.4
Temperature	ºC	8.3	8.1	8.3	8.6	8.6	8.6	8.5	8.1	8.2	8.1	8.1	9.6	8.7	8.7	8.6
DO	mg/L	1.0	1.9	1.0	1.6	1.1	1.2	1.6	1.8	1.1	0.9	1.1	1.6	1.4	1.1	2.0
ORP	mV	-80	163	317	-63	170	222	228	-67	382	379	364	-69	349	335	330
Free Chlorine	mg/L	–	1.0	1.0	–	1.0	1.0	1.0	–	1.0	1.0	1.0	–	3.0	3.0	3.0
Total Chlorine	mg/L	–	3.0	3.0	–	3.0	3.0	3.0	–	3.0	3.0	3.0	–	3.0+	3.0+	3.0+
Total Hardness	mg/L[a]	283	279	278	–	–	–	–	–	–	–	–	–	–	–	–
Ca Hardness	mg/L[a]	188	185	185	–	–	–	–	–	–	–	–	–	–	–	–
Mg Hardness	mg/L[a]	94.4	93.7	93.0	–	–	–	–	–	–	–	–	–	–	–	–
As (total)	µg/L	36.9	37.6	10.1	35.0	72.0[c]	17.9[c]	18.3[c]	34.0	36.0	12.0	13.0	33.9 34.3	34.1 35.8	10.5 10.9	10.6 11.0
As (total soluble)	µg/L	35.7	11.4	10.0	–	–	–	–	–	–	–	–	–	–	–	–
As (particulate)	µg/L	1.2	26.2	0.1	–	–	–	–	–	–	–	–	–	–	–	–
As (III)	µg/L	35.7	1.5	1.8	–	–	–	–	–	–	–	–	–	–	–	–
As (V)	µg/L	<0.1	9.9	8.1	–	–	–	–	–	–	–	–	–	–	–	–
Fe (total)	µg/L	540	551	<25	548	1,002[c]	<25[c]	<25[c]	479	503	<25	<25	523 495	514 507	<25 <25	26.0 <25
Fe (soluble)	µg/L	520	<25	<25	–	–	–	–	–	–	–	–	–	–	–	–
Mn (total)	µg/L	115	115	62.6	123	124[c]	71.1[c]	69.9[c]	114	113	66.8	66.5	121 115	117 116	65.6 66.8	66.3 64.5
Mn (soluble)	µg/L	116	61.7	61.8	–	–	–	–	–	–	–	–	–	–	–	–

(a) as $CaCO_3$ (b) as PO_4 (c) Sample re-run due to high Mn and As readings. Both sample sets were similar in value.
IN = at wellhead; AC = after contact tanks; TA = after tank A; TB = after tank B; TT = after tanks combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 4 of 13)

Sampling Date		11/02/04			11/09/04				11/16/04				11/30/04		
Sampling Location Parameter	Unit	IN	AC	TT	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L[(a)]	304	304	287	304	304	299	304	328	308	312	324	313	309	296
Ammonia	mg/L	–	–	–	–	–	–	–	0.7	–	–	–	–	–	–
Fluoride	mg/L	0.2	0.2	0.6	–	–	–	–	–	–	–	–	0.6	0.6	1.4
NO_3-N	mg/L	<0.04	<0.04	<0.04	–	–	–	–	–	–	–	–	<0.04	<0.04	<0.04
Orthophosphate	mg/L[(b)]	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silica (as SiO_2)	mg/L	27.9	28.2	28.5	28.2	28.2	27.8	28.1	28.4	28.6	28.3	28.6	28.1	28.5	28.0
Sulfate	mg/L	120	120	120	–	–	–	–	–	–	–	–	120	120	120
Turbidity	NTU	5.3	0.4	0.1	6.0	0.5	0.5	0.3	6.3	0.9	0.5	0.5	6.8	0.7	0.5
pH	–	7.6	7.4	7.4	7.6	7.4	7.4	7.4	7.6	7.4	7.4	7.4	7.6	7.4	7.4
Temperature	ºC	9.0	8.7	8.6	9.1	9.1	8.7	8.9	9.0	9.1	9.1	9.1	9.3	8.6	8.5
DO	mg/L	1.4	1.9	1.4	1.4	1.8	1.4	1.9	1.5	1.9	1.5	1.9	2.2	2.3	2.5
ORP	mV	-66	309	347	-68	311	332	328	-70	314	326	330	-128	321	333
Free Chlorine	mg/L	–	1.0	1.0	–	1.0	1.0	1.0	–	1.0	1.0	1.0	–	1.0	1.0
Total Chlorine	mg/L	–	2.2	2.2	–	2.2	2.2	2.2	–	2.2	2.2	2.2	–	2.2	2.2
Total Hardness	mg/L[(a)]	238	240	239	–	–	–	–	–	–	–	–	222	219	241
Ca Hardness	mg/L[(a)]	151	154	153	–	–	–	–	–	–	–	–	148	146	162
Mg Hardness	mg/L[(a)]	87.0	86.1	86.1	–	–	–	–	–	–	–	–	74.3	73.4	79.1
As (total)	µg/L	39.3	38.7	16.3	34.1	33.8	9.3	9.9	34.9	35.1	9.9	10.3	51.4	41.6	19.0
As (total soluble)	µg/L	39.0	17.8	15.3	–	–	–	–	–	–	–	–	51.3	19.5	16.1
As (particulate)	µg/L	0.3	20.9	1.0	–	–	–	–	–	–	–	–	0.1	22.1	2.9
As (III)	µg/L	36.9	3.0	3.5	–	–	–	–	–	–	–	–	39.8	6.2	5.1
As (V)	µg/L	2.1	14.8	11.8	–	–	–	–	–	–	–	–	11.5	13.3	11.0
Fe (total)	µg/L	361	363	<25	520	550	<25	<25	508	538	<25	<25	524	448	36.8
Fe (soluble)	µg/L	354	<25	<25	–	–	–	–	–	–	–	–	505	<25	<25
Mn (total)	µg/L	113	112	69.2	131	135	78.5	78.9	126	128	74.6	74.0	125	109	68.2
Mn (soluble)	µg/L	114	64.9	66.5	–	–	–	–	–	–	–	–	125	75.0	69.1

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 5 of 13)

Sampling Date		12/07/04				12/14/04				01/04/05[c,d]			01/11/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT	IN	AC	TA	TB
Alkalinity	mg/L[a]	325	325	325	309	318	301	301	305	296	284	284	314	302	310	298
Ammonia	mg/L	0.8	–	–	–	0.7	–	–	–	–	–	–	0.6	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	0.7	0.7	1.5	–	–	–	–
NO_3-N	mg/L	–	–	–	–	–	–	–	–	<0.04	<0.04	<0.04	–	–	–	–
Orthophosphate	mg/L[b]	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Silica (as SiO_2)	mg/L	27.9	28.5	28.5	29.1	28.9	28.9	28.6	28.8	29.0	29.7	29.8	29.8	29.7	29.3	28.5
Sulfate	mg/L	–	–	–	–	–	–	–	–	130	120	120	–	–	–	–
Turbidity	NTU	6.9	0.6	0.4	0.5	8.3	1.1	1.0	0.3	3.0	1.3	0.4	4.9	1.0	0.2	0.2
pH	–	7.6	7.4	7.3	7.3	7.5	7.4	7.4	7.4	7.6	7.4	7.4	7.6	7.5	7.5	7.4
Temperature	ºC	8.8	8.5	8.4	8.4	8.5	8.8	8.7	8.4	8.4	8.5	8.5	8.4	8.3	8.2	8.4
DO	mg/L	2.5	1.9	1.9	2.2	1.8	1.7	1.5	2.5	1.0	1.8	1.7	1.0	1.3	1.5	2.1
ORP	mV	-68	289	295	298	-89	301	298	304	-77	315	307	-80	242	247	252
Free Chlorine	mg/L	–	0.2	0.2	0.2	–	0.2	0.2	0.2	–	1.5	1.5	–	0.8	0.8	0.8
Total Chlorine	mg/L	–	0.9	0.9	0.9	–	0.9	0.9	0.9	–	2.2	2.2	–	1.4	1.4	1.4
Total Hardness	mg/L[a]	–	–	–	–	–	–	–	–	215	214	215	–	–	–	–
Ca Hardness	mg/L[a]	–	–	–	–	–	–	–	–	139	138	140	–	–	–	–
Mg Hardness	mg/L[a]	–	–	–	–	–	–	–	–	76.5	75.8	75.5	–	–	–	–
As (total)	µg/L	33.4	33.4	10.4	10.3	36.4	35.6	9.5	13.7	32.3	32.8	6.0	35.1	35.5	5.8	7.2
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	33.3	4.5	4.8	–	–	–	–
As (particulate)	µg/L	–	–	–	–	–	–	–	–	<0.1	28.3	1.2	–	–	–	–
As (III)	µg/L	–	–	–	–	–	–	–	–	32.6	0.9	1.2	–	–	–	–
As (V)	µg/L	–	–	–	–	–	–	–	–	0.7	3.6	3.6	–	–	–	–
Fe (total)	µg/L	551	564	<25	<25	651	616	<25	<25	376	1,499	<25	463	1186	67.2	63.6
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	342	<25	<25	–	–	–	–
Mn (total)	µg/L	122	120	70.2	69.7	137	135	75.9	71.4	116	118	70.3	125	126	89.0	94.6
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	112	67.1	68.3	–	–	–	–

(a) as $CaCO_3$ (b) as PO_4 (c) Iron addition began on January 3, 2005 (d) On-site measurements were taken on January 5, 2005
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 6 of 13)

Sampling Date		01/18/05[c]				01/25/05				02/01/05				02/08/05		
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L[a]	308 329	321 299	321 321	317 317	319	324	324	297	337	355	355	337	334	339	334
Ammonia	mg/L	0.7 0.6	–	–	–	0.6	–	–	–	0.8	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.4	0.4	0.9
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Orthophosphate	mg/L[b]	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	29.3 29.2	28.8 28.2	28.3 28.1	28.5 28.5	27.5	27.7	27.4	27.3	27.8	27.1	27.3	27.3	28	27.8	28
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	154	155	155
Turbidity	NTU	5.8 5.3	0.6 1.0	<0.1 0.2	0.1 0.1	5.6	1.1	<0.1	<0.1	6.4	1.4	0.1	0.1	6.4	0.4	<0.1
pH	–	7.6	7.6	7.6	7.6	7.6	7.5	7.5	7.5	7.5	7.4	7.4	7.3	7.5	7.5	7.4
Temperature	ºC	8.8	8.5	8.5	8.6	8.9	8.7	8.5	8.4	8.8	8.4	8.4	8.4	9.1	9.1	9.1
DO	mg/L	1.2	1.4	1.9	1.7	1.7	1.2	1.2	1.7	1.8	1.5	1.4	1.4	2.5	2.0	1.6
ORP	mV	-86	267	258	259	-74	268	274	279	-79	299	307	305	-81	286	258
Free Chlorine	mg/L	–	1.0	1.0	1.0	–	1.5	1.5	1.5	–	1.6	1.6	1.6	–	1.6	1.6
Total Chlorine	mg/L	–	2.2	2.2	2.2	–	2.2	2.2	2.2	–	2.2	2.2	2.2	–	2.2	2.2
Total Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	244	236	234
Ca Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	156	153	153
Mg Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	88.6	82.9	80.7
As (total)	µg/L	35.0 35.9	35.1 36.3	6.0 7.3	7.2 7.1	33.6	32.8	5.8	5.6	34.9	18.5	5.3	6.4	37.3	33.6	6.0
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	37.4	18.3	5.4
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	15.3	0.6
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	34.0	1.4	1.4
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	3.4	16.9	4.0
Fe (total)	µg/L	565 523	1,478 1,340	<25 81.4	51.2 81.7	515	1,255	<25	<25	723	1,686	37.1	83.6	529	515	26.3
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	507	<25	<25
Mn (total)	µg/L	131 137	143 136	85.8 74.7	104 74.9	121	122	65.1	62.9	132	141	76.8	81.0	114	110	57.2
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	114	59.0	55.5

(a) as $CaCO_3$ (b) as PO_4 (c) On-site measurements were taken on January 19, 2005
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 7 of 13)

Sampling Date		02/16/05				02/22/05				03/01/05				03/08/05		
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L[(a)]	334	317	334	334	360	333	328	328	540	535	562	544	334	326	334
Ammonia	mg/L	0.7	–	–	–	0.7	–	–	–	0.6	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.5	1.0
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	30.5	30.5	29.9	30.6	28.8	29.4	27.6	28.6	28.3	28.4	28.1	27.8	29.9	29.9	29.8
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	149	144	144
Turbidity	NTU	7.2	1.4	0.2	0.2	5.7	1.2	0.2	<0.1	4.9	6.7	0.6	0.7	5.8	1.3	0.2
pH	–	7.6	7.5	7.5	7.5	7.6	7.5	7.5	7.5	7.7	7.6	7.6	7.6	7.6	7.5	7.5
Temperature	ºC	9.8	8.6	8.4	8.4	9.1	8.8	8.5	8.8	8.4	8.4	8.6	8.6	8.5	8.5	8.5
DO	mg/L	1.7	1.2	1.4	1.4	1.9	1.4	1.5	1.5	1.6	0.7	1.0	1.6	1.1	1.2	1.7
ORP	mV	-82	240	262	265	-80	252	256	259	-82	238	237	243	-78	212	223
Free Chlorine	mg/L	–	1.3	1.3	1.3	–	0.9	0.9	0.9	–	1.1	1.1	1.1	–	0.6	0.6
Total Chlorine	mg/L	–	2.2	2.2	2.2	–	1.9	1.9	1.9	–	2.0	2.0	2.0	–	1.2	1.2
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	208	207	202
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	139	146	143
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	68.5	61.3	58.9
As (total)	µg/L	35.5	37.9	7.1	7.4	32.1	33.6	5.5	5.7	37.6	42.1	6.7	6.1	34.4	35.7	8.0
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	38.3	13.5	7.6
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	22.1	0.4
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	38.5	2.1	2.4
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	11.4	5.3
Fe (total)	µg/L	569	1,791	107	122	581	1,425	31.1	36.0	449	1,985	38.2	37.1	455	1,198	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	427	<25	<25
Mn (total)	µg/L	123	139	69.6	71.8	117	126	92.3	90.8	120	128	97.1	126	123	133	126
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	127	82.0	82.0

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 8 of 13)

Sampling Date		03/15/05				03/22/05				03/29/05				04/05/05		
Sampling Location **Parameter**	**Unit**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TT**
Alkalinity	mg/L[(a)]	334	334	326	330	320	324	320	324	327	318	323	318	339	330	326
Ammonia	mg/L	0.6	–	–	–	0.7	–	–	–	0.8	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.6	0.6	1.2
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.6
Silica (as SiO_2)	mg/L	29.6	30.5	30.4	30.3	29.3	29.4	29.1	28.7	28.8	29.1	29.2	29.1	28.9	29.4	29.1
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	105	103	107
Turbidity	NTU	5.5	1.3	0.2	0.1	5.5	1.1	0.1	0.3	4.1	1.1	0.2	0.4	7.5	1.1	<0.1
pH	–	7.6	7.6	7.5	7.6	7.5	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.4
Temperature	ºC	9.1	8.7	8.9	8.8	9.0	9.0	9.1	9.1	9.0	8.7	9.5	9.0	8.9	8.9	9.0
DO	mg/L	1.6	0.8	1.4	1.3	1.3	1.5	1.2	1.2	2.1	1.3	1.0	1.0	1.9	1.34	1.4
ORP	mV	-79	228	246	243	-67	218	234	236	-69	222	226	230	-72	219	236
Free Chlorine	mg/L	–	0.6	0.6	0.6	–	0.5	0.5	0.5	–	0.5	0.5	0.5	–	0.8	0.8
Total Chlorine	mg/L	–	1.2	1.2	1.2	–	1.2	1.2	1.2	–	1.2	1.2	1.2	–	1.4	1.4
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	243	239	246
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	158	158	161
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	84.7	80.5	84.3
As (total)	µg/L	34.3	36.6	6.4	6.9	38.4	39.0	9.0	9.7	33.4	33.4	7.0	6.5	36.3	36.8	8.7
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	36.3	12.5	8.8
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	24.3	<0.1
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	33.7	2.8	2.3
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	2.6	9.7	6.5
Fe (total)	µg/L	484	1,254	57.0	50.2	570	1,327	80.8	77.9	520	1,196	<25	<25	625	1,397	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	649	<25	<25
Mn (total)	µg/L	133	149	115	104	137	137	118	111	128	130	83.6	81.0	127	136	114
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	137	83.5	86.4

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 9 of 13)

Sampling Date		04/12/05				04/19/05				04/26/05				05/03/05		
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L[(a)]	333 333	333 337	333 324	333 333	401	343	334	339	337	342	337	333	329	333	333
Ammonia	mg/L	0.6 0.7	–	–	–	0.7	–	–	–	0.6	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.5	1.0	0.5
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Orthophosphate	mg/L[(b)]	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	29.2 29.5	26.8 29.8	28.9 29.2	29.1 29.3	28.9	29.5	28.9	28.6	29.4	28.7	28.5	29.4	28.7	28.9	28.8
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	130	126	129
Turbidity	NTU	6.1 4.9	1.1 2.3	0.1 0.2	0.2 0.5	7.3	1.5	0.4	0.2	5.4	1.2	0.2	0.4	4.5	0.2	1.0
pH	–	7.4	7.3	7.4	7.4	7.4	7.4	7.3	7.4	7.5	7.4	7.3	7.4	7.5	7.4	7.4
Temperature	ºC	9.0	8.7	9.0	8.7	10.0	9.3	9.3	9.3	8.8	9.0	8.9	9.0	8.9	8.9	8.9
DO	mg/L	2.0	2.0	1.3	1.3	2.0	1.8	1.8	1.6	1.9	1.6	1.7	1.6	1.9	2.5	1.9
ORP	mV	-74	220	223	229	-74	224	229	232	-75	223	226	231	-75	226	234
Free Chlorine	mg/L	–	0.8	0.8	0.8	–	0.8	0.8	0.8	–	0.8	0.8	0.8	–	0.7	0.7
Total Chlorine	mg/L	–	1.4	1.4	1.4	–	1.6	1.6	1.6	–	1.5	1.5	1.5	–	1.3	1.3
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	202	201	196
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	134	134	132
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	67.9	67.3	64.3
As (total)	µg/L	34.7 32.1	34.8 31.9	5.6 5.8	5.6 5.8	36.0	32.4	5.8	6.3	35.6	35.9	6.0	6.4	35.2	33.8	7.1
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	35.9	11.5	6.6
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	22.3	0.4
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	34.2	1.4	1.5
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	1.8	10.1	5.1
Fe (total)	µg/L	592 529	1,461 1,462	53.0 49.1	58.0 62.3	553	1,469	32.4	39.8	529	1,291	37.1	38.4	484	1,264	72.1
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	473	<25	<25
Mn (total)	µg/L	124 130	131 139	105 94.3	94.8 89.7	127	140	94.1	93.9	112	122	93.9	94.6	137	141	123
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	141	89.1	91.5

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 10 of 13)

Sampling Date		05/10/05[c]				05/17/05				05/24/05				05/31/05		
Sampling Location Parameter	**Unit**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TT**
Alkalinity	mg/L[a]	334	330	330	330	339	334	334	343	308	326	334	326	332	345	346
Ammonia	mg/L	0.7	–	–	–	0.6	–	–	–	0.7	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.4	0.4	0.8
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.05	<0.05	<0.05
Orthophosphate	mg/L[b]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	29.2	29.2	28.7	28.8	29.8	29.6	29.4	29.4	28.8	28.6	28.2	27.9	28.9	29.0	29.0
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	127	127	121
Turbidity	NTU	5	1.3	0.7	0.7	6.6	1.3	0.2	0.2	5.6	1.3	0.3	0.5	6.3	1.4	0.5
pH	–	7.4	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.4	7.4
Temperature	ºC	9.3	9.2	9.2	9.3	9.0	8.9	8.5	8.7	9.0	8.9	8.9	8.9	11.2	10.8	10.1
DO	mg/L	1.9	1.1	1.6	1.5	1.5	1.7	1.2	1.2	1.5	1.5	1.5	1.4	1.7	1.6	1.1
ORP	mV	-76	221	220	223	-76	219	223	225	-79	216	218	222	-75	217	225
Free Chlorine	mg/L	–	0.7	0.7	0.7	–	0.8	0.8	0.8	–	0.9	0.9	0.9	–	0.8	0.8
Total Chlorine	mg/L	–	1.2	1.2	1.2	–	1.3	1.3	1.3	–	1.5	1.5	1.5	–	1.3	1.3
Total Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	217	219	224
Ca Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	148	145	148
Mg Hardness	mg/L[a]	–	–	–	–	–	–	–	–	–	–	–	–	69.8	73.9	76.6
As (total)	µg/L	34.2	34.6	7.8	8.6	34.9	36.0	7.1	6.8	36.0	36.3	7.3	8.2	37.4	37.2	9.3
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	37.9	12.2	6.9
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	25.0	2.4
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	38.2	2.2	1.9
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	10.0	5.0
Fe (total)	µg/L	563	1,371	75.3	96.5	518	1,228	67.2	42.8	506	1,188	<25	48.2	539	1,200	104
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	519	<25	<25
Mn (total)	µg/L	138	142	109	101	129	135	102	119	128	131	128	106	123	121	83.7
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	124	79.9	79.4

(a) as $CaCO_3$ (b) as PO_4 (c) On-site measurements performed on May 11, 2005.
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 11 of 13)

Sampling Date		06/07/05				06/14/05				06/21/05				06/28/05		
Sampling Location Parameter	Unit	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TA	TB	IN	AC	TT
Alkalinity	mg/L[(a)]	308	339	334	343	334	326	330	326	330	330	330	330	308	330	308
Ammonia	mg/L	0.8	–	–	–	0.7	–	–	–	0.7	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.3	0.3	0.9
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.1	<0.05	0.1
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	29.3	29.3	29.0	28.8	29.5	29.4	29.4	29.9	28.6	28.4	28.2	28.0	28.9	28.9	28.8
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	110	100	118
Turbidity	NTU	8.8	1.6	0.5	1.2	5.6	1.5	0.3	0.5	6.3	1.5	1.0	0.3	18.0	15.0	0.7
pH	–	7.4	7.3	7.3	7.3	7.4	7.3	7.3	7.4	7.4	7.3	7.3	7.3	7.4	7.4	7.4
Temperature	ºC	9.3	9.0	8.8	8.9	8.7	8.8	8.8	8.9	8.7	8.7	8.7	8.7	10.9	10.6	10.4
DO	mg/L	0.7	0.9	1.0	1.3	1.1	1.3	0.8	0.9	1.4	1.3	1.1	1.6	1.3	1.2	1.1
ORP	mV	-80	233	238	241	-79	228	232	236	-75	235	236	240	-77	222	228
Free Chlorine	mg/L	–	1.3	1.3	1.3	–	1.1	1.1	1.1	–	0.9	0.9	0.9	–	1.0	1.0
Total Chlorine	mg/L	–	1.8	1.8	1.8	–	1.8	1.8	1.8	–	1.8	1.8	1.8	–	1.7	1.7
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	249	235	247
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	164	160	163
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	85.5	74.9	83.8
As (total)	µg/L	39.7	38.5	6.1	6.3	41.4	41.6	7.6	6.6	37.5	40.6	6.8	7.3	39.1	37.2	6.9
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	38.7	10.6	6.3
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.4	26.6	0.6
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	38.0	3.1	3.2
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.7	7.5	3.1
Fe (total)	µg/L	714	1,400	31.5	59.6	550	1,487	46.8	64.9	563	1,508	<25	<25	534	1,558	<25
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	526	32.1	<25
Mn (total)	µg/L	135	136	94.2	89.0	127	130	86.8	87.9	128	136	77.9	80.1	125	128	74.1
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	123	69.9	69.0

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 12 of 13)

Sampling Date		07/05/05				07/12/05				07/19/05				07/26/05		
Sampling Location Parameter	**Unit**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TA**	**TB**	**IN**	**AC**	**TT**
Alkalinity	mg/L[(a)]	308 308	308 308	308 308	308 308	321	330	317	317	308	308	308	308	317	321	317
Ammonia	mg/L	0.6 0.6	–	–	–	0.7	–	–	–	0.6	–	–	–	–	–	–
Fluoride	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.4	0.4
NO_3-N	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	0.1	0.1	0.1
Orthophosphate	mg/L[(b)]	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05 <0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	28.6 28.4	28.3 28.8	28.3 28.1	28.3 27.8	27.7	27.6	27.8	27.0	28.1	28.3	28.3	27.9	27.4	27.7	27.5
Sulfate	mg/L	–	–	–	–	–	–	–	–	–	–	–	–	114	119	117
Turbidity	NTU	4.2 4.4	1.3 1.2	0.2 0.2	<0.1 0.2	11.0	2.9	0.2	0.4	0.1	5.8	0.1	0.2	6.6	1.9	0.1
pH	–	7.5	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.4
Temperature	°C	9.0	9.1	9.4	9.0	9.1	8.9	8.9	9.0	9.1	9.0	8.9	9.0	8.8	8.8	8.8
DO	mg/L	0.4	1.0	1.0	1.4	0.7	1.0	0.5	1.0	0.7	0.9	0.8	0.5	0.7	0.6	0.9
ORP	mV	-75	239	236	233	-79	227	233	235	-82	230	235	239	-81	229	239
Free Chlorine	mg/L	–	1.0	1.0	1.0	–	0.5	0.5	0.5	–	0.4	0.4	0.4	–	0.7	0.7
Total Chlorine	mg/L	–	1.7	1.7	1.7	–	1.2	1.2	1.2	–	1.0	1.0	1.0	–	1.4	1.4
Total Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	205	218	225
Ca Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	136	145	150
Mg Hardness	mg/L[(a)]	–	–	–	–	–	–	–	–	–	–	–	–	69.2	73.3	75.3
As (total)	µg/L	33.2 33.4	33.1 33.7	6.5 7.9	7.7 7.9	36.1	36.2	7.2	7.4	35.4	34.8	7.6	7.9	33.5	33.8	7.1
As (total soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	33.6	10.5	5.4
As (particulate)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	23.3	1.7
As (III)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	34.3	1.9	2.0
As (V)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	<0.1	8.6	3.4
Fe (total)	µg/L	444 408	1,269 1,226	61.3 93.6	62.7 92.0	423	1,179	<25	<25	547	1,331	57.1	73.7	523	1,339	81.7
Fe (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	516	27.0	<25
Mn (total)	µg/L	130 122	127 124	102 81.9	106 82.6	148	148	107	100	130	135	86.8	148	148	107	100
Mn (soluble)	µg/L	–	–	–	–	–	–	–	–	–	–	–	–	132	82.2	78.8

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

Table A-1. Analytical Results from Long-Term Sampling, Climax, Minnesota (Page 13 of 13)

Sampling Date		08/02/05			
Sampling Location Parameter	Unit	IN	AC	TA	TB
Alkalinity	mg/L[(a)]	321	317	321	326
Ammonia	mg/L	0.7	–	–	–
Fluoride	mg/L	–	–	–	–
NO_3-N	mg/L	–	–	–	–
Orthophosphate	mg/L[(b)]	<0.05	<0.05	<0.05	<0.05
Silica (as SiO_2)	mg/L	27.7	27.7	27.0	27.2
Sulfate	mg/L	–	–	–	–
Turbidity	NTU	8.3	1.5	0.2	0.9
pH	–	7.5	7.4	7.4	7.4
Temperature	ºC	8.9	8.8	8.9	8.9
DO	mg/L	0.7	0.7	0.4	1.0
ORP	mV	-78	225	232	234
Free Chlorine	mg/L	–	1.2	1.2	1.2
Total Chlorine	mg/L	–	1.9	1.9	1.9
Total Hardness	mg/L[(a)]	–	–	–	–
Ca Hardness	mg/L[(a)]	–	–	–	–
Mg Hardness	mg/L[(a)]	–	–	–	–
As (total)	µg/L	31.2	31.8	5.2	6.1
As (total soluble)	µg/L	–	–	–	–
As (particulate)	µg/L	–	–	–	–
As (III)	µg/L	–	–	–	–
As (V)	µg/L	–	–	–	–
Fe (total)	µg/L	581	1,431	32.2	70.0
Fe (soluble)	µg/L	–	–	–	–
Mn (total)	µg/L	120	125	78.5	80.6
Mn (soluble)	µg/L	–	–	–	–

(a) as $CaCO_3$ (b) as PO_4
IN = at wellhead; AC = after contact tanks; TA = after Tank A; TB = after Tank B; TT = after Tanks A and B combined

APPENDIX B

ANALYTICAL DATA

Table B-1: Daily System Operation Log (Page 1 of 23)

		Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
Week No.	Date	Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
2	08/16/04	5.0	NA	307050	NA	70	60	60	41	10	10	29	110	NA	NA	NA	NA	NA	NA	NA
	08/17/04	NA	NA	348300	41	71	59	59	41	12	12	30	104	367.0	NA	NA	NA	NA	NA	NA
	08/18/04	7.8	NA	394840	47	68	60	60	41	8	8	27	107	414.1	47	NA	NA	NA	NA	NA
	08/19/04	4.0	NA	418120	23	68	60	60	41	8	8	27	108	438.5	24	NA	NA	NA	NA	NA
	08/20/04	7.6	NA	466000	48	65	65	62	41	0	3	24	124	488.2	50	NA	NA	NA	NA	NA
	08/21/04	8.7	NA	523000	57	65	65	65	41	0	0	24	122	549.5	61	NA	NA	NA	NA	NA
	08/22/04	10.6	NA	590700	68	67	53	53	41	14	14	26	120	622.8	73	NA	NA	NA	NA	NA
3	08/23/04	9.2	NA	645200	55	64	56	56	40	8	8	24	119	680.4	58	NA	NA	NA	NA	NA
	08/24/04	9.4	NA	705180	60	64	54	54	41	10	10	23	117	745.1	65	NA	NA	NA	NA	NA
	08/25/04	5.2	NA	737300	32	65	53	53	41	12	12	24	118	780.1	35	NA	NA	NA	NA	NA
	08/26/04	4.5	NA	765240	28	62	55	55	40	7	7	22	118	809.0	29	NA	NA	NA	NA	NA
	08/27/04	4.9	NA	797100	32	63	55	56	41	8	7	22	117	842.8	34	NA	NA	NA	NA	NA
	08/28/04	6.0	NA	835770	39	65	55	56	41	10	9	24	118	884.3	42	NA	NA	NA	NA	NA
	08/29/04	6.9	NA	880300	45	63	55	55	40	8	8	23	119	931.0	47	NA	NA	NA	NA	NA
4	08/30/04	3.3	NA	901550	21	64	56	56	41	8	8	23	119	953.0	22	NA	NA	NA	NA	NA
	08/31/04	14.8	NA	994280	93	65	56	56	41	9	9	24	117	1052.8	100	NA	NA	NA	NA	NA
	09/01/04	NA	6.0	1037180	43	69	60	60	41	9	9	28	139	1097.7	45	NA	NA	24.5	NA	NA
	09/02/04	NA	9.6	1109340	72	74	61	61	41	13	13	33	135	1174.6	77	NA	NA	24.5	NA	NA
	09/03/04	NA	4.4	1141780	32	72	59	59	41	13	13	31	138	1208.4	34	NA	NA	24.5	NA	NA

Table B-1: Daily System Operation Log (Page 2 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
4 (con't)	09/04/04	NA	3.8	1166780	25	69	59	59	41	10	10	28	144	1237.2	29	NA	NA	26.2	NA	NA
	09/05/04	NA	5.3	1210860	44	69	59	59	41	10	10	28	143	1280.7	44	NA	NA	26.2	NA	NA
5	09/06/04	NA	3.8	1238880	28	73	62	62	41	11	11	32	138	1310.3	30	NA	NA	26.2	NA	NA
	09/07/04	NA	6.2	1284700	46	73	64	64	41	9	9	32	136	1359.4	49	NA	NA	27.8	NA	NA
	09/08/04	NA	3.4	1310250	26	71	61	61	41	10	10	30	144	1386.2	27	NA	NA	27.8	NA	NA
	09/09/04	NA	3.9	1339150	29	72	59	59	41	13	13	31	136	1415.7	30	NA	NA	27.8	NA	NA
	09/10/04	NA	5.6	1381950	43	72	62	62	41	10	10	31	139	1460.3	45	NA	NA	29.5	NA	NA
	09/11/04	NA	3.8	1410220	28	73	62	62	40	11	11	33	137	1491.2	31	NA	NA	29.5	NA	NA
	09/12/04	NA	3.3	1435060	25	72	59	59	41	13	13	31	141	1517.3	26	NA	NA	31.2	NA	NA
6	09/13/04	NA	6.0	1480460	45	73	62	62	41	11	11	32	139	1564.8	48	NA	NA	31.2	NA	NA
	09/14/04	NA	4.4	1515480	35	73	63	63	41	10	10	32	138	1600.0	35	NA	NA	31.2	NA	NA
	09/15/04	NA	4.6	1547420	32	74	60	60	41	14	14	33	137	1633.8	34	NA	NA	32.9	NA	NA
	09/16/04	NA	4.3	1579600	32	73	60	60	41	13	13	32	138	1667.9	34	NA	NA	32.9	NA	NA
	09/17/04	NA	3.1	1602560	23	72	61	61	41	11	11	31	138	1691.9	24	NA	NA	34.5	NA	NA
	09/18/04	NA	5.6	1645770	43	70	60	60	41	10	10	29	139	1736.9	45	NA	NA	34.5	NA	NA
	09/19/04	NA	3.4	1671370	26	72	60	60	41	12	12	31	139	1763.8	27	NA	NA	34.5	NA	NA

Table B-1: Daily System Operation Log (Page 3 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
7	09/20/04	NA	3.8	1700440	29	70	60	60	41	10	10	29	142	1793.4	30	21	24	36.3	NA	NA
	09/21/04	NA	4.9	1737480	37	70	60	61	41	10	9	29	138	1831.7	38	21	24	36.3	NA	NA
	09/22/04	NA	4.3	1769760	32	73	59	59	41	14	14	32	140	1864.9	33	22	25	38.1	NA	NA
	09/23/04	NA	1.4	1780760	11	69	60	60	41	9	9	28	144	1875.6	11	22	25	38.1	NA	NA
	09/24/04	NA	7.2	1835860	55	70	61	61	41	9	9	29	140	1933.8	58	22	25	38.1	NA	NA
	09/25/04	NA	4.8	1871540	36	73	62	62	41	11	11	32	139	1970.7	37	22	25	38.1	NA	NA
	09/26/04	NA	4.9	1908140	37	74	63	63	41	11	11	33	138	2008.7	38	23	26	39.8	NA	NA
8	09/27/04	NA	4.7	1944060	36	70	60	60	41	10	10	29	143	2045.8	37	23	26	39.8	NA	NA
	09/28/04	NA	4.8	1979880	36	73	61	61	40	12	12	33	138	2081.9	36	23	26	39.8	NA	NA
	09/29/04	NA	4.8	2016080	36	74	64	64	41	10	10	33	136	2118.3	36	24	27	41.5	NA	NA
	09/30/04	NA	4.6	2051560	35	70	60	60	41	10	10	29	138	2153.9	36	24	27	41.5	NA	NA
	10/01/04	5.6	NA	2087000	35	64	55	55	41	9	9	23	118	2189.7	36	24	27	41.5	NA	NA
	10/02/04	4.6	NA	2117460	30	63	54	54	41	9	9	22	123	2221.1	31	25	28	43.3	NA	NA
	10/03/04	3.6	NA	2132460	15	64	55	55	41	9	9	23	122	2252.2	31	25	28	43.3	NA	NA
9	10/04/04	6.5	NA	2172180	40	62	55	55	41	7	7	21	124	2286.9	35	26	29	45.0	NA	NA
	10/05/04	6.6	NA	2225180	53	65	55	55	41	10	10	24	118	2332.0	45	26	29	45.0	NA	NA
	10/06/04	5.5	NA	2260160	35	65	56	56	41	9	9	24	118	2368.3	36	26	29	45.0	NA	NA

Table B-1: Daily System Operation Log (Page 4 of 23)

		Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
Week No.	Date	Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
9 (con't)	10/07/04	4.8	NA	2291000	31	62	55	55	41	7	7	21	124	2400.1	32	27	30	46.7	NA	NA
	10/08/04	6.1	NA	2328580	38	63	56	56	41	7	7	22	122	2439.2	39	27	30	46.7	NA	NA
	10/09/04	5.3	NA	2365220	37	65	56	56	41	9	9	24	118	2477.4	38	27	30	46.7	NA	NA
	10/10/04	5.6	NA	2402050	37	62	55	55	41	7	7	21	123	2515.5	38	28	31	48.5	NA	NA
10	10/11/04	5.6	NA	2438560	37	62	56	56	40	6	6	22	122	2553.4	38	28	31	48.5	NA	NA
	10/12/04	6.5	NA	2481460	43	62	56	56	40	6	6	22	122	2596.3	43	29	32	50.2	NA	NA
	10/13/04	4.7	NA	2511620	30	64	56	56	40	8	8	24	119	2627.5	31	29	32	50.2	NA	NA
	10/14/04	4.7	NA	2541420	30	63	56	56	40	7	7	23	123	2657.8	30	30	33	51.9	NA	NA
	10/15/04	6.5	NA	2584280	43	63	56	56	40	7	7	23	121	2702.1	44	30	33	51.9	NA	NA
	10/16/04	5.2	NA	2610280	26	64	56	56	40	8	8	24	121	2728.1	26	30	33	51.9	NA	NA
	10/17/04	37.6	NA	2621000	11	62	54	54	40	8	8	22	124	2740.4	12	31	34	53.6	NA	NA
11	10/18/04	9.0	NA	2678600	58	65	55	55	41	10	10	24	124	2801.2	61	32	35	55.3	NA	NA
	10/19/04	7.4	NA	2693220	15	65	55	55	41	10	10	24	122	2816.3	15	32	35	55.3	NA	NA
	10/20/04	6.6	NA	2735340	42	62	54	54	40	8	8	22	125	2859.3	43	33	36	57.0	NA	NA
	10/21/04	2.9	NA	2754540	19	63	56	56	41	7	7	22	120	2879.2	20	33	36	57.0	NA	NA
	10/22/04	2.9	NA	2773660	19	65	56	56	40	9	9	25	120	2899.1	20	34	37	60.2	NA	NA

Table B-1: Daily System Operation Log (Page 5 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
11 (con't)	10/23/04	2.1	NA	2783660	10	63	56	56	40	7	7	23	118	2909.1	10	Fail	NA	NA		
	10/24/04	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
12	10/25/04	NA	NA	2806130	NA	64	56	56	40	8	8	24	122	2933.0	NA	35	38	62.0	NA	NA
	10/26/04	9.2	NA	2831550	25	64	56	56	40	8	8	24	121	2959.6	27	35	38	62.0	NA	NA
	10/27/04	13.6	NA	2858650	27	63	52	52	40	11	11	23	120	2987.3	28	35	38	62.0	NA	NA
	10/28/04	7.9	NA	2909150	51	61	52	54	40	9	7	21	125	3039.8	53	36	39	63.8	NA	NA
	10/29/04	15.1	NA	2937450	28	62	53	53	40	9	9	22	122	3070.0	30	36	39	63.8	NA	NA
	10/30/04	6.9	NA	2984850	47	62	53	53	40	9	9	22	121	3119.7	50	36	39	63.8	NA	NA
	10/31/04	4.3	NA	3012960	28	63	56	56	40	7	7	23	120	3147.2	28	37	40	65.7	NA	NA
13	11/01/04	NA	4.9	3050770	38	67	56	58	40	11	9	27	142	3187.4	40	37	40	65.7	NA	NA
	11/02/04	NA	5.6	3094040	43	67	55	55	40	12	12	27	144	3232.2	45	38	41	67.5	NA	NA
	11/03/04	NA	4.1	3126530	32	67	56	56	40	11	11	27	143	3265.4	33	38	41	67.5	NA	NA
	11/04/04	NA	4.3	3160360	34	68	56	56	40	12	12	28	141	23.3	NA	38	41	67.5	NA	NA
	11/05/04	NA	4.2	3192660	32	68	56	56	40	12	12	28	140	56.4	33	39	42	69.4	NA	NA
	11/06/04	NA	5.8	3239980	47	67	55	55	40	12	12	27	144	104.5	48	39	42	69.4	NA	NA
	11/07/04	NA	4.3	3272280	32	67	55	55	40	12	12	27	143	138.6	34	39	42	69.4	NA	NA

Table B-1: Daily System Operation Log (Page 6 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
14	11/08/04	NA	4.1	3304550	32	68	55	58	40	13	10	28	142	171.4	33	40	43	71.2	NA	NA
	11/09/04	NA	4.9	3343060	39	68	55	58	40	13	10	28	142	211.2	40	40	43	71.2	NA	NA
	11/10/04	NA	5.6	3386260	43	71	55	59	40	16	12	31	142	255.9	45	41	44	73.0	NA	NA
	11/11/04	NA	2.7	3407620	21	71	55	59	40	16	12	31	141	278.0	22	41	44	73.0	NA	NA
	11/12/04	NA	5.6	3450540	43	70	57	58	40	13	12	30	140	322.6	45	41	44	73.0	NA	NA
	11/13/04	NA	5.2	3499810	49	71	55	55	41	16	16	30	144	364.2	42	42	45	74.8	NA	NA
	11/14/04	NA	2.7	3512940	13	71	55	56	40	16	15	31	142	386.1	22	42	45	74.8	NA	NA
15	11/15/04	NA	5.2	3552670	40	71	56	58	40	15	13	31	140	428.2	42	42	45	74.8	NA	NA
	11/16/04	NA	4.1	3585830	33	68	56	56	40	12	12	28	145	461.8	34	43	46	77.7	NA	NA
	11/17/04	NA	5.1	3625530	40	68	56	56	40	12	12	28	144	502.8	41	43	46	77.7	NA	NA
	11/18/04	NA	3.5	3652760	27	67	55	57	40	12	10	27	145	529.6	27	45	48	82.9	NA	NA
	11/19/04	NA	5.6	3698840	46	67	55	56	40	12	11	27	144	575.9	46	45	48	82.9	NA	NA
	11/20/04	NA	2.9	3720640	22	68	56	57	40	12	11	28	143	599.5	24	45	48	82.9	NA	NA
	11/21/04	NA	5.6	3764700	44	67	55	56	40	12	11	27	144	608.1	9	45	48	82.9	NA	NA
16	11/22/04	NA	2.9	3787710	23	67	56	56	40	11	11	27	144	669.1	61	46	49	85.1	NA	NA
	11/23/04	NA	5.6	3831510	44	68	57	58	40	11	10	28	142	714.3	45	46	49	85.1	NA	NA

Table B-1: Daily System Operation Log (Page 7 of 23)

		Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
Week No.	Date	Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
16 (con't)	11/24/04	NA	3.5	3859560	28	67	55	56	40	12	11	27	144	742.5	28	47	50	86.8	NA	NA
	11/25/04	NA	5.0	3898840	39	67	55	56	40	12	11	27	143	783.9	41	47	50	86.8	NA	NA
	11/26/04	NA	0.1	3899940	1	67	56	57	40	11	10	27	141	783.9	0	47	50	86.8	NA	NA
	11/27/04	NA	3.2	3924810	25	67	56	59	41	11	8	26	145	809.8	26	49	51	90.1	NA	NA
	11/28/04	NA	4.7	3961790	37	67	57	59	40	10	8	27	142	847.6	38	49	51	90.1	NA	NA
17	11/29/04	NA	4.6	3997760	36	66	55	56	40	11	10	26	145	884.6	37	50	52	91.9	NA	NA
	11/30/04	NA	8.5	4041460	44	70	56	58	40	14	12	30	141	926.7	42	50	52	91.9	NA	NA
	12/01/04	2.4	NA	4077260	36	62	54	55	40	8	7	22	123	962.6	36	50	52	91.9	NA	NA
	12/02/04	5.9	NA	4116660	39	62	55	57	40	7	5	22	121	1001.5	39	51	53	93.7	NA	NA
	12/03/04	5.8	NA	4156000	39	63	56	58	40	7	5	23	124	1040.4	39	51	53	93.7	NA	NA
	12/04/04	4.2	NA	4184360	28	63	56	58	40	7	5	23	121	1068.4	28	51	53	93.7	NA	NA
	12/05/04	3.3	NA	4207380	23	60	51	53	40	9	7	20	128	1091.4	23	52	54	95.5	NA	NA
18	12/06/04	5.8	NA	4246680	39	60	51	53	40	9	7	20	125	1131.9	41	52	54	95.5	NA	NA
	12/07/04	4.6	NA	4277380	31	61	52	54	40	9	7	21	123	1163.1	31	53	55	97.2	NA	NA
	12/08/04	6.0	NA	4318280	41	60	52	54	40	8	6	20	125	1205.5	42	53	55	97.2	NA	NA
	12/09/04	5.9	NA	4358000	40	60	52	53	40	8	7	20	124	1246.6	41	53	55	97.2	NA	NA
	12/10/04	3.1	NA	4378500	21	59	51	52	40	8	7	19	126	1276.8	30	54	56	99.0	NA	NA

Table B-1: Daily System Operation Log (Page 8 of 23)

Week No.	Date	Well #1 Daily Operational (hr)	Well#2 Daily Operational (hr)	Totalizer to Treatment Totalizer (kgal)	Totalizer to Treatment Daily Volume (kgal)	Pressure Filtration IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flow/Totalizer to Distribution Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	Backwash TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Iron Solution Weight Lbs
18 (con')	12/11/04	5.9	NA	4419900	41	60	52	53	40	8	7	20	123	1309.6	33	54	56	99.0	NA	NA
	12/12/04	5.9	NA	4458320	38	64	52	53	40	12	11	24	119	1350.4	41	54	56	99.0	NA	NA
19	12/13/04	3.0	NA	4479540	21	60	51	53	40	9	7	20	128	1372.2	22	55	57	100.7	48	NA
	12/14/04	5.1	NA	4514180	35	61	52	53	40	9	8	21	124	1407.7	36	55	57	100.7	32	NA
	12/15/04	7.4	NA	4563300	49	62	53	54	40	9	8	22	121	1459.0	51	55	57	100.7	47.5	NA
	12/16/04	5.3	NA	4600350	37	61	51	53	40	10	8	21	125	1497.0	38	56	58	102.5	17	NA
	12/17/04	5.0	NA	4634350	34	61	52	55	40	9	6	21	121	1531.9	35	56	58	102.5	35	NA
	12/18/04	3.7	NA	4659360	25	60	51	52	40	9	8	20	126	1556.0	24	57	59	104.2	8	NA
	12/19/04	6.0	NA	4701000	42	60	51	52	40	9	8	20	123	1601.1	45	57	59	104.2	24	NA
20	12/20/04	5.3	NA	4736540	36	61	52	54	40	9	7	21	122	1637.7	37	57	59	104.2	42	NA
	12/21/04	4.8	NA	4770240	34	60	51	54	40	9	6	20	125	1671.1	33	58	60	106.0	17	NA
	12/22/04	4.2	NA	4799940	30	61	52	54	40	9	7	21	123	1701.2	30	58	60	106.0	36	NA
	12/23/04	5.6	NA	4838940	39	61	51	53	40	10	8	21	125	1740.4	39	59	61	107.8	10	NA
	12/24/04	5.4	NA	4875270	36	61	51	53	40	10	8	21	124	1778.4	38	59	61	107.8	28	NA
	12/25/04	4.4	NA	4904850	30	62	53	54	40	9	8	22	122	1808.4	30	59	61	107.8	46	NA
	12/26/04	4.4	NA	4935370	31	60	51	52	40	9	8	20	125	1839.3	31	60	62	109.5	16	NA

Table B-1: Daily System Operation Log (Page 9 of 23)

Week No.	Date	Well #1 Daily Operational (hr)	Well#2 Daily Operational (hr)	Totalizer to Treatment Totalizer (kgal)	Totalizer to Treatment Daily Volume (kgal)	Pressure Filtration IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flow/Totalizer to Distribution Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	Backwash TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Iron Solution Weight Lbs
21	12/27/04	4.7	NA	4968950	34	61	52	54	40	9	7	21	123	1872.6	33	60	62	109.5	36	NA
	12/28/04	5.7	NA	5007000	38	60	51	52	40	9	8	20	126	1911.8	39	61	63	111.3	11	NA
	12/29/04	4.1	NA	5035240	28	60	51	52	40	9	8	20	123	1940.5	29	61	63	111.3	31	NA
	12/30/04	6.2	NA	5076650	41	62	52	53	41	10	9	21	121	1982.2	42	61	63	111.3	46	NA
	12/31/04	3.2	NA	5099000	22	60	52	53	40	8	7	20	130	2005.2	23	63	64	112.2	0	NA
	01/01/05	4.9	NA	5134000	35	60	52	53	40	8	7	20	124	2040.6	35	63	64	113.9	23	NA
	01/02/05	5.2	NA	5168750	35	61	53	54	40	8	7	21	122	2076.0	35	63	64	113.9	34	NA
22	01/03/05	NA	2.3	5187850	19	65	53	56	40	12	9	25	148	2092.2	16	64	65	115.6	7	388
	01/04/05	NA	5.7	5232970	45	72	54	57	40	18	15	32	143	2139.0	47	64	65	115.6	24	279
	01/05/05	NA	3.5	5258390	25	72	51	55	40	21	17	32	140	2165.3	26	64	65	115.6	43	212
	01/06/05	NA	5.3	5298390	40	70	54	57	40	16	13	30	141	2203.7	38	65	66	117.6	17	106
	01/07/05	NA	4.3	5331420	33	73	55	57	40	18	16	33	140	2236.3	33	66	67	119.3	1	52
	01/08/05	NA	6.0	5378220	47	67	54	57	40	13	10	27	143	2283.5	47	66	67	119.3	31	362
	01/09/05	NA	4.3	5408050	30	67	54	56	40	13	11	27	139	2313.2	30	67	68	122.6	8	332
23	01/10/05	NA	4.2	5441150	33	68	56	58	40	12	10	28	143	2345.6	32	68	69	124.2	17	306
	01/11/05	NA	3.4	5467550	26	69	52	56	40	17	13	29	141	2371.2	26	68	69	124.2	37	290
	01/12/05	NA	6.5	5518960	51	68	54	57	40	14	11	28	143	2423.0	52	69	70	126.0	15	254

Table B-1: Daily System Operation Log (Page 10 of 23)

		Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
Week No.	Date	Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[(a)]	TB No.[(a)]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
23 (con't)	01/13/05	NA	4.4	5552000	33	68	56	57	40	12	11	28	141	2457.4	34	69	70	126.0	34	228
	01/14/05	NA	4.1	5583000	31	71	57	59	40	14	12	31	139	2488.7	31	70	71	126.9	5	228
	01/15/05	NA	3.2	5608200	25	67	54	56	40	13	11	27	142	2513.7	25	71	72	127.6	18	216
	01/16/05	NA	5.0	5648000	40	70	56	58	40	14	12	30	139	2553.1	39	71	72	127.6	36	188
24	01/17/05	NA	5.3	5688000	40	67	54	57	40	13	10	27	144	2595.1	42	72	73	128.6	16	158
	01/18/05	NA	5.1	5727350	39	71	54	57	40	17	14	31	138	2634.1	39	72	73	128.6	32	132
	01/19/05	NA	3.5	5754000	27	66	55	57	40	11	9	26	144	2661.4	27	73	74	129.6	4	113
	01/20/05	NA	6.5	5805900	52	72	56	58	40	16	14	32	138	2713.9	53	73	74	129.6	20	78
	01/21/05	NA	3.0	5827530	22	73	56	58	40	17	15	33	138	2737.1	23	73	74	129.6	43	61
	01/22/05	NA	6.2	5873430	46	70	56	59	40	14	11	30	140	2783.0	46	74	75	131.4	16	456
	01/23/05	NA	3.6	5901060	28	71	57	59	40	14	12	31	140	2811.3	28	74	75	131.4	35	436
25	01/24/05	NA	4.3	5934000	33	68	55	57	40	13	11	28	144	2844.5	33	75	76	132.4	0	412
	01/25/05	NA	4.9	5972380	38	69	55	57	40	14	12	29	140	2884.5	40	75	76	132.4	24	384
	01/26/05	NA	3.6	5999230	27	71	56	58	40	15	13	31	137	2912.3	28	75	76	132.4	44	366
	01/27/05	NA	3.2	6025080	26	68	56	57	40	12	11	28	143	2939.0	27	76	77	133.3	16	348
	01/28/05	NA	6.0	6071580	47	74	54	58	40	20	16	34	134	2986.7	48	76	77	133.3	35	316

Table B-1: Daily System Operation Log (Page 11 of 23)

Week No.	Date	Well #1 Daily Operational (hr)	Well#2 Daily Operational (hr)	Totalizer to Treatment Totalizer (kgal)	Totalizer to Treatment Daily Volume (kgal)	Pressure Filtration IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flow/Totalizer to Distribution Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	Backwash TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Iron Solution Weight Lbs
25 (con't)	01/29/05	NA	3.9	6102060	30	68	54	56	40	14	12	28	144	3018.2	32	78	79	134.4	0	294
	01/30/05	NA	3.5	6130000	28	68	54	57	40	14	11	28	141	3046.8	29	78	79	135.3	19	275
26	01/31/05	NA	3.0	6152610	23	73	53	54	40	20	19	33	138	3069.6	23	79	79	136.3	#1:0; #2:38	256
	02/01/05	7.9	NA	6205880	53	60	53	54	40	7	6	20	131	3124.2	55	82	81	140.9	0	213
	02/02/05	3.8	NA	6231688	26	61	51	52	40	10	9	21	127	3151.8	28	82	81	140.9	19	192
	02/03/05	4.5	NA	6262000	30	64	50	52	40	14	12	24	120	3182.1	30	82	81	140.9	37	168
	02/04/05	6.3	NA	6303500	42	60	53	53	40	7	7	20	130	3226.1	44	83	82	141.9	6	135
	02/05/05	5.4	NA	6339000	36	66	51	53	40	15	13	26	115	3262.2	36	83	82	141.9	25	106
	02/06/05	3.9	NA	6363740	25	67	53	55	40	14	12	27	113	11.3[b]	25	83	82	141.9	43	85
27	02/07/05[c]	5.3	NA	6399000	35	62	52	54	40	10	8	22	122	46.9	36	84	83	143.0	13	58
	02/08/05	5.2	NA	6433420	34	63	53	54	40	10	9	23	119	81.9	35	84	83	143.0	30	476
	02/09/05	4.7	NA	6565780	NA	60	52	53	40	8	7	20	131	114.8	33	85	84	143.9	1	451
	02/10/05	3.8	NA	6591340	NA	64	53	55	40	11	9	24	126	141.4	27	85	84	143.9	21	430
	02/11/05	3.3	NA	6512740	NA	65	48	51	40	17	14	25	117	162.6	21	85	84	143.9	42	411
	02/12/05	6.5	NA	6555340	43	60	50	51	40	10	9	20	130	207.5	45	89	86	150.6	14	377
	02/13/05	4.5	NA	6585420	30	63	50	52	40	13	11	23	121	239.0	32	89	86	150.6	32	352

Table B-1: Daily System Operation Log (Page 12 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
28	02/14/05	7.9	NA	6635000	50	60	50	52	40	10	8	20	131	291.1	52	90	87	151.6	7	311
	02/15/05	4.4	NA	6667000	32	63	51	53	40	12	10	23	122	323.8	33	90	87	151.6	20	286
	02/16/05	4.4	NA	6697260	30	60	50	51	40	10	9	20	130	355.2	31	91	88	152.6	17	262
	02/17/05	4.7	NA	6728000	31	63	53	54	40	10	9	23	121	387.1	32	91	88	152.6	37	238
	02/18/05	4.7	NA	6759640	32	60	51	52	40	9	8	20	131	420.8	34	92	89	153.6	8	211
	02/19/05	4.9	NA	6792000	32	64	53	54	40	11	10	24	127	451.1	30	92	89	153.6	27	184
	02/20/05	5.3	NA	6824700	33	66	50	52	40	16	14	26	114	488.5	37	92	89	153.6	44	156
29	02/21/05	5.3	NA	6859400	35	62	52	53	40	10	9	22	123	523.9	35	93	90	154.6	14	128
	02/22/05	3.9	NA	6880340	21	63	52	54	40	11	9	23	120	544.5	21	93	90	154.6	32	108
	02/23/05	4.1	NA	6907000	27	63	55	57	40	8	6	23	115	572.0	28	94	91	155.7	3	85
	02/24/05	3.7	NA	6932000	25	59	52	52	40	7	7	19	130	598.0	26	94	91	155.7	23	66
	02/25/05	3.9	NA	6957860	26	65	51	53	40	14	12	25	115	624.9	27	94	91	155.7	43	45
	02/26/05	7.1	NA	7005460	48	63	52	54	40	11	9	23	122	673.2	48	95	92	157.6	10	436
	02/27/05	4.5	NA	7036260	31	59	50	51	40	9	8	19	130	705.2	32	96	93	159.2	20	411
30	02/28/05	4.3	NA	7065060	29	63	53	54	40	10	9	23	124	735.2	30	96	93	159.2	38	388
	03/01/05	NA	4.5	7100780	36	66	54	56	40	12	10	26	145	771.2	36	97	95	161.6	10	364
	03/02/05	NA	1.1	7109480	9	67	53	55	40	14	12	27	144	780.5	9	97	95	161.6	30	359

Table B-1: Daily System Operation Log (Page 13 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
30 (con't)	03/03/05	NA	3.9	7140480	31	65	54	56	40	11	9	25	150	812.7	32	98	96	162.5	1	337
	03/04/05	NA	6.3	7190640	50	64	53	55	40	11	9	24	143	863.9	51	98	96	162.5	19	305
	03/05/05	NA	3.4	7217240	27	65	54	56	40	11	9	25	138	891.2	27	98	96	162.5	40	286
	03/06/05	NA	4.6	7254000	37	65	53	54	40	12	11	25	143	929.2	38	99	97	164.4	9	262
31	03/07/05	NA	1.5	7265670	12	65	53	52	40	12	13	25	145	940.6	11	100	98	165.4	21	254
	03/08/05	NA	4.1	7298170	33	68	52	53	40	16	15	28	138	974.4	34	100	98	165.4	40	233
	03/09/05	NA	3.7	7326070	28	66	55	57	40	11	9	26	146	1003.3	29	101	99	166.6	11	213
	03/10/05	NA	3.7	7355460	29	67	54	56	40	13	11	27	145	1033.7	30	101	99	166.6	31	193
	03/11/05	NA	4.0	7386160	31	66	55	57	40	11	9	26	148	1065.5	32	102	100	167.6	2	171
	03/12/05	NA	3.8	7416860	31	68	53	56	40	15	12	28	144	1096.2	31	102	100	167.6	22	150
	03/13/05	NA	3.3	7442460	26	69	52	54	40	17	15	29	140	1122.9	27	102	100	167.6	44	132
32	03/14/05	NA	3.9	7509360	67	64	53	55	40	11	9	24	151	1154.0	31	103	102	183.5	0	86
	03/15/05	NA	8.0	7535000	26	67	56	57	40	11	10	27	149	1217.7	64	103	132	183.9	33	69
	03/16/05	NA	2.9	7558000	23	65	54	55	40	11	10	25	150	1241.1	23	104	133	184.3	18	486
	03/17/05	NA	3.8	7588060	30	66	52	54	40	14	12	26	147	1272.3	31	104	133	184.6	39	466
	03/18/05	NA	4.3	7621280	33	65	54	55	40	11	10	25	150	1306.8	35	105	134	185.6	9	443

Table B-1: Daily System Operation Log (Page 14 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
32 (con't)	03/19/05	NA	3.6	7650240	29	66	52	55	40	14	11	26	148	1336.7	30	105	134	185.6	29	422
	03/20/05	NA	4.5	7686000	36	64	53	54	40	11	10	24	150	1373.8	37	106	135	186.5	10	398
33	03/21/05	NA	4.5	7722160	36	67	53	55	40	14	12	27	146	1411.5	38	106	135	186.5	29	374
	03/22/05	NA	3.4	7749160	27	64	53	55	40	11	9	24	151	1438.2	27	107	136	187.5	20	356
	03/23/05	NA	3.8	7779360	30	66	53	55	40	13	11	26	145	1470.4	32	107	136	187.5	40	335
	03/24/05	NA	4.0	7810460	31	64	53	55	40	11	9	24	151	1502.4	32	108	137	188.5	12	313
	03/25/05	NA	3.7	7840400	30	65	53	55	40	12	10	25	145	1533.1	31	108	137	188.5	31	296
	03/26/05	NA	4.4	7875200	35	64	54	55	40	10	9	24	150	1568.9	36	109	138	189.5	2	272
	03/27/05	NA	3.4	7902550	27	66	53	55	40	13	11	26	145	1597.2	28	109	138	189.5	23	253
34	03/28/05	NA	3.8	7932750	30	64	54	53	40	10	11	24	151	1628.2	31	109	138	189.5	42	232
	03/29/05	NA	5.6	7976350	44	65	54	57	40	11	8	25	144	1672.8	45	109	138	189.5	11	202
	03/30/05	NA	3.8	8007350	31	65	53	58	40	12	7	25	143	1703.4	31	111	186	204.9	15	182
	03/31/05	NA	3.3	8034950	28	67	54	58	40	13	9	27	140	1730.5	27	111	186	204.9	35	164
	04/01/05	4.1	NA	8060000	25	59	51	52	40	8	7	19	127	1757.2	27	112	187	205.9	6	141
	04/02/05	5.2	NA	8095580	36	60	50	52	40	10	8	20	123	1794.0	37	112	187	205.9	24	113
	04/03/05	4.8	NA	8127000	31	63	49	51	40	14	12	23	121	1826.3	32	112	187	205.9	42	88

Table B-1: Daily System Operation Log (Page 15 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[(a)]	TB No.[(a)]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
35	04/04/05	5.2	NA	8159300	32	60	52	53	40	8	7	20	128	1859.6	33	113	188	206.8	12	60
	04/05/05	4.2	NA	8188260	29	61	50	52	40	11	9	21	126	1889.3	30	113	188	206.8	31	42
	04/06/05	4.6	NA	8218320	30	59	50	51	40	9	8	19	130	1920.1	31	114	189	207.7	2	448
	04/07/05	5.6	NA	8257080	39	60	52	53	40	8	7	20	127	1960.1	40	114	189	207.7	19	418
	04/08/05	4.7	NA	8287480	30	63	49	51	40	14	12	23	122	1991.4	31	114	189	207.7	39	393
	04/09/05	5.1	NA	8319000	32	59	50	51	40	9	8	19	131	2023.8	32	116	191	210.3	0	366
	04/10/05	5.4	NA	8355840	37	61	50	51	40	11	10	21	125	2061.9	38	116	191	210.3	17	337
36	04/11/05	5.1	NA	8388640	33	63	49	51	40	14	12	23	120	2095.6	34	116	191	210.3	36	311
	04/12/05	5.5	NA	8422360	34	59	51	52	40	8	7	19	130	2130.5	35	117	192	211.3	6	281
	04/13/05	4.8	NA	8455460	33	60	50	51	40	10	9	20	126	2164.6	34	117	192	211.3	24	256
	04/14/05	5.2	NA	8489460	34	63	49	51	40	14	12	23	120	2199.7	35	117	192	211.3	44	229
	04/15/05	6.5	NA	8528760	39	59	51	52	40	8	7	19	130	2240.3	41	118	193	212.3	13	196
	04/16/05	8.7	NA	8587360	59	66	51	52	40	15	14	26	115	2300.7	60	118	193	212.3	29	149
	04/17/05	4.7	NA	8617250	30	67	49	51	40	18	16	27	110	2331.3	31	118	193	212.3	47	123
37	04/18/05	6.8	NA	8662000	45	63	53	54	40	10	9	23	122	2377.5	46	119	194	214.1	14	86
	04/19/05	3.5	NA	8676040	14	63	51	53	40	12	10	23	121	2390.2	13	119	194	214.1	35	496
	04/20/05	5.1	NA	8718450	42	60	50	51	40	10	9	20	127	2426.0	36	120	195	215.1	17	468

Table B-1: Daily System Operation Log (Page 16 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
37 (con't)	04/21/05	4.5	NA	8748358	30	63	50	52	40	13	11	23	120	2456.8	31	120	195	215.1	36	443
	04/22/05	7.4	NA	8790260	42	59	51	52	40	8	7	19	130	2507.9	51	121	196	216.1	4	404
	04/23/05	5.0	NA	8823760	34	60	50	51	40	10	9	20	126	2542.5	35	121	196	216.1	23	377
	04/24/05	5.5	NA	8858380	35	63	49	52	40	14	11	23	121	2578.4	36	121	196	216.1	40	347
38	04/25/05	5.7	NA	8895280	37	63	51	53	40	12	10	23	121	2615.4	37	122	197	217.0	11	317
	04/26/05	2.6	NA	8913180	18	61	49	50	40	12	11	21	125	2633.4	18	122	197	217.0	31	302
	04/27/05	5.2	NA	8947880	35	59	50	51	40	9	8	19	132	2668.1	35	123	198	217.9	1	276
	04/28/05	4.3	NA	8977890	30	60	50	51	40	10	9	20	125	2699.0	31	123	198	217.9	20	243
	04/29/05	4.6	NA	9007490	30	62	48	50	40	14	12	22	122	2730.7	32	123	198	217.9	40	228
	04/30/05	5.9	NA	9044340	37	63	51	53	40	12	10	23	121	2768.9	38	124	199	218.9	9	196
	05/01/05	NA	3.5	9072240	28	66	53	54	40	13	12	26	146	2797.5	29	124	199	218.9	28	178
39	05/02/05	NA	4.2	9105360	33	68	52	54	40	16	14	28	143	2831.7	34	124	199	218.9	47	157
	05/03/05	NA	9.5	9179660	74	65	51	52	40	14	13	25	147	2908.5	77	125	200	219.9	13	106
	05/04/05	NA	5.5	9221720	42	70	51	54	40	19	16	30	138	2952.2	44	125	200	219.9	31	77
	05/05/05	NA	9.5	9295820	74	65	54	56	40	11	9	25	147	3027.4	75	126	201	220.9	9	455
	05/06/05	NA	5.5	9337350	42	65	55	57	40	10	8	25	145	3069.3	42	127	202	221.9	8	424

Table B-1: Daily System Operation Log (Page 17 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[(a)]	TB No.[(a)]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
39 (con't)	05/07/05	NA	5.0	9376670	39	68	54	56	40	14	12	28	140	3110.0	41	127	202	221.9	27	398
	05/08/05	NA	7.5	9434920	58	65	54	56	40	11	9	25	147	3167.4	57	128	203	222.9	2	358
40	05/09/05	NA	4.1	9466660	32	70	56	57	40	14	13	30	140	3201.1	34	128	203	222.9	22	336
	05/10/05	NA	2.8	9488260	22	72	53	56	40	19	16	32	137	3221.8	21	128	203	222.9	42	322
	05/11/05	NA	6.0	9534690	46	66	53	54	40	13	12	26	144	3269.9	48	129	204	224.0	18	290
	05/12/05	NA	4.3	9568440	34	70	52	54	40	18	16	30	137	27.8	NA	129	204	224.0	36	268
	05/13/05	NA	4.2	9601380	33	65	55	56	40	10	9	25	144	61.5	34	130	205	225.0	8	246
	05/14/05	NA	4.1	9633480	32	68	54	56	40	14	12	28	141	94.5	33	130	205	225.0	27	225
	05/15/05	NA	4.2	9666180	33	69	52	56	40	17	13	29	140	128.1	34	130	205	225.0	46	202
41	05/16/05	NA	6.8	9720180	54	69	54	56	40	15	13	29	142	184.3	56	131	206	226.0	15	166
	05/17/05	NA	3.3	9745400	25	69	51	54	40	18	15	29	141	209.1	25	131	206	226.0	28	126
	05/18/05	NA	4.9	9782100	37	65	53	56	40	12	9	25	146	246.8	38	132	207	227.1	19	108
	05/19/05	NA	8.6	9849400	67	70	52	54	40	18	16	30	136	315.9	69	132	207	227.1	33	60
	05/20/05	NA	3.6	9875300	26	65	54	56	40	11	9	25	149	341.2	25	133	208	228.1	16	467
	05/21/05	NA	3.5	9903100	28	67	52	55	40	15	12	27	142	369.6	28	133	208	228.1	36	449
	05/22/05	NA	4.5	9938300	35	64	53	55	40	11	9	24	147	404.7	35	134	209	229.1	7	424

Table B-1: Daily System Operation Log (Page 18 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
42	05/23/05	NA	6.1	9986400	48	68	51	54	40	17	14	28	141	455.4	51	134	209	229.1	24	392
	05/24/05	NA	6.1	10033000	47	66	55	56	40	11	10	26	144	502.6	47	135	210	230.1	17	360
	05/25/05	NA	6.3	10081760	49	70	53	54	40	17	16	30	138	551.9	49	135	210	230.1	34	327
	05/26/05	NA	5.3	10121620	40	67	54	56	40	13	11	27	143	591.9	40	136	211	231.1	14	299
	05/27/05	NA	2.5	10141280	20	67	52	55	40	15	12	27	143	611.6	20	136	211	231.1	36	287
	05/28/05	NA	4.3	10174000	33	65	54	55	40	11	10	25	147	645.1	34	137	212	232.1	6	264
	05/29/05	NA	4.3	10209000	35	67	52	54	40	15	13	27	138	680.1	35	137	212	232.1	35	242
43	05/30/05	NA	4.3	10242440	33	68	53	54	40	15	14	28	136	715.2	35	137	212	232.1	45	220
	05/31/05	NA	9.4	10314260	72	67	54	56	40	13	11	27	144	788.2	73	138	213	233.2	14	168
	06/01/05	8.9	NA	10370560	56	60	50	52	40	10	8	20	126	846.8	59	138	213	233.2	29	120
	06/02/05	12.5	NA	10452060	82	63	57	53	40	6	10	23	121	931.1	84	139	214	234.2	5	55
	06/03/05	5.9	NA	10488120	36	59	50	51	40	9	8	19	133	968.0	37	140	215	235.3	4	453
	06/04/05	8.5	NA	10545620	58	60	50	51	40	10	9	20	126	1027.8	60	140	215	235.3	19	417
	06/05/05	5.5	NA	10579760	34	62	49	51	40	13	11	22	123	1063.0	35	140	215	235.3	37	378
44	06/06/05	6.4	NA	10624160	44	65	51	53	40	14	12	25	117	1109.0	46	141	216	236.3	6	344

Table B-1: Daily System Operation Log (Page 19 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
44 (con't)	06/07/05	5.3	NA	10659000	35	66	52	53	40	14	13	26	115	1143.8	35	141	216	236.3	24	315
	06/08/05	4.0	NA	10669360	10	66	53	55	40	13	11	26	114	1152.2	8	141	216	236.3	43	292
	06/09/05	7.8	NA	10721280	52	63	51	53	40	12	10	23	122	1206.4	54	142	217	237.3	12	250
	06/10/05	9.3	NA	10778980	58	61	52	53	40	9	8	21	124	1264.5	58	143	218	238.4	11	198
	06/11/05	8.1	NA	10832280	53	65	52	53	40	13	12	25	115	1318.9	54	143	218	238.4	24	154
	06/12/05	0.0	NA	10832280	0	66	53	55	40	13	11	26	114	1318.9	0	143	218	238.4	47	154
45	06/13/05	8.4	NA	10889880	58	63	51	53	40	12	10	23	127	1376.6	58	144	219	239.4	15	106
	06/14/05	8.7	NA	10948520	59	63	51	53	40	12	10	23	125	1438.0	61	145	220	240.4	12	58
	06/15/05	7.0	NA	10993000	44	65	50	52	40	15	13	25	116	1484.0	46	145	220	240.4	29	20
	06/16/05	4.6	NA	11020450	27	60	51	52	40	9	8	20	127	1511.1	27	146	221	241.4	18	426
	06/17/05	8.1	NA	11074350	54	66	50	52	40	16	14	26	113	1566.5	55	146	221	241.4	34	380
	06/18/05	10.9	NA	11142250	68	68	50	53	40	18	15	28	110	1636.2	70	147	222	243.8	43	318
	06/19/05	8.7	NA	11200350	58	63	51	52	40	12	11	23	123	1695.9	60	149	224	247.2	12	270
46	06/20/05	12.1	NA	11277220	77	62	53	54	40	9	8	22	121	1775.5	80	150	225	249.6	5	201
	06/21/05	12.0	NA	11358260	81	63	50	51	40	13	12	23	120	1859.8	84	151	226	251.3	10	133
	06/22/05	7.6	NA	11409380	51	63	51	53	40	12	10	23	124	1913.0	53	152	227	252.3	14	90
	06/23/05	9.4	NA	11467180	58	63	51	52	40	12	11	23	122	1972.5	60	153	228	253.2	6	464

Table B-1: Daily System Operation Log (Page 20 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
46 (con't)	06/24/05	7.6	NA	11517000	50	66	52	53	40	14	13	26	122	2024.4	52	153	228	253.2	23	420
	06/25/05	9.4	NA	11575580	59	62	51	52	40	11	10	22	121	2084.7	60	154	229	254.2	7	366
	06/26/05	5.4	NA	11610780	35	60	50	51	40	10	9	20	118	2121.1	36	154	229	254.2	20	336
47	06/27/05	7.3	NA	11655000	44	62	53	54	40	9	8	22	122	2166.0	45	155	230	255.2	4	296
	06/28/05	9.1	NA	11715000	60	63	54	54	40	9	9	23	119	2227.6	62	155	230	255.2	18	245
	06/29/05	3.7	NA	11737420	22	66	50	52	40	16	14	26	114	2250.5	23	155	230	255.2	34	224
	06/30/05	5.3	NA	11771000	34	66	50	53	40	16	13	26	113	2284.2	34	156	231	256.1	6	194
	07/01/05	NA	3.1	11795890	25	66	54	56	40	12	10	26	146	2308.4	24	156	231	256.1	27	177
	07/02/05	NA	7.8	11836000	40	64	54	56	40	10	8	24	144	2350.8	42	157	232	257.1	8	372
	07/03/05	NA	3.0	11856540	21	64	54	56	40	10	8	24	121	2371.7	21	158	233	258.0	19	351
48	07/04/05	NA	0.0	11856540	0	64	54	56	40	10	8	24	121	2371.7	0	158	233	258.0	43	351
	07/05/05	NA	8.8	11926440	70	63	51	52	40	12	11	23	133	2443.3	72	159	234	259.0	8	301
	07/06/05	NA	8.6	11966440	40	61	51	52	40	10	9	21	147	2484.7	41	160	235	259.9	2	274
	07/07/05	NA	4.4	12001240	35	62	52	53	40	10	9	22	130	2520.6	36	160	235	260.9	18	250
	07/08/05	NA	9.3	12051340	50	64	53	54	40	11	10	24	140	2573.2	53	163	237	263.0	8	208

Table B-1: Daily System Operation Log (Page 21 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[a]	TB No.[a]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
48 (con't)	07/09/05	NA	3.8	12081500	30	65	54	56	40	11	9	25	140	2604.1	31	164	238	264.0	20	187
	07/10/05	NA	10.9	12139400	58	64	53	54	40	11	10	24	140	2663.2	59	166	239	265.8	8	144
49	07/11/05	NA	3.6	12167900	29	65	55	55	40	10	10	25	146	2691.2	28	167	240	266.8	13	123
	07/12/05	NA	9.2	12239760	72	71	53	54	40	18	17	31	139	2766.3	75	167	240	266.8	28	72
	07/13/05	NA	5.8	12281160	41	64	54	55	40	10	9	24	147	2812.3	46	168	241	267.8	16	468
	07/14/05	NA	8.3	12349360	68	65	52	53	40	13	12	25	146	2877.8	66	168	241	267.8	30	424
	07/15/05	NA	6.7	12401000	52	66	55	56	40	11	10	26	145	2928.3	51	169	242	268.8	8	388
	07/16/05	NA	2.5	12421000	20	67	52	54	40	15	13	27	142	2948.4	20	169	242	268.8	29	375
	07/17/05	NA	6.7	12472550	52	66	55	56	40	11	10	26	144	3000.0	52	170	243	269.8	7	340
50	07/18/05	NA	5.2	12511750	39	69	54	55	40	15	14	29	141	3042.6	43	170	243	269.8	25	312
	07/19/05	NA	8.7	12577850	66	65	54	55	40	11	10	25	148	3108.9	66	171	244	270.8	7	268
	07/20/05	NA	10.2	12656700	79	65	54	56	40	11	9	25	141	3191.5	83	171	244	270.8	19	213
	07/21/05	NA	6.0	12704880	48	67	53	54	40	14	13	27	143	3240.7	49	172	245	271.8	12	182
	07/22/05	NA	8.2	12764880	60	65	54	55	40	11	10	25	147	25.5	NA	173	245	272.8	10	138
	07/23/05	NA	5.0	12804600	40	67	54	55	40	13	12	27	143	66.6	41	174	247	273.8	18	112
	07/24/05	NA	7.3	12860000	55	70	54	55	40	16	15	30	138	123.3	57	174	247	273.8	34	74

Table B-1: Daily System Operation Log (Page 22 of 23)

Week No.	Date	Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
		Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[(a)]	TB No.[(a)]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
51	07/25/05	NA	4.4	12893860	34	68	56	57	40	12	11	28	141	156.3	33	175	248	274.8	7	51
	07/26/05	NA	5.8	12937160	43	64	54	55	40	10	9	24	146	201.2	45	175	248	274.8	25	451
	07/27/05	NA	6.9	12991780	55	68	52	54	40	16	14	28	140	258.1	57	176	249	275.8	15	410
	07/28/05	NA	14.1	13098880	107	68	52	53	40	16	15	28	141	368.7	111	177	250	276.8	10	335
	07/29/05	NA	7.4	13154680	56	68	53	54	40	15	14	28	140	425.8	57	178	251	277.8	9	294
	07/30/05	NA	11.2	13238080	83	65	54	55	40	11	10	25	147	510.1	84	179	252	278.8	2	237
	07/31/05	NA	7.1	13292640	55	65	54	55	41	11	10	24	141	565.9	56	179	252	278.7	18	198
52	08/01/05	15.1	NA	13390900	98	65	50	52	40	15	13	25	112	667.3	101	180	253	278.7	4	115
	08/02/05	13.7	NA	13477200	86	59	50	51	40	9	8	19	127	757.1	90	181	254	280.2	0	36
	08/03/05	10.3	NA	13541900	65	60	50	51	40	10	9	20	126	822.7	66	182	255	281.2	8	420
	08/04/05	15.6	NA	13640260	98	64	51	52	40	13	12	24	125	925.0	102	183	256	282.6	3	334
	08/05/05	7.9	NA	13692160	52	60	51	52	40	9	8	20	122	979.2	54	183	256	282.6	19	298
	08/06/05	13.8	NA	13780660	89	65	50	52	40	15	13	25	114	1070.4	91	184	257	283.6	10	214
	08/07/05	9.0	NA	13835720	55	60	51	52	40	9	8	20	123	1126.6	56	185	258	284.6	6	164
53	08/08/05	10.3	NA	13902770	67	60	51	52	40	9	8	20	125	1195.9	69	185	258	284.6	20	108
	08/09/05	11.2	NA	13976000	73	65	50	51	40	15	14	25	119	1272.0	76	186	259	285.6	10	496

Table B-1: Daily System Operation Log (Page 23 of 23)

		Well #1	Well#2	Totalizer to Treatment		Pressure Filtration							Flow/Totalizer to Distribution			Backwash				Iron Solution
Week No.	Date	Daily Operational (hr)	Daily Operational (hr)	Totalizer (kgal)	Daily Volume (kgal)	IN (psig)	TA (psig)	TB (psig)	OUT (psig)	ΔP across Tank A (psig)	ΔP across Tank B (psig)	ΔP across System (psig)	Flowrate (gpm)	Totalizer (kgal)	Daily Volume (kgal)	TA No.[(a)]	TB No.[(a)]	Wastewater Produced (kgal)	Time Since Last BW (hr)	Weight Lbs
53 (con't)	08/10/05	12.2	NA	14048840	73	64	51	52	40	13	12	24	122	1348.3	76	187	262	287.5	0	398
	08/11/05	6.2	NA	14090140	41	60	52	52	40	8	8	20	125	1391.8	44	188	263	288.6	15	363
	08/12/05	7.1	NA	14136200	46	59	50	51	40	9	8	19	134	1439.4	48	189	264	290.4	14	322

NA = not available

(a) Cumulative count of number of backwashes for Vessel A and B

(b) Digital totalizer meter re-set itself automatically to zero.

(c) From February 7, 2005, forward corrected labeling of well numbers by operator.