

US EPA ARCHIVE DOCUMENT

Environmental Technology Verification Report

Removal of Arsenic in Drinking Water

Kinetico Inc. and Alcan Chemicals
Para-Flo™ PF60 Model AA08AS
with Actiguard AAFS50

Prepared by



NSF International

Under a Cooperative Agreement with
 EPA U.S. Environmental Protection Agency

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THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM



U.S. Environmental Protection Agency



NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	ARSENIC ADSORPTION MEDIA FILTER USED IN DRINKING WATER TREATMENT SYSTEMS	
APPLICATION:	REMOVAL OF ARSENIC IN DRINKING WATER	
TECHNOLOGY NAME:	PARA-FLO™ PF60 MODEL AA08AS WITH ACTIGUARD AAFS50	
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The U.S. Environmental Protection Agency (EPA) supports the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholders groups (consisting of buyers, vendor organizations, and permittees), and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

NSF International (NSF), in cooperation with the EPA, operates the Drinking Water Systems (DWS) Center, one of seven technology areas under the ETV Program. The DWS Center recently evaluated the performance of an adsorption media filter technology for the reduction of arsenic in drinking water. This verification statement provides a summary of the test results for the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 System. Gannett Fleming, Inc., an NSF-qualified field testing organization (FTO), performed the verification testing. The verification report contains a comprehensive description of the test.

ABSTRACT

Verification testing of the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 arsenic adsorption media filter system was conducted at the Orchard Hills Mobile Home Park (MHP) Water Treatment Plant (WTP) in Carroll Township, Pennsylvania from April 22, 2003 through October 28, 2003. The source water was untreated groundwater from one of the MHP's groundwater supply wells. The source water, with an average total arsenic concentration of 14 µg/L and a pH of 7.6, received no treatment or chemical addition prior to entering the treatment unit. When operated under the manufacturers' specified site conditions at a flow rate of 1.9 gpm ± 0.1 gpm, the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 arsenic adsorption media filter system removed arsenic from the feed water to less than the detection limit (2 µg/L) for approximately 8,000 bed volumes, to less than 10 µg/L for approximately 25,000 bed volumes, and to less than the predetermined test endpoint (11 µg/L) after approximately 2,350 hours of total equipment operation for a total of approximately 29,000 bed volumes.

TECHNOLOGY DESCRIPTION

The following technology description was provided by the manufacturer and has not been verified.

The arsenic adsorption media filter system included Kinetico Inc.'s Para-Flo™ PF60 Model AA08AS filter unit, which includes two pressure filter tanks and a filter control module. The control module houses water-driven gears and mechanically interconnected pulse-turbine meter and valves to automatically initiate and control filter backwashes. The movement of the gears determines the position of the filter valves. Following the throughput of a set total volume of water, the pulse-turbine meter triggers the water-driven gears to manipulate valves, so that the operating mode of one filter is switched from service to backwash, to purge, and finally returns to service. During a backwash event, one filter supplies treated water for the backwashing filter and treated water effluent. The filter tanks operate in parallel when both are in service. Each filter was loaded with Alcan Chemicals' Actiguard AAFS50 media, a proprietary granular iron-enhanced activated alumina media. Literature for Alcan Chemicals' Actiguard AAFS50 media states that it is certified to NSF/ANSI 61.

The treatment unit is intended for use on groundwater supplies not under the influence of surface water serving small communities having limited manpower and operating skills. However, the technology is also scalable for serving larger systems. The filter system does not require electricity to operate and can operate continuously or intermittently. The filter components are modular in nature and can be installed by a qualified plumber. The tanks are freestanding, requiring only a level surface capable of supporting the weight of the unit, maintenance of ambient temperature above 35°F (1.7°C), and a feed water pressure between 30 and 125 psi.

VERIFICATION TESTING DESCRIPTION

Test Site

The verification testing site was the Orchard Hills MHP WTP in Carroll Township, Pennsylvania. The source water was untreated groundwater from the WTP Well No.1, which is one of three wells currently

used to supply the MHP. The source water was of generally good quality, with relatively low turbidity, slightly basic pH, and moderate hardness of about 99 mg/L. The source water had a high concentration of manganese, 144 µg/L on average; an average total arsenic concentration of 14 µg/L, ranging from a minimum concentration of 12 µg/L to a maximum of 17 µg/L; an average iron concentration of 34 µg/L; an average silica concentration of 19.0 mg/L; and an average alkalinity concentration of 89 mg/L.

Methods and Procedures

Operations, sampling, and analyses were performed to provide an accurate evaluation of the treatment system under the field conditions. The verification testing was conducted in two phases. The first phase, the Integrity Test, was designed to evaluate equipment operation reliability under the environmental and hydraulic conditions at the WTP site during the initial two weeks of testing. The second phase, the Capacity Test, included testing designed to evaluate the capacity of the arsenic adsorption media filter system to remove arsenic from the Well No. 1 feed water.

The Integrity Test ran for 13 full days plus 8 hours, during which the field test operator was on-site to record test data twice per day. The treatment system was operated continuously using the manual mode of operation for Well No. 1 2 hours each day and operated intermittently during the remainder of each day. During the Capacity Test, the treatment unit operated intermittently in concert with the WTP well operation. The Capacity Test continued until an arsenic concentration of 11 µg/L was detected in the treated water for a minimum of 3 consecutive samples.

Flow rate, production volume, and pressure were monitored and recorded twice per day. Grab samples of feed and treated water samples were analyzed for pH, temperature, turbidity, alkalinity, calcium, magnesium, hardness, and fluoride by the field test operator. Grab samples were collected and delivered to the PADEP Laboratory for analysis of silica, aluminum, iron, manganese, chloride, sulfate, and total phosphorus. Arsenic samples were collected and sent to the NSF Laboratories for analyses. Sample collection for some water quality parameters was more frequent during the initial two-week Integrity Test period. Arsenic samples were also collected more frequently as the treated water total arsenic concentration approached the predetermined end-point concentration for a total number of 47 arsenic samples. Three sets of samples were speciated for arsenic during the Integrity Test, to determine the relative proportion of the total arsenic concentration that was soluble, that was in the As III species, and that was in the As V species. Samples for arsenic speciation were also collected periodically during the Capacity Test.

Complete descriptions of the verification testing results and quality assurance/quality control procedures are included in the verification report.

VERIFICATION OF PERFORMANCE

System Operation

The verification testing was conducted under the manufacturers' specified operating conditions. Contact time is a critical parameter for arsenic adsorption efficiency and is dependent upon maintaining the flow rate within the design range of 1.9 gpm ± 0.1 gpm. A non-integral pressure regulating valve and diaphragm valve on the treated water line were used to control and maintain the flow rate. A relatively constant flow rate was maintained with minimal flow rate adjustments required.

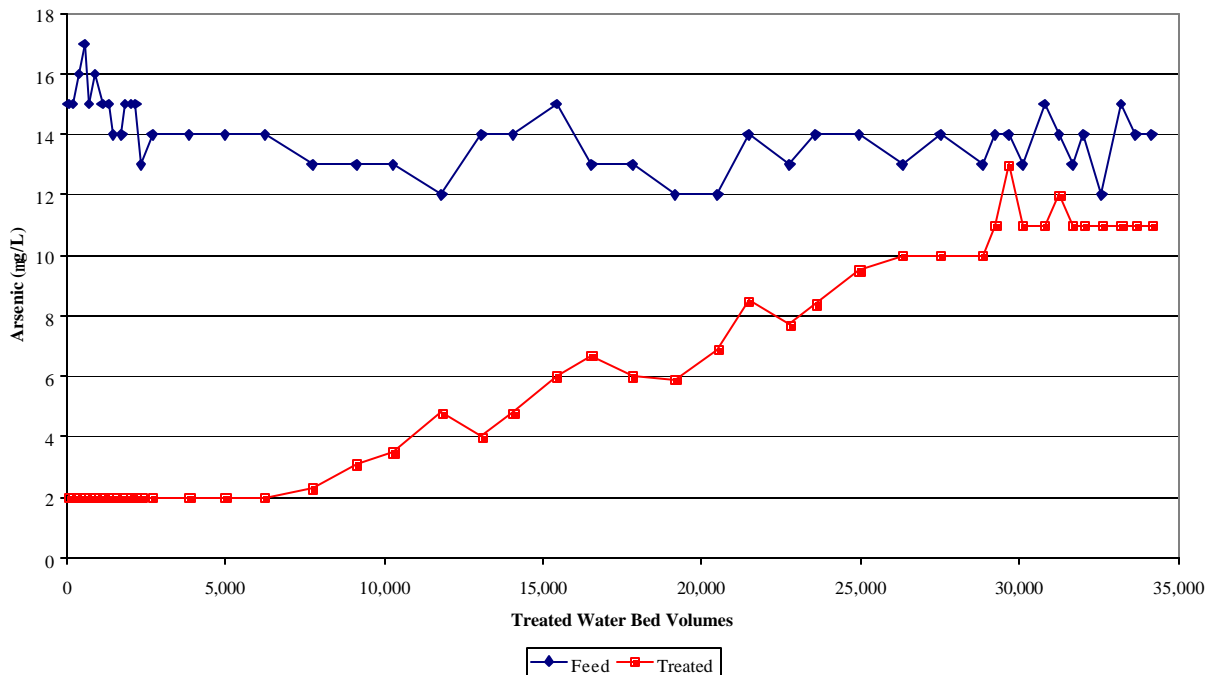
The system was operated continuously for a 2-hour period each day for the first 13 days plus 8 hours as part of the Integrity Test using the manual mode of operation for Well No. 1. The system operated intermittently in concert with the Well No. 1 operation during the remainder of the Integrity Test and throughout the Capacity Test. The filter unit operated for a total of 14.2 hours per day, on average.

The filter control module automatically initiates and controls backwashes based on a preset throughput volume. The treatment unit was set to backwash one filter following the throughput of approximately 10,500 gallons, plus or minus ten percent. A single filter was backwashed at a time. Therefore, each filter was backwashed every 21,000 gallons. Using the setscrew on the control module, filter backwashes were manually initiated at the end of the Integrity Test and monthly throughout the Capacity Test for the purpose of measuring backwash volume and testing backwash water quality. These manually initiated backwashes were performed for verification testing purposes only. Headloss across the filter unit averaged 1.1 psi during the test period, an amount only slightly greater than the 1.0 psi average headloss during the first two weeks of the test.

Water Quality Results

The feed water arsenic concentration averaged 14 µg/L, with approximately 4 µg/L as the arsenic III species and 10 µg/L as the arsenic V species. Treated water arsenic concentrations were less than or equal to the 2 µg/L detection limit during the initial 5 weeks of testing, or approximately 8,000 bed volumes of treated water. At the end of the verification test, the treated water arsenic concentration reached 11 µg/L following approximately 2,350 hours of equipment operation and treatment of approximately 28,800 to 29,200 bed volumes of water, based on the calculated media bed volume of 1.20 cubic feet. A steep breakthrough curve, which is typical with ion exchange processes, did not occur, as presented in Figure VS-1. The arsenic breakthrough curve may have been slowed by mixing of the filter media during filter backwashes.

Figure VS-1. Arsenic Breakthrough Curve
(Detection Limit = 2 µg/L)



At the beginning of the test, the treatment process reduced the pH from 7.3 in the feed water to 6.8 in the treated. As the media became conditioned by the feed water, the treated water pH increased such that, by the end of the first week of testing, the pH of the treated water was 7.5 compared to a pH of 7.7 in feed water. This pH reduction corresponded with a removal of alkalinity during the first two weeks of the test. Initially, the feed water alkalinity of 88 mg/L was reduced by 43%. However, by the end of the first week

of testing, the feed and treated alkalinity levels were essentially equal. The initial reduction in these water quality parameters was likely due to the acidic character of the coating on the virgin media.

Fluoride and silica were removed from the feed water initially, but as the total adsorption site area decreased, the preferentially favored arsenic ions out-competed the ions of fluoride and silica for the remaining adsorption sites. Initially, the feed water fluoride level of around 0.17 mg/L was reduced by up to 88%. Removal of this ion rapidly declined, so that by the end of the first two weeks of operation, fluoride was no longer being adsorbed by the media. Similarly, the initial feed water silica level of approximately 18 mg/L was reduced by up to 83%. Silica removal decreased within the first two weeks of operation to a range of 10% to 15% and remained at that level for approximately one month. Thereafter, levels of feed water and treated water silica were essentially equal.

The average feed water manganese level of 144 µg/L, which is almost three times the secondary maximum contaminant level of 50 µg/L, was reduced by an average 92% by the adsorption media. The initial treated water sulfate level (29.2 mg/L) exceeded the feed water sulfate level by 180%. Presumably, this was due to rinsing of excess coating from the media, which apparently contained a sulfate compound. After the first week of operations, the treated level of sulfate was only approximately 10% higher than the feed water sulfate. Thereafter, the feed and treated levels of sulfate were essentially equal.

The feed water total phosphorus level, which averaged 0.032 mg/L, was reduced during the entire period of verification testing. During the first 6 weeks of testing, between 60% and 70% of the total phosphorus was removed. Total phosphorus removal became more erratic thereafter, ranging between 20% and 68%. Turbidity was also reduced during the treatment process. However, concentrations of calcium, magnesium, hardness, aluminum, iron, and chloride were not significantly affected by the treatment process. Data tables presenting the on-site and laboratory water quality parameters collected during the Integrity Test and Capacity Test can be found in the verification report.

Operation and Maintenance Results

The two-phase verification test began on April 22, 2003 and ended following the conclusion of the Capacity Test on October 28, 2003. The treatment unit, including backwash cycles, operated automatically throughout the test. However, manually initiated backwashes were also performed as part of the testing process. Operator attention was required to verify and maintain a constant flow rate, to check for leaks in the piping and filter unit, and to verify that backwashes occurred as required based on throughput. Equipment operation required minimal operator attention.

Consumables and Waste Generation

No chemicals or electrical power were required. Wastewater from filter backwash, purge, and control module drive water was discharged to a sanitary sewer. The total water usage of approximately 83 gallons per backwash cycle represents less than 1 percent of the total finished water production.

Toxicity Characteristic Leaching Procedure (TCLP) and California Waste Extraction Tests (CA WET) were performed on spent Actiguard AAFS50 media. All concentrations of analyzed parameters were less than the current regulatory limits. A complete summary of the TCLP and CA WET results are provided in the verification report.

Quality Assurance/Quality Control

NSF provided technical and quality assurance oversight of the verification testing as described in the verification report, including an audit of nearly 100% of the data. NSF personnel also conducted a technical systems audit during testing to ensure the testing was in compliance with the test plan. A complete description of the QA/QC procedures is provided in the verification report.

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09/08/04

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Availability of Supporting Documents

Copies of the *ETV Protocol for Equipment Verification Testing for Arsenic Removal* dated April 2002, the verification statement, and the verification report (NSF report #04/08/EPADWCTR) are available from the following sources:

(NOTE: Appendices are not included in the verification report. Appendices are available from NSF upon request.)

1. ETV Drinking Water Systems Center Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140
2. NSF web site: <http://www.nsf.org/etv> (electronic copy)
3. EPA web site: <http://www.epa.gov/etv> (electronic copy)

August 2004

Environmental Technology Verification Report

Removal of Arsenic in Drinking Water

Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50

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Notice

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Foreword

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

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

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

Lawrence W. Reiter, Acting Director
National Risk Management Research Laboratory

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 G PADEP Laboratory Water Quality Data and Sample Submission Forms
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 I On-Site Arsenic Analyses Procedure
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 N Kinetico Owner’s Manual and Installation Guide
 O Preliminary Arsenic Speciation Analyses Reports and Sample Submission Forms
 P Signed Media Installation Certification
 Q NSF Laboratory Arsenic Data, Sample Submission Forms, and QA/QC Data
 R Performance Evaluation Results

Abbreviations and Acronyms

ANOVA	Analysis of Variance
ANSI	American National Standards Institute
AWWA	American Water Works Association
AA	Activated Alumina
BET	Brunauer, Emmett and Teller
CA WET	California Waste Extraction Tests
cm	Centimeter
°C	Degrees Celsius
C.U.	Platinum-Cobalt Color Units
D	Depth
DQO	Data Quality Objectives
EBCT	Empty Bed Contact Time
EPA	U. S. Environmental Protection Agency
ETV	Environmental Technology Verification
°F	Degrees Fahrenheit
FRP	Fiberglass Reinforced Plastic
FTO	Field Testing Organization
g	Gram
gpd	Gallons per Day
gpm	Gallons per Minute
H	Height
HazMat	Hazardous Material
HDPE	High Density Polyethylene
ICR	Information Collection Rule
ISE	Ion Selective Electrode
L	Liter
lb	Pound
LCD	Liquid Crystal Diode
LED	Liquid Emitting Diode
m	Meter
M	Mole
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/L	Milligram per Liter
MHP	Mobile Home Park
mL	Milliliter
mm	Millimeter
MDL	Method Detection Level
MSDS	Material Safety Data Sheets
N/A	Not Applicable
NA	Not Analyzed
ND	Not Detected
NEMA	National Electrical Manufacturers Association
NIST	National Institute of Standards and Technology

Abbreviations and Acronyms (continued)

NPDES	National Pollution Discharge Elimination System
NR	Not Reported
NSF	NSF International (formerly known as National Sanitation Foundation)
NTU	Nephelometric Turbidity Units
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PA	Pennsylvania
PADEP	PA Department of Environmental Protection
PE	Performance Evaluation
PRV	Pressure Reducing Valve
PSM	Process Safety Management
psi	Pounds per Square Inch
PSTP	Product Specific Test Plan
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource and Recovery Act
RMP	Risk Management Plan
SM	<i>Standard Methods for the Examination of Water and Wastewater</i>
SOP	Standard Operating Procedure
SS	Stainless Steel
TCLP	Toxicity Characteristic Leaching Procedure
TSTP	Technology Specific Test Plan
UPS	Uninterruptible Power Supply
µg/L	microgram per liter
W	Width
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

Acknowledgements

The Field Testing Organization, Gannett Fleming, Inc., was responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, data management, data interpretation, and the preparation of this report.

Gannett Fleming, Inc.
P.O. Box 67100
Harrisburg, PA 17106-7100
(717) 763-7212, Ext. 2109
(717) 763-1808 FAX
Contact: William Allis, Project Manager
E-mail: wallis@gfnet.com

The laboratory selected for laboratory analyses of all of the ETV water quality parameters (except arsenic) that were scheduled to be conducted by an EPA accredited and PADEP certified laboratory was:

Pennsylvania Department of Environmental Protection Laboratories
1500 North 3rd Street
Harrisburg, PA 17102
(717) 705-2197
(717) 783-1502 FAX
Contact: Ted Lyter, Inorganic Services Division Chief
E-mail: plyter@state.pa.us

Spent media toxicity analyses were performed by:

TriMatrix Laboratories, Inc.
5555 Glenwood Hills Parkway, SE
Grand Rapids, MI 49588
(616) 975-4500
Contact: Michael W. Movinski, Vice President, Sales and Marketing
Email: mmtrimatrix@comcast.net

Arsenic analyses were performed by the NSF Laboratory:

NSF International
789 N. Dixboro Road
Ann Arbor, MI 48105
(734) 769-8010
(734) 769-0109 FAX
Contact: Bruce Bartley, Project Manager
E-mail: bartley@nsf.org

The manufacturers of the equipment (joint venture) were:

Kinetico Inc.
10845 Kinsman Road
P.O. Box 193
Newbury, OH 44065
(440) 564-9111 Ext. 233
(440) 564-4222 FAX
Contact: Mark Brotman, Research Scientist
E-mail: mbrotman@kinetico.com

Alcan Chemicals
525 S. Washington Street
Suite No. 9
Naperville, IL 60540-6641
(630) 527-1213
(630) 527-1229 FAX
Contact: William Reid
E-mail: bill.reid@alcan.com

Gannett Fleming wishes to thank the following participants:

NSF International, especially Bruce Bartley, Dale Scherger, and Angela Beach, for providing guidance and program management.

The Orchard Hills MHP WTP owner, Robert Goodling.

Chapter 1 Introduction

1.1 ETV Purpose and Program Operation

The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by accelerating the acceptance and use of improved and more cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations; with stakeholder groups consisting of buyers, vendor organizations, and permittees; and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans responsive to the needs of stakeholders, by conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The EPA has partnered with NSF International (NSF) under the ETV Drinking Water Systems (DWS) Center to verify the performance of small drinking water systems that serve small communities. A goal of verification testing is to enhance and facilitate the acceptance of small drinking water treatment equipment by state drinking water regulatory officials and consulting engineers, while reducing the need for testing of equipment at each location where the equipment's use is contemplated. NSF meets this goal by working with manufacturers and NSF-qualified Field Testing Organizations (FTOs) to conduct verification testing under the approved protocols. It is important to note that verification of the equipment does not mean the equipment is "certified" by NSF or "accepted" by EPA. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations for those conditions tested by the FTO.

The DWS Center evaluated the performance of the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 System, which is an arsenic adsorption media filter used in drinking water treatment system applications. The verification test evaluated the ability of the absorptive media to remove arsenic from drinking water. This document provides the verification test results for the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 System.

1.2 Testing Participants and Responsibilities

The ETV testing of the Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50 System was a cooperative effort between the following participants:

NSF International
Gannett Fleming, Inc.
Kinetico Inc.
Alcan Chemicals
PA Department of Environmental Protection
U.S. Environmental Protection Agency
Orchard Hills Mobile Home Park (MHP)

The following is a brief description of each ETV participant and their roles and responsibilities.

1.2.1 NSF International

NSF is an independent, not-for-profit testing and certification organization dedicated to public health and safety and to the protection of the environment. Founded in 1946 and located in Ann Arbor, Michigan, NSF has been instrumental in the development of consensus standards for the protection of public health and the environment. NSF also provides testing and certification services to ensure products bearing the NSF Name, Logo, and/or Mark meet those standards. The EPA partnered with NSF to verify the performance of drinking water treatment systems through the EPA's ETV Program.

NSF provided technical oversight of the verification testing. An audit of the field analytical, data gathering, and recording procedures was conducted. NSF also performed all laboratory arsenic water quality analyses and provided review of the Product Specific Test Plan (PSTP) as well as this report.

Contact Information:

NSF International
789 N. Dixboro Rd.
Ann Arbor, MI 48105
Phone: (734) 769-8010
Fax: (734) 769-0109
Contact: Bruce Bartley, Project Manager
Email: bartley@nsf.org

1.2.2 Field Testing Organization

Gannett Fleming, Inc., a consulting engineering firm located in Harrisburg, Pennsylvania, conducted the verification testing of the Kinetico Inc. and Alcan Chemicals arsenic removal system. Gannett Fleming is an NSF-qualified FTO for the ETV Drinking Water Systems Center.

Gannett Fleming was responsible for conducting the Integrity Verification testing for 14 calendar days (13 full days plus 8 hours) and for conducting Capacity Verification testing until a pre-determined arsenic breakthrough concentration was achieved. Gannett Fleming provided all needed logistical support, established a communications network, and scheduled and coordinated activities of all participants. Gannett Fleming was responsible for ensuring the testing location and feed water conditions were such that the verification testing could meet its stated objectives. Gannett Fleming prepared the PSTP; oversaw the pilot testing; managed, evaluated, interpreted, and reported on the data generated by the testing; and evaluated and reported on the performance of the technology.

The Gannett Fleming field engineer conducted the on-site analyses (on-site or at the Gannett Fleming Treatability Lab) and data recording during the testing. Oversight of the daily tests was provided by Gannett Fleming's Project Manager.

Contact Information:

Gannett Fleming, Inc.
P.O. Box 67100
Harrisburg, PA 17106-7100
(717) 763-7212, Ext. 2109
(717) 763-1808 FAX
Contact: William Allis, Project Manager
E-mail: wallis@gfnet.com

1.2.3 Manufacturers

The treatment system is a joint venture, with the Para-Flo™ PF60 Model AA08AS filter unit manufactured by Kinetico Inc. and the Actiguard AAFS50 adsorption filter media manufactured by Alcan Chemicals.

The manufacturers were responsible for supplying a field-ready arsenic adsorption media filter system equipped with all necessary components, including treatment equipment, instrumentation and controls, and an operations and maintenance manual. The manufacturers were also responsible for providing logistical and technical support as needed, as well as providing technical assistance to the FTO during operation and monitoring of the equipment undergoing field verification testing.

Contact Information:

Kinetico Inc.
10845 Kinsman Road
P.O. Box 193
Newbury, OH 44065
(440) 564-9111 Ext. 233
(440) 564-4222 FAX
Contact: Mark Brotman, Research Scientist
E-mail: mbrotman@kinetico.com

Alcan Chemicals
525 S. Washington Street
Suite No. 9
Naperville, IL 60540-6641
(630) 527-1213
(630) 527-1229 FAX
Contact: William Reid
E-mail: bill.reid@alcan.com

1.2.4 Analytical Laboratories

The PADEP Laboratories performed all of the laboratory water quality analyses, excluding arsenic.

Contact Information:

Department of Environmental Protection Laboratories
Inorganic Services Division
1500 North 3rd Street
Harrisburg, PA 17102
(717) 705-2197
(717) 783-1502 FAX
Contact: Ted Lyter, Inorganic Services Division Chief
E-mail: plyter@state.pa.us

NSF laboratories performed all laboratory arsenic water quality analyses.

Tri-Matrix Laboratories performed TCLP and CA WET analyses on the spent media.

Contact Information:

TriMatrix Laboratories, Inc.
5555 Glenwood Hills Parkway, SE
Grand Rapids, MI 49588
(616) 975-4500
Contact: Mr. Michael W. Movinski, Vice President, Sales and Marketing
Email: mmtrimatrix@comcast.net

1.2.5 PA Department of Environmental Protection

The PADEP's mission is to protect Pennsylvania's air, land and water from pollution and to provide for the health and safety of its citizens through a cleaner environment.

The PADEP is the state agency largely responsible for administering Pennsylvania's environmental laws and regulations. Its responsibilities include: reducing air pollution, making sure Pennsylvania's drinking water is safe, protecting water quality in Pennsylvania's rivers and streams, making sure waste is handled properly, managing the Commonwealth's recycling programs, and helping citizens prevent pollution and comply with the Commonwealth's

environmental regulations. PADEP is committed to providing general environmental education and encouraging effective public involvement in setting environmental policy.

The roles and responsibilities of PADEP included laboratory analyses for all of the ETV water quality parameters (except arsenic) that were scheduled to be conducted by an EPA accredited and PADEP certified laboratory.

The PADEP was also responsible for reviewing the test plan and final report because this testing may also serve as a pilot study component of a water supply permit application for the installation of a full-scale version of this type of process at this site. Also, because the site is already a permitted public water supply, the PADEP needed to be involved with any modifications.

1.2.6 U.S. Environmental Protection Agency

The EPA, through its Office of Research and Development, has financially supported and collaborated with NSF under Cooperative Agreement No. R-82833301. This verification effort was supported by the DWS Center operating under the ETV Program. This document has been peer reviewed, reviewed by NSF and EPA, and recommended for public release.

1.3 Verification Testing Site

The verification testing site was Orchard Hills MHP Water Treatment Plant (WTP) located off of Windy Hill Road in Carroll Township, PA. The WTP is housed within a masonry block building located within the MHP. The building is heated to a minimum temperature of 50°F. Bordering the MHP boundary, in close proximity to the back of the WTP building, is land under cultivation. The WTP, with a permitted capacity of 30 gpm, supplies approximately 200 domestic connections. The sources of supply for the WTP are Well Nos. 1, 11, and 12, of which a portion of Well No. 1 discharge was used as the source water for the arsenic adsorption media filter verification testing. Well No. 1 is located near the entrance to the MHP, approximately 100 yards north of the WTP. The WTP process consists of five pressure manganese greensand filters, two chlorine contact/finished water storage tanks, two finished water pumps, and six hydropneumatic tanks.

Two chemicals are fed at the WTP: sodium hypochlorite for oxidation and disinfection, and polyphosphate for sequestration and corrosion control. The chemical feed points are located downstream of the arsenic adsorption media filter supply connection. The control of the wells/filtration process is based on a level control system in two finished water storage tanks, located within the WTP building. The well pumps operate based on level sensors in the finished water storage tanks. Water from the finished water storage tanks is pumped to hydropneumatic tanks via finished water pumps. Low- and high-pressure switches associated with the hydropneumatic tanks activate and deactivate the finished water pumps. The hydropneumatic tanks supply the distribution system and provide backwash water for the greensand filters.

The frequency and duration of well pump operation depends on distribution system demand and well water level/production capacity. Average daily well run time, as observed during this test,

was approximately 14 hours per day. The total combined WTP flow range for all wells, as reported by the operator, is 10 to 20 gpm.

During the ETV test, a portion of Well No.1 discharge, prior to any treatment, was diverted to the arsenic adsorption media filter. The arsenic adsorption media filter was set up inside the WTP building, directly in front of several of the manganese greensand filters. The treated water, control module water, and backwash wastewater from the arsenic adsorption media filter were discharged to an existing drainpipe inside the building and subsequently conveyed to the MHP Wastewater Treatment Plant (WWTP).

1.3.1 Source Water

The source water for the verification test was untreated groundwater from Orchard Hills WTP Well No. 1.

Well No. 1 source water is generally of good quality, with relatively low turbidity, slightly basic pH, and moderate hardness. The source water average manganese concentration of approximately 144 $\mu\text{g/L}$ is almost three times the Secondary Standard for drinking water. Black particles were frequently observed in the feed water samples. The feed water total arsenic concentration averaged approximately 14 $\mu\text{g/L}$, approximately 4 $\mu\text{g/L}$ of which was in the form of Arsenic III. The source water total arsenic concentration is below the current maximum contaminant level (MCL) of 50 $\mu\text{g/L}$, but exceeds the future MCL of 10 $\mu\text{g/L}$ that will become effective in January 2006. A summary of the feed water quality information is presented in Table 1-1 below. Additional feed water quality data are presented in Chapter 4.

Alcan Chemicals indicated that no pretreatment would be required for the arsenic adsorption media system. Alcan stated: "Manganese is very far down on the selectivity series, and Alcan Chemicals does not expect that it will be an issue. [Ion selectivity series is included in Table 2-3.] Additional work has shown media adsorption capacity for arsenic to be independent of the manganese in the water. In addition, iron is really only a problem if it is present in very high amounts as it precipitates and clogs the bed. This is easily rectified with a backwash or other type of agitation. This is a mechanical function that would be common to any granular bed, not a chemical interference. Again, there is no indication that iron in solution has any negative impact whatsoever on the media's ability to adsorb arsenic."

Table 1-1. Feed Water Quality during Testing

Parameter	Units	Number of Samples	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval
Arsenic	µg/L	47	14	12	17	1.1	14 - 14
pH	-	198	7.6	7.3	7.8	N/A	7.6 – 7.6
Temperature	°C	184	13.8	11.5	15.5	0.94	13.6 – 13.9
Turbidity	NTU	184	0.25	0.10	3.9	0.30	0.20 – 0.30
Alkalinity	mg/L	84	89	84	92	1.5	89 – 89
Calcium	mg/L	27	26.0	24.8	28.0	0.92	25.6 – 26.4
Magnesium	mg/L	27	8.3	7.3	8.7	0.50	8.1 – 8.5
Hardness	mg/L	27	99	96	104	1.7	98 – 100
Fluoride	mg/L	39	0.17	0.13	0.27	0.03	0.16 – 0.18
Silica	mg/L	40	19.0	17.4	21.1	0.80	18.7 – 19.3
Aluminum	µg/L	40	203	<200	339	22.0	<200 ⁽¹⁾ – 212
Iron	µg/L	28	34	<20	116	24	23 – 45
Manganese	µg/L	28	144	36	1481	286	16 – 272
Chloride	mg/L	28	18.7	16.8	20.4	0.85	18.3 – 19.1
Sulfate	mg/L	28	10.5	10.1	11.2	0.26	10.4 – 10.6
Total Phosphorus	mg/L	28	0.032	0.024	0.043	0.005	0.029 – 0.034

⁽¹⁾ The lower confidence interval level was calculated below the detection limit for this parameter.

1.3.2 Pilot Filter Discharges

The treated water, control module drive water, and backwash water from the arsenic adsorption media filter unit were discharged to an existing drainpipe inside the building and subsequently conveyed to the Orchard Hills WWTP. No discharge permits were required. At the request of PADEP, backwash wastewater, purge water, and control module drive water were monitored, sampled, and analyzed every second month to evaluate the quantity and quality of water discharged to the WWTP. Treated water quality and the quantity, as well as the quality of all backwash water discharged from the pilot filter unit to the MHP WWTP, are discussed in detail in Chapter 4.

Chapter 2 Equipment Description and Operating Processes

2.1 Equipment Description

The equipment tested was Kinetico Inc.'s and Alcan Chemicals' arsenic adsorption media filter system. The model tested was the Para-Flo™ PF60 Model AA08AS filter unit with Actiguard AAFS50 media. The major system components include two pressure filter tanks with adsorptive filter media, a control module, filter media, feed water pipe, treated water pipe, feed water sample tap, treated water sample tap, and two wastewater ports (rinse and backwash). The system configuration and major components are described in more detail in the following sections.

After the verification test, Kinetico renamed the tested model to reflect the use of a larger tank inlet and outlet facilitating faster flow rates. Please refer to Chapter 6, Vendor Comments, for additional details concerning these modifications.

2.1.1 Basic Scientific and Engineering Concepts of Treatment

The conceptual treatment process for the arsenic adsorption media filter is based on passing arsenic-contaminated feed water through a bed of media having a strong affinity for arsenic.

Activated alumina media historically has provided cost-effective, reliable performance as a material for producing a granular adsorbent media for removal of arsenic from feed water. Actiguard AAFS50 is an iron-enhanced activated alumina media, which has been determined to significantly promote the adsorption effectiveness of conventional activated alumina. As water passes down through a filter vessel containing this media, the arsenic concentration declines until it is no longer detectable. As the upper portion of the media becomes saturated, the treatment band (mass transfer zone) progresses downward until all adsorptive capacity is used and arsenic breakthrough occurs.

Adsorption is the attachment of the adsorbate (arsenic) to the surface of the adsorbent media grains (activated alumina). The removal capacity and effectiveness of the arsenic removal media is dependent on a number of factors, of which surface area is of primary importance. The surface area is a function of the porosity of the media grains. Adsorbent media contains a large quantity of very small pores throughout the media grains. Other factors determining the capacity and effectiveness of adsorbent media are accessibility of the pore sites for arsenic ions, time available for arsenic ions to migrate to pore sites, ions competing for pore sites, concentration of arsenic in the feed water, pH of the feed water, oxidation state of arsenic, and flow characteristics of the feed water conveying the arsenic into the bed of adsorbent media.

The Kinetico/Alcan Chemicals arsenic adsorption media filter system uses Actiguard AAFS50, a proprietary, granular, iron-enhanced, activated alumina media. Tests performed by Alcan Chemicals indicate that AAFS50 has up to five times⁽¹⁾ the arsenic adsorption capacity of

⁽¹⁾ As stated in the Alcan AAFS50 marketing brochure (see Appendix A).

standard activated alumina and that iron enhancement also enables the removal of As (III). Tables 2-1, 2-2, and 2-3 present information specific to this equipment and media.

Table 2-1. Manufacturing and Procedures Specific to Alcan Chemicals' Actiguard AAFS50 Adsorptive Media

Item	Manufacturing/Procedures
Raw Material (used to make adsorptive media)	Activated Alumina and Iron
Method of Manufacture	Chemical Processes: Proprietary Thermal Processes: Proprietary Sizing/Screening Methods: Proprietary Packaging Methods: Proprietary
Preconditioning Procedure	Wetting Requirements: 10 Bed Volumes of Feed Water
Regeneration Procedure	N/A
Regeneration Results	N/A

Filter operations are automatically controlled by the filter control module. The control module houses water-driven gears and mechanically interconnected pulse-turbine meter and valves. The movement of the gears determines the position of the filter valves. Following the throughput of a set total volume of water, the pulse-turbine meter triggers the water-driven gears to manipulate valves so that the operating mode of one filter is switched from service to backwash, to purge, and finally returns to service. The other filter remains in service, providing treated water for the backwashing filter.

Tables 2-2 and 2-3 present design criteria for the arsenic adsorption process and appurtenances.

Table 2-2. Equipment Design Criteria

Para-Flo™ PF60 Model AA08AS	
No. of Filter Tanks	2
Filter Tank Dimensions	
Inside Diameter (ID)	8 inches
Height (including integral control module)	46 inches
Height (vessel only)	40 inches
Mode of Operation	Parallel
Design Flow, Total	1.9 ± 0.1 gpm
Flow Range, Total	1.8 to 2.0 gpm
Design Capacity, Total	2.0 gpm
Empty Bed Contact Time (EBCT) at 2 gpm	4.6 minutes
Minimum Recommended Feed Pressure	30 psi
Filter Media	
Depth	21 inches
Freeboard Above Media	17.5 inches (Actual 18.25 inches)
Volume Per Tank	0.70 cu. ft. (Actual ~0.60 cu. ft.)
Weight Per Tank	39.76 lbs
Volume, Total (2 tanks)	1.4 cu. ft. (Actual ~1.20 cu. ft.)
Mesh Size (Tyler mesh series)	28 x 48
Media Expansion during Backwash	50%
Filter Tank Material	Polyester, Vinylester
Backwash Control	Automatic based on total throughput of 10,500 gallons ± 10%
Backwash	
Flow Rate	4.0 gpm
Duration	13 minutes
Time Between Backwash and Rinse	3 minutes
Purge	
Flow Rate	1.9 gpm ± 0.1 gpm
Duration	5 minutes
Pressure Gauges	
Manufacturer	Ashcroft® Duralife
Type	1084, Grade 2A
Pressure Range	0–100 psi (accuracy of ±0.5%)

Table 2-2. Equipment Design Criteria (continued)

Totalizer Meters	
Manufacturer	ABB
Type	Positive displacement
Series	V100 (feed)/C700 (filtrate)
Accuracy	± 1.5%
Rotameter	
Manufacturer	Blue-White
Model	F-50376N
Maximum Reading	2.0 gpm
Accuracy	No Data
Pressure, max	250 psi
Treated Water Throttling Valve	
Manufacturer	George Fischer
Type	Diaphragm
Material of Construction	Type 304, DN25, PVC-U
Size	1 inch
Control	Manual
Three Way Regulating Valve	
Manufacturer	Watts Industries, Inc.
Model No.	2A645
Maximum Inlet Pressure	300 psi
Reduced Pressure Range	3 to 50 psi
Y-Check Valve	
Manufacturer	George Fischer
Size Code/Size	1 inch
Material of Construction	Type 304, DN25, PVC-U

Table 2-3. Alcan Chemicals' Actiguard AAFS50 Media Specifications

Chemical Constituents	Weight, %
Al ₂ O ₃ + Proprietary Additive	83
Silicon as SiO ₂	0.020
Titanium as TiO ₂	0.002
Loss on Ignition	17
Physical Properties	
Bulk Density	0.91 g/cm ³ (56.8 lbs/ft ³)
BET ⁽¹⁾ Area	220 m ² /g
Attrition	0.3%
Voids	48%
Pore Size	No Data
Pore Volume	<0.35 cm ³ /g
Abrasion Loss	<5% (due to spray coating fines, smaller than 48 mesh)
Moisture (weight)	0-300°C: 25% 300-1000°C: 10%
Sieve sizes, US sieve series	28 x 48
Particle Size	No Data
Effective Size	0.37 mm
Uniformity Coefficient	1.48
Ionic Preference Series	
• Anions: OH ⁻ >HAsO ₄ ⁻ >Si(OH) ₃ >O ⁻ >F ⁻ >HSeO ₃ ⁻ >SO ₄ ²⁻ >CrO ₄ ²⁻ >HCO ₃ ⁻ >Cl ⁻ >NO ₃	
• Cations: Th>Al>U ⁽⁴⁾ >Zr>Ce ⁽⁴⁾ >Fe ⁽³⁾ >Ce ⁽³⁾ >Ti>Hg>UO ₂ >Pb>Cu>Ag>Zn>Co>Fe ⁽²⁾ >Ni>Tl>Mn	
Approvals	
• Certified to NSF/ANSI 61	
• Passed U.S. EPA TCLP	
NSF/ANSI 61 and TCLP approvals are indicated in Alcan Chemicals' Technical Bulletin for AAFS50 Media and Media Marketing Brochure, included in Appendix A.	
MSDS (See Appendix B)	

2.1.2 Filter System Components

The arsenic adsorption media filter is a modular equipment process consisting of the following components:

- Two pressure filter tanks (main and remote) piped for parallel operation;

⁽¹⁾ The BET theory is used to estimate the number of molecules required to cover the adsorbent surface with a monolayer of adsorbed molecules, N_m . Multiplying N_m by the cross-sectional area of an adsorbate molecule yields the sample's surface area.

- One control module situated on top of the main filter tank and consisting of a pulse-turbine meter, water-driven gear mechanism, and valves to control the filter modes of operation;
- One feed water sample tap and one treated water sample tap;
- One influent pipe and one effluent pipe connecting the main filter tank to the remote filter tank;
- One feed water pipe connected to the control module;
- One treated water pipe connected to the control module;
- Alcan Chemicals' Actiguard AAFS50 media in each filter tank; and
- Two waste ports incorporated in the control module for backwash wastewater and gear mechanism drive water discharge.

The following equipment was provided by Kinetico specifically for the ETV and is not normally included with the arsenic adsorption media filter:

- Two pressure gauges, one located on the feed water pipe and one located on the treated water pipe;
- One Y-check valve located on the feed water pipe, just upstream of the pilot filter;
- Two totalizer water meters, one located on the feed water pipe and one located on the treated water pipe;
- One diaphragm valve for flow regulation located on the treated water pipe just upstream of the rotameter;
- One rotameter located on the treated water pipe downstream of the diaphragm valve; and
- One pressure regulating valve located just upstream of the diaphragm valve on the treated water pipe.

2.1.3 *Photographs of Equipment*

Photographs of the equipment installed at the WTP are included below. Additional photographs are included in Appendix C.



Figure 2-1. Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50, as installed at the Orchard Hills MHP WTP.

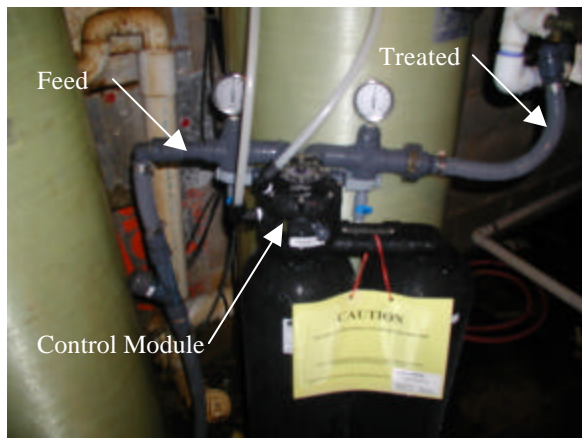


Figure 2-2. Kinetico Inc. and Alcan Chemicals Para-Flo™ PF60 Model AA08AS with Actiguard AAFS50, as installed at the Orchard Hills MHP WTP.

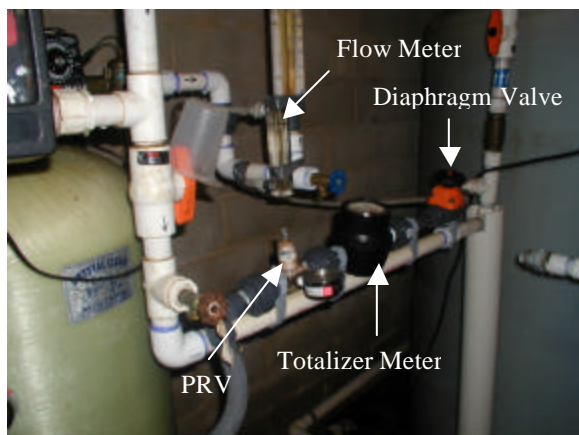


Figure 2-3. Treated water line showing auxiliary flow control equipment, as installed at the Orchard Hills MHP WTP.

2.1.4 Drawing of Equipment

A schematic drawing of the equipment is shown in Figure 2-4.

2.1.5 Data Plate

A data plate was installed on the arsenic adsorption media filter main tank to provide the following information:

Equipment Name :

Para-Flo™ PF60 with Actiguard Media
 Model Number: AA08AS
 Media Number: AAFS50

Manufacturers' Names and Addresses:

Kinetico Incorporated	Alcan Chemicals
10845 Kinsman Road	525 S. Washington Street
Newbury, Ohio 44065	Suite #9
	Naperville, Illinois 60540

Additional Information:

Serial Number: 0052690

Service flow: 1.8 – 2.0 gpm

Unit installed for NSF and EPA Environmental Technology Verification Program.

Call (440) 564.4233 for more information.

Warning and Caution Statements:

Testing in progress, please do not disturb.

This unit is designed to operate with minimum and maximum inlet pressures of 30 psi and 125 psi, respectively.

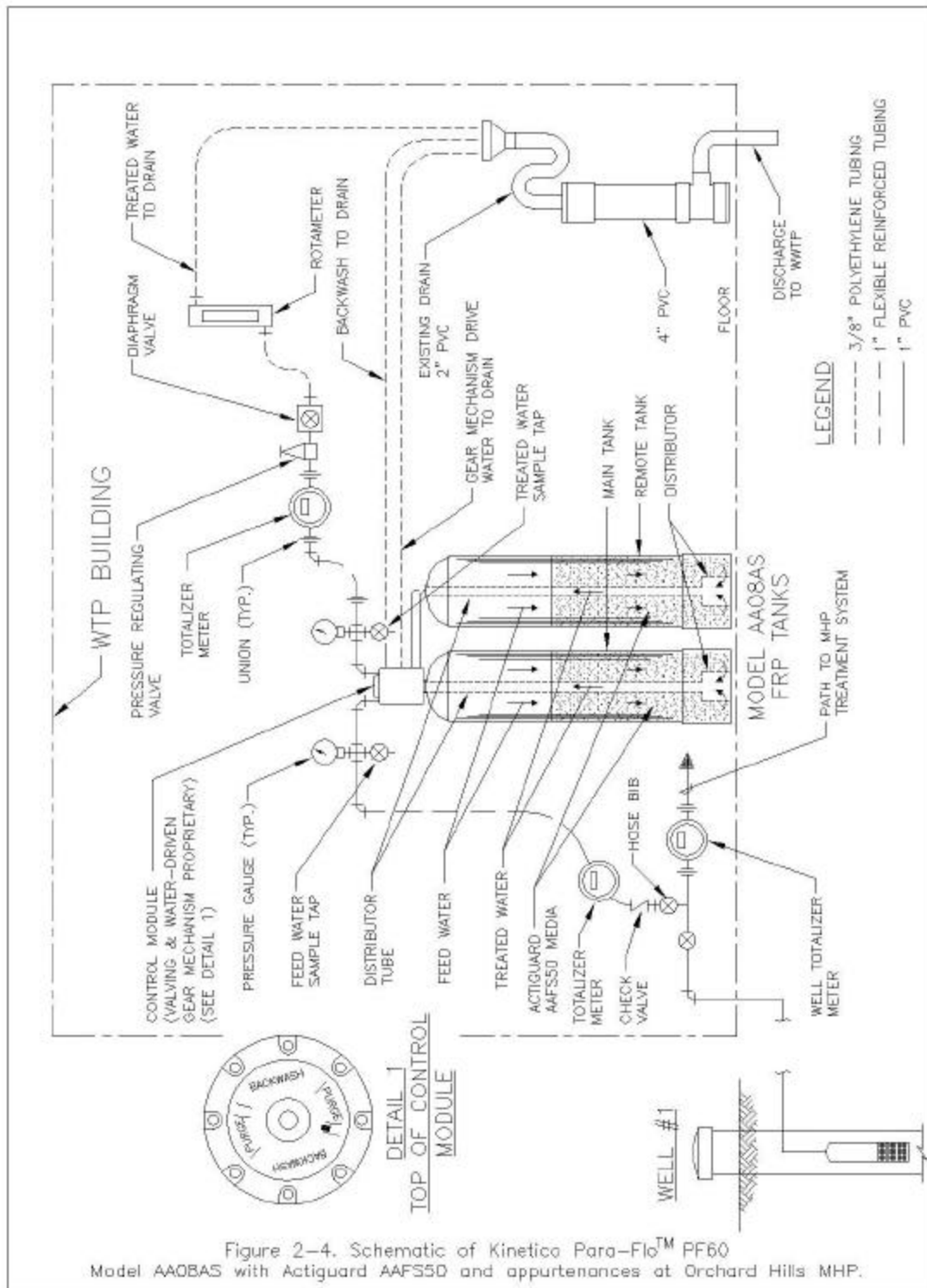


Figure 2-4. Schematic of Kinetico Para-Flo™ PF60 Model AA0BAS with Actiguard AAF550 and appurtenances at Orchard Hills MHP.

2.2 Operating Process

This modular filter system consists of dual, pressurized filter tanks designed for parallel operation in the downflow mode. The filter system does not require electricity to operate. Both filter tanks are in service except when one filter tank is off-line for backwashing. During a backwash event, one filter tank supplies the treated water production, control module drive water, and treated water for backwashing the other filter. The filter system can operate either intermittently or continuously. Modes of operation are automatically controlled, based on volume of throughput, using a proprietary control module containing a pulse-turbine meter. Valve operation is controlled by a water-driven gear mechanism within the control module that is mechanically interconnected with the pulse-turbine meter. The gear mechanism drive water is required only during backwash and purge and is supplied by the filter remaining in service. There are no other triggers for automatic initiation of operating modes. The control module has a set-screw for manually adjusting the actuator to conduct a manual backwash; this procedure is described in the proprietary Technical Manual, which was on file at NSF International and Gannett Fleming during the test.

The combined total flow and flow rate from the filter tanks was monitored with two accessory totalizer meters and a rotameter. Flow rate was adjusted with a nonintegral diaphragm valve, located on the treated water side of the filter tanks. There are no flow gauges to monitor the rate of backwash wastewater. This was checked using the “bucket and stopwatch” method. Collection of backwash and purge water for volume determination and water quality analyses was performed once during the Integrity Test and once every other month during the system Capacity Test. The incremental throughput readings from each totalizer meter were used to estimate the quantity of water used in backwash cycles for the instances when backwashes occurred and the wastewater was not collected. The incremental feed water totalizer meter reading minus the incremental treated water totalizer meter reading equals the estimated volume of backwash, purge, and control module drive water used for both filter tanks. Also, two totalizer meters provided redundancy. If one totalizer meter had failed, the other meter would have served as a backup. The difference in feed water and treated water pressure readings provided the determination of loss of head across both filters.

Grab samples for on-site and laboratory analyses were collected from the feed water and treated water sample taps, located immediately upstream and downstream of the adsorption media filter tanks, as shown on Figure 2-1. Samples from these taps were collected following the opening of their respective ball valves and a flush period of approximately five seconds.

The manufacturer states that Actiguard AAFS50 is regenerable. However, the additional adsorption capacity of this media compared to conventional activated alumina offers an advantage, because regeneration may not be economical for a small system. Alternatively, the media may be removed and replaced with new media prior to breakthrough, based on a predetermined life of media for a specific site water quality. The manufacturer indicates the media has passed the U.S. EPA TCLP test and is landfillable. Regeneration was not considered for this test.

2.2.1 Operator Requirements

The arsenic adsorption media filter was operated with Well No. 1 in an automatic on-demand mode during the adsorptive media Integrity and Capacity Verification Tests. The MHP WTP well pumps were controlled based on the finished water storage tank level, started on a low level setpoint, and stopped on a high level setpoint. Therefore, operator attention was minimal during the tests and consisted mainly of monitoring the equipment to confirm proper operation and data collection.

Because Well No. 1 normally operated for only brief periods in automatic mode, the well pump was operated manually by the Gannett Fleming field engineer during the 13-day plus 8 hour Integrity Test for the required minimum of 2 hours of continuous operation on a daily basis. The well supply and arsenic adsorption media filter operated automatically for the remainder of the six-month Capacity Test, except during the backwashes observed by Gannett Fleming. During the observed and monitored backwashes, Well No. 1 was operated manually by the Gannett Fleming field engineer to produce continuous operation and to provide more accurate measurement of backwash, purge, and drive water flow rates.

Spent Actiguard AAFS50 media can be removed and replaced by the operator following breakthrough of arsenic. After the conclusion of the Capacity Test, data were generated representing the volume of water treated by the Actiguard AAFS50 media and the resultant treated water arsenic concentrations. The results of Capacity Testing are included in Chapter 4.

The system was designed to backwash automatically after a throughput of 10,500 gallons \pm 10%. Operator initiation was not required during automatic backwashes. The system also automatically re-initiated service operation of the backwashed filter. The position of an indicator dot on top of the control module actuator (see Figure 2-1) provided evidence that a backwash had occurred during those periods when the plant was not staffed.

The manually initiated backwash required approximately 1.5 to 2.0 hours of operator time. Operator time included setup, approximately 25 minutes of backwash time, on-site water quality analyses, sample collection for laboratory water quality analyses, documentation, and equipment cleanup. The manually initiated backwash, monitoring, and data collection were requested by PADEP as special conditions of the test plan and are not general equipment operating requirements.

2.2.2 Required Consumables

The system does not use electricity or chemicals during normal treatment operations and requires only treated water for each backwash cycle. The required consumables are limited to the adsorption media and treated water for backwash use, as described below:

- Actiguard AAFS50 activated alumina media: approximately 0.7 cubic feet per filter tank (~1.4 cubic feet total) per manufacturer specifications. Approximately 1.20 cubic feet were installed in the 2-filter test unit, based on volumetric calculations included in Appendix D.

- Treated water: 62 gallons of backwash and rinse per cycle per manufacturer specifications. The actual treated water usage during backwash (including purge and control module drive water) averaged approximately 83 gallons.

2.2.3 Rates of Waste Production

The manufacturer indicated approximately 62 gallons of filter backwash wastewater and purge (rinse) wastewater would be generated for every 10,500 gallons \pm 10% of throughput. The observed wastewater volume was approximately 83 gallons, including approximately 9.75 gallons of control module drive water. The total volume of water used per filter unit backwash was consistent for each manually initiated and observed backwash. Backwash water quantity and water quality characteristics are described in more detail in Chapter 4.

2.2.4 Equipment Performance Range

The equipment flow range and minimum recommended pressure are presented in Table 2-2. The manufacturer has stated their arsenic adsorption media system may not be appropriate for feed water quality containing high levels of potentially interfering ions, such as sulfate, silica, fluoride, and phosphate, depending on the feed water pH. However, the manufacturer has stated these interferences can be mitigated by pretreatment, if necessary.

2.2.5 Applications of Equipment

The manufacturer stated the process is appropriate for groundwater not under the influence of surface water at “very small” and “small” systems having limited manpower and operating skills. It is also appropriate for “medium” systems. The EPA defines “very small” systems as those systems serving a population of 25-500 people, “small” systems as those systems serving a population 501-3,300 people, and “medium-size” systems as those serving 3,301 to 10,000 people.

MHP Well No. 1 has relatively high manganese levels that were not treated prior to passing through the system. However, the manufacturers indicate the arsenic adsorption capacity is independent of the manganese concentration in the feed water.

2.2.6 Licensing Requirements Associated with Equipment Operation

States generally require a specific grade of waterworks operator permit in order to operate a filter process on a public water supply. However, this requirement did not apply for the ETV because all treated water was discharged to waste.

In Pennsylvania, to operate a full-scale version of this treatment technology for the Orchard Hills MHP public drinking water supply, a D9 license would be required; “D” refers to a capacity of 0.1 mgd or less and “9” refers to inorganics removal.

Chapter 3 Methods and Procedures

3.1 Experimental Design

This verification test was developed to provide verifiable information related to the performance of the Kinetico Inc. and Alcan Chemicals arsenic adsorption media system. Field operations, sampling, and analytical methodologies were performed in a manner assuring the quality of data collected would provide an accurate evaluation of the treatment system under the field conditions.

The ETV testing was conducted in two phases. The first phase, the Integrity Test, was designed to evaluate the reliability of equipment operation under the environmental and hydraulic conditions at the MHP WTP site during the initial two weeks of testing. The second phase, the Capacity Test, included testing designed to evaluate the capacity of the arsenic adsorption system to remove arsenic from the Well No. 1 feed water.

3.1.1 Objectives

The objectives of the verification test were:

- Produce data to meet the Data Quality Objectives (DQOs) shaped by the manufacturers' performance objectives;
- Present data on the impact of variations in feed water quality, such as turbidity, arsenic, pH, silica, fluoride, iron, and manganese on equipment performance;
- Evaluate the logistical, human, and economic resources necessary to operate the equipment;
- Evaluate the reliability, ruggedness, cost factors, range of usefulness, and ease of operation of the equipment; and
- Evaluate the arsenic adsorption capacity of the equipment under field conditions.

3.1.2 Equipment Characteristics

3.1.2.1 Qualitative Factors. The equipment was operated in such a way as to maintain its operating parameters within the manufacturers' recommendations. Contact time is a critical parameter for arsenic adsorption efficiency and is dependent on maintaining flow within the design range. The nature and frequency of the changes required to maintain the operating conditions were used in the qualitative evaluation of the equipment.

Frequent and significant adjustments would have indicated a relatively lower reliability and higher susceptibility to environmental conditions, as well as the degree of operator experience that may be required. However, as discussed in more detail in Chapter 4, flow rate adjustments were minimal. The effect of operator experience on the treatment results was evaluated.

The modular nature of the filter components, similar to a residential ion exchange water softener, makes equipment installation easy and straightforward. The equipment can be installed by a

qualified plumber. The equipment is also easy to move and reinstall at another location. The filter tanks are freestanding, requiring only a level surface capable of supporting 210 pounds and maintenance of ambient temperature above 35°F.

3.1.2.2 Quantitative Factors. The following factors were quantified for site-specific conditions, based upon data collected during this testing program:

- Backwash water quantity and quality;
- Backwash and purge duration and frequency; and
- Estimated labor hours for operation and maintenance.

These quantitative factors were used as an initial benchmark to assess equipment performance and to develop operation and maintenance costs.

3.2 Equipment Operations and Design

The *EPA/NSF ETV Protocol for Equipment Verification Testing for Arsenic Removal*, including *Chapter 6: Testing Plan - Adsorptive Media Processes for the Removal of Arsenic*, specifies the procedures used to ensure the accurate documentation of both equipment performance and treated water quality. Strict adherence to these procedures result in the definition of verifiable performance of the equipment. Chapter 5 includes information on the ETV Protocol and other documents used in the preparation of this report.

3.3 Field Test Equipment

Table 3-1 presents the analytical and calibration equipment used on-site.

Table 3-1. Field Analytical and Calibration Equipment

Equipment	Manufacturer/Model/Specs
Turbidimeter	Hach Model 2100P Portable Ratio™ Optical System (meets or exceeds USEPA Method 180.1 criteria)
pH/ISE Meter	Orion Model 290A with Triode pH Electrode Model 91-578N (resolution 0.1/0.01/0.001, accuracy ± 0.005); and Fluoride Combination Electrode Model 96-09 (reproducibility ± 2%)
Thermometer	Miller & Weber (range 0-32°C; NIST traceable)
Arsenic Field Test Kit	Industrial Test Systems (ITS), Inc. Model QUICK Low Range II (optimum accuracy below 6 µg/L)
Dead Weight Pressure Gauge Tester	Amthor Testing Instrument Co. Inc. (Type No. 460; range 0-6000 psi)
Burettes (for analytical titrations)	50 mL capacity with 0.1 mL subdivisions and 1000 mL reagent reservoir
Stopwatch and “Bucket”	Digital stopwatch and 2.0 L graduated cylinder with 10 mL increments for rotameter, totalizer meters, and control module drive water calibration checks. Fifty gallon container for backwash wastewater flow calibration
Platform Scale	Triner Scale Model 303, Serial No. 87D-065, Capacity 202 lbs.

3.4 Communications, Documentation, Logistics, and Equipment

It was Gannett Fleming’s responsibility to coordinate communication between all verification testing participants. Gannett Fleming maintained all field documentation. Bound field logbooks were used to record all water treatment equipment operating data. Each page was sequentially numbered and labeled with the project name and number. Completed pages were signed and dated by the individual responsible for the entries. Errors had one line drawn through them and this line was initialed and dated. Any deviations from the approved final PSTP were thoroughly documented in the field logbook. Copies of the logbook pages are included in the appendices of this report.

All field activities were thoroughly documented using the following forms of record:

- Field Logbook
- Field Data Sheets
- Photographs
- Laboratory Submission Sheets and Reports

Laboratory submission forms accompanied all samples shipped to the PADEP and NSF Laboratories. Copies of laboratory submission forms for all samples are included in the appendices of this verification report.

3.5 Equipment Operation and Water Quality Sampling for Verification Testing

The field activities conformed to requirements in the PSTP developed and approved for this verification test. The sampling and sample analyses that occurred during this verification testing program were performed according to the procedures detailed by Gannett Fleming in the PSTP. Any unanticipated or unusual situations that altered the plans for equipment operation, water quality sampling, or data quality were discussed with the NSF technical lead and PADEP. Any deviations from the approved final PSTP were documented.

During routine operation, the following were documented daily:

- The number of hours the arsenic adsorption media filter was operated;
- The number of hours the operator was working at tasks at the treatment plant related to the operation of the arsenic adsorption media filter; and
- Description of tasks performed during arsenic adsorption media filter operation.

3.6 Recording Data

The following information was recorded on-site:

- Experimental run number
- Water type (feed, treated, waste type)
- Hours of operation (calculated)
- Feed water flow rate
- Treated water flow rate
- Feed water production
- Treated water production
- Feed water pressure
- Treated water pressure
- Feed water temperature
- Treated water temperature
- Feed water turbidity
- Treated water turbidity
- Feed water pH
- Treated water pH
- Feed water arsenic concentration (qualitatively with field test kit)
- Treated water arsenic concentration (qualitatively with field test kit)
- Occurrence of a backwash
- Backwash water flow rate (when field engineer is present)
- Backwash duration (when field engineer is present)
- Backwash total volume (measured directly when field engineer is present)

3.7 Recording Statistical Uncertainty for Assorted Water Quality Parameters

For the analytical data obtained during verification testing, 95% confidence intervals were calculated by Gannett Fleming for arsenic data and for all other water quality data where the sample set contains eight or more values.

The consistency and precision of water quality data were evaluated with the use of the confidence interval. A confidence interval describes a population range in which any individual population measurement may exist with a specified percent confidence. The following formula was used for confidence interval calculation:

$$\text{confidence interval} = \bar{X} \pm t_{n-1, 1-\frac{a}{2}} (S/\sqrt{n})$$

where: \bar{X} is the sample mean;
 S is the sample standard deviation;
 n is the number of independent measures included in the data set;
 t is the t distribution value with n-1 degrees of freedom; and
 a is the significance level, defined for 95% confidence as: $1 - 0.95 = 0.05$.

According to the 95% confidence interval approach, the a term is defined to have a value of 0.05, thus simplifying the equation for the 95% confidence interval in the following manner:

$$95\% \text{ confidence interval} = \bar{X} \pm t_{n-1, 0.975} (S/\sqrt{n})$$

Results of these calculations were expressed as the sample mean, plus or minus the width of the confidence interval.

pH statistics were calculated on a log basis.

3.8 Verification Testing Schedule

Verification testing activities included equipment set up and shakedown, equipment Integrity Verification Testing, Adsorption Capacity Testing, and water quality sampling and analysis. The test schedule was developed to encompass all of these activities.

The Integrity Test began on April 22, 2003. The Integrity and Adsorption Capacity Verification Tests were initiated simultaneously. The Integrity Verification Test ran for a 2-week (13 full days plus 8 hours) period, ending May 5, 2003. The Adsorption Capacity Verification test continued until 11 $\mu\text{g/L}$ ⁽¹⁾ of arsenic was detected in the treated water for a minimum of three consecutive samples. Three consecutive treated water samples with arsenic concentrations greater than or equal to 11 $\mu\text{g/L}$ were required to ensure the predefined endpoint had in fact been

⁽¹⁾ Kinetico/Alcan Chemicals originally requested that 12 $\mu\text{g/L}$ be used as the stopping point to ensure the threshold of 10 $\mu\text{g/L}$ had actually been crossed and the reading was not due to analytical error or method variability. Due to relatively slow arsenic breakthrough and reduced feed water arsenic concentrations, the manufacturer, NSF, and Gannett Fleming agreed to revise the stopping point to 11 $\mu\text{g/L}$.

reached and the end of the test would not be influenced an analytical error. The capacity test ended on October 28, 2003. The equipment was disassembled by the manufacturer and filter core samples were taken by Gannett Fleming on November 4, 2003.

3.9 Task 1: System Integrity Verification Testing

3.9.1 Introduction

During Task 1, Gannett Fleming evaluated the reliability of the equipment operation under the environmental and hydraulic conditions at Orchard Hills MHP WTP Well No. 1. The Integrity Verification Test was performed to determine whether the treatment objectives could be achieved for arsenic removal at the design operating parameters for the arsenic adsorption media system. The adsorption media filter was operated for Integrity Test purposes within the operational range presented in the equipment design criteria.

3.9.2 Experimental Objectives

The experimental objectives for the Integrity Test phase of the verification testing are summarized below:

- Evaluate equipment operational reliability under field conditions;
- Document feed water quality and arsenic concentration; and
- Collect operational and water quality data under field conditions.

3.9.3 Work Plan

Initial shakedown testing was performed on the adsorption filter unit to establish basic operability. Two sets of feed and treated speciated arsenic samples were used to establish the capability of the filter unit to remove arsenic from the feed water. Following the initial shakedown testing, a pressure-reducing valve was added to the system upstream of the diaphragm valve to maintain a constant flow rate under variable feed water pressures.

Prior to beginning the Integrity and Capacity Test phases, the manufacturer installed new Actiguard AAFS50 media in each of the two adsorption filter tanks. A platform scale was used to weigh the media prior to installation into each filter tank. The weight of the media and the measurement of “freeboard” from the top of the media to the top of the unit (top of the opening in each filter tank where the media is added) were recorded.

Following the protocol for startup, as detailed in the Alcan Chemicals’ Technical Bulletin for Actiguard AAFS50 in Appendix A, the initial 10 bed volumes of treated water (flushing water) should be discounted prior to recording the totalizers’ startup readings. The manufacturer actually used approximately 350 gallons, or 36 bed volumes, during startup to wash the media and to verify the operation of the filter control module. This water volume, used for startup, was documented when recording the initial totalizer reading prior to initiation of the Integrity and Capacity Tests.

The Integrity Test monitoring and on-site data collection were performed at frequencies shown in the schedule presented in Table 3-2. The treatment system primarily operated intermittently due to the intermittent operation of Well No. 1. However, the treatment system was required to operate continuously for at least 2 hours each day during the Integrity Test, as specified in the test plan. The 2-hour continuous operation each day was performed and witnessed by the Gannett Fleming field engineer and used the manual mode of operation for Well No. 1 at the WTP well pump control panel.

Grab samples for on-site and laboratory analyses were collected according to the sampling schedule presented in Table 3-3. The feed water and treated water sample taps were flushed for at least five seconds prior to sample collection. A sampling plan for arsenic that includes the Integrity Verification Test is presented in Table 3-4. Three days of the daily feed water and treated water samples were collected to speciate arsenic, as specified in Table 3-4. The protocol for arsenic speciation (from the TSTP) is presented in Appendix E. Daily and weekly samples collected for on-site analysis were analyzed immediately after collection during the 2-hour period of continuous operation. Alkalinity, total hardness, calcium hardness, and fluoride were analyzed in the Gannett Fleming Treatability Lab within two hours of leaving the site. Sample collection and handling procedures followed *Standard Methods 3010 B*. Daily and weekly samples for laboratory analysis were collected during the 2-hour period of continuous operation. At least one hour of operation occurred prior to sample collection for arsenic.

All of the samples were collected by the Gannett Fleming field engineer in appropriate sample bottles prepared with preservatives, as required, specific to the analytical methods to be used. Additionally, the samples were stored and shipped in accordance with appropriate procedures and holding times, as specified by the PADEP and NSF. A water quality sampling protocol for PADEP Laboratory analysis, describing volumes, preservation, holding times, and laboratory sample identification for each water quality parameter, is presented in Table 3-8. The methods used by the laboratory for the analytical procedures are presented in Section 3.13.4 and described in Task 5, Quality Assurance/Quality Control. All on-site data and observations were recorded by the Gannett Fleming field engineer in a series of bound logbooks. Copies of the original logbooks and on-site Water Quality Data are included as Appendix F. All PADEP Laboratory water quality data and sample submission forms are included in Appendix G. PADEP Laboratory QA/QC Summary Tables are included in Appendix H. Complete QA/QC documentation is on file at NSF.

Two backwashes occurred during the System Integrity Verification Test, one of which was manually initiated and witnessed by the field engineer. Backwash water flow, duration, and volume were monitored volumetrically and recorded. Backwash water quality was analyzed as listed in Table 3-6. Complete results and data analysis are presented in Chapter 4.

3.9.4 Analytical Schedule

The arsenic adsorption media filter system operational data were monitored following the procedures and at the frequencies prescribed in the test plan, as summarized below and in Table 3-2.

- The treated water flow rate was monitored and adjusted, as needed, using the rotameter and diaphragm valve located on the treated water pipe. The treated water flow rate was recorded twice per day, before and after any necessary adjustment. The flow rate was set and maintained at 1.9 gpm ± 0.10 gpm.
- The feed water and treated water production were monitored and recorded twice per day at the totalizer meters located on the feed water and treated water pipes.
- Well pump run time is not totalized at the WTP motor control center. Therefore, run time was back-calculated from the totalizer readings and flow rate.
- The feed water pressure was monitored twice per day at the pressure gauge located on the feed water pipe. Minimum and maximum operating pressures for the filter tanks are 30 psi and 125 psi, respectively.
- The treated water pressure was monitored twice per day at the pressure gauge located on the treated water pipe. This reading was performed at the same time as the feed water pressure measurement. The difference between these values represents the headloss through the system.

Table 3-2. On-Site Equipment Operating Parameter Monitoring and Data Collection Schedule

Parameter	Monitoring Frequency	Monitoring Method
Treated Water Flow Rate	Check & record twice per day (adjust when 5% above or below target record before and after adjustment)	Rotameter
Feed Water and Treated Water Production	Check & record twice per day	Feed and treated totalizer meters
Hours of Production	Calculate & record once per day	Calculated from totalizer meter and flow rate data
Feed Water Pressure	Check & record twice per day	Feed water pressure gauge
Treated Water Pressure	Check & record twice per day	Treated water pressure gauge

Water quality data were collected as described below:

- The water quality of the feed water and treated water were characterized by analysis of the water quality parameters listed in Table 3-3. The water quality analyses presented in Table 3-3 were conducted to provide state drinking water regulatory agencies with background data on the quality of the feed water being treated and the quality of the treated water.
- Samples were collected during the 2-hour period of continuous operation, following a minimum of 1 hour of operation.
- Temperature, pH, turbidity, and qualitative arsenic were analyzed on-site.

Table 3-3. Water Quality Sampling Schedule for System Integrity Verification Testing

Parameter	Sampling Frequency	Test Streams to be Sampled	Standard Method ⁽¹⁾	EPA Method ⁽²⁾	Hach Method
<i>On-Site Analyses</i>					
Arsenic	⁽³⁾	Adsorptive Media Feed Water & Treated Water		(See Appendix I)	
pH	Twice Daily	Adsorptive Media Feed Water & Treated Water	4500-H ⁺ B	--	--
Temperature	Daily	Adsorptive Media Feed Water & Treated Water	2550 B	--	--
Turbidity	Daily	Adsorptive Media Feed Water & Treated Water	2130 B	--	--
Alkalinity ⁽⁴⁾	Daily	Adsorptive Media Feed Water & Treated Water	--	--	8221
Calcium ⁽⁴⁾	Weekly	Adsorptive Media Feed Water & Treated Water	--	--	8222
Magnesium ⁽⁴⁾	Weekly	Adsorptive Media Feed Water & Treated Water	--	--	Calculated (8226-8222)
Hardness ⁽⁴⁾	Weekly	Adsorptive Media Feed Water & Treated Water	--	--	8226
Fluoride ⁽⁴⁾	Daily	Adsorptive Media Feed Water & Treated Water	4500-F C	--	--
<i>Laboratory Analyses</i>					
Arsenic ⁽⁵⁾	Daily	Adsorptive Media Feed Water & Treated Water	--	200.8	--
Silica	Daily	Adsorptive Media Feed Water & Treated Water	--	200.7	--
Aluminum	Daily	Adsorptive Media Feed Water & Treated Water	--	200.7	--
Iron	Weekly	Adsorptive Media Feed Water & Treated Water	--	200.7	--
Manganese	Weekly	Adsorptive Media Feed Water & Treated Water	--	200.7	--
Chloride	Weekly	Adsorptive Media Feed Water & Treated Water	--	300.0	--
Sulfate	Weekly	Adsorptive Media Feed Water & Treated Water	--	300.0	--
Total Phosphorus	Weekly	Adsorptive Media Feed Water & Treated Water	--	365.1	--

⁽¹⁾ APHA, AWWA and WPCF (1995). *Standard Methods for Examination of Water and Wastewater*. 19th ed. Washington, D.C. APHA.

⁽²⁾ EPA Methods Source: EPA Office of Ground Water and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

⁽³⁾ See Table 3-4. An arsenic field test kit was used for periodic qualitative arsenic checks.

⁽⁴⁾ Analyzed on-site or at the Gannett Fleming Treatability Lab.

⁽⁵⁾ The NSF Laboratory performed laboratory arsenic analyses. The PADEP Laboratory performed all other laboratory analyses during the Integrity Test.

Table 3-4. Arsenic Sampling Plan

Test Period	Sample Sources	Sample Frequency	Sampling Period	No. of Days Samples Speciated ⁽²⁾	Hold Samples	Total No. Analyses
<i>Laboratory Analyses</i>						
Shakedown	Feed, Treated	Daily	2 days	2	None	12
Integrity Verification	Feed, Treated	Daily	13 days 8 hours	3	None	40
Adsorption Capacity Verification	Feed, Treated	Weekly	First 6 months ⁽¹⁾	2 ⁽²⁾	None	56
Adsorption Capacity Verification	Feed, Treated	Daily	Final 2 months ⁽¹⁾	1 ⁽²⁾	12 per week	min: 20 max: 124
<i>On-Site Qualitative Analyses⁽³⁾</i>						
Integrity Verification	Feed, Treated	Weekly	13 days 8 hours	N/A	N/A	4
Adsorption Capacity Verification	Feed, Treated	Weekly	First 6 months ⁽¹⁾	N/A	N/A	48
Adsorption Capacity Verification	Feed, Treated	3/week	Final 2 months ⁽¹⁾	N/A	N/A	48

⁽¹⁾ The estimated sampling period was 8 months. If breakthrough did not occur within 8 months, the test and sampling plan would have continued until breakthrough occurred.

⁽²⁾ This was considered the minimum number of days samples are speciated during the capacity verification testing. If arsenic was detected in the treated water, feed and treated water samples collected the following week would have been speciated and analyzed.

⁽³⁾ Method procedure presented in Appendix I.

3.9.5 Evaluation Criteria and Minimum Reporting Requirements

A table and time series plots were produced to present all feed water and treated water quality data which varied with time from the system Integrity Verification test. The system Integrity Verification test demonstrates the initial ability of the adsorptive media to remove the feed water arsenic concentration to below detectable levels in the treated water. All water quality parameters, operational parameters, backwash flow rates, and quantities were tabulated and plotted, as appropriate. The backwash waste stream and control module discharge flow rates were tabulated. A plot of feed and treated water pressure and system headloss is presented. System headloss information was used to infer power requirements for a system that will pump directly through the treatment unit. No direct measurement of power was possible because the system does not require electricity. Test results are summarized, plotted, and discussed in Chapter 4. All raw data are included in appendices, as referenced in Chapter 4.

3.10 Task 2: Adsorption Capacity Verification Testing

3.10.1 Introduction

The objectives of the Adsorption Capacity Test were to produce operational and water quality data up through and including what Kinetico Inc. and Alcan Chemicals have defined as the breakthrough arsenic level for their arsenic adsorption system. The performance of the adsorptive media is a function of feed water quality, contact time, rest time, and type of adsorptive media used. Arsenic breakthrough is highly dependent on the concentration and adsorptive characteristics (isotherm) of the arsenic to be treated by the adsorptive media. Design and empty bed contact time (EBCT) will help define the performance of the media for a given feed water quality. Adsorption capacity verification testing was performed one time for the arsenic adsorption media system, using the feed water from Well No. 1 at Orchard Hills MHP.

3.10.2 Experimental Objectives

The experimental objective was to provide equipment operating and water quality data related to the adsorptive media capacity to remove arsenic from the feed water to the pre-defined arsenic breakthrough concentration.

3.10.3 Work Plan

Task 2 Adsorption Capacity Verification Testing began simultaneously with Task 1, System Integrity Verification Testing. The operating conditions were as stated under 3.9.3 Work Plan for Task 1: System Integrity Verification Testing.

3.10.4 Analytical Schedule

- Operational Data Collection
 - The treated water flow rate was monitored and adjusted, as needed, using the rotameter and diaphragm valve located on the treated water pipe. The treated water flow rate was recorded twice per day, before and after any necessary adjustment. The flow rate was set and maintained at $1.9 \text{ gpm} \pm 0.10 \text{ gpm}$.
 - The feed water and treated water production was monitored and recorded twice per day at the totalizer meters, located on the feed water and treated water pipes.
 - Well pump run time is not totalized at the WTP motor control center. Therefore, run time was back-calculated from the totalizer readings and flow rate.
 - The feed water pressure was monitored twice per day at the pressure gauge located on the feed water pipe. Minimum and maximum operating pressures for the filter tanks are 30 psi and 125 psi, respectively.
 - The treated water pressure was monitored twice per day at the pressure gauge located on the treated water pipe. This was performed at the same time as the feed water pressure measurement. The difference between these values represents the headloss through the system.

- Sample Holding
 - As indicated in Table 3-4, as the media approached 70% of its predicted capacity, samples for laboratory arsenic analyses were collected on a daily basis and held (approximately 2 weeks) pending the results of the weekly arsenic samples. This was done in the event arsenic breakthrough was missed with the weekly sampling. Arsenic hold samples for the final 4 weeks of the Capacity Test were submitted for analysis. Fluoride, silica, iron, manganese, and aluminum samples were collected weekly during Task 2.

- Water Quality Data Collection
 - The adsorptive media feed water quality, treated water quality, and wastewater quality were characterized by the analysis of the water quality parameters listed in Tables 3-5 and 3-6. The sampling frequency is also described in Tables 3-5 and 3-6. This frequency was intended to provide sufficient water quality data to effectively characterize the breakthrough profile of arsenic and to develop a representative wastewater quality profile.
 - Grab samples of backwash wastewater were collected for water quality analyses at the frequency presented in Table 3-6. The backwash and purge water collection procedure is for one of the two filter tanks. The samples were mixed to maintain a relatively homogenous suspension during sample collection.

- Arsenic Speciation
 - The minimum arsenic speciation frequency is presented on Table 3-4.

- Spent Media Analysis
 - TCLP and CA WET were performed on spent Actiguard AAFS50 media, as required by the test plan. The physical condition of the spent media was noted and reported, along with the result of the TCLP and CA WET testing in Chapter 4 and Appendix J.
 - A 1.5-inch thin-walled copper tube, 4 feet in length, was used to core one sample of spent Actiguard AAFS50 adsorption media from each of the two filter tanks. The Kinetico procedure for media replacement in Appendix K was followed through Step 8a. (with the exception of emptying the media into the bucket) to gain access to the media contained in each filter tank and to decant the water out of each tank. Following decanting, the copper tube was used to obtain a core sample through the entire depth of the media from each tank. Each core was discharged into a large plastic bag. The bag was vigorously shaken to provide a homogenous media sample. The sample was used for TCLP and CA WET analyses.
 - A media gradation analysis was performed on the spent Actiguard AAFS50 media and compared to the gradation analysis of new media, presented in Appendix L, to determine the extent of media physical degradation, if any.
 - The result of all testing on spent media are discussed in Chapter 4.

Table 3-5. Water Quality Sampling Schedule for Media Adsorption Capacity Verification Testing

Parameter	Sampling Frequency	Test Streams to be Sampled	Standard Method ⁽¹⁾	EPA Method ⁽²⁾	Hach Method
<i>On-Site Analyses</i>					
Arsenic	(3)	Adsorptive Media		(See Appendix I)	
		Feed Water & Treated Water			
pH	Daily	Adsorptive Media	4500-H ⁺ B	--	--
		Feed Water & Treated Water			
Temperature	Daily	Adsorptive Media	2550 B	--	--
		Feed Water & Treated Water			
Turbidity	Daily	Adsorptive Media	2130 B	--	--
		Feed Water & Treated Water			
Alkalinity ⁽⁴⁾	3/Week	Adsorptive Media	--	--	8221
		Feed Water & Treated Water			
Calcium ⁽⁴⁾	Weekly	Adsorptive Media	--	--	8222
		Feed Water & Treated Water			
Magnesium ⁽⁴⁾	Weekly	Adsorptive Media	--	--	Calculated
		Feed Water & Treated Water			(8226-8222)
Hardness ⁽⁴⁾	Weekly	Adsorptive Media	--	--	8226
		Feed Water & Treated Water			
Fluoride ⁽⁴⁾	Weekly	Adsorptive Media	4500-F C	--	--
		Feed Water & Treated Water			
<i>Laboratory Analyses</i>					
Arsenic	Weekly ⁽⁵⁾	Adsorptive Media	--	200.8	--
		Feed Water & Treated Water			
Silica	Weekly	Adsorptive Media	--	200.7	--
		Feed Water & Treated Water			
Aluminum	Weekly	Adsorptive Media	--	200.7	--
		Feed Water & Treated Water			
Iron	Weekly	Adsorptive Media	--	200.7	--
		Feed Water & Treated Water			
Manganese	Weekly	Adsorptive Media	--	200.7	--
		Feed Water & Treated Water			
Chloride	Weekly	Adsorptive Media	--	300.0	--
		Feed Water & Treated Water			
Sulfate	Weekly	Adsorptive Media	--	300.0	--
		Feed Water & Treated Water			
Total Phosphorus	Weekly	Adsorptive Media	--	365.1	--
		Feed Water & Treated Water			
TCLP ⁽⁶⁾	Once	Spent Actiguard AAFS50	--	SW-846	--
		Adsorptive Media		EPA 1311	
CA WET ⁽⁶⁾	Once	Spent Actiguard AAFS50			
		Adsorptive Media		(See Appendix M)	

⁽¹⁾ *Standard Methods for Examination of Water and Wastewater*. 19th ed. Washington, D.C. APHA.

⁽²⁾ EPA Methods Source: EPA Office of Ground Water and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

⁽³⁾ An arsenic field test kit was used for periodic qualitative arsenic checks, as specified in Table 3-6.

⁽⁴⁾ Analyzed on-site or at the Gannett Fleming Treatability Lab.

⁽⁵⁾ See arsenic sampling plan in Table 3-4.

⁽⁶⁾ TriMatrix Laboratories, Inc. performed the TCLP and CA WET analyses.

Table 3-6. Monitoring, Sampling, and Analyses for Backwash Wastewater, Purge Water, and Control Module Drive Water

Parameter	Purge and Backwash Wastewater Sample Type	Control Module Drive Water Sample Type	Frequency ⁽²⁾	Method
Flow Rate	Volumetric	Volumetric	Every second month	“Bucket” ⁽³⁾⁽⁴⁾ & stopwatch
Volume	Direct measurement	Direct measurement	Every second month (directly)	Graduated container ⁽³⁾
Duration	Manually timed	Manually timed	Every second month	Stopwatch
Turbidity	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	SM 2130-B
pH	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	SM 4500-H ⁺
Arsenic	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	EPA 200.8
Manganese	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	EPA 200.7
Iron	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	EPA 200.7
Aluminum	Grab ⁽¹⁾	Grab ⁽¹⁾	Every second month	EPA 200.7

⁽¹⁾ Grab samples were collected using a 2-liter beaker from a continuously mixed batch tank. Backwash and purge wastewaters were collected in 50- and 30-gallon containers, respectively. Grab sample for control module drive water were collected with a 2-liter beaker.

⁽²⁾ Frequencies indicated per request of PADEP.

⁽³⁾ The “buckets” were 50- and 30-gallon containers for calibrating backwash and purge flow rates, respectively. Increments in liters were marked on the sides of these containers, based on incrementally filling the containers beforehand with a 2-liter graduated cylinder.

⁽⁴⁾ A 2.0 graduated cylinder was the “bucket” for determining control module drive water discharge flow rate.

3.10.5 Evaluation Criteria and Minimum Reporting Requirements

The results of Adsorption Capacity Testing are presented in Chapter 4 and include the following:

- Record of Arsenic Removal:
 - An arsenic breakthrough curve was plotted showing the adsorptive media treated water concentrations versus volumes treated. Feed water arsenic concentrations were included on the same plot.
 - A spreadsheet of arsenic feed water concentrations and calculations of the average feed water arsenic concentration was tabulated.
- Process Control:
 - The adsorptive media feed water and treated water arsenic, pH, pressure, and water production were tabulated and used to calculate incremental feed and treated water production, differential pressure, and cumulative arsenic removed. The adsorptive media feed water average, standard deviation, and confidence interval were included for each parameter, when appropriate.

3.11 Task 3: Documentation of Operating Conditions and Treatment Equipment Performance

3.11.1 Introduction

During each day of verification testing, arsenic adsorption media filter operating conditions were documented, including the rate of headloss gain. The volumetric flow rate through an adsorptive media vessel is a critical parameter and was thoroughly monitored and documented. Adsorptive media performance is affected by the EBCT, which varies directly with volumetric flow rate through the vessel.

3.11.2 Experimental Objectives

The objective of this task was to accurately and fully document the operating conditions and performance of the equipment.

3.11.3 Work Plan

During the verification test, treatment equipment operating parameters were monitored and recorded on a routine basis. This included a complete description of all applicable data.

3.11.4 Schedule

Table 3-7 presents the schedule for observing and recording equipment operation and performance data.

Table 3-7. Schedule for Observing and Recording Equipment Operation and Performance Data

Operational Parameter	Action
Treated water flow rate	Check and record in logbook twice per day; adjust when >5% above or below target. Record before and after adjustment.
Filter system feed water and treated water pressures	Record in logbook: initial clean bed feed water and treated water pressure at the start of the run; thereafter, record twice per day.
Total hours operated per day	Record at end of day or at beginning of the following workday, as calculated from totalizer meter readings and flow rate.
Tasks performed during equipment operation	Record tasks performed daily in logbook.
Number of hours per day operator attends to all tasks related to the treatment process	Record number of hours required by operator to accomplish all tasks.
Totalizer Meter Readings	Record totalizer meter readings twice daily.

3.11.5 Evaluation Criteria

The data developed from the Integrity and Capacity Tests were used to evaluate the performance of the adsorption media filter. An objective evaluation of the difficulty of operations was based on an assessment of time required for process monitoring and hydraulic control.

3.12 Task 4: Data Management

3.12.1 Introduction

The data management system that was used in this verification involved the use of computer spreadsheet software and manual recording of system operating parameters.

3.12.2 Experimental Objectives

The objective of this task was to establish a viable structure for the recording and transmission of field-testing data by Gannett Fleming, such that NSF received sufficient and reliable data for verification purposes.

3.12.3 Work Plan

The following procedures were implemented for data handling and data verification by Gannett Fleming:

The field-testing operator recorded operating and water quality data and calculations by hand in a laboratory notebook.

- Daily measurements were recorded on specially prepared data log sheets.
- The logbook is permanently bound with consecutively numbered pages.
- The logbook indicates the starting and ending dates that apply to entries in the logbook.
- All pages have appropriate headings to avoid entry omissions.
- All logbook entries were made in black water-insoluble ink.
- All corrections in the logbook were made by placing one line through the erroneous information and were initialed by the field-testing operator.
- The pilot operating logs include a description of the adsorptive media equipment, description of test run(s), names of visitors, description of any problems or issues, etc; such descriptions were provided in addition to experimental calculations and other items.

The original logbook was photocopied at least once per week and copies forwarded to the Gannett Fleming project engineer. This protocol not only eased referencing of the original data, but offered protection of the original record of results.

The database for this verification test program was set up in the form of custom-designed spreadsheets. The spreadsheets were capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets were entered into the

appropriate spreadsheets. Data entry was conducted off-site by the designated field-testing operator. All recorded calculations were also checked at this time. Following data entry, the spreadsheet was printed out and the printout was checked against the handwritten data sheet by another individual. Any corrections were noted on the hard copies and corrected on the screen; then a corrected version of the spreadsheet was printed out. Each step of the verification process was initiated by the field-testing operator or supervisor performing the entry or verification step.

Each experiment (e.g., each test run) was assigned a run number that was then tied to the data from the experiment through each step of data entry and analysis. As samples were collected and sent to the PADEP and NSF Laboratories, the data were tracked by use of a system of run numbers. Data from the PADEP and NSF Laboratories were received and reviewed by the field-testing operator. These data were entered into the data spreadsheets, corrected, and verified in the same manner as the field data.

3.13 Task 5: Quality Assurance/Quality Control (QA/QC)

3.13.1 Introduction

Quality assurance and quality control for the operation of the arsenic adsorption media filter and the measured water quality parameters were maintained during the verification testing program, as described in this section.

3.13.2 Experimental Objectives

The objective of this task was to maintain strict QA/QC methods and procedures during this verification test. Maintenance of strict QA/QC procedures was important in that, if a question were to arise when analyzing or interpreting data collected for the arsenic adsorption media filter, it would be possible to verify the exact conditions at the time of testing.

3.13.3 Work Plan

Equipment flow rates were verified and recorded on a routine basis. A routine daily walk-through during testing was established to verify each piece of equipment or instrumentation was operating properly. The items listed below are in addition to any specified checks outlined in the analytical methods.

It was extremely important that system flow rates be maintained at set values and monitored frequently. Doing so allowed maintenance of a constant and known EBCT in the adsorptive media. Adsorptive media performance is directly affected by the EBCT, which, in turn, is proportional to the volumetric flow rate through the media. Therefore, an important QA/QC objective was the maintenance of a constant volumetric flow rate through the adsorptive media by frequent monitoring and documentation for possible needed adjustment. Documentation included an average and standard deviation of recorded flow rates through the adsorptive media.

- Weekly QA/QC Verifications
 - In-line rotameter (clean any foulant buildup, as needed, and verify flow rate volumetrically);
 - In-line totalizer meters (clean any foulant buildup, as needed, and verify flow rate); and
 - Tubing (verify good condition of all tubing and connections; replace as necessary).

3.13.4 Analytical Methods

The analytical methods utilized in this study for on-site and laboratory monitoring of adsorptive media feed and treated water quality are described in the section below.

- **Arsenic**

Arsenic analyses were performed at the NSF Laboratory according to EPA Method 200.8. These analyses were the most critical for the entire ETV test. Minimum analytical turnaround time was required to achieve optimum process control. This method required ultra-pure (optimum) grade nitric acid be used, not reagent grade, to avoid the trace amounts of arsenic, which can be present in reagent grade nitric acid.

Arsenic analyses were also performed on-site for qualitative purposes. These used the Model QUICK Low Range II field test kit from Industrial Test Systems (ITS), Inc. The arsenic field test kit has an optimum accuracy below 6 µg/L and a reaction time of less than 15 minutes. The complete method procedure is presented in Appendix I.
- **pH**

Analyses for pH were performed on-site according to Standard Method 4500-H⁺ B (Electrometric Method). A three-point calibration of the pH meter used in this study was performed once per day. Certified pH buffers 4.0, 7.0, and 10.0 were used. The pH electrode was stored in an appropriate solution, as defined in the instrument manual.
- **Alkalinity**

Analyses for alkalinity were performed at the Gannett Fleming Treatability Lab according to Hach Method 8221 (Buret Titration Method).
- **Fluoride**

Analyses for fluoride were performed at the Gannett Fleming Treatability Lab according to Standard Method 4500-F⁻ C (Ion-Selective Electrode Method).
- **Chloride**

Analyses for chloride were performed at the PADEP Lab according to EPA Method 300.0.
- **Sulfate**

Analyses for sulfate were performed at the PADEP Lab according to EPA Method 300.0.

- **Silica**
Analyses for silica were performed at the PADEP Lab according to EPA Method 200.7.
- **Aluminum**
Analyses for aluminum were performed at the PADEP Lab according to EPA Method 200.7.
- **Total Phosphorus**
Analyses for phosphate were performed at the PADEP Lab according to EPA Method 365.1.
- **Calcium**
Analyses for calcium were performed at the Gannett Fleming Treatability Lab according to Hach Method 8222 (Buret Method), with 0.020 N titrant.
- **Hardness**
Analyses for hardness were performed at the Gannett Fleming Treatability Lab according to Hach Method 8226 (ManVer 2 Buret Titration), with 0.020 N titrant.
- **Magnesium**
Magnesium results were calculated by subtracting the calcium result (Hach Method 8222) from the Hardness result (Hach Method 8226).
- **Iron**
Analyses for iron were performed at the PADEP according to EPA Method 200.7.
- **Manganese**
Analyses for manganese were performed at the PADEP Lab according to EPA Method 200.7.
- **Turbidity**
Turbidity analyses were performed on-site according to Standard Method 2130 B using a portable turbidimeter.
- **Temperature**
Temperature was analyzed on-site according to Standard Method 2550 B.

3.13.5 Samples Shipped Off-Site for Analysis

Samples for inorganic analysis, including arsenic, chloride, sulfate, silica, aluminum, total phosphorus, iron, and manganese, were collected and preserved in accordance with Standard Method 3010 B. Particular attention was paid to the sources of contamination as outlined in Standard Method 3010 C. The samples were refrigerated at approximately 2° to 8°C immediately upon collection (except for the arsenic samples), shipped in a cooler, and maintained at a temperature of approximately 2° to 8°C. The PADEP Lab maintained the

samples at approximately 2° to 8°C until initiation of analysis. Table 3-8 presents the sampling protocol followed during the ETV for samples analyzed by the PADEP Laboratory.

Table 3-8. Water Quality Sampling Protocol

Parameter	Sample Bottle	Sample Volume	Sample Preservation	Sample Hold Time	DEP Sample ID Protocol		Sample Submission Sheet				NSF Test Tracking ID	
					Feed	Treated	SAC ⁽¹⁾ No.	Bottle Cap ID	Collector No.	Date/Time Collected	Integrity	Capacity
<i>Laboratory</i>												
Aluminum & Silica	125 mL HDPE	100 mL	Nitric Acid to pH <2.0; iced	6 months	101	102	107	M	1749	✓	I	II
Iron & Manganese	125 mL HDPE	100 mL	Nitric Acid to pH <2.0; iced	6 months	201	202	106	M	1749	✓	I	II
Sulfate & Chloride	500 mL HDPE	250 mL	Iced	28 days	201	202	106	N/A	1749	✓	I	II
Total Phosphorus	125 mL HDPE	100 mL	Sulfuric Acid to pH <2.0; iced	28 days	201	202	106	P	1749	✓	I	II
TCLP	Plastic Bag		N/A	N/A	N/A	N/A	242	N/A	1749	✓	N/A	II

⁽¹⁾ Information also required on sample bottle.

3.14 Operations and Maintenance

Gannett Fleming reviewed Kinetico’s O&M Manual; comments related to the applicability of the manual are included in Chapter 4. The Owner’s Manual and Installation Guide are included in Appendix N; the technical sheets are on file at Gannett Fleming and NSF. These manuals present specific information on the mechanical operation of the filter tanks for a variety of media types, including Actiguard AAFS50.

Chapter 4 Results and Discussion

4.1 Introduction

The ETV testing of Kinetico Inc.'s and Alcan Chemicals' arsenic adsorption filter system was conducted in two phases, including an Integrity Verification Test and an Adsorption Capacity Test. Prior to initiation of the Integrity and Capacity Testing, equipment shakedown was performed; this included collection and analysis of two days of speciated feed and treated water samples. The two-week (13 full days plus 8 hours) Integrity Verification Test was initiated on April 22, 2003 and concluded on May 5, 2003. The initiation of the Adsorption Capacity Test coincided with the Integrity Verification Test and continued until an arsenic breakthrough concentration of 11 $\mu\text{g/L}$ was detected in three consecutive treated water samples. Following confirmed breakthrough of arsenic, the treatment unit was shutdown on October 28, 2003. Spent media samples were collected on November 4, 2003, which concluded the verification test.

This section of the ETV report presents a summary of the equipment startup and preliminary arsenic speciation sample analyses, results of the Integrity Verification Test, results of the Adsorption Capacity Test, and a discussion of the results. The results and discussion encompass the concentration and speciation of arsenic in the feed and treated water, analysis of other key feed and treated water quality parameters, the quantity and rate of treated water production, backwash water quantity and water quality, spent media analyses, and equipment operation characteristics, as well as quality assurance and quality control procedures.

4.2 Task 1: System Integrity Verification Testing

The verification test site was the Orchard Hills MHP WTP, located in Carroll Township, Pennsylvania. The WTP and arsenic adsorption filter system are described in detail in Chapter 2.

4.2.1 *Equipment Installation, Startup, and Shakedown*

The arsenic adsorption media filter system equipment was installed by Kinetico Inc. personnel in September 2002. Initial arsenic speciation tests were performed on the feed and treated water in December 2002, prior to PSTP finalization. These initial arsenic tests were used to make a preliminary assessment of the ability of the system to remove arsenic under the existing water quality conditions at the site and to evaluate the speciation of arsenic in the feed water. During the Integrity Verification Test, Gannett Fleming evaluated the reliability of equipment operation under the environmental and hydraulic conditions at the Orchard Hills MHP WTP site, while the equipment was supplied feed water by Well No. 1. The adsorption media filter was operated for Integrity Verification testing purposes for 13 days plus 8 hours within the operational range presented in the equipment design criteria.

Preliminary arsenic speciation analyses indicated a total feed water arsenic concentration of approximately 17 $\mu\text{g/L}$. Arsenic III was not detected in the feed water above the 4 $\mu\text{g/L}$ detection limit. Arsenic was not detected in the treated water. Preliminary arsenic speciation results are presented in Table 4-1. Analytical test reports and sample submission forms for the

preliminary arsenic speciation analyses are included in Appendix O. The anion exchange resin columns used for these preliminary arsenic speciations were later found, during later performance evaluation testing, to be only approximately 70% effective in the recovery of arsenic III. Laboratory arsenic analyses for the preliminary samples with an arsenic method detection limit of 4 µg/L were performed at the PADEP Laboratory. Subsequent speciations were made during the Integrity and Capacity Verification Tests, with a new batch of ion exchange columns (prepared by NSF). The arsenic analyses were performed with a method detection limit of 2 µg/L at the NSF Laboratory. These analyses indicated an arsenic III concentration of approximately 4 µg/L in the feed water as described later in this chapter. Arsenic speciation using NSF-prepared ion exchange columns resulted in a 100% recovery of arsenic III in performance evaluation testing. Performance evaluation testing results for arsenic speciation and on-site water quality analyses are presented later in this chapter. The NSF-prepared anion exchange resin columns were used for arsenic speciation during the Integrity Verification and Adsorption Capacity testing.

Table 4-1. Preliminary Arsenic Speciation

Sample Date	Feed Water				Treated Water			
	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V ⁽¹⁾ (µg/L)	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V (µg/L)
12/10/2002	16.7	15.4	<4.0	>11.4	<4.0	<4.0	<4.0	<4.0
12/11/2002	17.2	16.2	<4.0	>12.2	<4.0	<4.0	<4.0	<4.0

⁽¹⁾ The laboratory minimum reporting limit is used for all statistical calculations. For preliminary (i.e., Shakedown) arsenic analyses only, the laboratory minimum reporting limit is 4 µg/L.

Several physical modifications were made to the system prior to the initiation of testing on April 22, 2003. Modifications included installation of a second totalizer meter ahead of the treatment unit, a Y-check valve, and a pressure regulating valve located downstream of the treatment unit, but upstream of the diaphragm flow control valve. The pressure regulating valve was added in response to the widely variable WTP pressures in order to maintain a constant pressure at the diaphragm valve. A constant pressure at the diaphragm valve allows a constant and adjustable flow rate to be maintained through the treatment unit. The second totalizer meter was added to function as a backup to the treated water totalizer meter and to allow calculation of the estimated volume of water used during a backwash cycle. The manufacturer also replaced the treatment unit control module with a control module calibrated at their lab to automatically initiate a filter backwash cycle at an interval of approximately 11,230 gallons of treated water.

The manufacturer installed new Actiguard AAFS50 media on February 11, 2003, prior to initiation of the Integrity and Capacity Verification Testing. The media installation was witnessed by Gannett Fleming. A platform scale and 5-gallon bucket were used to measure and install 39.76 pounds of media in each of the two treatment unit tanks. Following the media installation, the manufacturer certified that the media installation, including the total weight of media installed into each tank, met the manufacturer’s requirements. A copy of the signed certification is included in Appendix P. The 39.76 pounds of dry, uncompacted media per unit resulted in a “freeboard,” or depth to the wetted, compacted media, of approximately 18-1/4 inches from the top of the media to the top of the opening in each filter tank, as summarized in

Table 4-2. The optimum freeboard, based on the manufacturer’s specifications, is 17-1/2 inches. The freeboard was measured again following the Adsorption Capacity Test. At the end of the testing, the depth to the wetted, compacted media was approximately 18-1/2 inches in the main tank and 19-1/2 inches in the remote tank.

Table 4-2. Weight of Media Installed and Freeboard in Each Filter Tank

Tank	Media Weight (lb)	Freeboard (in.)
Primary	39.76	18.25
Remote	39.76	18.25

Based on the reported media density of 56.8 pounds per cubic foot, the 39.76 pounds of media installed per unit should have resulted in a bed volume of approximately 0.7 cubic feet per tank, for a total bed volume of 1.4 cubic feet. However, given a total tank height of 40 inches and a tank diameter of 8 inches, as reported by the manufacturer, the actual bed volume was estimated to be approximately 0.63 cubic feet per tank, or approximately 1.27 cubic feet total. The media volume was calculated without accounting for the tank wall thickness, the round bottom of the tank, or subtraction of the volume of the internal flow distribution apparatus, all of which could be significant. Therefore, the bed volume was more accurately measured following the test by sealing the internal flow distributor and carefully measuring the amount of water required to achieve the originally measured freeboard of 18-1/4 inches to the top of the tank. The media bed volume, as determined by liquid measure, was 0.60 cubic feet per tank for a total media bed volume of 1.20 cubic feet. Media bed volume calculations are included in Appendix D. The PSTP indicated, “Data will be generated that will represent the actual volume of water treated by the 1.4 cubic feet of Actiguard AAFS50 media...”. This difference in bed volume could make a significant difference in the apparent media capacity. Therefore, the more accurate total bed volume of 1.20 cubic feet was used for media capacity calculations, included later in this chapter.

Equipment startup was performed by the manufacturer and witnessed by Gannett Fleming. The protocol for startup is included in Alcan Chemicals’ Technical Bulletin for Actiguard AAFS50 in Appendix A. The manufacturer specified the initial 10 bed volumes of treated water should be used as media flushing water and, therefore, should be discounted prior to recording the totalizers’ startup readings. The treated water totalizer meter reading during media installation, prior to any flow through the newly installed media, was 471,665 gallons. Prior to initiation of the Integrity Verification and Adsorption Capacity Testing on April 22, 2003, the totalizer meter reading was 472,015 gallons, indicating 350 gallons had been used by the manufacturer during startup. The corresponding feed water totalizer reading was 342 gallons. The initial feed water totalizer reading at installation was 0.0 gallons. Based on an approximate media bed volume of 1.20 cubic feet, the actual volume of water wasted during startup was equal to approximately 39 bed volumes, which is 3.9 times the stated 10 bed volumes required to pre-wash the media. The manufacturer indicated the additional water was used to verify proper operation of the filter unit control module. Water used during startup was not included in the treated water volume used to assess the capacity of the media.

4.2.2 *Experimental Objectives*

As established in the PSTP, the experimental objectives for Integrity Verification testing were as follows:

- Evaluate equipment operational reliability under field conditions;
- Document feed water quality and arsenic concentration; and
- Collect operational and water quality data under field conditions.

4.2.3 *Integrity Test Operational Data*

Following initiation of testing, the arsenic adsorption media filter system operated intermittently in concert with the operation of Well No. 1. However, during the Integrity Verification Test, the treatment system was operated continuously for at least 2 hours daily and operated intermittently during the remaining 22 hours each day, as required in the ETV protocol. The 2 hours of continuous operation per day were initiated using the manual mode of operation for Well No. 1 at the WTP control panel and were witnessed by the Gannett Fleming field engineer. During the 2-hour continuous operation period, a ball valve on the Well No. 1 discharge pipe was throttled by the field engineer to provide the required minimum feed water pressure of 30 psi. Throttling was necessary when only Well No. 1 was operating, because the low flow rate from a single well resulted in little headloss through the WTP piping and treatment process. The backpressure measured at the treatment unit would have been less than 20 psi, which is less than the required minimum operating pressure for the Kinetico treatment unit, without throttling the well discharge ball valve. .

Monitoring and on-site data collection were performed, as scheduled, to verify the equipment performance. Table 4-3 summarizes the arsenic adsorption media filter unit operational data during the Integrity Verification Test. Copies of the original logbook data sheets and compiled Integrity Test operational data are included in Appendix F.

The treatment unit operated for an average of 14 hours per day during the Integrity Test. The combination of the pressure regulating valve and diaphragm valve maintained a relatively constant flow rate, as shown. However, flowmeter calibration at the end of the Integrity Verification Test indicated an actual flow rate of 2.0 gpm was produced when the rotameter (flow rate meter) indicated a flow rate of 1.9 gpm. Therefore, the average flow rate during the Integrity Test was higher than the target of 1.9 gpm, but was within the manufacturer's specified range of 1.8 to 2.0 gpm. Following the Integrity Test, the flow rate set-point was adjusted and verified to produce a rate of 1.9 gpm. The adjusted set-point was maintained during the Adsorption Capacity Test.

The feed water pressure averaged 56.4 psi during the Integrity Test, which was well within the manufacturer's specified operating pressure range of 30 psi to 125 psi. Headloss across the treatment unit was relatively low, with a pressure differential averaging 1.0 psi, and did not appear to vary significantly as a function of run time during the two-week test, as shown in Figure 4-1. This indicates that, despite the particulate manganese and turbidity observed in the

feed water as discussed in Section 4.2.4, headloss did not significantly accumulate between filter backwashes. Therefore, the production volume between backwashes could have been increased.

Table 4-3. Integrity Test Operational Data

	Flow Rate Before Adjustment (gpm)	Flow Rate After Adjustment (gpm)	Feed Pressure (psi)	Treated Pressure (psi)	Pressure Differential (psi)	Daily Run Time Average (hours/day)
Number of Samples	39	39	30	30	30	39
Mean	1.99	2.00	56.4	55.4	1.0	13.8
Minimum	1.90	1.90	53.0	51.5	0.5	12.6
Maximum	2.00	2.00	60.0	59.0	1.5	24.0 ⁽¹⁾
Standard Deviation	0.03	0.02	2.1	2.1	0.4	1.7
95% Confidence Interval	1.98 - 2.00	1.99 - 2.00	55.5 - 57.3	54.5 - 56.3	0.8 - 1.2	13.2 - 14.5

⁽¹⁾ During 2-hour continuous operation.

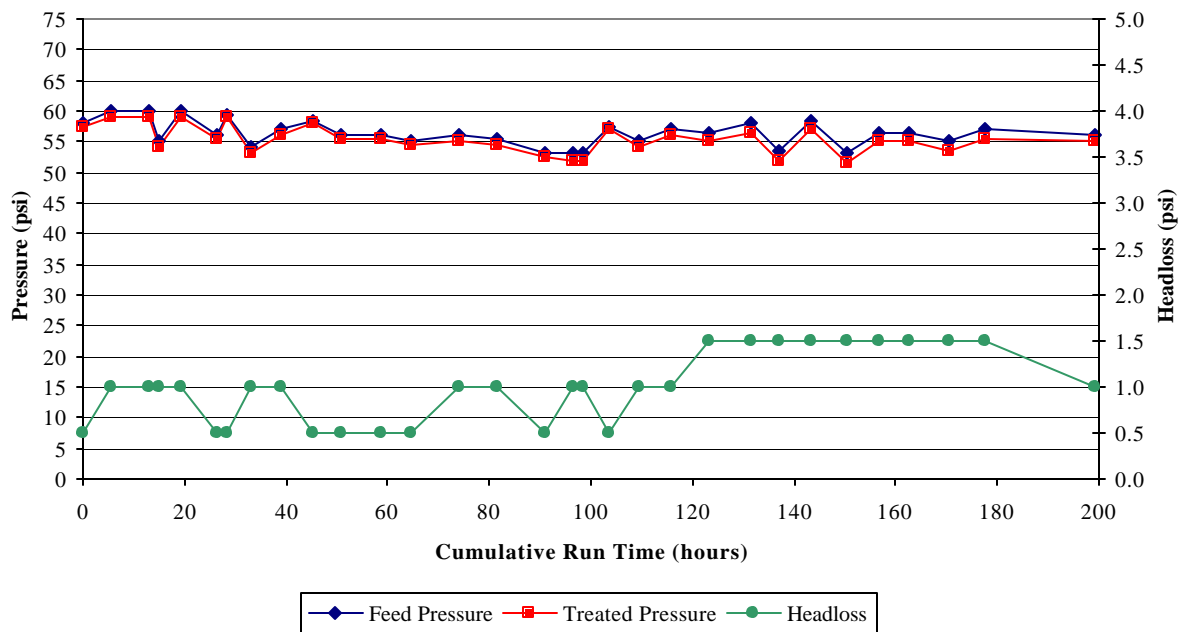


Figure 4-1. Integrity Test headloss and pressure as a function of cumulative run time.

4.2.4 Integrity Test On-Site Water Quality Analyses

The results of on-site water quality analyses are summarized in Table 4-4. Copies of the original logbook data sheets and compiled Integrity Test on-site water quality data are included in Appendix F.

Table 4-4. Integrity Test On-Site Water Quality Data

Parameter	Units	Number of Samples	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval
<i>Feed Water</i>							
pH	-	28	7.6	7.3	7.7	N/A	7.5 – 7.7
Temperature	°C	14	12.0	11.5	12.3	0.2	11.9 – 12.2
Turbidity	NTU	15	0.55	0.15	3.9	0.96	0 – 1.2
Alkalinity	mg/L	14	87	84	90	2.2	86 – 89
Calcium	mg/L	3	28.0	28.0	28.0	N/A	N/A
Magnesium	mg/L	3	7.6	7.3	8.3	N/A	N/A
Hardness	mg/L	3	101	100	104	N/A	N/A
Fluoride	mg/L	14	0.19	0.15	0.27	0.03	0.17 – 0.21
<i>Treated Water</i>							
pH	-	28	7.3	6.8	7.6	N/A	7.2 – 7.5
Temperature	°C	14	12.0	11.6	12.3	0.2	11.9 – 12.2
Turbidity	NTU	15	0.20	0.10	0.75	0.17	0.10 – 0.30
Alkalinity	mg/L	14	81	50	90	11	74 – 89
Calcium	mg/L	3	26.4	26.4	26.4	N/A	N/A
Magnesium	mg/L	3	8.3	8.3	8.3	N/A	N/A
Hardness	mg/L	3	100	100	100	N/A	N/A
Fluoride	mg/L	14	0.05	0.02	0.12	0.03	0.03 – 0.07

N/A = Not Applicable. Standard Deviation and 95% Confidence Intervals were not calculated for parameters with data sets of fewer than 8 values.

The pH was reduced within the treatment unit during the two-week Integrity Verification Test, as shown in Figure 4-2. This reduction in pH is a function of the ion exchange process and consumption of alkalinity, as shown in Figure 4-5.

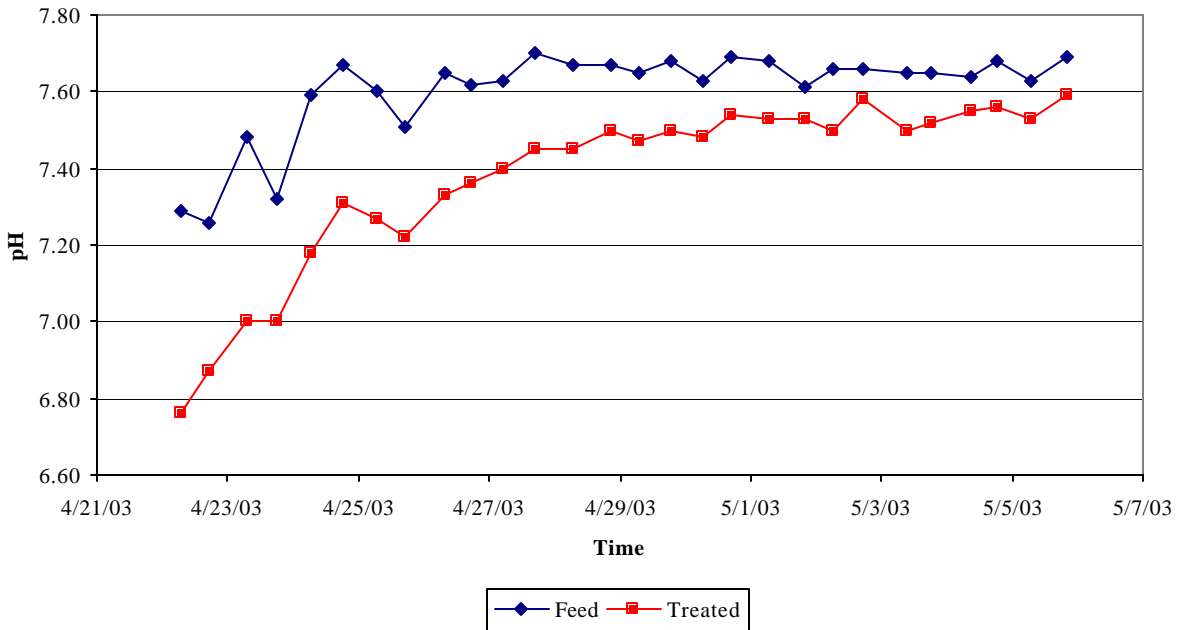


Figure 4-2. Integrity Test pH (4/22/03 to 5/5/03).

Due to a relatively short hydraulic detention time, the feed and treated water temperatures were nearly equal throughout the test. Feed water temperature varied less than 1°C during the two-week test period, as shown in Figure 4-3.

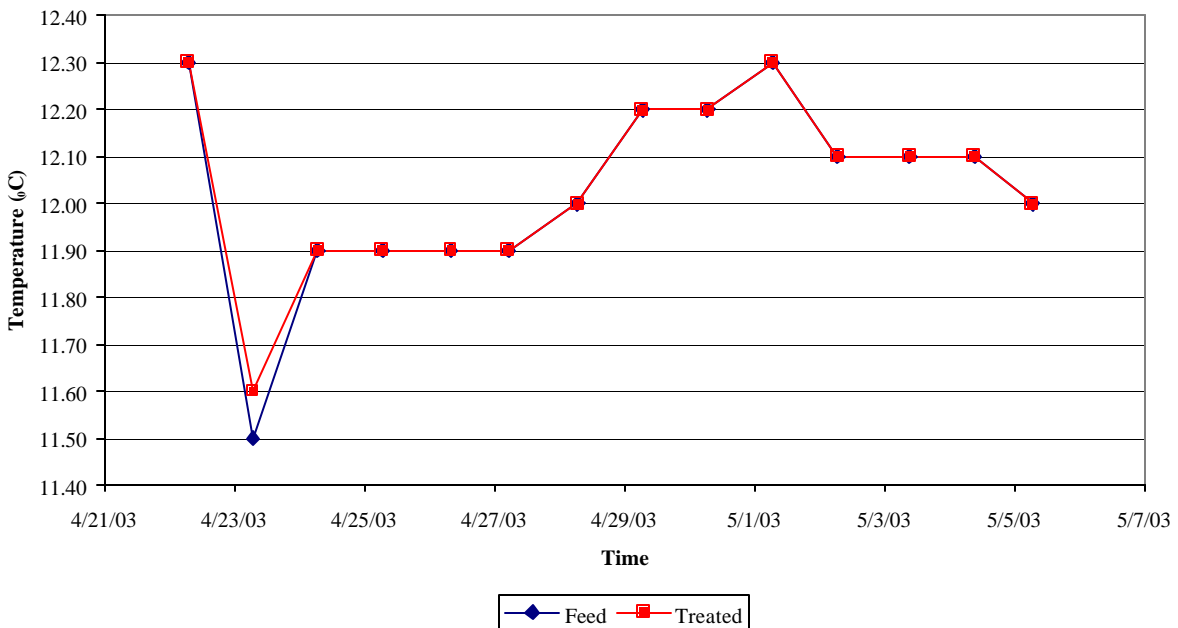


Figure 4-3. Integrity Test temperature (4/22/03 to 5/5/03).

Figure 4-4 shows the Integrity Test feed and treated water turbidity as a function of time. The feed water turbidity was generally low, averaging approximately 0.55 NTU, but was somewhat variable. The variability in feed water turbidity appeared to result from black particles, possibly oxidized manganese, which periodically appeared in the feed water. Treated water turbidity was consistently very low, with a 95% confidence interval of 0.10 to 0.30 NTU. The lower treated water turbidity likely was due to physical removal or filtering by the filter unit media.

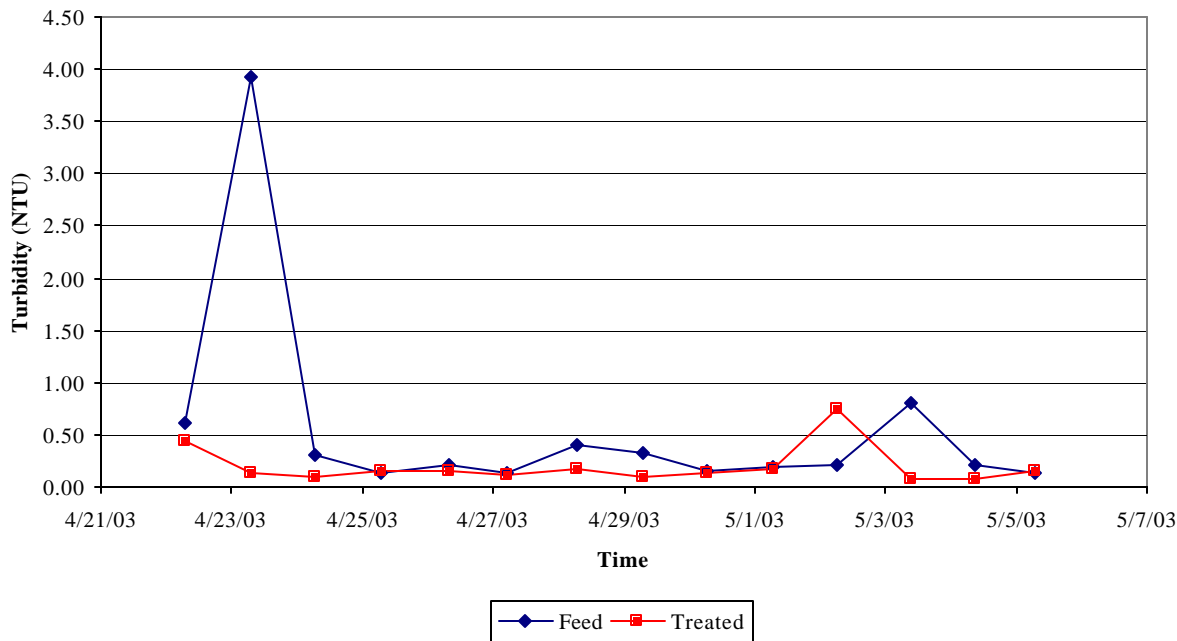


Figure 4-4. Integrity Test turbidity (4/22/03 to 5/5/03).

As shown in Figure 4-5, the media consumed approximately 38 mg/L as CaCO₃ of alkalinity during the initial day of the test. Alkalinity consumption gradually decreased to nearly zero by the end of the first week of operation.

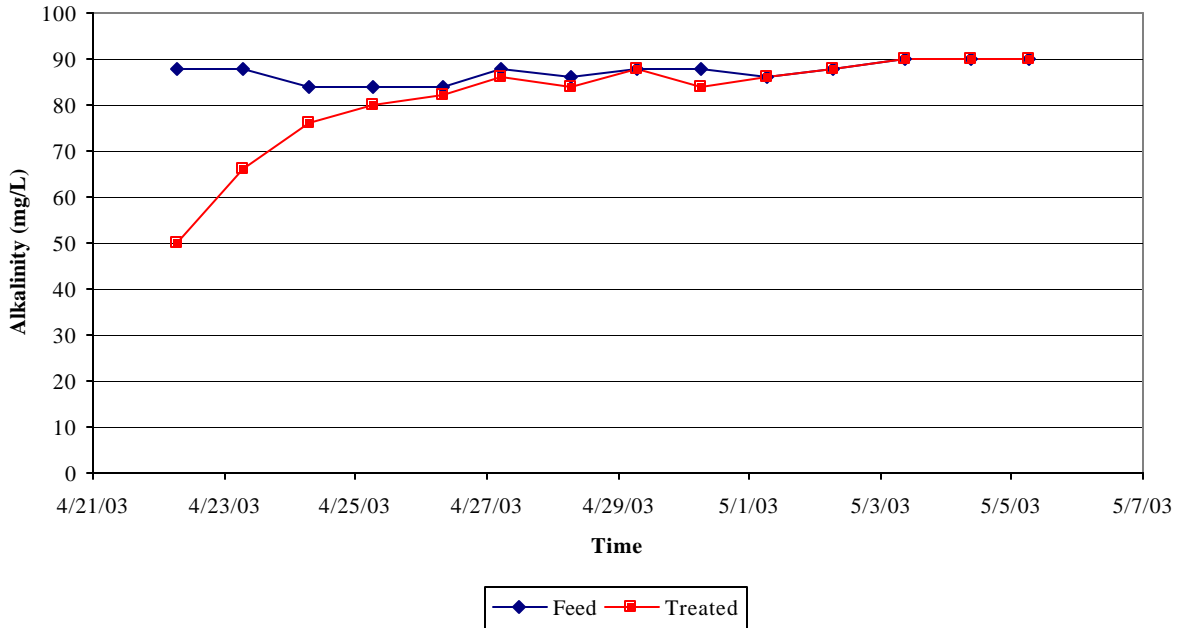


Figure 4-5. Integrity Test alkalinity concentration (4/22/03 to 5/5/03).

Initially, fluoride was nearly entirely removed through the treatment process, as shown in Figure 4-6. However, treated water fluoride levels gradually increased during the Integrity Test period. The manufacturer has indicated that fluoride competes with HAsO_4^- for adsorption. However, the media has a lower affinity for fluoride than for arsenic. Therefore, fluoride breakthrough should be observed prior to arsenic breakthrough as the total adsorption site area is reduced, resulting in arsenic out-competing fluoride for the remaining sites. Integrity Test results indicate fluoride removal efficiency was decreasing as the Integrity Test ended.

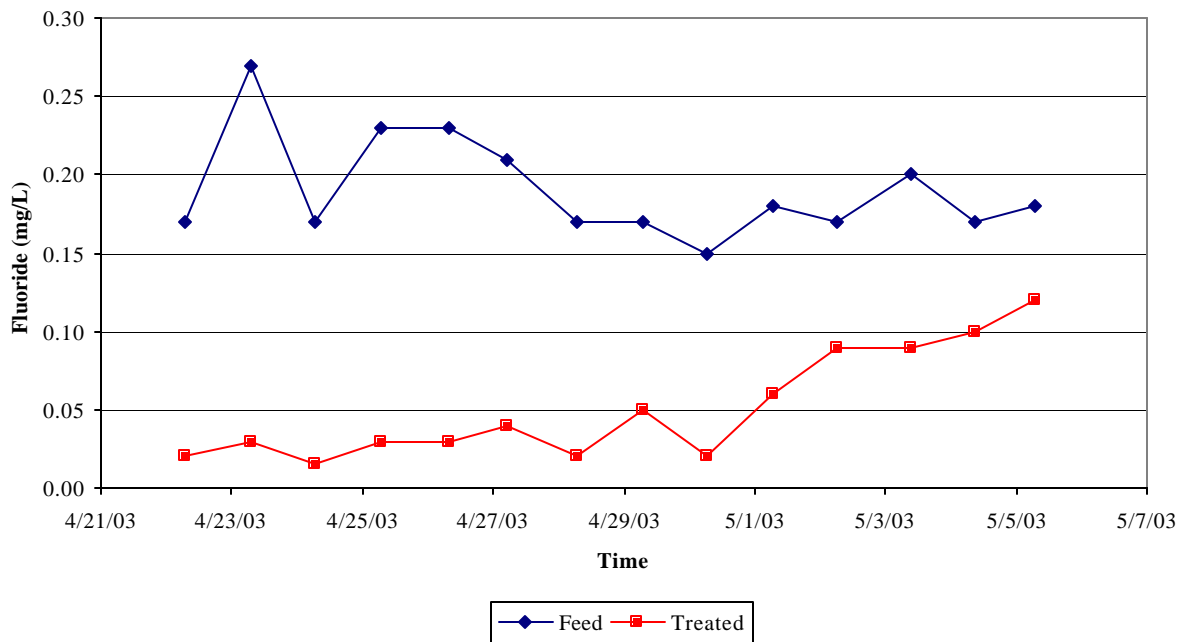


Figure 4-6. Integrity Test fluoride concentration (4/22/03 to 5/5/03).

Water quality analyses results indicate calcium, magnesium, and total hardness concentrations in the feed water were apparently unaffected by the treatment process. However, Integrity Testing included only three tests for these parameters. The Capacity Test provided additional data. Therefore, detailed analyses for hardness, calcium, and magnesium are included only in the Capacity Test results (Section 4.3).

4.2.5 Integrity Test Laboratory Water Quality Analyses

The results of Integrity Test water quality analyses performed at the PADEP Laboratory are summarized in Table 4-5. Compiled data, copies of the analytical test reports, and sample submission forms are included in Appendix G. The raw data are on file at NSF.

Table 4-5. Integrity Test Laboratory Water Quality Data

Parameter	Units	Number of Samples	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval
<i>Feed Water</i>							
Silica	mg/L	14	18.9	17.9	19.7	0.50	18.6 – 19.3
Aluminum	µg/L	14	210	<200	339	37.1	<200 – 235
Iron	µg/L	2	23	<20	26	N/A	N/A
Manganese	µg/L	2	306	79	532	N/A	N/A
Chloride	mg/L	2	18.9	18.8	19.0	N/A	N/A
Sulfate	mg/L	2	10.3	10.3	10.3	N/A	N/A
Total Phosphorus	mg/L	2	0.027	0.024	0.030	N/A	N/A
<i>Treated Water</i>							
Silica	mg/L	14	10.1	3.00	14.3	3.42	7.82 – 12.4
Aluminum	µg/L	14	<200	<200	<200	0	<200 -<200
Iron	µg/L	2	<20	<20	<20	N/A	N/A
Manganese	µg/L	2	42	15	69	N/A	N/A
Chloride	mg/L	2	18.9	18.5	19.2	N/A	N/A
Sulfate	mg/L	2	20.3	11.3	29.2	N/A	N/A
Total Phosphorus	mg/L	2	<0.010	<0.010	<0.010	N/A	N/A

N/A = Not Applicable. Standard Deviation and 95% Confidence Intervals were not calculated for parameters with fewer than 8 values.

Note: The laboratory minimum reporting limit was used for statistical calculations for sample results less than the laboratory minimum reporting limit.

The analyses indicate silica was initially removed from the feed water by the treatment process. However, silica concentrations in the treated water increased, as shown in Figure 4-7, during the two-week Integrity Test. Like fluoride, as discussed previously, silica competes with arsenic for adsorption sites on the media. However, the media has a lower affinity for silica than for arsenic. Therefore, the increasing treated water silica concentration indicates that, as the total adsorption site area decreases, the arsenic ions out-compete silica ions for the remaining sites. The ionic preference series for Actiguard AAFS50 media is included in Table 2-3.

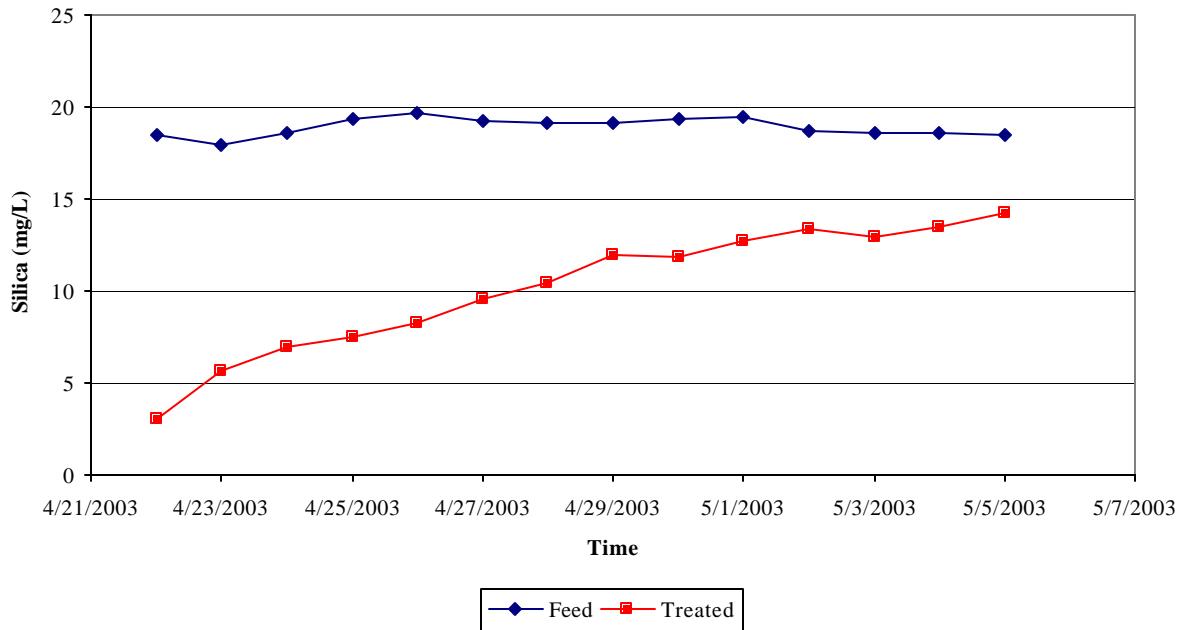


Figure 4-7. Integrity Test silica concentration (4/22/03 to 5/5/03).

Aluminum concentrations were apparently unaffected by the treatment process. Only one feed water sample result was greater than the MDL of 200 $\mu\text{g/L}$ and no aluminum was detected in the treated water. These data indicate the media was not releasing aluminum to the treated water above detectable levels. The feed and treated water aluminum concentrations are shown in Figure 4-8.

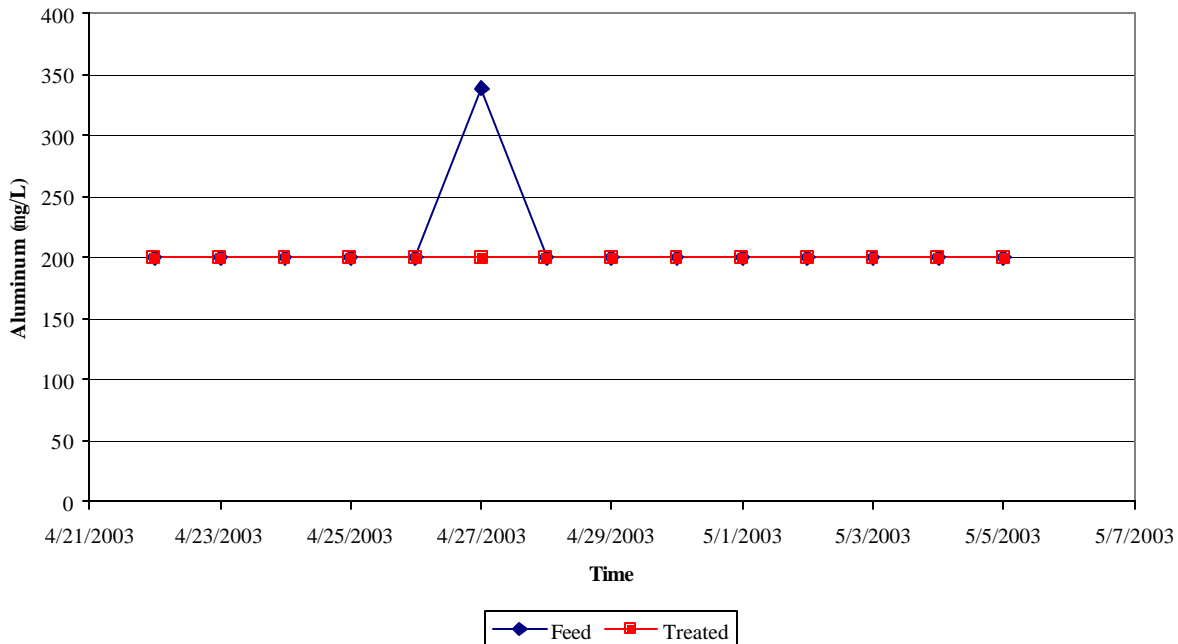


Figure 4-8. Integrity Test aluminum concentration (4/22/03 to 5/5/03).

Only two samples were collected for laboratory analyses for iron, manganese, chloride, sulfate, and phosphorus during the Integrity Test. Therefore, the description of results for these parameters is included in the Capacity Test analyses (Section 4.3).

4.2.6 Integrity Test Arsenic Analyses

Feed water and treated water arsenic samples were collected daily during the Integrity Verification Test. Three of the sample sets were speciated to determine the distribution of the total soluble arsenic between the arsenic III and the arsenic V species. The fraction of arsenic III in the feed water affects the treatability of the water, because arsenic III is non-ionic at normal drinking water pH ranges and is therefore generally more difficult to remove by ion exchange treatment processes. The results of the laboratory arsenic analyses performed at the NSF Laboratory are summarized in Table 4-6. During the Integrity Test, the feed water total arsenic concentration averaged 15 $\mu\text{g/L}$, with approximately 5 $\mu\text{g/L}$ as the arsenic III species and 10 $\mu\text{g/L}$ as the arsenic V species. Treated water arsenic concentrations were all less than or equal to the 2 $\mu\text{g/L}$ method detection limit during the Integrity Test. Approximately 2,337 bed volumes were treated during approximately 178 hours of equipment run time. Feed and treated arsenic concentrations, as a function of treated water bed volumes, are shown in Figure 4-9. Complete arsenic analyses results including a summary table, analytical test reports, sample submission forms, and raw data are included in Appendix Q.

Table 4-6. Integrity Test Laboratory Arsenic Data

	<i>Feed Water</i>				<i>Treated Water</i>			
	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V (µg/L)	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V (µg/L)
Number of Samples	14	3	3	3	14	3	3	3
Mean	15	15	5	10	<2	<2	<2	<2
Minimum	14	14	4	8	<2	<2	<2	<2
Maximum	17	17	6	12	2	<2	<2	<2
Standard Deviation	0.83	N/A	N/A	N/A	0	N/A	N/A	N/A
95% Confidence Interval	15 - 16	N/A	N/A	N/A	<2 - <2	N/A	N/A	N/A

N/A = Not Applicable. Standard Deviation and 95% Confidence Intervals were not calculated for parameters with fewer than 8 values.

Note: The laboratory minimum reporting limit was used for statistical calculations for sample results less than the laboratory minimum reporting limit.

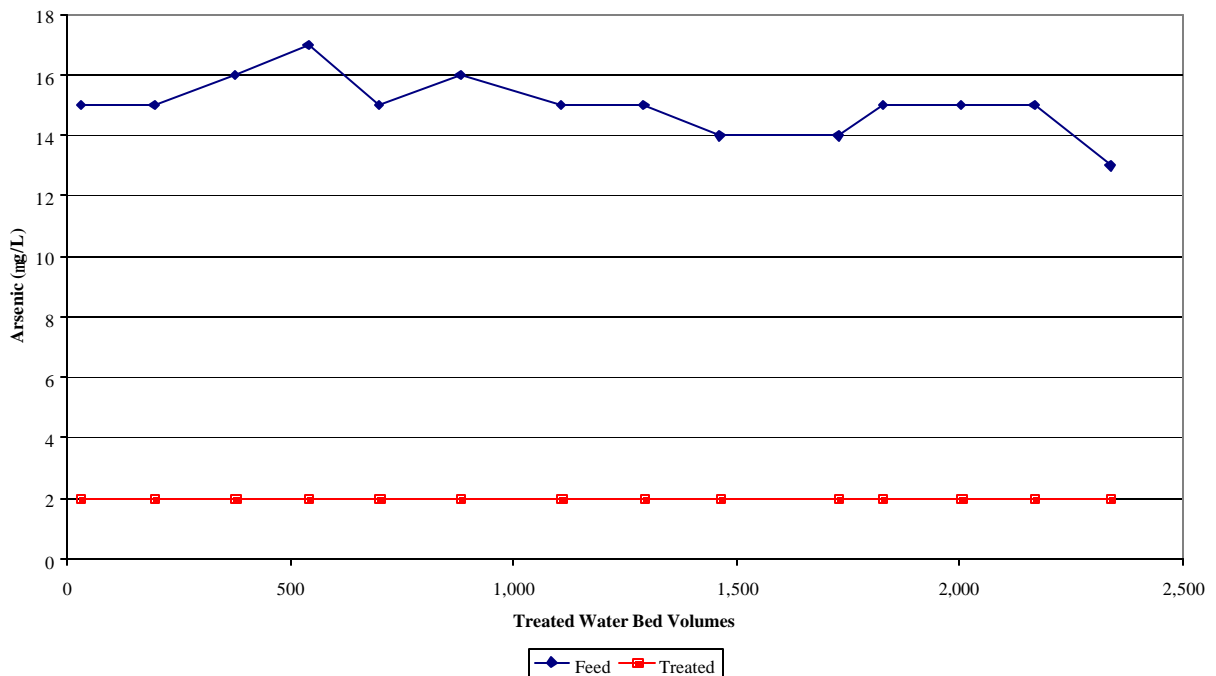


Figure 4-9. Integrity Test arsenic concentration (4/22/03 to 5/5/03).

Field arsenic analyses were also performed using the ITS QUICK Low Range II test kit to monitor the feed and treated water arsenic concentrations onsite. On-site arsenic data is included in the logbook copies in Appendix F.

4.3 Task 2: Adsorption Capacity Verification Testing

Adsorption Capacity Testing began on April 22, 2003, coinciding with the initiation of Integrity Verification Testing. Water quality sampling and analysis, system monitoring, and data collection were performed as scheduled in the test plan and as described in Chapter 3. The treated water arsenic concentration reached the pre-defined breakthrough concentration of 11 $\mu\text{g/L}$ on October 3, 2003. The treatment system was shutdown on October 28, 2003, following receipt of laboratory arsenic analyses results indicating more than three consecutive treated water arsenic samples with an arsenic concentration greater than or equal to 11 $\mu\text{g/L}$. The treated water arsenic concentration reached 11 $\mu\text{g/L}$ following approximately 2,350 hours of equipment operation and treatment of approximately 28,800 to 29,200 bed volumes of water, based on the calculated media bed volume of 1.20 cubic feet. Spent media samples were collected by Gannett Fleming, and the treatment unit was disassembled and removed by Kinetico Inc., on November 4, 2003. The results of the Adsorption Capacity Testing are detailed in the following sections. Adsorption Capacity Test data include data collected during the Integrity Test.

4.3.1 *Experimental Objectives*

The experimental objective of the Adsorption Capacity Testing is to provide operating and water quality data relative to the ability of the arsenic adsorption media filter system to remove arsenic from feed water under field conditions.

4.3.2 *Capacity Test Operational Data*

The treatment unit operated intermittently in concert with the operation of Well No. 1 during the Capacity Test. Well No. 1 was operated in manual mode only to provide continuous flow for the filter backwashes, which were observed and sampled by Gannett Fleming. Monitoring and on-site data collection were performed as scheduled to verify the equipment performance. Table 4-7 summarizes the arsenic adsorption media filter unit operational data during the Capacity Test. Copies of the original logbook data sheets and compiled operational data are included in Appendix F. The non-integral flow control system, consisting of a pressure regulating valve and diaphragm valve, maintained a relatively constant flow rate averaging 1.9 gpm.

Table 4-7. Capacity Test Operational Data

	Before Flow Rate Adjustment (gpm)	After Flow Rate Adjustment (gpm)	Feed Pressure (psi)	Treated Pressure (psi)	Pressure Differential (psi)	Daily Run Time Average (hours/day)
Number of Samples	384	385	375	375	375	384
Mean	1.90	1.91	51.2	50.1	1.1	14.2
Minimum	0.00	1.80	27.0	24.0	0.5	12.6
Maximum	2.00	2.00	60.0	59.0	3.0	24.0 ⁽¹⁾
Standard Deviation	0.11	0.04	5.1	5.2	0.3	0.6
95% Confidence Interval	1.89 - 1.91	1.90 - 1.91	50.6 - 51.8	49.5 - 50.7	1.0 - 1.1	14.1 - 14.3

⁽¹⁾ During 2-hour continuous operation.

The equipment operated approximately 14 hours per day, on average. The feed water pressure was maintained within the manufacturer’s recommended pressure limits of 30 to 125 psi, with the exception of one day during which the recorded feed water pressure was only 27 psi. The filter bed headloss did not accumulate significantly as a function of run time, as shown in Figure 4-10. Headloss across the treatment unit averaged 1.1 psi, only slightly greater than the 1.0 psi average headloss observed during the two-week Integrity Test. However, the headloss became more variable and reached the maximum pressure differential observed during the test as the media capacity for arsenic removal reached exhaustion. The clean-bed headloss, observed at the initiation of testing, was approximately 0.5 psi.

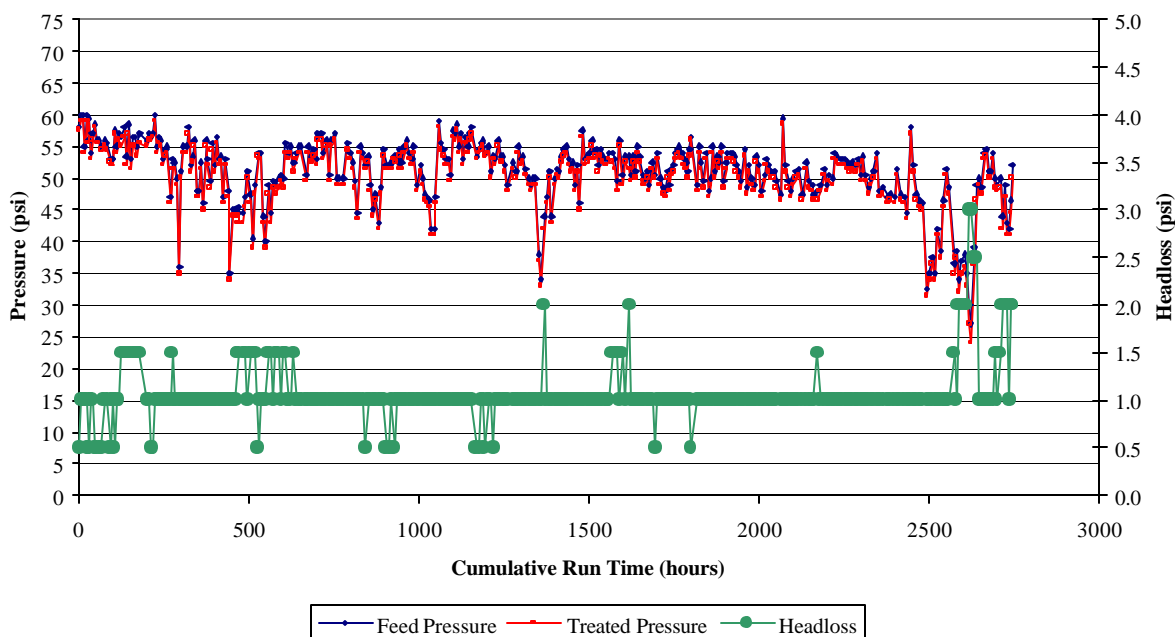


Figure 4-10. Capacity Test headloss and pressure as a function of cumulative run time.

4.3.3 Capacity Test On-Site Water Quality Analyses

The results of on-site water quality analyses are summarized in Table 4-8. Copies of the original logbook data sheets and compiled Integrity Test on-site water quality data are included in Appendix F.

Table 4-8. Capacity Test On-Site Water Quality Data

Parameter	Units	Number of Samples	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval
<i>Feed Water</i>							
pH	-	198	7.6	7.3	7.8	N/A	7.6 – 7.6
Temperature	°C	184	13.8	11.5	15.5	0.94	13.6 – 13.9
Turbidity	NTU	184	0.25	0.10	3.9	0.30	0.20 – 0.30
Alkalinity	mg/L	84	89	84	92	1.5	89 - 89
Calcium	mg/L	27	26.0	24.8	28.0	0.92	25.6 – 26.4
Magnesium	mg/L	27	8.3	7.3	8.7	0.50	8.1 – 8.5
Hardness	mg/L	27	99	96	104	1.7	98 - 100
Fluoride	mg/L	39	0.17	0.13	0.27	0.03	0.16 – 0.18
<i>Treated Water</i>							
pH	-	198	7.5	6.8	7.8	N/A	7.5 – 7.6
Temperature	°C	184	13.8	11.6	15.7	0.94	13.6 – 13.9
Turbidity	NTU	184	0.15	0.05	0.75	0.10	0.10 – 0.15
Alkalinity	mg/L	84	88	50	92	5.4	87 – 89
Calcium	mg/L	27	25.8	24.0	26.4	0.58	25.6 – 26.1
Magnesium	mg/L	27	8.4	7.3	9.2	0.41	8.2 – 8.6
Hardness	mg/L	27	99	96	100	1.3	99 – 100
Fluoride	mg/L	39	0.12	0.02	0.17	0.05	0.10 – 0.14

As discussed in the Integrity Test results (Section 4.2.4), the treatment process significantly reduced the pH from the feed water compared to the treated water, at the beginning of the test. The pH reduction is likely a function of the removal of alkalinity. Following the initial period of approximately two weeks of significant pH reduction, the feed and treated water pH were essentially equal for the remainder of the Capacity Test, as shown in Figure 4-11. On average, the treated water pH was nearly equal to the feed water pH.

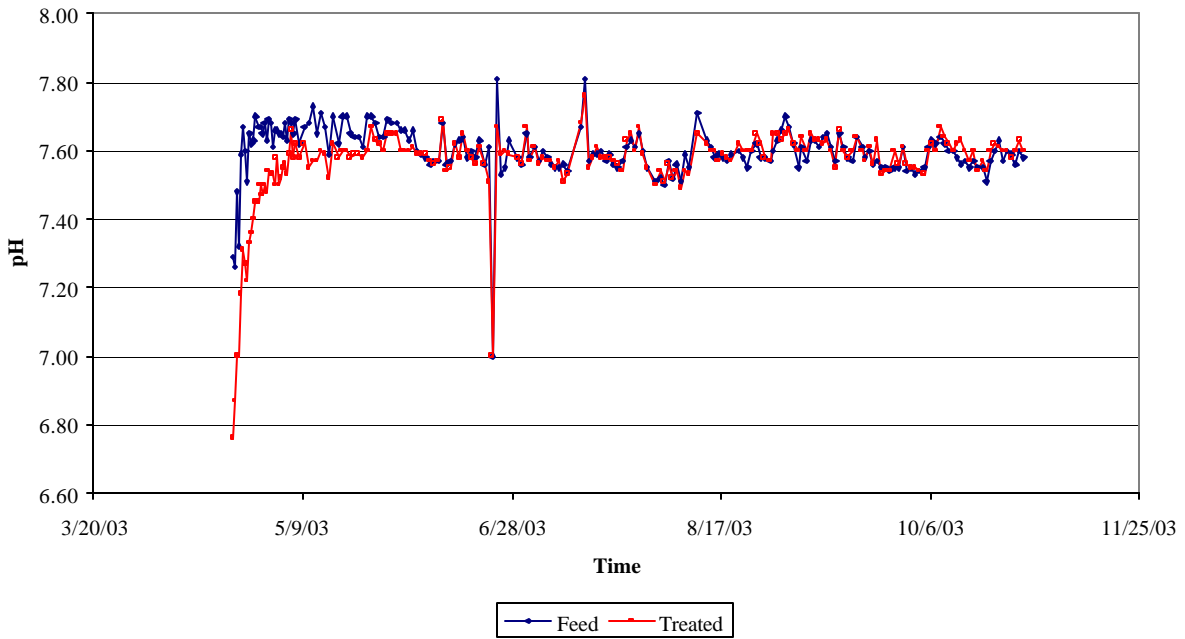


Figure 4-11. Capacity Test pH.

Due to the relatively short hydraulic detention time, the feed and treated water temperatures were nearly equal throughout the test, as shown in Figure 4-12. Due to seasonal temperature changes, the water temperature varied by approximately 4°C during the test.

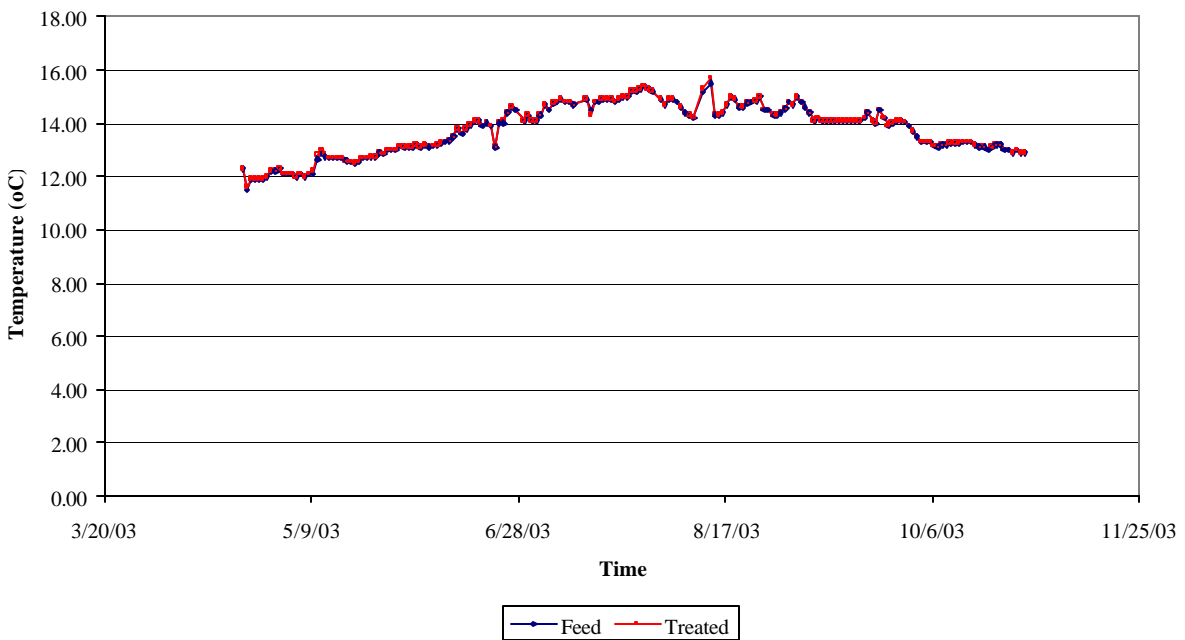


Figure 4-12. Capacity Test temperature.

With the exception of several brief feed water turbidity spikes, the feed water turbidity was generally low, averaging less than 0.25 NTU. Black particles, believed to be oxidized manganese particles, were often observed in the feed water during the turbidity spikes. The treated water turbidity was also consistently low, averaging 0.15 NTU. The lower treated water turbidity was likely due to filtering by the treatment unit. The feed water turbidity and treated water turbidity observed during the Capacity Test are shown in Figure 4-13.

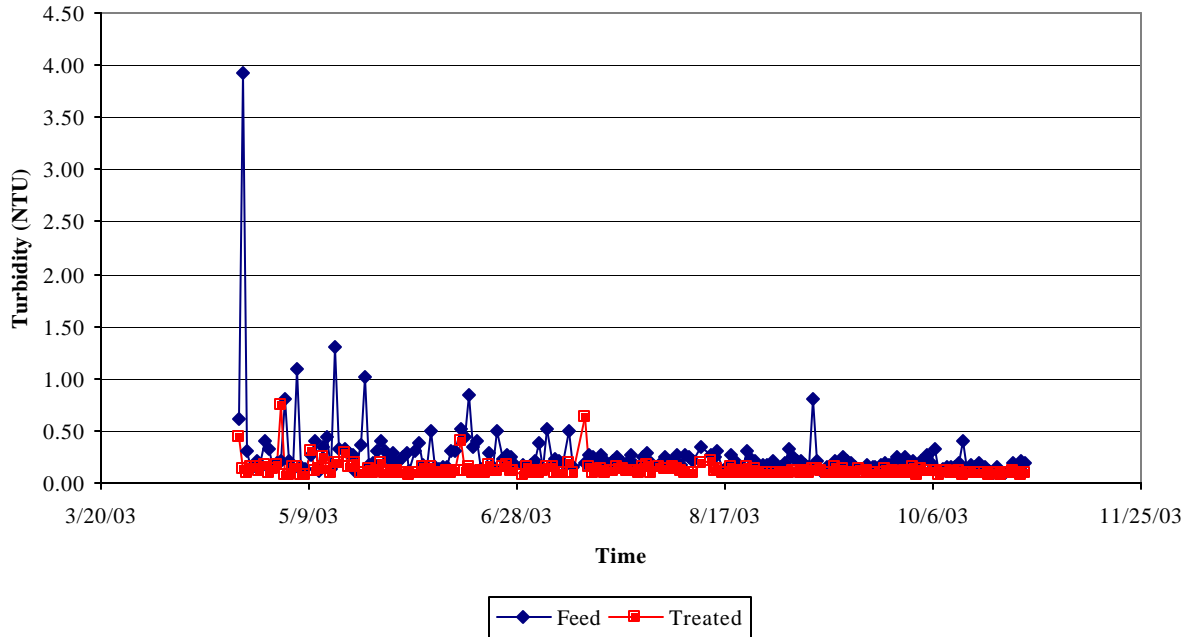


Figure 4-13. Capacity Test turbidity.

As discussed in the Integrity Test results, the treatment process consumed alkalinity during the first week of operation. Following the first week of operation, the feed and treated water alkalinity was essentially equal, as shown in Figure 4-14.

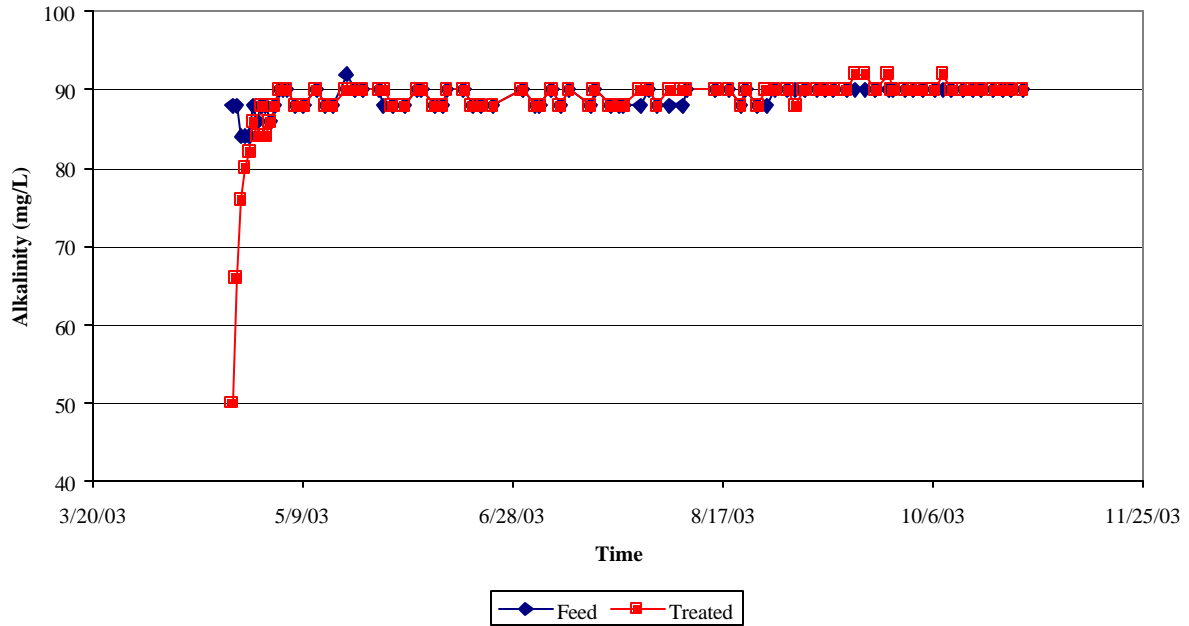


Figure 4-14. Capacity Test alkalinity concentration.

Initially, fluoride was almost entirely removed through the treatment process. However, as shown in Figure 4-15, treated water fluoride levels gradually increased during the Integrity Test period. The manufacturer has indicated fluoride competes with HAsO_4^- for adsorption. However, the media has a lower affinity for fluoride than for arsenic. Therefore, fluoride breakthrough should be observed prior to arsenic breakthrough, as arsenic ions out-compete fluoride ions for the remaining sites. Capacity Test results indicate that complete fluoride breakthrough occurred by the end of the third week of testing, following treatment of approximately 3,600 bed volumes.

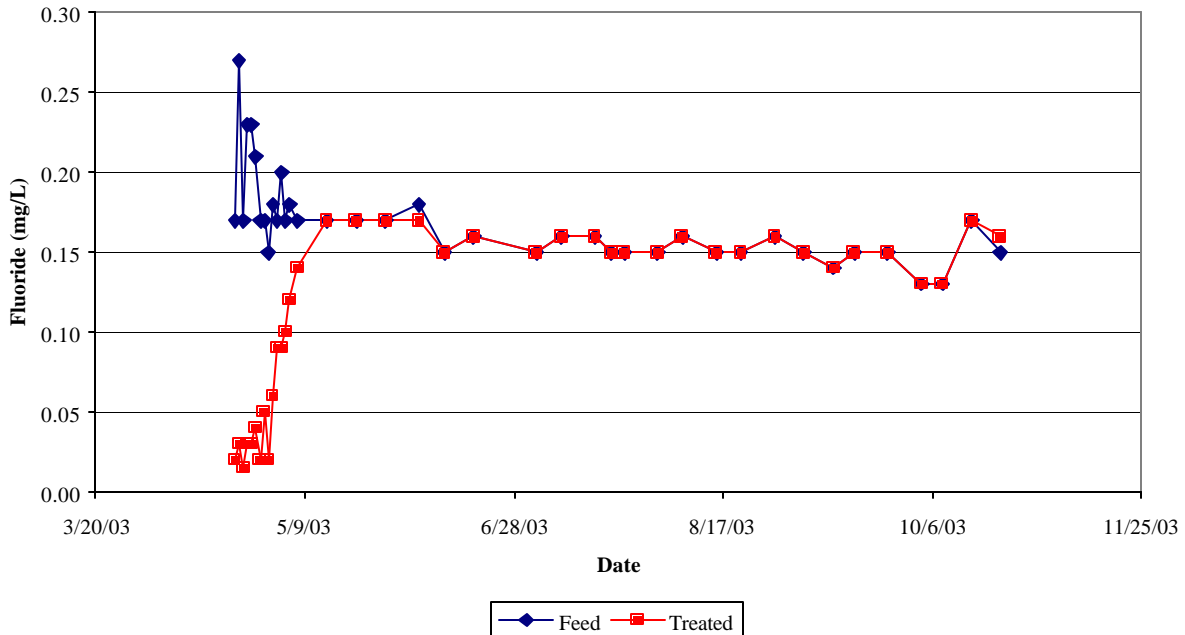


Figure 4-15. Capacity Test fluoride concentration.

Capacity test water quality analyses indicate calcium, magnesium, and total hardness concentrations in the feed water were relatively consistent during the test period and were apparently unaffected by the treatment process, as shown in Figure 4-16.

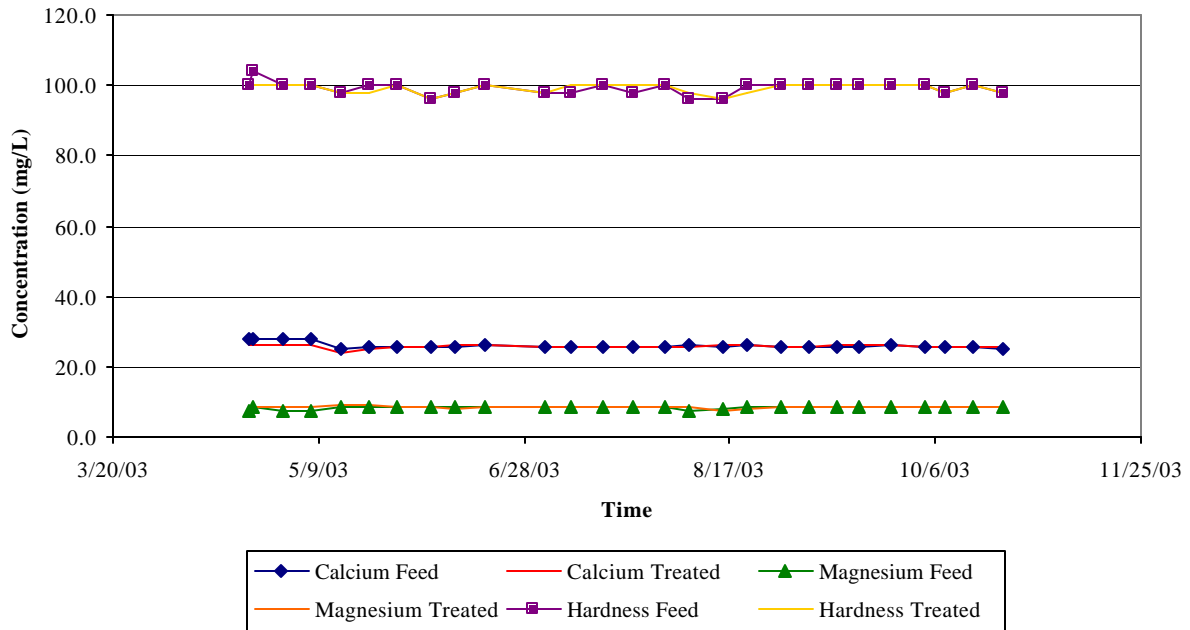


Figure 4-16. Capacity Test calcium, magnesium, and total hardness.

4.3.4 Capacity Test Laboratory Water Quality Analyses

The results of water quality analyses performed at the PADEP Laboratory are summarized in Table 4-9. Laboratory water quality data are summarized and the analytical test reports and sample submission forms are included in Appendix G. The raw data are on file at NSF.

Table 4-9. Capacity Test Laboratory Water Quality Data

Parameter	Units	Number of Samples	Mean	Minimum	Maximum	Standard Deviation	95% Confidence Interval
<i>Feed Water</i>							
Silica	mg/L	40	19.0	17.4	21.1	0.80	18.7 – 19.3
Aluminum	µg/L	40	203	<200	339	22.0	<200 – 212
Iron	µg/L	28	34	<20	116	24	23 – 45
Manganese	µg/L	28	144	36	1481	286	16 – 272
Chloride	mg/L	28	18.7	16.8	20.4	0.85	18.3 – 19.1
Sulfate	mg/L	28	10.5	10.1	11.2	0.26	10.4 – 10.6
Total Phosphorus	mg/L	28	0.032	0.024	0.043	0.005	0.029 – 0.034
<i>Treated Water</i>							
Silica	mg/L	40	15.3	3.00	20.4	4.46	13.7 – 17.0
Aluminum	µg/L	40	<200	<200	<200	0	<200 - <200
Iron ⁽¹⁾	µg/L	27	21	<20	32	4	<20 – 23
Manganese	µg/L	28	12	<10	69	11	<10 – 17
Chloride	mg/L	28	18.8	17.0	20.2	0.82	18.4 – 19.2
Sulfate	mg/L	28	11.3	10.3	29.2	3.5	9.7 – 12.9
Total Phosphorus	mg/L	28	0.014	<0.010	0.023	0.004	0.012 – 0.016

⁽¹⁾ The treated water iron concentration of 666 µg/L on 7/3/03, as reported by the laboratory, was believed to be in error and was not included in the statistical analyses.

The analyses indicate silica was initially removed from the feed water by the treatment process. However, as shown in Figure 4-17, silica concentrations in the treated water increased during the capacity test, until a complete breakthrough was achieved and the feed and treated water silica concentrations were equal. Like fluoride, as discussed above, silica competes with arsenic for adsorption on the media. The media has a lower affinity for silica than for arsenic. Therefore, the increasing treated water silica concentration indicates the total adsorption site area has decreased to the point where arsenic ions out-compete silica ions for the remaining media sites. The ionic preference series for Actiguard AAFS50 media is included in Table 2-3.

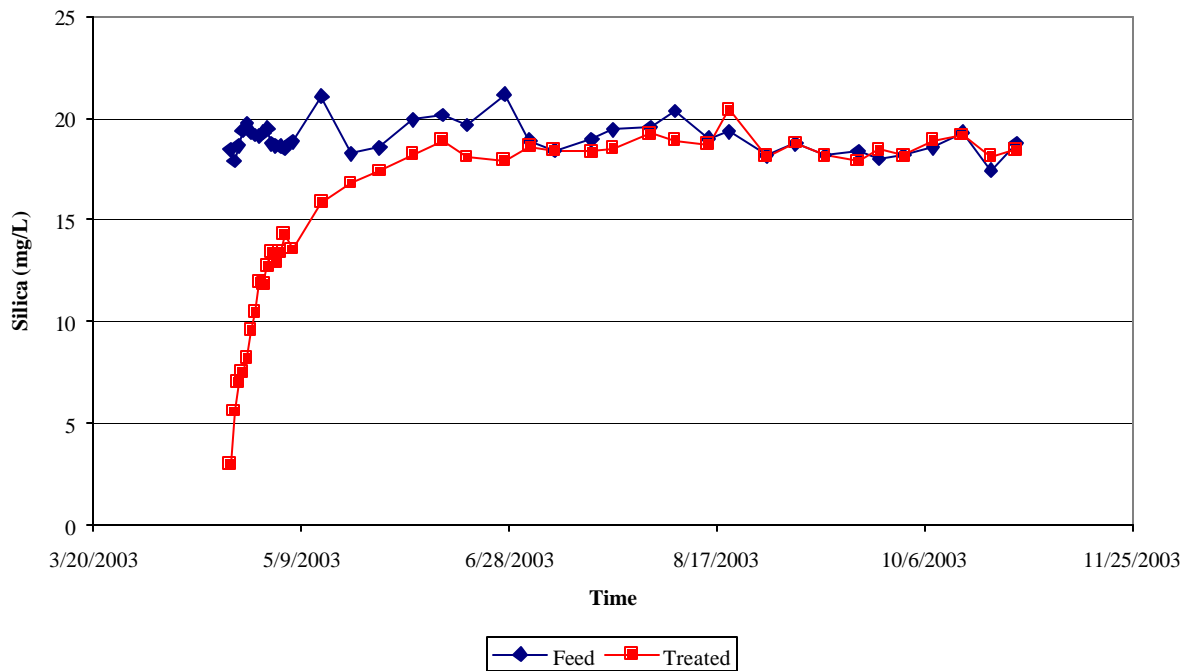


Figure 4-17. Capacity Test silica concentration.

Aluminum concentrations were apparently unaffected by the treatment process. Only one feed water sample result was greater than the MDL of 200 $\mu\text{g/L}$ and no aluminum was detected in the treated water. These data indicate that the media was not releasing aluminum to the treated water above detectable levels. The feed and treated water aluminum concentrations are shown in Figure 4-18.

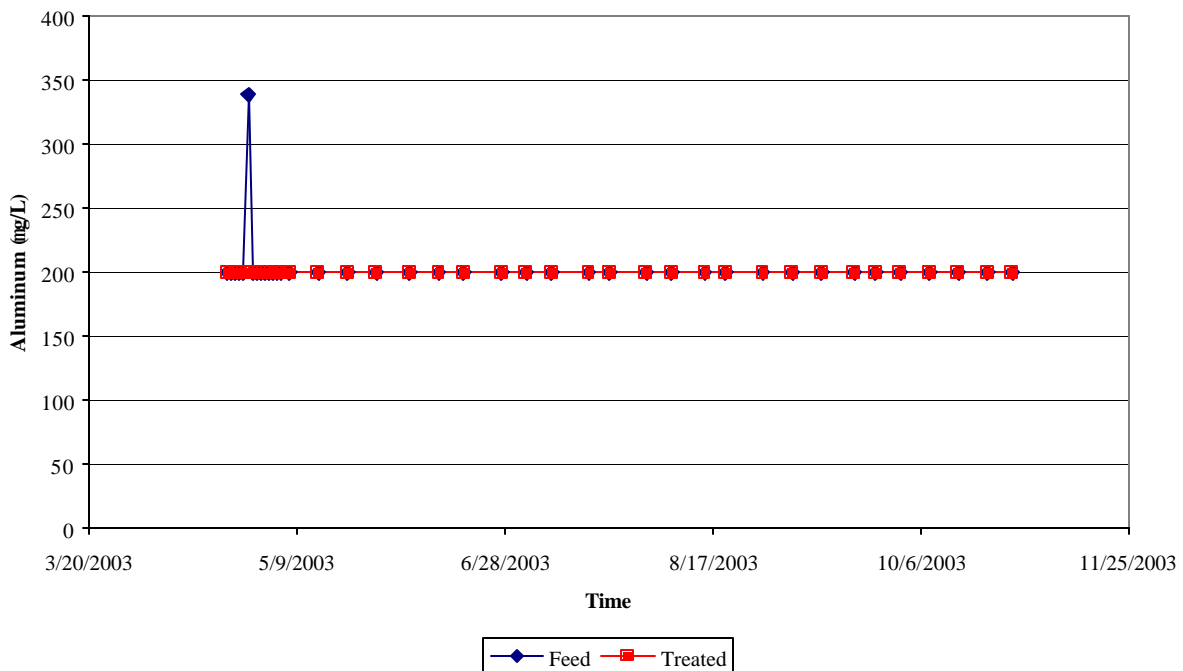


Figure 4-18. Capacity Test aluminum concentration.

Treated water iron levels were reduced in the treatment process to at or near the MDL of 20 $\mu\text{g/L}$, as shown in Figure 4-19.

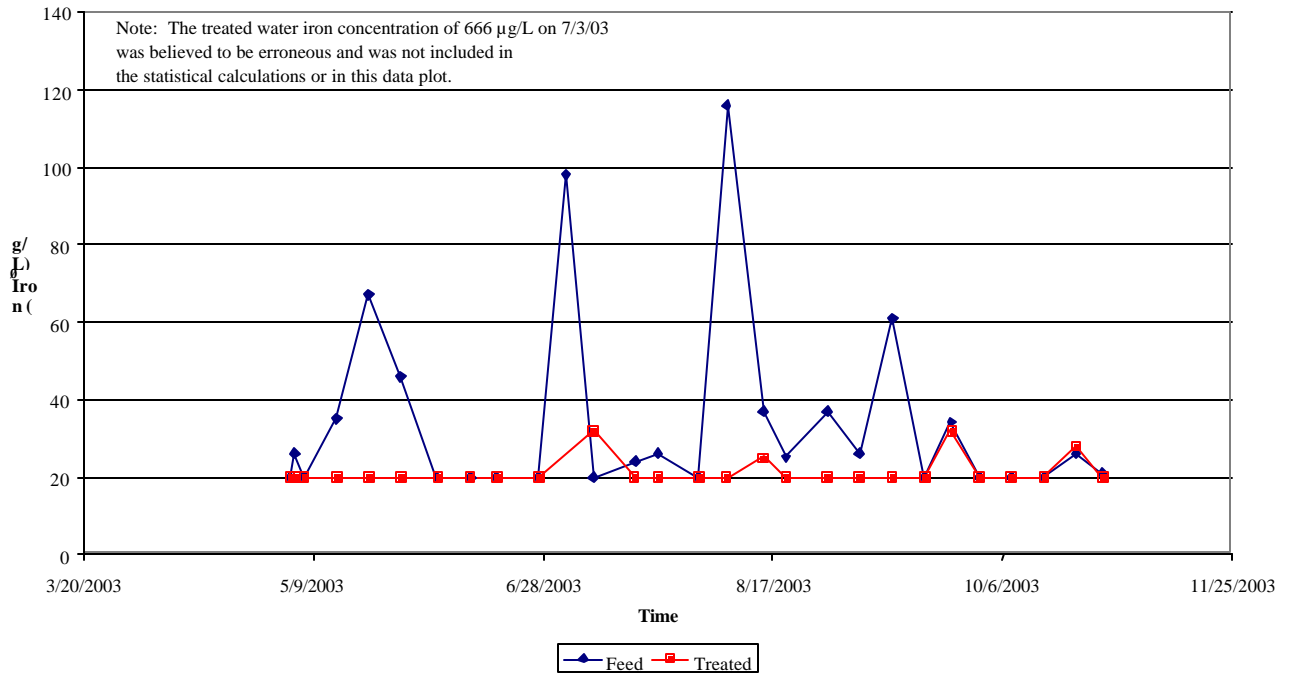


Figure 4-19. Capacity Test iron concentration.

The feed water manganese concentration averaged 144 $\mu\text{g/L}$ during the Capacity Test. Feed water manganese concentrations were somewhat variable, with concentrations spiking during periods when particles of oxidized manganese were observed in the feed water. As shown in Figure 4-20, manganese in the feed water was removed in the treatment process to a concentration at or below the MDL of 10 $\mu\text{g/L}$ for most of the weekly water quality samples. A portion of the manganese may have been removed as a result of physical removal (i.e., filtration) of particulate manganese. During the filter backwashes observed by Gannett Fleming, the backwash water was black in color and had manganese concentrations of 5,620 to 17,500 $\mu\text{g/L}$. These high levels of manganese in the backwash water indicate some manganese was physically filtered from the water and was easily removed during backwash, rather than adsorbed onto the filter media.

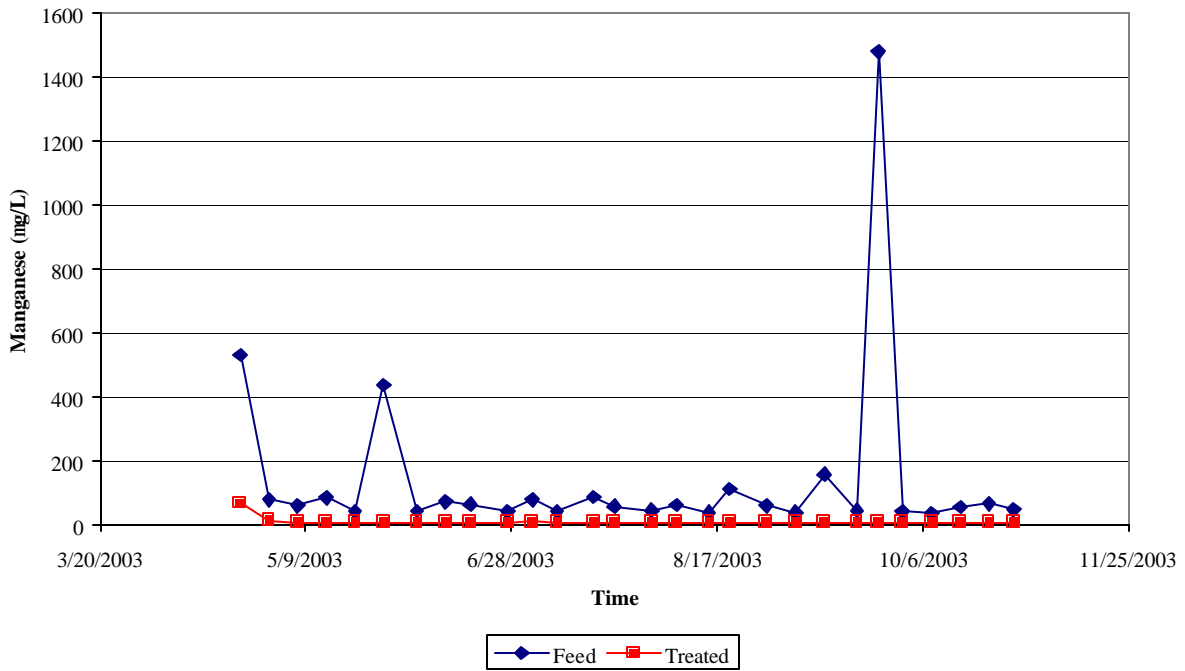


Figure 4-20. Capacity Test manganese concentration.

Chloride concentrations were apparently unaffected by the treatment process, as shown in Figure 4-21.

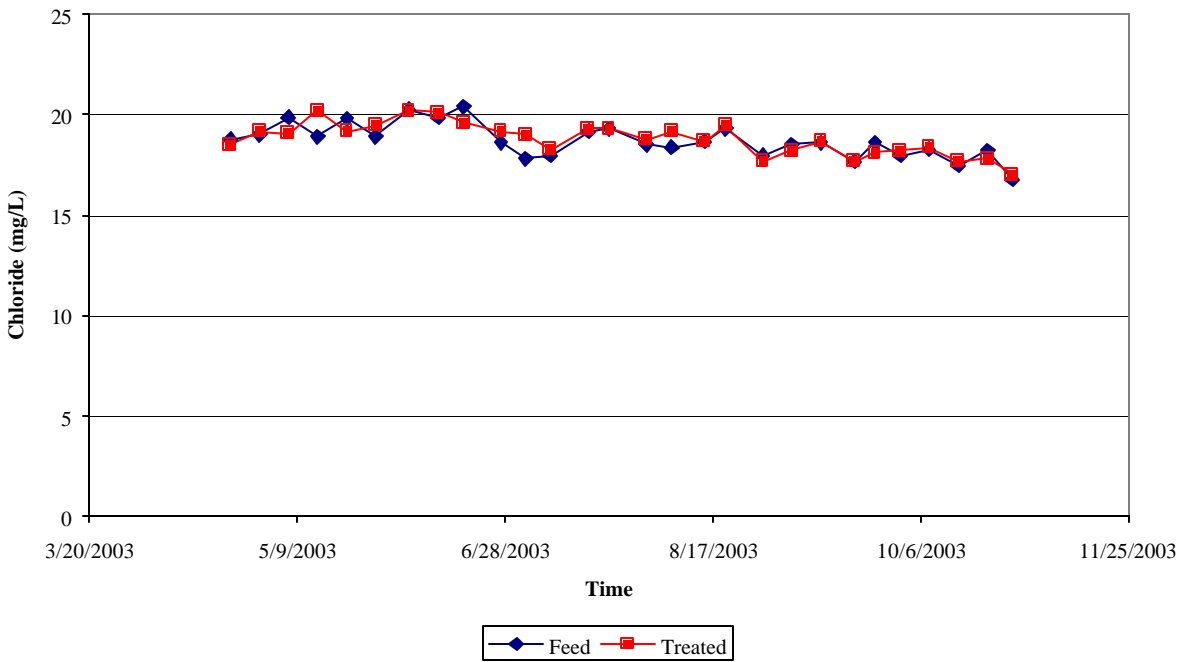


Figure 4-21. Capacity Test chloride concentration.

Sulfate concentrations were apparently unaffected by the treatment process during most of the Capacity Test, with an increase in the average sulfate concentration in the treated water of less than 1 mg/L. However, as shown in Figure 4-22, during the first few weeks of operation, the treated water sulfate concentration was greater than the feed water concentration, possibly indicating the treatment equipment or media were contributing to the treated water sulfate concentration.

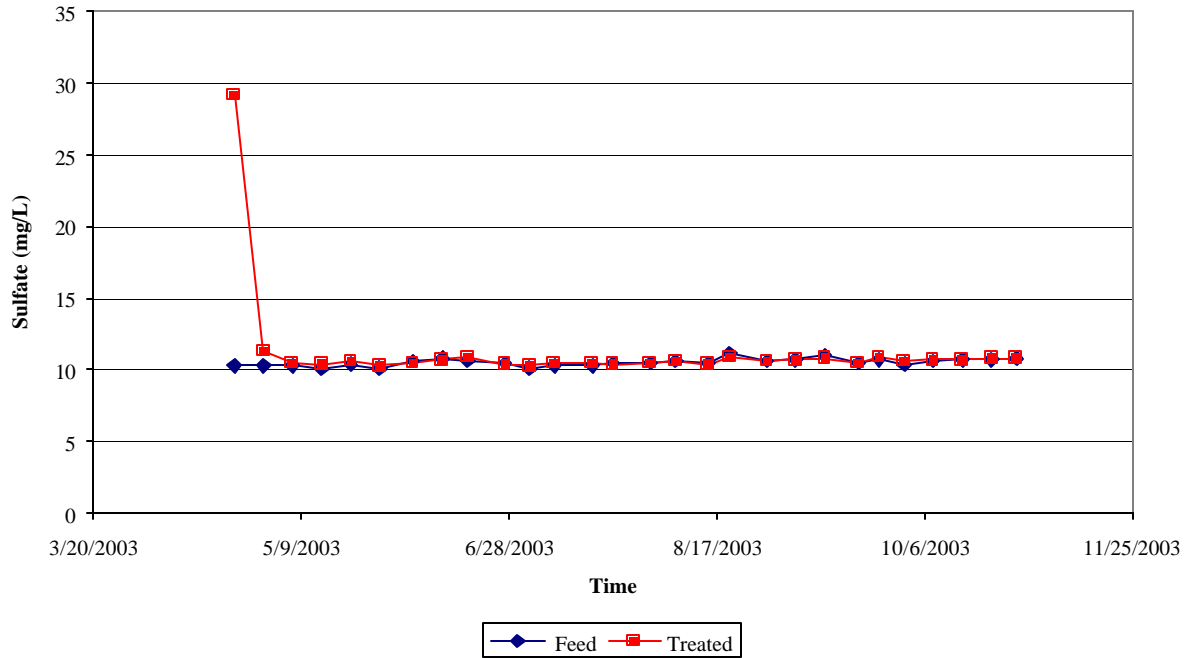


Figure 4-22. Capacity Test sulfate concentration.

As shown in Figure 4-23, phosphorus was initially removed from the feed water to below the MDL (0.010 mg/L). As the media adsorption capacity was consumed, phosphorus removal efficiency decreased and the treated water phosphorus concentration began to approach the feed water concentration.

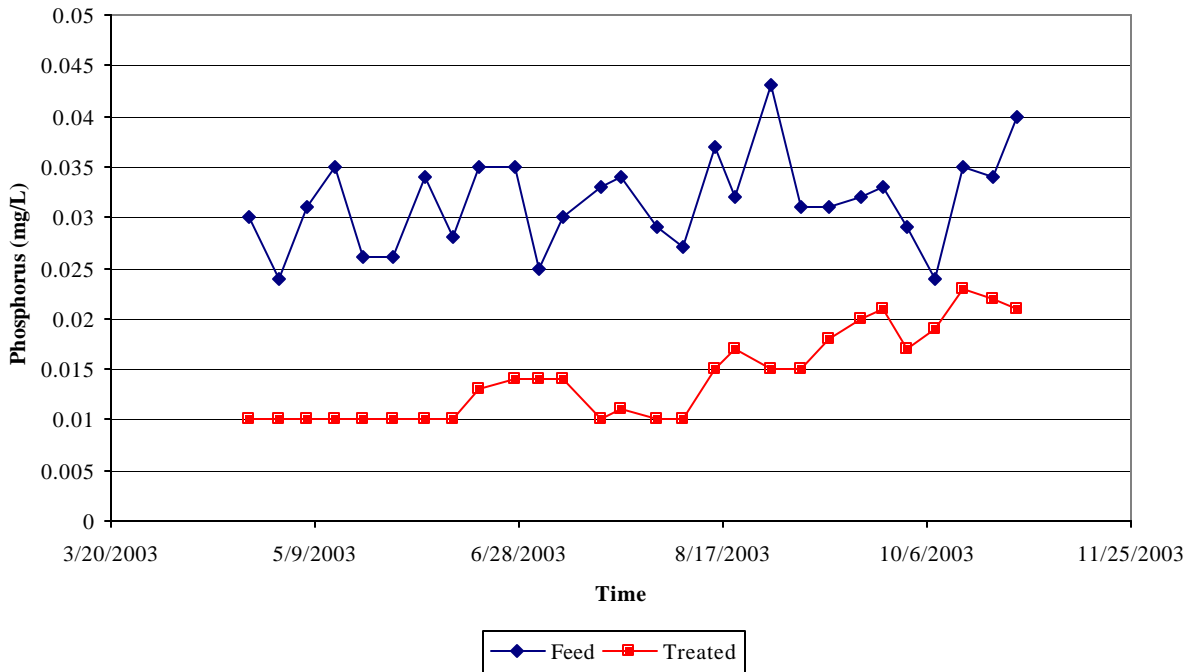


Figure 4-23. Capacity Test phosphorus concentration.

4.3.5 Capacity Test Arsenic Analyses

The results of arsenic analyses performed by the NSF Laboratory are summarized in Table 4-10. Feed water and treated water arsenic samples were collected daily during the Integrity Verification Test and weekly during the Capacity Test. As the treated water arsenic concentration approached the pre-defined breakthrough concentration of 11 $\mu\text{g/L}$, samples were collected three times per week. Seven of the sample sets were speciated to determine the distribution of total soluble arsenic between the arsenic III and the arsenic V species. The fraction of arsenic III in the feed water affects the treatability of the water, because arsenic III is generally more difficult to remove by known treatment processes. The feed water total arsenic concentration averaged approximately 14 $\mu\text{g/L}$, with approximately 4 $\mu\text{g/L}$ as the arsenic III species and 10 $\mu\text{g/L}$ as the arsenic V species. As described in the previous section, the feed water manganese concentration was significant and was observed to include particulate manganese, which could impact the apparent arsenic removal capacity of the media by enhancing arsenic removal.

Treated water arsenic concentrations were all less than or equal to the 2 $\mu\text{g/L}$ method detection limit during the initial 5 weeks of testing, which included approximately 621 to 727 hours of equipment operation and approximately 8,000 to 9,113 bed volumes of water treated. The treated water arsenic concentration reached 11 $\mu\text{g/L}$ following 2,350 hours of equipment

operation and treatment of approximately 28,800 to 29,200 bed volumes of water, based on the calculated media bed volume of 1.20 cubic feet. The treated water arsenic concentration increased slowly to the pre-defined breakthrough concentration. A steep breakthrough curve, which is typical with ion exchange process, did not occur. The arsenic breakthrough may have been slowed by mixing of the filter unit media during filter backwashes. Feed and treated water arsenic concentrations as a function of treated water bed volumes are shown in Figure 4-24. Complete arsenic analyses results, including a summary table, analytical test reports, raw data, and sample submission forms, are included in Appendix Q.

Table 4-10. Capacity Test Laboratory Arsenic Data

	<i>Feed Water</i>				<i>Treated Water</i>			
	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V (µg/L)	Total Arsenic (µg/L)	Soluble Arsenic (µg/L)	Arsenic III (µg/L)	Calculated Arsenic V (µg/L)
Number of Samples	47	7	7	7	47	7	7	7
Mean	14	14	4	10	6	4	<2	3
Minimum	12	13	<2	8	<2	<2	<2	1
Maximum	17	15	6	12	13	10	<2	8
Standard Deviation	1.1	N/A	N/A	N/A	4	N/A	N/A	N/A
95% Confidence Interval	14 – 14	N/A	N/A	N/A	5 – 7	N/A	N/A	N/A

N/A = Not Applicable. Standard Deviation and 95% Confidence Intervals were not calculated for parameters with fewer than 8 values.

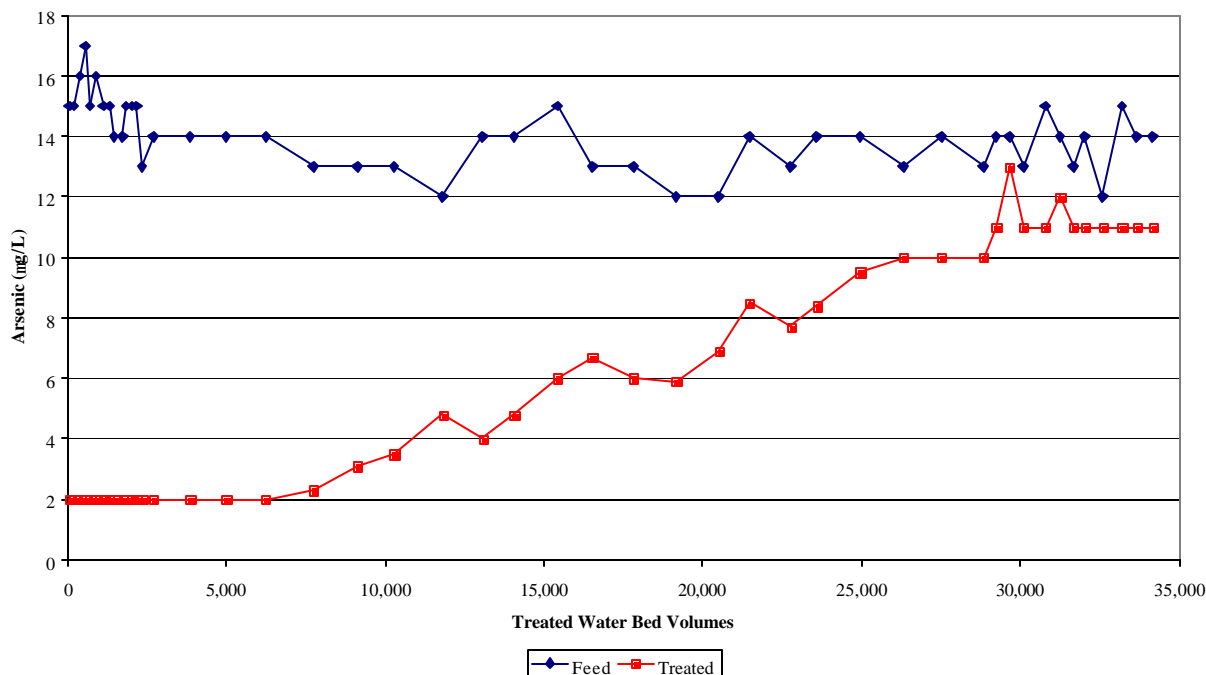


Figure 4-24. Capacity Test arsenic concentration.

4.4 Equipment Operation

During the Verification Test, minimal time and/or attention were required to operate the equipment, although significant time was spent on-site for testing purposes. The time required for daily operation of the treatment unit included a 5-minute check of the flow rate and verification there were no leaks in the system. Permanent installation of the equipment would also require periodic on-site arsenic analyses (requiring approximately 15 to 20 minutes to perform), and/or collection of samples for laboratory arsenic analyses. The filter unit control module automatically initiated filter backwashes, with no operator attention required.

4.5 Backwash Water Quality, Quantity, and Flow Rate

The filter unit control module automatically initiated filter backwashes, with no operator attention required. The unit backwashed a single filter unit at an interval of 11,000 to 12,000 gallons of treated water. Therefore, each filter was backwashed at an interval of 22,000 to 24,000 gallons. The filter unit not being backwashed continued to operate and produce treated water (for consumption, but discharged to waste for this test), treated water used for the filter backwash and purge, and treated water used for control module drive water. During the filter backwashes, which were witnessed by Gannett Fleming, it was observed that the high combined flow rate through the unit resulted in a headloss of approximately 10 psi. During manually initiated backwashes, Well No. 1 was operated in manual mode, with the well discharge ball valve set to maintain a minimum pressure of 30 psi. Due to the additional headloss during the backwash cycle, the treated water pressure was reduced to less than 20 psi, which was the setting of the non-integral pressure-regulating valve used in the flow control system. Therefore, the treated water production was reduced to approximately 1.2 gpm. Four filter backwashes were initiated and witnessed by the Gannett Fleming field-test engineer. Backwash, purge, and control module drive water flow rate, total quantity of flow, and water quality results are summarized in Tables 4-11 through 4-13. The backwash water was generally highly turbid and black in color, which correlates with the very high concentration of manganese detected in the laboratory samples. The elevated level of iron in the backwash water was unexpected given that feed and treated water iron analyses results were primarily less than the 20 $\mu\text{g/L}$ detection limit. The backwash water iron concentration could be a result of the buildup of particulate iron from the feed water on the media and/or the result of media attrition.

The backwash water arsenic concentration averaged 24 $\mu\text{g/L}$, which is significantly greater than the average feed water arsenic concentration of approximately 14 $\mu\text{g/L}$. The increased arsenic concentration in the backwash water could have resulted from the removal of adsorbed arsenic buildup within the filter unit or, more likely, from the removal of arsenic associated with the iron and manganese in the backwash. The source of arsenic in the backwash could also be media attrition. The aluminum concentration in the backwash water was greater than concentrations in the feed water for the first two backwashes sampled, indicating the media may have contributed to the level of aluminum in the backwash water. The third and fourth sampled backwash water aluminum samples had concentrations less than the MDL.

During the backwash cycle, a high flow rate of more than 4 gpm (backwash and production flow) was passing through a single treatment unit tank. This flow rate is much greater than the normal production rate of 1.9 gpm; the minimal contact time of less than 1 minute could be the

cause of arsenic concentrations in the purge and drive water samples greater than those in the treated water samples.

The automatic filter backwash process occurred regularly, as described in the manufacturer’s literature. However, the total volume of backwash water, flow rate, and time varied somewhat from the manufacturer’s specifications. The filter backwash duration was approximately 18.3 minutes at a flow rate of 3.0 gpm, compared to the specified filter backwash of 13 minutes at 4.0 gpm. Similarly, the purge cycle spanned approximately 5.9 minutes at a flow rate of approximately 3.0 gpm, compared to a specified flow rate of 1.9 gpm for a 5-minute period. The time between the backwash and rinse (purge) stages was just under 1 minute, as opposed to the specified 3-minute interval. Also, the total volume of backwash and rinse water was indicated in the equipment specifications as 62 gallons. The actual water use for backwash and rinse was approximately 73 gallons, with an additional 9.8 gallons used for control module drive water, for a total usage of approximately 83 gallons for the entire backwash cycle. Given a total production of approximately 11,000 to 12,000 gallons between filter backwash cycles, the quantity of backwash water used represents less than 1% of the total production. Backwash water quality characteristics are sourcewater-dependent. The impact of this backwash water on the wastewater treatment plant NPDES permit requirements was not evaluated.

Table 4-11. Backwash Water Characteristics

Date/Time	Volume (gallons)	Duration (min.)	Flow Rate (gpm)	pH (unit)	Turbidity (NTU)	Arsenic (µg/L)	Iron (µg/L)	Manganese (µg/L)	Aluminum (µg/L)	Silica (mg/L)
5/5/2003	55.5	16.50	3.1	7.48	42.9	24	2,690	17,500	658	17.1
7/3/2003	55.0	18.58	3.0	7.55	31.0	23	1,250	5,650	201	19.3
9/25/2003	56.0	18.08	3.1	7.56	15.5	27	1,111	5,751	<200	18.7
10/28/2003	55.0	20.17	2.7	7.50	15.0	21	1,440	5,620	<200	18.4
Number of Samples	4	4	4	4	4	4	4	4	4	4
Average	55.4	18.33	3.0	7.5	26.1	24	1,623	8,630	315	18.4
Minimum	55.0	16.50	2.7	7.5	15.0	21	1,111	5,620	200	17.1
Maximum	56.0	20.17	3.1	7.6	42.9	27	2,690	17,500	658	19.3

Table 4-12. Purge Water Characteristics

Date/Time	Volume (gallons)	Duration (min.)	Flow Rate (gpm)	pH (unit)	Turbidity (NTU)	Arsenic (µg/L)	Iron (µg/L)	Manganese (µg/L)	Aluminum (µg/L)	Silica (mg/L)
5/5/2003	18.0	5.58	3.2	7.55	0.40	3	<20	42	<200	15.0
7/3/2003	17.5	5.75	3.0	7.64	0.45	7	25	39	<200	19.1
9/25/2003	18.0	5.55	3.2	7.53	0.40	11	44	48	<200	17.9
10/28/2003	17.8	6.67	2.7	7.50	0.44	12	46	39	<200	18.2
Number of Samples	4	4	4	4	4	4	4	4	4	4
Average	17.8	5.89	3.0	7.6	0.40	8	34	42	<200	17.5
Minimum	17.5	5.55	2.7	7.5	0.40	3	<20	39	<200	15.0
Maximum	18.0	6.67	3.2	7.6	0.45	12	46	48	<200	19.1

Table 4-13. Control Module Drive Water Characteristics

Date/Time	Volume (gallons)	Duration (min.)	Flow Rate (gpm)	pH (unit)	Turbidity (NTU)	Arsenic (µg/L)	Iron (µg/L)	Manganese (µg/L)	Aluminum (µg/L)	Silica (mg/L)
5/5/2003	9.75	24.50	0.4	7.56	0.14	3	<20	<10	<200	16.2
7/3/2003	9.75	26.60	0.37	7.57	0.50	6	368	<10	<200	19.3
9/25/2003	9.75	25.80	0.38	7.54	0.14	11	<20	<10	<200	19.2
10/28/2003	9.80	29.00	0.34	7.54	0.17	12	<20	<10	<200	18.0
Number of Samples	4	4	4	4	4	4	4	4	4	4
Average	9.8	26.48	0.4	7.6	0.25	8	107	<10	<200	18.2
Minimum	9.8	24.50	0.3	7.5	0.15	3	<20	<10	<200	16.2
Maximum	9.8	29.00	0.4	7.6	0.50	12	368	<10	<200	19.3

The original backwash operational and on-site water quality data are included in the logbook copies in Appendix F. Laboratory water quality analyses reports are included in Appendix G and Appendix Q.

4.6 Spent Media Analyses

Following completion of the Adsorption Capacity Test, spent media core samples were extracted from each filter tank, for the purposes of verification testing, using a 1.5-inch diameter, thin-walled copper tube. The core samples were combined and thoroughly mixed in a large plastic bag, then divided into two separate samples, one for TCLP and CA WET analyses to verify the spent media exhibits no toxicity characteristics, and one for a media gradation analysis.

The complete results of TCLP and CA WET analyses, including QA/QC data, are included in Appendix J. The results are summarized in Table 4-14. Arsenic was not detected in the TCLP analysis of the spent media. Only barium and cadmium were detected in TCLP analyses, both at concentrations less than the regulatory limit (RCRA). The arsenic concentration detected by CA WET analyses was 0.25 mg/L (250 µg/L), well below the regulatory limit of 5 mg/L. Other metals detected by CA WET analyses included barium, cadmium, copper, and zinc. All concentrations were less than the regulatory limits.

Table 4-14. Spent Media Characterization

Parameter	TCLP		CA WET		TCLP ⁽¹⁾	CA WET ⁽²⁾
	Result (mg/L)	Reporting Limit (mg/L)	Result (mg/L)	Reporting Limit (mg/L)	Regulatory Limit (mg/L)	Regulatory Limit (mg/L)
Arsenic	ND	0.20	0.25	0.20	5.0	5.0
Barium	4.12 ⁽³⁾	0.20	6.30 ⁽³⁾	0.20	100.0	100.0
Cadmium	0.015	0.010	0.032 ⁽³⁾	0.010	1.0	1.0
Chromium	ND	0.080	ND	0.050	5.0	5.0
Copper	ND	0.020	0.13	0.010	N/A	25
Lead	ND	0.10	ND	0.10	5.0	5.0
Mercury	ND	0.0004	ND ⁽³⁾	0.0040	0.2	0.2
Nickel	ND	0.010	ND ⁽³⁾	0.010	N/A	20
Silver	ND	0.010	ND	0.010	5.0	5.0
Zinc	ND	0.20	0.32	0.05	N/A	250

⁽¹⁾ 40 CFR 261.24 Toxicity Characteristics.

⁽²⁾ California Regulations 66261.24.

⁽³⁾ Laboratory data qualifications included in Appendix J.

ND = Non-Detect.

N/A = Not Applicable.

Visual observation and comparison of the spent media and new media revealed no observable physical degradation. This observation was supported by gradation analyses performed by Gannett Fleming, the results of which indicated almost identical new and spent media particle size distributions. Gradation analyses reports are included in Appendix L.

4.7 Task 3: Documentation of Operating Conditions and Treatment Equipment

4.7.1 Introduction

During each day of verification testing, arsenic adsorption media filter operating conditions and treatment equipment performance were documented, as described in Section 3.11. The volumetric flow rate through an adsorptive media vessel is a critical parameter and was thoroughly monitored and documented. Adsorptive media performance is affected by the EBCT, which varies directly with volumetric flow rate through a vessel.

4.7.2 Experimental Objectives

The objective of this task was to accurately and fully document the operating conditions and performance of the equipment. This task was performed in conjunction with both the system Integrity Verification Testing and the Adsorption Capacity Verification Testing.

4.7.3 Operations and Maintenance

The following are recommendations for criteria to be included in the Para-Flo™ Operation and Maintenance (O&M) Manual for adsorptive media removal of arsenic, as described in the Technology Specific Test Plan (TSTP) within the ETV Protocol.

4.7.3.1 Operations. Kinetico Inc. provided an Owner's Manual and Installation Guide, which provided much of the data and information needed to conduct the test. Technical sheets intended for Gannett Fleming and NSF review only and not for publication were also submitted. The Owner's Manual and Installation Guide are included in Appendix N; the technical sheets are on file at Gannett Fleming and NSF. These manuals present specific information on the mechanical operation of the filter tanks for a variety of media types, which include Actiguard AAFS50.

Kinetico Inc. and Alcan Chemicals provided readily understood information on the required or recommended procedures (task-specific SOPs) related to the proper operation of the arsenic adsorption media filter. Gannett Fleming discussed the following issues with Kinetico Inc. and Alcan Chemicals prior to testing:

- Monitoring of Preconditioning of Adsorptive Media
 - Utilizing the manufacturer's specific procedure for Actiguard AAFS50 adsorptive media, including backwashing initially with at least 10 bed volumes to remove fines;
 - Backwash parameters (flow rate and time);
 - Volume of wastewater; and
 - Wastewater disposal requirements.
- Monitoring of Operation
 - Use of an arsenic field test kit for the purpose of monitoring feed and treated arsenic levels;
 - Feed water pressure;
 - Treated water flow rate;
 - Treated water pressure;
 - Maintenance and operator labor requirements; and
 - Spare parts requirements.
- Operability

During verification testing and during compilation of process operating data, attention was given to the arsenic adsorption media filter operability aspects. Among the factors that were considered are:

 - Fluctuation of flow rates, as well as the time interval at which flow adjustment was needed;
 - Ease of adjusting the flow rate when outside the design range; and
 - Contacting the state regulatory agency to acknowledge the volumes and nature of wastewater residue from the preconditioning of the media and backwash wastewater.

4.7.3.2 Maintenance. Kinetico Inc. and Alcan Chemicals provided readily understood information on the required or recommended maintenance schedule for each piece of operating equipment including, but not limited to:

- manual valves
- on-line measuring instruments
- control module

Kinetico Inc. and Alcan Chemicals provided readily understood information on the required or recommended maintenance schedule for non-mechanical or non-electrical equipment including, but not limited to:

- adsorptive media vessels
- feed lines

4.8 Task 4: Data Management

The data management plan was executed as presented in Section 3.12.3. Data were entered into computer spreadsheets and submitted in electronic and hard copies. QA/QC forms, field notebooks, and photographs are included in the appendices of this report.

4.9 Task 5: Quality Assurance/Quality Control (QA/QC)

4.9.1 Introduction

Appropriate quality assurance and quality control measures were performed to ensure the quality and integrity of all measurements of operational and water quality parameters during the ETV testing. QA/QC procedures for the operation of the arsenic adsorption media filter and the measured water quality parameters were maintained during the verification testing program as specified in the test plan, and as described in Section 3.13.

On-site QA/QC activities were recorded in the logbooks and are included as Appendix F. QA/QC activities included fluoride electrode, pH meter, turbidimeter, flow meter, and rotameter calibrations, as well as collection and analysis of duplicate, blank, and spike samples, as specified in the PSTP.

QA/QC efforts also included review of laboratory raw data (run logs and bench sheets); calibration of on-site analytical instrumentation; calibration of totalizer meters; calibration of the flow meter; analyses of split samples to verify Hach Test Kit analyses for alkalinity, calcium, and hardness; pressure gauge calibration; collection of duplicate samples for on-site and laboratory analyses; and spiked sample analyses. Performance evaluation analyses were also performed by Gannett Fleming to demonstrate proficiency and accuracy of the analytical equipment and of the laboratory techniques required for all on-site water quality analyses. All data entry performed by the field engineer was checked by a second person.

An on-site system inspection and audit for sampling activities and field operations were conducted by NSF. The Gannett Fleming QA officer also conducted an on-site inspection during the first two weeks of operation.

4.9.2 Data Quality Indicators

Data quality indicators include the following:

- Representativeness
- Accuracy
- Precision
- Statistical Uncertainty
- Completeness

4.9.2.1 Representativeness. Representativeness refers to the degree to which the data accurately and precisely represent the conditions or characteristics of the parameter represented by the data. Representativeness was ensured by executing a consistent sample collections protocol, by using each method to its optimum capability to achieve a high level of accuracy and precision, and by collecting sufficient data to be able to detect a change in operations.

4.9.2.2 Accuracy. Accuracy refers to the difference between a sample result and the true or reference value. Accuracy was optimized through equipment calibrations, performance evaluation sample analysis, collection of split samples, analysis of duplicate samples, and analysis of spiked samples, as specified in the PSTP. Periodic calibration of field test equipment included calibration of pressure gauges, rotameter, totalizer meters, portable turbidimeter, pH meter, and fluoride meter/electrode, as specified in Table 4-15.

Table 4-15 Field Instrument Calibration Schedule

Instrument	Calibration Method	Frequency	Acceptable Accuracy
Pressure Gauges	Dead weight calibration tester	Biannual	± 10%
Rotameter	Volumetric “bucket & stop watch”	Weekly	± 10%
Totalizer Meters	Volumetric “bucket & stop watch”	Weekly	± 1.5%
Portable Turbidimeter	Secondary turbidity standards	Daily	PE sample
	Primary turbidity standards	Weekly	
Portable pH/ISE Meter with Combination pH/Temperature Electrode	Three-point calibration using 4.0, 7.0 and 10.0 buffers	Daily	± 5%
Thermometer (NIST-traceable)	Calibration not required	N/A	
Portable pH/ISE Meter with Fluoride Ion Selective Electrode	0.1 mg/L or 0.5 mg/L fluoride standard, and 10.0 mg/L fluoride standard	Daily	± 2%

4.9.2.2.1 Split Samples. Split samples for alkalinity, calcium, and total hardness were collected and analyzed by the PADEP Laboratory during each of the first two days of the Integrity Test to verify the accuracy of the Hach methods for on-site analyses of these parameters. The results of the split sample analyses by the PADEP Laboratory, as shown in Tables 4-16 and 4-17, were within the allowable 30% limit of difference established by NSF. As a result, the Hach methods were utilized for the remainder of the verification test.

Table 4-16. Split-Samples (April 22, 2003)

Parameter	<i>Feed Water</i>			<i>Treated Water</i>		
	GF Lab	PADEP Lab	% Difference	GF Lab	PADEP Lab	% Difference
Alkalinity (mg/L as CaCO ₃)	88.0	94.8	7.2%	50.0	53.4	6.4%
Calcium (mg/L)	28.0	24.5	14.3%	26.4	24.8	6.5%
Hardness (mg/L as CaCO ₃)	100.0	95	5.3%	100.0	96	4.2%

Table 4-17. Split-Samples (April 23, 2003)

Parameter	<i>Feed Water</i>			<i>Treated Water</i>		
	GF Lab	PADEP Lab	% Difference	GF Lab	PADEP Lab	% Difference
Alkalinity (mg/L as CaCO ₃)	88.0	97.8	10.0%	66.0	73.8	10.6%
Calcium (mg/L)	28.0	24.0	16.7%	26.4	23.0	14.8%
Hardness (mg/L as CaCO ₃)	104.0	93	12%	100.0	90	11%

4.9.2.2.2 Performance Evaluation Samples for Water Quality Testing. Performance evaluation (PE) samples are samples of known concentration prepared by an independent performance evaluation laboratory and provided as unknowns to an analyst to evaluate his or her analytical performance. Analyses of laboratory PE samples were conducted before the initiation of verification testing. The control limits for the PE samples were used to evaluate the field analytical method performance.

A PE sample comes with statistics derived from the analysis of the sample by a number of laboratories using EPA-approved methods. These statistics include a true value of the PE sample, a mean of the laboratory results obtained from the analysis of the PE sample, and an acceptance range for sample values. The field laboratory and the PADEP Laboratory provided results from the analysis of the PE samples, which meet the performance objectives of the verification testing.

PE sample results for the PADEP Laboratory and the results of PE checks for on-site water quality parameters are included in Appendix R.

The results of arsenic speciation column performance evaluation tests are also included in Appendix R. The initial speciation column test produced less than acceptable accuracy for arsenic III recovery. It was determined that the speciation columns were not functioning properly and a second batch of columns (prepared by NSF) were tested and

provided acceptable accuracy. This second batch of columns was used for Integrity Verification Test arsenic speciation.

4.9.2.2.3 Spike Sample Analyses. Matrix spikes were not performed for the on-site water quality parameters, including alkalinity, calcium, hardness, and fluoride; however, analysis of spiked blanks for each parameter were analyzed for accuracy at a 10% minimum frequency. A summary of on-site water quality spike sample analyses, including calculated percent recoveries for each test, is included in Appendix F. Percent recoveries for all of the spiked blanks for the on-site water quality parameters were within the acceptable accuracy range of 30%.

The results of spike sample analyses performed by the PADEP Laboratory are included in the laboratory analysis summary tables included in Appendix H. Spike sample analyses were performed by the PADEP Laboratory at a frequency of 10%. Spike sample analysis percent recoveries for iron, manganese, aluminum, and silica were within the acceptable accuracy range of 30%. Spike sample results for chloride and sulfate were within the acceptable accuracy range of 20%, while total phosphorus was within the acceptable accuracy range of 10%.

The results of NSF Laboratory spike sample analyses for arsenic are included in the laboratory QA/QC data in Appendix Q. Percent recoveries for arsenic were within the acceptable accuracy range of 30%.

4.9.2.3 Precision. Precision refers to the degree of mutual agreement among individual measurements. It provides an estimate of random error and can be measured by replication of analyses. The precision levels for all duplicate analyses were calculated.

On-site water quality relative percent deviation calculations are included with the on-site water quality data in Appendix F. Duplicate analyses for on-site water quality parameters were performed at a 10% minimum frequency. One set of duplicates for turbidity had a precision level of 31%; all other precision levels for the on-site water quality data were within the acceptable precision level of 30%.

PADEP Laboratory relative percent deviation calculations for field duplicates are included in Appendix G. Field duplicates of PADEP Laboratory samples were collected at a 10% minimum frequency. A single duplicate sample for iron was not within the acceptable level of precision of 30%, but all other field duplicate analyses performed by the PADEP Laboratory were well within acceptable precision levels.

PADEP Laboratory relative percent deviation calculations for laboratory duplicates are included in Appendix H. The PADEP Laboratory performed duplicate analyses at a 10% minimum frequency. All PADEP Laboratory duplicate analyses were within the acceptable levels of precision.

NSF relative percent deviation calculations for field and laboratory arsenic duplicates are included in Appendix Q. All NSF Laboratory arsenic duplicate analyses were within the acceptable precision level of 30%.

4.9.2.4 Statistical Uncertainty. Statistical uncertainty of water quality parameters (for data sets of eight or more parameters) was evaluated through the calculation of the 95% confidence interval around the sample mean.

4.9.2.5 Completeness. Completeness refers to the amount of valid, acceptable data collected from a measurement process compared to the amount expected to be obtained. The completeness objective for data generated during this verification test was based on the number of samples collected and analyzed for each parameter and/or method. Completeness was defined as the following for all measurements:

$$\%C = (V/T) \times 100$$

where: % C = percent completeness;
 V = number of measurements judged valid; and
 T = total number of measurements.

Calculation of data completeness was made for on-site water quality measurements, PADEP Laboratory water quality measurements, and arsenic measurements. These calculations are presented in Appendices F, G, and Q of this report, respectively. During the Integrity Test, no duplicates were collected for the on-site water quality parameters, including pH, temperature, turbidity, alkalinity, and fluoride; however, the level of completeness for these parameters was deemed acceptable for the amount of data collected during the Capacity Test, which included Integrity Test data. 94% completeness was achieved for the feed and treated water alkalinity measurements during the Capacity Test, which is below the 95% completeness objective outlined in the ETV protocol. The level of completeness for all other parameters either met or exceeded the completeness objectives.

Chapter 5 References

The following references were used in the preparation of this report:

Standard Methods for Examination of Water and Wastewater. 19th ed. Washington, D.C. APHA. 1995.

U.S. EPA/NSF International. *ETV Protocol for Equipment Verification Testing for Arsenic Removal*, April 2002.

Chapter 6 Vendor Comments

Kinetico Inc. submitted the following comments concerning the ETV test and report. These statements were not validated in the verification test and are the opinion of Kinetico, Inc.:

“The Para-Flo™ PF60 Model AA08AS was tested in the ETV process. In the time between submitting the equipment and the writing of this report, our marketing department has re-named much of Kinetico’s product line. The new model name for this arsenic treatment system is the 2060f-OD (UltrAsorb-A) with Actiguard AAFS50. Although the new name reflects the use of a larger tank inlet and outlet to facilitate faster flow rates, the fact that the flow must be restricted to obtain a minimum empty bed contact time means that the arsenic treatment process will not be materially affected in any way.”