THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**ULTRAFILTRATION AND REVERSE OSMOSIS**
APPLICATION:	**REMOVAL OF CHEMICAL AND MICROBIAL CONTAMINANTS FROM A SURFACE DRINKING WATER SOURCE**
PRODUCT NAME:	**EXPEDITIONARY UNIT WATER PURIFIER (EUWP), GENERATION 1**
VENDOR:	**VILLAGE MARINE TEC.**
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NSF International (NSF) manages the Drinking Water Systems (DWS) Center under the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) Program. The DWS Center evaluated the performance of the Village Marine Tec. Generation 1 Expeditionary Unit Water Purifier (EUWP). The EUWP, designed under U.S. Military specifications for civilian use, employs ultrafiltration (UF) and reverse osmosis (RO) to produce drinking water from a variety of sources. This document provides the verification test results for the EUWP system evaluated at a fresh surface water site at Selfridge Air National Guard Base in Michigan.

EPA created the 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, stakeholder groups (consisting of buyers, vendor organizations, and permitters), and with the voluntary 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.

PRODUCT DESCRIPTION

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

The EUWP was developed to treat challenging water sources with variable turbidity, chemical contamination, and very high total dissolved solids (TDS) including seawater, during emergency situations when other water treatment facilities are incapacitated. The EUWP components include feed pumps, a UF pretreatment system, a one or two pass RO desalination system with an energy recovery device, storage tanks, and product pumps. It has chemical feed systems for optional pretreatment coagulation and post treatment chlorination. Clean-in-place systems (CIP) are included with the UF and RO skids. During this verification test, coagulation pretreatment was employed, but chlorination was not evaluated.

Design specifications indicate that the UF system alone has a production capacity up to 250,000 gallons per day (gpd) from a fresh water source with up to 500 mg/L TDS and a temperature of 25°C. The combined UF and RO system is designed to produce from 98,000 gpd up to 162,000 gpd, depending on the TDS of the source water and the recovery settings of the RO process.

VERIFICATION TEST DESCRIPTION

Test Site

The testing site was Lake St. Clair at Selfridge Air National Guard Base in Michigan. The source water for testing was raw lake water. Initial characterization samples of raw lake water were collected in August 2006, and again in May 2007 for the second round of testing. Highlights of the source water characterization are presented in Table VS-i. The measured concentrations of regulated metals, phosphorus, nitrite, and nitrate are not shown here, but are presented in the final report, because they are either below the laboratory reporting limit or below the limit in the EPA National Primary Drinking Water Regulations (NPDWR) limit.

Table VS-i. Lake St. Clair Raw Water Characterization Data

	Sample Date	
Parameter	**08/16/06**	**05/31/07**
Total Organic Carbon (TOC, mg/L)	2.9	NM[1]
UV Light Absorbance at 254 nanometers (UV_{254}, Abs)	0.0668	NM
Total Suspended Solids (TSS, mg/L)	<5	<2
TDS (mg/L)	130	140
Alkalinity (mg/L as $CaCO_3$)	70	86
Total Hardness (mg/L as $CaCO_3$)	95	110
Total Silica (mg/L as SiO_2)	1.1	1.1
Specific Conductance (µmhos/cm)	NM	250
Cryptosporidium (oocysts/L)	<1	NM
Giardia (cysts/L)	<1	NM
Heterotrophic Plate Count (HPC, CFU/mL)	500	NM
Total Coliforms (CFU/100 mL)	291	NM
Bacillus Endospores (CFU/100 mL)	NM	689

(1) NM = not measured

Methods and Procedures

Initial testing of the EUWP was conducted in September and October of 2006 by the U.S Army Tank-Automotive Research, Development, and Engineering Center (TARDEC), with assistance from the U.S. Bureau of Reclamation (USBR). Immediately prior to the ETV test, the initial UF pressure decay tests indicated that pressure was being lost at a higher than desirable rate. The problem was investigated, and was found to be the o-ring seals between the membrane modules and filtrate collection tubes. As a temporary fix, polytetrafluoroethylene (Teflon®) thread sealing tape was wrapped around the o-rings to increase the seal surface between the o-rings and membrane cartridges, and the test proceeded. After testing was complete, the UF performance data indicated that the temporary fix did not maintain sufficient membrane integrity. Therefore, a second test employing only the UF system was conducted in July and August of 2007 after permanent repairs were made. Issues concerning the seal problems and subsequent repairs are discussed in the ETV verification report.

The testing activities followed a test/quality assurance plan (TQAP) prepared specifically for the project. The TQAP was developed in accordance with the ETV Protocols *EPA/NSF Protocol for Equipment Verification Testing for Removal of Inorganic Constituents* – April 2002, and the *EPA/NSF Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* – September 2005.

The 2006 verification test began on September 25, and ran for the planned 30 day test period, ending on October 25. The UF system was operated each day on semi-continuous basis, automatically shutting down when the RO feed tank was full. A typical operating day for the UF system was 15-17 hours (h) in duration. The RO system was setup to operate continuously, and typically ran 22 to 24 h per day. The RO system was shutdown periodically for various maintenance activities, or when alarms occurred and shut the system down. When alarms and shutdown occurred during unattended operation at night, the entire system would remain shutdown until an operator arrived in the morning.

The 2007 UF system retest was conducted from July 30 to August 24. The retest was stopped short of 30 days because the intent of the test as stated in the ETV test protocol – operation until a membrane cleaning was needed – was met. During the retest, the UF system was in operation an average of 14 h per day, not including down time for backwashes, cleanings, and other maintenance activities.

Flow, pressure, conductivity, and temperature recordings were collected twice per day when possible to quantify membrane flux, specific flux, flux decline, and recovery. Turbidity and pH readings were also recorded twice per day. The UF skid included in-line particle counters which recorded particle counts every five minutes. Pressure decay tests were conducted daily on the UF system to verify membrane integrity. Once per week samples were collected from the UF and RO process streams for analysis of alkalinity, hardness, total silica, TDS, TOC, TSS, UV_{254}, HPC (2006 test only), and total coliforms (2006 test only). For the 2007 test, *Bacillus* endospores were substituted for HPC and total coliforms.

VERIFICATION OF PERFORMANCE – 2006 TEST

Finished Water Quality

The UF system reduced the turbidity from a mean of 4.77 Nephelometric Turbidity Units (NTU) in the feed water to a mean of 0.14 NTU in the UF filtrate. The UF system reduced the turbidity of the feed water by a mean value of 95.9%. All filtrate turbidity measurements were below the NPDWR of 1 NTU. The second NPDWR criterion for turbidity is that 95% of the daily samples in any month must be ≤0.3 NTU. Only one filtrate turbidity measurement out of 58 was above 0.3 NTU: 0.47 NTU on October 5. Therefore, the EUWP UF system met the second NPDWR turbidity requirement, as 98% of the turbidity measurements were ≤0.3 NTU.

The RO membranes provided additional turbidity removal, resulting in a mean turbidity of 0.09 NTU from the permeate grab samples. The maximum measured RO permeate turbidity was 0.18 NTU. In general, the RO system provided an additional turbidity reduction in the range of 40% to 66%.

The UF system showed only a minor reduction in organic material as measured by the TOC data. The UF feed TOC concentrations ranged from 2.1 to 2.7 mg/L, and the UF filtrate levels were typically only 0.1 to 0.4 mg/L lower. These data indicate that most of the organic material, as measured by TOC, was dissolved in the feed water. The RO system reduced the permeate TOC to below the detection limit of 0.1 mg/L.

The RO system also reduced the dissolved ions in the water, as measured by conductivity, with a mean percent reduction of 99.4%. The mean conductivity of the RO permeate was 1.8 microSiemens per centimeter (µS/cm) compared to a mean RO feed conductivity of 287 µS/cm. The maximum measured permeate conductivity was 4.9 µS/cm. Hardness, alkalinity, TDS, and total silica were all removed to below the detection limit in the RO permeate.

UF and RO Membrane Integrity

Daily pressure decay tests were used to document UF membrane integrity, and HPC and total coliforms were measured in the UF feed and filtrate as a microbial membrane integrity indicator. The in-line particle counters provided an additional measurement of membrane integrity, and the capability of the system to remove particulate and microbial contaminants.

As discussed in the Methods and Procedures section, prior to the 2006 test TARDEC and USBR discovered that the seals between the UF elements and membrane module housings were not as tight as desired. After the problem was temporarily fixed, the pressure decay rate was measured as 0.37 pounds per square inch, gauge (psig) per minute (min). While this was higher than desired, there was no critical pressure decay rate to achieve, so the test proceeded. The mean daily pressure decay rate for the test was 0.29 psig/min, with a maximum observed decay rate of 0.43 psig/min.

While the turbidity data indicated that the UF system performed satisfactorily, the microbiological data showed higher than expected UF filtrate counts. The UF feed geometric mean HPC count was 2810 CFU/mL, and the filtrate geometric mean HPC count was 1670 CFU/mL. Mean total coliform counts were not calculated because only five sets of samples were collected. The UF feed total coliform counts ranged from 41 to 532 CFU/100 mL, while the filtrate counts ranged from 11 to 94 CFU/100 mL. High numbers of HPC and total coliforms were also found in the RO permeate. The mean RO permeate HPC count was 247 CFU/mL and the RO permeate total coliform counts ranged from <1 to 95 CFU/100 mL. This phenomenon has been observed in other published membrane studies, but it was beyond the scope of this study to determine whether the observed HPC and total coliform levels were breaching the membrane, or were a result of microbial contamination and growth downstream of the UF and RO membranes from previous field tests of the EUWP.

There is no reportable particle count data for the 2006 test because after the test was completed it was discovered that the particle counters had been improperly calibrated.

Direct integrity measurements of the RO system were performed prior to the start of the verification test, and again at the end of the test. A dye marker test was conducted, where a food-grade dye was added to the RO feed water, and UV absorbance levels were compared among the feed, permeate, and concentrate streams over a ten minute period. For the pre-verification test, the dye rejection rate was 99.6%, while that for the post-verification dye test was 99.8%. As with the UF pressure decay tests, there was no critical rejection level.

UF System Operation

UF process operations data for the 2006 test are presented in Table VS-ii. The intake flow is defined as the source water pumped into the UF feed water tank. The mean UF feed water flow rate of 246 gallons per minute (gpm) was below the design feed flow rate of 259 gpm specified for the system. The UF water recovery was 89.5% based on the mean feed water and filtrate flow rates. The UF system only operated 15 h per day, on average, but the 220 gpm mean filtrate flow corresponds to a 24-h production rate of 316,800 gallons (gal). The UF system target production rate was 250,000 gpd (not including backwash water). The backwash process used about 900 gal of UF filtrate per event, and a backwash was conducted every 30 minutes. For 24 h of operation, a total of 43,200 gal of UF filtrate would be used for backwashes. Subtracting the backwash water from the calculated daily UF filtrate production results in 273,600 gpd of UF product water, which was above the performance goal of 250,000 gpd.

Table VS-ii. 2006 Test UF Operations Productivity Data

Parameter	Count	Mean	Median	Minimum	Maximum	Standard Deviation	95% Confidence Interval
UF Operation per day (h)	31	15.0	17.2	3.4	21.5	4.85	±1.71
Intake Flow (gpm)	58	298	299	278	302	3.34	±0.86
Feed Flow (gpm)	59	246	248	175	268	16.0	±4.07
Filtrate Flow (gpm)	59	220	222	149	243	16.1	±4.10
Retentate Flow (gpm)	59	26	26	21	31	1.81	±0.46
Backwash Flow (gpm)			Estimated at 900 gal per backwash cycle				
Feed Pressure (psig)	59	21	21	12	33	4.26	±1.09
Retentate Pressure (psig)	59	19	19	10	31	4.20	±1.07
Filtrate Temperature (°F[1])	59	52	52	43	60	5.16	±1.32

(1) °F = degrees Fahrenheit

A chemical coagulant (ferric chloride) was not used at the beginning of the verification test. At the start of the test on September 25, the trans-membrane pressure (TMP) was 11 psig. However, it quickly rose to 26 psig on September 29. As the TMP rose, the specific flux declined from 3.56 gallons per square foot per day (gfd)/psig on September 25 to 1.38 gfd/psig on September 29. It was evident that a coagulant should be used to attempt to lengthen the time between UF cleanings. The UF system was shut down on September 30 and cleaned. The CIP was successful as the specific flux rose to 3.52 gfd/psig. Ferric chloride was injected to the feed water upstream of the UF feed tank from September 29 through the end of the test. The addition of the coagulant improved performance, and the system was able to maintain filtrate production with the TMP below 20 psig until the last two days of the test. The specific flux varied between 3.0 and 4.5 gfd/psig from September 29 to October 18, and then it dropped down to 2.46 gfd/psig on October 19. From October 19 to the end of the test on October 25, it ranged from approximately 1.5 to 3.0 gfd/psig.

RO System Operation

The RO process operations data for the 2006 test are presented in Table VS-iii. The mean RO permeate flows of 53 gpm for Array 1 and 21 gpm for Array 2 yield a mean total permeate production of 74 gpm. The mean feed water flow of 107 gpm for Array 1 and 53 gpm for Array 2 were below the target feed rates of 116 gpm and 58 gpm, respectively. The recovery for Array 1 was 49.5%, (design target 50%) and the recovery for Array 2 was 39.6% (design target 48%).

Over the 30-day verification test, the RO feed water totalizer showed 5,382,670 gal of water fed to the RO unit. At an average recovery of 47% (prorated between Array 1 at 49.5% and Array 2 at 39.6%), the total volume of permeate produced was approximately 2,530,000 gal or an average of 84,330 gpd over the entire test period. The target flowrate fell short of the goal of producing 100,000 gpd of finished water.

The RO system maintained a steady permeate flow rate for both arrays throughout the verification test. The feed pressure was increased over the duration of the test to maintain feed water flow rates. The Array

1 feed pressure increased from 387 psig on September 25 to a maximum of 539 psig on October 24. The concentrate pressure from Array 1 was used by the energy recovery device to increase feed water pressure for Array 2. Based on the small pressure loss from the transfer of pressure between the Array 1 concentrate and the Array 2 feed water, the energy recovery device worked properly during the test.

Table VS-iii. RO System Operations Productivity Data for 2006 Test

Parameter	Count	Mean	Median	Minimum	Maximum	Standard Deviation	95% Confidence Interval
Array 1 Feed Flow (gpm)	59	107	107	104	110	1.38	± 0.35
Array 1 Permeate Flow (gpm)	59	53	53	44	56	2.0	± 0.50
Array 1 Concentrate Flow (gpm)	59	54	54	48	62	2.4	± 0.61
Array 2 Feed Flow (gpm)	59	53	52	49	59	2.3	± 0.60
Array 2 Permeate Flow (gpm)	59	21	21	19	24	1.1	± 0.27
Array 2 Concentrate Flow (gpm)	59	32	31	27	37	2.3	± 0.58
Array 1 Feed Pressure (psig)	59	444	428	374	539	45.9	± 11.7
Array 1 Concentrate Pressure (psig)	59	346	330	286	419	40.5	± 10.3
Array 2 Feed Pressure (psig)	59	345	327	284	436	42.5	± 10.8
Array 2 Concentrate Pressure (psig)	59	255	238	204	325	35.2	± 8.98
Array 1 and 2 Combined Permeate Pressure (psig)	59	28	27	15	39	4.6	± 1.2

The specific flux calculations show that the RO membranes were slowly being fouled during operation. Over the 30-day test, the specific flux dropped by approximately 31% for Array 1, from 0.050 to 0.035 gfd/psig and 26% for Array 2, from 0.054 to 0.040 gfd/psig. The RO system was chemically cleaned on October 6 using a citric acid low pH solution. The specific flux just before the start of the cleaning was 0.043 gfd/psig, and the cleaning increased the specific flux to 0.047 gfd/psig. Given the slow but steady trend of decreasing specific flux, an anti-scalant was fed to the RO system beginning on October 12. This chemical feed continued through the end of the verification test.

VERIFICATION OF PERFORMANCE – 2007 UF SYSTEM RETEST

The 2007 retest was conducted from July 31 to August 24. Prior to starting the retest, each membrane cartridge was individually integrity tested, and several were found to have broken fibers that required plugging. This is a typical practice prior to installation of hollow-fiber membrane modules. After plugging these fibers, each cartridge was again pressure tested. The results showed that 15 of the 16 modules were acceptable, so TARDEC and USBR decided to operate the UF system with only 15 membranes. After completion of the individual module pressure decay tests and repairs, the full system pressure decay rate was 0.025 psig/min. This value was more than ten times lower than the mean value of 0.29 psig/min obtained during the 2006 verification test. This indicated that the repairs made to the UF system following the 2006 test were providing better membrane module pressure-hold capability.

Finished Water Quality

For the 2007 retest, the UF system reduced the turbidity from a mean of 2.3 NTU in the feed water to a mean of 0.14 NTU in the UF filtrate. Despite the UF system integrity issues during the 2006 test, the 2006 mean filtrate turbidity was the same as for the 2007 test. Turbidity in the feed water was reduced by a mean value of 92.5%. There were two spikes in the feed water turbidity – on August 6, and from August 20 to 22. Both spikes were likely caused by rain events on these days. These feed water turbidity spikes did cause small increases in the filtrate turbidity, but only one measurement – 0.51 NTU on August 22 – was above 0.3 NTU. Therefore, the UF system also met the NPDWR turbidity requirements during the 2007 test.

UF Membrane Integrity

Pressure decay tests were again conducted daily for the 2007 UF system retest. The observed pressure decay rates were 5-10 times lower than those from the 2006 test, with a mean value of 0.025 psig/min. These direct integrity test results were indicative of membrane modules with no significant observable breaches.

The mean 2 to 3 μm particle count for the feed water was 13,376/10 mL. The range of 2 to 3 μm particle counts for the feed water was 1 to 39,418/10 mL. The filtrate had a mean particle count in the 2 to 3 μm size of 112/10 mL with a median of 55/10 mL and a range of 0 to 13,908/10 mL. However, the maximum particle count of 13,908 may not be indicative of typical performance. The UF system went through a backflush cycle every half-hour, and during these backflushes the particle counts were still being recorded. Consequently, the filtrate particle count data included numerous spikes. The backflushes were not time-stamped, so the spikes due to backflushes could not be identified with certainty and removed from the data set. As evidenced by the low mean and median filtrate counts, most of the counts were less than 200/10 mL. The UF system reduced the 2 to 3 μm particles by a mean value of 2.21 $\log_{10}$.

The mean 3 to 5 μm particle count for the feed water was 24,634/10 mL. The range of 3 to 5 μm particle counts for the feed water was 0 to 91,595/10 mL. The filtrate had a mean 3 to 5 μm particle count of 157/10 mL with a median of 77/10 mL and a range of 0 to 14,059/10 mL. As with the 2 to 3 μm maximum count, the 3 to 5 μm maximum count of 14,059 may not be indicative of UF performance due to particle count data being collected during the backflushes. The UF system reduced the 3 to 5 μm particles by a mean value of 2.33 $\log_{10}$.

The geometric mean UF feed *Bacillus* endospore count was 1,562 CFU/100 mL, with range of 862 to 7,420 CFU/100 mL. The mean filtrate endospore count was 203 CFU/100 mL, with a range of 78 to 996 CFU/100 mL. The mean log reduction was 0.88 $\log_{10}$ with a range of 0.07 to 1.74 $\log_{10}$ for the feed and filtrate sample pairs. This was a lower reduction than predicted based on the observed pressure decay rates and the particle count data. To explore the concern of membrane module integrity further, additional studies were conducted on selected modules from this UF skid. Results from these additional studies conducted at the NSF testing facility in Ann Arbor, MI, are not presented in this verification report. The following reference report provides separate ETV verification testing results for the laboratory challenge study of selected EUWP UF modules: "Removal of Microbial Contaminants in Drinking Water: Koch Membrane Systems, Inc. Targa® 10-48-35-PMC™ Ultrafiltration Membrane, as Used in the Village Marine Tec. Expeditionary Unit Water Purifier", EPA/600/R-09/075, http://www.epa.gov/etv.

UF System Operation

The 2007 UF system retest operations data are presented in Table VS-iv. With only 15 modules in operation, the mean feed and filtrate flow rates of 232 gpm and 206 gpm, respectively, were lower than those for the 2006 test. Based on the mean flow rates, the mean water recovery for the UF system was 88.8%. The 206 gpm mean filtrate flow corresponds to a 24-h production rate of 296,640 gpd. Subtracting the backwash water from the calculated daily filtrate production results in 253,440 gpd of UF product water, which is still above the design UF production of 250,000 gpd, despite being short one module.

Actual UF filtrate production was tracked using the RO feed totalizer. The total filtrate produced (not including backwash water) was 3,551,000 gal over 350.1 h of operation. This yields a mean useable UF filtrate production of 242,500 gpd. If the filtrate water used for backwashing the system is added (595,730 gal) to this production volume, then the mean total filtrate production is 283,200 gpd.

Table VS-iv. UF System Operations Productivity Data for 2007 Test

Parameter	Count	Mean	Median	Minimum	Maximum	Standard Deviation	95% Confidence Interval
UF Operation per day (h)	25	13.8	14.3	4.0	21.5	4.6	± 1.8
Intake Flow (gpm)	44	288	296	235	303	16.2	± 4.8
Feed Flow (gpm)	45	232	237	174	271	19.7	± 5.7
Filtrate Flow (gpm)	45	206	212	148	245	19.6	5.7
Retentate Flow (gpm)	44	26	26	25	28	0.7	± 0.2
Backwash Flow (gpm)	Not measured – approximately 900 gal per backwash						
Feed Pressure (psig)	45	24	25	13	32	5.9	± 1.7
Retentate Pressure (psig)	45	22	23	11	31	5.8	± 1.7
Filtrate Temperature (°F)	45	74	75	62	84	5.3	± 1.6

From August 2 through 7, the feed water pressure needed to be increased every day to maintain the target filtrate flow rate. During this time, TMP increased from 7 to 17 psig. On August 7, the UF system was shutdown for a chemical cleaning, and put back into service on August 9. The TMP did not drop as a result of the cleaning, but instead further increased up to 22 psig on August 12. Therefore, the feed pressure was increased to 30 psig in order to maintain water flow rates. The UF system was again shutdown and a second chemical cleaning performed on August 13. This cleaning dropped the TMP down to 16 psig. The feed water pressure was increased again to over 30 psig on August 14 and TMP increased accordingly. A decision was made to operate the UF system at the higher feed water pressure and TMP, since these pressures were still within the design specification and operating specification for the unit. The UF feed pressure remained steady for several days and was actually lower during the last week of the test. TMP remained fairly steady at around 20 psig for the duration of the test.

As the TMP increased, the specific flux declined. The CIP was successful in stabilizing the drop in specific flux, but did not result in returning the membrane to the specific flux attained at the beginning of the test. The specific flux at the start of the test on July 30 was 4.62 gfd/psig. The specific flux dropped to 1.78 gfd/psig on August 7, then remained between 1.12 and 2.18 gfd/psig for the remainder of the test.

Ferric chloride was also used as a coagulant during the retest. During the initial test runs for the retest, jar tests showed a ferric chloride dose of 1 mg/L as Fe should be the target feed rate. This feed rate was maintained until the rapid increase in TMP and drop in specific flux occurred. After the chemical cleaning on August 7 and 8, the ferric chloride feed rate was increased to 2 mg/L as Fe. Subsequent jar tests suggested that with the low source water turbidity, the ferric chloride feed should actually be decreased. The ferric chloride feed was shut off on August 10 and remained off until the CIP was required on August 13. The rapid loss of flux and rise in TMP indicated that the coagulant should be used in the system, but at a lower dose than used at the start of the test. The ferric chloride feed was set at 0.2 mL/min (0.02 mg/L as Fe) and continued at that rate for the remainder of the test.

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

NSF provided technical and quality assurance oversight of the verification testing as described in the verification report, including a review of 100% of the data. NSF QA personnel also conducted a technical systems audit during testing to ensure the testing was in compliance with the test plan. One important finding was that the particle count data from the 2006 test was incorrect due to improper calibration of the particle counters. The particle counters were calibrated properly for the 2007 retest, so only the particle count data from the 2007 test is reported.

A complete description of the QA/QC procedures is provided in the verification report.

Original signed by Sally Gutierrez 11/24/09

Sally Gutierrez Date
Director
National Risk Management Research Laboratory
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Original signed by Robert Ferguson 12/14/09

Robert Ferguson Date
Vice President
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Availability of Supporting Documents

Copies of the test protocol, the verification statement, and the verification report (NSF report # NSF 09/28/EPADWCTR) are available from the following sources:

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