FIELD OPERATIONS DOCUMENT

EPA/NSF ENVIRONMENTAL TECHNOLOGY VERIFICATION TEST OF
THE OXI GENERATOR MODEL OXI-2B
AT SJWD WATER DISTRICT DRINKING WATER PLANT, LYMAN, SOUTH CAROLINA

Prepared for NSF International, Inc. Ann Arbor, MI.
and OXI Company, Inc., Virginia Beach, Virginia

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ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are presented here for subsequent reference in the Field Operations Document.

AC	alternating current
CT	contact time
DBP	disinfection by-product
DC	direct current
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
FOD	field operations document
gpm	gallons per minute
HAAs	haloacetic acids
HPC	heterotrophic plate count
HRT	hydraulic retention time
KWh	kilo watt hour
Lb	pound
LCS	laboratory control spike
LSCD	laboratory control spike duplicate
mg/l	milligrams per liter
MS/MSD	matrix spike/matrix spike duplicate
Nm	nanometer
OSHA	Occupational Safety & Health Administration
PEA	performance evaluation audit
PE(S)	performance evaluation (sample)
QAPP	quality assurance project plan
QA/QC	quality assurance, quality control
TDS	total dissolved solids
TOC	total organic carbon
TSA	technical system audit
TTHMs	total trihalomethanes
EPA	Environmental Protection Agency
UVA	ultra violet absorbance

EXECUTIVE SUMMARY

This Field Operation Document (FOD) is intended to meet the requirements outlined under NSF International's and the United States Environmental Protection Agency's Environmental Technology Verification (ETV) program's *Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminants*. The equipment being tested is the OXI-2B mixed oxidant generation system manufactured by OXI Co. ARCADIS Geragthy & Miller will serve as the Field Testing Organization during this verification program. On behalf of OXI Co., ARCADIS Geraghty & Miller has generated this FOD and will oversee the implementation of the verification program on site as specified in the EPA/NSF Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminants. The host site for this demonstration is the SJWD Water District Drinking Water Treatment Plant in Lyman, South Carolina. The actual verification interval will be 30 days in length and will commence June 12, 2000.

The principle of on-site mixed oxidant generation is an electrolytic cell using ion selective membrane technology to produce an oxidant gas that consists of chlorine and other short lived chlorine and oxygen radicals. In water, these products react to form compounds that are identical to those found when chlorine is dosed directly. The mixed oxidant gases produced are aspirated directly into the water stream. Additional equipment shall consist of two baffled 200-gallon tanks in series to establish a concentration time (CT) value of about 70.

The test is intended to verify that the OXI-2B onsite generator uses a maximum of 2 LB of salt (NaCl) and a maximum of 2.6 AC kilowatt hours of power to produce at least 1 LB of total chlorine in water. Also, the OXI-2B system will produce a 4 log kill of *P. aeruginosa* bacteria when chlorine is dosed to achieve a CT of 70 in water with a pH between 6.0 and 8.0 and turbidity of 20 NTU or less, organic carbon concentrations between 1.0 and 3.0 and an alkalinity less than 20 mg/l as $CaCO_3$.

Multiple untreated and treated water quality parameters will be monitored during the test period. These parameters include: pH, temperature, turbidity, disinfectant residual, alkalinity, total dissolved solids (TDS), total organic carbon (TOC), UV absorbance at 254 nm (UVA), true color, iron, manganese, chloride, sodium, total coliforms, and heterotrophic plate count (HPC) bacteria. Sampling will be performed during steady-state operation of the disinfection equipment. In addition, a 2-hour challenge test will be performed to verify the *Pseudomonas aeruginosa* kill.

Sampling and operational data shall be recorded and summarized in a comprehensive test report to be submitted to NSF two weeks after the last data have been received from the laboratory. This date is estimated to be in early August, 2000.

EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

This Field Operation Document (FOD) is intended to serve as a protocol under the United States Environmental Protection Agency's Environmental Technology Verification program (ETV) for the verification of an innovative on-site mixed oxidant generator system (model OXI-2B) manufactured by OXI Co., (Virginia Beach, VA). OXI Co. will be responsible for the supply, initial installation, and start-up of the OXI-2B generator at the verification site. In addition, OXI Co. has directed the development of the purpose statements for this verification program and has contributed to this document by supplying information about the principles of operation.

Roles and Responsibilities

ARCADIS Geragthy & Miller will serve as the Field Testing Organization (FTO) during the OXI-2B verification program. On behalf of OXI Co., ARCADIS Geraghty & Miller has prepared this FOD and will oversee the implementation of the verification program on site as specified in the Protocol for Equipment Verification Testing for Inactivation of Microbiological Contaminants. The ARCADIS Geraghty & Miller project manager, Michiel Doorn, will be responsible for the performance of the verification program as outlined below. David Liles, an environmental microbiologist with ARCADIS Geraghty & Miller and will be responsible and on-site for the microbiological challenge testing. An organization chart that provides the ARCADIS Geraghty & Miller personnel structure for the project is provided in Figure 1 and Table 1 contains the primary points of contact for the OXI-2B verification program. Following the completion of the OXI-2B verification program, ARCADIS Geraghty & Miller will generate and submit a report summarizing the results of the equipment verification. During the performance of this work, ARCADIS Geraghty & Miller will utilize the services of selected subcontract labs and the laboratory at SJWD to perform analytical testing. Mr. Doug Waldrop will serve as the primary SJWD contact. Ms. Jennifer Shiffer is the manager of the SJWD laboratory and will be the primary analytical contact at SJWD. Environmental Health Labs (EHL) of South Bend, Indiana and Magellan Laboratory of Morrisville, North Carolina will serve as off-site subcontract labs during the completion of this verification program. These laboratories will be responsible for generating laboratory results in compliance with the methods listed in this FOD.

TABLE 1. PRIMARY POINTS OF CONTACT FOR THE OXI-2B VERIFICATION PROGRAM

Name	Organization	Mailing Address	E-mail Address	Phone Number Fax Number	Role in Project
Michiel Doorn	ARCADIS Geraghty & Miller	4915 Prospectus Dr., Ste F Durham, NC 27713	mdoorn@gmgw.com	(919) 544-4535 (919) 544-5690	Project Manager
Dave Liles	ARCADIS Geraghty & Miller	4915 Prospectus Dr., Ste F Durham, NC 27713	dliles@gmgw.com	(919) 544-4535 (919) 544-5690	Microbiologist Challenge Testing
Ms. Libby Beach	ARCADIS Geraghty & Miller	4915 Prospectus Dr., Ste F Durham, NC 27713	Lbeach@gmgw.com	(919) 544-4535 (919) 544-5690	QA/QC
Jerry Revis	ARCADIS Geraghty & Miller	4915 Prospectus Dr., Ste F Durham, NC 27713	jrevis@gmgw.com	(919) 544-4535 (919) 544-5690	Project Safety Officer
Dr. Jane McLamarrah, PE	ARCADIS Geraghty & Miller	420 Park avenue, Greenville SC 29602		(864) 242 1717 (864) 235 9062	Field Coordinator Field QA person
Randy Hildebran PE	ARCADIS Geraghty & Miller	2301 Rexwoods Dr., Ste 102 Raleigh, NC 27607		(919) 782-5511 (919) 752-5905	Project Engineer, Water Specialist
Don Meyers	OXI Co.	700 Oriole Drive, Unit 111A, Virginia Beach, VA 23451	donald.e.meyers@worldnet.att.net	(757) 422-0177 (757) 422-9716	Manufacturer Contact
Doug Waldrop	SJWD Drinking Water Plant	161 Groce Road Lyman, SC 29365	dwaldro@mail.lig.bellsouth.net	(864) 439-4423 (864) 949-3511	Site Representative
Ms. Carol Becker	NSF International	P.O. Box 130140 Ann Arbor, MI 48113-0140	Becker@nsf.org	(800) 673-6275	NSF Assistant Project Manager
Jeff Adams	US EPA-ETV	690 EPA, 26 West Martin Luther King Dr. Cincinnati, OH 45268	Adams.jeff@epamail.epa.gov	(513) 569-7835	EPA Project Officer

Test Site

The host site for this demonstration is the SJWD Water District Drinking Water Treatment Plant in Lyman, South Carolina. The SJWD Water District Drinking Water Treatment Plant draws water from the Middle Tyger River. The Middle Tyger River is identified as watershed 03050107-040 and is located in Greenville and Spartanburg Counties (See Figure 2). The watershed occupies 64,948 acres of the Piedmont region of South Carolina. The predominant soil types consist of an association of the Cecil series. Land use/land cover in the watershed includes: 9.02 percent urban land, 23.85 percent agricultural land, 0.77 percent scrub/shrub land, 1.08 percent barren land, 64.32 percent forested land, and 0.95 percent water. There are several ponds and lakes (16-500 acres) in this watershed used for recreation, industrial, municipal and irrigation purposes. There are a total of 120.3 stream miles in the Middle Tyger River. There are three monitoring sites along the Middle Tyger River. The three sites are illustrated in Figure 2. Aquatic life uses are fully supported at the upstream site based on the macroinvertebrate community, but may be threatened by a significantly increasing trend in turbidity, occurrences of zinc, and a very high concentration of cadmium measured in sediment. Aquatic life uses are fully supported at the midstream site but may be threatened by a significantly decreasing trend in pH. Aquatic life uses are fully supported at the downstream site based on physical, chemical and macroinvertebrate community data. Recreational uses are not supported at any site due to fecal coliform bacteria excursions and there is a significantly increasing trend in fecal coliform bacteria concentration.

At the SJWD Drinking Water Treatment Plant, Middle Tyger River water is withdrawn into a flash mixer where sodium hydroxide, alum and free chlorine are added. Next the water moves through 4-stage flocculators and into sedimentation basins. Following the sedimentation basins, the water being processed goes through dual media sand/anthracite filters into a clear well where addition of sodium hydroxide, phosphate, and occasionally free chlorine takes place. The clear well effluent goes into a storage reservoir prior to being distributed to the public.

SJWD generously offered to provide a suitable roofed storage structure in which to site the OXI-2B during the verification interval. Through existing river access, SJWD will allow ARCADIS Geraghty & Miller to withdraw 23 gallons per minute (gpm) of raw water from the Middle Tyger River for the verification project. Figure 3 illustrates the SJWD Water District drinking water plant, the location of the OXI-2B, and the proposed route for raw and discharged water flow. SJWD personnel have authorized the discharge of all treated water to the alum sludge pond.

EQUIPMENT CAPABILITIES AND DESCRIPTION

Statements of Performance Capabilities

The OXI-2B onsite generator uses a maximum of 2 LB of salt (NaCl) and a maximum of 2.6 AC kilowatt hours of power to produce at least 1 LB of total chlorine in water.

The OXI-2B system will produce a 4 log kill of *P. aeruginosa* bacteria when chlorine is dosed to achieve a CT of 70 in water with a pH between 6.0 and 8.0 and turbidity of 20 NTU or less, organic carbon concentrations between 1.0 and 3.0 and an alkalinity less than 20 mg/l as $CaCO_3$.

Equipment Description and Scientific Concepts

To test the OXI-2B system without interfering with the existing operations of the SJWD facility, a parallel treatment system has been established for the purposes of this demonstration program. The system begins with a pump that will draw from an existing intake sump on the Middle Tyger River. This pump will have a capacity larger than that needed for this demonstration and a throttling valve to regulate the flow to 23 gpm. The verification system set-up is shown in Figure 4.

The disinfectant gas generation unit supplied by OXI Co. for the verification program is the OXI-2B. The unit uses sodium chloride (NaCl) brine to produce disinfectant gas that consists of chlorine and short-lived oxygen radicals, as was stated by the manufacturer. This gas is sucked into a side stream of the water by means of a venturi. Figures 5 and 6 are photographs of the front and back of the unit. Figure 7 is a simplified installation drawing provided by OXI.

The key part of the unit consists of an anode and cathode compartment separated by a proprietary membrane. The membrane will allow positively charged ions to pass through but will block negatively charged ions. When NaCl is dissolved in water it ionizes to (CL^-) and (Na^+) ions and when a DC voltage is imposed across the cell, the positively charged ions (Na^+) are attracted to the negatively charged cathode and pass through the membrane. The (Cl^-) ions are attracted to the positively charged anode and stay in the anode compartment. Since an electrolyte is initially electrically neutral, an imbalance is created because the positive ions have passed through the membrane leaving the negatively charged (Cl^-) ions without a neutralizing positive charge. To compensate for this, (Cl^-) ions combine to form Cl_2 molecules thereby releasing two electrons. The chlorine initially reacts with water, thereby creating hypochlorite and hydrochloric acid which will lower the pH in the anode compartment.

Reactions at anode:

- $2\,Cl^- \rightarrow Cl_2 + 2\,e^-$
- $Cl_2 + 2H_2O \leftrightarrow HOCl + HCl$

At a pH of about 2, an equilibrium is reached where free Cl_2 gas does not react with water anymore and is released to the air in the upper part of the anode compartment, where it reacts with air to form mixed oxidants. Next, the mixed oxidant gases are sucked into the stream of water by means of a venturi. In water, the mixed oxidant gases quickly form products comparable to those from standard chlorine/hypochlorite dosage and can, therefore, be quantified as free or total chlorine. Because the mixed oxidants are short-lived it is difficult to identify them separately in the water. Also, there is no established method to measure mixed oxidants. While in the gas phase, before they enter the water, the mixed oxidants may possibly be speciated with a mass spectrometer in a laboratory. This is considered to be beyond the scope of this field test.

At the cathode, sodium (Na^+) ions combine with OH^- ions to form NAOH (sodium hydroxide). The cathode side of the OXI unit produces 1.1 g of sodium hydroxide for each g of chlorine produced. A timer is factory preset to periodically add water to the cathode compartment keeping the sodium hydroxide concentration in the 5% - 10% range. During this water addition cycle, the diluted sodium hydroxide overflows into the drain manifold on the rear of the stand where it mixes with the (slightly) acidic overflow from the anode compartment. The result is a high pH solution with a total dissolved solids (TDS) content of about 120 mg/l that is be piped to a drain or waste collector.

Reactions at cathode:

- $2\ H_2O + 2\ e^- \rightarrow H_2\uparrow + 2\ OH^-$
- $Na^+ + OH^- \rightarrow NaOH$

On a direct molar basis the cathode generates 11.2 liters of hydrogen for each 35.5 gram (g) of chlorine. A fitting and a tube on the cathode compartment lid are used to vent this small amount of hydrogen produced to a safe distance away from the generator.

In order to have sufficient salt to sustain operation it is necessary to continually flow brine through the anode compartment. Brine is continually pumped into the anode compartment by a diaphragm pump with an adjustable stroke, causing a slight overflow. This overflow enters the drain manifold on the rear of the stand, where it mixes with the sodium hydroxide from the cathode compartment.

The brine tank holds a large reserve of salt and brine, as well as a sequestering agent. A sequestering agent is used to inhibit chemical precipitation of calcium carbonate to avoid clogging the OXI membrane. The OXI sequestering agent is a proprietary product developed by the Mayo Chemical Company specifically for OXI. Salt must be added manually to the brine tank about every 15 days of actual operation. The brine tank is fed by a tap water hose and has a floater valve that controls the tap water supply.

The system operates in automatic mode, with the mixed oxidant gas being injected (sucked) under a slight vacuum into a side stream of raw water. The side stream is then mixed with the main raw water flow. The combined flow then enters a contactor consisting of two baffled, 200-gallon tanks in series to establish a minimum CT of 70. Finally the flow will be discharged in the alum settling sludge holding pond. (See Figure 4.)

The OXI system power supply uses a Zero Current Switching (ZCS) technology to convert 115 or 220 volt AC to 10 volt DC. ZCS offers reliable high power density with fast response, very low conducted and radiated noise, and requires minimal cooling. The advantages of using this technology as a DC supply for the OXI electrolytic cell are a significantly lower AC power requirement with less heat generation in the cell and the ability to mount the power supply components in a gas tight box so that all power supply components are completely protected from corrosion. The control system for the OXI unit is preset at the factory on the internal control boards of the unit. Manual control of the current for the unit is performed at the door panel. Once adjusted this amperage will be maintained until manually changed. The rate of mixed oxidant generation can be manually controlled by the operator or automatically controlled by a chlorine residual or ORP controller.

Construction and Components

The OXI system consists of two cell halves bolted together for shipment, a brine tank and pump, a stand with the power supply and piping attached, and a box of accessories. The cell is PVC and is strapped to the pallet for shipping. It will last indefinitely if not dropped. The power supply is in a fiberglass enclosure mounted to an aluminum stand which is in turn mounted to the pallet. The brine pump is also mounted to the pallet and the plastic brine tank sits on the pallet. Where possible, all components are plastic. Table 2, includes a component list.

TABLE 2: OXI-2B LIST OF COMPONENTS

Component	**Material**	**Remarks**
Brine tank	Plastic	Makes and holds brine
Anode and cathode compartment	PVC	
Anode	Metal	Titanium coated with rare earth metal (proprietary)
Membrane	Ceramic	(proprietary)
Cathode	Metal	Perforated stainless steel
Injector tubing	Kynar	
Water supply lines	Plastic	
Injector	Kynar	
Inlet filter	Plastic	Screen for suspended solids
Flow control valve	PVC and rubber	Fixed value flow control
Cathode	Stainless steel	perforated
Membrane	proprietary	Ion selective
Overflow	PVC	
Power supply	miscellaneous	Zero current, AC/DC converter
Pallet	PVC	Permanent base for components

General Environmental Requirements and Limitations, Weight, Transportability, and Ruggedness

The weight of the unit is 225 lb. The unit is shipped assembled on a plastic pallet and is, therefore, easy to handle. The dimensions are 48" wide x 40" deep x 48" high.

The preferred installation location for the OXI-2B is indoors. Outdoor installation is acceptable provided that it is placed under a shed type roof with sufficient drop siding to protect the unit from direct rainfall. If an outdoor location is chosen, freeze protection for the water lines should be considered, depending on climatic conditions. Brine and sodium hydroxide, at the recommended operating conditions, should not be subject to freezing at normally encountered conditions.

Currently there are no known drinking water treatment processes that are incompatible with the addition of mixed oxidant gases generated by the unit. Regarding the performance of the unit, the manufacturer acknowledges that extremes in raw water quality could negatively affect its performance. Primarily, unforeseen extremes in the either organic or inorganic oxidizable species could result in a requirement for more mixed oxidant gas than a particular system has been engineered to provide. According to the manufacturer, the Middle Tyger River is a qualified source of raw water for conventional drinking water treatment. The OXI unit is expected to be capable of successfully treating all types of normal raw water as may be expected from the Middle Tyger River. The pH values should be between 6.5 and 7.5, whereas maximum values for other parameters are:

Turbidity	50 NTU
Alkalinity	20 mg/L CaCO3
Hardness	10 mg/L CaCO3
Iron	2.9 mg/L
Manganese	2.0 mg/L
TOC	3.0 mg/L
Total Solids	70 mg/L

Finished water, as well as waste will be discharged to the alum sludge pond. This procedure has been allowed by SJWD staff and a letter was sent to inform the state of South Carolina. In a telephone conversation with Dr. Jane McLamarrah of ARCADIS Geraghty & Miller, Mr. Greg McGlohorn of South Carolina, DHEC {(803) 898-3480} informed ARCADIS that the State has no objection to the test.

Typical Rates of Consumption and Performance Range

The quantity of mixed oxidant gas generated by the OXI cell is a linear function of the DC amperage input to the cell. For example, the OXI-2B produces 2 kg (4.4 lbs) of mixed oxidant (measured as free and/or total chlorine) gas in a 24 hour period at the factory set maximum DC amperage of 60 amps. Thus, reducing the DC amperage to 30 cuts the production by 50% to 1 kg (2.2 lbs) in 24 hours of operation. Table 3 includes a material balance.

Consumables for this system are electricity, salt, minimal potable water, and a minimal amount of proprietary sequestering agent. The characteristics of pelletized sodium chloride are well known and documented in the literature and will not be further investigated during this test. The price of this material will be reported based on quotes from two or more bulk chemical suppliers in the final report.

TABLE 3: MATERIAL BALANCE FOR THE OXI-2B

Input per day		Output per day			
Salt	Power	Chlorine*	H_2	NaOH	Waste stream
kg (lbs)	kWh	kg(lbs)	liter (cu. ft)	kg(lbs)	liter (gal)
4 (8.8)	11	2 (4.4)	623 (22)	2.2 (4.84)	33 (8.5)

*Mixed oxidant (measured as free and/or total chlorine)

Operation of the OXI cell results in the output of two waste products. Hydrogen gas from the cathode compartment is vented to the atmosphere. Sodium hydroxide in the cathode compartment, and chloride products, as well as a slight brine overflow from the anode compartment, are combined in a high pH waste stream. On a direct molar basis an OXI cell generates 11.2 liters of hydrogen for each 35.5 gram (g) of mixed oxidant (measured as free and/or total chlorine) produced.

Licensing Requirements

There are no special licensing requirements associated with the operation of the equipment.

Relationship to Existing Equipment

The supply of raw water for the verification program will be the river water intake for the SJWD plant, parallel to the plant intake. After treatment by the OXI-2B, the finished water will be discharged to the alum sludge holding pond. Thus the installation and operation of the OXI-2B will not affect regular plant processes.

Purpose of Equipment

The OXI mixed oxidant generators use brine to produce an oxidant gas that is measured as free and/or total chlorine. The OXI units can be applied to any application where chlorine or its derivatives are used. Drinking water disinfection, sewage treatment, cooling tower algae and slime control, and microorganism contamination control in food processing are a few applications. The primary advantage of the OXI systems are that they produce a very powerful oxidant gas on site, as needed, which is aspirated directly into the water to be treated thus eliminating all transportation, handling and storage problems associated with conventional treatment chemicals. At the SJWD site the mixed oxidant product from the OXI-2B would be envisioned as direct replacement for the chlorine gas currently used for disinfection.

EXPERIMENTAL DESIGN

This section will identify the qualitative and quantitative factors of OXI-2B operation that will be addressed during the verification program. It is the goal of the verification program described in this document to provide information pertinent to understanding the factors described below.

Qualitative Factors

As with any piece of equipment, operator time required by the OXI-2B will play a principal role in the practicality of its use. If the equipment requires only infrequent adjustments, a high degree of reliability and operating ease is reflected and results in potential savings to the equipment owner. Estimations of man-hours and dollars required to operate the system per thousand gallons of water processed will be made during the verification test to facilitate a qualitative evaluation of ease of use during report generation. Notes recorded in a logbook located near the OXI-2B will document the extent of operator time that is required to keep the system in working order. This notebook will not include entries that are pertinent only to the verification of the equipment. For example, time spent obtaining a grab sample of the treated effluent will not be entered into the logbook if the sample is pertinent only to the goals of the verification test.

Correlation of frequent and significant equipment adjustments with changes of inlet water quality could indicate equipment susceptibility to variable inlet water quality or environmental conditions. The requirements for such equipment adjustment will be evaluated during project report generation by interpretation of the logbook entries.

Operators do not require safety equipment while operating the OXI-2B unit, however, safety goggles and gloves should be worn when opening the system for service or maintenance. Before it is neutralized, sodium hydroxide produced in the cathode cell, is very corrosive and can cause severe burns. Chlorine produced in the OXI generator is aspirated directly to the treatment point and consequently, there is little opportunity for chlorine build up in the area. If some operational mishap does result in chlorine gas build up, the area should be vacated and ventilated until the chlorine has dissipated. Chlorine gas is a strong irritant, which attacks the upper and lower respiratory tracts. Hydrogen, in certain proportions with air, can be explosive. To avoid the possibility of explosion, adequate ventilation should be maintained, and smoking or open flames prohibited in the vicinity of the OXI generator. The hydrogen generated in the cathode compartment should be vented outside the room where the unit is installed using the vent tube fitting on the cathode lid.

The verification program in general and specifically operator input will qualitatively verify the OXI-2B’s compliance with all applicable safety concerns.

Quantitative Factors

The operation of the OXI-2B will be verified in terms of the concentration of mixed oxidant produced (measured as free and/or total chlorine concentration in the side stream), the electrical power consumption required per pound of available chlorine, the sodium chloride consumption per pound of available chlorine, the volume of potable make-up water consumed per pound of available chlorine, as well as the amount of waste generated. In addition, the estimated labor hours for operation and maintenance per pound of available chlorine will be semi-quantitatively estimated using the operator logbook discussed above.

To confirm the mixed oxidant concentration (as free and/or total chlorine) in the side stream, two samples will be collected per day. The samples will be analyzed for free and/or total chlorine content with a HACH DR/4000 spectrophotometer. Four samples will also be submitted during the verification program for chloride, chlorite, and chlorate analysis to complete the chlorine speciation. Determination of the volume of mixed oxidant solution consumed will be accomplished by routinely taking a volumetric sample from the injector line, which will be fitted with a T for this purpose.

An electrical meter will be used to total the kWh of power required. This number can be compared with mixed oxidant concentration and volume to determine the amount of electricity required per pound of available free and/or total chlorine. The sodium chloride consumption will be determined based on a comparison of the mass of sodium chloride added to the OXI-2B and the mixed oxidant concentration (as free and/or total chlorine) and volume of solution utilized. The data generated from tracking the consumption of these raw materials will be used during the final report generation to establish equipment performance and develop operation and maintenance costs.

A flow diagram with required hardware is included in Figure 4. The raw river water will be pumped to the OXI-2B in 2-inch PVC pipe using a cast iron centrifugal pump. A side stream of the raw water will be directed to the OXI unit, where mixed oxidant will be aspirated into it (M.O. stream). The M.O. stream will be reunited with the main water stream (treated water). The treated water will then flow through 2-inch PVC pipe into two 200-gallon baffled polypropylene tanks with the influent and effluent of each tank being at the top. After leaving the tanks (finished water), a side stream of water will be directed to an HACH Model 1720D in-line turbidimeter. Once turbidity analysis is complete, the side stream will re-join the rest of the flow and enter a drain for transport to the alum sludge holding pond. Figure 4 illustrates the position of sampling ports for raw water, M.O. stream, treated water, and finished water, as well as valves and rotometers.

The flow of water through the tanks is not anticipated to constitute a true plug flow situation but if a plug flow situation is assumed, the contact time generated by placing the two tanks in series is calculated at 19 minutes (See next section). To achieve a CT of 70, 3.6.mg/l of residual chlorine is required. The chlorine demand of the raw water at SJWD plant is estimated by the operators to average about 2 mg/l. Thus, the target dose for the OXI system is an output of approximately 5.6 mg/l.

Hydrodynamic Tracer Test

As part of an earlier verification test on a comparable disinfectant dosage system (Exceltec), a tracer test was performed on March 18, 2000 to provide a profile of the tracer concentration through the disinfection equipment as a function of time. The compound chosen to serve as the tracer was potassium chloride (KCl). In preparation for the tracer test, raw water background concentrations of potassium were determined. The concentrated KCl solution was added continuously through a dosing port for 190 minutes.

Chlorine contact chamber effluent samples were taken at 10-minute intervals throughout the 190-minute tracer test, with the first sample taken at 10 minutes after testing began. The target potassium concentration in the feed water to the unit (at 23 gpm) was 30 mg/l, which is greater than 10 times the background concentration, measured to be 2.6 mg/l during the test (note that the 10-minute effluent sample yielded a potassium concentration of only 1.5 mg/l, implying that the actual feed water background potassium concentration is variable and often less than the 2.6 mg/l measured on the referenced grab sample). Grab samples of the feed background, stock solution and effluent (at 10-minute intervals) were sent to Savannah Laboratories for analysis. The raw data results are included in the draft Exceltec Test Report and summarized in Table 4.

TABLE 4. TRACER TEST DATA.

Time (min)	Total K (mg/l)	F (%)
0	0	0.0%
10	1.5	5.2%
20	3.9	13.4%
30	11	37.9%
40	21	72.4%
50	24	82.8%
60	27	93.1%
70	29	100.0%
80	29	100.0%
90	29	100.0%
100	28	96.6%
110	28	96.6%
120	28	96.6%
130	28	96.6%
140	29	100.0%
150	28	96.6%
160	30	103.4%
170	29	100.0%
180	30	103.4%
190	27	93.1%

The results were plotted in an F-curve, as described in many chemical engineering and reactor analysis texts (Levenspiel, 1972). The F-curve shows the percentage of tracer recovered at discrete points in time (i.e., not cumulative) in the effluent versus time after starting the continuous tracer feed. The actual hydraulic retention time was calculated as the area above the curve, per the equation below (DiGiano, Weber, 1996).

$$HRT = t_m = \int_0^\infty t \cdot dF(t)$$

The F-curve was plotted on grid paper with a relatively fine grid resolution and the number of grid squares above the curve (up to 100% recovery) were manually counted. The hydraulic residence time (HRT) was then calculated per the equation below.

$$HRT = 213 squares \times \frac{0.04F}{grid} \times \frac{4\,\mathrm{min.}}{grid} = 34.1\,\mathrm{min.}$$

The chlorine contact chamber (CCC) for this system had a nominal capacity of 750 gallons. However, because of the location of the effluent overflow pipe and the head loss induced by piping between the three tanks employed, the actual volume of water contained in the CCC was approximately 850 gallons. At a volumetric capacity of 850 gallons and a measured flow rate of 23 gpm (87 l/min), the theoretical HRT for the CCC is 37 minutes. The actual experimentally measured HRT of 34.1 minutes indicates that while there was some short-circuiting, as expected, the overall performance of the experimental CCC was quite good (within 10% of theoretical).

The only difference between the Exceltec system and the OXI system is that for the OXI system uses two residence tanks and the Exceltec system used four residence tanks.

During the Exceltec tracer test it was established that the system from disinfectant injection point to the first tank has a volume of 50 liters. The HRT for this section is 50/87 = 0.57 minutes. Further it was measured that each tank has a volume of 795 liter. The pipe that connects the tanks has a negligible volume and the upstream and down stream components of the flow system are identical for Exceltec and OXI. As mentioned, the hydraulic retention time (HRT) for the four-tank system was 37 minutes at 23 gpm (87 l/min) corresponding to a total volume of 3,230 liters. Subtracting the two tanks (3,230 – 2 x 795 = 1640 liter) provides the HRT for the OXI set-up (two tanks) being 1640/87 = 19 minutes. Similarly the HRT for the section of the system to the sampling port after the first tank can be calculated, i.e., (1640 – 795)/87 = 10 minutes.

Range of Key Water Quality Parameters

Table 5 provides the typical variation in water quality parameters for the Middle Tyger River as summarized by SJWD personnel.

TABLE 5. TYPICAL RAW WATER PARAMETERS FOR THE MIDDLE TYGER RIVER

Parameter	Units	Quantity
DO	mg/L	<1.0 - Saturated
pH	S.U.	6.5 - 7.5
Turbidity	NTU	10 - >500
Alkalinity	mg/L $CaCO_3$	<20
Hardness	mg/L $CaCO_3$	<10
Phosphate	mg/L	0.3 - 0.6
Iron	mg/L	0.1 - 2.9
Manganese	mg/L	0.05 - 2.0
TOC	mg/L	2.0 - 3.0
SUVA	TOC/UV-254	2.0 - 4.0
Total Solids	mg/L	30 -70
Coliform	colonies/100 ml	0 - >100
Temperature	° C	4 - 28
Algae	Present/Absent	Present

Data Recording Protocol

During the verification interval, the OXI-2B will be visually inspected by SJWD operators or ARCADIS Geraghty & Miller staff a minimum of once per 8-hour shift. These visits will be regularly documented in a bound logbook that will be dedicated to the OXI-2B. The logbook will be utilized by SJWD operators during daily documentation of qualitative equipment performance. During the start-up of the OXI-2B, ARCADIS Geraghty & Miller anticipates a training session for SJWD staff that encompasses not only equipment operation but also focuses on proper documentation. ARCADIS Geraghty & Miller intends to have personnel at SJWD twice a week during the verification program. During these visits, ARCADIS Geraghty & Miller will verify that the logbook is being properly utilized and that the entries being made are informative.

All sampling data will be entered manually into sampling sheets which are stored in a binder that is located permanently in the laboratory of SJWD. In addition, turbidity measurements of finished water will be stored electronically in a spreadsheet. The system used is supplied by HACH Instruments as part of the turbidimeter package. The HACH AquaTrend® Interface with HACH Signal Output Module (SOM) is a microprocessor-based user interface designed to provide precise control of the 1720D system network. The HACH Serial I/O Module (SIO) provides a direct link between the 1720D/AquaTrend® network and a computer or printer via RS232 communication.

The data in the spreadsheets shall be checked daily against the manually entered data in the sample sheets.

A number of routine tests pertaining to water quality, including pH, temperature, turbidity, chlorine residual, hydrogen sulfide, alkalinity, dissolved solids, and total coliform and HPC bacteria will be performed in SJWD's existing laboratory. The results of these analyses will be available to ARCADIS Geraghty & Miller for use during final report generation in the same manner as SJWD's analytical results are available upon request to officials within South Carolina's drinking water regulatory community. Once the results of these analyses are made available in hard copy, the data will be entered into an electronic spreadsheet format at the ARCADIS Geraghty & Miller office.

Analyses for ammonia nitrogen, total organic carbon, true color, iron, manganese, bromide, sodium, potassium, chlorite, chloride, and chlorate, HAAs, and TTHMs will be shipped off-site to Environmental Health Laboratories (EHL). Also, the heavy metals scan will be done by EHL. EHL has been issued a certificate by the State of South Carolina (Certification No. 95005001) for various drinking water analyses including HAAs. Electronic or hard copy data will be returned from EHL and entered into spreadsheet format at the ARCADIS Geraghty & Miller office.

Confidence Interval Calculation Procedure

This procedure is fully standard and shall be identical to the procedure described in the ETV/NSF protocol, page 1-21. The volume of data collected for several analyses that are critical to the verification program will be substantial enough to justify the calculation of confidence intervals. Analyses that are performed at least daily such as pH, temperature, turbidity, total coliform enumeration, HPC enumeration, and chlorine residual will generate large data sets for which the calculation of confidence intervals will be an important part of the verification test data summary. Other analytes that are scheduled for weekly monitoring include alkalinity, ammonia nitrogen, UVA, and true color. The calculation of confidence intervals is also potentially justified for these parameters although these analytes are not expected to be as critical to the verification program as the daily analytes above. Confidence intervals will also be calculated for the *P. aeruginosa* enumeration analyses generated during the bacterial challenge testing (see Field Operations Procedures).

FIELD OPERATIONS PROCEDURES

Operation and Report Generation Schedule

ARCADIS Geraghty & Miller proposes the time schedule as laid out in Table 6 below. A detailed Sampling and Analysis Plan is included in Table 8.

TABLE 6: TIME SCHEDULE

Activity	Time Frame
OXI-2B Installation & Shake Down	May
Initiation of the Verification Test	June 12
NSF Site inspection	Tbd
Bacterial Challenge Testing	June 20 (tentative)
Final Verification Testing Sample Collection	July 12
Receipt of Bacterial Challenge Testing Data	July 10
Draft Report by ARCADIS Geraghty & Miller	August 1 (tentative)
Draft Report Review by NSF & OXI Co.	tbd
ARCADIS Geraghty & Miller Response to NSF Comments	tbd
Submittal of second draft by ARCADIS Geraghty & Miller	14 days after receipt of comments
Peer Review and EPA ETV Draft Report Review	tbd
ARCADIS Geraghty & Miller Response to Comments	tbd
Submittal of Final Report by ARCADIS Geraghty & Miller	14 days after receipt of comments

It is intended that the OXI-2B be operational around the clock for the period between June 12 and July 12 with the exception of a two hour long process control portion of the bacterial challenge testing during which mixed oxidant will be wasted. During the entire 30-day interval, the analyses indicated in Table 8 (Sampling and Analysis Plan) will be conducted at the frequency indicated.

Task 1-Equipment Operation and Disinfection Production Capabilities

Consistent with Performance Statement 1, the objectives of Task 1 include the generation of data that describe the operation of the OXI-2B and that can be used to develop an economic assessment of operational costs during the reporting phase of the project.

Task 1 will involve the collection and recording of data for the entire 30-day verification interval. The data generated by the operation of the OXI-2B include the rate of consumption of power and salt. Additionally, the total generated volume and concentration of mixed oxidant will be determined and recorded. This will be done by determining the volume of the side stream (M.O. steam) into which the mixed oxidant was dispersed, and the concentration of mixed oxidant (as free and/or total chlorine in mg/l). The mixed oxidant is dosed into the raw water to achieve a CT of approximately 70. Once per week a temporary connection will be established to flow potable water to the OXI aspirator. The purpose is to obtain a precise measurement of the M.O. dose (as total chlorine) as it is produced by the system. The free and total chlorine of the M.O. stream and the incoming potable water of will be measured. Subtraction will provide a precise quantification of the chlorine produced by the OXI. Prior to the measurement, the system will be flushed out with potable water for at least five minutes. (The flow through the line is approximately 3 gpm.)

Also, the electric power consumption of the system will be monitored. The raw water flow rate will be recorded twice daily. These recorded flow measurements will be used to calculate the total number of gallons that the OXI-2B treats during the verification program. The waste flow rate from the OXI system will be recorded twice daily and the waste composition will be determined once during the 30-day test. Waste components that will be measured include sodium, alkalinity, free and total chlorine, TDS, and NaOH. Also, a heavy metals (priority pollutants) scan will be performed on the waste stream from the system. Analytes will be: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc.

Table 7 summarizes the frequency and type of operational data to be recorded during Task 1 activities. Raw water flow will be determined by reading the scale of the rotometers shown in Figure 4. The power meter will total the OXI-2B power consumption during the verification interval. Totalized power consumption will be recorded daily. During the start-up and shakedown interval, SJWD and ARCADIS Geraghty & Miller personnel will be trained in how to properly read the various meters, totalizers, and rotometers.

TABLE 7. SUMMARY OF LOGBOOK MEASUREMENTS AND RECORDING FREQUENCY

Measurement	Recording Frequency
Total Raw Water Flow	Twice Daily
Waste Flow Rate	Twice Daily
Waste Stream Composition	Once per test
Totalized Power Consumption	Daily
M.O Stream Flow	Daily
Oxidant Concentration (as chlorine) in raw water	Twice Daily
Oxidant Concentration (as chlorine) in pot. water	Weekly
Visual Inspection for Leaks	Daily
Visual Inspection for Alarms	Once Per Shift
Man Hours Required to Operate the Unit	Daily

Task 2-Microbiological Contaminant Inactivation

The objective of this task is to characterize the OXI-2B's efficacy for inactivation of *P. aeruginosa*. *P. aeruginosa* has been selected by ARCADIS Geraghty & Miller as the bacterial challenge test organism. The Field Testing Organization anticipates that the choice of *P. aeruginosa* will provide acceptable specificity for the bacterial challenge test. The *Pseudomonas* species background in the raw water is expected to be negligible. The laboratory that will supply the *P. aeruginosa* culture and downstream enumeration is Magellan Laboratory in Morrisville, NC.

As indicated in Performance Statement 2, OXI Co. maintains that the mixed oxidant generated by the OXI-2B is capable of generating a 4-log kill of *P. aeruginosa* when dosed to achieve a CT of 70.

The target concentration for *P. aeruginosa* in broth culture is 1 x 10^8 cells/ml. Approximately one gallon of this cell suspension will be shipped to the SJWD Water Treatment Plant on ice. The broth will be subsampled to create a trip control that will remain on ice during the bacterial challenge-testing interval and then accompany the post-treatment samples to the analytical laboratory. Below, the different steps for the challenge test are spelled out:

1. In the absence of chlorine, a peristaltic pump and autoclaved tubing will be used to inject *P. aeruginosa* into the raw water line at a rate of 22.4 ml/min intended to establish a *P. aeruginosa* concentration of at least 5 x 10^5 CFU/100 ml. The flow rate of 22.4 ml/min is chosen to maximize microorganism concentration during the consumption of 1 gallon of growth broth over the course of the challenge test interval. The exact *P. Aeruginosa* concentration will be dependent on actual cell density in the growth broth, which can not be defined precisely. The pump flow rate will be confirmed using a graduated cylinder and stop watch as necessary. The raw water flow will be maintained at 23 gpm for a period of time equivalent to 3 hydraulic retention times (of 20 minutes each, equaling 60 minutes).

2. At the end of the 60-minute period, ARCADIS Geraghty & Miller will begin collecting three samples for *P. aeruginosa* at 10-minute intervals. After the collection of the third sample at 80 minutes of total elapsed time, ARCADIS Geraghty & Miller will commence adding chlorine at a dose of 5.6 mg/l.

3. After the elapse of 3 additional hydraulic retention times (60 minutes, or 150 minutes total) ARCADIS Geraghty & Miller will collect three sets of three samples for *P. aeruginosa* enumeration in the presence of chlorine disinfectant. For the first set of samples at 140 minutes total elapsed time, a sample will be collected from the 2nd contact tank (20 minute contact time), a sample will be collected from pipe between the 1st and 2nd contact tanks (10 minute contact time) and a sample will be collected from a sampling point prior to entering the 1st contact tank (0.6 seconds contact time). These samples will be collected with 10 minutes of elapsed time between them such that the test will conclude after the elapse of 160 total minutes.

4. Following collection, the samples will be shipped to Magellan Laboratory in Morrisville, NC for *P. aeruginosa* enumeration using Standard Methods 9213 E. Membrane Filter Technique for *P. aeruginosa*. Based on past experience, turbidity is less than 20 NTU. Should the turbidity be higher than 20 NTU at the time of the challenge test, ARCADIS will recommend postponing the challenge test until the turbidity is below 25 NTU.

5. The log removal shall be calculated according to the following equation: Log removal = log(concentration live *P. aeruginosa* in/concentration live P. *aeruginosa* out)

TABLE 8: SAMPLING AND ANALYSIS PLAN

Parameter	Sampling Frequency	Test Stream	Analytical Method	Analytical Laboratory	Reporting Limit	Hold Time	Container/ Preservative
pH	1/Day	Raw, Treated, Finished water, Waste	4500 H	SJWD	N/A	Analyze Immediately	
Temperature	1/Day	Raw, Treated, Finished water, Waste	2550 B	SJWD	N/A	Analyze Immediately	
Raw Water Turbidity	1/Day	Rawwater	2130 B	SJWD	0.1 NTU	48 hours	
Finished Water Turbidity	In-line	Finished water	Hach 1720D	NA	0 – 100 NTU	NA	NA
Chlorine Residual	2/Day	Raw, Finished water, M.O. stream (weekly for pot. Water)	4500-Cl F (as free and total chlorine)	SJWD	0.05 mg/L	Analyze Immediately	250-mL poly
Hydrogen Sulfide	1/Week	Raw	SM 4500-S2-A4c	SJWD	0.1 mg/L	Not specified	100-mL glass 4 drops zinc acetate
Alkalinity	1/Week	Raw, Finished, Waste	2320 B	SJWD	10 mg/L	14 days	250-mL poly/4 °C
TDS	2/Verification Test	Raw, Finished, Waste	2540 C	SJWD	5 mg/L	7 days	250-mL poly/4 °C
Total Coliform Bacteria	5/Week	Raw, Finished	9222 B	SJWD	2 MPN/100 ml	24 hours	Sterile, 100-mL poly/4 °C, 0.008% $Na_2S_2O_3$
HPC Bacteria	5/Week	Raw, Finished	9215 B	SJWD	1000 CFU/L	8 hours	Sterile, 100-mL poly/4 °C, 0.008% $Na_2S_2O_3$
Ammonia Nitrogen	1/Week	Raw, Finished	4500-NH_3 G	EHL	0.03 mg/L	28 days	100-mL poly/4 °C pH<2 W/ H_2SO_4
TOC	4/Verification Test	Raw, Finished	5310 C	EHL	1 mg/L		Glass/4 C
UVA	1/Week	Raw, Finished	5910 B	EHL			Glass/4 C
True Color	1/Week	Raw, Finished	2120 B	EHL	5 PCU	48 hours	250-mL poly/4 °C
Chloride	1/Week	Raw, Finished	300.0	EHL	1 mg/L	28 days	100-mL poly
Chlorite	1/Week	Raw, Finished	300.0 B	EHL	1 mg/L		
Chlorate	1/Week	Raw, Finished	300.0	EHL	1 mg/L		
Iron	2/Verification Test	Raw, Finished	200.7	EHL	50 ug/L	Analyze Immediately	250-mL poly/4 °C 2 ml HCL/100 ml
Manganese	2/Verification Test	Raw, Finished	200.7	EHL	10 ug/L		
Sodium	2/Verification Test	Raw, Finished	200.7	EHL	500 ug/ml	24 hours	Acid washed/4 C
Sodium hydroxide	2/Verification Test	Waste					
Heavy metals scan	2/Verification Test	Waste					
Potassium	See Tracer Test Protocol	Finished	200.7	EHL	1000 ug/L	24 hours	Acid washed/4 C
TTHMs	2/Verification Test	Raw, Finished	524.2	EHL	Analyte specific	14 days	2- 44.7 ml vials w/ 25 mg ascorbic acid & 0.3 ml HCl
HAAs	2/Verification Test	Raw, Finished	552.1	EHL	Analyte specific	14 days	3-44.7 ml amber vials w / 5 mg of NH_4Cl
P. aeruginosa Enumeration	See Challenge Test Protocol	1/Day Raw, Balance Finished and Controls	See Challenge Test Protocol	Magellan Laboratory	10/100 mL	24 hours	Autoclaved 1 liter glass

NA – Not Applicable; TBD – To be determined

M.O. stream is side stream of water with mixed oxidant coming from the unit, (see Figure 4)

Treated water is water immediately after having been dosed with M.O. water (see Figure 4)

Finished water is water after having gone through the entire system (see Figure 4)

Task 3-Finished Water Quality

The objective of this task is to assess the impact that treatment with mixed oxidant generated by the OXI-2B has on finished water quality.

ARCADIS Geraghty & Miller has prepared a summary of the types of finished water quality samples required during the verification program, the frequency with which individual analyses will be performed, the analytical methodologies that will be followed, and the reporting limits, holding times and sampling containers required. This information is summarized in which also lists the laboratory that is to perform individual analytical tests. Analyses to be performed at SJWD will be taken to the SJWD laboratory and either analyzed immediately or temporarily stored according to the guidelines in Table 8. ARCADIS Geraghty & Miller personnel will be at SJWD to collect analytical samples intended for shipment to off-site laboratories.

Operation and Maintenance

The list below includes all in-line equipment. See also Figures 4 and 7.

1. Centrifugal pump (Teel, from Grainger 2P104)
2. Rotometers (from McMaster 4400K59)
3. Check valve (off the shelve item)
4. Valves (of the shelve item)
5. Power meter (of the shelve item)
6. PVC piping and tubing (of the shelve item)
7. Baffled polyethylene tanks (of the shelve item)
8. Bulkhead fittings (of the shelve item)
9. Inline turbidimeter (Hach 1720D with AquaTrend interface)
10. OXI – 2B unit

Items 1 through 8 do not require maintenance during the test period. The operation of these items is automatic. ARCADIS Geraghty & Miller will inspect items 1 through 8 bi-weekly for proper operation and damage, e.g., leaks.

The HACH turbidimeter (item 9) requires no operational actions once it has been installed, calibrated, and started up. ARCADIS Geraghty & Miller personnel will visually inspect the instrument bi-weekly, which will include an inspection of the cell. If the cell shows visual signs of fouling or if the readings have become suspicious (e.g. erratic), ARCADIS Geraghty & Miller will clean and recalibrate the instrument according to manufacturer's instructions. The subsequent QA/QC entitled "Water Quality And Operational Control Checks" describes the QA/QC verifications that are required for the turbidimeter. (Note that EPA required recalibration and cleaning of the turbidimeter is once every three months.)

The OXI-2B and all its parts operate automatically. The following maintenance is required:

Daily: None

Weekly:

1. Check specific gravity of the sodium hydroxide in the cathode compartment using the hydrometer supplied with the unit to confirm that the water addition system is holding the specific gravity between the top of the red range and 10mm (3/8") over the top of the red range.
2. Check the drain line to assure that the anode compartment overflows as brine is added from the brine tank. This assures that sufficient brine is being made to sustain operation. Increase the % setting on the brine pump if brine overflow is not occurring.

Monthly:

1. Check salt usage. Salt usage is a function of "on time" and / or amperage. Salt addition is normally required every 15 days when the unit is operating at its rated amperage. Operation at lower amperages will increase the time between salt charges. If the unit is low on salt, the amperage will drop and the amperage control knob on the power supply front panel will not act as a control. Sequestering agent should be added with the salt to the brine tank.
2. Cleaning of the membrane is recommended every 90 operating days as long as recommended salt and sequestering agent are used. The life of the membrane is 6 to 12 months and is a function of the calcium content of the salt and the hardness and turbidity of the water. At the end of the 30-day test, ARCADIS Geragthy & Miller will clean the membrane following the manufacturers instructions in the O&M manual (see Appendix B)

The OXI-2B will be installed and started up by a OXI Co. Technician. This technician will provide operator training to ARCADIS Geraghty & Miller and SJWD personnel. Following installation and training the OXI-2B will become operational for a 24 to 48 hour interval for “shake-down”. During the shakedown interval, ARCADIS Geraghty & Miller and OXI Co. employees will be verifying the correct installation of the OXI-2B and establishing a photographic record of the unit and surrounding engineering improvements. At this time, detailed installation, trouble-shooting, and operation instructions included in the Operations Manual will be discussed with ARCADIS Geraghty & Miller and the SJWD staff.

In the event that operational problems develop during the verification interval, SJWD personnel or ARCADIS Geraghty & Miller staff will use the OXI Co. O&M Manual to trouble shoot the operational problem and report on the effectiveness of the O&M Manual in the logbook. A separate section in the verification report will summarize operational issues and the effectiveness of the O&M Manual. If troubleshooting by ARCADIS and SJWD fails to correct the operational issue, OXI Co. will be consulted.

QUALITY ASSURANCE PROJECT PLAN

Purpose And Scope

This QAPP documents the QA/QC procedures planned for verification tests performed under the ETV/NSF Inactivation of Microbiological Contaminants protocol. It specifies the procedures to be used to ensure data quality and integrity for the on-site mixed oxidant generator system developed by OXI Co. Careful adherence to these procedures will ensure that data generated from the verification testing at SJWD Drinking Water Treatment Plant will provide sound analytical results that can serve as the basis for performance verification. Any deviations from the plan will be documented and approved prior to implementation.

Quality Assurance Responsibilities

ARCADIS Geraghty & Miller will be the Field Testing Organization for this verification. Mr. Michiel Doorn is the Project Manager and will be responsible for the overall quality of the demonstration.

Ms. Laura Beach is ARCADIS Geraghty & Miller's Raleigh/RTP Office Quality Assurance Manager. She will be responsible for ensuring that all EPA/ETV QA/QC requirements are met for the verification testing. She will provide input and review on the QAPP and test plan. She will be responsible for planning and performing internal assessments to ensure that the project is performed according to plan and that any deviations from this QAPP are adequately documented. She will also provide laboratory data review and input to the final report.

Data Quality Indicator Goals For Critical Measurements

Critical measurement parameters are defined in Table 9 and data quality indicator (DQI) goals in terms of accuracy and precision are established for each critical measurement. These criteria will be evaluated throughout the duration of the project using quality control checks or audit samples and any measurements that do not meet these criteria will be assessed for usability. Any measurements exceeding these limits will be discussed in appropriate sections of the verification reports.

Accuracy

For water quality analyses, accuracy refers to the difference between a sample result and the reference or true value for the sample. Loss of accuracy can be caused by errors in standard preparation, equipment calibrations, loss of target analyte in sample preparation/extraction, interferences, and systematic errors within the analytical system. Loss of accuracy for microbial species can be caused by such factors as error in dilution or concentration, systematic errors or contamination from one sample to the next, or improper enumeration techniques. Accuracy for the parameters listed in Table 9 as analyzed by EHL will be assessed as follows. EHL will provide results of a laboratory control spike (LCS) as part of the AG&M Level II data package that we will request (we also intend to specifically request, and they have agreed to provide at no additional charge a laboratory control spike duplicate (LCSD)). They will also provide results of a batch specific matrix spike/matrix spike duplicate (MS/MSD a spiked sample from one of the batch of twenty samples associated with our samples, although not necessarily our sample). Finally they participate in an EPA sponsored performance evaluation sample (PES) study and will provide historical results for these studies for the past several years, which include many of the analytes required for our test program. Note however that a few parameters such as UVA and true color are not amenable to the preparation of such spiked samples. This strategy provides three measures of accuracy in similar although not identical matrices to our samples. Accuracy for the analysis of HAAs at EHL will be determined from the results of a Quality Control Sample, reported as part of the level "B" package we intend to request, as well as from the results of a batch specific matrix spike/matrix spike duplicate. Finally the laboratory has been certified for HAA testing under the EPA's Information Collection Rule and has continued to run single blind PE's for HAAs twice per year. Results of these PE's will be provided. Recovery of spiked analytes must fall within limits shown in Table 9 to be considered acceptable.

Accuracy of equipment/instrumentation used in the field for sampling will be verified using checks with traceable standards. Accuracy for on-site measurements including flow rates, pH, temperature and turbidity will be assessed by performing checks on measurement equipment against a known standard. The pH meter accuracy will be checked on a daily basis with a certified buffer using a 2-point calibration. Thermometer accuracy will be verified by calibrating against a NIST-certified thermometer once per week. The turbidimeter will be calibrated during start-up according to manufacturers instructions using manufacturer supplied calibration kit and checked daily against a calibrated bench-top model. The bench-top model shall be calibrated weekly to standards of 0.1, 0.5, and 3.0 NTU and checked with a secondary standard daily. The turbidimeter will be visually inspected weekly and if deviations are noted, and cleaned if necessary.

Precision

Precision is the degree of mutual agreement among individual measurements and provides an estimate of random error. Analytical precision is a measure of how far an individual measurement may be from the mean of replicate measurements and is referred to as relative standard deviation (RSD). Precision will be determined for the parameters analyzed by Savannah labs based on the relative percent difference of the LCS/LCSD and batch specific MS/MSDs described earlier. In addition a field duplicate is planned for TOC and *P. aeruginosa*. Precision for the analysis of HAAs at EHL will be determined from the relative percent difference of results of the batch specific MS/MSD. Precision for measurements made in the field will be determined from the relative percent difference of results of duplicate samples for critical parameters as discussed in the section "Water Quality and Operational Control Checks" or through replicate measurements and calculating relative standard deviation (%RSD). Field duplicates will be collected for chlorine residual, total coliform, and heterotrophic plate count analyses at a rate of one per every 10 regular samples. The results of these duplicate analyses can be used to determine the precision of the above listed analyses. Precision must fall within the limits given on Table 9 to be considered acceptable.

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. In this verification testing, representativeness will be ensured by executing consistent microbiological challenge spiking procedures and consistent sample collection procedures, including sample locations, timing of sample collection, sampling procedures, sample preservation, sample packaging and sample shipping. Representativeness will also be ensured by using each method at its optimum capability, to provide results that represent the most accurate and precise measurement it is capable of producing. For equipment operating parameters, representativeness entails collecting a sufficient quantity of data during operation to be able to detect a change in operation.

TABLE 9. DATA QUALITY INDICATOR GOALS FOR CRITICAL MEASUREMENTS

Parameter	Method	Accuracy	Precision (%RPD)
Flow Rates	Rotometer	± 2 g/min	N/A
M.O. stream conc.	4500-Cl F	N/A	40
M.O. stream flow	Rotometer	± 2 ml/min	N/A
Waste stream flow	Graduated cylinder/stop watch	± 10 ml/min	30
Bacteria Dose Rate	Peristaltic pump	± 4 ml/min	20
pH	4500H	± 0.1 pH unit	Not listed
Temperature	2550B	N/A	10
Turbidity	2130B	80-120% Rec.	25
Chlorine Residual	4500-Cl F	N/A	40
Hydrogen sulfide	Hach Spectrometer	90-110% Rec.	20
Alkalinity	2320B	75-120% Rec.	30
Total dissolved solids	2540C	80-120% Rec.	25
Ammonia-N	4500-NH3 G	80-120% Rec.	25
Total organic carbon	5310C	80-120% Rec.	25
UVA	5910B	85-1205 Rec.	20
Color	2120B	N/A	40
Iron	EPA Method 200.7	85-115% Rec.	20
Manganese	As above	85-115% Rec.	20
Chloride	EPA Method 300	90-110% Rec.	30
Bromide	EPA Method 300	85-115% Rec.	30
Sodium	EPA Method 200.7	85-115% Rec.	20
Potassium	EPA Method 200.7	85-115% Rec.	20
Total coliform	9221B	N/A	200
HPC bacteria	9215B	N/A	N/A
TTHMs	EPA Method 524.2	70-130% Rec.	40
Chlorite	EPA Method 300 B	90-110% Rec.	30

Statistical Uncertainty

As discussed in the sections discussing the experimental design, statistical uncertainty of the water quality parameters analyzed will be evaluated through calculation of the 95% confidence level around the sample mean. Confidence intervals will be calculated for volume data collected for analytes that are critical to the verification program. In addition, 95% confidence intervals will also be calculated for critical measurements that are performed at least daily, such as pH, temperature, turbidity, total coliform enumeration, HPC enumeration, and chlorine residual. Confidence intervals may also be calculated for alkalinity, ammonia nitrogen, UVA, true color, potassium, and *P. aeruginosa* enumeration data sets. Confidence interval calculations will be summarized in verification test data summaries.

Sampling and Analytical Procedures

Sampling Procedures

ARCADIS Geraghty & Miller will monitor the water treatment system for 30 days. The challenge test associated with this demonstration is described in more detail in the Experimental Design section. Equipment will be operated for a one-month testing period at each set of operational conditions and raw water qualities for which verification is desired.

Multiple untreated and treated water quality parameters will be monitored during the test period. These parameters include: pH, temperature, turbidity, chlorine residual, hydrogen sulfide, alkalinity, total dissolved solids (TDS), ammonia nitrogen, total organic carbon (TOC), UV absorbance at 254 nm (UVA), true color, iron, manganese, chloride, sodium, total coliforms, and heterotrophic plate count (HPC) bacteria. Sampling will be performed during steady-state operation of the disinfection equipment.

Analytical samples will be collected from various positions within the overall system. With the exception of the in-line turbidimeter, grab samples will be collected to satisfy analytical needs. The collection of all grab samples will consist of running a slow, steady stream from the sample tap, triple rinsing a dedicated sample beaker or sample container in this stream, and allowing the intended sample to flow down the side of the beaker or sample container to minimize bubble entrainment. Sample bottles should be double-rinsed with the sample before filling. For the case of cold water samples that cause the container to fog preventing accurate readings for some measurements, the container should be allowed to warm up by partial submersion into a warm water bath for approximately 30 seconds.

Samples to be analyzed for total organic carbon (TOC) and UVA at 254 nm will be collected in glass bottles supplied by the laboratory and shipped at 4 °C for analysis. The samples will be preserved, held and shipped in accordance to the standard method.

Samples for the analysis of *P. Aeruginosa* will be collected in bottles supplied by the analytical laboratory. Samples will be refrigerated at approximately 2-8 °C immediately after collection. Such samples will be shipped in a cooler and maintained at that temperature during shipment. The laboratory will process samples within 24 hours of collection.

Simulated Distribution System testing for disinfection by-product (DBP) formation will be conducted as a one-time event. Six samples will be collected in one-liter amber bottles with Teflon lined caps. The samples will be pH adjusted to 8.0 ± 0.2 using either 1M HCL or NAOH and dosed with 0.8 ± 0.1 percent mixed oxidant to yield a target chlorine residual of 1.0 ± 0.4 mg/L after storage. The samples will be capped with zero head space and stored for 24 hours in the dark at 20 ± 1 °C. Following incubation, the six samples will be reanalyzed for chlorine residual. The two samples with chlorine residuals closest to the 1.0 ± 0.4 mg/L range will be analyzed for TTHMs and HAAs by EHL.

ARCADIS Geraghty & Miller does not currently plan to conduct testing for the optional DBP parameters as the OXI-2B performance statements do not make any claims about the formation of DBPs.

Chlorine Residual

Because free-chlorine in aqueous solutions is unstable, the free chlorine concentration in treated water samples will decrease rapidly. Exposure to sunlight or other strong light, or agitation will accelerate free chlorine loss. For this reason, analysis of free and/or total chlorine samples will begin immediately after sampling, and excessive light or agitation will be avoided.

Glassware to be used for chlorine analyses shall be chlorine demand free. Chlorine demand free glassware is prepared by soaking glassware in a 50 mg/L chlorine bath for a period of 24 hours. At the end of this time, all glassware will be triple-rinsed with organic-free water that has a TOC concentration of <0.2 mg/L. Glassware will then be dried at room temperature for 24 hours. During the drying process, bottle openings will be covered with aluminum foil to prevent contamination. Analysis procedures are the same for measuring chlorine dioxide and bromine residual as well.

Sample Custody

Samples will be collected in appropriate containers prepared by the analytical laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and hold times, as specified by the analytical methods. Samples will be shipped to a laboratory that is certified, accredited, or approved by the state, a third party organization, or the EPA. Original field chain-of-custody forms will accompany all samples shipped off-site. Copies of the chain-of-custody forms will also be provided to NSF.

ARCADIS Geraghty & Miller intends to utilize three subcontract analytical laboratories plus the SJWD on-site laboratory. EHL possesses a South Carolina drinking water certification (Certification Nos. 98001001 & 95005001 respectively). The laboratory to perform *P. aeruginosa* enumeration is Magellan Laboratory in Morrisville, North Carolina. The SJWD on-site laboratory is certified by the state of South Carolina to perform selected drinking water analyses (Certificate No. 42012001). SJWD processes yearly performance evaluation samples prepared by the state and is re-certified on a three-year cycle. The SJWD certificate is current through July of 2002.

Analytical Procedures

Laboratories will use the standard methods listed below. Any deviations from these methods or use of alternate methods must be approved and documented.

pH: EPA Method 4500H, Evaluation of Water and Wastewater
Temperature: Method 2550B, Evaluation of Water and Wastewater
Turbidity: EPA Method 2130B, Evaluation of Water and Wastewater
Alkalinity: Method 2320B, Evaluation of Water and Wastewater
TDS: Method 2540C, Evaluation of Water and Wastewater
Ammonia-N: Method 4500-NH3G, Evaluation of Water and Wastewater
TOC: EPA Method 5310C, Evaluation of Water and Wastewater
UVA: Method 5910B, Evaluation of Water and Wastewater
True Color: Method 2120B, Evaluation of Water and Wastewater
HPC Bact.: Method 9215B, Evaluation of Water and Wastewater
Total Col.: Method 9221B, Evaluation of Water and Wastewater
TTHMs: EPA Method 524.2
HAAs: EPA Method 552.1

Iron, manganese, sodium, and potassium will be analyzed by inductively coupled plasma spectroscopy (ICP) using EPA Method 200.7. Chlorite, chlorate, and chloride will be analyzed by ion chromatograph (IC) using EPA Method 300.0.

Water Quality And Operational Control Checks

In addition to method specified QA/QC samples, duplicate samples will be collected analyzed for chlorine residual, total coliform, HPC bacteria, *P. aeruginosa*, and TOC to determine the precision of analysis. A duplicate will be taken following every 10th regular sample for each of these parameters.

Method blanks will be used by the laboratory to evaluate analytical method-induced contamination, which has the potential to cause false positive results. The laboratory will perform laboratory blanks with each set of samples analyzed. Method blanks will not be used for microbiological analyses. The criteria for acceptable method blanks are often stated in the analytical methods. Acceptability of data in light of field, trip or method blank results will be assessed during data validation using procedures found in US EPA data validation documents (EPA-540/R-94-013, EPA/540/R/94/090). Where method blank acceptance criteria are not provide by individual methods, the implication of any detection of an analyte in the method blank will be evaluated using the rules in the sections on method blanks in the following documents:

- USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review, EPA-540/R-94/012
- USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, EPA-540/R-94/013

One trip blank will be prepared, accompany samples to the analytical laboratory and be analyzed for every 20 non-volatile, analytical samples processed. Analytes to be covered by this trip blank include ammonia-nitrogen, UVA, true color, iron, manganese, chloride and sodium. Results will be an indication of contamination that may occur at the site or during shipping. A trip blank will accompany any sample shipments that include volatile analytes. A Trip Control for the *P. aeruginosa* will be provided to the analytical laboratory to evaluate travel-related contamination.

These QA/QC verifications will be conducted during each test period:

- Chemical raw pump flow will be verified volumetrically (daily)
- Flow to turbidimeter will be verified volumetrically (daily)
- In-line turbidimeter readings will be checked against a properly calibrated bench-top model (daily)
- The in-line rotometers will be inspected and cleaned (bi-weekly)
- In-line turbidimeter will be cleaned out and re-calibrated if necessary, according to manufacturer's recommendations (bi-weekly)
- Tubing and pipes will be inspected for signs of leaks and/or degradation (before test period begins and bi-weekly).

Microbial Viability Controls

Control experiments will be conducted to evaluate the stability of microbiological viability in the absence of any disinfectant. These control experiments will be conducted in a manner identical to the disinfection experiments except that no disinfectant shall be added to the reactor. The results of the control experiments will allows for the quantification of the microbiological viability in the absence of any disinfectant over the time course of the disinfection experiments. Microbial viability testing will be performed on microbiological travel samples (trip-control) in order to confirm viability of organisms from point of addition to laboratory analysis.

Die-away of organisms during shipping is not unusual, however, if greater than one log of microbial die-away is observed through the travel sample study, then the procedures for provision of organisms to the site for seeding studies will be evaluated and corrective action will be taken.

Data Reduction, Validation, and Reporting

To maintain good data quality, the specific procedures detailed in the following subsections will be followed. Data reduction refers to the process of converting raw results from the equipment into concentration or other data in a form to be used in the comparison. The purpose is to provide data which will be used to verify the statement of performance capabilities. These data shall be obtained from logbooks, instrument outputs, and computer outputs as appropriate.

The operator shall verify the completeness of the appropriate data forms and the completeness and correctness of data acquisition and reduction. The Field Team Supervisor will review calculations and inspect laboratory or field logbooks and data sheets to ensure accuracy and completeness. Calibration and QC data will be examined by the appropriate instrument operators, the laboratory supervisor, and the QA Officer. Laboratory and Project Managers will verify that all instrument systems are in control and that QA objectives for accuracy, precision, and method detection limits have been met.

Analytical outlier data are those data that do not meet the established data quality indicator goals shown in Table 9. Should QC data be outside of the data quality indicator goals, the laboratory supervisor will investigate the cause of the problem. If the problem involves an analytical problem, the samples will be reanalyzed if possible, or another sample will be collected and analyzed. If the problem can be attributed to the sample matrix, the result will be flagged with a data qualifier. This data qualifier will be included and explained in the final analytical report.

Data Reporting Task 1 (Equipment Operation and Disinfection Production Capabilities)
Task 1 data which will be collected and included in the final report are listed below.

- General operational performance including:
  - A temporal profile of raw water flow rate over the 30-day testing period. One temporal profile graph (at daily resolution) will be provided for each set of operational conditions and/or water qualities evaluated during Verification Testing
  - A temporal profile of waste stream flow rate measured during the one-month testing period.
  - A table of residual free and total chlorine concentrations (from the mixed oxidant) in the M.O. stream and finished water stream during the one-month testing period.
- The rate of consumption of salt for mixed oxidant generation. The quality of salt required for mixed oxidant generation will also be reported.
- Power consumption, including a table of horsepower requirements, motor efficiency, and consumed amperage for the testing period, as measured for each set of operational conditions.
- Waste stream characterization:
  - A table of waste stream quality parameters (chlorine, chloride, alkalinity, TDS, and pH) measured during the one-month testing period, as well as heavy metals.
- A table of the calculated or estimated hydraulic retention time in the disinfectant contacting system for each set of operational conditions evaluated during the one-month testing period.

Data Reporting Task 2 (Microbiological Contaminant Inactivation)
A total of nineteen (19) *P. aeruginosa* enumerations are planned for Task 2. This total includes 3 positive control samples, 9 treated samples (at 3 different HRTs), 2 raw water background samples, 2 positive control samples collected prior to entering the CCC, 2 trip controls and one duplicate.

Each analysis will produce an estimated *P. aeruginosa* concentration in CFUs/mL of water. The data will be statistically analyzed as discussed in the Task 1 workplan above and included in the final report. More specifically, Task 2 reporting will include:

- A table of raw water and finished water concentrations of the *P. aeruginosa*, for the challenge-, process-, and trip-control test
- Trip control results
- A bar graph of log10 inactivation results for the three runs and all control test runs
- The variability of the results from microbial inactivation tests which will be represented with the bar graphs as 95% confidence intervals.

Data Reporting Task 3 (Finished Water Quality) and Miscellaneous Data
Other data, including Finished Water Quality data (Task 3) that will be reported include:

- Daily raw water and finished water levels of pH, temperature and turbidity during each test period.
- Weekly raw water and finished water levels of alkalinity and ammonia nitrogen during each test period.
- Raw water and finished water levels of TDS, iron, manganese, chloride, bromide, and sodium during each test period.
- Twice daily chlorine residuals during each test period.

- Weekly raw water and finished water levels of UVA and true color during each test period.
- Raw water and finished water levels of TOC during each test period.

- Instantaneous, and DBP formation testing (for finished water only), raw water (one sample), and finished water concentration of TTHMs and HAAs monitored during each test period.
- Instantaneous, and DBP formation testing if applicable (for finished water only), raw water (one sample), and finished water concentration of chlorite during each test period.

- Raw water and finished water levels of Total Coliform bacteria (TC) and HPC bacteria during each test period.
- TC and HPC $\log_{10}$ inactivation during each test period.

All other QC information relevant to this demonstration will be included in the appendices of the final report. This will include information on calibrations, blanks, and reference samples. Raw analytical data will also be included in an appendix.

Systems and Performance Audits

Audits are an integral party of any quality assurance program. Through systematic checking, audits confirm that appropriate quality assurance procedures are being followed and that project performance meets specified standards. Audits performed by ARCADIS Geraghty & Miller are considered internal audits. Audits performed by a third party, such as NSF International, are considered external. During the course of a project, there are generally three types of audits that may be performed. There are technical systems audits (TSAs), performance evaluation audits (PEAs), and data quality audits (DQAs).

TSAs are generally conducted prior to or in the early stages of a project. The TSA is a qualitative, on-site evaluation that determines whether or not a project or analysis is being performed as described in existing test plans, QAPPs, or standard methods.

Quantitative evaluations are made using PEA samples. A PEA involves the evaluation of a measurement system using a reference material with a known value or composition. At this time, no PEA samples are planned for this demonstration.

Data quality audits evaluate methods used to collect, interpret, and report project results. Selected samples are tracked through laboratory analysis, data processing, and statistical analysis procedures to determine whether all data modifications and the reasons for those modifications were adequately documented.

Internal Audits

At least one internal TSA will be conducted by the ARCADIS Geraghty & Miller QA Officer at the demonstration site. Any problems identified during the TSA will be reported immediately to the ARCADIS Geraghty & Miller Project Manager. A written audit report detailing any findings and necessary corrective actions will be completed and submitted to all parties involved within 15 days of the completion of the TSA.

The ARCADIS Geraghty & Miller QA Officer will audit at least 10% of the reported data in a data quality audit. This will involve inspection of raw data from laboratory reports and review of field data sheets and project notebooks. Calculations performed on raw data will be verified and tabulated results validated. If problems are found in the 10% data review, review of a greater percentage of data may be warranted.

Reporting Procedures

Status Reports

Periodic reports detailing project progress, problems and associated corrective actions, and future scheduled activities associated with the verification testing will be issued by the QA Officer on a regular basis. Each report will include an executive summary at the beginning to introduce the pertinent issues occurring during the test period. When problems exist, OXI-2B and ARCADIS Geraghty & Miller project managers will discuss them, and estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems.

Inspection/Audit Reports

Any internal or external QA inspections or audits that take place in the field or in the analytical laboratory while the verification testing is being conducted will be formally reported by the ARCADIS Geraghty & Miller QA Officer to NSF and the vendor. A draft audit report will be circulated for review within one week of the audit date and the final audit report will be distributed within 30 days.

Corrective Actions

Corrective actions will be initiated whenever data quality indicator goal acceptance criteria detailed in Table 9 are not met or exceeded. Routine corrective action may result from common monitoring activities including: routine inspections, technical systems audits (TSAs) and quality control checks.

Corrective actions begin with the identification of the source of the problem. Potential problem sources include failure to adhere to prescribed measurement procedures, equipment malfunction, or systematic contamination. The respective corrective actions appropriate for these problems are more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, and removal of the source of contamination (e.g., disposal of contaminated reagents). Once corrective actions have been completed, if data affected by the problem can also be corrected, attempts will be made to do so. If data cannot be corrected, it may be necessary to repeat some testing.

The ARCADIS Geraghty & Miller Project Manager approves all corrective actions and has the primary responsibility for directing the initiation and completion of corrective actions required for this project. Problems may be identified by sampling personnel, operation personnel, QA staff or test engineers. If further staff training is required, the Project Manager is responsible for ensuring it takes place. The ARCADIS Geraghty & Miller QA Officer is responsible for monitoring the progress of major corrective actions and ensuring that they proceed in a timely manner and are adequately documented.

DATA MANAGEMENT AND ANALYSIS

As discussed in the Data Reporting Section, SJWD operators during daily documentation of qualitative equipment performance will utilize a logbook. This logbook will also be used to report raw water flow rates.

A number of routine tests pertaining to water quality will be performed in SJWD's existing laboratory. These data will be reported in a separate logbook. EHL Labs will perform analyses of the remaining samples. ARCADIS Geraghty & Miller will obtain the raw data from EHL and will include all raw data, as well as the processed data in the test report. In addition, we shall provide NSF with the data in electronic format (Excel spreadsheet).

The test report shall include the following sections:

Verification Statement
Introduction
Description and Identification of Product Tested
Procedures and Methods used
Results and Discussion
References
Appendices
FOD
QA/QC report

The template provided by NSF will be used for the verification report.

REFERENCES

Levenspiel, O. 1972. *Chemical Reaction Engineering*. Second Edition. John Wiley & Sons, Inc.

DiGiano, F.A., W.J. Weber, Jr. 1996. *Process Dynamics in Environmental Systems*. First Edition. John Wiley & Sons, Inc.

EPA Contract Laboratory Program, National Functional Guidelines for Organic Data Review, Multi-Media, Multi-Concentration (ILMO 1.0 and Low Concentration Water (OLCO 1.0), EPA/540/R/94/090

EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, EPA-540/R-94-013.