US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

VERIFICATION TEST PLAN FOR THE SUNTEC ENVIRONMENTAL UV DISINFECTION SYSTEM FOR SECONDARY EFFLUENT APPLICATIONS VERSION 3.0

February 2003

Prepared for
NSF International
Ann Arbor, MI

and

US Environmental Protection Agency
Edison, NJ

by:

O. Karl Scheible
Egon T. Weber II

HydroQual, Inc.
Mahwah, NJ

CONTENTS

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

FIGURES

Figure Page

US EPA ARCHIVE DOCUMENT

TABLES

US EPA ARCHIVE DOCUMENT

SECTION 1

INTRODUCTION

1.1 ETV OBJECTIVES

The Environmental Technology Verification (ETV) program was created to accelerate the development and commercialization of environmental technologies through third party verification and reporting of performance. The goal of the ETV program is to verify performance characteristics of commercial-ready environmental technologies through the evaluation of objective and quality assured data so that potential buyers and regulators are provided with an independent and credible assessment of the technology that they are buying or permitting.

Disinfection for secondary effluent and reuse application has been identified as one of the technology categories to be verified under the EPA/NSF Water Quality Protection Center ETV.

This Verification Test Plan (VTP) applies to ultraviolet radiation technologies that meet the general criteria set forth in the "Verification Protocol for Secondary Effluent and Water Reuse Disinfection Applications" (NSF International, October 2002). Details of this VTP focus on the selected Field Test Organization (FTO), and this VTP is modified to reflect a specific disinfection system provided by an independent vendor. Guidance is provided on the conduct of the testing, data reduction and analysis, and reporting required to validate the particular technology.

There are three major UV system operation and performance elements addressed in the Verification Protocol, comprising up to 10 individual verifications. A vendor may choose to conduct verifications covering any one or combination of these test elements:

1. **Dose-Delivery Verification**

   Quantitative assessment of the ability of the UV equipment to deliver dose at liquid UV transmittances (at 254 nm) that are representative of the desired application(s):

   a. Secondary Effluent
      - 55% Transmittance
      - 65% Transmittance
      - 75% Transmittance

   b. Reuse Applications (Based on NWRI/AWWARF 2000)
      - Granular or Fabric Media Filtered Effluent – 55% Transmittance
      - Membrane Filtered Effluent – 65% Transmittance
      - Reverse Osmosis Effluent – 90% Transmittance

US EPA ARCHIVE DOCUMENT

2. Dose-Delivery Reliability Verification

a. Quartz Surface Maintenance

Assessment of the efficacy of a UV systems automatic cleaning device to consistently maintain the quartz surfaces in a clean state, efficiently transmitting the UV energy to the liquid

b. System Reliability

System response control and a qualitative assessment of UV system monitors, alarms and/or indicators

c. Process Control

The ability of the UV system to automatically monitor and/or adjust UV doses to changing conditions

3. UV Design Factor Verification

a. Quartz-Fouling Factor Determination

Quantitative determination of the long-term attenuation factor for quartz transmittance losses

b. Lamp-Age Factor Testing

Quantitative determination of the relative UV output after continuous normal operation for the vendor-prescribed effective life

Under this VTP, SUNTEC environmental Inc. will verify performance of their UV system for secondary effluent applications at 55%T and 65%T only. Verification at 75% will not be conducted. As such, only one major test element, dose delivery is addressed in this VTP. Dose delivery is defined as the ability of a specific system to deliver an effective dose to meet a selected level of inactivation. This is accomplished by determining the system's "delivered dose," that is the dose actually received by the microbes in the wastewater, using a bioassay procedure.

This Verification Test Plan implemented for SUNTEC environmental Inc. addresses the dose delivery for secondary effluent applications where the pretreatment of the water results in transmittances of 55%T or 65%T. This test plan does not involve verification for secondary effluent applications where the transmittance is 75%T.

In addition, dose-delivery is directly related to the hydraulic behavior of the reactor. Therefore, residence time distributions (RTD) will be developed, and headlosses will be measured as a means of assessing the reactor's conformance to acceptable near-plug flow conditions.

US EPA ARCHIVE DOCUMENT

SECTION 2

ROLES AND RESPONSIBILITIES OF PARTICIPANTS IN THE VERIFICATION TESTING

2.1 NSF INTERNATIONAL (NSF)

The Water Quality Protection Center ETV is administered through a cooperative agreement between USEPA and NSF International, Inc. (NSF), its verification partner organization. NSF administers the program, and has selected a qualified FTO, HydroQual, Inc. (HydroQual) to develop and implement this Verification Test Plan (VTP).

NSF's other responsibilities include:

- Review and approval of the VTP;
- Oversight of quality assurance including the performance of technical systems and data quality audits as prescribed in the Quality Management Plan for the Water Quality Protection Center ETV;
- Coordination of verification report peer reviews including review by the Stakeholder Advisory Group and Technology Panel;
- Approval of the Verification Report;
- Preparation and dissemination of the Verification Statement.

Key contacts at NSF relating to this VTP include:

Mr. Thomas Stevens, Program Director
Ms. Maren Roush, Project Coordinator
NSF International
789 Dixboro Road
Ann Arbor, MI 48105
(734) 769-5347

2.2 U.S. ENVIRONMENTAL PROTECTION AGENCY (USEPA)

The USEPA's National Risk Management Research Laboratory provides administrative, technical and quality assurance guidance and oversight on all Water Quality Protection Center activities. The USEPA will have review and approval responsibilities through various phases of the verification project:

- Verification Test Plan
- Verification Report
- Verification Statement
- Dissemination of the Verification Report and Verification Statement

US EPA ARCHIVE DOCUMENT

Key USEPA contacts for this specific VTP are:

Mr. Ray Frederick
USEPA – NRML Urban Watershed Management Branch
2890 Woodbridge Avenue (MS-104)
Edison, NJ 08837-3679
(732) 321-6627
(732) 321-6640 (fax)
Frederick.ray@epamial.epa.gov

2.3 FIELD TESTING ORGANIZATION (FTO), HYDROQUAL, INC.

The selected FTO is HydroQual, Inc., Mahwah, New Jersey. HydroQual has a well-established, international reputation for expertise in the area of ultraviolet disinfection technologies.

Mr. O. Karl Scheible, Project Director, will provide overall technical guidance for the verification test program. Mr. Egon T. Weber II, Ph.D. will serve as the Project Manager and be responsible for day-to-day operations, project administration, and laboratory setup and oversight. Mr. Michael C. Cushing will be the lead field-technician, responsible for system installation, startup, sampling and record keeping. Mr. Prakash Patil will be the project microbiologist. Other HydroQual personnel who will have support roles during the verification project include Ms. Joy McGrath (QA/QC Officer) and Messrs. Wilfred Dunne, and Francisco Cardona (Field/Lab Support). HydroQual may also use additional in-house staff as required.

HydroQual's responsibilities include:

- Develop the VTP in conformance with the Verification Protocol, including its revisions in response to comments made during the review period;
- Coordinate the VTP with the Vendor and NSF, including documentation of equipment and facility information, and specifications for the VTP;
- Contract with sub-consultants and general contractors as needed to implement the VTP;
- Coordinate and contract, as needed, with the Host test facility and arrange the necessary logistics for activities at the plant site;
- Manage the communications, documentation, staffing and scheduling activities to successfully and efficiently complete the verification;
- Oversee and/or perform the verification testing per the approved VTP;
- Manage, evaluate, interpret, and report the data generated during the verification testing;
- Prepare the Draft Verification Report.

US EPA ARCHIVE DOCUMENT

HydroQual's main office is located in Mahwah, New Jersey and has a staff of nearly 110. The mailing address is:

HydroQual, Inc.
One Lethbridge Plaza
Mahwah, New Jersey 07430
(201) 529-5151
(201) 512-3825 Fax
http://www.hydroqual.com

Dr. Weber will be the primary contact person at HydroQual.

Telephone extension: 7401 or
Email: eweber@hydroqual.com

Mr. Scheible can be reached at extension 7378 or

Email: kscheible@hydroqual.com

2.4 ETV HOST SITE PARSIPPANY TROY-HILLS (PTRH) WASTEWATER TREATMENT PLANT

The Parsippany Troy-Hills (PTRH) Wastewater Treatment Plant located in Parsippany, New Jersey will be the host facility for conducting this ETV.

The host site's responsibilities include:

- Dedicating the required area(s) for test equipment and setup;
- Provide reasonable access to the facility for non-plant employees;
- Provide some logistical support including personnel and/or equipment;
- Review, approve and/or assist activities affecting the plant, such as electrical connections from plant main feed.

The plant is located at:

1139 Edwards Road
Parsippany, New Jersey 07054
(973) 428-7953

Mr. Phil Bober, P.E., is the designated ETV liaison for PTRH. He can be reached at the above telephone number.

Figure 2-1 shows the project area dedicated for ETV testing at the plant. Figures 2-2, and 2-3 show a more detailed site plan and a test facility schematic.

US EPA ARCHIVE DOCUMENT

2.5 UV TECHNOLOGY VENDOR – SUNTEC ENVIRONEMTAL INC. (A DIVISION OF PHOTOSCIENCE JAPAN CORP.)

The UV system to undergo verification is provided by SUNTEC environmental Inc. and represents a scalable version of their LPX200 UV disinfection system. SUNTEC environmental's responsibilities will include:

- Provide the test unit for verification and all ancillary equipment, instrumentation, materials and supplies necessary to operate, monitor, maintain and repair the system;
- Provide documentation and calculations necessary to demonstrate the system's conformity to commercial systems, hydraulic scalability and to the requirements to the protocol;
- Provide descriptive details of the system, its operation and maintenance, its technical capabilities and intended function in secondary effluent applications;
- Provide technical support for the installation and operation of the UV system including designation of a staff technical support person and an on-site technician for training and system startup;
- Certify that installation and startup of system is in accordance with the manufacturer's recommendations;
- Review and approval of the VTP; and
- Review and comment on the Verification Report and Verification Statement.

SUNTEC environmental Inc. is located in Ontario at the following address:

SUNTEC environmental, Inc.
106 Rayette Road – Unit #1
Concord, Ontario
CANADA L4K 2G3
(905) 669-4450
(905) 669-4451 Fax

Dr. Elliott Whitby will be the primary contact for SUNTEC environmental. He can be reached at above telephone number or

Email: ewhitby@suntecuv.com

US EPA ARCHIVE DOCUMENT

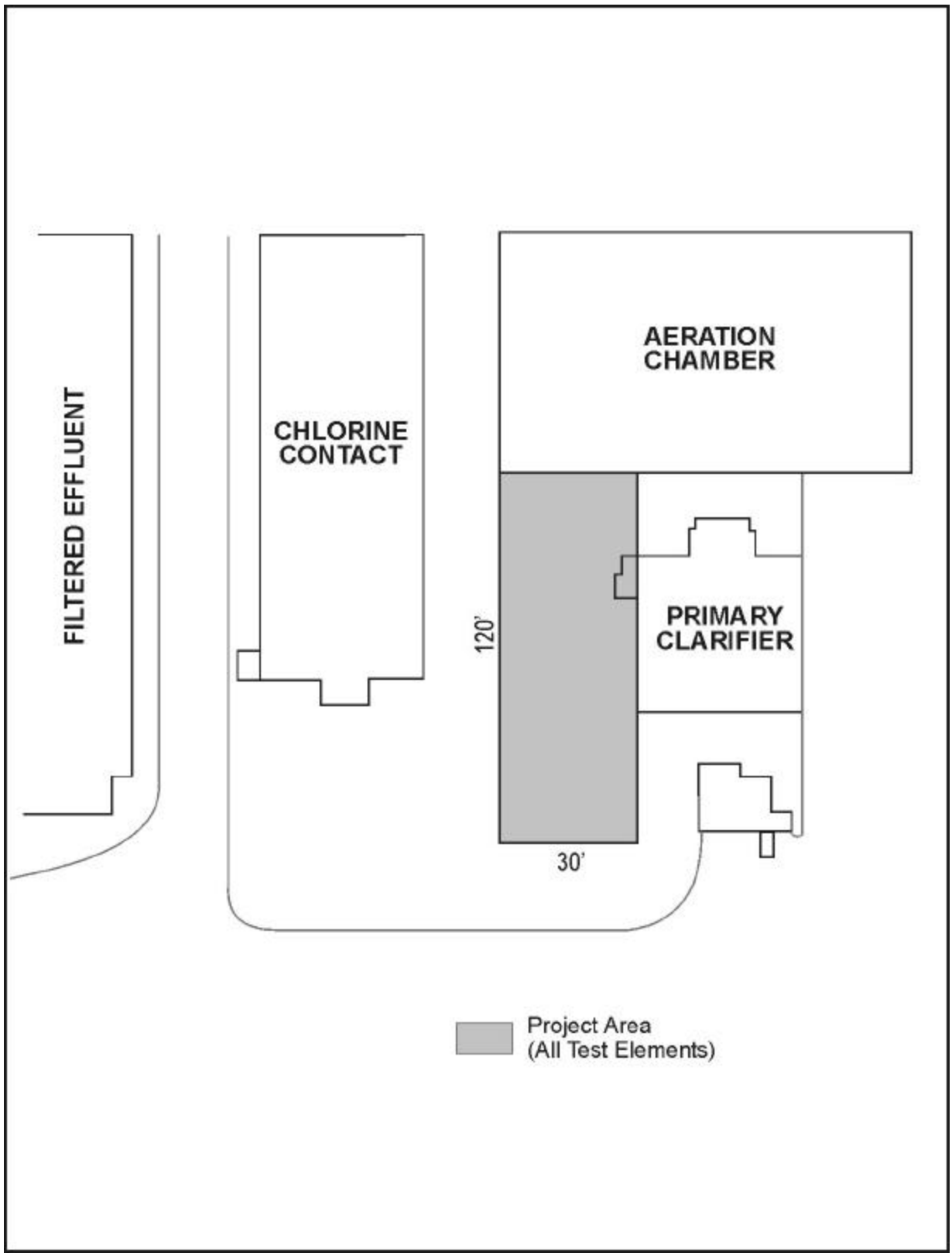


Figure 2-1. Project Area for ETV Testing at the Parsippany-Troy Hills WWTP.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

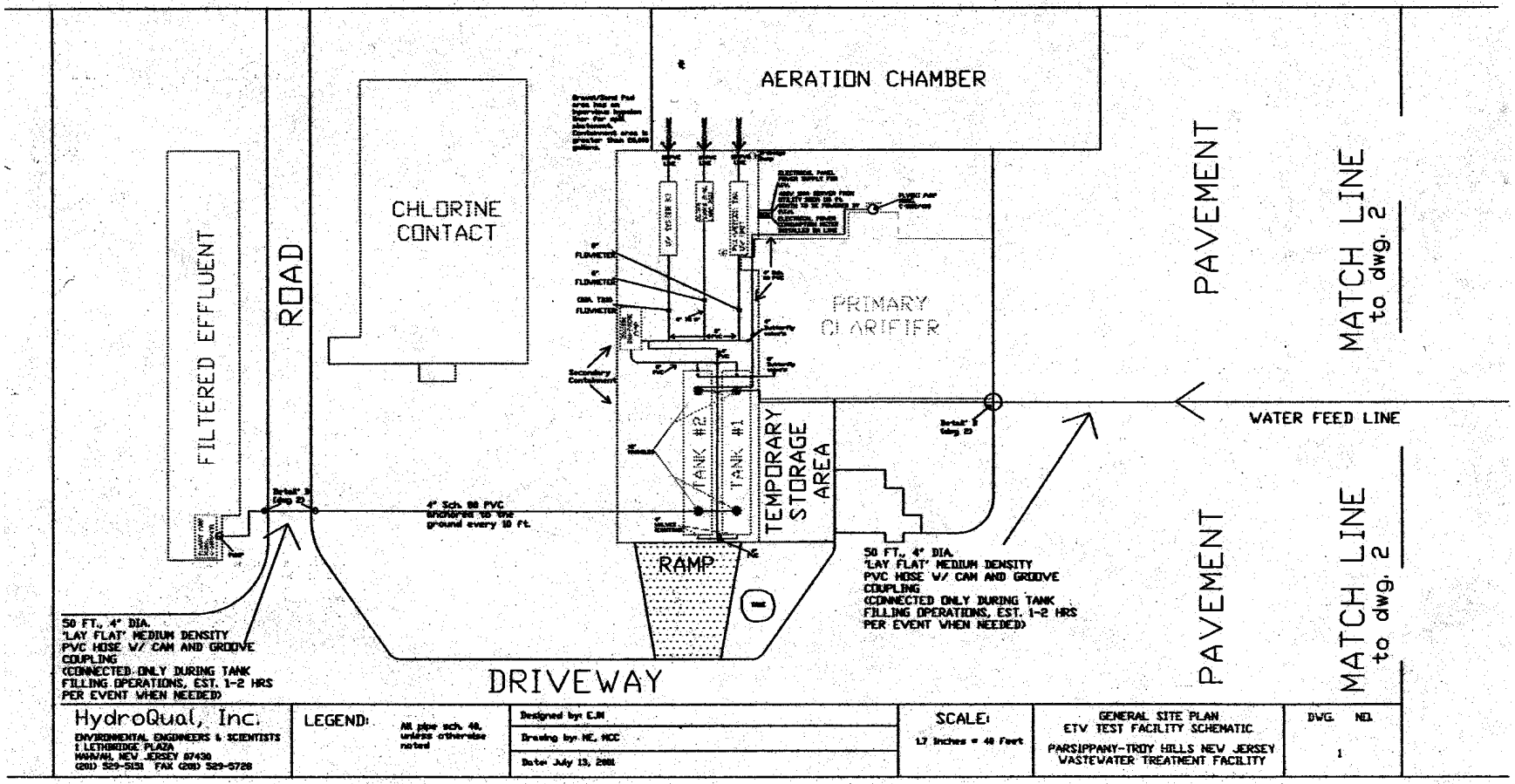


Figure 2-2. General Site Plan of the ETV Test Facility at the Parsippany-Troy Hills WWTP.

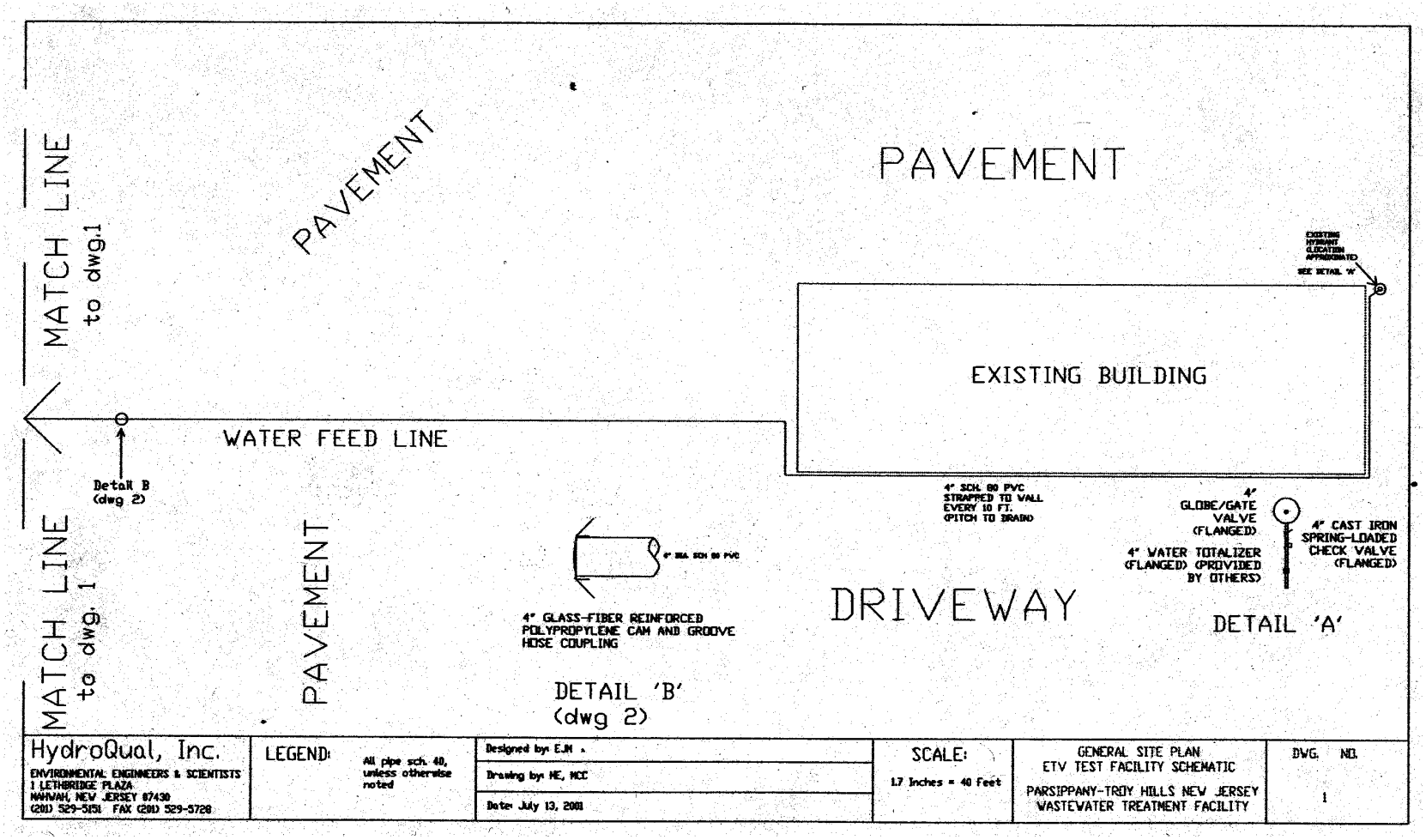


Figure 2-3. General Site Plan of the ETV Test Facility at the Parsippany-Troy Hills WWTP.

US EPA ARCHIVE DOCUMENT

2.6 SUPPORT ORGANIZATIONS

The FTO has identified one other organization that will provide support for activities that cannot be provided by NSF, EPA, HydroQual or SUNTEC environmental Inc. This organization will be a subcontractor of and subordinate to HydroQual.

International Light, Inc.
17 Graf Road
Newburyport, Massachusetts 01950
Photodetector and radiometer calibrations

2.7 TECHNOLOGY PANEL ON HIGH-RATE DISINFECTION

The ETV Technology Panel on Secondary Effluent and Water Reuse Disinfection Application will serve as a technical and professional resource during all phases of the verification, including the review of test plans and the issuance of verification reports.

US EPA ARCHIVE DOCUMENT

SECTION 3

TECHNOLOGY DESCRIPTION

3.1 SUNTEC ENVIRONMENTAL UV DISINFECTION SYSTEM

3.1.1 Lamps and Sleeves

The LPX200 UV unit supplied by SUNTEC environmental utilizes high-output, low-pressure lamps (GXO74T5LS), oriented horizontally and parallel to the direction of flow (Figure 3-1). Each has a UV output rating of approximately 60 Watts at 254 nm and a total power draw of 200 Watts. The lamps have an effective arc length of 162 cm.

The quartz sleeves are test-tube type, with one sealed end and an outer diameter of 23 mm. The sleeves are composed of Type 214 clear fused quartz with a wall thickness of 1.50 mm resulting in a UV transmittance of approximately 90%. Figure 3-1 presents a schematic of the test unit configuration.

3.1.2 Lamp Aging

A lamp-aging test has been conducted at the wastewater treatment plant in Horse Cave Kentucky, USA. The LPX200 system contained 24 of the same lamps (GXO74T5LS) and ballasts used for this verification testing. The system was operated nearly continuously with few on/off cycles.

Lamp intensity was measured with a lamps mounted in a LPX200 quartz sleeve inside a laboratory-scale water-cooled test apparatus. Recirculated deionized water at 15° C was used as the cooling medium, and the lamps were allowed 24 hours to stabilize before the readings were taken. The intensity was measured with an IL-1700/SUD-240 radiometer through a quartz window mounted halfway along the length of the lamp. The lamps were driven with a ballast identical to those used in the full-scale system.

At the start of operation, the outputs of six lamps were measured after a 100h burn-in to establish a baseline for lamp degradation. At 5,925 hours, the outputs of the six lamps were measured again. At 11,338 hours 18 lamps outputs were measured again.

Figure 3-1 shows the lamp aging data acquired during the Horse Cave experiment. While the final outputs average approximately 85% of the starting outputs, the lowest intensities are approximately 70%. Based on these results, SUNTEC has requested the verification tests to be conducted at 70% lamp output. This is more conservative than the requirements in the Verification Protocol and is intended to be a worse case scenario.

US EPA ARCHIVE DOCUMENT

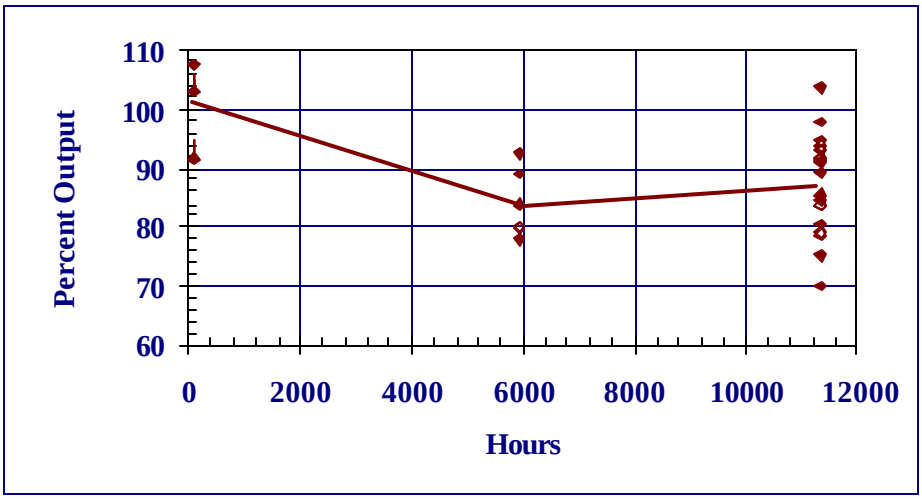


Figure 3-1. Lamp Intensity vs. Operational Age.

3.1.3 Lamp Intensity vs. Temperature

The UV radiation output of low-pressure mercury discharge lamps varies with the operating temperature of the lamp. This can change the effective germicidal dose delivered to the wastewater stream depending on the operating conditions. To address this operating variable SUNTEC has conducted tests to determine the relative lamp output as a function of temperature.

While the operating temperature of the lamp is the main control on this variability, the temperature of the water in which the lamp/sleeve assembly is submerged is the practical operational variable to be quantified. As such, SUNTEC environmental performed these lamp intensity experiments in a chamber in which the water temperature could be controlled. These experiments were performed in the same test rig described in Section 3.1.2 however, the water temperature was set to different values in the range of 5°C to 30°C, and the lamp was allowed to stabilize before measurements were taken.

Eight lamps were used and were driven by two different ballasts. The lamp intensity data is shown in Figure 3-2. While there is some variability in the behavior of the lamp/ballast configurations, it is clear that there is an intensity maximum in the range of 15°C to 20°C. The data set for each lamp was normalized to the maximum intensity and calculated as percent intensity. The average behavior of all eight lamps is presented in Figure 3-3.

US EPA ARCHIVE DOCUMENT

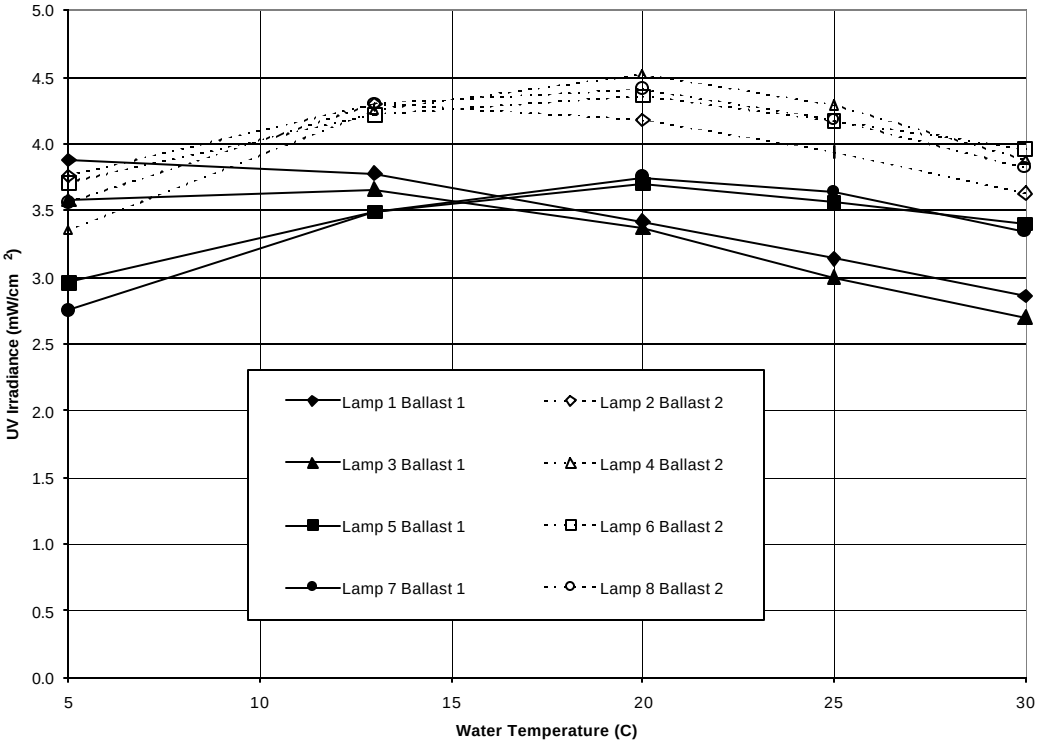


Figure 3-2. Lamp Intensity vs. Temperature for 8 Lamps.

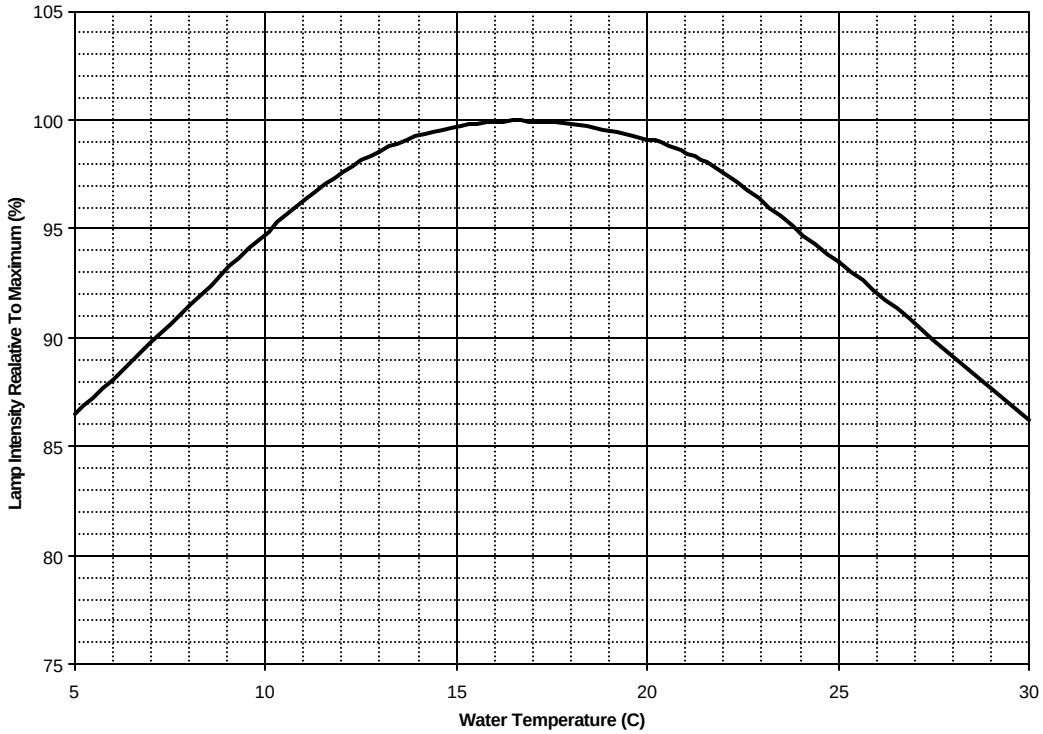


Figure 3-3. Average Percent Lamp Intensity as a Function Temperature.

US EPA ARCHIVE DOCUMENT

As shown in Figure 3-3, the maximum lamp output occurs when the water temperature is approximately 17°C. Further, water temperatures in the range of 10°C to 23°C will result in a reduction of lamp output intensity to only 95%.

3.1.4 Lamp Modules

The lamp modules supplied for this ETV consist of two columns of five lamps each (Figure 3-4). Two such modules are mounted parallel in the channel for a 20-lamp, 5 x 4 matrix configuration (Figure 3-5). The resulting lamp array has a uniform lamp spacing of 8.9 cm.

Each lamp is driven by a single electronic ballast. This ballast in enclosed in a round, stainless steel housing at the head end of the quartz sleeve assembly, and is submerged in the wastewater for cooling. The ballast is concentric with the quartz sleeve and is attached with an o-ring compression fitting for a water-tight seal.

Each column of lamp/ballast assemblies is supported by two thin vertical, stainless steel supports. The wiring conduits supplying the ballasts are in line with each lamp column for a minimal hydraulic cross section.

3.1.5 Sleeve Cleaning System

Each lamp module is equipped with an automatic sleeve cleaning system that will clean all sleeves on a module simultaneously. This system consists of metallic spring-type wipers that are driven the full length of the quartz sleeve with a motor and lead-screw drive. The control panel allows a cleaning interval of 1 to 999 hours, and can also permit the manual cycling of the wipers.

The wipers will not be active operational during the verification testing because the sleeves will be cleaned manually before each flow series. The wiping system is installed, however, to simulate the hydraulic behavior of the standard module assembly.

3.1.6 Electrical Controls

The LPX200 system supplied for this ETV is controlled and driven with the standard Power Distribution Center (PDC) computerized control offered by SUNTEC environmental Inc. This PDC system is enclosed in a NEMA 4x enclosure with a user interface and display. This system contains a Programmable Logic Controller (PLC) with monitors for individual lamp status, elapsed time counters, and detector inputs to control the disinfection process. The power supply to the system is a 120V split-single phase service.

The PDC contains electronic ballast boards, each of which drives five ballasts. The failure of one lamp or ballast will not interfere with the operation of the other four lamps. The ballast boards are interfaced with the PLC to allow adjustment of lamp output from 50% to 100% via lamp current adjustment.

US EPA ARCHIVE DOCUMENT

3.1.7 Detectors

The system will be supplied without any detector assemblies. These are not necessary for the secondary effluent verification test. However, the PLC allows the interface of detectors to monitor the disinfection performance as the water properties change and as the lamp/sleeve condition deteriorates.

3.1.8 Design Operational Envelope

Because the LPX200 disinfection system is employed for a variety of wastewater disinfection applications, various operational scenarios can be employed.

For example, the system can also be operated with an intensity feedback system which can monitor and adjust the lamp power and dose delivery based on lamp intensity and the flow rate of the wastewater. In contrast, a system could be operated without a detector feedback system but this would require a regular maintenance schedule involving sleeve cleaning and lamp replacement at the manufactures recommended intervals.

This system is designed to be operated at flow rates of up to 1500 gpm. This corresponds to a scalable flow rate of up to 75 gpm per lamp. Higher flow rates would create too large a headloss to keep the lamps properly covered.

In terms of intensity reduction due to lamp aging and quartz fouling, this verification program will simulate a lamp output of 70%, which is slightly more conservative than the 75% suggested in the Generic Verification Protocol.

3.2 UV PILOT TEST UNIT SPECIFICATIONS

3.2.1 Test Channel

The reactors are housed in an open stainless steel channel 6.5 m long (Figure 3-4). The effective disinfection zone is approximately 0.36 m wide and 1.62 m long. The channel is fitted with 1.07 m square influent approach box with a flow diverting baffle and 1 m straight exit after the second reactor and before the weir. An automatic level control gate adjusts the water level in the channel with a pivoting weight system that operates over a wide range of flow rates. This controls the level of the water so that the effluent end of the lamps are submerged under 1 to 2 cm of water.

3.2.2 Scaling Considerations

The LPX200 system to be tested under this verification program is one possible configuration offered by SUNTEC environmental Inc. Larger disinfection needs can be met by the expansion of the lamp matrix in both vertical and horizontal directions. The lamp modules are offered in configurations containing up to 16 lamps in two eight-lamp columns (the present unit contains two five-lamp columns.). Adding parallel lamp modules can expand each lamp bank in the horizontal direction.

US EPA ARCHIVE DOCUMENT

The scalability of the results from this verification program are predicated on the assumption that certain operating conditions will be identical in a full scale system. Obviously the full-scale system must use the same lamps, sleeves, ballasts, driving circuitry, and lamp/sleeve mounting hardware. Geometric conditions that must be similar between pilot and full-scale systems are lamp spacing, distance between the lamps and the walls, and submersion of the upper lamp row. The systems must be operated in the same range of wastewater flow velocities and/or detention times.

The verification results cannot be used on smaller systems but can be extended to systems up to 10x of the pilot unit. Thus, the maximum sized system in a single channel can have up to 200 lamps. Greater flow capacities must be met with multiple, parallel channels.

3.3 VERIFICATION TEST CLAIMS

The overall objective of this ETV is to validate the performance of the SUNTEC environmental Inc. LPX200 UV disinfection system for secondary effluent applications. The transmittances of the test waters will be adjusted to simulate secondary effluent applications and the lamp intensity will be reduced to simulate a dose delivery reduction to 70% due to fouled sleeves and aged lamps. Within this goal three objectives are identified:

1) Verify the flow-dose relationship for secondary effluent applications with wastewaters having UV transmittances at 254 nm of 65%.

2) Verify the flow-dose relationship for secondary effluent applications with wastewaters having UV transmittances at 254 nm of 55%.

3) Verify the hydraulic characteristics of the system by using hydraulic tracer analysis and quantifying headloss.

Note: the performance of this disinfection system in wastewaters of 75% will not be validated in this test program.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

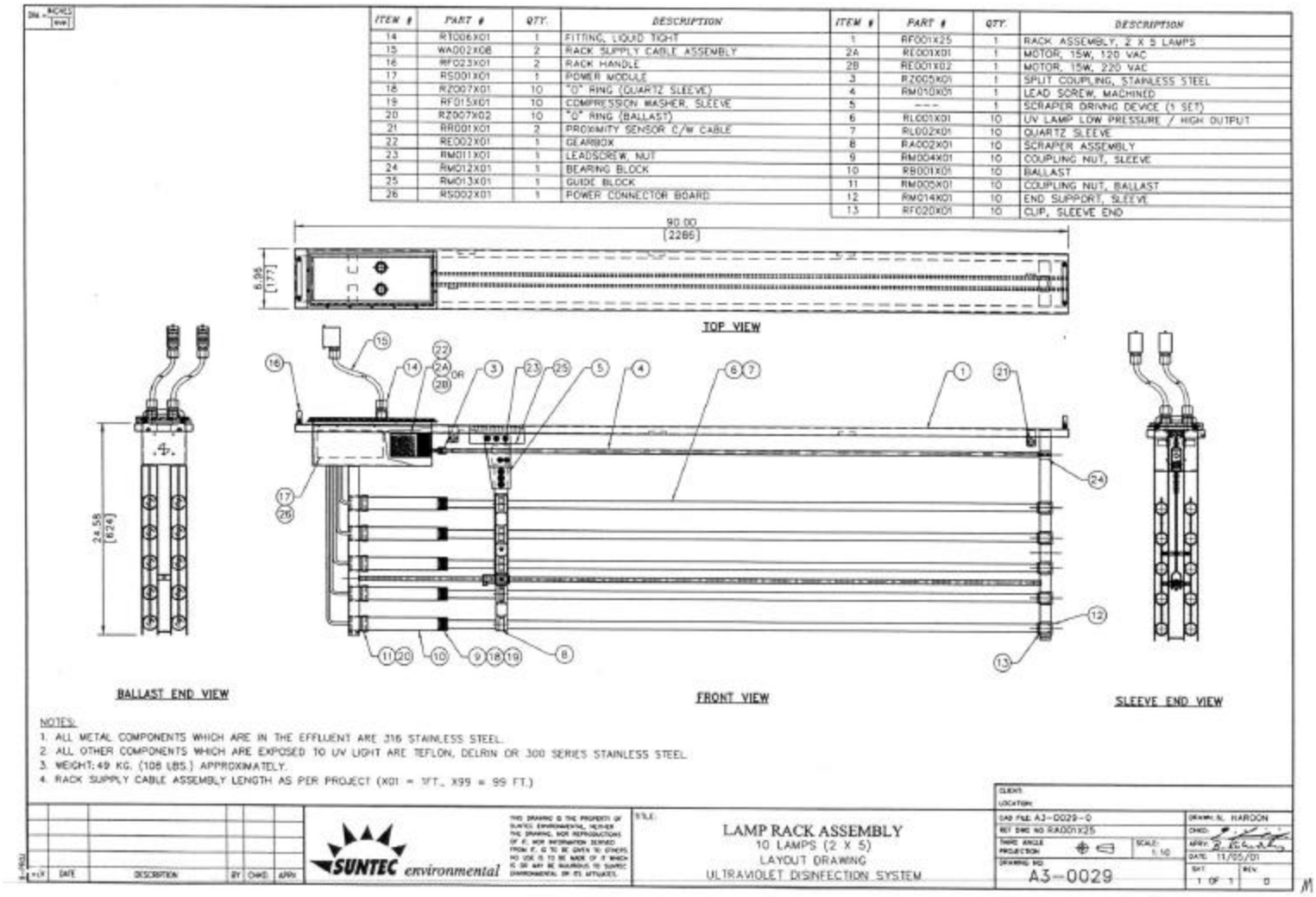


Figure 3-4. Diagram of Lamp Rack Assembly Used for Pilot Test.

US EPA ARCHIVE DOCUMENT

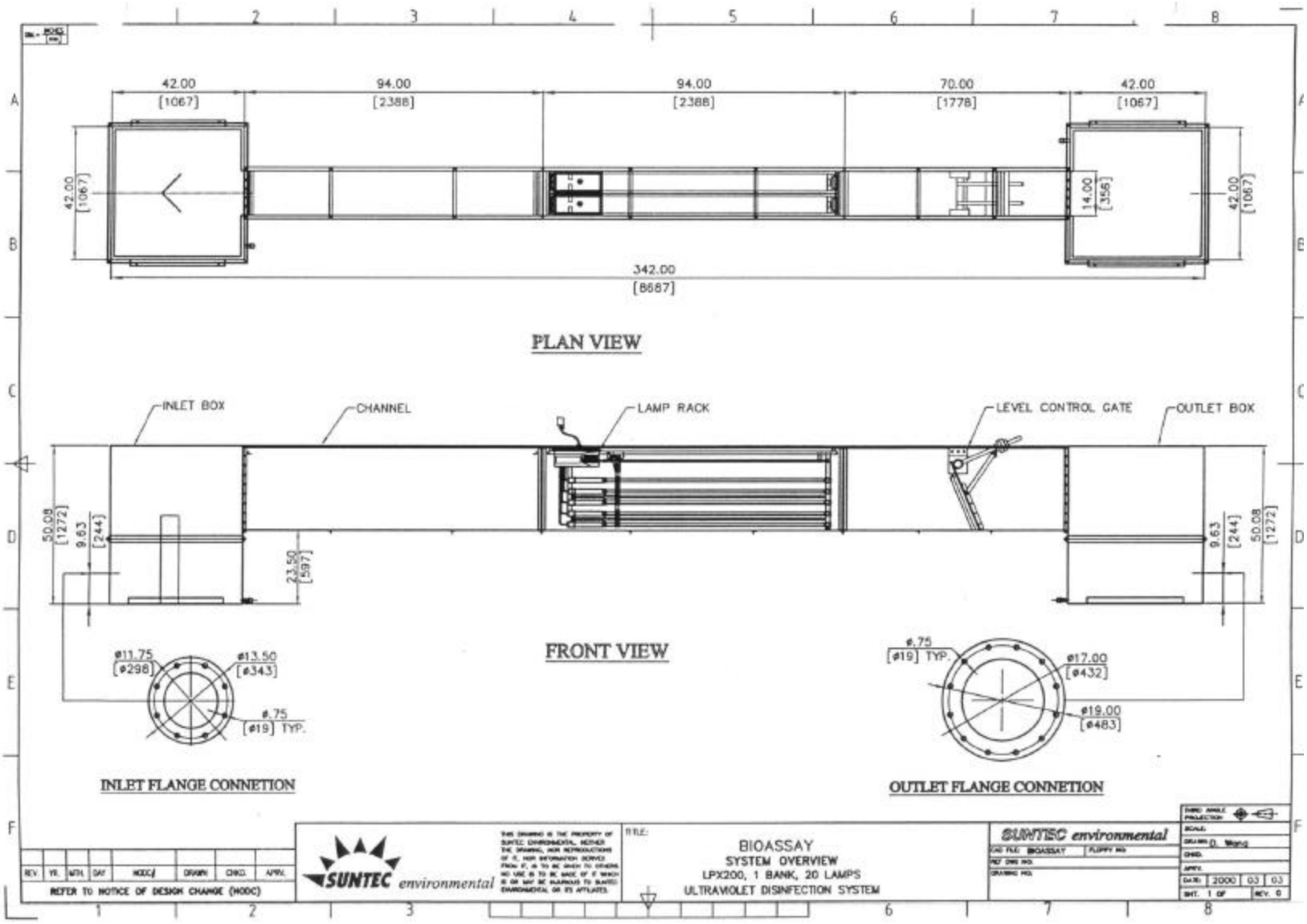


Figure 3-5. Schematic of SUNTEC Pilot Test Unit.

SECTION 4

DOSE DELIVERY VERIFICATION TEST PLAN

4.1 GENERAL TECHNICAL APPROACH

By its nature, the effectiveness of UV is dependent on the upstream processes used for pretreatment, particularly for particle removal or reduction, and for oil/grease and organics removal. The design basis typically developed for a UV system application incorporates the characteristics of the wastewater to be treated, including particulates, the nature and size distributions of the particulates, bacterial levels to be disinfected, flow rates, and the UV transmissibility (or, conversely, the absorbance) of the wastewaters. These are all established to reflect a planned level of pretreatment, and the expected variability in quality and quantity. Finally, the dose required to meet specific target levels is determined, typically established from direct testing (e.g., collimated-beam, dose-response methods) of the wastewaters or similar wastewaters. Once this "design basis" is established, independent of the UV equipment, the next step is to select equipment that can meet these specific dose requirements under the expected wastewater conditions.

This ETV technical objective is met by demonstrating, or verifying, the ability of a specific system to deliver an effective dose. This is the "delivered dose", which is the dose actually received by the microbes in the wastewater. Although recent research has been directed to modeling the delivered dose (particularly methods utilizing computational fluid dynamics in conjunction with computed intensity fields), direct biological assay procedures have generally been used to estimate the delivered dose for specific reactor configurations, typically as a function of the hydraulic loading rate. It is a viable and accepted method and has been used successfully for many years, whereby the results are often applied to qualification requirements in bid documents for wastewater treatment plant applications.

The bioassay procedure uses a known microorganism, which is cultured and harvested in the laboratory and then subjected to a range of discrete UV doses. These doses are applied with a laboratory-scale, collimated-beam apparatus, which can deliver a known, accurately measured dose. Measuring the response to these doses (log survival ratio), a dose-response relationship is developed for the specific organism. A culture of the same organism is then injected into the large-scale UV test unit, which is operated over a range of hydraulic loadings (thus yielding a range of exposure times). The response of the organism can then be used to infer, from the laboratory-based dose-response relationship, the dose that was delivered by the UV unit. These tests are run in "clean" water (from a potable water supply) which has been adjusted by chemical means to mimic the UV transmittances expected under secondary effluent conditions. In addition, effective disinfection and scaling assumptions are predicated on the acceptable hydraulic behavior within the UV reactor. To

US EPA ARCHIVE DOCUMENT

this end, residence time distribution (RTD) needs to be developed and analyzed as a means for assessing the UV system's conformance to near plug-flow condition and low axial dispersion.

Table 4-1 presents a summary of the primary and support tasks that need to be completed under this Verification and reference to pertinent VTP sections and protocols.

4.2 TEST FACILITY DESCRIPTION

4.2.1 Site Preparation Requirements

The designated host site is the Parsippany Troy-Hills Wastewater Treatment Plant located in Parsippany, New Jersey. All site preparations will be coordinated between HydroQual's Project Manager and the PTRH's designated project liaison.

The verification testing will take place at one central location at the plant allowing for access to primary, secondary and potable water sources (refer to Figures 2-1 through 2-3).

Figure 4-1 presents the flow schematic for conducting the dose delivery verification assays. The major ancillary support needs include a batch tank, electrical sources, a pump, and a potable water source. Support instrumentation includes a flow meter, a radiometer with an appropriate UV sensor, and ammeter. Note that this setup is independent of the host-site.

Potable water for cleaning and test purposes is drawn from a local fire hydrant. The hydrant is piped (4-inch diameter Schedule 40 PVC with glued joints) to the batch tank. Water consumption is metered via an in-line totalizer. At full open the maximum water delivery capacity is approximately 300 gpm. All water that passes through the tank, pump and UV system is discharged into the aeration tank for biological treatment through a 12-inch diameter, Schedule 40 PVC discharge line from the UV unit.

Two 20,000-gallon (nominal) capacity mobile frac tanks will be provided by Adler Tank Rentals (Newark, New Jersey). The tanks have epoxy linings to prevent rusting. The tank covers a footprint area about 50 feet by 9 feet and stands approximately 11 feet high. Each tank has an eight-inch flange connection on the front and a four-inch flange connection on the back. A four-inch diameter Schedule 40 PVC line serves as a recirculation loop and as a feed line to the main discharge pump. There is ladder access to the railed top area of the tank where there are two 2-foot diameter access manways. These manways are where additives (e.g., transmittance-altering substances or challenge organisms) are added.

Flow from the batch tank to the UV system is through an automatic-priming, diesel-powered centrifugal pump (Godwin Pumps, Inc., Bridgeport, New Jersey), Model Number CD150M or equivalent. The pump has eight-inch inlet and outlet flanged connections; based on estimated head losses, the maximum pump capacity is about 2000 gpm. The pump covers a footprint area about 6 ft by 10 ft.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

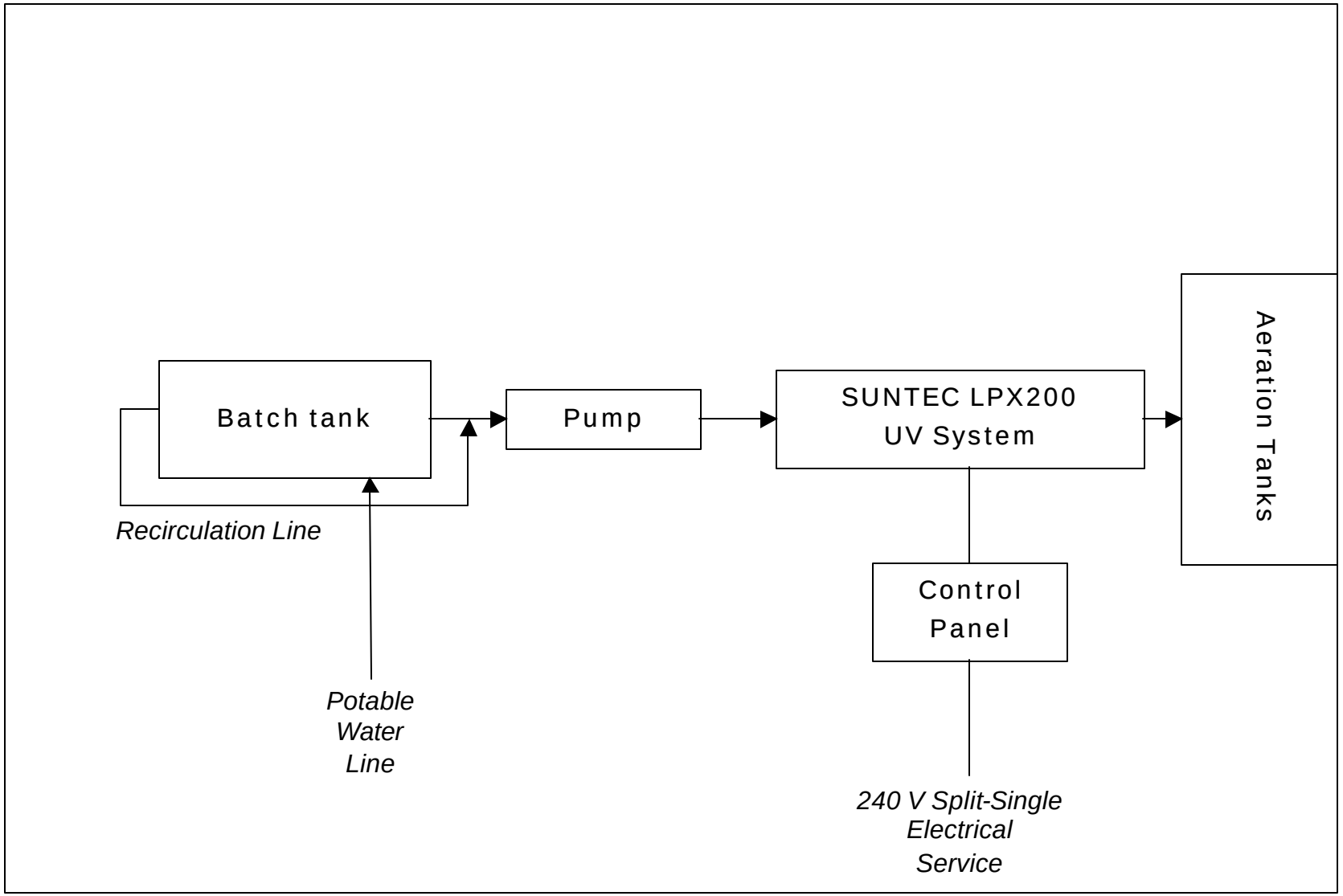


Figure 4-1. Flow Schematic for Conducting This ETV.

Table 4-1. Dose Delivery Verification Primary and Support Tasks.

Task/Subtask	Pertinent VTP Section	Pertinent Protocols or Procedures
Site Installation Requirements	4.2.1, Figure 2-1 and 2-2	Appendix A
System Startup and Shakedown	4.3.3	
Flow Meter Calibration	4.3.3.1	Field Protocol – 1 Appendix C
Lamp Burn-In	4.3.3.2	Field Protocol – 2 Appendix C
Headloss Measurements	4.3.3.3	Field Protocol – 3 Appendix C
Power Consumption and Stability	4.3.3.4	Field Protocol – 4 Appendix C
Residence Time Distribution	4.3.4	Field Protocol – 8 Appendix C
Shakedown Flows	4.3.3.6	Field Protocols – 5, 6 and 7 Appendix C
Dose Response Calibration		
Selection, Culturing and Harvesting of Test Organism	4.3.4.1	Special Laboratory Protocol – 1 Appendix D
Intensity Calibration for the Collimated Beam and Sensor	4.3.4.3	Special Laboratory Protocol – 2 Appendix D
Dose Response Test Procedure	4.5.4.5	Special Laboratory Protocol – 3 Appendix D
Dose-Flow Assays		
Test Batch Preparation	4.3.5.1	Field Protocol - 6 Appendix C
Set Quartz Surface Condition	4.3.5.2.1	Field Protocol - 5 Appendix C
UV Transmittance of Test Water	4.3.5.2.2	LM – 29, Field Protocol – 6 Appendix C
Lamp Output	4.3.5.2.4	N/A
Water Temperature	4.3.5.2.5	N/A
Hydraulic Loading Rates	4.3.5.2.6	N/A
Test Procedure	4.3.653.1, Tables 4-2 thru 4-4	Field Protocols - 5, 6 and 7 Appendix C
System Monitoring	4.3.5.3.3	N/A

US EPA ARCHIVE DOCUMENT

Metered direct electrical service is provided by the host site.

Flow metering is measured by a Fischer and Porter Model (10D1462) six-inch diameter magnetic flow meter.

A critical measurement is the UV output of the system at 254 nm. This is measured by an International Light Model 1700 Research Radiometer using an SED240 detector with a quartz wide-eye diffuser and NS254 narrow band filter. Detector calibration dates are 6/2001, and 2/2002.

Another important measurement is the UV transmittance of the test batch. A UV-Vis spectrophotometer (Shimadzu 1200) will be kept on-site for measuring the UV transmittance of samples. Transmittance will be verified at the lab with a Perkin-Elmer Lambda-6 spectrophotometer.

Technical specifications for the support equipment described in this section can be found in Appendix A.

4.2.2 Facilities

A small field trailer/office will be setup at the test site to provide copier needs, security for on-site equipment (e.g., radiometer and spectrophotometer), and storage area for supplies. The plant's restroom facilities are provided for use throughout the project duration.

4.2.3 Equipment and Supplies

Equipment needed to support the operation of the test facility, other than what may have already been described, include a forklift for moving heavy items (such as the UV test channel); this assistance will be provided by the host site.

HydroQual, Inc will provide the major supply items required to support the analytical and sampling needs of the ETV. Appendix B contains pertinent methods from HydroQual's Laboratory Method Manual, which includes general information pertaining to the treatability laboratory and appropriate method protocols. Equipment and supply needs associated with each analysis are presented within the description of each procedure.

4.3 OPERATING PLAN

The operating plan for the ETV verifications is comprised of several activities, some of which can be implemented simultaneously. These include the field and laboratory setup, UV equipment installation, shakedown runs, verification test runs and demobilization and removal of the test units.

US EPA ARCHIVE DOCUMENT

4.3.1 Field and Laboratory Setup

The field installation is essentially as shown on the plan layout (refer to Figure 2-1 through Figure 2-3). No other support equipment or facilities will be necessary from those already described. The same system will be used for both the 55% T and 65% T dose-delivery verifications.

All laboratory analyses will be conducted at HydroQual's laboratory facility in Mahwah, New Jersey or in the field by HydroQual personnel. The laboratory is equipped to conduct all of the analyses required under this ETV.

Some laboratory analyses, due to their nature, must be conducted on-site. This includes measurement of UV transmittance, detection of disinfection residual (e.g., total chlorine), pH, and temperature. To this end, equipment for conducting these tasks will be maintained in a dedicated area of the field office.

4.3.2 Field Sampling Locations

There are four (4) locations that will be sampled. These are shown in Figure 4-2. Procedures for sampling and analysis are discussed later sections.

All samples will be manually collected as grabs. A description of the sampling locations is as follows:

M1: Batch Effluent

Location M1 is the access manway on top of the batch tank.

S1: UV System Influent

Location S1 is the upstream portion of the UV reactor channel, approximately 1 foot ahead of the reactor. Samples are taken by dipping directly into the wastewater.

S2: UV System Effluent

Location S2 is the downstream portion of the UV reactor channel near the effluent weir, approximately 1 foot downstream from the effluent end of the lamp modules. Samples are taken by dipping directly into the wastewater.

P1: Pump Recirculation Line

Location P1 is a ball valve on the pump that allows sampling of the recirculating solution. This allows a sample to be taken without the technician climbing on top of the tank, thus enhancing operator safety. A comparison of samples taken here versus the manway shows no difference.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

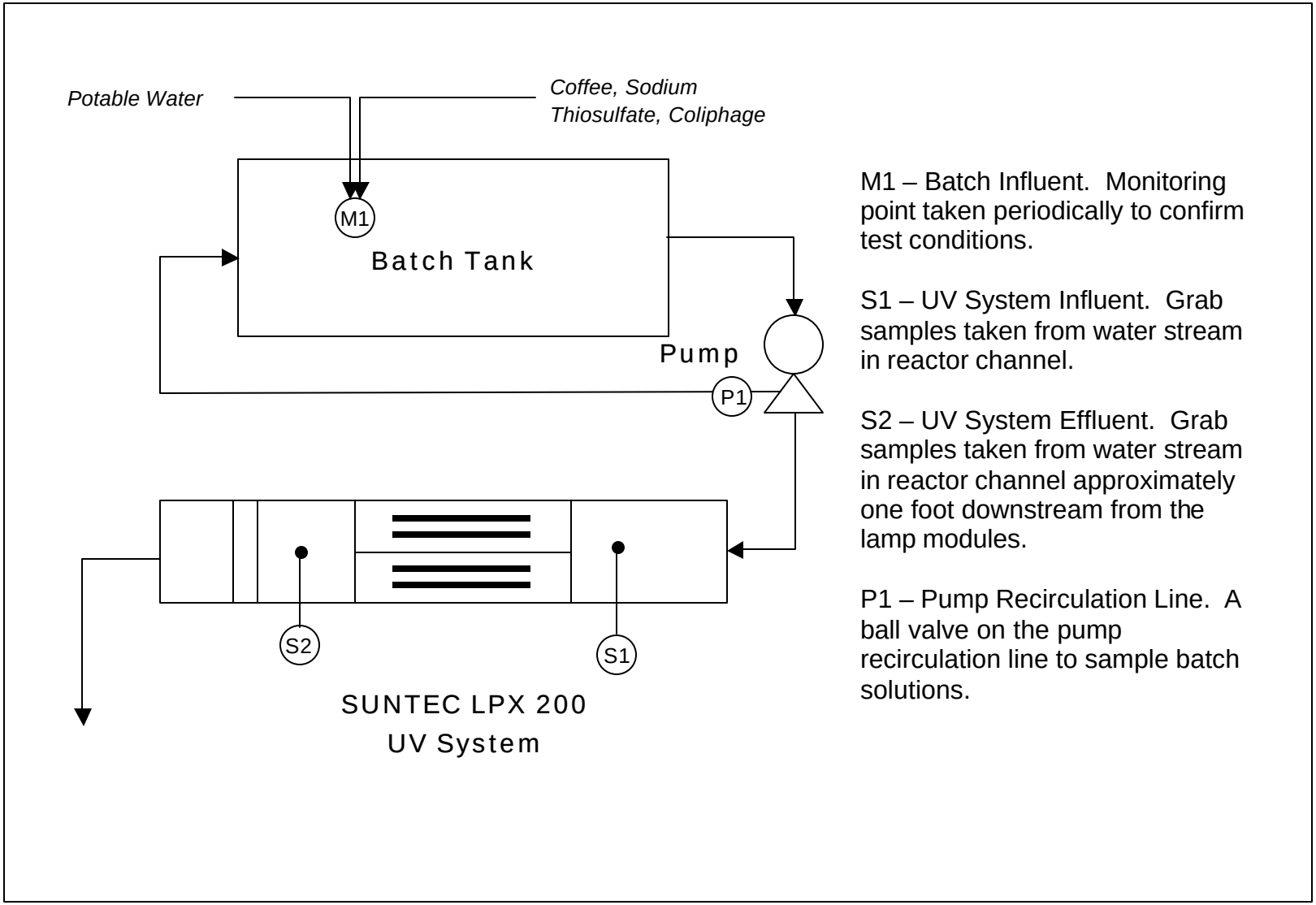


Figure 4-2. Schematic of Sampling and Monitoring Points.

4.3.3 System Startup and Shakedown

System startup and shakedown encompasses tasks aimed at applying operating and/or sampling protocols based on field conditions and making any minor modifications as required. This is also when main system-wide calibration checks are conducted, as well as limited performance testing to be able to assess that the system is operating per the manufacturer's recommendations and expectations prior to initiating the validation test runs. The manufacturer, in conjunction with the FTO, shall ensure that all monitors, indicators and alarms are functioning as designed.

4.3.3.1 Flow Meter Calibration

The system will have a 6-inch magnetic flow meter located between the pump and the influent chamber of the UV system installed per the manufacturer's recommendations.

The meter's calibration will be checked before the start of the ETV. Primary calibration will be done by measuring draw down in the batch tank over time to imply the flow. Calibration will be conducted at flow settings covering the range of flows used for the system validation.

Flow meter calibration checks will be conducted once for every fifteen active days of field testing or at least once during this ETV.

The Flowmeter Calibration Protocol (Field Protocol – 1) can be found in Appendix C.

4.3.3.2 Lamp "Burn-In"

After system installation is completed, it is necessary to burn-in the UV lamps for a period of at least 100 hours before any performance testing. This is required because the UV output of the lamps will not reach steady-state before the first 100 hours. The system will start with new, un-burned in lamps.

The Lamp Burn-in Protocol (Field Protocol – 2) can be found in Appendix C.

4.3.3.3 Headloss Measurements

After completion of the flow meter calibration check, headloss as a function of flow will be measured for the system using water depth measurements in the channel at several locations.

The Headloss Measurement Protocol (Field Protocol – 3) can be found in Appendix C.

4.3.3.4 Measurement of Power Consumption and Stability

During this ETV a series of experiments will be performed to evaluate the intensity output and power consumption of the pilot disinfection system. These will be performed with two goals: (1) To determine the power consumption of the system for dose-delivery normalizations; and, (2) To validate the conditions under which the flow-dose assays are conducted.

The experiments involve three phases of system behavior:

US EPA ARCHIVE DOCUMENT

(1) A two-hour monitoring period with the lamp output set at 100% to determine the minimum lamp warm-up time for stable UV output, and to determine the power usage of the overall system and ballast control boards.

(2) A series of measurements of intensity and power during a cycle of lamp power adjustments. This is to determine the response of the system to such adjustments and to test the repeatability of lamp turn-down adjustments.

(3) A monitoring period with the lamp power set at the simulated EOL conditions (70% output).

The Power Consumption and Stability Protocol (Field Protocol - 4) can be found in Appendix C.

4.3.3.5 Hydraulic Testing (Residence Time Distribution)

The hydraulic behaviour of the pilot test unit will be characterized by performing residence time distribution (RTD) analysis on the water flowing through the disinfection zone. In brief, a transmittance reducing substance (e.g., coffee solution) will be continuously injected just upstream of the lamp bank and monitored with a detector at the downstream end of the lamp bank. Once a steady state flow is established, the injector will be stopped and the behaviour of the clean water exiting the disinfection zone will be characterized.

The step-response curve will be digitized and analyzed numerically for various hydraulic performance parameters using methods based on USEPA (1986). Residence time distributions will be developed at 200, 500, 800, 1100, and 1500 gpm.

The Residence Time Distribution (RTD) Protocol (Field Protocol – 8) can be found in Appendix C.

4.3.3.6 Shakedown Flows

Before the start of any verification test runs, the FTO, in conjunction with the vendor will ensure that each system is installed correctly (hydraulically and electrically) and that the FTO is fully trained in all aspects of system operation and monitoring. This will include demonstration of all electrical controls, procedures for installing lamps and quartz sleeves, and elementary trouble-shooting logic. SUNTEC environmental will provide copies of their system Operations & Maintenance (O&M) manual to HydroQual for training and for troubleshooting reference.

The system will be pre-tested at three flows. This will be done with one test batch prepared with a 65% transmittance and an influent phage concentration of at least 1 x 10^6 pfu/mL.

These runs will be conducted following the same protocols used for the verification test runs (Field Protocols 5, 6 and 7). These results will be reviewed by SUNTEC environmental Inc. as a

US EPA ARCHIVE DOCUMENT

performance check and indicator that the field installation and the system operation is consistent with its design and performance expectations.

4.3.4 Dose–Response Calibration

Key elements of the bioassay process are the selection and harvesting of a test organism, and the accurate calibration of its response to UV exposure.

4.3.4.1 Selection, Culturing and Harvesting of Test Organism

The test organism that will be used is F-specific RNA bacteriophage MS2. F-specific RNA bacteriophage are bacterial viruses which can infect a specific host strain with F- or sex-pili, producing clear areas, or plaques, within a confluent lawn of grown host strain. The methodology for detection and enumeration of F-specific RNA bacteriophage is presented in (ISO 10705-1, 1995).

A 10 Liter stock of MS2 will be cultured and harvested by the methods outlined in (ISO 10705-1, 1995) to meet the needs for the entire SUNTEC environmental ETV. Bacteriophage stocks shall be kept separate and will be labeled with a sequential identifier number. The coliphage culturing procedure in included in Special Laboratory Protocol – 1 (Appendix D).

4.3.4.2 Collimated Beam Apparatus

The dose-response calibration will be conducted using HydroQual's collimated beam apparatus (Figure 4-3). The lamp housing is a horizontal tube, constructed of an opaque and non-reflective material. The lamp housing is ventilated continuously via a blower. The collimating tube, also constructed of an opaque non-reflective material, extends downward from the center of the lamp housing. The housing contains two conventional G64T5 low-pressure mercury discharge lamps, which emit almost all of their energy at 254 nm. The lamp temperature is monitored continuously via a digital thermometer with a thermocouple mounted on the lamp skin.

It is important that the intensity across the cross-sectional plane at the bottom of the collimating tube be relatively uniform. The irradiance across the surface plane of the sample dish is mapped with a radially symmetric pattern containing 19 points. Ninety percent of the data points shall have a ratio of single value to the average between 0.9 and 1.1. This procedure (detailed as Special Laboratory Protocol – 2 in Appendix D) ensures minimal variation of intensity across the surface of the sample. This procedure will be repeated every 120 hours of operation. The intensity of the dosing field will be verified at the beginning and end of each dose-response series.

All bacteriological samples will be exposed in a petri-type dish, with straight sides and a flat bottom. The outer perimeter of the sample container is always within the diameter of the collimator.

US EPA ARCHIVE DOCUMENT

4.3.4.3 Intensity Calibration for the Collimated Beam and Sensor

The UV intensity emitted from the collimating tube is measured with a radiometer (IL 1700 with an SED 240 detector by International Light, Newburyport, Massachusetts, or equivalent), calibrated using standards traceable to the National Institute of Standards and Technology. Detector calibration dates are 6/2001, and 2/2002.

4.3.4.4 Collimator Verification

The latter part of the dose calculation expression comprises a depth-correction for the incident intensity, such that the dose is computed with the average intensity in the sample. This assumes that the depth is not too deep, there is adequate mixing, and all other facets of the collimator are correct.

Collimator verification involves a test of the intensity and depth corrections for transmittance during UV exposure under the collimated beam. At a minimum, three transmittances will be tested: at 55%, at 65%, and at the transmittance laboratory saline solution (~99%). This validation requires that the dose required to achieve a given response should be within 10% of the dose for unadjusted waters. This verification will occur as a part of the dose-response on the seeded influent waters for water reuse applications.

The laboratory UV exposure will occur under conditions where the intensity at the bottom of the dish is greater than 25% of the surface intensity.

US EPA ARCHIVE DOCUMENT

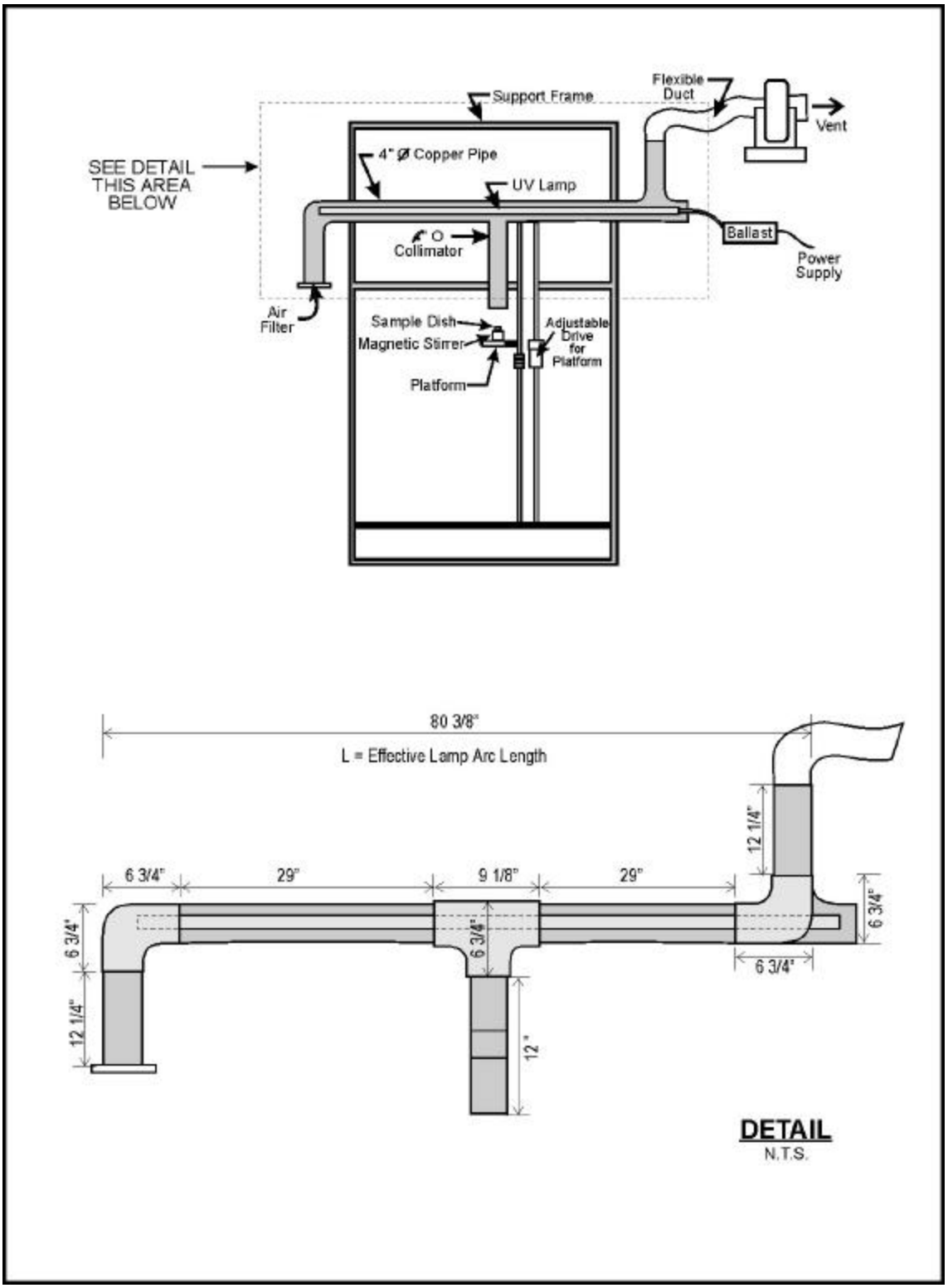


Figure 4-3. HydroQual Collimator Apparatus for Conducting Dose Response Tests.

US EPA ARCHIVE DOCUMENT

4.3.4.5 Dose-Response Test Procedure

Dose-response data will bracket the expected range of operating doses of the UV test unit. Doses between 10 and 100 mJ/cm^2 will be evaluated for quality control purposes. At least 80 percent of the dose-response data must fall in the area bound by:

$$-\log_{10}(N/N_0) = 0.044 \times [\text{UV dose, mJ/cm}^2] + 0.700 \quad (4\text{-}1)$$

$$-\log_{10}(N/N_0) = 0.036 \times [\text{UV dose, mJ/cm}^2] + 0.134 \quad (4\text{-}2)$$

Where:

N = Concentration of infective MS2 after UV exposure.

N_0 = Concentration of infective MS2 at dose zero.

The remaining dose points can lie outside the boundaries, however, all data points in the appropriate dose range shall be included in the regression analysis for the calibration curve.

The dose-response runs will be conducted before the field-testing is initiated, and through the term of the field tests for a minimum of 5 runs. If doses delivered by the pilot unit are outside the 10 and 100 mJ/cm^2 range then the appropriate dose response data must be generated to bracket the field-delivered doses. Samples will be plated in triplicate at two dilutions.

The procedure to be followed is presented as Special Laboratory Protocols – 1 and 3 in Appendix D.

4.3.5 Field Dose-Flow Assay

4.3.5.1 Test Batch Preparation

Batching will be used for preparing test water of consistent quality with respect to UV transmittance, dechlorination, and bacteriophage seeding. The batch tank is equipped with a recirculation system to adequately and efficiently mix the tank contents. Once the batch is prepared, the test water can be delivered to the UV system under controlled conditions.

The transmittance of the test water will be adjusted by adding instant coffee. Coffee has been found to be very effective at reducing the UV transmittance at 253.7 nm and testing has shown that it does not have an effect on MS2 phage at the levels routinely used for adjustment of the transmittance.

The test water is from a potable source, and as such the water needs to be dechlorinated before it is used in the assay. Dechlorination will be accomplished by adding sodium thiosulfate directly into the batching vessel. Sufficient sodium thiosulfate will be added above the calculated stoichiometric requirements. After mixing, the total chlorine will be measured. The use of the batch water shall proceed only after it is confirmed that there is non-detectable residual chlorine (less than 0.05 mg/L).

US EPA ARCHIVE DOCUMENT

The stock MS2 phage suspension will be added directly into the batching vessel in sufficient quantity to achieve a density between 10^6 and 10^7 pfu/mL. A typical HydroQual bacteriophage stock has a concentration of $10^{11\text{-}12}$ pfu/mL. This requires the addition approximately 1 L of stock to a full batch of water (~20,000 gallons).

With each new stock of bacteriophage, a test will be conducted to confirm that the bacteriophage are unaffected by the addition of thiosulfate and coffee at the test levels. This will be verified by dose responses on seeded influent water.

The Batch Preparation Protocol (Field Protocol – 6) can be found in Appendix C.

4.3.5.2 Test Conditions

Test conditions that need to be defined are the condition of the quartz surfaces, UV transmittance of the test water, indicator organism densities, lamp output, temperature and flow rates.

4.3.5.2.1 Quartz Surface Condition

The objective of this verification is to assess the performance of the system with respect to dose delivery, when the quartz surfaces are clean. The test unit's quartz sleeves will be manually cleaned before each "batch run" or, at minimum, once each day before startup of the unit.

This will be done by removing the lamp modules from the channel, spraying/wiping the quartz with a cleaner (e.g., Lime-Away), rinsing the surface with clean water. The lamp racks will be returned to the channel, flow will be introduced and the lamps will be started to verify that all are functioning. See Quartz Cleaning Protocol (Field Protocol – 5) in Appendix C.

4.3.5.2.2 UV Transmittance of the Test Water

The dose–flow assay will be conducted at two different UV transmittances representative of the range of UV transmittances observed with secondary effluent applications. The dose-flow assay will be conducted using test waters having UV transmittances of 55% and 65%.

The transmittance of the test water shall be adjusted as described in Field Protocol – 6. Transmittance shall be measured on-site and at the laboratory, using a UV spectrophotometer. Distilled water will be used as a reference and matched quartz cuvettes will be used to hold the samples and reference water.

4.3.5.2.3 MS2 Phage Densities

The density of the MS2 phage in the test water will be high enough to yield a measurable density after treatment at the highest applied dose. The target initial density will be between 10^6 to 10^7 pfu/mL. The minimum effluent density will be approximately 50 pfu/mL.

4.3.5.2.4 Lamp Output

US EPA ARCHIVE DOCUMENT

The lamps installed in the pilot unit will be new, and will be "burned-in" for a period of 100 hours (Field Protocol – 2, Appendix C). The testing shall then be conducted with the lamp output adjusted to 70% of the 100h burn-in output. This setting will be used to simulate the 100% output condition present after decreased lamp output and fouled sleeves present approaches the end-of-life (EOL) operating conditions, which require maintenance and lamp replacement.

In this ETV, the reduced lamp output will be 70% instead of the 75% required in the generic protocol; this results in more conservative simulation conditions. The 70% reduction was chosen based on the lamp aging data (Section 3.1.2), and SUNTEC environmental's LPX200 operational philosophy, which balances the slightly lower dose delivery of the system when approaching EOL with a longer interval between extensive maintenance procedures.

To achieve the 70% lamp output setting, the power to the system will be stepped down by using the lamp current adjustment on the PLC. The current level setting used will be verified in the power/intensity monitoring procedure. The reduction in UV intensity will be measured with a fixed UV intensity reading. The lamp output reading will be allowed to stabilize before flow testing commences.

4.3.5.2.5 Temperature

Lamp output will vary with temperature in this system (see Section 3.1.3). While the generic protocol permits bioassay flow tests to take place with 10° C to 30° C water, tests for this ETV will be performed with a water temperature range of 10°C to 20° C, allowing a decrease in lamp output of no more than 5%. The temperature of the test waters will be documented for each run.

4.3.5.2.6 Hydraulic Loading Rates

A minimum of five hydraulic loading rates shall be tested in quadruplicate. The hydraulic loading rate (HLR) is defined as the flow (Lpm) divided by the number of lamps. Alternatively, the HLR can be defined as the flow per Total Input Watts or nominal UV Watts in the system. In either case the flow is the primary variable. The flow rates to be tested are shown in Table 4-2.

US EPA ARCHIVE DOCUMENT

Table 4-2. Bioassay Test Flow Rates.

% Transmittance	Flow Rate
(%T/cm)	(gpm)
55	100
55, 65	200
55, 65	500
55, 65	800
55, 65	1100
65	1500

4.3.5.3 Test Procedures, Sampling, System Monitoring

4.3.5.3.1 Test Procedure

Each dose-flow assay shall be conducted using the same batch preparation procedure, thereby insuring similar test water characteristics with respect to organism density and UV transmittance. A minimum of four runs shall be conducted, each comprising five different doses. Influent and effluent samples will be collected in triplicate at each flow condition. Test flows will be conducted at the flow rates shown in Table 4-2. These flow rates may be adjusted after the startup/shakedown phase is completed after equipment installation. An addendum to this VTP will be prepared if there are any significant changes with respect to the test flows.

After a sample is collected, it will be capped, placed in a cooler and the cooler lid closed to prevent any exposure to sunlight. Samples will be plated within 48 hours after collection in triplicate at two dilutions. Samples collected for the determination of percent transmittance shall be kept at 4 ºC and analyzed within 48 hours of collection.

Refer to Field Protocols 5, 6, and 7 in Appendix C.

4.3.5.3.2 Field and Analytical Schedule

Table 4-3 summarizes the test schedule for assays to be conducted under this verification. The schedule covers 14 in-field test days and basic test operational parameters. Table 4-4 presents a summary of the analytical schedule associated with the field effort.

4.3.5.3.3 System Monitoring

The intensity of the lamps will be measured with the SUD detector before and after lamp turndown to assure that the 70% turn down is achieved accurately.

US EPA ARCHIVE DOCUMENT

Because power monitoring during flow tests is cumbersome due to the submerged nature of the ballasts, such tests result in loss of valuable test batch solution. As such, one flow series will be conducted while monitoring the power consumption of the ballasts and the overall system.

The flow-dose results from this limited flow series will be statistically compared to the rest of the data set for similarity at the 95% confidence interval. This will allow an extension of the power monitoring results to the rest of the data set.

The power consumption data collected during the flow test cannot be used for dose delivery per watt normalizations because the system is run at a lower power setting during bioassay flow tests to simulate the reduced performance at the end of life conditions.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

Table 4-3. Testing Schedule and Relevant Operating Conditions

SUNTEC environmental Secondary Effluent ETV

Test Day #	Nominal %T	Flow 1	Flow 2	Flow 3	Flow 4	Flow 5	Flow 6	Comments
SD	65%	200	800	1500				Shakedown Flows
1	65%	200	500	800	1100			
2	65%	200	500	800	1100	1500a	1500b	
3	65%	200	500	800	1100	1500		
4	65%	200a	500	800	1100	1500	200b	
5	55%	200	500	800	1100	1500		
6	55%	200	500	800	1100	1500		
7	55%	100	200a	500	800	1100	200b	
8	55%	100	200	500	800	1100	200N	
9	65%	200	800	1100				
10	55%	10a0	10b0	500	800			Power Validation Flows
11	55%	100a	100b	200	500			

(1) Flows designated “a” or “b” are duplicate flow events.
(2) Flows designated “N” are no-dose controls. All lamps turned off.

4.3.6 Data Compilation and Analysis

All data generated from the ETV dose-delivery verification will be compiled, analyzed and presented in the Verification Report. These data specifically address the components related to dose-response calibration, hydraulic characteristics, and the dose-flow evaluation on the test unit.

4.3.6.1 Dose-Response Data Analysis

The theoretical UV disinfection model follows first order kinetics according to the following equation:

$$N = N_0 e^{KIt}$$

Where:

N = the organism density remaining after exposure to UV, pfu/mL
N_0 = the initial organism density, pfu/mL
K = the inactivation rate constant, $cm^2/W\text{-}s$
I = the intensity of UV radiation, mW/cm^2
t = the exposure time, seconds

The product (It) is the applied UV dose. The above equation can be expressed as a linear relationship by graphing the logarithm of N/N_0 as a function of the applied UV dose. The resulting slope of a linear regression analysis is equal to the inactivation rate constant, K.

The data generated by a dose-response analysis are N, N_0 and the applied UV doses. These data are analyzed using the above equation to yield a log survival dose-response curve for the organism.

Under ideal conditions, the data from a dose-response analysis should be expected to intercept the origin, and should be linear throughout the full dose range. This is generally not the case. The observed data do not yield a y-intercept at zero, and there is evidence of tailing at the higher dose levels. The deviation of the observed data from the theoretical model results from the non-ideal conditions under which the tests are performed. For the purposes of developing a dose-response curve, it is more appropriate to apply a model that better represents the observed data. Figure 4-4 presents a non-linear regression of the example dose-response data.

For each stock culture harvested for this ETV, the controls and exposed residual phage, transmittance (absorbance), and exposure time data shall be compiled and tabulated, and the resultant dose and log survival ratio ($\log N/N_0$) computed and tabulated. The log survival ratio shall be plotted against the dose, and a non-linear correlation expression developed for each relevant

US EPA ARCHIVE DOCUMENT

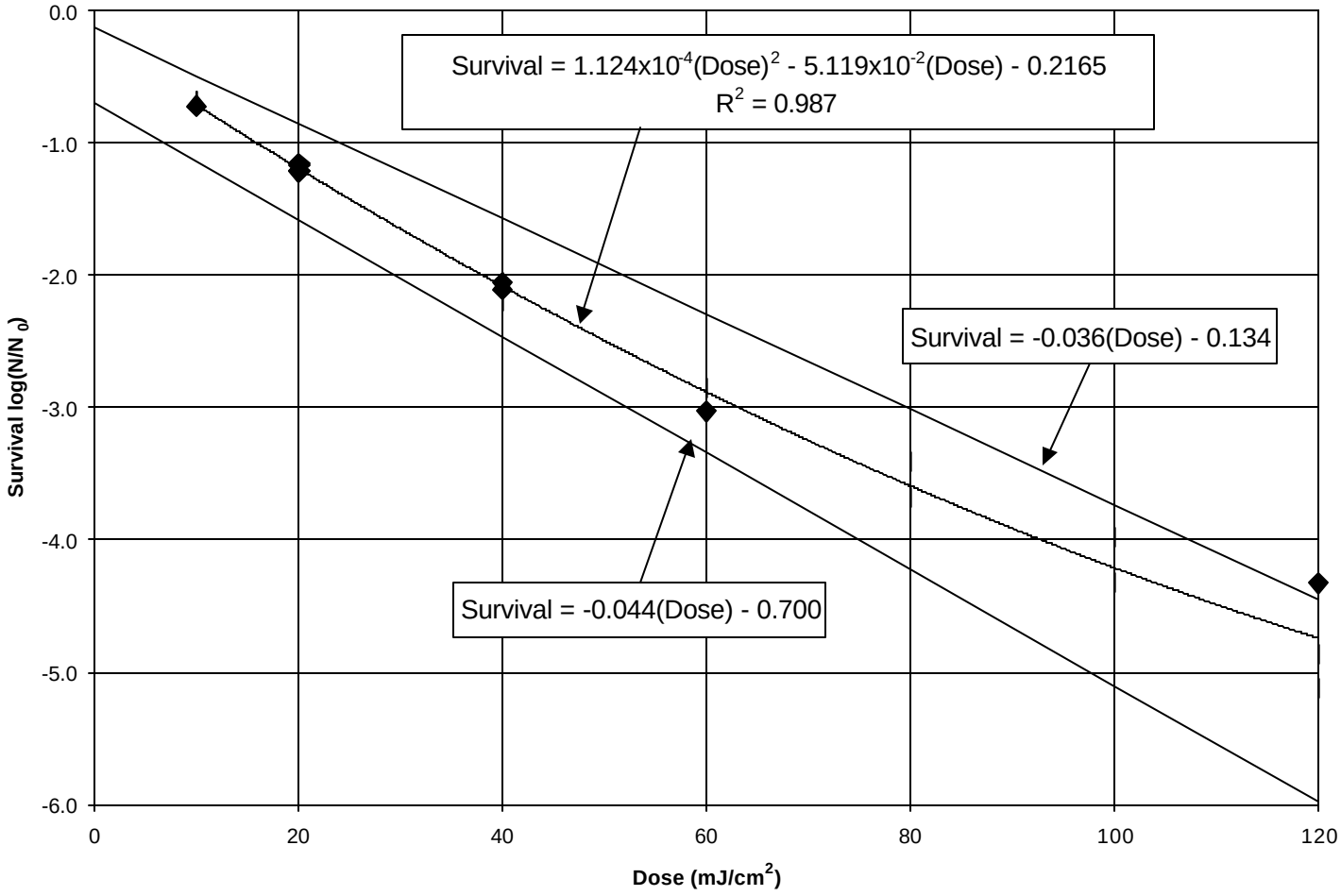


Figure 4-4. Example MS2 Dose-Response Correlation.

US EPA ARCHIVE DOCUMENT

stock as described above. The data shall adhere to the QA/QC criteria outlined in Section 4.3.4.5. If it falls outside the limits of the composite data, the Project QA/QC officer shall decide what corrective action or actions should be undertaken. Such actions may include the preparation of a new stock, repeating the dose-response tests, and/or acceptance of the stock after verifying its dose-response by the repeated tests.

4.3.6.2 Hydraulic Characterization

Residence time distribution (RTD) analyses provide information on the actual or anticipated hydraulic behavior of a unit. Note that the critical hydraulic design requirement for UV reactors is that the system approach ideal plug-flow conditions and minimize any degree of advective mixing. Parameters that indicate these conditions are derived from an analysis of the RTD curves.

RTD curves developed for the test unit will be presented in the verification report. There will be digitized tracer recordings for each test. The first derivative of the tracing will be calculated showing the slope of the curve as a function of time. Lastly, the cumulative area under the residence time curve as a function of time, effectively showing the distribution of residence times in the system, will be generated.

Key quantitative parameters derived from these RTD analyses will be tabulated. The flow rates and equivalent velocities through the lamp battery will be given. The theoretical detention time will be computed as the volume (less the quartz/lamp assembly) divided by flow (V/Q), while the mean residence time (è) is computed as the first moment of the residence time curve.

Several dimensionless ratios will be derived from the RTD analyses that are useful in evaluating hydraulic characteristics.

- è/T The ratio of the mean residence time to the theoretical residence time. This should fall between 0.8 and 1.2.
- t_p/è The ratio of the time at which the peak tracer level occurs to the mean residence time. An acceptable level is greater than 0.9, indicating absence of any skew in the residence time due to back mixing, dead spaces or eddying effects.
- t_{50}/è The ratio of the time for 50 percent of the tracer to pass to the mean residence time is also a measure of the skew and should be greater than 0.9 for effective plug flow.
- t_i/è The ratio of the time the tracer first appears to the mean residence time is a measure of short-circuiting, and should be greater than 0.5.
- t_{90}/t_{10} The ratio of the time for 90 percent of the tracer to pass to the time for 10 percent of the tracer to pass. Also known as the Morrill Dispersion Index, it is a measure of the spread of the residence time distribution curve; a value of 1.0 would indicate

US EPA ARCHIVE DOCUMENT

ideal plug flow, and 21.9 for ideal complete mix. A value of 2.0 or less is generally required for UV systems.

E The dispersion coefficient. E can vary from zero to infinity, approaching zero under ideal plug flow conditions. An E less than 100 cm^2/sec is generally targeted for UV disinfection reactors.

d The dimensionless dispersion number. d should fall below an acceptable upper limit of 0.05 for plug-flow conditions

Headloss and RTD data will be presented as tabular summaries.

4.3.6.3 Dose-Flow Relationships

The influent and effluent phage data from each test unit evaluation will be tabulated, along with the associated flow and transmittance data. The log survival ratio, or response, will be used to determine the delivered dose, by comparing it to the dose-response relationship developed by the collimated beam method. This equivalent dose is then computed and plotted against the flow rate for each of the transmittances tested. A non-linear regression analysis shall be conducted to develop a dose-flow relationship. This relates the dose as an inverse function of flow.

The flow shall be expressed as a hydraulic loading as follows:

1. Flow per lamp (Lpm/Lamp)

2. Flow per Total Watt Input

A dose relationship shall be developed for both of these parameters, in addition to the dose-flow relationship. The power-normalized calculations will be made using the 100% lamp output power measurements acquired during the Power Consumption and Stability experiments. Figure 4-5 presents an example of a dose-hydraulic loading (expressed as gpm/Lamp) relationship.

Other relevant data collected as part of the test program shall be compiled and presented, including:

- Intensity readings at the different flow settings and calibration steps
- Temperatures recorded for ambient air and water, and relevant system temperatures
- Other Measurements and certifications relevant to the specific ETV, e.g., flow meter calibration checks, collimator verification, sensor calibration checks, head loss, etc.

US EPA ARCHIVE DOCUMENT

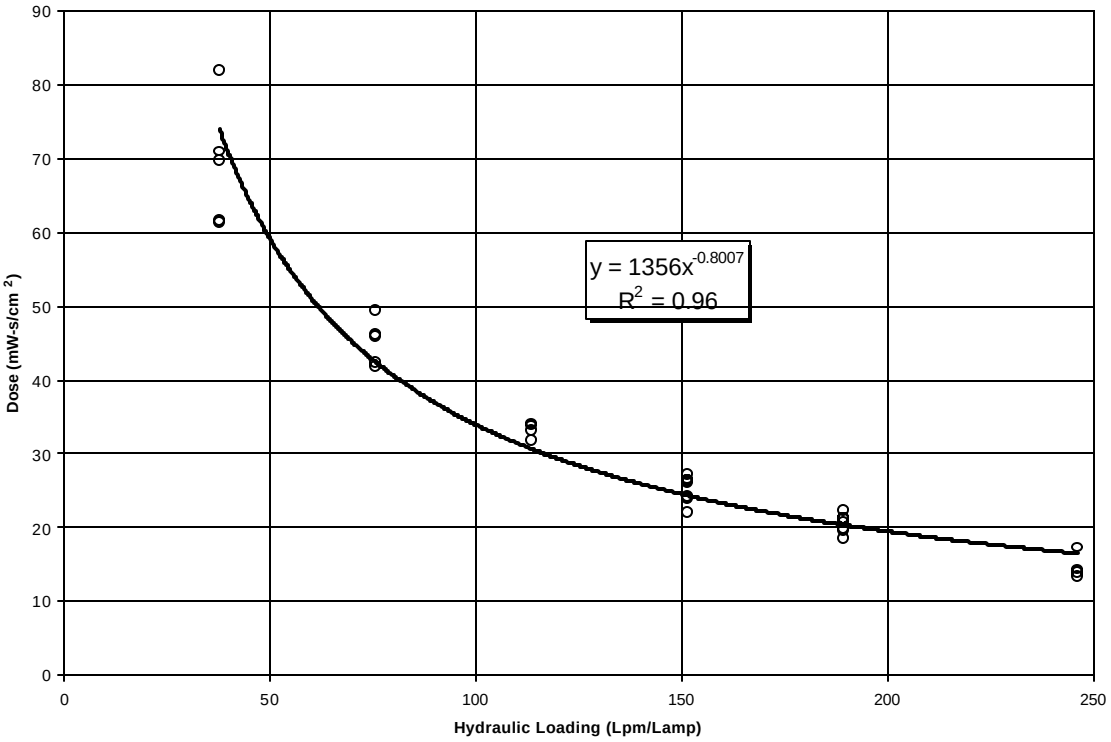


Figure 4-5. Example Relationship of Dose and Hydraulic Loading.

US EPA ARCHIVE DOCUMENT

SECTION 5

QUALITY ASSURANCE PROJECT PLAN

This Quality Assurance Project Plan (QAPP) has been prepared to support the USEPA Environmental Technology Verifications being undertaken by SUNTEC environmental Inc. under the Water Quality Protection Center ETV.

5.1 PROJECT DESCRIPTION, OBJECTIVES AND ORGANIZATION

5.1.1 Purpose of Study

The Environmental Technology Verification (ETV) program was created to accelerate the development and commercialization of environmental technologies through third party verification and reporting of performance. The goal of the ETV program is to verify performance characteristics of commercial-ready environmental technologies through the evaluation of objective and quality assured data so that potential buyers and regulators are provided with an independent and credible assessment of the technology that they are buying or permitting.

Disinfection for secondary effluent and reuse applications has been identified as one of the technology categories to be verified under the EPA/NSF Water Quality Protection Center ETV.

This Verification Test Plan (VTP) applies to ultraviolet radiation technologies that meet the general criteria set forth in the "Verification Protocol for Secondary Effluent and Water Reuse Disinfection Applications," (NSFI, October 2002). Details of this VTP focus on the selected Field Test Organization (FTO) and the verification protocols are modified to reflect a specific disinfection system provided by an independent vendor. Guidance is provided on the conduct of the testing, data reduction and analysis, and reporting required to validate the particular technology.

5.1.2 SUNTEC environmental Technology

The SUNTEC environmental Inc. UV system represents newer low-pressure lamp UV systems that have modified the design for increased germicidal output. These types of lamps take advantage of the high power conversion efficiency of the low-pressure lamps, while getting higher outputs. The output UV of the SUNTEC environmental lamp is nominally 2.25 times greater in UV output than the conventional low-pressure lamp. It is configured in a conventional open-channel design, with the lamps oriented horizontally and parallel to the direction of flow. The unit is equipped with an auto-wiper for maintenance of the quartz sleeves that enclose the lamps.

US EPA ARCHIVE DOCUMENT

5.1.3 Facility and Pilot-Plant Description

The designated host site is the Parsippany Troy-Hills Wastewater Treatment Plant located in Parsippany, New Jersey. All site preparations will be coordinated between HydroQual's project manager and the PTRH's designated project liaison.

The plant is a conventional activated sludge plant with final sand filtration prior to dissipation. The verification testing will take place at a single location within the plant allowing access to primary, secondary and filtered effluent as needed.

5.1.4 Project Objectives

The overall objective of this ETV is to validate the performance of the SUNTEC environmental Inc. LPX200 UV disinfection system for secondary effluent applications. The transmittances of the test waters will be adjusted to simulate secondary effluent applications and the lamp intensity will be reduced to simulate a dose delivery reduction to 70% due to fouled sleeves and aged lamps. Within this goal three objectives are identified:

1) Verify the flow-dose relationship for secondary effluent applications with wastewaters having UV transmittances at 254 nm of 65%.

2) Verify the flow-dose relationship for secondary effluent applications with wastewaters having UV transmittances at 254 nm of 55%.

3) Verify the hydraulic characteristics of the system by using hydraulic tracer analysis and quantifying headloss

Note: the performance of this disinfection system in wastewaters of 75% will not be validated in this test program.

5.2 ROLES AND RESPONSIBILITIES OF PARTICIPANTS IN THE VERIFICATION TESTING

Refer to Figure 5-1 for an organization chart for this ETV.

5.2.1 NSF International (NSF)

The Water Quality Protection Center ETV is administered through a cooperative agreement between USEPA and NSF International, Inc. (NSF), its verification partner organization. NSF administers the Pilot, and has selected a qualified FTO, HydroQual, Inc. (HydroQual) to develop and implement this Verification Test Plan (VTP).

NSF's other responsibilities include:

- Review and approval of the VTP;

US EPA ARCHIVE DOCUMENT

- Oversight of quality assurance including the performance of technical systems and data quality audits as prescribed in the Quality Management Plan for the Water Quality Protection Center;
- Coordination of verification report peer reviews including review by the Stakeholder Advisory Group and Technology Panel;
- Approval of the Verification Report
- Preparation and dissemination of the Verification Statement.

Key contacts at NSF relating to this VTP include:

Mr. Thomas Stevens, Program Director
Ms. Maren Roush, Project Coordinator
NSF International
789 Dixboro Road
Ann Arbor, MI 48105
(734) 769-5347

5.2.2 U.S. Environmental Protection Agency (USEPA)

The USEPA's National Risk Management Research Laboratory provides administrative, technical and quality assurance guidance and oversight on all Water Quality Protection Center activities. The USEPA will have review and approval responsibilities through various phases of the verification project:

- Verification Test Plan
- Verification Report
- Verification Statement
- Dissemination of the Verification Report and Verification Statement

Key contacts for this specific VTP include:

Mr. Ray Frederick
USEPA – NRML Urban Watershed Management Branch
2890 Woodbridge Avenue (MS-104)
Edison, NJ 08837-3679
(732) 321-6627
(732) 321-6640 (fax)
Frederick.ray@epamial.epa.gov

5.2.3 Testing Organization (FTO), HydroQual, Inc.

The selected FTO is HydroQual, Inc., Mahwah, New Jersey. HydroQual has a well-established, international reputation for expertise in the area of ultraviolet disinfection technologies.

Mr. O. Karl Scheible, Project Director, will provide overall technical guidance for the verification test program. Mr. Egon T. Weber II, Ph.D. will serve as the Project Manager and be

US EPA ARCHIVE DOCUMENT

responsible for day-to-day operations, project administration, and lab setup and oversight. Mr. Michael C. Cushing will be the lead field-technician, responsible for system installation, startup, sampling and record keeping. Mr. Prakash Patil will be the project microbiologist. Other HydroQual personnel who will have support roles during the verification projects include Ms. Joy McGrath (QA/QC Officer) and Messrs. Wilfred Dunne and Francisco Cardona (Field/Laboratory Support). HydroQual may also use additional in-house expertise as required.

HydroQual's responsibilities include:

- Develop the VTP in conformance with the Verification Protocol, including its revisions in response to comments made during the review period;
- Coordinate the VTP with the Vendor and NSF, including documentation of equipment and facility information, and specifications for the VTP;
- Contract with sub-consultants and general contractors as needed to implement the VTP;
- Coordinate and contract, as needed, with the Host test facility and arranging the necessary logistics for activities at the plant site;
- Manage the communications, documentation, staffing and scheduling activities to successfully and efficiently complete the verification;
- Oversee and/or perform the verification testing per the approved VTP;
- Manage, evaluate, interpret, and report the data generated during the verification testing;
- Prepare and view of the Draft Verification Report.

HydroQual's main office is located in Mahwah, New Jersey and has a staff of nearly 110. The mailing address is:

HydroQual, Inc.
One Lethbridge Plaza
Mahwah, New Jersey 07430
(201) 529-5151
(201) 512-3825 Fax
http://www.hydroqual.com

Dr. Weber will be the primary contact person at HydroQual, Inc.

Telephone extension: 7401 or
Email: eweber@hydroqual.com

Mr. Scheible can be reached at extension 7378 or

Email: kscheible@hydroqual.com

US EPA ARCHIVE DOCUMENT

5.2.4 ETV Host Site Parsippany Troy-Hills (PTRH) Wastewater Treatment Plant

The Parsippany Troy-Hills Wastewater Treatment Plant located in Parsippany, New Jersey will be the host facility for conducting this ETV.

The host site's responsibilities include:

- Dedicating the required area(s) for test equipment and setup
- Provide reasonable access to the facility for non-plant employees
- Provide some logistical support including personnel and/or equipment
- Review, approve and/or assist activities affecting the plant, such as electrical connections from plant main feed.

The plant is located at:

139 Edwards Road
Parsippany, New Jersey 07054
(973) 428-7953

Mr. Phil Bober, P.E. is the designated ETV liaison for PTRH. He can be reached at the above telephone number.

5.2.5 UV Technology Vendor SUNTEC environmental Inc. (A Division of Photoscience Japan Corp.)

The UV system to undergo verification is provided by SUNTEC environmental Inc. and represents a scalable version of their LPX200 UV disinfection system. SUNTEC environmental's responsibilities will include:

- Provide the test unit for verification and all ancillary equipment, instrumentation, materials and supplies necessary to operate, monitor, maintain and repair the system;
- Provide documentation and calculations necessary to demonstrate the system's conformity to commercial systems, hydraulic scalability, and to the requirements to the protocol;
- Provide descriptive details of the system, its operation and maintenance, its technical capabilities, and intended function in reuse applications;
- Provide technical support for the installation and operation of the UV system including designation of a staff technical support person, and an on-site technician for training and system startup;
- Certify that installation and startup of system is in accordance with the manufacturer's recommendations;
- Review and approval of the VTP; and
- Review and comment on the Verification Report and Verification Statement.

SUNTEC environmental Inc. is located in Ontario at the following address:

US EPA ARCHIVE DOCUMENT

SUNTEC environmental, Inc.
106 Rayette Road – Unit #1
Concord, Ontario
CANADA L4K 2G3
(905) 669-4450
(905) 669-4451 Fax

Dr. Elliot Whitby will be the primary contact for SUNTEC environmental Inc. He can be reached at the above telephone number or:

Email: ewhitby@suntecuv.com

5.2.6 Support Organizations

The FTO has identified one other organization that will provide support for activities that cannot be provided by NSF, EPA, HydroQual or SUNTEC environmental. This organization will be a subcontractor of and subordinate to HydroQual.

International Light, Inc.
17 Graf Road
Newburyport, Massachusetts 01950
Photodetector and radiometer calibrations

5.2.7 Technology Panel on High Rate Disinfection

The ETV Technology Panel on High-Rate Disinfection will serve as a technical and professional resource during all phases of the verification, including the review of test plans and the issuance of verification reports.

US EPA ARCHIVE DOCUMENT

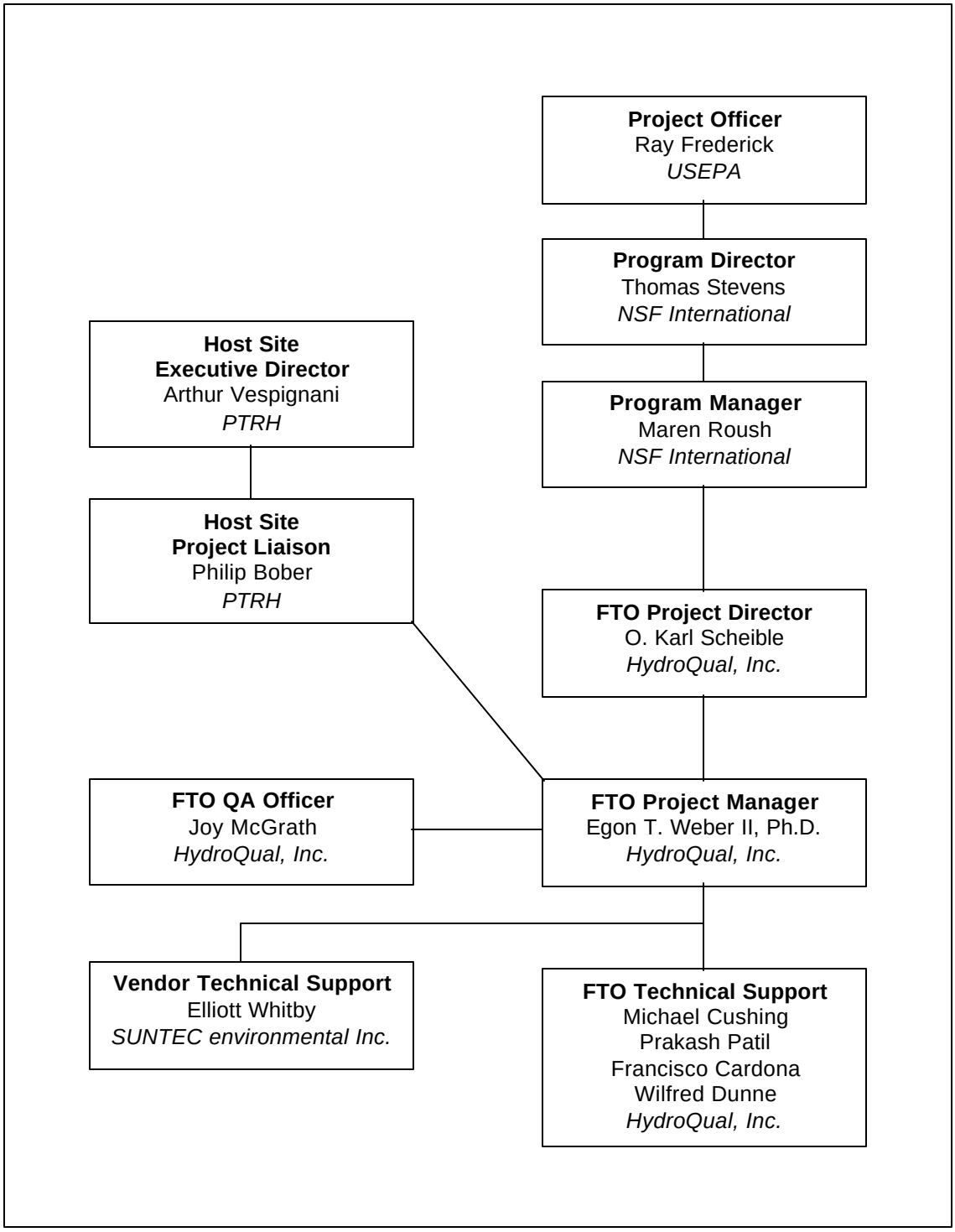


Figure 5-1. Key Technical and QA/QC Personnel for this ETV.

US EPA ARCHIVE DOCUMENT

5.3 GENERAL TECHNICAL APPROACH

5.3.1 Dose Delivery Verification

The ETV's first technical objective is met by demonstrating, or verifying, the ability of a specific system to deliver an effective dose. This is the "delivered dose", which is the dose actually received by the microbes in the wastewater. Direct biological assay procedures have generally been used to estimate the delivered dose for specific reactor configurations, typically as a function of the hydraulic loading rate. It is a viable and accepted method and has been used successfully for many years, whereby the results are often applied to qualification requirements in bid documents for wastewater treatment plant applications.

Under this ETV bioassays are run in a "clean" water matrix (from a potable water supply) that has been adjusted by chemical means to mimic the transmittances encountered under typical secondary effluent applications, in this case, dose delivery will be verified at 55% and 65% UV transmittance. The range of hydraulic loadings will be between 100 and 1500 gpm.

The hydraulic behavior of the reactor will be assessed for the range of the test flow by generating residence time distribution (RTD) curves via the step-response method; headlosses will also be measured.

5.4 PHYSICAL, ANALYTICAL, OR CHEMICAL MEASUREMENTS TO BE TAKEN DURING THIS STUDY

There are many physical, chemical or analytical analyses that will be conducted on the samples relevant to the Test Elements (Table 5-1). The sample collection and preservation requirements of both critical and non-critical parameters are presented in Table 5-2.

Table 5-1. Description of Parameter Measurements

	Parameter	Description
1	Temperature	The average temperature of the batch will be measured during the flow tests.
2	pH	The pH of the test batches will be measured.
3	Total Chlorine	Total chlorine will be measured on potable source water before and after dechlorination.
4	%Transmittance	Each grab influent sample for the UV unit will be analyzed for percent transmittance at 254 nm (%T).
5	MS2 Coliphage	All grab samples will be analyzed for coliphage.
6	Headloss	Headlosses will be measured during the shakedown phase.
7	Depth	The depth will be verified at each flow event.
8	Relative UV Intensity	The intensity will be measured before and after power adjustments.
9	Lamp Hours	The cumulative lamp hour readings will be recorded at each sampling.

US EPA ARCHIVE DOCUMENT

	Parameter	Description
8	Voltage/Current	Voltage and Current of the system will be measured during shakedown, and during one flow test series.

Table 5-2. Summary of Required Measurements and Sample Preservation.

Parameter/ Technology	Critical/ Non-Critical	Sample Quantity	Container	Preservation	Holding Time
Temperature	N	120 mL	Plastic	N/A	Inst.
pH	N	120 mL	Plastic	N/A	Inst.
Total Chlorine	C	120 mL	Plastic	N/A	Inst.
%Transmittance	C	120 mL	Plastic, Sterile	Ice/4ºC	48 Hours
MS2 Coliphage	C	120 mL	Plastic, Sterile	Ice/4ºC	48 Hours
Headloss	C	-	-	-	-
Depth	C	-	-	-	-
UV Intensity	C	-	-	-	-
Lamp Hours	N	-	-	-	-
Voltage/Current	N	-	-	-	-
Flow	C	-	-	-	-

5.4.1 Sampling and Monitoring Points

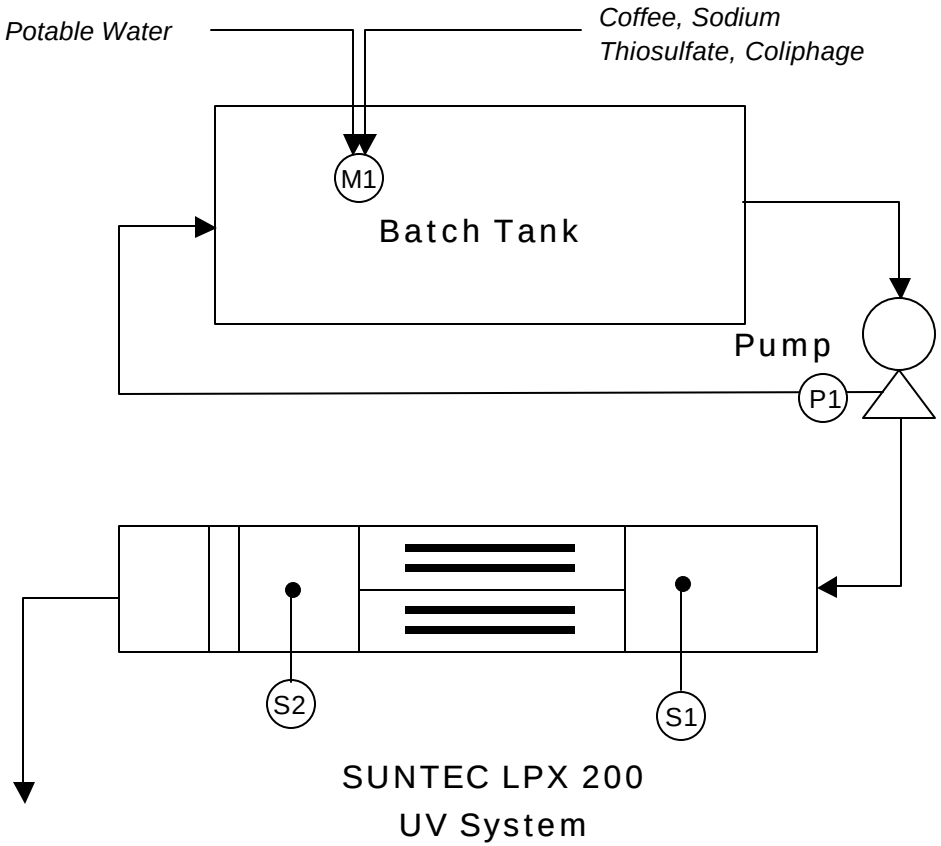
Sampling points identified are presented on Figure 5-2.

5.4.2 Frequency of Sampling/Monitoring

Refer to Tables 4-3 and 4-4 for the default sampling/analytical schedule. The lamp output turndown will be verified before each flow series. Power consumption will be measured during the shakedown phase and during one flow series.

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT



M1 – Batch Influent. Monitoring point taken periodically to confirm test conditions.

S1 – UV System Influent. Grab samples taken from water stream in reactor channel.

S2 – UV System Effluent. Grab samples taken from water stream in reactor channel approximately one foot downstream from the lamp modules.

P1 – Pump Recirculation Line. A ball valve on the pump recirculation line to sample batch solutions.

Figure 5-2. Sampling and Monitoring Points

5.4.3 Planned Approach for Evaluating Objectives (i.e. Data Analysis)

After data validation and reduction, the data will be used to quantify the projects overall objectives. These include:

- Delivered dose at discrete hydraulic loadings at UV transmittances of 55% and 65% using coliphage as indicator organism.
- Hydraulic characteristics as determined from the residence time distribution tests and head loss measurements.

Plots and comparisons to be made include:

Coliphage Calibration: Dose vs. Survival Ratio.

Dose Flow Relationships: Field delivered dose vs. hydraulic loading.

RTD: Residence time and dispersion as compared to theoretical values.

Headloss: Headloss vs. flow rate.

5.4.4 QA/QC Sampling

Quality control for the coliphage samples collected will consist of an evaluation of the triplicate samples collected at each flow condition. This will allow an analysis of the combined variability of the sampling and analytical procedures. Multiple measurements of %T of the influent samples will be made for each flow series (i.e., each batch). See table 4-4.

5.5 SAMPLING PROCEDURES

5.5.1 Method Used to Establish Steady-state Conditions

Based on previous experience and manufacturer's recommendations, steady state is contingent upon lamp output. During the shakedown phase a correlation between elapsed time and output (measured by a fixed point intensity measurement) will be developed. The SUNTEC environmental system will be allowed a minimum of thirty minutes warm-up time unless the elapsed time vs. output correlation demonstrates otherwise.

5.5.2 Sampling/Monitoring Procedure

Sterile plastic cups for samples will be on a grab basis. Sample containers may include sterile 120 mL specimen cups for coliphage analyses, total chlorine, and pH analyses. The coliphage containers will be transported on ice, in closed coolers to avoid any contact with sunlight.

5.5.3 Sample Container/Identification Labeling

For samples to be transported to the lab, sample containers will be indelibly marked with the vendor, date of collection, and unique sample identification (e.g., 500 gpm INF-A).

US EPA ARCHIVE DOCUMENT

5.5.4 Suitability of Sampling Procedure With Respect to Matrix

All sampling/monitoring procedures are appropriate for the associated chemical, analytical or physical parameter.

5.5.5 Sampling/Monitoring Equipment Calibration for Those Associated with Critical Parameters

Flow: The meter's calibration will be checked periodically as described in Section 4 and will be flow inferred by tank drawdown vs. time measurements. Prior to startup of the test unit, the flow meter check and calibration will be performed, adjusting the meter calibrations/settings until there is a conformance among meters (plus or minus 5 percent of the average, and within 5 percent of the primary flow measurements. These tests will be conducted at a minimum of three flows.

UV Intensity: The detector calibration dates are 6/2001, and 2/2002.

5.5.6 How Cross-Contamination Between Samples will be Avoided

All sample containers will be filled directly at each location. No secondary sampling device will be used.

5.5.7 Assure that Representative Samples are Collected

Each sampling location was chosen so that representative samples could be collected (see Fig. 5-2).

5.5.8 List of Sample Quantities to be Collected, Container Type, Sample Preservation, Holding Times

Refer to Table 5-2 for the required measurements (chemical, physical, or analytical) for this ETV.

5.6 TESTING AND MEASUREMENT PROTOCOLS

The standard methods used to make the critical measurements required for this study are listed in Table 5-3 along with the analysis agency.

5.6.1 Standard Methods/Non-standard Methods

Analytical methods for the required parameters are summarized in Tables 5-3. Tables 5-4 and 5-5 outline QA objectives for coliphage and dose-response measurements.

US EPA ARCHIVE DOCUMENT

Table 5-3. Summary of Standard Methods and Procedures.

Parameter	Sample Type	Analytical Agency	Method Title	Method Type	Reference and Method
Temperature	Potable Challenge Water	HQI	Temperature – Laboratory & Field Measurements	Direct Measurement	2550-B APHA, (1995)
pH	Potable Challenge Water	HQI	pH Value	Test Strips	0.1 maximum resolution.
Total Chlorine	Potable Challenge Water	HQI	Total Chlorine	Colorimetric	HQI LM-6;(1) HACH 8167; 10070
% Transmittance	Potable Challenge Water	HQI	UV Transmittance at 254 nm	Direct measurement	HQ LM-29(1)
MS2 Coliphage	Potable Challenge Water	HQI	Enumeration of F-specific coliphage	Double-Plating	Special Laboratory Protocol-1 Appendix D

(1) HQI-LM – HydroQual, INC. Laboratory Method Manual, Appendix B

US EPA ARCHIVE DOCUMENT

5.7 QA/QC CHECKS

5.7.1 Quantitative QC Objectives

5.7.1.1 Precision

The precision will be evaluated based on duplicate measurement. The relative percent differential (RPD) will be used to present precision as follows:

$$RPD = \frac{y_1 - y_2}{(y_1 + y_2)/2} \times 100\%$$

where y_1 and y_2 are two measurements.

5.7.1.2 Accuracy

For measurements where a standard reference material (SRM) is used, the accuracy is calculated as follows:

$$\%R = \left(\frac{y_m}{y_{srm}} \right) \times 100\%$$

where:

%R = percent recovery

y_m = measured value of SRM

y_{srm} = actual value of SRM

5.7.1.3 Completeness

Unless otherwise specified in each Test Element, data completeness will be greater than 80%. The completeness is defined as follows for all measurements:

$$\%C = \left(\frac{V}{T} \right) \times 100\%$$

where:

%C = percent completeness

V = number of measurements judged valid

T = total number of measurements

US EPA ARCHIVE DOCUMENT

5.7.1.4 QC Objectives for Water Analysis

QC for water analysis parameters such as %T is addresses by replicate analysis. See Table 4-4.

5.7.1.5 QC Objectives for Coliphage Enumeration Procedures

The Coliphage enumeration procedure (Special Laboratory Protocol-1) must follow the QC criteria in Table 5-6. Some Objectives are automatically checked by the Excel data reduction spreadsheets that will flag data that does not meet the criteria.

Table 5-4. Coliphage Enumeration QA/QC Criteria.

QC Objective	Frequency	Acceptance Criteria
30-300 pfu/mL	Every Sample	At least two plates must fall in this range for each sample enumerated.
Plating Replication	Every Sample	Identical dilutions meeting the 30-300 pfu/mL criteria must not vary more than factor of three (0.46 log units).
Blanks	Every influent effluent pair	Less than three plaques.
Sample Replicates	As noted in daily work plan.	Log survival ratios within 0.5 log units.

5.7.1.6 QC Objectives for Dose Response Results

The dose-response results (Special Laboratory Protocol-3) are to be verified according to the criteria in Table 5-7.

Table 5-5. Dose Response QC Criteria

QC Objective	Frequency	Acceptance Criteria
Field Intensity Mapping	Before and after every D/R event	Ninety percent of the data points shall have a ratio of single value to the average between 0.9 and 1.1.
0-Control and Final-Control	Each D/R event	Percent difference must be less than 50% (0.32 log units)
Representativeness	Each D/R event	80% of the D/R data must fall within 0.5 log units of historical HydroQual D/R results

5.7.2 Qualitative QC Objectives

5.7.2.1 Comparability

Comparability will be achieved by using consistent and standardized analytical methods and National Institute of Standards Technology (NIST) traceable standards. Procedures, data presentation, and units will be consistent with accepted conventions.

US EPA ARCHIVE DOCUMENT

5.7.2.2 Representativeness

Each sampling location was chosen so that representative samples could be collected. Locations were identified where natural mixing would prohibit settling of solids, which could bias analytical results (see Fig. 5-2).

5.7.3 Consequences of Not Meeting QC Objectives

If the QC objectives for a measurement are not met, an investigation of the difficulties will be conducted and, if necessary, corrective action taken. Data failing to meet any QC objective will be flagged in the final technical memorandum. As long as the completeness objectives are met with unflagged data, the QC objectives will have been met.

5.8 DATA REPORTING, DATA REDUCTION AND DATA VALIDATION

5.8.1 Reporting Requirements

Table 5-6 summarizes reporting requirements for all chemical and physical measurements.

Table 5-6. Reporting Requirements For Chemical/Physical Measurements

Analysis/Measurement	Units
Temperature	°C
pH	s.u.
Total Chlorine	mg/L
% Transmittance	%/cm @ 254 nm
MS2 Coliphage	pfu/mL
Headloss	cm
UV Intensity	mW/cm^2
Voltage/Current/Power	Volts/Amps/Watts
Flow	gpm

5.8.2 Documentation

All field and laboratory activities must be thoroughly documented. Field documentation will include field notes, field data sheets. Laboratory documentation will include laboratory bench sheets, and printouts of data reduction spreadsheets..

Field notes and data sheets will be gathered in a bound notebook. Each page must be labeled with the project name, date, and project number. Pertinent field data sheets can be found with their associated Field Protocols and are in Appendix B.

Any deviations from the approved final test plan shall be thoroughly documented in the field or laboratory notes. As appropriate, electronic data storage and retrieval capabilities shall be employed in order to maximize data collection and minimize labor hours required for monitoring.

US EPA ARCHIVE DOCUMENT

5.8.3 Document Handling

All original copies of any document are to be kept in a secure environment. All originals shall be kept in a central file at HydroQual in the office of the Project Manager. Two (2) sets of copies will be made; a set for the laboratory and a set for central filing. Other copies may be distributed to the vendor or other parties at the discretion of the Project Manager.

Daily activities and notes will be recorded in the notebook or on the pertinent data sheets (e.g., System Operation and Inspection Log).

5.8.4 Data Reduction/Validation and Reporting

5.8.4.1 Data Reduction

All measurements/analytical results must be reduced into units that are consistent with the methods and which meet the comparability objective. In general, all raw data will be recorded in laboratory notebooks or on worksheets in standardized format by the analyst performing the test. Each analytical method will contain detailed instructions and equations for calculating the respective parameters.

5.8.4.2 Data Validation

Data validation is the process of filtering data and accepting or rejecting these data on the basis of sound criteria. Validation procedures will include:

- Ensuring close adherence to the specified preparation, cleanup, and analysis procedure;
- Data transferred from bench-sheet to spreadsheet will be visually checked by another technician;
- Examination of precision, accuracy, and other quality control data generated during the project;
- Ensuring the use of properly calibrated equipment and maintaining analytical instrumentation.

Data acquired for routine analyses where laboratory data reduction is performed daily (e.g. dose-responses, %T etc.) will be validated daily by Egon Weber II. The Project Manger will perform periodic reviews of data QA/QC objectives. The Project QA officer will perform one audit.

Where QC criteria is completed automatically by spreadsheet, the algorithms will be verified by a second party, either the Project Manager or the QA Officer.

Final and interim reports will be checked against the laboratory printouts for errors.

US EPA ARCHIVE DOCUMENT

QC results outside of the data quality objectives specified in Section 5.4 and 5.7 are considered outliers for this project. Records of all data will be maintained even those judged to be outliers or of questionable value.

5.8.4.3 Data Reporting

All original laboratory data will be recorded in a permanent manner, and will be readily traceable through all steps of the data generation/reduction/validation/review process. Field measurements will be recorded in appropriate field notebooks/data sheets and results will be reported in tabulated summary form.

5.9 ASSESSMENTS

The project QA Officer will be responsible for making unannounced field and laboratory audits to observe adherence to cleaning/operational protocols, sample collection, sample handling practices and analytical procedures/methodologies.

At least one internal field audit and one laboratory audit shall be conducted during the ETV while the verification testing is underway. The auditor shall observe all aspects of the field and/or laboratory tests being conducted at that time. The QA Officer shall confirm that all sampling, operational, field measurements and laboratory analyses are conducted within the guidelines of these protocols and in strict accordance with the procedures presented within. Any deviations must be documented and technically justified.

US EPA ARCHIVE DOCUMENT

SECTION 6

GLOSSARY

Terms and acronyms used in this Protocol that have special meaning are defined here:

Accuracy - A measure of the closeness of an individual measurement or the average of a number of measurements to the true value and includes random error and systematic error.

EPA - The United States Environmental Protection Agency, its staff or authorized representatives.

Field Testing Organization - An organization qualified to conduct studies and testing of UV disinfection technology in accordance with the Verification Protocol.

Generic Verification Protocol - A written document that clearly states the objectives, goals, and scope of the testing under the ETV Program and that establishes the minimum requirements for verification testing and for the development of a verification test plan. A protocol shall be used for reference during Manufacturer participation in the verification testing program.

NSF - NSF International, its staff, or other authorized representatives.

Precision - A measure of the agreement between replicate measurements of the same property made under similar conditions.

Quality Assurance Project Plan (QAPP) - A written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project. The QAPP is a required component of a Verification Test Plan.

Representativeness - A measure of the degree to which data accurately and precisely represent a characteristic of a population parameter at a sampling point or for a process condition or environmental condition.

US EPA ARCHIVE DOCUMENT

Standard Operating Procedure - A written document containing specific procedures and protocols to ensure that quality assurance requirements are maintained.

Vendor - A business that assembles or sells UV Disinfection Technology.

Verification - To establish the evidence on the range of performance of equipment and/or device under specific conditions following an established protocol(s) and test plan(s).

Verification Test Plan (VTP) - A written document that establishes the detailed test procedures for verifying the performance of a specific technology. It also defines the roles of the specific parties involved in the testing and contains instructions for sample and data collection, sample handling and preservation, and quality assurance and quality control requirements relevant to a given test site.

Verification Report - A written document that summarizes a final report reviewed and approved by NSF on behalf of EPA or directly by EPA.

US EPA ARCHIVE DOCUMENT

SECTION 7

REFERENCES

APHA (1995) American Public Health Association, American Water Works Association (AWWA). Water Environment Federation (WEF). 1998. Standard Methods for the Examination of Water and Wastewater, 20th ed. Washington, D.C.: American Public Health Association.

Bolton, J.R., trans. (1997). "UV-Desinfektionsanlagen fur die Trinkwasserversorgung – Anfrorderungen und Prufung," (UV Systems for Disinfection in Drinking Water Supplies – Requirements and Testing). Bonn, Germany: Deutscher Verein des Gas – und Wasserfaches e.V. (DVGW) (German Association on Gas and Water).

HydroQual, INC., (January 2002). "Generic Verification Protocol for Secondary Effluent and Water Reuse Disinfection Applications" version 3.4. Prepared for NSF International and the U.S. Environmental Protection Agency under the Environmental Technology Verification Program, Source Water Projection Pilot. Mahwah, NJ.

ISO 10705-1: International Standards Organization (ISO). (1995). "Water Quality-Detection and Enumeration of Bacteriophage. Part I: Enumeration of F-Specific RNA Bacteriophage." Switzerland: International Standards Organization.

NWRI/AWWARF, (2000) National Water Research Institute and American "Water Works" Association Research Foundation. "Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse". Fountain Valley, California.

United States Environmental Protection Agency (USEPA). (1986). "Design Manual, Municipal Wastewater Disinfection". EPA/625/1-86/021.

US EPA ARCHIVE DOCUMENT