PROTOCOL FOR THE VERIFICATION OF WASTEWATER TREATMENT TECHNOLOGIES

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with support from the
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FOREWORD

In 1995, the U.S. Environmental Protection Agency (EPA) instituted a program, the Environmental Technology Verification Program (ETV), to verify the performance characteristics of commercial-ready environmental technologies through the evaluation of objective and quality-assured data. Managed by EPA's Office of Research and Development, ETV was created to substantially accelerate the entrance of innovative environmental technologies into the domestic and international marketplaces. ETV provides purchasers and permitters of technologies with an independent and credible assessment of the technology they are purchasing or permitting.

During its pilot phase, EPA has cooperatively managed twelve ETV pilots in conjunction with partner organizations, including states, federal laboratories, associations, and private sector testing and standards organizations. The pilots have focused on each of the major environmental media and various categories of environmental technologies and have been guided by the expertise of a Stakeholder Group. Stakeholder Groups consist of representatives of all verification customer groups for the particular technology sector, including buyers and users of technology, developers and vendors, state and federal regulatory personnel, and consulting engineers. All technology verification activities are based on testing and quality assurance protocols that have been developed with input from the major stakeholder/customer groups.

NSF International is an independent, not-for-profit organization, dedicated to public health, safety, and protection of the environment. NSF develops standards, provides educational services, and offers superior third-party conformity assessment services, while representing the interests of all stakeholders. In addition to well-established standards-development and certification programs, NSF specifically responds to and manages research projects, one-time evaluations and special studies.

NSF is the verification partner organization for three pilots under EPA's ETV Program: Drinking Water Systems, which has completed the pilot stage and is now a center, Wet Weather Flow Technologies, and Source Water Protection Technologies. This Protocol for the Verification of Wastewater Treatment Technologies was developed under the Source Water Protection Pilot, whose goal is to verify the performance of commercial-ready technologies used to protect ground and surface waters from contamination. Testing conducted under the ETV program using this protocol does not constitute an NSF or EPA certification of the product tested. Rather, it recognizes that the performance of the equipment has been determined and verified by these organizations.

Verification differs from certification in that it employs a broad, public distribution of test reports and does not use pass/fail criteria. In addition, there are differences in policy issues relative to certification versus verification. Certification, unlike verification, requires auditing of manufacturing facilities, periodic retesting, mandatory review of product changes and use of the NSF Mark. Both processes are similar, however, in regard to having standardized test methods and independent performance evaluations and test result preparation. This protocol is subject to revision; please contact NSF to confirm this revision is current.

ACKNOWLEDGEMENTS AND PREFACE

EPA and NSF acknowledge and thank those persons who participated in the preparation and review of this protocol, *Protocol for the Verification of Wastewater Treatment Technologies*. Without their hard work and dedication to the project, this document would not have been approved through the process that has been set forth for this ETV project.

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GLOSSARY OF TERMS

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.

Bias - the systematic or persistent distortion of a measurement process that causes errors in one direction.

Commercial Wastewater - wastewater that is generated at a commercial business establishment. It may contain sanitary wastewater from the facility.

Comparability – a qualitative term that expresses confidence that two data sets can contribute to a common analysis and interpolation.

Completeness – a qualitative term that expresses confidence that all necessary data have been included.

Core Parameters – the minimum wastewater quality and O&M performance parameters required to be measured for Verification Testing.

Domestic Wastewater – wastewater from residential facilities.

Effluent - the treated product liquid stream produced by a wastewater treatment technology.

Industrial Wastewater - wastewater that contains primarily process wastewater. It may also contain sanitary wastewater from the facility.

Influent - wastewater introduced to the wastewater treatment technology under evaluation for treatment.

Normally Distributed Data – data that meets the following: the data forms a bell-shaped curve when plotted as a graph, the mean is at the center of the distribution on the graph and the curve is symmetrical about the mean, the mean equals the median, the data is clustered around the middle of the curve with very few values more than three standard deviations away from the mean on either side.

Owner – the owner of a test site used for verification testing of a wastewater treatment technology.

Performance Data – removal efficiency and effluent concentration data for core and supplemental parameters.

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

Protocol – a written document that clearly states the objectives, goals, scope and procedures for the study. A protocol shall be used for reference during Vendor participation in the verification testing program.

Quality Assurance Project Plan – a written document that describes the implementation of quality assurance and quality control activities during the life cycle of the project.

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.

Residuals – waste streams, excluding final effluent (e.g., sludge, retentate) that may be continuously or intermittently discharged from the wastewater treatment technology.

Sanitary Wastewater – wastewater from washrooms, shower facilities and non-commercial kitchens.

Stakeholder Advisory Group for Decentralized Wastewater Treatment Technologies - a group of individuals overseen by a verification organization and consisting of any or all of the following: buyers and users of wastewater treatment technologies, developers and Vendors, consulting engineers, the finance and export communities, and permit writers and regulators.

Standard Operating Procedure – a written document containing specific instructions and protocols to ensure that quality assurance requirements are maintained.

Start-Up - The period between the time the wastewater treatment technology is put on-line and when stable operating conditions are achieved.

Stable Operation – the period during which the wastewater treatment technology performs in a consistent manner following a start-up period, within the range of Vendor-specified operating conditions.

Supplemental Parameters – wastewater quality and O&M performance parameters, in addition to the core parameters, that are necessary to verify a Vendor's claim.

Target Constituents – wastewater parameters that are specifically removed by the wastewater treatment technology.

Technology Panel - a group of individuals with expertise and knowledge in wastewater treatment technologies.

Test Plan – a written document that describes the procedures for conducting a test or study according to the verification protocol requirements for the application of a wastewater treatment technology at a particular site. At a minimum, the Test Plan shall include detailed instructions for sample and data collection, sample handling and preservation, precision, accuracy, goals, and quality assurance and quality control requirements relevant to the particular site.

Testing Organization – an organization qualified to conduct studies and testing of wastewater treatment technologies in accordance with protocols and Test Plans.

Upset Condition - a condition that causes the wastewater treatment technology performance to be outside of the range achieved during operation under the stable conditions defined by the Vendor. Such conditions may include, but are not limited to, equipment installation or operator error, unforeseen change in the influent wastewater characteristics, acts of God, or other unusual conditions. Sub-standard performance does not necessarily indicate the occurrence of an upset.

Vendor – a business that manufactures, assembles or sells wastewater treatment technologies.

Verification – To establish evidence on the performance of a wastewater treatment technology under specific conditions, following a predetermined study protocol(s) and Test Plan(s).

Verification Organization – the party responsible for overseeing test plan development, overseeing testing activities in conjunction with the Testing Organization, and overseeing the development and approval of the Verification Report and Verification Statement for the wastewater treatment technology. NSF is the Verification Organization for the ETV Source Water Protection Pilot.

Verification Report – a written document, often prepared by the Testing Organization, containing all raw and analyzed data, all QA/QC data sheets, descriptions of all collected data, a detailed description of all procedures and methods used in the verification testing, and all QA/QC results.

Verification Statement – A written document, approved by USEPA, which is prepared for a verification test conducted under the ETV Source Water Protection Pilot and summarizes the content of the Verification Report.

ABBREVIATIONS AND ACRONYMS

ANSI	American National Standards Institute
ASQC	American Society for Quality Control
BOD_5	five-day biochemical oxygen demand
$CBOD_5$	five-day carbonaceous biochemical oxygen demand
COD	chemical oxygen demand
DQI	data quality indicators
ETV	environmental technology verification
FOG	fats, oils and grease
gpd	gallons per day
kW	kilowatt
MG	million gallons
MSDS	material safety data sheets
NH_3-N	ammonia-nitrogen
NO_2-N	nitrite-nitrogen
NO_3-N	nitrate-nitrogen
NSF	NSF International (formerly National Sanitation Foundation)
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
P	phosphorus
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
QMP	quality management plan
SCADA	supervisory control and data acquisition
SOP	standard operating procedure
TKN	total Kjeldahl nitrogen
TSS	total suspended solids
USEPA	United States Environmental Protection Agency

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1.0 INTRODUCTION TO VERIFICATION TESTING

This document contains the generic protocol to be employed for the verification testing of commercially available, prefabricated technologies for the decentralized treatment of wastewater. Technologies eligible for evaluation under this protocol include all technologies for the decentralized treatment of non-residential wastewater (commercial or industrial), in addition to residential wastewater treatment technologies with a design average flow of greater than 1,500 gallons per day (gpd).

The protocol has been prepared under the United States Environmental Protection Agency (USEPA) Environmental Technology Verification (ETV) program.

1.1 The Environmental Technology Verification Program

The Environmental Technology Verification (ETV) Program was established by the USEPA and is intended to:

- evaluate the performance of innovative and commercially available environmental technologies;
- provide permit writers, buyers and users, among others, with objective information about technology performance; and,
- facilitate "real world" implementation of promising technologies.

The verification testing protocol is intended to serve as a template for conducting verification tests for various wastewater treatment technologies. The goal of the verification testing process is to generate high quality data for verification of equipment performance.

The ETV Program is subdivided into twelve individual pilot projects, one of which is the Source Water Protection Pilot. The ETV Source Water Protection Pilot developed the *Wastewater Treatment Technologies* protocol in order to conduct verification testing of prefabricated technologies that are appropriate for decentralized treatment of domestic, commercial and industrial wastewater. Other technology areas addressed by the ETV Source Water Protection Pilot include Nutrient Reduction[(1)] and Disinfection[(2)].

It is important to note that verification of a technology through the ETV Source Water Protection Pilot does not mean that it is "certified" or "endorsed" by NSF or USEPA. Instead, the verification process is a formal mechanism by which the performance of wastewater treatment technologies can be determined by these two Agencies, and which results in the issuance of a Verification Report and Verification Statement. Whilst a technology may not be "certified", the Verification Report and Verification Statement serve as means for independent verification of a Vendor's claims which can be used by decision makers when acquiring a technology.

1.2 Objectives of Verification Testing

The objectives of the proposed verification testing should be specific to the treatment claims made by the Vendor and the desired results of the evaluation, as will be presented in the Verification Report and Verification Statement.

In general, the objectives of verification testing shall be to determine the following:

- the performance of a specific wastewater treatment technology relative to the Vendor's stated range of technology capabilities, operating under field conditions;
- the necessary inputs (power, chemicals, labor, etc.) and the operating costs of the technology;
- the range of operating conditions and the ease of operation and maintenance of the equipment; and,
- the effect of the equipment operating cycle, including start-up, dynamic operation, and shutdown on treatment performance, and operational and maintenance performance.

Verification testing conducted at a single site may not represent the complete range of wastewater treatment capabilities of the wastewater treatment technology being tested. However, it will provide quality assured performance data to enable potential users of the technology to determine the applicability of the technology for the treatment of similar wastewaters. The Vendor may decide to conduct verification testing at multiple sites to demonstrate that a technology is capable of treating wastewaters with significantly different characteristics (e.g., domestic and slaughterhouse wastewaters).

1.3 Purpose and Scope of Protocol

This document contains guidance on verification testing of wastewater treatment technologies for Verification Organizations, Testing Organizations, Vendors, and test facility Owners. Instructions are provided for preparation of Test Plans, execution of testing, data management and analysis, and reporting.

Adherence to the guidelines presented in this document is intended to provide sufficient information to the Verification Organization to make a determination about the performance of particular equipment tested at specific sites, and can lead to issuance of a Verification Report and Verification Statement.

1.4 Verification Testing Process

The verification testing process consists of three phases, as shown in Figure 1. These three phases are briefly described below.

1.4.1 Planning

Prior to the verification testing of any wastewater treatment technology, the testing program must be properly planned. The planning phase involves a number of characterization activities culminating in the preparation of a site-specific Test Plan. A separate Test Plan is required for each site used for verification testing. The planning phase is carried out by the technology Vendor, the Testing Organization, and the Verification Organization.

The main activities involved in the planning stage are as follows:

- identifying the individuals or organizations that will be involved in the testing, and the responsibilities of all parties;
- identifying the general and specific objectives of the testing;
- identifying a suitable test site;
- obtaining influent wastewater characterization data;
- designing the experimental program for the testing, including a monitoring and maintenance schedule, and scheduling and procedures for sampling and analysis;
- determining the quality assurance (QA) and quality control (QC) program;
- determining how data will be handled and verified; and,
- preparing a site-specific Test Plan.

An outline of the Test Plan requirements and a brief discussion on specific sections of the Test Plan are presented in Appendix A.

1.4.2 Verification Testing

This phase includes the actual verification testing activities, using the activities and procedures specified in the Test Plan. The wastewater treatment technology will be operated in order to assess its ability to meet the objectives identified in the planning stage. Verification Testing is carried out by an independent Testing Organization.

1.4.3 Data Assessment and Reporting

This last phase includes all data analysis and data verification steps, as well as Verification Report and Verification Statement preparation. Data assessment and reporting are typically carried out by the Testing Organization. In order to expedite the process, the Verification Organization may opt to hire a consultant to draft the Verification Report.

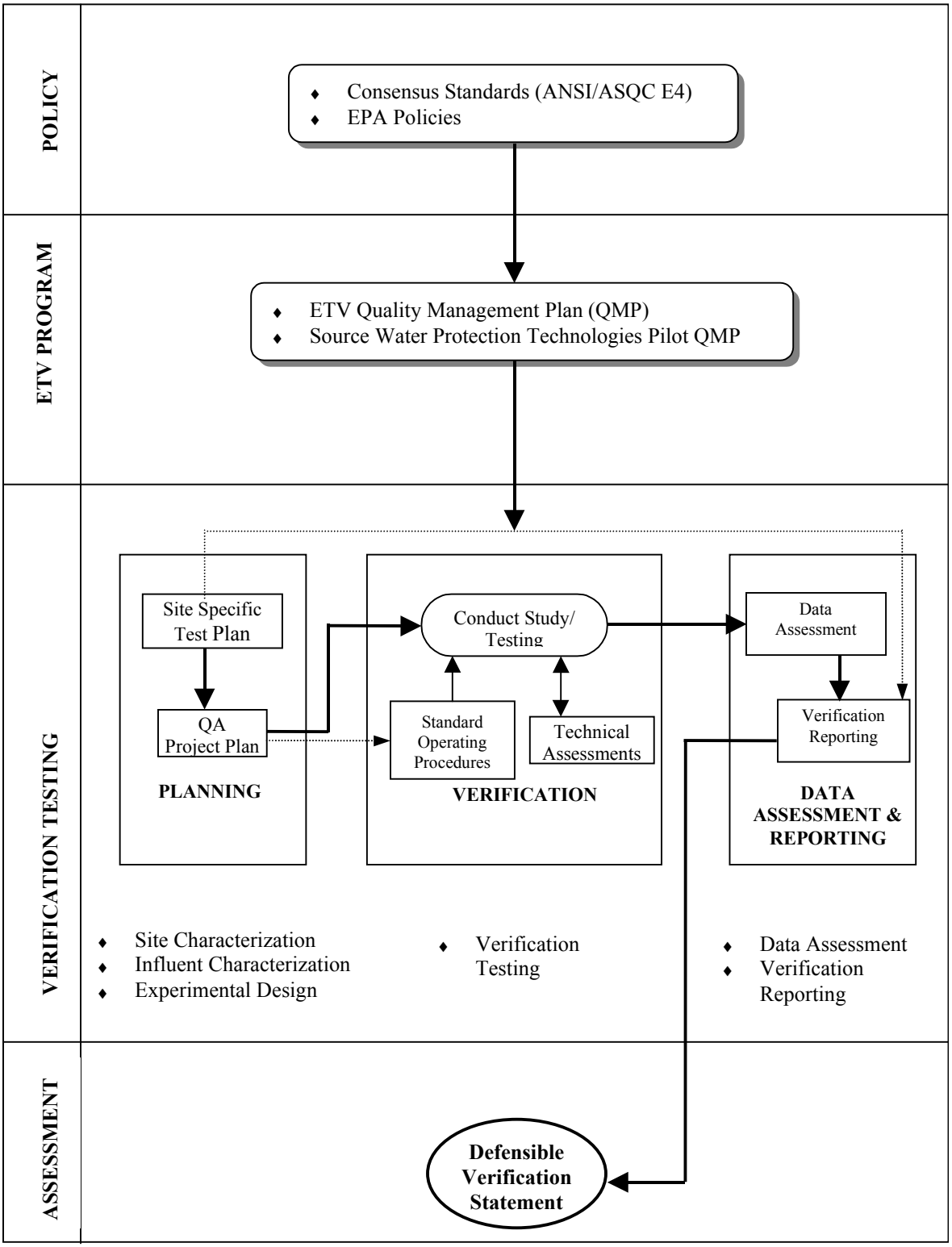
1.5 Policies and Program Specifications and Guidelines

Figure 1 also shows the relationship of the verification testing process to USEPA policies and consensus standards such as ANSI/ASQC E4[3], and quality management plans (QMPs).

The ETV QMP[4] provides specifications and guidelines on test-specific activities. The ETV Source Water Protection Technologies Pilot QMP[5] addresses the quality systems for testing activities.

For testing conducted under the ETV Source Water Protection Pilot, the verification testing process will be in accordance with USEPA and ETV policies, specifications and guidelines. Further information on USEPA policies and ETV Program QMPs is available from NSF/USEPA and on the ETV website (http://www.epa.gov/etv).

Figure 1: Verification Testing Process



2.0 RESPONSIBILITIES OF INVOLVED AGENCIES

The testing of wastewater treatment technologies will usually involve seven parties, each with responsibilities during verification testing. Agencies that will be involved include the following:

- the Vendor of the wastewater treatment technology (Vendor);
- the Testing Organization;
- the test facility owner (Owner);
- the Verification Organization;
- the USEPA;
- the Technology Panel; and,
- the Stakeholder Advisory Group.

The responsibilities of each party are presented in the following sub-sections.

Due to their approval and permitting powers, regulatory agencies can have an important role to play following verification testing. In addition, as testing is carried out at an operational facility, regulatory agency approval may be required prior to verification testing. It is therefore recommended that the appropriate regulatory agencies be advised of proposed testing, and that they are requested to indicate their particular requirements or issues. In turn, the Testing Organization, in conjunction with the Vendor and Owner, should incorporate regulatory agency requirements and issues within the site-specific Test Plan as much as possible.

2.1 Vendor

The Vendor shall have the following responsibilities:

- initiation of application to ETV for testing;
- selection of the Testing Organization;
- provision of verification testing objectives to be incorporated into the Test Plan;
- selection of a proposed test site;
- provision of any available site data (e.g., representative historical flow and characterization data);
- review and approval of the site-specific Test Plan;
- conduct preliminary influent wastewater characterization if deemed necessary by the Testing Organization and/or Verification Organization for site acceptance;
- provision of complete, field-ready equipment and the operations and maintenance (O&M) manual(s) typically provided with the technology (including instructions on installation, start-up, operation and maintenance) for verification testing;
- provision of existing relevant performance data for the wastewater treatment technology if it has been tested/operated at other locations;
- provision of logistical and technical support as required; and,

- provision of assistance to the Testing Organization on the operation and monitoring of the equipment during the verification testing on an "as needed" basis.

2.2 Testing Organization

The Testing Organization shall have the following responsibilities:

- preparation of the site-specific Test Plan (or assisting a third party, such as a consultant, with Test Plan development);
- conducting verification testing, according to the Test Plan;
- operation and maintenance of the wastewater treatment technology equipment in accordance with the Vendor's O&M manual(s);
- controlling access to the area where verification testing is being carried out;
- maintaining safe conditions at the test site for the health and safety of all personnel involved with verification testing (including compliance with OSHA and state regulations);
- scheduling and coordinating all the activities of all verification testing participants, including establishing a communication network and providing logistical and technical support on an "as needed" basis;
- managing, evaluating, interpreting and reporting on data generated by verification testing; and,
- evaluation and reporting on the performance of the equipment.

2.3 Owner

The Owner shall have the following responsibilities:

- provision of logistical and technical support as may be agreed upon by the Testing Organization, Vendor, and Owner;
- provision of assistance during testing as may be agreed upon by the Testing Organization, Vendor, and Owner; and,
- notifying the Testing Organization of any significant changes in site operations that may affect the flow and/or quality of wastewater produced at the site.

2.4 Verification Organization

The Verification Organization shall have the following responsibilities:

- qualification of test sites;
- qualification of Testing Organizations;
- reviewing and commenting on the site-specific Test Plan and coordinating its review by members of the Technology Panel;
- coordinating the approval of the Test Plan by the Vendor and the EPA Pilot Manager;

- carrying out an on-site audit of test procedures;
- reviewing, commenting on and disseminating the Verification Report and Verification Statement; and,
- preparation and the dissemination of the Verification Report and Verification Statement. For technology verifications performed under the ETV Source Water Protection Pilot, Verification Reports and Verification Statements shall be posted on the ETV and NSF web sites.

2.5 USEPA

This protocol was developed with financial and quality assurance assistance from the Environmental Technology Verification (ETV) Program, which is overseen by the EPA Office of Research and Development. For testing conducted under the ETV Source Water Protection Pilot using this protocol, the EPA Pilot Manager will approve Test Plans prior to the onset of testing. Verification Reports developed under the ETV Program will be subject to EPA approval. Verification Statements will be subject to the approval of the ORD laboratory director.

2.6 Technology Panel

The Technology Panel consists of a group of individuals with expertise and knowledge in wastewater treatment technologies. The Panel will assist the Verification Organization in reviewing and commenting on the site-specific Test Plan.

2.7 Stakeholder Advisory Group

The Stakeholder Advisory Group has assisted in the review and revision of this protocol.

3.0 WASTEWATER TREATMENT TECHNOLOGY CAPABILITIES AND DESCRIPTION

3.1 Wastewater Treatment Technology

For the purpose of this verification testing program, wastewater treatment technologies are defined as prefabricated, commercially available systems for the decentralized treatment of domestic wastewater with a design average flow rate of more than 1,500 gpd, in addition to all prefabricated, commercially available systems for the treatment of commercial or industrial wastewater.

The technology will typically provide total treatment of wastewater, rendering it suitable for disposal to a particular environment. However, some technologies may require some form of pre-treatment (e.g., screening, pH correction) or post-treatment (e.g., disinfection). Wastewater treatment technologies can be biological, physical or physical-chemical in nature.

3.2 Performance Objectives

The performance objectives of the technology are provided by the Vendor's stated claim of technology capabilities. In addition to the Vendor's claims, there is a minimum requirement for performance objectives, which are the core treatment performance parameters to be measured for all technologies tested.

The performance evaluation of wastewater treatment technologies is based on the assessment through site-specific testing of the following:

- treatment performance measured as effluent concentrations for specific wastewater quality parameters under a normal range of influent conditions;
- treatment performance measured by removal efficiencies for specific wastewater quality parameters under a normal range of influent conditions, including performance reliability and changes; and,
- O&M performance measured by a number of quantitative and qualitative O&M indicators, including the use of consumables (i.e., water, chemicals and power), labor requirements, residual generation, ease of operation, and any other factors. Performance reliability and changes will also be assessed.

The specific wastewater quality parameters and O&M performance parameters used to assess treatment performance include two categories of parameters.

- The core parameters used in testing at all sites. The core parameter list is the minimum required for testing purposes.
- Supplemental parameters that may be necessary to verify Vendor claims. The Testing Organization will select supplemental parameters in conjunction with the Vendor.

The parameters required for influent and effluent wastewater streams are discussed in Sections 4.4.3.4. O&M parameters are discussed in Section 4.4.3.5.

3.3 Acceptability for Testing

The Verification Organization and the USEPA are committed to fairness for all wastewater treatment technology Vendors. However, the Verification Organization and the USEPA reserve the right to reject offered wastewater treatment technologies that do not have a demonstrable application for wastewater treatment or which, for technical reasons, cannot be accommodated in the evaluation.

3.4 Description of Environmental Technology

A detailed description of the wastewater treatment technology to be evaluated by verification testing shall be included in the Test Plan. Refer to Appendix A for further information on the required details.

4.0 EXPERIMENTAL DESIGN

4.1 Test Plan

A Test Plan shall be prepared delineating the specific objectives and tasks for the verification testing; the verification testing experimental design, and the specific procedures to be followed throughout verification testing. The experimental approach for influent wastewater characterization, wastewater treatment technology start-up, and verification testing shall be presented in the Test Plan. The Test Plan shall address quality assurance/quality control (QA/QC), and data handling and presentation. An environmental, health, and safety plan shall also be presented in the Test Plan.

While certain input into the Test Plan will be required of the Vendor, the Testing Organization, or a qualified third party such as a consultant, is primarily responsible for preparing the Test Plan. The Verification Organization shall review and coordinate the approval of the Test Plan prior to the start of verification testing.

The required content for the Test Plan are as listed below:

A. Title Page/Approval by Project Participants/ Table of Contents
B. Project Description and Objectives
C. Project Organization and Personnel Responsibilities
D. Test Site Description
E. Wastewater Treatment Technology Description
F. Experimental Design
G. Field Procedures
H. Sampling Procedures
I. Analytical Procedures
J. Quality Assurance Project Plan (QAPP)
K. Data Management, Analysis and Reporting
L. Assessments
M. Environmental, Health, and Safety Plan
N. References
O. Appendices

The content requirements for the Test Plan are discussed in more detail in Appendix A.

4.2 Influent Wastewater Characterization

4.2.1 Introduction

Influent is defined as the influent wastewater stream to the technology (including any pretreatment stage). For example, if a technology is designed to treat septic tank effluent, then the influent wastewater is the septic tank effluent stream.

Influent characterization data is necessary to develop an appropriate Test Plan. Average, peak and minimum flowrates and patterns, and loadings must be reasonably known or projected. The

Vendor is responsible for identifying the influent wastewater stream to the technology and for supplying the Testing Organization with influent characterization information.

Influent characterization data is to be used by the Testing Organization for determining site suitability and to define influent pretreatment/post-treatment requirements, system operating conditions, and process monitoring requirements. This data is not used for performance evaluation. The influent characterization results shall be presented in the final verification testing report.

4.2.2 Objectives

The objectives of the influent wastewater characterization task are to:

- determine the hydraulic flow characteristics of the wastewater source that is to be used for verification testing; this includes flow patterns and minimum, average, and peak-day flowrates;
- evaluate the concentrations and daily mass loadings of target constituents to be removed by the wastewater treatment technology;
- determine any pretreatment and/or post-treatment requirements (e.g. removal of floatables);
- determine process monitoring requirements; and
- record and document all influent characterization conditions and results.

4.2.3 Requirements

The Vendor is responsible for the accuracy of the influent characterization data. The following requirements apply to the Vendor for influent characterization:

- Where available, review at least two years existing historic flow data (e.g., monthly flow) to determine if there is a potential for seasonal changes in wastewater flow. Seasonal fluctuations in wastewater flow shall be taken into account when carrying out verification testing.
- Obtain sufficient hydraulic flow data so that average daily, peak day, and minimum daily flows, and expected flow patterns are delineated. At a minimum, two months of daily flow monitoring is required. The flow stream to be monitored shall be that which will be introduced to the treatment technology to be tested. The Vendor may choose to monitor instantaneous flows if such flows are expected to impact the performance of the treatment technology. If instantaneous flows are not critical, water use may be measured by a water meter(s) installed on the water supply line(s) and recorded daily, or more frequently as needed. If water use data is collected, any significant water use that does not contribute to the wastewater flow (e.g., water that enters the product at a manufacturing site) should be metered separately.

- At a minimum, four 24-hour flow-composited samples for target constituents shall be collected, with at least one sample taken during an expected peak-flow period. The sampling conditions shall be documented. Industry standard procedures (e.g., USEPA Methods[6], Standard Methods for the Examination of Water and Wastewater[7]) shall be employed for analytical samples (sample volume/collection, preservation, storage/transportation, analysis, etc.). If the Vendor can provide a good estimation of the influent quality based on data obtained from and experience with similar sites (i.e., actual data from a similar site or data provided in the literature), then the influent sampling and analysis may not be required. Some examples of these sites may be schools, offices or other commercial establishments. These data and experience from similar sites shall be provided to the Testing Organization for incorporation to the Test Plan. The Verification Organization can request Influent Characterization sampling and analysis at the test site if it considers that the estimated wastewater quality data from other sites are not acceptable.

- Review site historical wastewater quality data, where available. If historical data are available, consider if site operations and/or wastewater management techniques have changed substantially from the time the available data were collected, and make appropriate judgment as to whether historical data are valid for comparison to current conditions. Valid historical data can help to assess whether limited characterization results are representative.

- Determine the pre-treatment and/or post-treatment requirements, if any, for the technology to be tested.

- Provide all characterization data and results to the Testing Organization.

Note – This protocol does not address methods for adding components to the influent wastewater stream (such as the addition of Giardia lamblia to verify a vendor's claim for pathogen reduction). Therefore, influent spiking shall not be performed for technologies verified under this protocol.

Table 1 presents a summary of flow monitoring and sampling requirements for influent characterization.

Table 1: Flow Monitoring and Sampling Summary for Characterization

Flow Monitoring:	• Review historic flow data to determine any seasonal changes in flow • Minimum two months of daily flow monitoring at representative location
Influent Quality:	• With no site data, minimum four 24-hour flow-composited samples for target constituents with at least one sample taken during an expected peak-flow period • Based on data for similar sites, an estimation of influent quality may be made

The influent characterization data shall be used to develop an appropriate Test Plan. The following requirements apply to the Testing Organization or designated Test Plan preparer:

- Include the Vendor-supplied characterization data and results in the Test Plan.
- Develop procedures to be included in the Test Plan for meeting any pre-treatment and/or post-treatment requirements specified by the Vendor.
- Determine process monitoring requirements and prepare procedures to be included in the Test Plan.

4.3 Start-up

4.3.1 Introduction

The wastewater treatment technology to be tested shall be started-up in accordance with Vendor instructions provided in the O&M manual(s), which are incorporated into and attached to the Test Plan. The Vendor shall indicate a length of time required for start-up, typically the time needed to attain Vendor-specified, stable operating conditions. The Vendor shall specify the stable operating characteristics of the wastewater treatment technology, factors that may affect start-up, and modifications or procedures that may be required to achieve stable operation. This information shall also be incorporated into the Test Plan. The start-up conditions, observations, and results shall be presented in the final verification testing report.

Equipment that has been previously installed at a test site may be used for verification testing, provided that the equipment is emptied and cleaned such that a complete start-up phase is carried out (as per new installations). This includes draining all equipment and removing any solids (including biological growth used as part of the treatment process) or other residuals.

4.3.2 Objectives

The objectives of the start-up tasks are to:

- start-up the wastewater treatment technology in accordance with Vendor O&M manuals;
- make modifications as needed to achieve stable operation;
- reach stable operation of the wastewater treatment technology; and,
- record and document all start-up conditions, observations and results.

4.3.3 Requirements

A work plan shall be prepared and included as a part of the Test Plan. The work plan shall address the following start-up requirements:

- The Testing Organization shall start-up the wastewater treatment technology in accordance with Vendor O&M manuals(s).

- The Testing Organization shall conduct start-up for the period specified by the Vendor. At the end of this start-up period, the Testing Organization shall assess whether the wastewater treatment technology has reached a stable state, as specified in the O&M manual, such that verification testing can begin. If the wastewater treatment technology operation is not assessed to be stable, then start-up shall continue, up to a maximum of two times the Vendor-specified start-up period. If stable operations have not been attained by then, the Testing Organization shall review the Test Plan for applicability and determine where adjustments and modifications are required.
- The flow monitoring and recording that will be used for the Verification Testing shall be initiated.
- Sampling and analysis of influent and effluent shall be performed to assess the status of the wastewater treatment system. For Vendor-specified start-up periods of one month or greater, 24-hour flow composited samples for target constituents shall be taken once per month. Industry standard procedures (e.g., USEPA Methods[6], Standard Methods for the Examination of Water and Wastewater[7]) shall be employed for analytical samples (sample volume/collection, preservation, storage/transportation, analysis, etc.). If the Vendor-specified start-up period is less than one month, then no sampling is required during start-up.
- The Vendor shall identify any additional equipment, process maintenance, changes in operating conditions, or other modifications needed to ensure effective operation of the system and/or to attain stable conditions.
- The Testing Organization shall document conditions, observations and results throughout the entire start-up period, to be presented in the Verification Report.

Table 2 presents a summary of flow monitoring and sampling requirements during start-up.

Table 2: Flow Monitoring and Sampling Summary for Start-Up

Flow Monitoring:	Initiate flow monitoring to be used in Verification Testing
Influent and Effluent Quality:	For Vendor-specified start-up periods of one month or greater, 24-hour flow composited samples for target constituents shall be taken once per month to assess status of wastewater treatment technology start-up

4.4 Verification Testing

4.4.1 Introduction

Wastewater treatment technology performance in a field setting with a specific waste stream will be evaluated and documented during verification testing. In addition, operating conditions will be monitored and documented, and certain O&M criteria will be evaluated and documented. Verification testing conditions, observations, and results shall be presented in the Verification Report.

4.4.2 Objectives

The general objectives of verification testing are to:

- evaluate the treatment performance of the wastewater treatment technology, relative to removal of target constituents, operating under Vendor-specified conditions;
- evaluate wastewater treatment technology O&M criteria; and,
- record and document test conditions, observations and results; other more specific verification testing objectives shall be defined by the Vendor and included in the Test Plan.

4.4.3 Requirements

The following requirements for verification testing shall be addressed in the Test Plan.

4.4.3.1 Verification Testing Period

A minimum of one verification testing period shall be performed. The verification testing period may commence after the start-up period is complete, as defined in Section 4.3. The verification testing period shall run a minimum of twelve consecutive months and include all seasons, with no more than 10% upset conditions or downtime (approximately 36 days). The verification testing period shall be adjusted, as needed, to make up for time lost during upset conditions or downtime beyond 36 days. The verification testing test period shall encompass the full range of flow and influent quality characteristics of the test site establishment. Longer test periods may be needed depending on the wastewater treatment technology to be tested and Vendor specifications, site characteristics, and influent characteristics, among others. The potential need for a longer verification testing period shall be identified by the Vendor and presented in the Test Plan.

In cases where the wastewater treatment technology to be tested is a non-biological system, a shorter verification testing period may be performed. For these technologies, the minimum test period shall be three consecutive months or a period covering the expected full variation in influent wastewater characteristics, whichever is the longest. Where it is considered that the verification testing period shall be greater than three and less than twelve consecutive months, a discussion on how the verification testing period was chosen shall be included in the Test Plan. There shall be no more than 10% upset conditions or downtime and the verification testing period shall be adjusted, as needed, to make up for time lost during upset conditions or downtime beyond the 10% limit.

The verification testing period is summarized in Table 3.

Table 3: Verification Testing Period Required

Biological Systems:	Minimum 12 consecutive months after start-up; no more than 36 days upset or downtime.
Non-biological Systems:	Minimum 3 consecutive months after start-up completed; no more than 9 days upset or downtime.

4.4.3.2 Flow Monitoring During Verification Testing

Flow monitoring of the influent to and effluent from the wastewater treatment technology is required during the testing period. Flow data required include total daily flow and daily peak instantaneous flow. Flow monitoring shall be carried out at representative locations. These flow monitoring locations shall be clearly identified in the Test Plan.

If the flow into the wastewater treatment technology equals, or nearly equals, the flow out of the treatment technology (i.e., there are minimal or no byproduct streams), then only the influent flow or effluent flow needs to be monitored.

4.4.3.3 Analytical Sampling Periods and Frequency

Analytical sampling for Verification Testing shall occur under average, peak-day, and minimum flow conditions. At least one-third of the samples shall be taken during average flow periods and one-third during peak-day flow periods.

Note - If the test location establishment has days where flows are not generated, then these days shall not be included in the sampling periods.

There must be a sufficient number of samples collected for analytical testing during Verification Testing so that a reasonable conclusion regarding the wastewater technology treatment performance can be reached.

All samples shall be collected over a four-day event, except for those parameters requiring grab samples (refer to Tables 5 and Table 6). Sampling shall consist of four discrete 24-hour composite samples that are analysed separately or combined prior to analysis. The method to be used for each wastewater parameter is dependent on the maximum sample holding time and preservation required, as per industry standard procedures (e.g., USEPA Methods[6], Standard Methods for the Examination of Water and Wastewater[7]). The average and range of all samples shall be reported in the Verification Report.

For biological systems, there shall be a minimum of 16 sampling events carried out over the verification testing period, which includes one for each month of testing. Each sampling event shall be either four discrete 24-hour composite samples, combined 24-hour composite samples, or four grab samples, as required for each parameter measured.

The minimum number of Verification Testing analytical samples shall comply with the following:

- For biological systems, there shall be a minimum of twelve "monthly" four-day sampling periods for each target constituent (either as four discrete 24-hour composite samples, combined 24-hour composite samples, or four grab samples, as required by industry standard procedures, e.g., USEPA Methods[6], Standard Methods for the Examination of Water and Wastewater[7]). "Monthly" samples shall be taken each calendar month no less than ten days after the preceding "monthly" sample.

- There shall be a minimum of four additional "supplemental" four-day sampling periods for each target constituent. These "supplemental" samples may be scheduled immediately preceding or following any one of the "monthly" sampling events such that data is gathered over a total of eight consecutive days. It may be appropriate to incorporate one "supplemental" four-day sampling period during each season (i.e., spring, summer, fall, winter).

- In cases where the wastewater treatment technology to be tested is a non-biological system and a shorter Verification Testing period has been approved (see Section 4.4.3.1), there shall be a minimum of twelve four-day sample periods for each target constituent.

The Testing Organization shall present the full Verification Testing sampling schedule in the Test Plan for all "monthly" and "supplemental" samples.

Footnote: A four-day sampling period was selected so that the average treatment performance could be analyzed over a longer time period, without requiring an exorbitant number of samples. The treatment performance will be studied over a wider range of influent variability as well.

Flow Note: The test location establishment may not have peak or average flows over a continuous four-day period. In this case, the sampling events for peak and average flows shall be scheduled, to the extent possible, so as to be "centered" on the four-day period. For example, the establishment may have peak flows typically occurring on Friday and Saturday, and no flows generated on Monday. In this example the sampling event would be scheduled to start on Thursday and continue through Sunday.

Table 4 presents a summary of the periods and frequency of analytical sampling.

Table 4: Analytical Sampling Periods and Frequency

Analytical Sampling Periods:	Occur under average, peak-day, and minimum flow conditions; at least one-third of samples taken during average flow conditions and one-third during peak-flow conditions
Analytical Sampling Frequency for Verification Testing Period **Biological Systems:**	"Monthly": Minimum of 12 four-day sampling periods, one each month, at least ten

	days between sampling events. "Supplemental": Minimum of 4 four-day sampling periods to be scheduled at the discretion of the Testing Organization.
Non-Biological Systems:	Minimum of 12 four-day sampling periods.

4.4.3.4 Sampling and Analysis

Samples of influent and effluent shall be analyzed to assess the treatment performance of the wastewater treatment technology. Due to the variability in target constituents from test to test, a set of core parameters for sampling and analysis will apply to all Verification Tests. Depending on the target constituents specified by the Vendor, appropriate supplemental parameters for sampling and analysis shall be selected and specified in the Test Plan. The core parameters and supplemental parameters are presented in further detail in the following sections.

Industry standard procedures (e.g., USEPA Methods[6] , Standard Methods for the Examination of Water and Wastewater[7]) shall be employed for analytical samples (sample volume/collection, preservation, storage/transportation, analysis, etc.). Standard procedures for field analysis (e.g., pH, temperature) shall be contained in the Test Plan.

All composite samples shall be flow proportional. Sample collection using a refrigerated automatic sampler is recommended for flow composited samples. The sampling equipment shall be described in the Test Plan.

Core Parameters

The influent and effluent shall be analyzed for the respective core parameters listed in Table 5. Unless specified as a field measurement, all analyses shall be performed by a Verification Organization-qualified laboratory.

Table 5: Core Parameters for Verification Testing

		Sample Location		
Parameter	**Sample Type**	**Influent**	**Effluent**	**Testing Location**
pH	Grab	√	√	Test Site
Temperature (°C)	Grab	√	√	Test Site
TSS (mg/L)	Flow composite[1]	√	√	Analytical Laboratory
$CBOD_5$ (mg/L)	Flow composite[1]	√	√	Analytical Laboratory
COD (mg/L)	Flow composite[1]	√	√	Analytical Laboratory

[1]Samples collected during each sampling period shall be flow composited over the maximum allowable time according to industry standard procedures (e.g., USEPA Methods[6], Standard Methods for the Examination of Water and Wastewater[7]).

At minimum, the field measurements pH and temperature shall be taken via grab samples immediately preceding and following the "monthly" and "supplemental" sampling events discussed in Section 4.4.3.3. These field measurements shall be recorded and reported along with the analytical results for the "monthly" and "supplemental" samples. The Testing Organization in conjunction with the Vendor shall assess the need for continuous online monitoring of these and other process parameters (conductivity, dissolved oxygen, turbidity, etc.)

Supplemental Parameters

Depending on the Vendor-specified target constituents, sampling for supplemental parameters may be required. The Testing Organization shall determine the appropriate supplemental parameters, based on Vendor-specified target constituents. Example supplemental parameters are presented in Table 6.

Table 6: Example Supplemental Parameters for Verification Testing

		Sample Location		
Parameter	**Sample Type**	**Influent**	**Effluent**	**Testing Location**
Food Preparation Facility (including but not limited to restaurant, cafeteria, bakery, etc.)				
FOG	Flow composite[1]	√	√	Analytical Laboratory
Nutrient Reduction – Nitrogen Removal:				
TKN	Flow composite[1]	√	√	Analytical Laboratory
NO_3-N and NO_2-N	Flow composite[1]	√	√	Analytical Laboratory
NH_3-N	Flow composite[1]	√	√	Analytical Laboratory
Alkalinity	Flow composite[1]	√	√	Analytical Laboratory
Nutrient Reduction – Phosphorus Removal:				
Total P	Flow composite[1]	√	√	Analytical Laboratory
Soluble P	Flow composite[1]	√	√	Analytical Laboratory
Disinfection[2]:				
Fecal coliform	Grab	√	√	Analytical Laboratory
E. coli	Grab	√	√	Analytical Laboratory
Other:				
Any other parameters specified by Vendor	Depends on parameters; present in Test Plan	√	√	Depends on parameters; present in Test Plan

[1]Samples collected during each sampling period shall be flow composited over the maximum allowable time according to industry standard procedures (e.g., USEPA Methods[(6)], Standard Methods for the Examination of Water and Wastewater[(7)]).

[2]If the verification testing is strictly for testing a technology for disinfection only, refer to the ETV Source Water Protection Pilot *Protocol for the Verification of Disinfection Technologies for Wastewater Treatment*.

Sampling and Analysis Plan

A sampling and analysis plan shall be provided in the Test Plan that addresses the following:

- The sampling and analysis plan shall identify sampling collection, labeling, preservation, storage, and transporting methods; and sampling locations, times, and frequency. Methods shall comply with industry standard procedures. Sampling locations shall be selected to provide representative samples. Sampling times and frequency shall comply with the minimum requirements presented in Section 4.4.3.3. A sampling schedule shall be provided.
- The sampling and analysis plan shall present the core parameters and any supplemental parameters for which influent and effluent samples are to be analyzed.
- Field measurements and sample collection shall be performed by the Testing Organization.
- Laboratory analyses shall be performed by a Verification Organization-qualified analytical laboratory.
- Details of sampling events (personnel involved, dates, times, and methods) shall be recorded. Laboratory chain of custody forms shall accompany all samples for analysis and copies shall be attached to the final test report.

4.4.3.5 Monitoring, Maintenance, and O&M Performance Indicators

The wastewater treatment technology shall require regular monitoring and maintenance throughout verification testing to maintain stable operating conditions (as defined by the Vendor) and proper operating effectiveness. The Testing Organization, or another hired party may perform the maintenance; however, all monitoring and maintenance activities shall be coordinated with the Testing Organization in advance and the credentials of all personnel involved in monitoring and maintenance shall be stated in the Test Plan. If an outside party is hired, that party shall be familiar with wastewater processes and equipment maintenance, and have worked with similar equipment. Employees of the test site establishment are not recommended for performing the maintenance unless they meet the above criteria.

Core Parameters

A monitoring and maintenance plan shall be included in the Test Plan, which addresses the following requirements:

- A schedule delineating monitoring and maintenance activities shall be provided.
- Equipment and components shall be monitored for proper operation throughout the test period. Equipment and components shall be maintained in accordance with O&M manuals provided by Vendor.
- Calibration of equipment and components shall be in accordance with O&M manuals. Frequency of calibration checks/re-calibration shall be in accordance with O&M manuals, at minimum, and recorded in the test site log.
- Environmental conditions shall be monitored and, to the extent possible, maintained within the range of Vendor-specified levels in the Test Plan (e.g., system temperature, pH, chemical feed rate, nutrient supply, biomass level, etc.). The Vendor shall assess the need for continuous online monitoring of process parameters such as pH, temperature, conductivity, dissolved oxygen, turbidity, etc.
- All monitoring and maintenance activities shall be documented. Detailed reports for each monitoring or maintenance event should be completed that identify the site name, date, time, name of person(s) completing work and report, work performed, site/system observations, and results of work. These reports shall be kept in a monitoring and maintenance log at the test site and included with the Verification Report.

Another goal of the verification testing is to evaluate certain qualitative and quantitative O&M performance indicators. The means/methods to evaluate or quantify O&M performance indicators shall be identified in the Test Plan, along with a schedule for collecting the information.

Qualitative O&M performance indicators shall include, but are not limited to, the following:

- **Visual Observations:** Visual inspections of effluent quality (e.g., color, turbidity) and wastewater treatment technology conditions (e.g., foaming in reactor, floating solids) shall be performed each sampling period.
- **Operability and Reliability:** Observations regarding the ease of start-up and operation during testing and the reliability of the technology shall be recorded. A log of operating problems and how they were handled shall be recorded during the testing.
- **O&M Manual:** The usefulness and quality of the Vendor-supplied O&M Manual shall be noted.
- **Operator Skills:** The level of operator expertise required to operate and maintain the wastewater treatment technology shall be noted.

Quantitative O&M performance indicators shall include the following:

- **Time Demand:** The personnel time required to start-up, shutdown, and maintain the wastewater treatment technology shall be recorded in the monitoring and maintenance log.

- **Residuals:** Residuals (e.g., waste sludge) volumes, mass generation rates and concentrations shall be measured during verification testing. Results shall be reported as gallons and pounds per thousand gallons treated.
- **Chemical Use:** Usage rates and concentrations of any chemicals used in conjunction with operation of the wastewater treatment technology during verification testing shall be monitored and recorded. Results shall be reported as gallons or pounds of raw chemical used per thousand gallons treated.
- **Power Consumption:** The power consumed by the wastewater treatment technology shall be monitored. kWh per thousand gallons treated shall be calculated.
- **Other Consumables**: The use of any other consumables shall be monitored.

Supplemental Parameters

Depending on Vendor claims, supplemental monitoring, maintenance and O&M performance indicators may be required. These should be outlined in the Test Plan.

4.4.3.6 Upset Conditions

The Testing Organization shall notify the Vendor immediately when an upset condition is identified. The Testing Organization shall correct upset conditions as soon as possible in order to bring the wastewater treatment technology back to stable operating conditions within Vendor-specified limits. For unusual upset conditions, the Testing Organization shall work with the Vendor to identify and correct the problem.

Results of sampling performed during upset conditions shall not be included in the statistical analysis for the Verification Report, but shall be identified and discussed in the Verification Report. Replacement sampling shall be performed and used in the statistical analysis, once the upset conditions are corrected and acceptable test conditions prevail. The occurrence of all upset conditions, the cause(s), the results, and the means to correct the upset shall be documented in the Verification Report. If the cause of the condition cannot be determined and/or the condition cannot be qualified as a true upset, then the sampling results shall be used in the statistical analysis for the Verification Report.

4.5 Reporting Verification Testing Results

The results of the entire verification testing process shall be presented in a Verification Report. The report shall include all results from influent characterization and wastewater treatment technology start-up to the conclusion of the verification testing, including all monitoring and maintenance activities and any changes in performance over time. Historical data from testing at comparable sites used may also be presented in the Verification Report.

The draft report shall be reviewed by the Verification Organization, the Vendor, and Quality Assurance personnel. The final Verification Report will be submitted to the Verification Organization after all comments have been resolved. For testing conducted under the ETV Source Water Protection Pilot, the Verification Report and Verification Statement, once approved, will be posted on the Internet on both the USEPA/ETV and NSF web sites.

The report shall include the following topics:

- Executive Summary
- Introduction and Background
- Identification and Description of Wastewater Treatment Technology

  Include wastewater treatment technology capabilities.
- Experimental Setup and Wastewater Treatment Technology Configuration

  Include site plan with wastewater treatment technology layout shown.
- Test Procedures and Methods

  Include methods and procedures for characterization, start-up, verification testing, field analyses, and laboratory analyses.
- Influent Wastewater Characterization

  Include observations (including any performance changes over time), conditions, reduced data in graphs and/or tables, results.
- Start-up Period

  Include observations, conditions, reduced data in graphs and/or tables, results.
- Verification Testing Period

  Include observations, conditions, reduced data in graphs and/or tables, results.
- Final Results and Discussion

  Discuss final results. Present reduced data in graphs and/or tables.
- Statement of Verification

  Provide a final statement regarding the treatment performance of the wastewater treatment technology under specific test conditions.
- References
- Appendices

  Test Plan
  Vendor-Supplied O&M Manual(s)
  QA/QC Procedures and Results
  Laboratory Reports with QA/QC Records, Chain of Custody Forms
  Monitoring and Maintenance Records/Logs
  Raw Data

5.0 TEST SITE DESCRIPTION AND ACCEPTANCE

The Vendor may select or work with the Verification Organization to identify the site(s) where verification testing will be performed. Any approval(s) required by a regulatory agency will be received prior to submitting the Test Plan.

The criteria for site selection should be consistent with the Vendor-specified treatment performance, operating levels and known limitations for the wastewater treatment technology. The influent should challenge the capabilities of the wastewater treatment technology with respect to hydraulic and mass loadings, but should not be beyond the reasonable range of flow and wastewater quality parameters suitable for treatment by the wastewater treatment technology as identified by the Vendor.

Configuration of the wastewater treatment technology to be tested should be compatible with the test site with minimal modifications and disturbances, at the discretion of the Vendor and with approval of the site Owner. The Vendor shall be responsible for leaving the site in a condition acceptable to the Owner.

The Verification Organization shall accept site locations for verification testing. At a minimum, the Vendor shall provide the Verification Organization with the following information to facilitate site acceptance:

- a detailed description of the site location/establishment operations (e.g., fast food restaurant with 20 seats, full service restaurant with 50 seats, private high-school for 100 students, etc.);
- written approval from the appropriate regulatory agency (if required) that testing may be carried out at that site;
- background on wastewater generation and management practices at facility. This may include information obtained from key facility personnel regarding approximate wastewater flows and flow periods, work performed during flow periods that impact wastewater flow and quality, any chemicals or additives that are used that are introduced to the wastewater flow stream, etc.
- a plot plan of the site, including the location of any existing system and planned location of wastewater treatment technology to be tested;
- a hydraulic profile of the wastewater treatment technology to be tested;
- a description of how the wastewater treatment technology will be installed, how influent will be diverted to the technology, and how effluent and residuals will be disposed of;
- the proposed monitoring and sampling locations;
- representative historical influent wastewater flow and quality data, if available; and,
- other relevant or unique features of the test site.

If historical data are not available, the Verification Organization may require that the Vendor perform preliminary characterization of the influent wastewater so that the Verification

Organization can assess whether or not the site is suitable for verification testing. The Verification Organization may also require other information or data that has not been listed above.

6.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

QA activities and procedures for the verification testing shall be provided in a Quality Assurance Project Plan (QAPP), which will be prepared by the Testing Organization. The QAPP shall provide information on data review, validation, and verification requirements, including the criteria used to review and validate data, validation and verification methods, and reconciliation with data quality objectives.

The QAPP shall apply to all organizations involved in verification testing, including analytical laboratories. The Testing Organization shall have the primary responsibility for ensuring that all individuals involved in verification testing comply with QA/QC procedures. The Verification Organization shall monitor and audit subcontracting laboratories in accordance with their corporate Quality Assurance Manual. A copy of the Test Plan QAPP shall be forwarded to all parties involved with verification testing, including analytical laboratories.

Reference shall be made to USEPA's Guidance for Quality Assurance Project Plans[8] and Guidance for the Data Quality Objectives Process[9].

6.1 Verification of Test Data

A statistical analysis shall be carried out on data obtained for all performance measurements carried out. As part of the assessment of data quality, six data quality indicators (DQIs) can be used to interpret the degree of acceptability or utility of the data. The QAPP shall include a protocol for assessing the following DQIs (refer to Glossary of Terms for definitions), and acceptable limits and criteria for each of these indicators.

The DQIs include the following:

- precision;
- bias;
- accuracy;
- representativeness;
- comparability; and,
- completeness.

The acceptable values or qualitative descriptors for all DQIs shall be determined in advance of verification testing as part of the experimental design in the Test Plan. The assessment of data quality will require specific field and laboratory procedures to determine the data quality indicators. All details of DQI selection and values shall be documented in the QAPP.

6.2 Project Management

The QAPP shall include documentation on the management of the project, the project history, and objectives, and the responsibilities of each of the participants. The purpose of this element is to ensure that the project approach and goals are clearly stated and understood by all participants. This area shall include a list of individuals involved in the project, their roles and responsibilities, a concise definition of the purpose of the study, a project schedule including a task chart, documentation of the data quality objectives, special training and certification requirements, and a complete list of required documentation for the study.

6.3 Measurement and Data Acquisition

The QA discussion shall include specific information on all aspects of the experimental design including a detailed description of each component. Specific requirements in the area of measurement and data acquisition are described below.

- A schedule of project sampling, analysis, and peer review activities must be provided.
- Any assumptions made in the design of the experiment and all procedures for locating and selecting environmental samples must be documented.
- Any non-standard sampling or measurement techniques and equipment used to assess the potential impact on the representativeness of the data generated must be validated.
- The requirements for sample handling and custody in the field, laboratory, and in transport must be described. The description shall include examples of sample labels, custody forms, and sample custody logs.
- Analytical methods, equipment, and the specific performance for each method must be documented. Reference may be made to USEPA Methods[6] or Standard Methods[7]. The laboratory to be used for analysis must be approved by the Verification Organization.
- Required measurement quality control checks for both the field and the laboratory must be identified. Information presented shall include the frequency of each type of QC check and references for the procedures used to calculate each of the QC statistics.
- All equipment calibration requirements including standards for calibration, and calibration methods must be identified.
- Any types of data needed for project implementation obtained from non-measurement sources must be identified, including definition of acceptance criteria and discussion on the limitations on the use of any such data.

6.4 Assessment

The QAPP shall include a detailed section on the methods to be used to assess the effectiveness of the implementation of the QA/QC activities. Specifically, this section shall provide information on the types of assessments to be completed, description of response actions, and details on the types of reports to management to be completed.

The number, frequency, and type of assessment activities to be used in the project shall be specified including a definition of the scope of the authority of the assessors and when they are

authorized to act, how responses to non-conforming conditions would be addressed, and the individuals responsible for implementation of the response action.

7.0 DATA MANAGEMENT, ANALYSIS AND PRESENTATION

Data that will be generated by verification testing include, but are not limited to, water and wastewater flow data, wastewater quality data, treatment performance of wastewater treatment technology under specific operating conditions, and O&M parameters such as chemical use, residual generation rates, system reliability and operability, and labor demand. This data will be managed, analyzed and presented as described in the following sub-sections.

7.1 Data Management

The Test Plan shall present the procedures to be followed for data collection, recording, and storage. Data shall be collected by electronic and/or manual means, whichever the Testing Organization deems most appropriate for the experimental design.

7.1.1 Manual Data

If manual data recording is employed, the Testing Organization shall record all data and calculations by hand in bound laboratory notebooks with carbon copies. Daily measurements shall be recorded on specially prepared data log sheets, as appropriate. The original notebooks shall be stored onsite and the carbon copy sheets shall be forwarded to the project manager of the Testing Organization at least once per week. Logs shall include a description of the system, dates and times, any problems or issues, names of visitors, calculations, and other pertinent items.

7.1.2 Electronic Data

Data in electronic format shall be included in commercially available programs for word processing, spreadsheet or database processing, or commercial software developed especially for data collection and processing on a specific hardware instrument or piece of equipment. Backup of the computer databases should be performed on a daily basis, if possible.

7.1.2.1 Verification Testing Database

A database for the project shall be set up in the form of custom-designed spreadsheets. The spreadsheets shall be capable of storing and manipulating the wastewater quality data from each sampling event along with the corresponding operational parameters, sampling location, day and time, etc.

All data shall be kept and maintained in a central location. All manually entered data from the laboratory notebooks and data log sheets shall be entered into the appropriate spreadsheet on a weekly basis at minimum. All recorded calculations shall also be checked at this time. Following data entry, the spreadsheet shall be printed out and the printout shall be checked against the handwritten data sheet, preferably by other Testing Organization personnel not involved with the data entry. Any corrections shall be noted on the hardcopies and corrected on the screen, and then a corrected version of the spreadsheet shall be printed out. The printouts shall be initialed and dated by the Testing Organization personnel performing the checking and data verification. The printouts shall be stored in chronological order in a project binder. Copies of the checked and corrected printouts shall be forwarded to the project manager of the Testing

Organization at least once per week. At least two electronic backups of the data spreadsheets shall be kept (e.g., one copy on computer hard drive and one copy on disk).

Formulae and functions written into the spreadsheets for data manipulation and calculations shall be checked periodically to ensure that they are being used and entered correctly. The spreadsheets shall undergo a monthly audit, at minimum, by the Testing Organization to ensure the formulae and functions are being used and are entered correctly. The checking may involve reviewing sample formulae and making sure the correct cells are referenced, the formula is entered correctly (e.g., parenthesis and operations are correct), as well as performing a few random hand calculations and comparing the results to those calculated by the spreadsheet program. The spreadsheet audits shall be recorded in a log with the date, reviewer initials, name and timeframe of data set inspected for identification, audit findings, and any modifications made to the spreadsheets.

Each sampling event shall be assigned a specific identification number that will be tied to all data from that sampling event through each step of data entry and analysis. The data from a sampling event shall include the wastewater quality data as well as system/operational settings and conditions, flow rates, sampling locations, day, time, personnel involved, etc. Samples delivered to Verification Organization-qualified analytical laboratories, along with the results in the laboratory reports, shall be tracked by the identification numbers. Laboratory reports shall be received and reviewed by the Testing Organization. These data will be entered into the data spreadsheets, cross-checked, and verified in the same manner as previously discussed.

The QA/QC procedures for managing, reviewing and checking data shall be presented in the QAPP contained in the Test Plan. The means to obtain, record, check, and store data obtained manually and electronically (data loggers, computers, etc.) shall be discussed in the QAPP. Refer to Section 6.0 for further QA/QC information.

7.1.2.2 SCADA

If available, a Supervisory Control and Data Acquisition (SCADA) system may be used for automatic entry of test data into computer databases. A specific parcel of the computer databases for operational and wastewater quality parameters should then be downloaded by manual importation into spreadsheet software as a comma-delimited file. These specific database parcels will be identified based upon discrete time spans and monitoring parameters. In spreadsheet format, the data will be manipulated into a convenient framework to allow analysis of system operation.

7.2 Data Analysis and Presentation

The data obtained in the verification testing shall be statistically analyzed, reduced, and presented in tables, graphs and/or charts in a clear and concise manner. Raw data (including data collected during upset conditions) shall be included as an appendix to the final verification testing report.

Note that it must be possible to tie the results as presented to the original raw data and test conditions under which the results were obtained. The QAPP contained in the Test Plan shall address this requirement.

A detailed discussion of the results shall accompany the tables, graphs, and charts and shall be presented in the final verification testing report (see Section 4.5). The Testing Organization shall provide and discuss conclusions drawn from the test results.

7.2.1 Flow Data

Flow data obtained during the verification testing period shall be analyzed and presented as follows:

- Graphs showing average daily, weekly and monthly influent flows, and the respective 95% confidence intervals.
- Graphs showing peak instantaneous influent flows.
- Graphs showing peak daily influent flows.
- Date, month, day, time, and sample number corresponding to the data presented shall be shown on the graphs, as applicable.

7.2.2 Wastewater Quality Data

Valid wastewater quality data obtained during the verification testing period shall be analyzed and presented as follows:

- Graphs showing all the influent sampling results.
- Graphs showing the average monthly influent concentration for the sampling events and the 95% confidence interval.
- Graphs showing variations in influent concentrations as a function of season, time of week, etc., as applicable.
- Graphs showing all the effluent sampling results.
- Graphs showing the average monthly effluent concentration for the sampling events and the 95% confidence interval.
- Graphs showing variations in effluent concentrations as a function of season, time of week, etc., as applicable.
- Tables showing the average removal efficiency by the wastewater treatment technology and the 95% confidence limit for each parameter.
- Date, month, day, time, and sample number corresponding to the data presented shall be shown on the graphs, as applicable.

7.2.3 Equations

Equations to be used in the data analysis for normally distributed data are provided below in Table 7. For data that is not normally distributed, appropriate alternative equations will be used. The equations used for all statistical analyses will be provided in the Verification Report.

Table 7: Equations for Statistical Analysis of Normally Distributed Data

Removal Efficiency	$= \frac{(C_{Influent} - C_{Effluent}) \times 100\%}{C_{Influent}}$ Where: $C_{Influent}$ is the influent concentration $C_{Effluent}$ is the effluent concentration
Sample Mean (Average)	$y_{bar} = \Sigma v / n$ Where: y_{bar} is the sample mean Σv is the sum of the sample values n is the number of samples
Standard Deviation	$s = (\Sigma (y - y_{bar})^2 / n)^{1/2}$ Where: n is the number of samples s is the sample standard deviation y is an individual sample value y_{bar} is the sample mean
95% Confidence Interval	$= y_{bar} \pm t_{\alpha/2} (s / n^{1/2})$ Where: y_{bar} is the sample mean s is the sample standard deviation n is the number of samples $t_{\alpha/2}$ is the Student's t-distribution with n-1 degrees of freedom, with $\alpha/2=0.025$ and $t_{\alpha/2}$ = 2.201 for n=12 = 2.131 for n=16 = 2.069 for n=24

	Refer to statistical references for other values.

7.2.4 O&M Performance Indicators

Results of O&M performance indicators (see Section 4.4.3.5) during verification testing shall be presented in tables, graphs or other appropriate format and thoroughly discussed in the Verification Report. The following O&M information shall be included in the Verification Report:

- a summary of visual observations;
- a summary of system operability and reliability (including both stable and upset conditions);
- a summary of usefulness of the O&M manual(s);
- a summary of the reliability of the technology equipment and any changes in O&M performance observed during verification testing;
- a summary of operator skill level needed;
- average monthly time required for maintenance;
- residual generation over time;
- chemical use and cost over time;
- average monthly chemical use and cost;
- power use and cost over time;
- average monthly power use and cost; and,
- use and cost of any other consumables.

8.0 ENVIRONMENTAL, HEALTH, AND SAFETY

The Testing Organization shall strictly follow and enforce environmental, health, and safety measures during the period of involvement with the verification testing program. An environmental, health, and safety plan shall be included in the Test Plan. The plan shall identify all environmental concerns and potential hazards associated with the testing and the test location, and the required measures to prevent exposure to them. The Testing Organization shall be responsible for informing other personnel at the test site, including employees/workers not associated with the testing program, of the potential hazards at the test site and the safety measures to be employed. Environmental, health, and safety procedures in the plan shall address the following, as applicable:

- Permitting requirements for equipment operation, effluent discharge, and waste disposal.
- Biological, chemical and electrical hazards.
- Handling, storage, and disposal of all chemicals associated with the testing.
- Handling and disposal of residuals and wastes associated with the testing.
- Material Safety Data Sheets (MSDS).
- Conformance with the local electrical code.
- Conformance with the local plumbing code.
- Ventilation of equipment, trailers or buildings housing equipment if gases generated by the equipment could present a safety hazard.
- Confined space entry hazards.
- Fire safety.
- Emergency contacts for 911, the nearest hospital (provide directions), local fire department, the site manager, etc.
- OSHA safety devices.
- Any other environmental, health, or safety issues specific to the test location or wastewater treatment technology to be tested

A copy of the Test Plan environmental, health, and safety plan, including all MSDS, shall be maintained and readily accessible at the test site. A one page summary of emergency contacts, phone numbers, and nearest hospital address, phone number and directions, placed inside a clear plastic cover, shall be kept at the verification testing test unit.

9.0 REFERENCES

(1) ETV Source Water Protection Pilot: *Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction*, 2000. Ann Arbor, Michigan.

(2) ETV Source Water Protection Pilot: *Protocol for the Verification of Wastewater Disinfection Technologies for Small Systems*, in progress. Ann Arbor, Michigan.

(3) ANSI/ASQC: Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs (E4), 1994.

(4) United States Environmental Protection Agency: *Environmental Technology Verification Program - Quality and Management Plan for the Pilot Period (1995 – 2000)*, EPA/600/R-98/064, 1998. Office of Research and Development, Cincinnati, Ohio.

(5) NSF International, Environmental Technology Verification – *Source Water Protection Technologies Pilot Quality Management Plan*, 1999. Ann Arbor, Michigan.

(6) United States Environmental Protection Agency: *Methods for Chemical Analysis of Water and Wastes*, USEPA/600/4-79-020, 1983. Office of Research and Development, Washington, DC.

(7) American Public Health Association, American Water Works Association and Water Environment Federation. 1998. *Standard Methods for the Examination of Water and Wastewater*. 20th Edition.

(8) United States Environmental Protection Agency: *EPA Guidance for Quality Assurance Project Plans, EPA QA/G-5*, EPA/600/R-98-018, 1998. Office of Research and Development, Washington, DC.

(9) United States Environmental Protection Organization, *Guidance for the Data Quality Objectives Process, EPA QA/G-4*, EPA/600/R-96-055, 1996. Office of Research and Development, Washington, DC.

APPENDIX A

TEST PLAN OUTLINE AND CONTENT REQUIREMENTS

1.0 OUTLINE OF TEST PLAN

The Testing Organization shall prepare the site-specific Test Plan. The specific contents of the Test Plan may vary from site to site. As a minimum, the Test Plan must contain the following components.

- Title Page/Approval by Project Participants/ Table of Contents
- Project Description and Objectives
- Project Organization and Personnel Responsibilities
- Test Site Description
- Wastewater Treatment Technology Description
- Experimental Design
- Field Procedures
- Sampling Procedures
- Analytical Procedures
- Quality Assurance Project Plan (QAPP)
- Data Management, Analysis and Reporting
- Assessments
- Environmental, Health, and Safety Plan
- References
- Appendices

A brief description of selected Test Plan requirements is presented in the following sections.

2.0 OBJECTIVES AND DESCRIPTION OF VERIFICATION TESTING

This section of the Test Plan shall include the following:

- the objectives (including Vendor claims) and an overview of the testing to be performed;
- a description of the test site and the wastewater to be used for testing;
- a map showing the location of the test site;
- the site name and address, including street number/fire number, state, county, and telephone number;
- the name and address of the site Owner;
- a summary of site operations, including the type of establishment and, where relevant, capacity of establishment (e.g., number of seats for a restaurant), number of employees, occupancy/use data (e.g., number of customers per month for a restaurant);
- a description of any current method(s) of wastewater handling/treatment at the test site;

- a summary of any existing data on the wastewater flowrate and strength;
- details on the fraction of wastewater that is to be used for verification testing and how wastewater is to be diverted to the system;
- a description of how the technology will be installed;
- a site plan/layout showing the configuration of the wastewater treatment technology to be tested; and,
- approximate timeframes for system installation, start-up, attainment of stable operating conditions, and the verification testing period.

3.0 VERIFICATION TESTING RESPONSIBILITIES

Key staff in the Testing Organization and other organizations involved in the verification testing shall be identified. A description of the responsibilities for all parties shall be provided. Contact details for key staff within each party shall be provided.

4.0 WASTEWATER TREATMENT TECHNOLOGY DESCRIPTION

The Test Plan shall include the following information on the wastewater treatment technology to be tested:

- a simple schematic of the technology, showing all major components, including any pretreatment process;
- a brief introduction and discussion of the engineering and scientific concepts (process kinetics and hydraulics) on which the wastewater treatment equipment and processes are based;
- a description of any scaling up or down of the test equipment compared to a typical full-scale installation, and the impact this may have on treatment performance;
- a description of the wastewater treatment technology, including the following:
    - specifications;
    - full description of each unit process, along with relevant photographic perspectives or schematics;
    - equipment capacity and dimensions;
    - physical construction/components of the equipment, including materials of construction;
    - general environmental requirements and limitations;
    - required consumables; and,
    - weight, transportability, and power requirements;
- a description of the applications of the technology, the flow and load capacity and the expected removal capabilities of the technology;

- an estimate of the O&M requirements, including chemicals and materials requirements (specifying type and purpose), power requirements and labor requirements;
- instructions on installation, start-up, operation, routine maintenance, and troubleshooting;
- environmental controls required for the technology (e.g., nutrient supply, pH control, dissolved oxygen level, biomass concentration, etc.);
- a description of the physical and chemical nature of wastes generated by the technology, and rates of waste produced (e.g., concentrates, residues, waste products, materials replacement frequencies);
- requirements and/or recommendations for residuals handling;
- identification of any special licensing requirements associated with the operation of the technology;
- the level of operator skill required to successfully operate the technology; and,
- noise and/or odor control and housing requirements.

Data plates provided by the Vendor shall be permanent and securely attached to each piece of equipment used for verification testing. The data plate shall be easy to read in English or the language of the intended user, located where it is readily accessible, and contain at least the following information:

- equipment name;
- model number;
- serial number;
- Vendor's name and address;
- electrical requirements (volts, phase, amps, Hertz);
- shipping requirements and special handling precautions;
- warning and caution statements in legible and easily discernible print size; and,
- capacity or output rate (where applicable).

In addition, the Vendor shall provide O&M manual(s) and all OSHA required safety devices (where applicable) normally supplied with the equipment. O&M manuals should include information on installation, start-up, operation, maintenance requirements, restart after a period of shutdown, component calibration and replacement, troubleshooting, spare parts, optimum operating/environmental conditions, and tolerance to changes in conditions.

5.0 EXPERIMENTAL DESIGN

5.1 Work Plan for Influent Wastewater Characterization

This work plan shall present the plan and procedures for influent characterization. The work plan shall include, but is not restricted to, the following information:

- a discussion on the methods for flow and constituent characterization, including the flow pattern, and minimum and maximum flow;
- a schedule for flow monitoring and influent sampling that identifies the locations, number and types of samples to be collected;
- details on the laboratory providing analytical services;
- any special considerations such as sampling times corresponding to peak flow and/or load periods;
- any relevant information obtained from historical wastewater quality records and/or key site personnel; and,
- methods to be used for documenting the results.

5.2 Work Plan for Start-Up

This work plan shall provide the procedures for start-up of the technology to be tested. The work plan shall include, but is not restricted to, the following information:

- the estimated length of time required for start-up and for achieving stable operation of the technology;
- the initial operating and environmental conditions required for start-up, and the range for any conditions that may require modification during the start-up period; this should include flowrates, chemical additive concentrations, component calibration and settings;
- the operating methods and monitoring required to ensure stable operation has been achieved, including the limits for each parameter; and,
- the methods for documenting the start-up and attainment of stable operating conditions.

5.3 Verification Testing Work Plan and Experimental Design

The work plan and experimental design for verification testing shall be provided. This section shall present, but is not limited to, the following details regarding operating the technology at a stable state:

- the following sampling and analysis details:
  - sampling locations
  - sampling methods
  - sampling frequency and periods
  - type of sampling (e.g., 24-hour composite, grab) and sampling equipment
  - sample preservation and storage
  - type of analysis
  - details on the analytical laboratory performing the analysis

- type of flow monitoring and flow monitoring equipment details

- O&M procedures that contain details on the following:
  - type(s) of environmental conditions to be monitored (e.g., temperature, pH of influent), and the methods, frequency and period of monitoring
  - type(s) of consumables to be monitored (e.g., chemicals, water, etc.), and the method(s), frequency and period of monitoring
  - the method(s), frequency and period of monitoring of power consumption
  - the type(s) of O&M parameters to be monitored, and the method(s) to be used for monitoring O&M labor requirements and other maintenance requirements
  - the type(s) and method(s) to be used for visual observations of in-plant conditions (e.g., foaming) and effluent variability (e.g., color, turbidity)
  - procedures for managing and reporting the data collected; and,
  - the methods used to obtain statistically valid sampling results.

6.0 PROCEDURES

The Test Plan shall identify field, sampling, and analytical procedures to be followed throughout the entire verification testing process. Field procedures may include instructions for mixing and introducing chemical additives to the system, wasting residues, calibration of components, etc.

Sampling procedures shall include instructions regarding sample location, type, frequency, method of sample collection, container type, sample preservation, QA/QC samples, holding times, transporting, chain of custody requirements, sample logging, etc. Analytical procedures shall identify the approved measurement methods (USEPA, Standard Methods) for sample analyses, system calibration procedures, etc.

7.0 QUALITY ASSURANCE PROJECT PLAN (QAPP)

A Quality Assurance Project Plan (QAPP) shall be included in the Test Plan, which addresses the following:

- a description of the methodology for using analytical method blanks, the materials used, the frequency of use, the criteria for acceptable method blanks, and the actions to be taken if criteria are not met;
- a description of the methodology for using spiked samples, the materials used, and the frequency of use;
- a description of any specific procedures appropriate to the analysis of performance evaluation samples;
- an outline of the procedure for determining samples to be analyzed in duplicate or triplicate, including the frequency and approximate number;

- a description of the methodology and/or equations used to measure any necessary data quality indicators for performance measurements, which includes precision, bias, accuracy, representativeness, comparability and completeness;
- an outline of the format, content and frequency of Testing Organization self-assessments and their technical systems;
- an outline of the format, content and frequency of assessment reports to the Verification Organization;
- the development of a corrective action plan responding to audit findings;
- the requirement to provide all QA/QC information such as calibrations, blanks and reference samples in an appendix to the report; all raw data shall also be reported in an appendix; and,
- the provision of all data in hardcopy and electronic form in a common spreadsheet or database format.

8.0 DATA MANAGEMENT, ANALYSIS AND PRESENTATION

8.1 Data Management

The Test Plan shall present a plan for data management and handling. The Test Plan shall identify the various types of data that will be generated throughout the verification testing process, e.g., field notes, maintenance forms, laboratory reports, computer spreadsheets, graphs, tables, photographs, and videotapes. The Test Plan shall present the methods for verifying the data.

The Testing Organization shall designate a person or group of persons responsible for data handling in the Test Plan. It is recommended that one person be responsible for data management to ensure consistency and correctness, and that another person be responsible for QA/QC for the data set.

8.2 Data Analysis and Presentation

The Test Plan shall detail the methods to be used for analysing and reducing the data. Details on statistical references/equations shall be provided. A discussion on statistical analysis of the data is provided in Section 7.2 of the protocol.

The Test Plan shall identify the data to be presented and the format of presentation (e.g., tables, graphs).

9.0 ASSESSMENTS

The Test Plan shall identify all internal systems audits and internal performance audits (where applicable) to be performed, as well as information on the party(ies) responsible for performing the audits.

The corrective action procedures to be performed in response to audit findings shall be provided, together with the responsible party(ies) for implementing corrective actions, and the party(ies) that will receive the audit reports. The types and frequencies of audits required for verification testing can be found in the Source Water Protection Pilot Quality Management Plan[5].

10.0 APPENDICES

The following shall be provided as appendices to the Test Plan:

- O&M manuals supplied by the Vendor;
- Environmental, Health and Safety Plan, including material safety data sheets;
- Historical influent flow and wastewater quality data; and,
- other documentation and data as applicable.