TASK 2

Quality Assurance Project Plan
For
Evaluation of On-Site Sewage System Nitrogen Removal Technologies

Grant C1200130 and C1200142

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Prepared by
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Office of Shellfish and Water Protection
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EAP: Environmental Assessment Program, Washington State Department of Ecology
WQ: Water Quality Program, Washington State Department of Ecology
WWTP: Wastewater Treatment Plant

DISTRIBUTION LIST

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Paper copies of this document will not be distributed, due to paper reduction strategies employed by WSDOH. Email communication will be used to notify interested parties when the QAPP is posted and any time updates to the QAPP have been approved by Bill Kammin, Ecology's QA Manager and Ecology's NEP QA Coordinator, Tom Gries. In addition to the members of the stakeholder advisory committee, the people included on these lists will be notified:

- Everyone with Approval Authority
- Everyone included in Table 2, Employees Involved with the Project

EXECUTIVE SUMMARY

This quality assurance project plan (QAPP) is designed to verify the nutrient reduction capabilities of three treatment technologies under the Environmental Technology Verification (ETV) Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction, November 2000. Verification testing will be carried out by faculty from the University of Washington Civil & Environmental Engineering (UWCEE) at the Snoqualmie Wastewater Testing Facility (WWTF), located in Snoqualmie, Washington. During the testing, each technology will be loaded with influent wastewater from a sanitary sewer at the design hydraulic rate of 480 US gallons per day.

The period of testing will consist of up to an eight-week startup period, followed by a twelve-month testing period incorporating five stress periods with varying stress conditions, simulating real household conditions.

The verification of performance will be determined by measuring the constituents with respect to nutrient reduction while maintaining performance with respect to the conventional parameters; dissolved oxygen, biological oxygen demand, nitrogen species, and total phosphorus along with other parameters such as alkalinity, chemical oxygen demand, suspended solids, and fecal coliform. Field measurements and operational characteristics such as electric use, labor to perform maintenance, maintenance tasks, durability of the hardware, noise and odor production will be monitored. The field measurements will be used to gain a better understanding for the variation of system performance over time. The data from the field measurements will not be factored into the ETV verification testing.

Deliverables from the testing will be in the form of a final report that includes sampling event reports, water quality data summary reports, an operation and maintenance report, and a quality control and analytical report.

The three on-site sewage treatment technologies are as follows:

1. A specific vegetated recirculating gravel filter (VRGF) system which is similar to a recirculating gravel filter, except that emergent plants are added to the surface and it contains a horizontal flow subsurface denitrification zone. VRGFs are also known as recirculating vertical flow constructed wetlands.
2. A passive two stage denitrification system that includes a recirculating sand filter (RSF) followed by a vegetated denitrifying woodchip bed.
3. An enhanced recirculating gravel filter that includes a means for passive alkalinity addition and a bottom upflow denitrification zone.

A desired result of the project is to develop standards for the uses of these technologies in Washington if, after the year-long field verification period, the ETV results sufficiently show the technologies are effective and reliable. Detailed descriptions and drawings of the systems are available in Appendix C - Technology Description.

ACKNOWLEDGEMENT

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1.0 INTRODUCTION

The majority of on-site sewage treatment technologies in operation are aerobic processes providing a high degree of nitrification, and little or no denitrification. This can result in the transportation of high nitrate concentrations in groundwater and surface water. Nitrogen loading is a major environmental problem in areas of Puget Sound, such as Hood Canal and the South Puget Sound. Excess nitrogen fuels the growth of algae. When algae die they decay and consume oxygen. This process contributes to depleted dissolved oxygen conditions in Puget Sound marine waters, and can eventually cause fish kills.

Unfortunately existing treatment technologies that reduce total nitrogen to or below 20 mg/L (Washington State technology- based standard) are often unreliable, unstable, and very expensive for system owners. Therefore, it is necessary to evaluate cost effective, reliable, and low maintenance public domain treatment technologies that have high nitrogen removal efficiencies, and are capable of providing sufficient bacteriological reductions.

This quality assurance project plan sets forth the experimental design, methods, measurements, quality assurance/quality control (QA/QC) measures and reports which will be used by UWCEE Faculty to test and verify the nutrient removal performance of three treatment technologies. In addition to the UWCEE's verification measures, WSDOH will conduct field measurements of treatment process parameters. The data from the field measurements will be used to develop operation, monitoring, and maintenance procedures.

1.1 Background

1.1.1 Nutrient Reduction

Verification of residential wastewater treatment technologies under the ETV Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction, November 2000 is designed to verify the nutrient removal performance of residential (individual household) wastewater treatment technologies, in addition to the removal performance of the oxygen-demanding contaminant load.

The reduction of nutrients in wastewater discharged within watersheds is desirable from two standpoints:

1 Reduction of watershed nitrogen inputs helps meet drinking water quality standards for nitrate and nitrite.
2 Reduction of both nitrogen and phosphorus helps protect the water quality of the watershed surface waters from eutrophication and the consequent loss in ecological, commercial, recreational and aesthetic uses of these waters.

Technologies that remove nutrients in on-site domestic wastewater include the following types of biologically mediated technologies:

- Aerobic fixed film processes such as trickling filters, moving bed biofilm reactors (MBBRs), submerged media filters, sand filters, peat filters, and rotating biological contactors (RBCs).
- Aerobic suspended growth processes such as extended aeration activated sludge systems, sequencing batching reactors (SBRs), and membrane bioreactors (MBRs).
- Soil absorption-based technologies.

Removal of nutrients can also be accomplished chemically through the use of ion-exchange filters and chemical precipitation systems.

1.1.2 Literature Review

A literature review titled, *Nitrogen Reducing Technologies – Report to the Puget Sound Action Team* (http://www.doh.wa.gov/ehp/ts/WW/n-red-tech.pdf) was completed by the Washington State Department of

Health in 2005. An additional literature review was conducted by the Florida Department of Health in 2009 (http://www.doh.state.fl.us/environment/ostds/research/Nitrogen/Task_A-Lit_Review.pdf). These reviews provided technical information used in designing this project.

1.1.3 Verification Testing

This verification testing consists of the installation of three residential wastewater treatment technologies at the Snoqualmie WWTP. The testing facility has a source of suitable domestic wastewater that originates from primarily residential sources. The technologies will be dosed daily with wastewater at a rate of 100% of their rated capacity, except for periods of stress testing, using a daily flow-pattern which mimics the generation of wastewater in a residence. Dosing during stress test sequences is described in Section 3.1.5. Up to an eight-week startup period will be followed by a twelve-month testing period.

Composite influent and effluent samples are collected on a monthly basis, with additional samples collected during the five stress periods.

1.1.4 Testing Goals and Objectives

The overall goal of this project is to evaluate and verify nitrogen reduction associated with three public domain technologies capable of treating domestic wastewater prior to subsurface dispersal in the environment. If the testing shows the technologies are effective in achieving annual averages total nitrogen-N less than or equal to 20 mg/L, DOH shall begin to take the appropriate steps to develop standards for these nitrogen removal technologies for use in Washington.

The testing objectives include verifying the removal of nutrients and oxygen-demanding contaminants, and reporting on the operating characteristics of the test unit. The removal of influent wastewater contaminants will be determined by laboratory analyses. Nutrient analyses include ammonia-N, nitrate-N and nitrite-N (combined), total nitrogen-N, and total phosphorus-P. Other parameters to be measured during the testing program include: 5-day carbonaceous and total biochemical oxygen demand ($CBOD_5$ and BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), volatile suspended solids (VSS), fecal coliform, pH, temperature, alkalinity (as $CaCO_3$), and dissolved oxygen. WSDOH will collect in situ effluent quality measurements of pH, temperature, conductivity, dissolved oxygen, turbidity, nitrate, and ammonia to provide information for improved operation, monitoring and maintenance of these systems.

Testing will include the collection of data describing operation and maintenance characteristics of the technology, including the performance and reliability of the technology components and the level of required operator maintenance. The test will identify and assess environmental inputs and outputs including chemical usage, energy usage, generation of by-products or residuals, noise and odors.

1.1.5 Test Site Description

The Snoqualmie wastewater treatment plant (WWTP) is located in Snoqualmie, Washington. Domestic wastewater is supplied from a sanitary sewer that collects all domestic wastewater from the historical town of Snoqualmie, from the newly constructed Snoqualmie Ridge project, and from the Echo Glen Children's Center. Raw wastewater flows are also introduced at the headworks by the in-plant pump station. These flows include domestic wastewater from the Weyerhaeuser Mill site, the Salish Lodge, and all wastewater produced by the daily operation of the wastewater treatment plant and the water treatment plant. There are no significant industrial discharges in the City's treatment system.

The Snoqualmie WWTP influent wastewater data indicate that the wastewater characteristics fall within the guidelines for typical domestic wastewater as listed in the NSF International (NSF) ETV Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction (2000) which are as follows:

- BOD_5 = 100-450 mg/L
- TSS = 100-500 mg/L
- Total Phosphorus (as P) = 3-20 mg/L
- TKN (N) = 25-70 mg/L
- Alkalinity = greater than 60 mg/L- $CaCO_3$
- pH = 6-9 units
- Temperature greater than 10° C and less than 30°C

For the year 2010, the average monthly influent concentrations for the Snoqualmie WWTP ranged from 245-315 mg/L, 274-351 mg/L, 23-44 mg/L, and 4.0 to 8.1 mg/L for BOD_5, TSS, NH_3-N, and total P, respectively. Note that TKN concentrations in influent wastewater are typically 40-50% higher than NH_3-N concentrations.

Method of Dosing

Raw (influent) wastewater is pumped from a dosing channel at the Snoqualmie's WWTP headworks to each test site. Dosing is accomplished by individual pumps, one per technology, set in the dosing channel. Volumetric doses are controlled by a programmable logic controller, and occur in 15 equal dosing events of 32 gallons per dose.

Dosing rates are verified by volumetric calibration checks (i.e. measuring the volume per dose), which are carried out at each test site on a weekly basis. Daily dosage volumes are calculated by multiplying the dosage rate by the number of dosage events in a 24-hour period. The computer control program determines the number of dosage events by dividing the daily dose for each test unit by the calibrated dosage volume. The calculated daily dosage volume is verified by monitoring of the daily volume pumped from the individual test unit treated effluent sumps (i.e. multiplying the calibrated sump-pump pumping rate by the total pumping time per day).

For the ETV testing program, the dosage frequency is set to conform to the following dosing pattern of three dosing periods per day, to represent typical periods of maximum sewage flow from a single-family residence:

- 6 a.m. – 9 a.m. 33% of total daily flow
- 11 a.m. – 2 p.m. 27% of total daily flow
- 5 p.m. – 8 p.m. 40% of total daily flow

The average total daily flow must be within 100% ± 10% of the rated capacity of the technology undergoing testing, based on a thirty (30) day average, with the exception of periods of stress testing described in Section 3.1.6.

Effluent

Effluent from the test units flows by gravity into a distribution box at each test site, and then flows into a 4-inch diameter collection pipe to a drain for treatment at the municipal treatment plant.

1.1.6 Summary of Technology Costs

A summary of the cost, in 2011 dollars, of the three on-site sewage technologies currently listed for Nitrogen Reduction in the State of Washington, along with the three technologies being tested, is outlined in Table 1. **Please note the cost estimate is based on the price of the materials and baseline equipment. It does not include all costs related to purchasing a system including upgraded models, the designer, local permitting fees, installation, and soil dispersal components (drainfields).** The costs of the technologies to be tested are rough estimates. More accurate estimations will be available after the testing is complete. In all cases, the cost of these technologies will vary depending on the installation location. This is because the costs are dependent on the price of materials and complications with installation, in addition to the costs listed above.

Table 1 Summary of Technology Costs

Summary of N Reducing Technologies Registered in WA (2011)				
System Name	**Registered for Use in Washington State**	**Technology**	**Description of Process**	**Cost** (2011)
SeptiTech M400D System SeptiTech, Inc. 220 Lewiston Road Gray, Maine 04039	Yes	Two stage fixed film trickling filter using a patented highly permeable hydrophobic media	Clarified septic tank effluent flows by gravity into the recirculation chamber of the SeptiTech unit. A submerged pump periodically sprays wastewater onto the attached growth process and the wastewater percolates through the patented packing material. Treated wastewater flows back into the recirculation chamber to mix with the contents. Treated water flows into a clarification chamber and is periodically discharged to a disposal unit (drainfield, drip irrigation, etc.).	$9,000
Bio-Microbics MicroFAST 0.5 Bio-Microbics 8450 Cole Parkway Shawnee, KS 66227	Yes	Attached and suspended growth process	The MicroFAST 0.5 wastewater treatment system uses separation and settling processes prior to the effluent entering the MicroFAST® treatment module. A remote-mounted, above-ground blower introduces air (oxygen) into the treatment module to facilitate a robust circulation of wastewater through the media's channeled flow path. The fixed film media provides a high surface-to-volume ratio to maintain exceptional microbial growth. Bacteria become "fixed" or attached to the stationary media where the abundant, diverse and self regulating population of microbes is consistently maintained in the aeration zone to metabolize the incoming waste. Clear and odorless wastewater is ready for dispersal.	$6,000
Orenco Systems Inc. AX20RT & AX20 814 Airway Avenue Sutherlin, Oregon 97479	Yes	Attached Growth Multipass Packed Bed Filter	In an AdvanTex system, effluent trickles through and between the textile sheets. In this moist, oxygen-rich (aerobic) environment, naturally occurring microorganisms nitrify the effluent. The effluent is recirculated through a zone that does not have oxygen. The oxygen forms (nitrite and nitrate) of nitrogen are converted by bacteria into nitrogen gas and water.	$6,500 (This estimate does not include the cost of a pretreatment/ septic tank)

Summary of N Reducing Technologies To Be Verified/Tested (2011)				
System Name	**Registered for Use in Washington State**	**Technology**	**Description of Process**	**Cost*** (2011)
Vegetated Recirculating Gravel Filter (VRGF)	Not as of 2011	Anoxic zone combined with aeration from media and plants. Carbon source added by plant detritus.	Wastewater is distributed into the root zone, trickles through the pea gravel filter media on its passage by gravity through the bottom gravel layer. The media has voids that promote both fluid and air movement. As organic and pathogenic contaminants are removed, ammonia is microbially oxidized to nitrate (nitrification). The nitrified effluent mixes with incoming septic tank effluent at the inlet of the bottom layer. In this anaerobic environment, microbes convert the dissolved nitrate to nitrogen gas, which is released to the atmosphere.	$4,750
Passive Two Stage Denitrification (recirculating sand filter (RSF)) - vegetated denitrifying woodchip bed (VDWB).	Not as of 2011	Aeration zone followed by an anoxic bed with a carbon source.	The wastewater is exposed to air by trickling over sand. Bacteria in the bed reduce the organic strength of the wastewater and convert the ammonia-nitrogen to nitrate (nitrification process). The RSF effluent diverted by gravity is further treated at the VDWB. The woodchip media is always submerged and serves as a carbon source for denitrification. This "flooded" condition maintains anoxic to anaerobic conditions within the VDWB, forcing the bacteria to use to nitrate (NO_3) in lieu of oxygen for carbon oxidation with subsequent conversion of NO_3 to nitrogen gas.	$6,000
Enhanced Recirculating Gravel Filter (ERGF)	Not as of 2011	Aeration zone followed by upflow anoxic zone with carbon from septic tank effluent.	Recirculated flow from the ERGF effluent is distributed over a layer of oyster shells with gravity flow in the gravel media/oyster shell upper zone in which oxygen is available for biological nitrification of ammonia to nitrate/nitrite. Effluent from the upper section flows into a side chamber for contact with septic tank effluent and is then distributed through the underdrain system across the bottom of and up through gravel media anoxic zone. The submerged conditions and septic tank effluent carbon and influent nitrate/nitrite assures anoxic conditions for biological reduction of nitrate/nitrite to nitrogen gas.	$4,800

* Material costs are variable from region to region in Washington State, but the relative cost of each system should not change

1.2 Critical Measurements

1.2.1 Critical Measurement

For this test plan, a critical measurement is defined as a measurement whose absence would significantly lower the confidence in the data and would affect the ability to verify system performance. In the event data is lost or is deemed otherwise unacceptable, critical measurements must be repeated within a time period that would allow substitution so as not to impair the final data set.

1.2.2 Test Plan Schedule

The test plan schedule includes three phases:

1. Pre-installation communication between the verification and testing organizations and installation professionals.
2. Startup period of up to eight weeks, wherein UWCEE is provided with time for the technology to come to a steady-state operational condition. WSDOH has the option of indicating when the technology is ready to begin testing.
3. Twelve-month operational testing period.

A detailed weekly schedule of the testing period is provided in Table 3 – 2.

2.0 PROJECT ORGANIZATION AND SCHEDULE

Table 2 lists the people involved in this project. Figure 1 displays the organizational structure. The schedule may be limited by staff workload priorities or dates that all lab data is received.

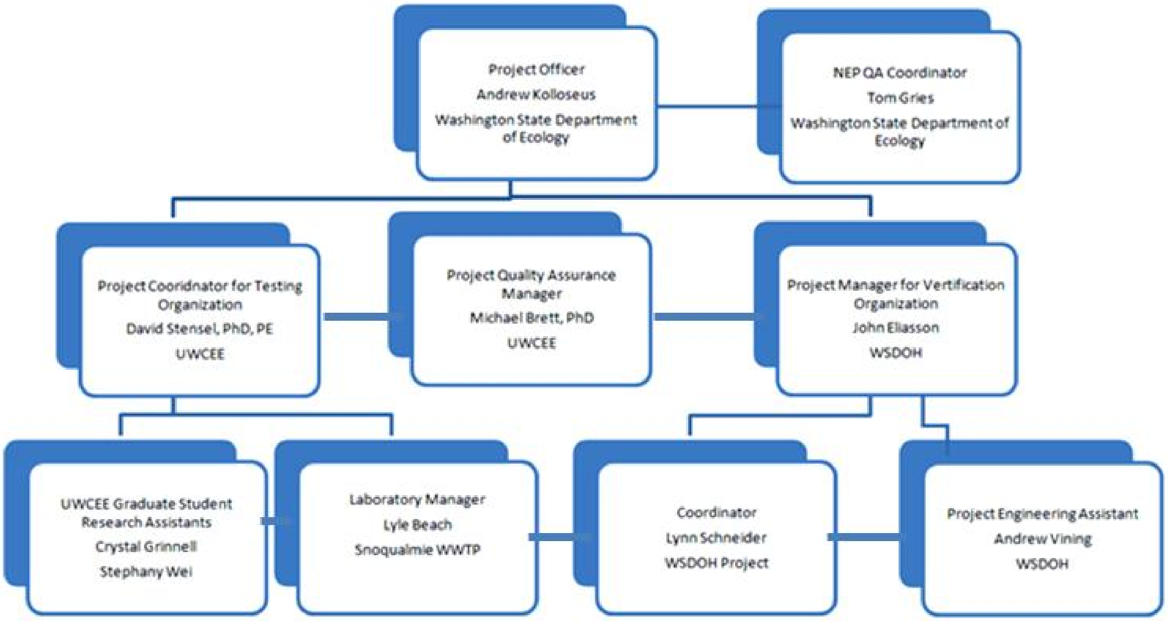
Table 2 Project Staff and Responsibilities

Staff	Title	Responsibilities
Michael Cox US Environmental Protection Agency Region 10 Phone: (206) 553-1597 Email: Cox.Michael@epamail.epa.gov	NEP Grant Coordinator	Oversees grant management
Andrew Kolosseus Washington State Department of Ecology – Water Quality Phone: (360) 407-7543 Email: akol461@ecy.wa.gov	Project Officer	Grant Manager
Tom Gries Washington State Department of Ecology – Environmental Assessment Program Phone: (360) 407-6517 Email: tgri461@ecy.wa.gov	NEP QA Coordinator	Reviews the draft QAPP.
William R. Kammin Washington State Department of Ecology – Environmental Assessment Program Phone: (360) 407-6964 Email: wkam461@ecy.wa.gov	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.
John Eliasson Washington State Department of	Project Manager	Writes the QAPP. Oversees/conducts field

Health – Wastewater Management Section Phone: (360) 236-3041 Email: john.eliasson@doh.wa.gov		sampling. Conducts QA review of data, analyzes and interprets data. Reviews and approves the draft and final report.
Lynn Schneider Washington State Department of Health – Wastewater Management Section Phone: (360) 236-3379 Email: lynn.schneider@doh.wa.gov	Project Coordinator	Writes the QAPP. Oversees/conducts field sampling. Conducts QA review of data, analyzes and interprets data. Reviews the draft and final report.
Andrew Vining Washington State Department of Health – Wastewater Management Section Phone: (360) 236-3323 Email: andrew.vining@doh.wa.gov	Project Engineering Assistant	Develops specifications /conducts field sampling.
David Stensel University of Washington – Civil and Environmental Engineering Phone: (206) 543-9358 Email: stensel@u.washington.edu	Project Coordinator for Testing Organization	Writes the QAPP. Oversees/conducts verification testing. Conducts QA review of data, analyzes and interprets data. Drafts final report.
Michael Brett University of Washington – Civil and Environmental Engineering Phone: (206) 616-3447 Email: mtbrett@u.washington.edu	Project Quality Assurance Manager	Writes the QAPP. Oversees quality control of the project. Conducts QA review of data, analyzes and interprets data. Drafts final report.
Crystal Grinnell University of Washington – Civil and Environmental Engineering Phone: (206) 543-9358 Email: crystalh@efn.org	Research Assistants – Field Staff	Conducts verification testing. Conducts QA review of data, analyzes and interprets data. Drafts final report.
Stephany Wei University of Washington – Civil and Environmental Engineering Phone: (206) 543-9358 Email: spw6422@gmail.com	Research Assistants – Field Staff	Conducts verification testing. Conducts QA review of data, analyzes and interprets data. Drafts final report.
Lyle Beach Snoqualmie Wastewater Treatment Laboratory Phone: (425) 888-4153	Laboratory Manager	Oversees quality control of the laboratory.

Organizational Structure

Figure 1 Organizational Structure



Responsibilities of the Project Team:

Verification Organization (WSDOH):

- Prepare the draft QAPP
- Establish and maintain stakeholder advisory committee
- Coordinate with UWCEE Faculty and the Stakeholder Advisory Committee relative to completing the final approved QAPP
- Coordinate with UWCEE Faculty to identify and secure the site for the technology verification
- Coordinate with UWCEE Faculty and oversee the specific design of the technology
- Provide a complete field-ready version of the technologies of the selected capacity for verification and assist with the UWCEE Faculty with installation at the test site
- Provide operation and maintenance (O&M) manuals with the technologies (including instructions on startup, operation and maintenance) for verification testing
- Process, select, and manage a subawardee to complete the installation of the systems
- Coordinate with the UWCEE faculty and Ecology to oversee the evaluation and laboratory(ies) testing associated with the technology verification
- Conduct *in situ* effluent quality measurements during operation and monitoring of each technology undergoing verification testing
- Provide technical support to the UWCEE FACULTY during operation and monitoring of the technology undergoing verification testing as requested
- Remove equipment associated with the technology and any discarded items from the test sites following termination of the verification evaluation
- Review data generated during testing
- Coordinate with Ecology to review and approve the Verification Report
- Distribute and post on website the final documents (i.e. QAPP, Verification Report)

Verification Organization Project Manager (WSDOH):

Oversee the technical direction of the project, responsible of adherence to procedures in this plan and to work closely with the UWCEE faculty.

Testing Organization (UWCEE):

- Coordinate with WSDOH to identify and secure a site for the technology verification
- Coordinate with WSDOH to finalizing the QAPP, and project standard operating procedures (SOP)s
- Coordinate with WSDOH to complete the design and installation of the technology
- Obtain approval of the QAPP by Ecology prior to commencement of testing
- Conduct verification testing according to the approved QAPP
- Oversight of the startup, operation and maintenance of the technology
- Coordinate with and report to WSDOH during the technology verification process
- Control access to the area where verification testing is carried out
- Maintain safe conditions at the test site for the health and safety of all personnel involved with verification testing
- Scheduling and coordinating all activities of the verification testing participants including establishing a communication network and providing logistical and technical support as needed
- Assume all roles and responsibilities of day-to-day coordination with the laboratory(ies), ensure the laboratory(ies) properly implement the QAPP, resolve any quality concerns that may be encountered, and report all findings to WSDOH
- Manage, evaluate, interpret, and report data generated by verification testing
- If necessary, document changes in plans for testing and analysis and notify WSDOH of any and all such changes before changes are executed
- Write draft and final Verification Report in accordance with the Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction / EPA Environmental Technology Verification Program (November, 2000)

Project Quality Assurance Manager (UWCEE Faculty):

Responsible for management of the Project Quality Assurance Plan to ensure that set technical standards, data analysis and reporting procedures are maintained.

Stakeholder Advisory Committee:

Provide project technical and oversight review, and input for finalizing the draft QAPP and project Verification Report.

2.1 Milestones and Schedules

Milestones for the testing:

		Dates
1	Completion of the Final Approved QAPP	February 15, 2012
2	Completion of the technology installation and startup	April 1, 2012
3	Completion of the startup period (up to eight weeks)	June 1, 2012
4	Completion of the twelve month testing period	June 1, 2013
5	Reporting of data	June 15, 2013
6	Draft Verification Report	July 15, 2013
7	Completion of Final Approved Verification Report	Aug 31, 2013

3.0 EXPERIMENTAL DESIGN

3.1 Test Conditions

3.1.1 Installation, Startup and Repairs

The systems shall be designed, installed and filled in accordance with the WSDOH specifications and standards at the Snoqualmie Wastewater Technology Testing Facility (WTTF). The WSDOH shall inspect each system for proper installation and, if no defects are detected and the systems are determined to be structurally sound, it shall be placed into operation in accordance with WSDOH startup procedures. If WSDOH does not provide a filling procedure, 2/3 of the system's capacity shall be filled with water and the remaining 1/3 shall be with residential wastewater.

When possible, electrical or mechanical defects shall be repaired to prevent evaluation delays. All repairs shall be recorded in the test log.

3.1.2 System Operation

Each system shall be operated in accordance with WSDOH's instructions. Routine service and maintenance of the system shall not be permitted during the performance and evaluation period unless specified in the O&M manual by WSDOH. All maintenance or service performed on the system during the startup and testing phase of the evaluation shall be documented in the field log.

3.1.3 Contingency Measures

An adaptive management strategy will be employed throughout verification testing. This method is a continuous, integrated process of system monitoring, compilation and evaluation of data assessing system performance, and making adjustments or modifications that are judged to best serve the overall project goal. The technologies to be tested at the test site will be generally well understood and characterized prior to installation. Therefore, the evaluation of technologies will be one of choosing a design and deployment; then verifying and documenting treatment performance and salient features of operation under that chosen condition. The need for adaptive management decision making will be manifest only in the event of unexpected results and unforeseen outcomes. Examples of modifications could include adjustments in operational strategies, such as modifications of recommended recirculation flow rates; modifications of dosing distribution systems to unsaturated recirculating filter infiltrative surfaces, or perhaps other hydraulic modifications. These types of changes will always be evaluated from the perspective of the general desirability of providing continuous datasets under given operational conditions and minimizing manipulation of treatment processes. Operational modifications would be implemented only if judged to be advantageous to the overall testing objectives.

During verification testing, corrective actions may also be required for two other types of problems: analytical or equipment problems and nonconformance problems. Analytical or equipment problems may occur during sampling, sample handling, sample preparation, field measurements, laboratory analyses, and data review. Nonconformance problems may develop at any time during these activities and are often discovered during data review. Analytical laboratory contingency measures are discussed in Section 6.8.

Equipment problems or nonconformance problems will be reported to the Test Organization Project Manager. The project team will then document the condition, its cause, any other related information, and the proposed corrective action. The project team will implement the corrective actions and document them in the field log. If appropriate, the project team will ensure that no additional work that is dependent on the nonconforming activity is performed until the corrective actions are competed.

Examples of corrective actions for field measurements included:

- Repeat the measurement to check the error;
- Check for all proper adjustments for ambient conditions, such as temperature;

- Check instrument batteries;
- Recalibrate instrument or device; and
- Replace the instrument or measurement device.

3.1.4 Phases of Testing

Each system shall undergo design loading of wastewater for a minimum of one year following a maximum startup period of eight weeks. When the technology performance has stabilized during the startup period UWCEE Faculty shall advise the WSDOH that the evaluation period can commence. The stability of each technology during the startup period will be determined by three consecutive day sample events with effluent ammonia-nitrogen results less than 10 mg/L. WSDOH will notify UWCEE to begin the official test procedures in writing. The one-year evaluation period will allow for an assessment of the impact of seasonal variations on performance.

3.1.5 Influent Flow Pattern

The influent dosed to individual technologies will be through the use of timed pump operation and will conform to the following pattern as representative of a typical residence(s) scenario:

- 6 a.m. – 9 a.m. approximately 33% of total daily flow in 5 equal doses
- 11 a.m. – 2 p.m. approximately 27% of total daily flow in 4 equal doses
- 5 p.m. – 8 p.m. approximately 40% of total daily flow in 6 equal doses

Total daily flow shall be within 100% ± 10% of the rated capacity of the test unit (i.e. 480 gpd ± 48.0 gpd), based on a thirty (30) day average with the exception of periods of stress testing described in Section 3.1.5. Influent dosing pumps are controlled by a programmable logic controller which controls the dosing accuracy of the fifteen individual doses to the second.

3.1.6 Stress Testing

One stress test shall be performed following every two months of normal operation during the technologies evaluations, so that each of the five stress scenarios described below is addressed within the twelve month evaluation period.

Stress testing shall involve the following simulations:

1. Wash-Day Stress
2. Working Parent Stress
3. Low-Loading Stress
4. Power/Equipment Failure Stress
5. Vacation Stress

Wash-day stress simulation shall consist of three wash-days in a five day period with each washday separated by a 24-hour period. During a washday, the technology shall receive the normal flow pattern (Section 3.1.4); however, during the course of the first two dosing periods per day, the hydraulic loading shall include three wash loads [three wash cycles and six rinse cycles]. The volume of wash load flow is 28 gallons per wash load. The hydraulic loading rate is adjusted so that the loading on washdays do not exceed the design loading rate. Common detergent (Arm and Hammer) and non-chlorine base beach is added to each wash load at the manufacturer's recommended amount during the course of the wash load dosing periods via the first compartment of the septic tank. The same detergent and bleach use rates shall be used for each of the stress sequences.

Working parent stress simulation shall consist of five consecutive days when the technology is subjected to a flow pattern where approximately 40% of the total daily flow is received between 6 a.m. – 9 a.m. and approximately 60% of the total daily flow is received between 5 p.m. and 8 p.m., which shall include one wash load [one wash cycle and two rinse cycles].

Low-loading stress simulation shall consist of testing the technology for 50% of the design flow loading for a period of 21 days. Approximately 35% of the total daily flow is received between 6 a.m. – 11 a.m., approximately 25% of the flow is received between 11 a.m. – 4 p.m., and approximately 40 % of the flow is received between 5 p.m. and 10 p.m.

Power/equipment failure stress simulation shall consist of a standard daily flow pattern until 8 p.m. on the day when the power/equipment failure stress is initiated. Power to the technology shall then be turned off at 9 p.m. and the flow pattern shall be discontinued for 48 hours. After the 48-hour period, power shall be restored and the technology shall receive approximately 60% of the total daily flow over a three hour period which shall include one wash load [one wash cycle and two rinse cycles].

Vacation stress simulation shall consist of a flow pattern where approximately 35% of the total daily flow is received between 6 a.m. and 9 a.m. and approximately 25% of the total daily flow is received between 11 a.m. and 2 p.m. on the day that the vacation stress is initiated. The flow pattern shall be discontinued for eight (8) consecutive days with power continuing to be supplied to the technology. Between 5 p.m. and 8 p.m. of the ninth day, the technology shall receive 60% of the total daily flow, which shall include three wash loads [three wash cycles and six rinse cycles].

3.2 Sampling and Monitoring Locations

3.2.1 Influent Wastewater

A composite influent wastewater sample will be collected from the same location as the influent pumps feeding the individual technologies. The composite sample will be made up of discrete sub-samples collected each time the test unit is dosed.

At the time the influent composite sample is sent to the laboratory for analysis, a grab sample will be withdrawn from the influent sampling point for pH and temperature measurement.

3.2.2 Intermediate Effluent (Applicable only to the RSF in System 2)

Intermediate effluent (composite) samples in System 2 will be collected from the RSF 4-inch effluent line, at a point nearest the effluent discharge of the unit. The composite sample will be made up of discrete sub-samples collected each time the test unit is dosed.

At the time the intermediate effluent (RSF) composite sample is sent to the laboratory for analyses, a grab sample will be withdrawn from the final effluent sampling point (during periods when flow is occurring at the sampling point), and subjected to pH, temperature and dissolved oxygen measurement as well as fecal coliform analyses. Dissolved oxygen will be measured at the treated effluent location when flow across the sampling point is occurring. (Refer to Table 3 - 1).

3.2.3 Final Effluent

Final effluent (composite) samples will be collected from the 4-inch effluent line of the unit, at a point nearest the effluent discharge of each technology. The composite sample will be made up of discrete sub-samples collected each time the test unit is dosed.

At the time the final effluent composite sample is sent to the laboratory for analyses, a grab sample will be withdrawn from the final effluent sampling point (during periods when flow is occurring at the sampling point), and subjected to pH, temperature and dissolved oxygen measurement as well as fecal coliform analyses. Dissolved oxygen will be measured at the treated effluent location when flow across the sampling point is occurring. (Refer to Table 3 - 1).

Table 3 – 1 Sampling Matrix

Parameter	Sample Type	Sample Location			Testing Location	Number of Samples Collected for Each Sample Event	Field Duplicates
		Influent	Inter-mediate*	Final Effluent			
BOD_5	24 Hour composite	√			Laboratory	1	1
$CBOD_5$	24 Hour composite		√	√	Laboratory	4	1
COD	24 Hour composite	√	√	√	Laboratory	5	1
Total Suspended Solids	24 Hour composite	√	√	√	Laboratory	5	1
Volitile Suspended Solids	24 Hour composite	√	√	√	Laboratory	5	1
Alkalinity (as $CaCO_3$)	24 Hour composite	√	√	√	Laboratory	5	1
Nitrogen, Total (as N)	24 Hour composite	√	√	√	Laboratory	5	1
Ammonia (as N)	24 Hour composite	√	√	√	Laboratory	5	1
Nitrate + Nitrite (as N)	24 Hour composite		√	√	Laboratory	4	1
Phosphorus, Total (as P)	24 Hour composite	√		√	Laboratory	4	1
Dissolved Oxygen	Grab		√	√	Test Site	4	1
pH	Grab	√	√	√	Test Site	5	1
Temperature	Grab	√	√	√	Test Site	5	1
Fecal Coliform	Grab	√	√	√	Laboratory	5	1

***I**ntermediate effluent sampling applicable only to System 2 (RSF effluent) verification

3.3 Sampling Frequency and Types

3.3.1 Sampling Frequencies

Sampling will normally be carried out at a minimum frequency of once per month. Additional samples will be taken in conjunction with the stress tests and the final week of sampling, as outlined in the following sections.

Stress Test

Samples will be collected each day the stress simulation is initiated and when approximately 50% of each stress test has been completed. (Note: For the Vacation and Power/Equipment failure stresses, there is no 50% sampling).

Beginning twenty-four (24) hours after the completion of washday, working-parent, low-loading, and vacation stress scenarios, samples shall be collected for six (6) consecutive days.

Beginning forty-eight (48) hours after the completion of the power/equipment failure stress, samples shall be collected for five (5) consecutive days.

Final Week

Samples will be collected for five (5) consecutive days at the end of the year-long evaluation period.

Table 3 - 2 shows a hypothetical sampling schedule based on the NSF/ETV Nutrient Reduction Protocol requirements.

3.3.2 Sample Types

Composite samples will be collected using automated samplers at each sample collection point cited in Section 3.2.1 and Table 3 - 1. Automated samplers will be programmed to draw equal volumes of sample from the waste treatment stream at the same frequency, number (15), and timing as the influent wastewater doses to each test unit. Samples taken in this manner will therefore be flow-proportional composite samples. Initiation of individual automated sampler events will be offset or delayed to correspond to the passage of a flow pulse through the relevant sample collection point. Field personnel will ensure proper operation of the automated samplers prior to leaving the test site in accordance to the Field Methods for Automated Composite-Samplers (FM 11).

Grab Samples

Grab samples for pH, temperature, and fecal coliform will be obtained from the influent wastewater stream at the location of the automated sampler intake. Grab samples for pH, temperature, dissolved oxygen, and fecal coliform will be obtained at the same locations as the automated sampler intakes for the intermediate technology effluent and the final technologies effluent. Grab sampling methods will be in accordance with the Field Methods for Collecting Wastewater Grab Samples (FM 12).

QC Samples

Each of the monthly influent and effluent composite samples will be split, and the duplicate field samples will be submitted to the laboratory for the purpose of assessing QC. The samples will not be identified in the laboratory as duplicates.

During stress testing, composite influent and effluent field samples will also be split, and the duplicates submitted to the laboratory, at least once per stress event.

Raw Sample Retention

Sample remaining in the bulk composite sample containers shall be retained at 4 degrees Celsius for 24 hours following field sampling. In the event of transportation or laboratory sample loss, this retained sample may provide additional sub-sample volume for analysis.

3.4 Sampling Strategy and Procedures

3.4.1 Sampling Location Selection Rationale

Influent Samples

The influent sampling site selection rationale is based upon the layout of the dosing channel at the headworks of the Snoqualmie WWTP. The influent wastewater sampling site will be located near the dosing pump of each technology to ensure a representative sample of wastewater is obtained.

Intermediate Technology (RSF-System 2)

For the RSF effluent in system 2, the sampling site will be located in the distribution box, where the effluent pipe leading from the test unit discharge. During installation and setup of the unit, a sampling point consisting of a tee-cross with sump of sufficient size to retain sample volume for both grab and automated sampler will be installed on the end of this pipe. Note that the sump is only large enough to retain approximately one liter of fluid and be readily flushed and replenished by the normal flow of treated effluent. The sump is also accessible so that it may be cleaned of attached and settled solids on a regular basis prior to sampling dates.

Effluent Samples

For the test unit's effluent, the sampling site will be located in the distribution box, where the effluent pipe leading from the test units discharge. During installation and setup of each unit, a sampling point consisting of a tee-cross with sump of sufficient size to retain sample volume for both grab and automated sampler will be installed on the end of this pipe. Note that the sump is only large enough to retain approximately one liter of fluid and be readily flushed and replenished by the normal flow of treated effluent. The sump is also accessible so that it may be cleaned of attached and settled solids on a regular basis prior to sampling dates.

3.4.2 Sample Type Selection Rationale

The ETV Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction dictates selection of the types of samples (i.e. grab or composite). The selection of composite samples for the majority of parameters reflects the tendency of a composite sample to provide a more representative sample in the face of the established daily variability of influent wastewater strength and character, and is a compromise with sample holding time restrictions. In contrast, grab samples for pH, temperature, dissolved oxygen, and fecal coliform are parameters best measured from fresh sample obtainable as a grab.

3.4.3 Sample Frequency and Critical Measurement Selection Rationale

The ETV Protocol for the Verification of Residential Wastewater Treatment Technologies for Nutrient Reduction has established selection of the frequencies of sampling. Samples shall be collected at a minimum interval of once per month at all sampling locations (See Table 3 - 2).

Table 3 – 2 Sampling Schedule for Technology Verification

Period	Comment	Sample Collection
Startup Period (up to 8 weeks):		Once during week 3, 5, 6, and 7
Testing Period:		
Week 1-8:		Day 1 of week 4 and 8
Week 9:	**Wash Day Stress** initiated on Day 1 of Week 9.	Day 1, 3, 6 and 7 of Week 9
Week 10:		Day 1, 2, 3 and 4 of week 10
Week 11-17		Day 1 of week 14 and 17
Week 18	**Working Parent Stress** initiated on Day 1 of week 18.	Day 1, 3, 6 and 7 of Week 18
Week 19		Day 1, 2, 3 and 4 of Week 19
Week 20-27		Day 1 of week 23 and 27
Week 28	**Low-loading Stress** initiated on Day 1 of Week 28	Day 1 of Week 28
Week 29-30		Day 4 of Week 29
Week 31		Day 1, 2, 3, 4, 5, and 6 of Week 31
Week 32-38		Day 1 of week 35 and 38
Week 39	**Power/Equipment Failure** stress initiated on Day 1 of Week 39	Day 6 and 7 of Week 39
Week 40		Day 1, 2 and 3 of Week 40
Week 41-47		Day 1 of week 44 and 47
Week 48	**Vacation Stress** initiated on Day 1 of Week 48	Day 1 of Week 48
Week 49		Day 4, 5, 6 and 7 of Week 49
Week 50		Day 1 of Week 50
Week 51		No sample will be taken this week
Week 52		Day 1, 2, 3, 4 and 5 of Week 52

NOTE: Duplicate (split) samples are to be collected once per month during routine testing and once during each stress test period.

For this test plan, a critical measurement is defined as a measurement whose absence would significantly lower the confidence in the data and would affect the ability to verify system performance. In the event data is lost or is deemed otherwise unacceptable, critical measurements must be repeated within a time period that would allow substitution so as not impair the final data set. A table outlining the target parameters and critical measurement determination is also provided (See Table 3 - 3).

Table 3 - 3 Target Parameters

Operational Venue	Measurement Type	Target Analytes or Measure	Critical	Non-Critical
Influent Wastewater	Chemical Analysis	BOD_5	X	
		pH		X
		Total and soluble COD		X
		Alkalinity	X	
		TN	X	
		TP	X	
		Ammonia (as N)	X	
	Biological Determination	Fecal Coliform	X	
	Assay	Suspended Solids	X	
	Physical	Temperature		X
		Volume	X	
Final Effluent	Chemical Analysis	$CBOD_5$	X	
		Soluble COD		X
		pH		X
		Alkalinity	X	
		TN	X	
		Ammonia (as N)	X	
		Nitrate + Nitrite (as N)	X	
		TP	X	
		Dissolved Oxygen		X
	Biological Determination	Fecal Coliform	X	
	Assay	Suspended Solids	X	
	Physical	Temperature		X
By-products/ Residues	Assay	TSS	X	
		VSS		X
	Physical	Volumetric	X	
Environmental	Assay	Noise		X
		Odor		X
Operation & Maintenance	Physical	Power Consumption	X	
Monthly Alarms Test		Alarm light and buzzer		X
Electrical Components		Failure/Bearings/ Deterioration of control/junction boxes		X
Structural Integrity & Hydrostatic		Operator Observation		x

3.5 Evaluation of Verification Objectives

3.5.1 Evaluation of Field Measurements and Analytical Data

The data produced by the field analytical measures will be evaluated as falling within acceptable QA/QC limits for those measures, based on performing a calibration check (i.e. DO and pH measurements) and measurements with a duplicate device (i.e. temperature measurement), as described in WSDOH's SOPs.

Validation includes calibrations, test procedures, acceptance criteria and documentation of results.

Laboratory analytical data will be evaluated for acceptance based on the data falling within QA/QC limits as reported by UWCEE and Snoqualmie WWTP Laboratories, and outlined in the laboratory QA protocol for the parameters analyzed during this test.

Measurements of influent flow will be evaluated for acceptance on the basis of meeting the stated QA/QC objectives for those measures based on two methods of measurement (weekly volumetric dosage checks and effluent sump pumped volumes), as described in the Snoqualmie WTTF.

Observations of each test unit's operational characteristics, environmental characteristics and measures, and alarm tests will be evaluated on the basis of the measure's compliance with the relevant QA/QC requirements for recording observations, electric use, and alarm tests. Standard Field logs will be used to record equipment operation data during each field sampling event.

3.6 Safety and Hygiene Plan

The Snoqualmie WWTP safety plan and the UWCEE laboratories health and safety plan are on file and can be made available upon request.

4.0 FIELD OPERATION PROCEDURES

4.1 Method to Establish Completion of System Startup

The UWCEE will notify DOH when all three systems have three consecutive sample events with effluent ammonia-nitrogen results less than 10 mg/L. Upon agreement of both parties, the 52 week verification period will begin. As noted in the protocols, this period may not extend beyond 8 weeks.

4.2 Site Specific Factors Affecting Sampling or Monitoring Procedures

There are no site-specific factors affecting sampling or monitoring procedures.

4.3 Site Preparation Needed Prior to Sampling Monitoring

4.3.1 Tee-Cross Sampling Points

Installation of PVC tee-cross sampling location in the effluent sump will be required during the installation of each technology. This tee-cross will be installed as described in section 3.4.1.

4.4 Monitoring Procedures for the Snoqualmie WWTP

4.4.1 Collection of Representative Samples

The collection of representative samples is ensured through the use of ISCO automated composite-samplers, which will be used to collect all major samples, except grab samples for the purposes of measuring pH, temperature, dissolved oxygen, and fecal coliform. Programming of the automated samplers is to be synchronized with influent dosing events, and ensures that samples collected are flow-proportional.

Sample volumes delivered by the automated samplers are self-calibrated by the sampler and calibrated by hand on a monthly basis and recorded in the Field Log as per the Filed Methods for Automated Composite-Samplers (FM 11). Irregularities in sample volumes can be detected by verifying that the total sample volume is the same each day. This is simply carried out by operations staff through comparison with liquid levels in the sample container.

The composite sample container will be inverted by hand four times prior to pouring into sample bottles for transport to UWCEE laboratories, this will ensure the sub-samples are representative of the original composite sample.

4.5 Split Samples

As noted above, the comparison of duplicate field sample results and laboratory QA/QC results will be used to assess sampling and analytical error. The identity and presence of split samples (duplicates) is known only by UWCEE Faculty (i.e. blind samples).

4.6 Sample Containers, Volumes and Holding Times

Sample containers, volumes, and holding times are shown in Table 4 – 1.

4.7 Sample Labeling, Transport and Archiving

Samples will be labeled with the standard UWCEE adhesive label. Information required to complete this label includes the following items of information: (Example of anticipated data is in parenthesis)

- Sample Client: (UWCEE)
- Sample Date: (1/1/12)
- Time of Collection: (09:15)
- Location: (Snoqualmie WWTP)
- Sampling ID: (VRGF influent) (VRGF effluent)
- Collected by: (Wayne)
- Analysis Requested (BOD, CBOD, COD NO_3, NO2, NH_3,TN, TP,TSS, VSS, alkalinity, Fecal Coliform)
- Preservative: (Ice)

4.8 Sample Chain of Custody

Chain of custody forms will be provided by the UWCEE Laboratory and used to document the transfer of sample from UWCEE field personnel to the UWCEE and Snoqualmie WWTP Laboratories, as described in Section 6.5. One chain of custody form will be filled out for each set of samples and placed inside the cooler.

4.9 Sample Transport

UWCEE field personnel will transport samples to the UWCEE laboratory via automobile and to the Snoqualmie WWTP Laboratory by foot. The samples will be in coolers packed with ice to maintain the temperature of all transported samples at 4 °C. Travel time from the Snoqualmie WWTP to UWCEE is approximately 45 minutes. Travel time to the Snoqualmie WWTP Laboratory us approximately 1 minute by foot. Travel blanks will be used during the test, as described in Section 6.4.1.

4.10 Sample Handling and Archiving

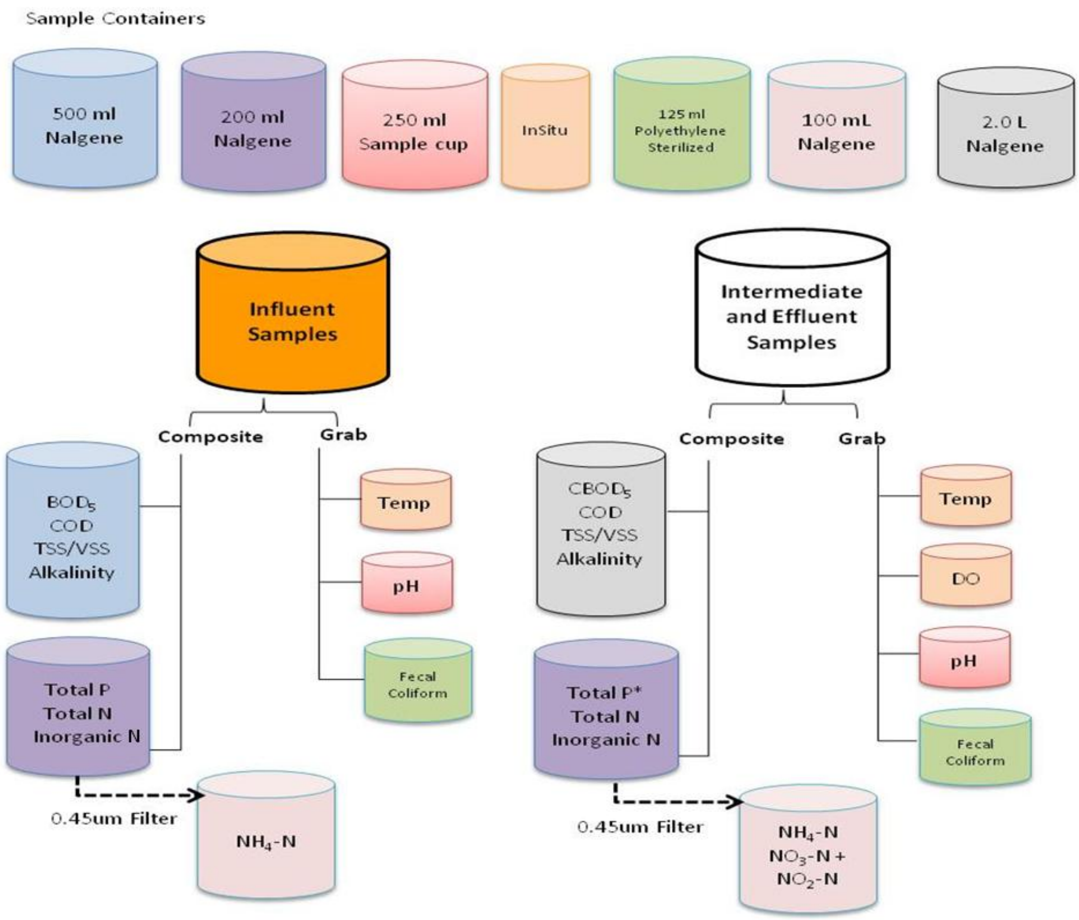
Samples will be collected and held according to requirements outlined in Table 4 - 1 and specified in Figure 4. All unused raw composite will be retained for 24 hours at 4 °C at the Snoqualmie WWTP.

Table 4 - 1 Sample Holding-Time Requirements

Analyte	Location	Holding Time
BOD_5	Influent	48 hr
$CBOD_5$	Effluent	48 hr
COD	All	28 days
Total Suspended Solids	All	24 hr
Volatile Suspended Solids	All	24 hr
pH[1]	All	Immediate
Temperature[1]	All	Immediate
Alkalinity	All	6 hr
Dissolved Oxygen[1]	Effluent	Immediate
Total Nitrogen[2]	All	24 hr
Ammonia[2]	All	24 hr
Nitrate + Nitrite (as N)[2]	Effluent	24 hr
Total Phosphorus[2]	All	24 hr
Fecal Coliform[3]	All	24 hr

1. pH, Temperature and Dissolved Oxygen will be measured immediately following recovery of sample
2. Sample will be filtered and frozen within 24 hours and holding time for frozen samples is 28 days from time of filtration
3. Collected by grab in pre-sterilized polyethylene bottles

Figure 4 Sample Collection Specifications



* Total P is not sampled for intermediate effluent.

5.0 ANALYTICAL PROCEDURES

5.1 Water Quality Methods

Water quality parameters used for product verification and field testing are listed in Table 5 - 1A and 5 - 1B, respectively.

Table 5 - 1A Technology Verification Analytical Methods

Pameter	Facility	Acceptance Criteria		Dectecton Limits[1]	Standard Method[2]
		Duplicates (%)	Spikes (%)		
BOD_5	UWCEE Laboratories	80-120	N/A	2.0 mg/L	Method #5210 B
$CBOD_5$	UWCEE Laboratories	80-120	N/A	2.0 mg/L	Method #5210 B
Total Suspended Solids	UWCEE Laboratories	80-120	N/A	1.0 mg/L	Method #2540D
Volatile Suspended Solids	UWCEE Laboratories	80-120	N/A	1.0 mg/L	Method #2540E
pH	On-site	90-110	N/A	0.1 SUs	Method #4500H B
Temperature (^{o}C)	On-site	90-110	N/A	0.1^{o} C	Method #2550
Alkalinity (as CaCO3)	UWCEE Laboratories	80-120	N/A	2.0 mg-$CaCO_3$/L	Method #2320
Dissolved Oxygen	On-site	80-120	N/A	0.1 mg-DO/L	Method #4500
Fecal Coliform	Snoqualmie WWTP Laboratory	80-120	N/A	1 Ct/100ml	Method #9222D
Total Phosphorus (TP)	UWCEE Laboratories	80-120	60-140	0.01 mg-P/L	Method #4500 P J + Method #4500 P G
Total Nitrogen (TN)	UWCEE Laboratories	80-120	60-140	0.10 mg- N/L	Method #4500 TKN + Method #4500 NO3 H
COD	UWCEE Laboratories	80-120	N/A	10.0 mg/L	Method #5220 D
Ammonia (as N)	UWCEE Laboratories	80-120	80-120	0.01 mg-N/L	Method #4500 NH3 G
Nitrate + Nitrite (as N)	UWCEE Laboratories	90-110	60-140	0.01 mg -N/L	Method #4500 NO3 H

[1] Detection limits are for wastewater samples. Actual minimum detection limits may vary due to sample concentrations and subsequent dilutions. The detection limit will be reported with the data.

[2]Standard Methods for the Examination of Water and Wastewater, APHA, 21th ed., (2005).

Table 5 - 1B Field Measurement Analytical Methods

Pameter	Facility	Acceptance Criteria		Method Dectecton Limits	Standard Method
		Duplicates (%)	Spikes (%)		
pH	On-site	90-110	N/A	0.1 SUs	Glass electrode Method #4500H B
Temperature (°C)	On-site	90-110	N/A	0.1° C	Thermometer Method #2550B
Conductivity	On-site	80-110	N/A	0 to 499.9 µS/cm	Conductivity cell Method #2510B
Dissolved Oxygen	On-site	80-120	N/A	0 to 20 mg-DO/L	Luminescent Method ASTM D888-09
Ammonia (as N)	On-site	90-110	N/A	0.1 to 18.00 mg-N/L	Ion selective electrode method #4500-NH_3-D
Nitrate (as N)	On-site	90-110	N/A	0.1 – 14.00 mg -N/L	Ion selective electrode method #4500-NO_3-D
Turbidity	On-site	80-120	N/A	0 to 1000 NTUs	Nephelometric sensor method EPA 180.1

5.2 Reporting Units

Reporting units are listed in Table 6 – 1

5.3 Calibrated Measurements

5.3.1 UWCEE Laboratory and Field Calibrations

Calibration procedures for analytes measured at the UWCEE facility in Table 5 - 1A are contained in the UWCEE Laboratories SOP available at UWCEE.

5.3.2 Snoqualmie WWTP Laboratory QA/QC

Summaries of QA/QC procedures for the fecal coliform sample analysis conducted by Snoqualmie WWTP Laboratory are contained in the Snoqualmie WWTP Laboratory assurance manual, available at the Snoqualmie WWTP.

5.3.3 WSDOH Calibrations

Calibration procedures for analytes measured by WSDOH on-site in Table 5 - 1B are contained in the WSDOH SOP available at WSDOH.

5.4 Other Measurements

5.4.1 Influent Wastewater

Measurement of operational facility and technology parameters other than those listed in Tables 5 - 1A & 5 - 1B, include volume of influent wastewater dosed to each test technology, electric use, chemical use, and by-product volumes and environmental consideration (noise and odors).

5.4.2 Electric Use

Snoqualmie WTTF operations personnel, as indicated on the dedicated electric meter serving test unit, will record electrical use biweekly in the Field Log. The meter's manufacturer and model number and any claimed accuracy for the meter will also be noted in the Field Log. Following the end of the testing period the electric meter will be checked for calibration, and the calibration data will be entered in the Field Log.

5.4.3 Chemical Use

For this ETV testing, the test units do not add process chemicals to achieve treatment.

5.4.4 Environmental Considerations

Noise

Noise levels associated with mechanical equipment will be verified during the evaluation period using a decibel meter. Measurements will be taken one meter (3 feet) from the source(s) at one and a half meters (4.5 feet) above the ground, at 90° intervals in four (4) directions. Any mitigation measures for noise control provided by the UWCEE Faculty shall be noted.

Noise levels shall be measured once during the evaluation, approximately one month after completion of startup period. The meter shall be calibrated prior to use. Meter readings shall be recorded in the Field Log. Three measurements at each quadrant shall be made to account for variations in ambient sound levels, and these replicate values will be recorded in the operations log for the test units.

Noise measurements will be made at times of the day when ambient noise levels are at their lowest (i.e. on a weekend morning and when wind speed is at a minimum).

Odors

The UWCEE Faculty will make monthly observations during the evaluation period with respect to odors generated by each test technology. The observation shall be qualitative and shall include odor strength (intensity) and type (attribute). Intensity shall be as non-detectable; barely detectable; moderate; and strong. Observations shall be made during periods of low wind velocity (<10 knots) and will be made standing upright at a distance of three (3) feet from the treatment unit, at 90° intervals in four (4) directions. All observations shall be made by the same UWCEE Faculty personnel, to the extent possible.

If the treatment system is buried, covered or otherwise has odor containment, the means of ventilating the compartment(s), including any odor treatment systems shall be noted in the Field Log.

5.4.5 Mechanical Components

Performance and reliability of the mechanical components (pump & air compressor) shall be observed and documented during the test period. This will include the recording in the Field Log of equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment.

Alarms

During the evaluation period, any alarm systems associated with each technology shall be operationally tested and verified at least once per month. Alarms which are activated by floats, and which are accessible, shall be operated by lifting the floats to activate the alarm. The response (i.e. if it made a noise or not) of the alarms to testing shall be recorded in the Field Log.

5.4.6 Electrical/Instrumentation Components

Electrical components, particularly those that might be adversely affected by the corrosive atmosphere of a wastewater treatment process, and instrumentation and alarm systems shall be monitored for performance and durability during the course of verification testing. Observations of physical deterioration shall be noted in the Field Log. Electrical equipment failure rates, replacement rates, and the existence and use of duplicate or standby equipment shall be noted and recorded in the Field Log.

5.4.7 Residuals and By-products

By-products or residuals, when generated, may include septage and sludge. The quantity and quality of residuals generated during the evaluation process will be recorded in the Field Log. Measurement of sludge depth will be made twice during the testing period: once after six months and once in the final month of testing. A coring sludge measurement tool (Sludge-Judge) will be used to estimate the depth of sludge/solids in the first chamber and second chamber of the 1,250 gallon septic tank. Measurement of the depth and areal extent of the solids deposits will be recorded in the Field Log.

In the event residuals/solids are removed as a matter of regular operation and maintenance of the technology, the volume, mass and other characteristics of the by-products or residuals (such as TSS, VSS, water content) shall be recorded in the Field Log.

Samples of the residuals/solids retained in each compartment of the tank during the evaluation shall be recovered from the Sludge-Judge during the final measurement period (month 14). The contents of the Sludge-Judge shall be emptied into a clean container, and the sample shall be analyzed for water content, TSS and VSS. Following this measurement and sampling, the contents of the tank will be vigorously mixed, as samples will be taken for total solids analysis.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 QA/QC Objectives

Quality assurance and quality control of the equipment calibration, equipment operation, process maintenance, measured water quality parameters, and strict adherence to safety measure shall be maintained throughout the verification program. The QA/QC objectives are in place to ensure that strict methods and procedures are followed during the verification program so that the data obtained from the testing are valid for use for the NSF ETV Nutrient Reduction Protocols. They are also designed to ensure that the conditions under which data are obtained are properly recorded and can be directly linked to the data, should a question arise as to its validity.

The laboratory, operational, and environmental data objectives are based on requirements outlined in the ETV protocol. The ETV protocol outlines data quality objectives that ensure sufficient analytical measurements of contaminant removal performance in order to credibly characterize the long-term removal performance of the technology under varying climatic (temperature) conditions.

The principal users of this data will be the Washington State Department of Health (WSDOH) to gain performance information to support the development of standards and guidance for use of the technologies. Secondary users of this data will be the various local health jurisdictions in Washington State. Other users of this data will be system installation engineers, designers, contractors, monitoring, and maintenance service providers and consumers.

6.2 Quality Control Indicators

6.2.1 Precision

Precision is defined as the degree of mutual agreement relative to individual measurements of a particular sample. As such, precision provides an estimate of random error. Precision is evaluated using analysis of field or matrix spiked duplicates. Method precision is demonstrated through the reproducibility of the analytical results. Relative percent difference (RPD) may be used to evaluate precision by the following formula:

$$RPD=[(C_1 - C_2) \div ((C_1 + C_2)/2)] \times 100\%$$

Where:

C_1= Concentration of the compound or element in the sample
C_2= Concentration of the compound or element in the duplicate

For precision of water quality samples, refer to Table 6 - 1.

6.2.2 Bias

For water quality analyses, bias is defined as the difference between the population mean and true value of the parameter being measured. Field and laboratory QC procedures, such as blanks, check standards, and spiked samples, provide a measure of any bias affecting measurements procedures. Field staff will minimize bias in field measurements and samples by strictly following measurement, sampling and handling protocols.

Bias estimates are frequently based on the recovery of the analyte of interested from certified reference materials or from matrix or surrogate spikes when reference materials are not available. The following equation is used to calculate percent recovery:

$$\text{Percent Recovery} = (A_r - A_o)/A_f \text{ x}100\%$$

Where:

A_r= Total amount detected in spiked sample;
A_o= Amount detected in un-spiked sample;
A_f= Spike amount added to sample.

Accuracy is described as the closeness of agreement between as observed value and a true or accepted reference value. When applied to a set of observed values, accuracy will be a combination of a random (precision) component and a systematic error (bias) component.

Analytical Accuracy

Analytical accuracy will be assessed by using prepared and analytical standards, as appropriate. Analytical accuracy is ensured by following individual analytical method SOPs and random spiking procedures for specific target constituents. For analytical method accuracy, refer to Table 6 - 1.

Table 6 – 1 Methodology for Measurement of Accuracy

Parameter	Precision	Bias
BOD_5 (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
$CBOD_5$ (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
COD (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Total Suspended Solids (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Volatile Suspended Solids (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Alkalinity (Report to the nearest 1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Ammonia (Report to the nearest 0.1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Total Nitrate/Nitrite (Report to the nearest 0.1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Total Nitrogen (Report to the nearest 0.1 mg/l)	One sample per sample event	UWCEE Laboratories SOP
Total Phosphorus (Report to the nearest 0.2 mg/l)	One sample per sample event	UWCEE Laboratories SOP
pH **(Report to nearest 0.1 pH unit)**	One sample per sample event	Daily 3-point calibration with certified pH buffers in range of measurements (4.0-10.0)
Temperature (Report to nearest 0.1 °C)	One sample per sample event	Quarterly verification against UWCEE Laboratories NIST thermometer.
Dissolved Oxygen **(Report to nearest 0.5 mg/l)**	One sample per sample event	Daily calibration to internal standard and reference to table of saturation values.
Conductivity **(Report to nearest 0.1 µS/cm)**	One sample per sample event	WSDOH's SOP
Turbidity **(Report to nearest 0.1 NTU)**	One sample per sample event	WSDOH's SOP
Fecal Coliform **(Report to nearest 1 CFU/100 mL)**	One sample per sample event or 10% of sample batch.	Snoqualmie WWTP Laboratory SOP

Field Sample Bias

Field sample bias will be minimized for analyses conducted at the Snoqualmie WTTF by use of the calibration standards and calibration procedures outlined in the Snoqualmie WWTP SOP and WSDOH's SOPs.

Field Process Systems Accuracy

Accuracy of influent dosing volumes are measured during the test program, and ensured by weekly calibration checks of the dosing pumps delivery, which are recorded in the field operations log.

Equipment Systems Accuracy

For equipment operating parameters, accuracy refers to the difference between the reported operating condition and the actual operating condition. For operating data, accuracy entails collecting a sufficient quantity of data during operation to be able to detect a change in system operations.

Influent Dosing Flow Rate

Assurance of the accuracy of influent flow rate to each technology is documented by the field assessment procedures in Section 8.1.1.

Electrical Usage

Accuracy of electrical usage measurement will be measured by regular biweekly recording of meter readings. Bias of the meter itself, as claimed by the meter manufacturer, shall be noted along with model number and serial number of meter. Following the end of the testing period the electric meter will be re-calibrated, and the calibration data will be entered in the Field Log.

Chemical Usage

Chemical use is not applicable to the technologies, as no process chemicals will be added to the treatment process.

6.2.3 Environmental Considerations Noise

Noise

The sound meter for measurement of noise levels will be calibrated prior to use and the calibration information will be noted in the Field Log. Accuracy will be minimized by conforming to ANSI/NSFI Standard 40 protocols for noise measurement (Refer to Section 5.4.4 above).

Odor

Use of the term accuracy is not appropriate for a qualitative measurement instrument (the human nose). However, the consistency of measurement of the monthly observations of odors will be ensured by use of consistent location of measurement instrument (the human nose), consistency on odor description or type, odor intensity and the measurement timing (Refer to Section 5.4.4 above for method of observations).

6.2.4 Representativeness

Representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The field operation and analytical procedures outlined in Sections 4 and 5 were selected to provide data representative of process conditions. Representativeness will be monitored through QA/QC audits (both field and laboratory), including review of the laboratory procedures for sample handling and storage, review and observation of the sample collection, and review of the field operation logs.

Analytical Procedures

Proper handling will ensure representativeness of laboratory procedures, storage, and analysis of samples so that the test results reflect the collected sample as accurately as possible. The laboratory will follow set standard operating procedures (in accordance with good laboratory practice) for thorough mixing of any samples prior to sub-sampling in order to ensure that samples are homogenous and representative of the whole sample.

Field Samples

The representativeness of all field data will be qualitatively assessed by determining if the data are consistent with known or anticipated water quality in the treatment system samples, and accepted scientific and engineering principles. Field measurements will also be checked for completeness of procedures and documentation of procedures and results. The representativeness of field samples will be assessed by the collection of field duplicates covering the range of concentrations for the particular parameter of interest encountered in this verification Test Plan.

The Test Plan design calls for grab and composite samples of influent and effluent to be collected and then analyzed. The sampling locations for the samples will be designed for easy access. The influent samples will be taken directly from a well-mixed area at the WWTP headworks and the effluent samples will be collected at a point nearest the effluent discharge of each technology. This design will help ensure that a representative sample of the wastewater is obtained in each grab or composite sample bottle. The sample handling procedure includes a thorough mixing of the composite container prior to pouring the samples into the individual containers. The tested technologies will be operated in a manner consistent with the operating manual, so that the operating conditions will be representative of a normal installation and operation for these systems. Additionally, to protect the quality of samples, the sampling equipment and field instruments will be kept clean in accordance to the procedures in the Field Methods for Cleaning/Decontamination Procedures (FM 13).

6.2.5 Completeness

Completeness of Startup Period

The completeness of the startup shall be determined when all three systems have three consecutive day sample events with effluent ammonia-nitrogen results less than 10 mg/L or by the completion of the eight week startup period, whichever comes first.

Analytical Results Completeness (Twelve-Month Sampling Period)

Influent Volumetric Measurements

Influent flow data completeness shall be determined as 85% of the total number of dosing days being valid and acceptable.

Electric Use

Electric use completeness shall be determined as 83% of the biweekly meter readings.

Sampling

Completeness of sampling for **monthly samples** shall be determined as 83% of valid sampling data from the monthly tests.

Completeness of sampling for **stress tests** will be determined as 83% valid sampling data from each of the stress tests.

Analytical Results Completeness

Analytical results completeness will be determined as 90% of samples delivered to UWCEE and Snoqualmie WWTP Laboratories shall be valid and acceptable.

6.2.6 Comparability

Comparability will be achieved by using consistent and standardized sampling and analytical methods. This information is documented in standard operating procedures (SOPs), outlined in WSDOH and UWCEE’s quality control manuals. All laboratory analyses will be performed using methods listed in Table 5 - 1A. To ensure the comparability of field measurements made throughout the duration of the technology verification period, all field samples will be measured immediately, and the same field instruments and measurement techniques will be used consistently. To ensure the comparability of analytical laboratory results, all samples will be transported to the laboratory promptly to ensure holding times are met, and the instruments and techniques used for sample collection will be used consistently. Calibrations will be performed in accordance with the manufacturer’s specifications and/or SOPs. Comparability of data for the Snoqualmie WWTP Laboratory is ensured by the regular laboratory certification program of the WA State Department of Ecology.

6.3 Sampling Equipment Calibration and Frequency

6.3.1 Automated Sampler Calibration

Calibration is accomplished using a subroutine in the regular sampler program. The sampler calibration procedure discharges a 100 mL sample volume into the composite sampling container. The sampled volume is then transferred to a graduated cylinder to measure and verify the sampled volume. The sampled volume is then entered into the calibration program, and the sample volume is adjusted accordingly. The sample volume is then re-verified by manually activating the sampler, and measuring the resulting sample volume using a graduated cylinder.

6.3.2 Calibration Frequency

The sampler shall be calibrated monthly to ensure that equal samples are drawn and that sufficient sample volume is drawn for the necessary analysis sub-samples. The amount normally drawn for each of the 15 samples is between 450 and 550 milliliters. This provides a total composite sample of between 6.75 and 8.25 liters.

6.4 Water Quality and Operational Control Checks

6.4.1 Water Quality Data

Spiked samples for each method will be analyzed at the rate outlined in the UWCEE Laboratories SOP and QA plans.

Method blanks will be performed at a frequency of one blank per 20 field samples collected.

Travel blanks will be provided to UWCEE Laboratories twice during the sample period.

UWCEE shall complete PE samples for analyses completed in this evaluation at least every six months during the course of the evaluation. Results of the PE samples shall be made available to the Verification Organization during project audits.

6.4.2 Quality Control for Equipment Operation

Laboratory analytical instruments shall be checked for accuracy based upon the SOP and QA plans for UWCEE and Snoqualmie WWTP Laboratories.

All analytical and sampling equipment at the Snoqualmie WTTF will be maintained and calibrated by Snoqualmie WTTF personnel according to the manufacturer's instructions and according to the Snoqualmie WTTF SOP.

6.5 Maintenance of Chain of Custody

6.5.1 Chain of Custody Forms

Chain of custody forms (COC) shall be filled out prior to sample transportation to the Snoqualmie WWTP laboratory. If the person transporting the samples is not the field sampler, the chain of custody form will indicate the transfer of samples. A copy of the COC shall be retained at the Snoqualmie WWTP laboratory for records of the samples that their facility will process (i.e., fecal coliform). All original COC forms will be returned to and stored at UWCEE lab.

Samples will be transported from Snoqualmie WTTF to UWCEE Laboratories in coolers packed with ice, immediately following completion of sample collection. Travel time to UWCEE Laboratories is approximately 45 minutes.

Upon receipt of samples at the UWCEE laboratory, the sample custodian notes date of receipt, client demographic information, the condition of samples and documents any deficiencies. If the sample integrity or identification is in doubt, the event is documented on a Sample Problem Form and the relevant individuals are notified immediately.

Samples to be subcontracted to the Snoqualmie WWTP Laboratory will be in the chain of custody to the UWCEE laboratory. Subcontract samples will be transported from the Snoqualmie WTTF to the Snoqualmie WWTP Laboratory immediate in coolers packed with ice held at 4^{o} C. Travel time to the Snoqualmie WWTP is approximately 1 minute on foot. A separate chain of custody will be created and accompany subcontract samples to the Snoqualmie WWTP Laboratory.

6.5.2 Cooler Receipts

Cooler receipts will be part of the chain of custody forms. The receipt will include the observed condition of samples and the sample temperature. Samples will be stored in appropriate facilities (freezers of refrigerators) at the UWCEE analytical laboratory.

6.6 Acceptance Criteria

Analytical acceptance criteria for QA objectives for each matrix are listed in Table 5 - 1A & 5 - 1B. The criteria for analytes in Table 5 - 1A are contained in the UWCEE Laboratory's SOP, available upon request. Acceptance criteria for analytes in Table 5 - 1B are discussed in WSDOH's SOPs.

6.6.1 Criteria for Acceptance of Operational Facility Parameters

Influent wastewater dose volumes are calibrated weekly with a volumetric test. Acceptance criteria for the measurements shall be that the thirty (30)-day average volume of the wastewater delivered to the technology shall be within 100% +/- 10% of the systems rated hydraulic capacity. An exception to this volume shall be during the Low Flow Stress Test when the 21-day average volumes accepted will be 100%+/- 10% of the daily reduced flow (50% of normal daily flow volume). For purposes of calculating the 21-day average volume, only the 21 days of the Low Flow Stress period are to be included.

6.6.2 Criteria for Acceptance of Technology Operational Parameters

Electrical use is manually recorded from the dedicated electric meter and criteria are the meter reading, and pertinent Field Log notations (date, time recorder's name). Accuracy of the meter as claimed by the manufacturer shall be noted in the Field Log. The meter shall be recalibrated following the end of the Test Period and the recalibration results entered in the Field Log.

6.7 Assessment of Additional QA Objectives (Mass Balance)

The use a mass balance approach to assess nitrogen removal performance is not contemplated at this time.

6.8 Corrective Action Plan

6.8.1 Analytical Methods

Corrective actions for analytical methods (listed in Table 5 - 1A & 5 - 1B) performed are outlined in the UWCEE Laboratory Manual. When analytical parameters fall outside of the relevant acceptance criteria, corrective action will be taken to rerun samples. Such actions may include: re-analysis of sample and standards; reanalysis with appropriate fresh reagents and standards. Corrective action may also take the form of measures to prevent future occurrence of the problem. Any problems with analysis will be noted in the relevant laboratory logbook and corrective actions taken will also be recorded in the laboratory logbook.

6.8.2 Sample Collection, Handling and Field Measures

Corrective actions for field sampling and field analytical procedures at the Snoqualmie WTTF are included in the Snoqualmie WTTF SOP. Whenever necessary or appropriate, shortcomings in the execution of this test plan revealed by audits will be corrected.

Sample Collection

Nonconformance of sample collection with procedures in this Test Plan and the Snoqualmie WTTF SOP will be noted in the Field Log. Likewise any corrective action taken will be recorded in the Field Log. Nonconformance can include: automated sampler malfunction due to electrical fault; improperly programmed sampler controller; failure to initiate sampler program; movement of suction line and loss of suction.

Sample Handling

Nonconformance with sample handling and transport will be recorded in the Field and Sample Logs and any corrective action taken recorded in the Field and Sample Logs.

Field Analytical Measurement

Nonconformance with field measures refers to measurement of Temperature, pH, and Dissolved Oxygen made at the Snoqualmie WTTF. Measurements that fall outside the acceptance criteria for these analyses will be noted in the Field Log. Corrective action shall be taken and noted in the Field Log.

For pH, corrective actions can include: measurements with the pH meter which appear to be anomalous can be repeated; buffers can be checked between measurements; sample duplicates are run at the prescribed rate in this document; the meter can be recalibrated, or recalibrated with fresh buffers, and the sample(s) re-analyzed.

Temperature is measured with a separate thermistor probe, and subsequently measured with a second thermistor on the pH probe. Corrective actions may include re-measurement of temperature.

Dissolved oxygen problems can include excessive drift during measurement; excessive temperature shift during measurement; and failure to agitate probe sufficiently during measurement. When problems with measurement occur, corrective actions may include: re-measurement; recalibration of the meter and probe; replacement of meter batteries with fresh; and replacement of probe membrane. Measurements that fall outside of the acceptance criteria for these analyses will be noted in the Field Log. Corrective action shall be taken and noted in the Field Log.

6.9 Samples Cross Contamination Preventive Measures

Composite sample containers shall be uniquely labeled identifying the technology, and sample location. Composite sample bottles are thus dedicated to a single technology and sampling point throughout the testing period. In the field facility, to minimize cross contamination while processing analytical subsamples and during field analytical measurements, samples will be processed beginning with the most highly treated effluent, then intermediate effluent and last the wastewater influent.

7.0 Reports and Other Deliverables

The data reporting parameters, reporting units, and method of recording are shown in Table 7 - 1. The final report will include a summary of the data and excel spreadsheets (and hard copies) chronologically summarizing all of the raw data collected for this project.

The data will be entered into the data report after it has passed QA review by the project QA manager within 2 days of completion of the analytical results. Data acceptability will be based on the analytical results being within the acceptable criteria for accuracy and precision described in the SOPs for each analyte. These include percent recovery in spiked samples, accuracy with known standards and relative percent differences with duplicates. The completeness of the analyses will be judged by the QA project manager by reviewing data entry sheets to determine that all specified steps have been followed for QA/QC and all required information has been appropriately entered.

Table 7 - 1 Data Reporting

Parameter	Reporting Units	Non-detect Value	Method
BOD_5	Milligrams/liter	1/2 the detection limit	CD and Paper
$CBOD_5$	Milligrams/liter	1/2 the detection limit	CD and Paper
COD	Milligrams/liter	1/2 the detection limit	CD and Paper
Conductivity	µS/cm	1/2 the detection limit	CD and Paper
Suspended Solids	Milligrams/liter	1/2 the detection limit	CD and Paper
pH	pH units		CD and Paper
Temperature	Degrees C.		CD and Paper
Alkalinity	Milligrams/liter $CaCO_3$	1/2 the detection limit	CD and Paper
Dissolved Oxygen	Milligrams/liter	1/2 the detection limit	CD and Paper
Total Nitrogen as N	Milligrams/liter	1/2 the detection limit	CD and Paper
Ammonia as N	Milligrams/liter	1/2 the detection limit	CD and Paper
Nitrate + Nitrite (as N)	Milligrams/liter	1/2 the detection limit	CD and Paper
Total Phosphorus as P	Milligrams/liter	1/2 the detection limit	CD and Paper
Fecal Coliform	Colonies/100 Milliliters	1/2 the detection limit	CD and Paper
Turbidity	NTUs	1/2 the detection limit	CD and Paper
Influent Wastewater	Gallons per day		CD and Paper

7.1 Data Quality Objective

7.1 Deliverables

The Verification Report will contain the final results of the tested treatment technologies' nitrogen reduction capabilities as well as a compilation of all the sampling, data summaries, operation and maintenance, and quality control and analytical reports. The following are deliverables from UWCEE faculty to be included as separate sections in the Final ETV Verification Report:

7.1.1 Sampling Report

A Sampling Report will be completed for each sampling event during the evaluation period following all sampling activities. This report will consist of a brief summary of the major actions performed, any problems encountered since the previous report, and all corrective actions taken. This information will be kept in project files along with the COC forms and the Field Log documenting the sampling activities.

7.1.2 Data Summary Report

UWCEE faculty will provide a Data Summary Report consisting of tabulated summaries of the data, including startup data, to the Verification Organization in both electronic and hard copy format. The summaries will show the sample identifiers, the analyses performed, and the measured concentration or effects, including all relevant qualifiers and validation flags. A brief narrative statement on the overall data quality and quantity will also accompany the tabulated summaries. The UWCEE Project Manager will coordinate with the QA Project Manager to define the format of these data summary reports. The UWCEE Project Manager shall also forward all data summary reports to the Verification Organization Project Manager following review. All data qualifier and validation flags that that are used in the data summary reports will be clearly defined in the glossary of terms and acronyms of the final Verification Report.

7.1.3 Operation and Maintenance Report

An Operation and Maintenance Report will be provided based on the operation and maintenance activities that are performed during the verification-testing period, by the UWCEE Project Coordinator. The report will consist of a summary of the recommended operation and maintenance activities for the technology and any additional operation or maintenance tasks that were required during the test period. This report shall clearly delineate when the WSDOH provided technical assistance to the Testing Organization.

The Operation and Maintenance Report will also comment upon the O&M manual as it relates to the 12 month operation and maintenance record of each technology. Comments could include: maintenance needed but not covered by the manual; clarification of technology O&M language, etc.

7.1.4 Quality Control and Analytical Report

A Quality Control and Analytical Report will be used to address the quality control practices employed during the project. The report will also summarize the problems identified in the sampling reports, which are likely to impact the quality of the data. The report will include:

1) The project description, including report organization and background information.
2) Summaries of the sampling procedures, sample packaging, sample transportation, and decontamination procedures at the Snoqualmie WTTF.
3) A summary of the UWCEE laboratory analytical methods, detection limits, quality control activities, deviations from planned activities, and a summary of the data quality for each analysis and matrix.
4) An assessment of the sampling and analyses techniques, an evaluation of the data quality of each parameter, and an evaluation of the usability of the data.
5) A summary of any field or analytical procedures that could be changed or modified to better characterize the raw influent and treated effluent in future evaluations.
6) An overall discussion of the quality of the environmental data collected during the evaluation and whether or not it meets the project objectives.
7) Identification of the QA samples that were split and sent to UWCEE and QA laboratories and to the QA laboratory.
8) All cooler receipts and COC forms associated with the required sample results.
9) A laboratory case narrative to be included in the results if nonconformance or other evaluation events affect the sample results.
10) The portion of the primary field sample results and associated batch QC results, which conform to the QA samples submitted to the QA laboratory.

7.1.5 Final Verification Report

The Verification Report will be a document containing all raw and analyzed data, all QA/QC data sheets, a description of all types of data collected, a detailed description of the testing procedure and methods, results and QA/QC results. The report will thoroughly present and discuss the findings of the verification test, conclusions regarding the performance of the test technologies and make a comparison with the performance goals for the verification test. Washington State's requirements for Total Nitrogen Reduction are based on full test averages. The effluent quality must meet 20 mg/L when presented as the full test average.

The final report will contain the sections outlined below, however, there may be some deviation from the order given below in order to present the findings in a clear and precise manner. Additional sections may be added as needed to properly present all of the findings. It is expected that the Verification Report will contain the following main sections:

- Verification Statement
- Preface
- Contents
- Acknowledgements
- Executive Summary
- Introduction and Background
- Description of Technology and Test Site
- Experimental Design
- Methods and Test Procedures (summarizing essential information from the Test Plan)
- Results and Discussion
    - Influent characteristics
    - Startup
    - Verification Test Period Results Including Values for Full Test Averages
- Conclusions
- Recommendations
- Glossary
- References
- Appendices
    - Technology O&M manuals
    - Verification Test Plan
    - Laboratory Methods – Standard Operating Procedures
    - Field Measurements – Standard Operating Procedures
    - Lab data and QA/QC data
    - Field Lab Log Book
    - Spreadsheets with calculation and data summary
    - Field Operations Logs

7.2 Data Reduction

7.2.1 UWCEE Laboratory

Data reduction procedures for the UWCEE Laboratory analysis of parameters are contained in the SOPs for each analyte/parameter.

7.2.2 Snoqualmie WWTP Laboratory

Data reduction procedures for Snoqualmie WWTP Laboratory analysis of parameters are contained in the SOPs for each analyte/parameter.

7.2.3 UWCEE Faculty

UWCEE faculty will do data reduction for influent flow calculations. The daily wastewater flow into the technology will be derived and reduced based on the procedures outlined in the Snoqualmie WTTF SOP.

8.0 ASSESSMENTS

8.1 Audits at Snoqualmie WTTF

UWCEE faculty will conduct audits of dosing pump calibrations, sampling and sample processing on a quarterly basis. For audits, a checklist of operations performed will be created.

8.1.1 Dosing Pumps

For the dosing pump calibrations the checklist will include calibration equipment set-up procedures, calibration procedure, and logging of calibration results.

8.1.2 Sampling

For sampling the audit checklist will include composite container preparation, installation and retrieval, sampler calibration check, and sampler programming.

8.1.3 Sample Processing

For sample processing the audit checklist will include the setup, calibration, and measurement of pH and dissolved oxygen meters, the measurement of temperature, the splitting of the composite sample into sub-sample containers, use of the COC, and sample preservation and transport.

8.1.4 Responsible Personnel

Personnel who are responsible for the above audits are: David Stensel, UWCEE faculty and Michael Brett, UWCEE faculty. Audits will be kept on file for reference by WSDOH.

8.2 Audits at UWCEE Laboratory

UWCEE laboratory audits are regularly conducted by UWCEE faculty for each analytical method in the Test Plan. Audits will be conducted by: Michael Brett, UWCEE faculty. Results of these audits are available upon request.

Audits by Ecology or EPA personnel may also be conducted prior to and/or during initiating the project.

8.3 Waste Management Plan

8.3.1 Liquid Waste

Liquid waste generated by the Testing Organization consists of: raw wastewater and process effluent from sample collection; 2% dilute bleach (sodium hypochlorite); and small volumes of pH and conductivity standards. These are disposed of into the sink and toilet drains at the test site. The effluent enters the facility sewer system to be treated at the Snoqualmie WWTP. Liquid waste generated by the Testing Organization in the laboratory does not enter or mix with the Test Facility influent wastewater. UWCEE laboratory waste is managed and disposed of using approved UW waste disposal procedures.

8.3.2 Solid Waste

Solid waste generated at the Testing Organization consists of paper and cardboard and other packaging materials. Disposal of these wastes go to the King County solid waste transfer plant. Residuals left in the septic tanks and process tanks are mixed (liquefied) and pumped into the Test Facility sewer to be treated at the Snoqualmie WWTP.

9.0 REFERENCES

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10.0 APPENDICES

APPENDIX A

STANDARD OPERATING PROCEDURES

SOP Number	Description
LM 1	BOD5/CBOD5 Laboratory Method
LM 2	Total /Volatile Suspended Solids Method
LM 3	COD Laboratory Method
LM 4	Alkalinity Laboratory
LM 5	Total Nitrogen Laboratory Method
LM 6	Nitrate –Nitrate Laboratory Method
LM 7	Ammonia Laboratory Method
LM 8	Total Phosphorus Laboratory Method
LM 9	Fecal Coliform Laboratory Method
FM 1	Field Methods for Automated Composite-Samplers
FM 2	Field Methods for Collecting Wastewater Grab Samples
FM 3	Field Methods for Cleaning / Decontamination Procedures
FM 4	Field Measurement of Temperature
FM 5	Field Measurement of pH
FM 6	Field Measurement of Specific Conductance
FM 7	Field Measurement of Dissolved Oxygen
FM 8	Field Measurement of Ammonia
FM 9	Field Measurement of Nitrate
FM 10	Field Measurement of Turbidity

APPENDIX B

Glossary and Acronyms and Abbreviations

GLOSSARY

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 (precision) and systematic error (bias).

Analyte – An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined.

Bias – The difference between the population mean and the true value.

Blank – A sample prepared to contain none of the analyte of interest. For example, in water analysis pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample.

Calibration – The process of establishing the relationship between the response of a measurement system and the value of the parameter being measured.

Chain of Custody (COC) – An unbroken trail of accountability that assures the physical security of samples, data, and records.

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

Completeness – A qualitative and quantitative term that expresses confidence that all necessary data is collected and valid to allow decisions to be made for which the study was designed.

Detection limit (limit of detection) – The concentration or amount of an analyte which, on an "a priori" basis, can be determined to a specified level of certainty to be greater than zero.

Duplicates – Two samples collected or measurements made at the same time and location, or two aliquots of the same sample prepared and analyzed in the same batch.

Matrix spike – A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects.

Method – A set of written instructions completely defining the procedure to be used.

Method blank – A blank prepared to represent the sample matrix and analyzed in a batch of samples.

Parameter – A specified characteristic of a population or sample.

Population – The hypothetical set of all possible observations of the type which is being investigated.

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.

Quality assurance (QA) – Adherence to a system for assuring the reliability of measurement data.

Quality Assurance Project Plan (QAPP) – A written document that describes the implementation of quality assurance and quality control (QA/QC) activities during the life cycle of the project.

Quality control (QC) – The routine application of statistical procedures to evaluate and control the accuracy of measurement data.

Relative percent difference (RPD) –The difference between two values divided by their mean and multiplied by 100.

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

Reproducibility – The precision that measures the variability among the results of measurements of the same sample at different laboratories.

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

Verification – To establish evidence on the performance of nutrient reduction technologies under specific conditions, following a predetermined study protocol(s) and test plan(s).

Verification Report – A written document 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. The Verification Test Plan(s) shall be included as part of this document.

ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
BOD_5	Biochemical Oxygen Demand (five day)
$CBOD_5$	Carbonaceous Biochemical Oxygen Demand (five day)
CFU	Colony Forming Unit
COC	Chain-of-Custody
COD	Chemical Oxygen Demand
ERSF	Enhanced Recirculating Sand Filter
ETV	Environmental Technology Verification
EPA	Environmental Protection Agency
mg/L	Milligrams per liter
gpd	US gallons per day
gpm	US gallons per minute
L	Liters
NELAC	National Environmental Laboratory Accreditation Council
NIST	National Institute of Standards and Technology
NH_3	Ammonia
NO_2	Nitrite
NO_3	Nitrate
NO_X	Nitrite + Nitrate
NSF	NSF International
NTU	Nephelometric Turbidity Unit
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RGF	Recirculating Gravel Filter
RSF	Recirculating Sand Filter
RPD	Relative Percent Difference
SCADA	Supervisory Control and Data Acquisition Treatment
SOP	Standard Operating Procedure
STP	Sewage Treatment Plant
SU	Standard Units(s)
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TS	Total Solids
TSS	Total Suspended Solids
UWCEE	University of Washington Civil & Environmental Engineering
VDWB	Vegetated Denitrifying Woodchip Bed
VRGF	Vegetated Recirculating Gravel Filter
VSS	Volatile Suspended Solids
WSDOH	Washington State Department of Health
WTTF	Wastewater Technology Testing Facility
WWTP	Wastewater Treatment Plant

APPENDIX C

TECHNOLOGY DESCRIPTION

System 1

A **vegetated recirculating gravel filter (VRGF)** is similar to a recirculating gravel filter, except that emergent plants are added to the surface and a horizontal-flow denitrification zone is installed in the bottom portion. VRGFs are also known as recirculating vertical flow constructed wetlands.

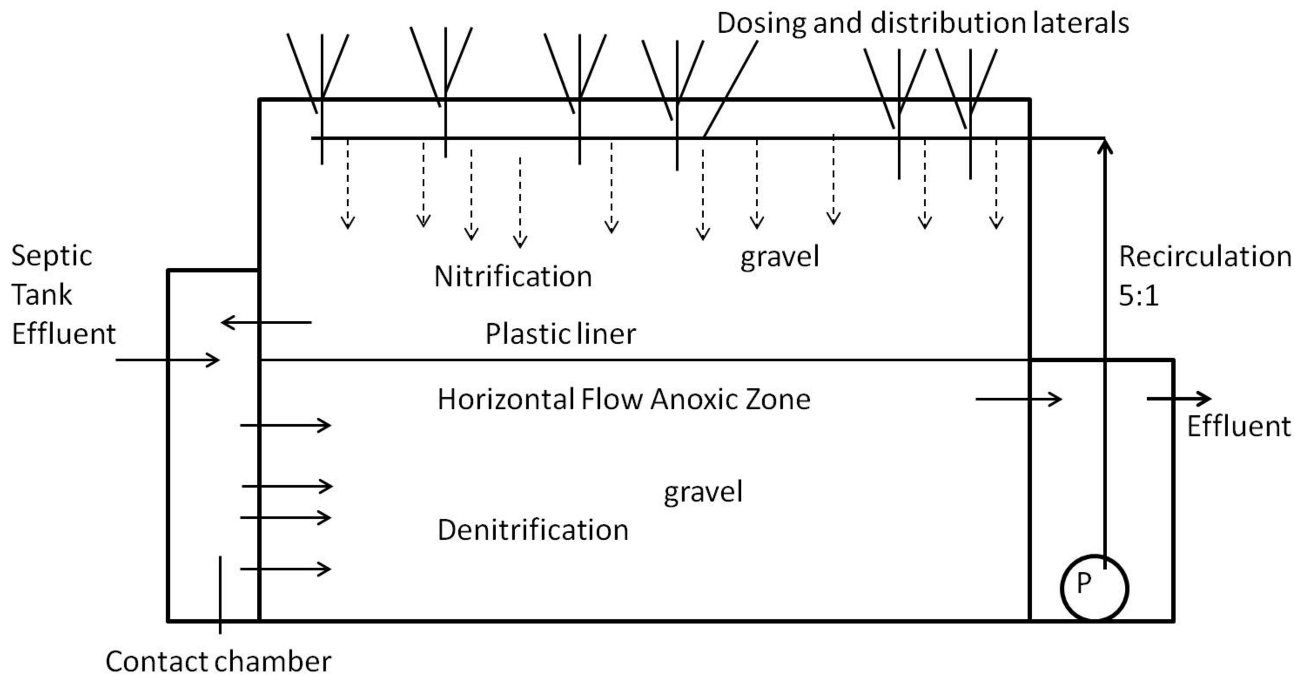
Design

The VRGF consists of a septic tank, bottom horizontal flow gravel layer, a small recirculation basin and a top vertical flow gravel layer. Influent raw wastewater enters a two compartment 1,250 gallon septic tank, where it undergoes primary settling and digestion. The VRGF with upper and lower gravel media sections separated by a polyvinyl chloride (PVC) liner is placed near the outlet of the septic tank. Effluent from the septic tank flows by gravity to a feeding inlet gravelless chamber at the bottom gravel layer of the PVC lined filter where it is treated by passing horizontally across the bottom gravel layer to the outlet manifold leading to the recirculation basin. The timer-controlled pump in the recirculation basin located outside the filter periodically recirculates effluent to the buried distribution pipe in the top layer of pea gravel in the upper portion of the VRGF. The operating cycle for the dosing is alternating periods (1-3 minutes) of dosing followed by a period of no dosing (20-30 minutes), repeated continuously over a 24-hour day, to provide a recirculation ratio of approximately 5:1. The effluent trickles vertically down through the aerobic upper zone, flows laterally across the impermeable PVC liner separating the two layers of gravel, and drops down into the uncovered portion of the bottom gravel layer at the inlet end of the filter from which it passes horizontally back to the pump basin. As treated effluent builds up in the pump basin, the pump starts another vertical flow recirculation cycle, or if the pump is in the resting cycle, the overflow effluent is discharged to a drainfield, mound system, subsurface drip system, or other approved soil dispersal component.

Treatment Theory

Raw wastewater entering the first chamber of the septic tank undergoes primary settling. Solids settle to the bottom of the chamber where they are gradually digested and fermented under anaerobic conditions, releasing short-chain volatile fatty acids (VFAs) and ammonia to solution. These solubilized anaerobic digestion by-products, combined with fine colloidal particles (which do not readily settle) and soluble organic and inorganic materials contained in the influent wastewater, form the constituents of the primary effluent, which provides a carbon source for biological activity in the anoxic bottom portion of the filter. Ammonia oxidation to nitrite and nitrate by autotrophic bacteria (nitrification) and further organic oxidation by heterotrophic bacteria occurs in the upper portion of the filter as water from the recirculation tank is distributed into the root zone and trickles through the pea gravel filter media on its passage by gravity to the bottom gravel layer. When flow from the recirculation tank is stopped the water in the upper zone drains and air fills media voids to provide oxygen for the subsequent nitrification and biological oxidation of organic substances. Pathogen capture and die off also occurs in the upper zone. The nitrified effluent mixes with incoming septic tank effluent at the inlet bottom gravel layer. In this anoxic environment, bacteria consume and oxidize the septic tank effluent organics by using dissolved nitrate/nitrite instead of oxygen to convert the inorganic nitrogen to nitrogen gas that is released to the atmosphere.

Figure A - 1 Vegetated Recirculating Gravel Filter (VRGF)



System 2

A passive two-stage denitrification system that includes a **recirculating sand filter (RSF) followed by a vegetated denitrifying woodchip bed (VDWB)**.

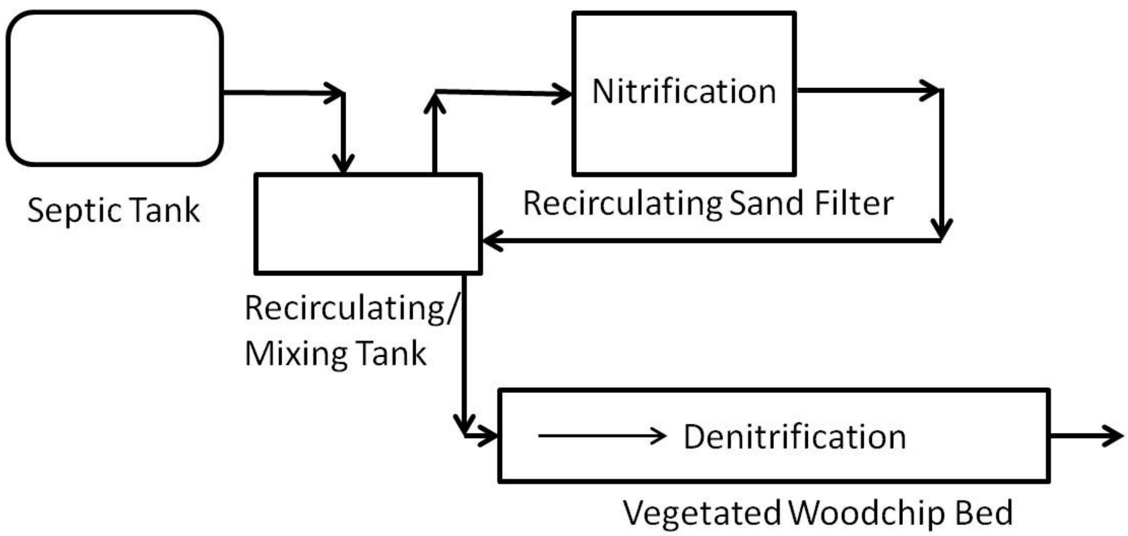
<u>Design</u>

The RSF-VDWB consists of a septic tank, recirculating sand filter, recirculation tank, flow splitting valve, a small recirculation basin, and an anoxic woodchip bed. The partially clarified effluent from the septic tank flows into a recirculation tank. The volume of the recirculation tank is equivalent to at least 1 day's raw wastewater flow. In the recirculation tank, raw effluent from the septic tank and the sand filter filtrate are mixed and pumped back to the sand filter bed. The sand filter is a bed with chambers on top of the gravel media to provide for uniform dispersion of the distributed effluent across the bed. Below the chambers there is a 6 inch layer of oyster shells on top of 2 feet of sand media. A layer of graded gravel (about 8 inches) is provided under the sand for support to the media and to surround the underdrain system. A portion of the mixture (septic tank effluent and sand filter filtrate) is dosed by a submersible pump through a distribution system that applies it evenly over the sand filter. The recirculating pump is controlled by a programmable timer in continuous cycles. This dosing schedule provides 48 dosing periods over 24 hours, allowing a recirculation ratio of 5:1. The filtrate from the gravel filter is collected by an underdrain that is located at the bottom of the bed through which conveyed to a recirculating splitter valve (RSV) assembly. The RSV is designed and located at a depth to return approximately 80% of the effluent to the recirculation tank and 20% of the effluent to the VDWB. The VDWB is a lined subsurface flow treatment wetland with a woodchip packing material. As the RSF effluent enters the VDWB treatment occurs as the effluent flows horizontally through the bed.

<u>Treatment Theory</u>

The high dosing frequency and void space in the RSF bed exposes the wastewater to air for the oxygen required for efficient treatment. The bacteria in the bed reduce the organic strength of the wastewater and convert the ammonia-nitrogen to nitrate/nitrite (nitrification process). Alkalinity addition is provided by the oyster shells in the sand filter bed. The RSF effluent diverted by gravity is further treated at the VDWB. The woodchip media is always submerged and serves as the major carbon source for denitrification. This "flooded" condition maintains anoxic to anaerobic conditions within the VDWB, forcing the bacteria to use to nitrate/nitrite as electron acceptors instead of oxygen during the biological oxidation of soluble organic substrate released from the plants and woodchip media. In this way the inorganic nitrogen is biologically converted to nitrogen gas and released from the system, resulting in denitrified wastewater. In addition to providing some nitrate removal, plants in the VDWB provide an important role in cycling carbon through the treatment system and insulating against low temperature effects.

Figure A - 2 RSF w/ Vegetated Denitrifying Woodchip Bed (RSF w/ VDWB)



System 3

An **enhanced recirculating gravel filter (RGF)** with passive alkalinity addition and upflow bottom denitrification zone.

Design

The System 3 design is similar to the System 1 design with the following changes/additions:

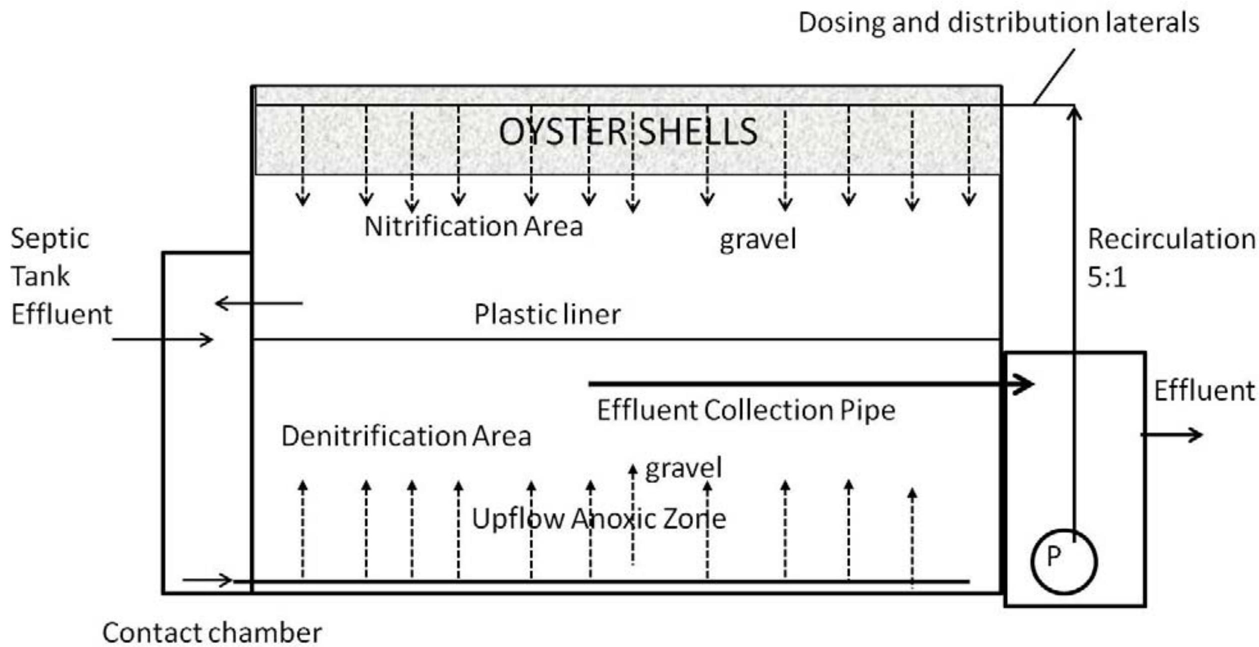
1. The feed from the recirculation tank to the aerobic upper portions is done through the feed distribution piping, which are contained inside gravelless chamber covers to provide for more uniform dispersion of the feed across the bed. The recirculation ratio is approximately 6.0 based on the average influent flow rate.
2. A 6 inch layer of oyster shells is located below the feed distribution piping.
3. Treated wastewater from the upper aerobic gravel filter section is collected in a bottom piping manifold that drains into a chamber across the inlet end of the filter. This same chamber receives septic tank effluent.
4. A series of underdrain collection pipes extend from the bottom anoxic gravel filter bed to the septic tank effluent chamber to receive the septic effluent and recirculation flow.
5. Flow from the bottom section underdrain piping travels up through the bottom anoxic zone where it enters a 4-6 inch layer of larger gravel for horizontal flow to the anoxic zone outlet.
6. At the discharge end of the large-gravel media depth above the upflow denitrification zone a collection pipe collects the anoxic zone effluent for discharge into the recirculation tank.

Treatment Theory

As in System 1 nitrification occurs in the upper portion of the RGF due to oxygen supply from the intermittent feed/drain cycles. Denitrification with nitrate/nitrite conversion to nitrogen gas also occurs in the bottom upflow anoxic zone due to the biological oxidation of organic substances in the septic tank effluent using nitrate/nitrite for electron acceptors. The features of System 3 that provide enhanced treatment are 1) alkalinity addition is provided by the oyster shells, 2) a higher recirculation ratio should result in a lower effluent nitrate/nitrite concentration, 3) Upflow denitrification beds may offer greater nitrogen removal efficiency than horizontal flow beds (WERF, 2010), and 4) the septic tank effluent feed to the anoxic zone is applied over a much larger surface area for the upflow denitrification filter compared to that for the horizontal flow denitrification filter, which should minimize solids clogging problems and maintenance over the long run.

The addition of alkalinity can help sustain a more favorable pH for biological nitrification and thus result in a higher nitrification efficiency and enhanced nitrogen removal. Many potable water sources in Western Washington have low alkalinity, which would therefore result in a lower alkalinity concentration in the wastewater and septic tank effluents. The biological nitrification process produces acid which consumes alkalinity and can result in pH values below 6.8 for low alkalinity wastewaters, which results in slower nitrification rates.

Figure A - 3 RSF Enhanced Recirculating Gravel Filter (RGF)



Septic Tank Size

Each septic tank for the ETV testing is a two-chamber 1,250 gallon tank. The first chamber volume is approximately 846 gal and the second chamber is approximately 411 gal. An effluent filter is placed in the outlet of the second chamber in each septic tank.

Technology Capacity

For normal household wastewater strength, each test unit has a design rated treatment capacity of 480 gallons per day.

Technology Capability

For normal residential wastewater strength, the expected effluent quality is $CBOD_5$ < 10 mg/L, TSS <10 mg/L, and total nitrogen >75% removal.