



Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task B.5

Quality Assurance Project Plan

Final Report

October 2010

44237.001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with



AET
Applied Environmental Technology

**OTIS
ENVIRONMENTAL
CONSULTANTS, LLC**

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.5 FINAL REPORT

Task B Field Testing Quality Assurance Project Plan

Prepared for:

Florida Department of Health
Division of Environmental Health
Bureau of Onsite Sewage Programs
4042 Bald Cypress Way Bin #A-08
Tallahassee, FL 32399-1713

FDOH Contract CORCL

October 2010

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

AET
Applied Environmental Technology



Table of Contents

Section 1.0	Introduction	1-1
1.1	Project Background.....	1-1
1.2	Project Scope and Purpose	1-1
1.3	Project Organization	1-2
1.4	Key Project Personnel and Responsibilities	1-3
Section 2.0	Task B Description.....	2-1
2.1	Activities Prior to Installation	2-3
2.1.1	Site Identification and Selection.....	2-3
2.1.2	Technology Identification and Selection	2-4
2.1.3	Homeowner Agreement.....	2-6
2.1.4	Technology Vendor Agreement	2-6
2.1.5	FDoH Notification.....	2-6
2.2	Technology Procurement.....	2-6
2.3	Installation at Residential Field Sites	2-7
2.3.1	Site Preparation	2-7
2.3.2	Technology Delivery and Installation	2-7
2.3.3	Verification of Operation	2-7
2.4	Operation and Monitoring	2-7
2.4.1	Flow and Volume	2-9
2.4.2	Energy, Chemicals and/or Additives Consumption.....	2-9
2.4.3	Chemical and Microbiological Analyses	2-9
2.4.4	Routine and Non-routine Maintenance	2-11

O:\44237-001R011\Wpdocs\Report\ Final

2.5	Performance Assessment.....	2-11
2.5.1	Flow and Volume	2-12
2.5.2	Energy, Chemicals and/or Additives Consumption.....	2-12
2.5.3	Chemical and Microbiological Performance ...	2-12
2.5.4	Routine and Non-routine Maintenance	2-12
2.6	Contingency Measures	2-12
Section 3.0	Quality Assurance and Quality Control.....	3-1
3.1	Data Quality Objectives (DQOs)	3-1
3.2	Field Activities	3-2
3.2.1	Sample Methods.....	3-2
3.2.1.1	Sample Collection	3-2
3.2.1.2	Sample Handling and Custody.....	3-4
3.2.1.3	Sample Analysis.....	3-5
3.2.1.4	QC Samples.....	3-10
3.2.2	Field Testing	3-12
3.3	Laboratory Activities.....	3-13
3.4	Documentation, Assessment, and Reporting.....	3-14
3.4.1	Documentation.....	3-14
3.4.2	Data Assessment.....	3-16
3.4.2.1	Precision	3-17
3.4.2.2	Accuracy	3-17
3.4.2.3	Representativeness	3-18
3.4.2.4	Comparability	3-18
3.4.2.5	Completeness	3-18
3.4.2.6	Validation	3-19

3.4.3	Reporting	3-19
3.5	QA Surveillance	3-20
Section 4.0	Health and Safety	4-1
4.1	Hazard Assessment.....	4-1
4.2	Personal Protection Requirements	4-5
4.3	Emergency Response.....	4-6
Section 5.0	References	5-1
Appendix A	Activity Hazard Analysis	A-1

List of Tables

Table 2.1	Technology Evaluation Process at Residential Field Sites.....	2-2
Table 2.2	Technologies Recommended for Testing in Task B	2-4
Table 2.3	General Monitoring Framework	2-8
Table 2.4	Chemical and Microbiological Parameters	2-10
Table 3.1	List of FDEP SOPs for Task B.....	3-2
Table 3.2	Task B Measurements.....	3-3
Table 3.3	Sample Analyses Methods	3-7
Table 3.4	Sample Analyses Requirements.....	3-8
Table 3.5	QA/QC Targets	3-9
Table 3.6	Total Monitoring Analyses for System Types	3-10
Table 3.7	Summary of QC Samples Collected and Analyses Conducted	3-12
Table 3.8	Duplicate Analyses	3-12
Table 4.1	Microorganisms Found in STE and Untreated Wastewater	4-2
Table 4.2	Pathogenic Microorganisms Found in STE and Untreated Wastewater.....	4-3

List of Figures

Figure 1-1	Task B Organization Chart	1-4
------------	---------------------------------	-----



Section 1.0

Introduction

1.1 Project Background

Nitrogen is an important concern for water quality and nitrate-nitrogen represents perhaps the most common groundwater pollutant. Animals, crops, ecosystems, and human health can be adversely impacted by the presence of nitrogen in water supplies. The environmental effects of nitrogen on groundwater and surface water can ultimately lead to the degradation of surface waters in watershed systems that have strong groundwater/surface water interactions. Nitrogen that enters surface water bodies via these interactions can lead to algal blooms and eutrophication. These processes lead to oxygen depletion in surface waters which can be harmful to natural aquatic life. In Florida, the protection of watersheds, in particular surface water bodies, has led to the legislation of protection of these areas (i.e., the Wekiva River Protection Act).

The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Project is implementing a multi-pronged approach to address nitrogen loading to the Florida environment from onsite sewage treatment and disposal systems (OSTDS). A central component of the FOSNRS project is the experimental evaluation of onsite wastewater nitrogen reduction technologies at field and home sites. A goal of the FOSNRS project is to evaluate technologies that are appropriate for onsite deployment and which achieve a high degree of nitrogen reduction. The classifications of onsite technologies that will be evaluated in Task B have been identified and prioritized in FOSNRS Tasks A.1 through A.9 and include two stage biofiltration using solid phase electron donor media for denitrification, addition of denitrification biofilters to existing aerobic nitrifying systems, and in situ vertical flow biofilters (Hazen and Sawyer, 2009a, 2009b, 2009c, 2009d). Technologies to be evaluated include passive two stage nitrogen reduction systems initially evaluated at bench-scale in the Florida Passive Nitrogen Removal Study (Smith, 2009; Smith, 2008a; Smith, 2008b; Smith et al., 2008).

1.2 Project Scope and Purpose

The overall goal of Task B is to perform field experiments under full scale actual operating conditions to critically assess nitrogen reduction technologies that have been identified in FOSNRS Task A.9. To accomplish this goal several objectives are identified:

O:\44237-001R005\Wpdocs\Report\Final

1. Identify homeowner test sites and establish homeowner agreements,
2. Identify specific technology vendors and establish vendor agreements,
3. Install technologies at test sites and document installation issues,
4. Document installation costs of technologies,
5. Monitor performance of treatment systems for nitrogen and other water quality parameters and assess performance,
6. Monitor the energy used and other operational costs associated with system operation,
7. Monitor routine and non-routine maintenance costs to support life cycle economic analysis, and
8. Site closure.

To meet these objectives a combination of field testing and monitoring is planned at various residential field sites. Field sites will be selected from regions in north Florida, the Wekiva area, and in other locations on the Florida peninsula. Monitoring at each site will include influent, effluent, and intermediate treatment locations where possible or applicable. The data sets generated will enable quantification of hydraulic, organic, and nitrogen loading rates; average influent and effluent concentrations; removal efficiencies for nitrogen and other parameters; and effluent nitrogen concentrations achieved. Documentation of installation, operation, and maintenance costs will enable comparative life cycle cost estimates to be made. The project approach is described in detail in Section 2.0. Execution of homeowner agreements will initiate in calendar year (CY) 2010 and will continue through CY 2011. Vendor agreements will be pursued in CY 10 through CY 11 and system installation will follow thereafter.

1.3 Project Organization

Task B is comprised of several interrelated subtasks that fall within six primary categories:

- 1) Selection of field test sites and technologies,
- 2) Agreements with homeowners and vendors,
- 3) Installation and operational verification,

- 4) Field monitoring and laboratory analyses,
- 5) Performance assessment and reporting, and
- 6) Site closure.

FOSNRS Tasks B.1 and B.2 of the contract entail establishment of test sites and vendor technology agreements. This Quality Assurance Project Plan (QAPP) under Task B.3 describes the proposed testing and monitoring framework for onsite technologies. While the work described in this QAPP encompasses the entire scope of the FOSNRS project, funding for the entire project has not been totally established. However, the general procedures described in this QAPP will be followed at all field sites. The project work scope is described in Section 2. The methods of data collection and handling to ensure the data quality objectives are met are described in Section 3. Finally, health and safety precautions required during project activities are described in Section 4.

1.4 Key Project Personnel and Responsibilities

A Task B organization chart is shown in Figure 1.1. Mr. Damann Anderson of Hazen and Sawyer is the FOSNRS Manager responsible for project management and oversight. Dr. Daniel P. Smith of Applied Environmental Technology is responsible for scientific and technical oversight. Mr. Anderson and Dr. Smith are co-principal investigators for the overall project. Dr. Smith is the Task B leader responsible for overall Task B operations and activities. The Task B leader is also responsible for ensuring that this project plan is completed and the data quality objectives (DQOs) are met.

Personnel from Hazen and Sawyer and other subcontractors will be responsible for conducting field activities and monitoring. For each field site, a field team leader from Hazen and Sawyer or other subcontractor will be identified and will be responsible for providing daily coordination of field activities, for interfacing with other subcontractors, and for interfacing with the Task B leader. Field personnel involved in onsite operations are responsible for notifying the field team leader of any nonconforming field events or problems and ensuring that all co-workers are aware of such problems. Field personnel are to perform only those tasks that they can do safely and immediately report any accidents and/or unsafe conditions to the field leader and/or Task leader. Field personnel include all individuals performing field tasks and will demonstrate the experience and/or ability to perform the assigned tasks. Equipment operators (e.g., drillers, backhoe operator, etc.) shall be able to verify training and experience for the required capabilities.

Prior to initiating field work, all field personnel will be required to attend a brief site orientation given by the field team leader that will cover the description of work to be performed (task orientation), standard operating procedures (SOPs), QA/QC measures, and

safe work practices. In addition, periodic “tailgate” meetings will be held to discuss potential concerns and refresh personnel on work tasks, QA/QC measures, and safe work practices. These field meetings will be documented in the field team leader’s logbook.

All project personnel are responsible for taking all reasonable precautions to prevent injury to themselves and to their fellow employees. The qualifications for key Task B personnel were provided in the proposal (Mr. Anderson, Dr. Smith, and Mr. Harmon Harden).

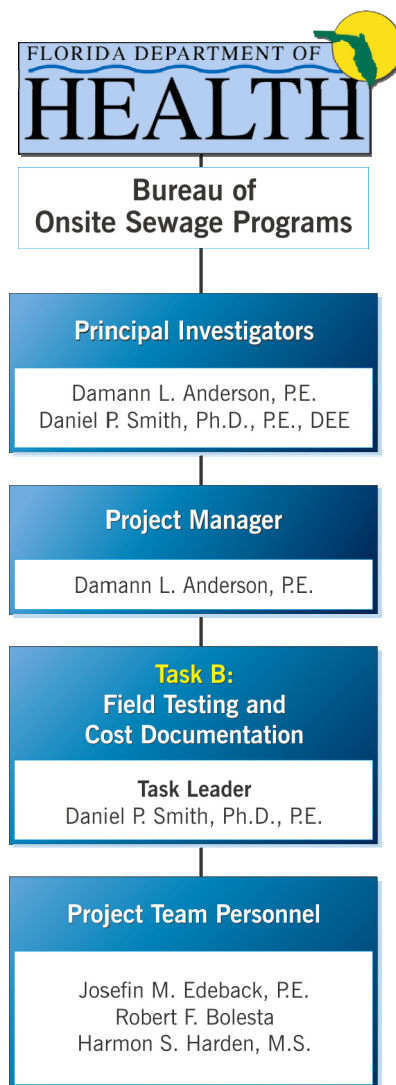


Figure 1-1: Task B Organization Chart



Section 2.0

Task B Description

Field testing will be conducted at residential sites established in various Florida locations. The number of individual installations implemented over the entire project is contingent on the total funding ultimately available. The testing of individual technologies will each be conducted using a general set of activities that are described in this Section. An overview of the technology evaluation process is presented in Table 2.1. The following sections describe the approaches to be taken in implementing the technology evaluation process.

O:\44237-001R011\Wpdocs\Report\ Final

Table 2.1
Technology Evaluation Process at Residential Field Sites

General Activity	Action	Approach/Activities	Product
Activities Prior to Installation			
1	Identify residential field sites	Availability of sites with homeowners amenable to testing; pre-existing technologies; sensitive sites; geographic distribution; site access; power supply	Establish homeowner agreement
2	Identify specific technology vendors	Task A.9 Technology Prioritization List for Testing; vendor contacts	Establish vendor agreement
3	FDOH notification	Summarize site, technology	Memo to FDOH
Technology Procurement			
4	Procure technology	Vendor contract purchase, component purchase orders, or donation	Purchased, donated or fabricated technology
Installation at Residential Sites			
5	Install technologies at field sites	Site preparation; vendor installation procedures; design of new technologies; site specific features; verify operation; document costs	Documentation of issues with installation and operational verification, costs
Operation and Monitoring			
6	Monitor performance of treatment systems for nitrogen and other water quality parameters	Twelve month or greater period of operation; water quality flowrate or volume; sample influent and final effluent ; sample intermediate treatment steps where applicable; monitor nitrogen species, physical and chemical parameters	Comprehensive datasets
7	Monitor operational costs of system operation	Electrical meter, chemical/additive use, routine operational checks	Documentation of operational costs under actual conditions
8	Track routine and non-routine maintenance	Record keeping of all routine and non-routine operation and maintenance issues	Operation and maintenance under actual field conditions

O:\44237-001R011\Wpdocs\Report\ Final

Table 2.1 (con't)
Technology Evaluation Process at Residential Field Sites

General Activity	Action	Approach/Activities	Product
Performance Assessment			
9	Removal efficiencies; effluent concentrations achieved; water quality parameters	Spreadsheet based data management system; data analysis.	Performance assessment under actual field conditions
Site Closure			
10	Site closure	Provide homeowner with operating instructions or remove technology	Closure agreement; transfer of technology to homeowner or removal

2.1 Activities Prior to Installation

Activities prior to installation include site identification and selection, technology identification and selection, completion of agreements with homeowner and vendor, and notification to FDOH.

2.1.1 Site Identification and Selection

The project team will identify residential field sites that will enable the objectives of Task B to be achieved. Site features to be evaluated include general geographic location, availability of a pool of homeowners who are amenable to testing, site access, pre-existing technologies at site, and energy availability. Practical considerations favor several groups of sites, with individual homeowner sites in each group located in relatively proximate locations. It is anticipated that sites will be identified in the following locations: North Florida (Wakulla County), Central Florida (Wekiva Study Area, Hillsborough County and environs), and South Florida areas (e.g. Lee County). Selection of homeowner sites will be guided by the desire to give preference to evaluating passive type nitrogen reduction systems as per the previous technology prioritization that was conducted and which is summarized in the following Section 2.2.1 (Hazen & Sawyer, 2009c). It is also intended, as a lower priority, to locate sites with pre-existing treatment technologies to which denitrification filters could be added to increase total nitrogen re-

duction (Hazen & Sawyer, 2009c). In this case, Task B monitoring would be conducted for the entire treatment system including the pre-existing technology.

2.1.2 Technology Identification and Selection

Technology identification will be guided by the recommendations presented in the previous Task A.9 report (Hazen & Sawyer, 2009c) and summarized in Table 2.2. The list of technologies recommended for testing is based on the ranking of technologies that was conducted in Task A.9. However, the actual number and order of system deployments may differ from Table 2.2 due to availability of funding, suitable test sites with amenable homeowners, geographical location of sites, vendor agreements, and readiness of technology. Passive two stage biofiltration systems and in-situ vertical flow systems containing denitrification media are currently being evaluated in PNRS II (Hazen & Sawyer, 2009d). Evaluation of these systems at field sites will be initiated based on PNRS II test results.

Table 2.2
Technologies Recommended for Testing in Task B (from Hazen & Sawyer, 2009c)

System	Technology	Comment
1	Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) Stage 2: Autotrophic denitrification with reactive media biofilter	<ul style="list-style-type: none"> • Top ranked system capable of meeting the lowest TN concentration standard • Suitable for new systems or retrofit
2	Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) Stage 2: Heterotrophic denitrification with reactive media biofilter	<ul style="list-style-type: none"> • Top ranked system capable of meeting the lowest TN concentration standard • Suitable for new systems or retrofit
3	Natural system: Septic tank/Drainfield with in-situ reactive media layer	<ul style="list-style-type: none"> • Lower cost natural system that is untested but appears capable of achieving 75-78% TN removal before reaching groundwater • Suitable for new systems or replacing existing systems at end of useful life
4	Natural system: Primary or secondary effluent with drip dispersal	<ul style="list-style-type: none"> • Suitable for reducing TN impacts on groundwater through enhanced TN removal and reduced TN loading on soil • Suitable for new systems or retrofit

Table 2.2 (con't)
Technologies Recommended for Testing in Task B (from Hazen & Sawyer, 2009c)

System	Technology	Comment
5	Mixed biomass fixed film system with recycle followed by heterotrophic denitrification with reactive media biofilter	<ul style="list-style-type: none"> • High performance aerobic treatment with anoxia for enhanced TN removal followed by second stage heterotrophic denitrification for high nitrogen removal • Suitable for new systems or nitrogen reduction upgrades
6	Mixed biomass fixed film system with recycle followed by an autotrophic denitrification with reactive media biofilter	<ul style="list-style-type: none"> • High performance aerobic treatment with anoxia for enhanced TN removal followed by second stage autotrophic denitrification for meeting low TN concentration standard • Suitable for new systems or nitrogen reduction upgrades
7	Mixed biomass integrated fixed film activated sludge system: Suspended growth with recycle	<ul style="list-style-type: none"> • High performance aerobic treatment • Suitable for new systems or nitrogen reduction upgrades
8	Mixed biomass integrated fixed film activated sludge system: Moving bed bioreactor	<ul style="list-style-type: none"> • High performance aerobic treatment with simultaneous denitrification • Suitable for new systems or nitrogen reduction upgrades
9	Mixed biomass suspended growth system: Suspended growth sequencing batch reactor	<ul style="list-style-type: none"> • Aerobic treatment • Suitable for new systems or nitrogen reduction upgrades
10	Membrane process system: Membrane bioreactor (MBR)	<ul style="list-style-type: none"> • Suitable for new systems or nitrogen reduction upgrades
11	Source separation system: Dry toilet (evaporative or composting)	<ul style="list-style-type: none"> • Eliminates liquid disposal of wastes
12	Source separation system: Urine separating (recovery) toilet	<ul style="list-style-type: none"> • Innovative system that is capable of removing 70-80% of the household TN at little capital cost • Provides potential for sustainable recovery of nutrients

2.1.3 Homeowner Agreement

For each test site, a homeowner agreement will be finalized that specifies the terms and conditions under which site testing will be performed. The project team will relay to the homeowner the type of technology, its physical and operational characteristics, and other pertinent features of the systems. The project will generally agree to pay for all expenses related to site preparation specific to the wastewater treatment system, for procurement of technology, installation, operation and maintenance during the study, energy, monitoring, permit fees, design and engineering fees, and maintenance entity fees if applicable. All project payments will terminate upon site closure. Homeowner requirements include site access and spatial needs during testing, non-tampering provisions, and understanding of site closure options.

2.1.4 Technology Vendor Agreement

For each vendor-supplied technology, a vendor agreement will be finalized that specifies the terms and conditions under which the technology will be procured, installed and tested. The vendor agreement must specify exactly what is provided by the vendor and what is not. Vendor will supply written cost estimate including delivery to the site. Vendor requirements include providing full description of technology and requirements for installation, operation and maintenance. Vendors may advise or inspect installation but will not be allowed to independently change or manipulate any aspect of technology once the testing has been initiated. Full or partial equipment donations by vendor will be subject to same rules and considerations as if the equipment were purchased on the open market.

2.1.5 FDOH Notification

FDOH will be notified of individual test site and technology combinations that have been chosen for testing by the project team.

2.2 Technology Procurement

Vendor supplied technology will be procured through purchase agreement as per 2.1.4, paid by project funds. For non-vendor systems, the project teams will purchase materials and components and fabricate technologies for deployment. Detailed cost records will be maintained to enable system cost estimates to be made.

2.3 Installation at Residential Field Sites

Installation activities include site preparation, technology delivery and installation, and verification of operation.

2.3.1 Site Preparation

Site preparation includes site work conducted prior to delivery of the technology to the site and may include providing access, clearing, excavating, leveling, and power supply.

2.3.2 Technology Delivery and Installation

The project team will provide personnel at the site to accept delivery of the technology. Installation will be conducted by licensed septic tank contractors according to vendor recommendations or according to installation requirements formulated by Task B co-PIs for the systems being tested in PNRS II or other non-vendor equipment.

2.3.3 Verification of Operation

Operational verification includes testing of all features pertinent to individual technologies, such as control panels, pumps, and blowers; testing of flow/volume and electrical meters, and, if necessary, manual verification of flows and volumes.

2.4 Operation and Monitoring

The general operating and monitoring schedule is shown in Table 2.3. Operation and monitoring includes monitoring of flowrate or volume treated; energy, chemical, or additives consumption; chemical and microbiological analyses; and routine and non-routine maintenance. The general operating and monitoring schedule is shown in Table 2.3.

Upflow and horizontal denitrification biofilters will have controlled submergence depths which will be maintained by the discharge elevation. Vertical stacked biofilters (In-situ simulators) will also have controlled submergence depths through u tube design. Saturated water levels will be assessed through field monitoring which will be dependent on the technology installed and the need to insure an operation that results in data sets.

Table 2.3
General Monitoring Framework

Task	Nominal Frequency¹	Actions	Product
Site Inspection	1 time/month	Visual inspection; ascertain operability; odors; read meters; examine drainfield observation ports	Completed inspection checklist; log entries; meter readings
Flow/volume	1 time/month	Record flow/volume meter; make spreadsheet entry	Updated flow/volume records; average daily volume calculation
Energy, chemical, or additives consumption	1 time/month	Record energy meter, chemical or additives use; make spreadsheet entry	Updated energy, chemical or additives records; average daily use and use per volume calculation
Routine maintenance by project personnel or maintenance entity	Per vendor recommendations or recommendations of project team	Perform routine maintenance actions	Maintenance log entries
Non-routine maintenance	As needed	Identify problem and perform non-routine maintenance actions	Maintenance log entries: documented cause of problem, action taken, cost of parts and labor
Chemical and microbiological monitoring	Maximum of 8 full monitoring events, minimum of 1 month between sampling events	Monitor chemical and microbiological parameters in influent, effluent and intermediate process points where applicable; make spreadsheet entries	Data set of chemical and microbiological parameters; log of removal efficiencies and effluent concentrations for total nitrogen, nitrogen species, and other water quality parameters

¹Frequency of monitoring tasks may be more frequent at start-up. Frequency will be dependent on technology and the need to insure an operation that results in data sets.

O:\44237-001R011\Wpdocs\Report\ Final

2.4.1 Flow and Volume

A flow/cumulative volume meter will be installed to measure flow to the treatment system. The meter will measure either influent flow to the treatment system or effluent flow from the treatment system. A raw sewage sampling device designed by CSM (Lowe et. al, 2009) will be employed to measure influent raw sewage volume to the septic tank if required.

2.4.2 Energy, Chemical and/or Additives Consumption

Energy consumption will be monitored using an electrical meter installed on the power line to provide cumulative kW-hour used for all energy requiring system components. Any chemical and/or additives use will be tracked by recording the volume or mass of these items supplied for system operation.

2.4.3 Chemical and Microbiological Analyses

The sample collection generally follows the approach that was initially implemented in PNRS I and is being continued in PNRS II. Where possible, monitoring will be based on collecting samples manually through in-line sampler pipes which extend vertically downwards from the effluent pipes and through which sample flows by gravity. Where necessary, samples will be collected using a peristaltic pump. Samples will be collected of the influent to the treatment system, which is onsite primary effluent, also known as septic tank effluent (STE). Influent for treatment technologies that do not utilize a septic tank will be sampled from the primary treatment zone of the unit or if necessary using a “Rotherator” device for influent to the septic tank. Effluent samples (i.e. final effluent) are collected from the final treatment system component (e.g. denitrification biofilter effluent in a two stage passive biofiltration process) and result in the final effluent quality for total nitrogen and individual nitrogen species. Intermediate sample collection can occur from one or more intermediate process points if they are amenable to sampling and enables the performance to be assessed for specific nitrogen species. For example, monitoring the effluent from an aerobic biological process before it enters a denitrification biofilter is used to assess nitrification performance and reduction in CBOD₅.

Chemical and microbiological parameters to be analyzed are listed in Table 2.4. The parameter list includes total kjeldahl nitrogen (TKN), ammonia nitrogen (NH₄⁺-N), and oxidized nitrogen (NO₃+NO₂)-N for delineation of nitrogen speciation; total and volatile suspended solids (TSS, VSS); bulk organic matter as five day carbonaceous oxygen demand (CBOD₅) and chemical oxygen demand (COD); total and orthophosphorus as macronutrient for biological processes; sulfate and hydrogen sulfide (H₂S) for technologies employing sulfur based biofiltration for denitrification; and fecal coliform (fc) and *E. Coli*

as microbiological indicators. Supporting inorganic parameters include temperature, pH, alkalinity, dissolved oxygen (DO), and oxidation reduction potential (ORP).

For multiple point monitoring, sample collection will generally be conducted starting with the downstream point and proceeding to the upstream point. This eliminates the effects of upstream sampling on downstream effluent quality. Liquid effluent samples will contact at most one intermediate sample collection bottle before being placed in pre-prepared sample bottles. Field parameters that employ probes may be used if possible by direct probe placement into locations within the process train as opposed to samples collected in external containers. Sample collection, handling and analyses methods will be in accordance with FDEP SOPs and are discussed in Section 3.0. Varied sample collection and additional sample analysis may be conducted for specific research purposes based on ongoing performance monitoring; these may entail additional analytes and/or instrumentation.

Table 2.4
Chemical and Microbiological Parameters

Systems	Sample points	Analytes
All systems	Influent, effluent, intermediate point(s) where applicable	Temperature
		pH
		DO
		ORP
		Alkalinity
		TKN
		NH ₄ ⁺ -N
		(NO ₃ +NO ₂)-N
		TSS
		VSS
		CBOD ₅
		COD
		Total phosphorus
		Orthophosphorus
		E. Coli
Sulfur denitrification biofilters	Influent and effluent	Fecal Coliform
		Sulfate
		H ₂ S

O:\44237-001R011\Wpdocs\Report\ Final

2.4.4 Routine and Non-routine Maintenance

Full documentation will be maintained of routine and non-routine maintenance activities under the actual operating conditions. Routine maintenance refers to scheduled activities that are recommended by the vendor or by the project team for non-vendor systems. Non-routine maintenance relates to equipment breakdowns and malfunctions requiring operator attention.

2.5 Performance Assessment

The performance assessment will be enabled by the acquisition of sufficient data to determine:

- flowrates or cumulative volumes treated;
- concentration of nitrogen species in influent, effluent, and intermediate process points where applicable;
- nitrogen removal efficiencies;
- concentrations of other organic and inorganic water quality parameters in influent, effluent, and intermediate process points where applicable;
- pH, alkalinity, and dissolved oxygen in influent, effluent, and intermediate process points where applicable, and changes of these parameters that occur from influent to effluent of treatment components;
- energy, chemical, and/or additives consumption under actual application conditions; and
- routine and non-routine operational and maintenance requirements.

Successful completion of the monitoring program will provide data sets for each biofilter under the selected design and operation. The datasets will include influent and effluent concentrations of total nitrogen and individual nitrogen species, and the datasets will be used to determine the nitrogen removal efficiencies of individual biofilters and of linked biofilter systems. The data will permit an evaluation of how the treatment technologies perform under given hydraulic and nitrogen loading rates and provide an understanding of the efficacy of nitrogen processing of individual treatment components in multi-step treatment systems. Monitoring of energy, consumables, and maintenance requirements will enable the project team to provide life cycle cost estimates for each system (including costs not related to installation).

Members of the field team will, as a normal part of their daily responsibilities, monitor ongoing work performance by themselves (self assessment) and other project personnel. All project personnel will promptly identify, report, and solicit approved corrections

for conditions adverse to quality. All findings and actions concerning equipment problems and nonconformance problems will be documented in field or office logbooks.

2.5.1 Flow and Volume

Flow and/or volume data will be used to estimate average daily volumes, ranges, and variability; hydraulic loading rates; and retention times in treatment systems. These operating features will provide correlative aspects for assessment of nitrogen reduction performance.

2.5.2 Energy, Chemical and/or Additives Consumption

Energy, chemical, and/or additives consumption under actual operating conditions will be used to estimate average consumption and consumption per volume treated. These estimates will be used in life cycle cost estimates for the technology that include both the cost of installation as well as the continuing operational costs that are needed to maintain effective performance.

2.5.3 Chemical and Microbiological Performance

Chemical and microbiological results will be used to assess performance. The concentration of nitrogen species in influent, effluent, and intermediate process points will be used to assess nitrogen removal efficiencies. Other organic and inorganic water quality parameters will also be used to facilitate evaluation of the nitrification and denitrification processes that are occurring.

2.5.4 Routine and Non-routine Maintenance

Documented maintenance requirements for the technology at the residential field sites will be used to develop system maintenance costs. System maintenance costs will be input into life cycle cost estimates that include all costs of system deployment, including initial installation and all recurring and non-routine costs that are needed to maintain effective performance.

2.6 Contingency Measures

An adaptive management strategy will be employed throughout Task B 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 goals of Task B. The technologies to be tested at residential field sites will be generally well understood and characterized prior to in-

stallation. Therefore, the evaluation of technologies at these sites 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 flowrates; modifications of dosing distribution systems to unsaturated biofilter 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 then be implemented only if judged to be advantageous to the overall testing objectives.

During Task B, 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 3.3.

Equipment problems or nonconformance problems should be reported to the Hazen and Sawyer project manager. The field team will then document the condition, its cause, any other related information, and the proposed corrective action. The field team will implement the corrective actions and document them in the field logbook. If appropriate, the field team will ensure that no additional work that is dependent on the nonconforming activity is performed until the corrective actions are completed.

Examples of corrective actions for field measurements include:

- 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.

Section 3.0

Quality Assurance and Quality Control

3.1 Data Quality Objectives (DQOs)

The general quality assurance (QA) objective for Task B is to ensure that the field data collected are of known and acceptable quality. When available, FDEP SOPs will be used for conducting field sampling to ensure that representative data will be collected. Specific Data Quality Objectives (DQOs) for Task B are to:

- ensure that the overall sample collection, preservation, analyses, and data reporting are correct and sufficient to meet Task B objectives;
- characterize the septic tank effluent quality at residential field sites to confirm that it is representative of typical household effluents from Florida residences (Lowe et al., 2009; Lowe et al., 2007);
- provide a systems check by verifying that the expected biochemical reactions are occurring in treatment units, and identify unforeseen operational conditions; and
- produce quality data sets of influent, effluent and intermediate monitoring point water quality that enable critical evaluation of process effectiveness for removal of nitrogen and other constituents.

Of key importance is to define the removal efficiency of total nitrogen; measure concentrations of individual nitrogen species in process effluents; measure effluent levels of biodegradable organics (CBOD₅); and to measure levels of water quality parameters that are indicative of favorable environments for nitrogen transforming biochemical reactions and that change as a result of those bioreactions (i.e. pH, alkalinity, dissolved oxygen, oxidation reduction potential). This data will enable critical performance evaluation of the treatment technologies under the regimes in which they are operated.

Data quality indicators will be used to collectively define the quality of the submitted data. These indicators include both qualitative and the quantitative quality control (QC) measures. Task B activities that affect data quality include the sampling methodology, laboratory analyses, and data analyses. The specific methods and quantitative data QA measures (e.g., accuracy, precision, completeness and detection limit) are described in the following sections. In addition, specific qualitative control measures to be used in

both the field and laboratory are described (e.g., data type, frequency of use, handling of failed QC measures).

3.2. Field Activities

The Task B sampling framework and methodology were described in Section 2. The following descriptions pertain to the field methods to be used. Laboratory activities are described in Section 3.3.

3.2.1 Sample Methods

To preserve the sample integrity, proper sample handling procedures will be employed from the time of sample collection in the field through sample analysis. Table 3.1 lists the FDEP SOPs that are pertinent to Task B. The SOPs will be used by field personnel performing field work for the project.

Table 3.1
List of FDEP SOPs for Task B

SOP	Description
FC 1000	Cleaning / Decontamination Procedures
FD 1000	Documentation Procedures
FQ 1000	Field Quality Control Requirements
FS 1000	General Sampling Procedures
FS 2400	Wastewater Sampling
FT 1000	General Field Testing and Measurement
FT 1100	Field Measurement of pH
FT 1200	Field Measurement of Specific Conductance
FT 1400	Field Measurement of Temperature
FT 1500	Field Measurement of Dissolved Oxygen
FT 1900	Field Continuous Monitoring

3.2.1.1 Sample Collection

As described in Section 2, several different types of samples will be collected in Task B. The monitoring program consists primarily of manually collected samples of treatment system influent (primary effluent, or septic tank effluent), final system effluent, and samples from intermediate process points (Section 2.4.3). Routine monitoring will include several field measurements including temperature, pH, dissolved oxygen (DO), and oxidation-reduction potential (ORP). Sampling methods will be in accordance with FDEP-SOPs (FS 1000). The sample collection frequency and analytes are described below

and are summarized in Table 3.2. Associated QC samples are summarized in Section 3.2.1.4.

Table 3.2
Task B Measurements

Sample frequency	Systems	Sample points	Analytes
One event per two months, maximum of eight full monitoring events	All systems	Influent, final effluent, intermediate point(s) where applicable ¹	Temperature
			pH
			DO
			ORP
			Alkalinity
			TKN
			NH ₄ ⁺ -N
			(NO ₃ +NO ₂)-N
			TSS
			VSS
			CBOD ₅
			COD
			Total phosphorus
			Orthophosphorus
			E. Coli
			Fecal Coliform
	Sulfur denitrification biofilters	Influent and effluent	Sulfate
			H ₂ S

¹ Intermediate monitoring points will be established based on technology and sampling access

Samples of influent (primary effluent), system final effluent, and intermediate wastewater will be collected in accordance with FS 2400, Wastewater Sampling. The exact sample locations are system dependent and will be established at the time that individual systems are installed. Gravity collection from in line ports will be used where possible and will provide whole effluent collection for a limited time period. Peristaltic pumps will be used as a second option if necessary. Samples will be collected into a single sample container, immediately subdivided into prepared sample storage and preservation containers for different analytes, and placed in a cooler in wet ice. All non-dedicated sampling equipment will be decontaminated (soap wash, triple DI rinse, and acid wash as required) between sampling locations in accordance with FDEP-SOPs (FC 1000) by a NELAC certified analytical laboratory.

3.2.1.2 Sample Handling and Custody

Sample handling procedures include the use of correct sample containers, labeling, documentation, preservation, and transport. Sample bottles will be precleaned and provided by a NELAC certified laboratory; certificates of cleanliness will be maintained in the project file. The bottles will be stored in a secured area to maintain integrity. Preservatives will consist of reagent grade chemicals and will be placed in the bottles prior to sample collection. Selection of sample containers is governed by sample type and size and the required analyses. Each sample aliquot will be labeled with the site ID, sample ID, date, time, and sampler initials and logged into laboratory notebooks. Duplicate samples will be designated with a "D" or "dup" after the last character of the sample designation. Equipment rinsates will be designated with an "ER" after the last character of the last sample collected prior to the equipment rinsate. Field blanks will be numbered consecutively.

Due diligence will be exercised to minimize the time between sample collection at the site and transport to the laboratory for analysis. After the samples have been collected, labeled and preserved, the samples will be placed in a cooler and transported in wet ice to a NELAC certified laboratory for analyses. Sample containers will be secured in packing material as appropriate to prevent damage and spills. Sample delivery will be conducted on a daily basis corresponding to executed sampling event.

A sample will be considered under custody if it is in:

- actual possession of a member of the sampling crew,
- in view of the sampling crew (constituting actual possession by the crew), or
- in actual possession of the sampling crew and locked in a secured area or vehicle in a manner such as to prevent tampering.

Chain of custody forms will be provided by the NELAC certified laboratory and used to document the transfer of samples from field personnel to the certified analytical laboratory. One chain of custody form will be filled out for each set of samples and placed inside the cooler.

The chain of custody form will list the following:

- regional location,

- sampler(s),
- sample identification,
- sample type,
- date and time of collection,
- analyses requested,
- preservative (if applicable),
- signature and date, and
- remarks.

Sample custody for samples received by the analytical laboratory will be performed according to the laboratory procedures. The analytical laboratory will be in compliance with the FDOH Environmental Laboratory Certification Program (ELCP) and ensure that all samples are properly stored, handled, and analyzed within the required holding time (see Section 3.3). The laboratory will be notified of upcoming field sampling activities and the subsequent transfer of samples to the laboratory. This notification will include information concerning the number and type of samples to be shipped, as well as the anticipated date of arrival.

3.2.1.3 Sample Analysis

Tables 3.3 and 3.4 list the analytical methods, target analytes, sample containers, preservatives, and holding times for samples of influent, system effluent and intermediate process points. Constituents of interest will be analyzed following standard methods as described in Table 3.3 (FDEP, 2008; APHA, 2005). Laboratory analysis of the samples shall be performed within the appropriate holding times as specified in individual analysis methods (Table 3.4). Accuracy and precision targets for analytical parameters are listed in Table 3.5. An analytical template showing the total number of samples to be analyzed at a single test site is summarized in Table 3.6 for four system cases: systems with and without an intermediate monitoring point, and systems with and without sulfur based denitrification. For all systems, system influent and final effluent will be measured.

For microbial analyses (*E. coli* and fecal coliforms), sample aliquots will be collected, placed into sterilized containers, and immediately placed on ice for microbial analyses. Both fecal coliforms and *E. coli* will be enumerated using either a modified version of the enzyme substrate test (APHA Method 9223B, modified by incubation at 45°C), or alternatively the membrane filtration (MF) technique (APHA 2005, Method 9222D). In the modified enzyme substrate test, samples are diluted and added to a chromogenic and fluorogenic substrate and the mixture is incubated at 45°C for 24 hours. The concentra-

tions of both fecal coliforms and *E. coli* are provided through a most probable number result based on the substrate color change or UV fluorescence. The incubation temperature in the modified enzyme substrate test is 45°C versus the manufacturer's recommendation of 35°C. The higher incubation temperature enumerates only fecal coliforms rather than total coliforms. Several groups have shown that the modified enzyme substrate test results in similar fecal coliform counts when compared to the membrane filtration method (Yakub *et al.*, 2002; Chihara *et al.*, 2005). Studies have shown that sample holding times of up to 24 hours have little impact on bacterial counts or coliphage numbers (Van Cuyk, 2003; Selvakumar *et al.*, 2004). Although effort will be made to minimize the time between sample collection and analyses, sample holding times of up to 24 hour may result.

Table 3.3
Sample Analyses Methods

Parameter	Detection Limits ¹	Method
Flow	Manufacturer Specification	Water meter
Temperature	0.1 °C	DEP FT1400
pH	0.1	DEP FT1100
DO	0.1 mg-DO/L	DEP FT1500
ORP	25mV	Electrode - (APHA method 2580B)
Alkalinity	2.0 mg-CaCO ₃ /L	Titration - (APHA method 2320B)
TKN	0.05 mg-N/L	U.S. EPA 351.2
Ammonia nitrogen	0.01 mg-N/L	U.S. EPA 350.1
NO _x -nitrogen (nitrate + nitrite)	0.01 mg-N/L (nitrate)	U.S. EPA 300.0
TSS (non-filterable residue)	1.0 mg/L	Gravimetrically, dried at 103–105°C - (APHA methods 2540D)
VSS (volatile non-filterable residue)	1.0 mg/L	U.S. EPA 160.4
CBOD ₅	2.0 mg/L	Carbonaceous 5-day test - (APHA method 5210B)
COD	10.0 mg/L	U.S. EPA 410.4
Total phosphorus	0.01 mg-P/L	Nitric acid-sulfuric acid method - (APHA method 4500-P)
Orthophosphorus	0.01 mg-P/L	U.S. EPA 300.0
Fecal coliform	1Ct/100mL	APHA method 9222D
<i>E. coli</i>	2Ct/100mL	APHA method 9223B
Sulfate	0.2 mg/L	U.S. EPA 300.0
H ₂ S	0.01 mg/L	APHA method 4500 SF

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.

Table 3.4
Sample Analyses Requirements¹

Parameter	Minimum Volume (mL)	Container Requirements	Preservative and Holding Time
Flow	NA	NA	NA
Temperature	20	Pre-cleaned plastic or glass	None, analyze immediately
pH	20	Pre-cleaned plastic or glass	None, analyze immediately
DO	20	Pre-cleaned plastic or glass	None, analyze immediately
ORP	20	Pre-cleaned plastic or glass	None, analyze immediately
Alkalinity, total	20	Pre-cleaned plastic or glass	<6°C, 14 days
TKN	100	Pre-cleaned plastic or glass	H ₂ SO ₄ to pH <2, 28 days
Ammonia-nitrogen	25	Pre-cleaned plastic or glass	H ₂ SO ₄ to pH <2, 28 days
NO _x -nitrogen (nitrate + nitrite)	50	Pre-cleaned plastic or glass	<6°C, H ₂ SO ₄ to pH <2, 28 days
TSS (non-filterable residue)	300	Pre-cleaned plastic or glass	<6°C, 7 days
VSS (volatile non-filterable residue)	300	Pre-cleaned plastic or glass	<6°C, 7 days
CBOD ₅	1000	Pre-cleaned plastic or glass	<6°C, 48 hours
COD	50	Pre-cleaned glass	<6°C, H ₂ SO ₄ to pH <2, 28 days
Total phosphorus	50	Pre-cleaned plastic or glass	<6°C, H ₂ SO ₄ to pH <2, 28 days
Orthophosphorus	25	Pre-cleaned plastic or glass	<6°C, 48 hours
Fecal coliform	100	Sterile plastic or glass	<6°C, 24 hours
<i>E. coli</i>	100	Sterile plastic or glass	<6°C, 24 hours
Sulfate	10	Pre-cleaned plastic or glass	<6°C, 28 days
H ₂ S	500	Pre-cleaned plastic or glass	NaOH + Zn Acetate, 7 days

¹ Requirements are consistent with: FDEP-SOP-001/01, General Sampling Procedures; APHA 2005, Standard Methods; and U.S. EPA Test Methods.

Table 3.5
QA/QC Targets

Analyte	Precision (%)	Accuracy (%)
Temperature	NA	NA
pH	1	95-105
DO	10	90-110
ORP	20	90-110
Alkalinity	26	80-120
TKN	10	90-110
NH ₄ ⁺ -N	10	90-110
(NO ₃ +NO ₂)-N	10	90-110
TSS	30	85-115
VSS	22	90-110
CBOD ₅	25	85-115
COD	32	85-115
Total phosphorus	25	75-125
Orthophosphorus	10	85-115
E. Coli	20	NA
Fecal Coliform	20	NA
Sulfate	10	85-115
H ₂ S	20	80-120

¹NA not applicable

Table 3.6
Total Monitoring Analyses for System Types

Sample frequency	Analyte	System ¹ with sulfur		System ¹ without sulfur	
		Influent (STE), final effluent	Influent (STE), final effluent, intermediate point	Influent (STE), final effluent	Influent (STE), final effluent, intermediate point
Eight monitoring events over a 12-16 month period	Temperature	16	24	16	24
	pH	16	24	16	24
	DO	16	24	16	24
	ORP	16	24	16	24
	Alkalinity	16	24	16	24
	TKN	16	24	16	24
	NH ₄ ⁺ -N	16	24	16	24
	(NO ₃ +NO ₂)-N	16	24	16	24
	TSS	16	24	16	24
	VSS	16	24	16	24
	CBOD ₅	16	24	16	24
	COD	16	24	16	24
	Total phosphorus	16	24	16	24
	Orthophosphorus	16	24	16	24
	E. Coli	16	24	16	24
	Fecal Coliform	16	24	16	24
	Sulfate	16	16	0	0
	H ₂ S	16	16	0	0

¹Total samples to be analyzed for a single test site system.

3.2.1.4 QC Samples

Routine QC checks of sampling and analysis procedures will be in accordance with FDEP-SOP FQ 1000 and consist of two parts: 1) field QC samples; and 2) laboratory QC samples. The number of QC samples collected will be 10% of the total number of samples collected in the overall Task B monitoring. The primary goal of the QC samples is to ensure that all data are of known quality and that the expected quality is appropriate for the desired use of the data. Field QC samples will be collected to ensure proper sample collection and handling. Laboratory QC samples will be analyzed to ensure

proper sample preparation and analytical techniques (see Section 3.3). Non-routine QC checks will include laboratory testing as needed to assure SOPs do not affect the sample quality. A summary of the QC samples is presented in Table 3.7.

Field QC samples will include field blanks, equipment rinsates, and duplicates. Field blanks will be collected to ensure that constituents of interest (i.e., nitrogen) are not introduced into the sample collection containers during the normal sampling procedures. Field blanks will be collected by transporting organic-free deionized water to the field along with sample containers, pouring deionized water into sample containers that are identical to sample containers used for analyses, and preserving and transporting field blanks to the analytical laboratory using the same procedure as regular samples. The deionized water and sample containers will all be supplied by the analytical laboratory. Field blanks will be analyzed for the parameters listed in Table 3.5. Equipment rinsates will consist of evaluating the washing and rinsing procedure applied to decontaminate intermediate sample containers and probes. The procedure is 1. wash/rinse with potable tap water three times, 2. rinse with deionized water two times. A sample container subject to this procedure will then be filled with deionized water and the container contents will be analyzed. Equipment rinsate samples will be analyzed for the parameters listed in Table 3.5.

Field duplicate samples will be collected with the regular samples to evaluate laboratory QA/QC. Duplicate analyses will be performed on the parameters listed in Table 3.8, which also lists the criteria for acceptance of duplicate results. Due to the objectives of Task B, the nitrogen analyses will receive a greater percentage of duplicates than other parameters (Table 3.8). Field duplicate collection will consist of a. collection of sample into the common collection container as per normal sampling, b. pouring sample from the common collection container into a sample bottle specific to an analyte, and c. pouring another sample from the same common collection container into a second sample bottle specific to that analyte. Duplicate samples will undergo the same laboratory analyses as regular samples. The identification numbers and locations of the duplicate and regular samples will be maintained in the field logbook. The analytical laboratory will not be provided with knowledge of the identity of duplicate samples (blind test). The majority of duplicated will be *intralaboratory* duplicates in which the duplicate samples are analyzed by the same laboratory. *Interlaboratory* duplicates (split samples) will be used in some cases to compare results from different laboratories.

Table 3.7
Summary of QC Samples Collected and Analyses Conducted

QC Sample	Frequency
Field blank	one per sampling event ¹
Equipment rinsate	one per sampling event ¹
Field duplicate	See Table 3.8 ¹
Laboratory blank	per laboratory SOPs
Laboratory spike	per laboratory SOPs
Laboratory duplicate	per laboratory SOPs
Non-routine method check	as necessary

¹Field QC samples collected will be 10% of total number of samples collected in overall Task B monitoring

Table 3.8
Duplicate Analyses

Analytes	% of Total	Duplicate Acceptance Criteria (% RE)
Alkalinity	6	26
TKN	15	10
NH ₄ ⁺ -N	15	10
(NO ₃ +NO ₂)-N	15	10
TSS	6	30
VSS	6	22
CBOD ₅	6	25
COD	6	32
Total phosphorus	6	25
Orthophosphorus	6	10
Sulfate	8	10
H ₂ S	5	20
TOTAL	100	-

3.2.2 Field Testing

Field testing will include operational monitoring using field instruments. The field equipment for Task B includes flow meters and meters for measuring temperature, pH, DO and ORP. Equipment used in the field will be maintained and calibrated in accordance with the manufacturers' specifications and will conform to FDEP SOPs as listed in Table 3.1. Field instruments will be thoroughly checked and calibrated before they are transported to the field. These instruments will be inspected for damage once they have arrived in the field. Damaged instruments will be immediately replaced or repaired. Service

and repair of field instruments will be performed by qualified personnel and will be recorded in the field logbook.

Instruments and equipment used to gather, generate, or measure environmental data will be calibrated with sufficient frequency and in such a manner that accuracy and reproducibility of results are consistent with the manufacturer's specifications. Calibration or calibration checks of field instruments and equipment will be performed at least daily or at more frequent intervals as specified by the manufacturer. Calibrations may be performed at the start and completion of each test run. However, calibrations will be reinitiated as appropriate after a period of elapsed time due to meals, work shift change, or if damage has occurred. Records of calibration procedures, frequencies, lot numbers of standard reference solutions used as calibration standards, and any repairs or replacements will be recorded in the calibration log and/or field logbook.

3.3 Laboratory Activities

All laboratory activities will meet the minimum QC as specified in the FDEP-SOPs and that meets the National Environmental Laboratory Accreditation Program (NELAP) requirements. However, if a certified laboratory is not identified, a waiver may be requested based on the research nature of this project (DEP 62-160.600 (1)(d) and (3)(f)). Regardless of if a waiver for the laboratory certification is obtained, all laboratories conducting work for this project will operate and maintain a QA Program consistent with NELAP standards. All laboratory methods to be utilized during Task B are standard methods. Should any non-standard laboratory methods be required, an addendum to this QAPP will be prepared.

Analytical methods, target analytes, sample containers, preservatives, and holding times for system influent (primary effluent, aka septic tank effluent), final system effluent, and intermediate sample points are discussed in Section 3.2.1.3 and listed in Tables 3.3 and 3.4. Once samples are received, the laboratory will have a document-control system including: sample labels, analysis logbooks, computer printouts, and raw data summaries. The analytical laboratory will be in compliance with the FDOH ELCP and ensure that all samples are properly stored, handled, and analyzed within the required holding time. A qualitative assessment of each sample container will be performed to note any anomalies, such as broken or leaking bottles and any labeling or descriptive errors. In the event of discrepant documentation, breakage, or any condition that would compromise sample integrity, the laboratory will immediately contact the field team. The samples will be stored at a temperature of approximately $<6^{\circ}\text{C}$ (as applicable) until analyses are performed.

O:\44237-001R011\Wpdocs\Report\ Final

The analytical laboratory will have approved SOPs for preventative maintenance for each instrument system and for required support activity. These records will be reviewed by auditors who perform internal and external system audits of the laboratory. All laboratory instrumentation maintenance and calibration will be performed and documented in accordance with the laboratory SOPs.

Laboratory QC procedures will include split samples, method blanks, spikes, and duplicate samples. The analytical laboratory will be in compliance with the FDOH ELCP and routinely analyze QC samples in accordance with their approved SOPs. Reagent blanks will be run for all appropriate analyses to verify that the procedures used do not introduce contaminants that affect the analytical results. Surrogate spike analysis is used to determine the efficiency of recovery of analytes in sample preparation and analysis. Calculated percent recovery of the spike is used as a measure of the accuracy of the analytical method. A surrogate spike is prepared by adding to an environmental sample (before extraction) a known amount of pure compound similar in type to the one to be assayed in the environmental sample. Surrogate spike recovery must fall within certain limits; if the recovery is not within these limits, corrective action will be implemented. Duplicate samples will be used to confirm laboratory method precision. Replicate samples should have a relative standard deviation as provided in Table 3.5. If the recovery is not within these limits, corrective action will be implemented. Laboratory duplicate samples will be prepared from the same sample in immediate succession with a regular sample.

Corrective actions at the analytical laboratory are required whenever an out-of-control event or potential out-of-control event is noted. Corrective action procedures are often handled at the bench level by the analyst, who reviews the preparation or extraction procedure for possible errors and checks the instrument calibration, spike and calibration mixes, instrument sensitivity, and other parameters. If the problem persists or cannot be identified, the matter is referred to the laboratory supervisor, manager, and/or QA department for further investigation. Each certified laboratory has written SOPs specifying the corrective action to be taken when an analytical error is discovered or when the analytical system is determined to be out of control.

3.4 Documentation, Assessment, and Reporting

To ensure representative data is collected to meet the DQOs, the following documentation, assessment, and reporting methods will be performed.

3.4.1. Documentation

Information to be documented will be in accordance with FDEP-SOPs (FD 1000). Logbooks will be used by the project team members and subcontractors responsible for

sample collection and analyses. Each team member will be responsible for recording daily activities and/or significant events, observations, and measurements. Enough information will be recorded such that clarification, interpretations, or explanations of the data and activities are not required from the originator of the documentation. Checklists and FDEP forms will be used as appropriate and maintained in the project files. Specifically, forms FD 9000-7, FD 9000-8, FD 9000-9, FD 9000-22, FD 9000-23, and FD 9000-24 are expected to be used. All logbooks will be bound books with entries signed and dated. All field data will be protected to prevent loss. All Task B documentation will be retained for a minimum of 5 years.

Entries in the logbooks will include the following when applicable:

- description of activity,
- date and time,
- location,
- weather conditions,
- names and affiliations of field team,
- work progress,
- test area and operational condition of treatment system(s),
- field measurements and observations,
- equipment maintenance and calibration (Section 3.2.2), and
- any unusual occurrences, depending upon the nature of the occurrence, such as:
 - delays,
 - unusual situations,
 - departure from established field procedures,
 - equipment breakdown and repairs,
 - instrument problems, and
 - accidents.

Minimum information on the sample bottle labels will include:

- unique sample identification number,
- analyses required,
- preservative used (if any),

- name or initial of sample collector(s), and
- date and time of sample collection.

All original data recorded in field logbooks, standard checklists, and sample labels will be written with black indelible ink. If a previously recorded value is discovered to be incorrect or if blank lines are left, the wrong information or blank lines will be crossed through with a single line, the correct value written in, and the change initialed and dated. If the change is made by someone other than the original author or if the change is made on a subsequent day, the reason for the change will be recorded at the current active location in the logbook, with cross reference to the original entry. All monitoring results will be entered into an electronic database such as Microsoft Access or Excel.

Laboratory documentation will be in accordance with FDOH ELCP requirements and at a minimum include:

- project information (e.g., client name, project number, etc.),
- sample information (e.g., source, location of sample, matrix, etc.)
- analysis results (e.g., analyte, result, units, comment, etc.),
- laboratory QC information (e.g., blank results, matrix spike information, RPD, etc.)
- instrumentation/equipment maintenance performed, and
- instrument calibration results.

The laboratory records shall contain sufficient information to allow independent reconstruction of all activities related to generating data that are submitted in data reports to the client (Hazen and Sawyer). All analytical results will be entered into an electronic database such as Microsoft Access or Excel.

3.4.2 Data Assessment

The data collected in Task B will be evaluated for precision, accuracy, representativeness, comparability, and completeness. When using these parameters as indicators of data quality, only precision and accuracy can be expressed in purely quantitative terms. The other parameters are mixtures of quantitative and qualitative expressions. All of these parameters are interrelated and can be difficult to evaluate separately. Primary data will also be graphically examined to identify obvious effects and trends and then subjected to classic statistical analyses, such as multifactor analysis of variance, prin-

principal components analysis, and/or multivariate regression analyses (e.g., Snedecor and Cochran, 1980; Minitab, 2000).

3.4.2.1 Precision

Measurements of data precision are necessary to demonstrate the reproducibility of the data. Precision objectives for field instruments are included in the SOPs for the instruments. To the extent possible, one set of field instruments will be used for the duration of the project.

All laboratory measurements will be made with high-purity materials, by knowledgeable laboratory personnel, and following internal QC. Duplicate samples will be collected and analyzed to assess the overall precision of laboratory procedures. Analytical precision may be expressed in terms of the standard deviation or RPD. RPD is calculated as follows:

$$RPD = ((X_1 - X_2) / X_{avg})(100)$$

where:

X_1 = analyte concentration of first sample

X_2 = analyte concentration of a duplicate sample

X_{avg} = average analyte concentration of first and duplicate samples.

3.4.2.2 Accuracy

The accuracy of a measurement is based on a comparison of the measured value with an accepted reference or true value. Accuracy of a procedure is best determined on a known quantity or quality. The accuracy of field measurements will be assessed through the use of calibration standards (e.g., pH standards), by comparing the measurement of a field instrument against a known standard. All calibration and instrument operations will be carried out using traceable standards and specified materials and methods.

Sampling accuracy can be estimated by evaluating the results obtained from blanks. The types of blanks to be used for this evaluation are field blanks and rinsates. The accuracy of laboratory measurements can be expressed as percent recovery (PR) and is calculated as follows:

$$PR = ((A - B) / C)(100)$$

where:

A = spiked sample concentration

B = sample concentration
C = concentration of spike added.

3.4.2.3 Representativeness

All data obtained should be representative of actual conditions. The field procedures and laboratory analyses outlined in Section 2.0 were selected to provide data representative of process conditions. 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.

To preserve the integrity of water quality data, water quality samples will be collected using appropriate collection and handling methods. Field measurements will be conducted either external to the treatment process with samples or if possible by probe insertion into the flowing process water (i.e. a flow-through cell). Additionally, to protect the quality of samples, the sampling equipment and field instruments will be kept clean.

3.4.2.4 Comparability

Consistency in the acquisition, handling, and analysis of samples is necessary so the results may be compared. Factors that will affect comparability are sample collection and handling techniques, sample matrix, field measurement techniques, and analytical methods. Results from two or more sampling events may be compared by specifying and standardizing these factors as much as possible. To ensure the comparability of field measurements made throughout the duration of the project, 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 approved SOPs.

3.4.2.5 Completeness

Field measurements will also be checked for completeness of procedures and documentation of procedures and results. Completeness of field efforts will be defined by comparing the planned scope to the actual field work completed (e.g., by comparing the total number of samples planned to be taken with the number of samples successfully received by the laboratory) and by evaluating the quality of the field work completed (e.g.,

by establishing that valid field data have been obtained through the use of proper procedures for field measurements and sample collection, etc.).

3.4.2.6 Validation

Field measurements will be made by competent engineers, environmental scientists, and/or technicians. Field data and analytical results will be validated using five primary procedures:

- Routine checks will be made during the processing of data to check for errors in data records.
- Internal consistency of a data set will be evaluated by plotting the data and testing for outliers.
- Comparison checks of related analytical results (e.g., ammonium-nitrogen + nitrate-nitrogen is less than 120% of TKN).
- Checks for consistency of the data set over time will be performed by visually comparing data sets against gross upper limits obtained from historical data sets, or by testing for historical consistency. Anomalous data will be identified.
- Checks will be made for consistency with parallel data sets, that is, data sets obtained from the similar home sites.

The purpose of these validation checks is to identify outliers or anomalies (i.e., an observation that does not conform to the pattern established by other observations). Outliers may be the result of transcription errors or instrumental breakdowns. Outliers may also be manifestations of a greater degree of spatial or temporal variability than expected. After an outlier has been identified, obvious mistakes in data will be corrected. If no plausible explanation can be found for an outlier, it may be excluded, but a note to that effect will be included in data reporting. In addition, an attempt will be made to determine the effect of an outlier when both included in and excluded from the data set.

3.4.3 Reporting

Reports of analytical results for Task B (Deliverable B.7, Monitoring Report) will contain data sheets and the results of analysis of QC samples. Sample reports will include a log of the sample identification numbers designated in the field and the corresponding laboratory sample numbers. Analytical reports will contain the following items:

- project identification,

- sample number,
- sample matrix description,
- date of sample collection,
- location of sample collection,
- date of sample receipt at the laboratory,
- analytical method and reference citation,
- date of analysis (extraction, first run, and subsequent runs),
- individual parameter results,
- quantification limits,
- dilution or concentration factors, and
- corresponding QC report.

Electronic data will be tab-delimited. The final project report will contain a compilation of all the QA/QC data generated, a discussion of out-of-control events, and any corrective actions taken.

3.5 QA Surveillance

The Hazen and Sawyer project manager will be responsible for QA/QC and will ensure compliance with this QAPP. Field surveillances and assessments will be performed by the field leader at the initiation of sampling associated with the controlled test site and again at the initiation of home site sampling. These QA surveillances of the field activities will focus on verifying proper use of field procedures for sample collection and documentation. All surveillances and necessary corrective actions will be documented in the field logbook. QA reports will include a discussion of the methods used for field activities and any items that differ from those described in this QAPP. QA reports will also include a short discussion of the quality of field documentation of data, instrument calibration, corrective actions, and other field information pertinent to the field effort.

Performance audits of the analytical laboratories will be conducted on a regular basis to verify the effectiveness and implementation of the laboratory QA/QC plan as specified in the laboratory SOPs. Results of the internal audits shall be documented and kept on file at the laboratory.

Section 4.0

Health and Safety

4.1 Hazard Assessment

Field activities will consist of test site preparation, installation of treatment technologies, operation and maintenance of treatment systems, water quality sampling and delivery of samples to analytical laboratories. An activity hazard analysis table will be available in the field at all times (see Appendix A). All field activities will be conducted in areas without inherent chemical hazards. Biological hazards are associated with exposure to high concentrations of microorganisms in household sanitation water. The most common bacterial pathogens found in untreated wastewater are *Salmonella* and *Shigella*, while other bacterial microorganisms include *Vibrio*, *Campylobacter*, and *Leptospira* (Bitton, 1999). The following are general personnel hazards with the potential to occur during Task B field work:

- 1) Infectious disease exposure;
- 2) Potential for contact with preservation chemicals;
- 3) Slip, trip, and fall potential;
- 4) Potential for pinch points and striking objects due to mechanical hazards; and
- 5) Potential electric shock from improperly grounded equipment.

Proper personal hygiene and use of personal protective equipment (PPE) will significantly reduce or eliminate biological and chemical safety hazards. Constant attention will be given to physical hazards encountered during work activities, which will be most present during installation. Qualifications (i.e., demonstrated experience and ability) with respect to the installation tasks to be performed will be required. Only qualified, competent personnel with prior experience will perform installation tasks. Slip, trip and fall potential during operation, maintenance and monitoring will be minimized by eliminating site or installation features that increase the potential of these mishaps and by conducting site work solely during daylight hours when at all possible.

Biological Hazards Three general categories of pathogenic organisms that may be present in wastewater include bacteria, viruses, and parasites (including protozoans and helminths). The principle pathogenic organisms found in STE and untreated wastewater and the corresponding infectious dose are shown in Table 4.1. Microorganisms of concern commonly found in STE include pathogenic bacteria at sustained high concentra-

tions and virus at highly variable and episodically released levels (Bicki *et al.*, 1984; Van Cuyk *et al.*, 1999). The most common pathogenic viruses found in groundwater are hepatitis, Norwalk-like agent, echovirus, poliovirus and coxsackie virus. Enteric virus includes 72 types of virus (e.g. polio, echo and coxsackie virus) that can cause gastroenteritis, heart anomalies, and meningitis. The diseases caused by common pathogens in wastewater are summarized in Table 4.2.

Table 4.1
Microorganisms Found in STE and Untreated Wastewater
(in MPN/100mL)

	Organism	Conc. in STE	Infectious Dose
Bacteria	Total Coliform	10^6 - 10^9	NA
	Fecal Coliform	10^5 - 10^8	10^6
	<i>Clostridium perfringens</i>	10^3 - 10^5	1 - 10^{10}
	Enterococci	10^4 - 10^5	NA
	Fecal streptococci	10^3 - 10^6	NA
	<i>Pseudomonas aeruginosa</i>	10^3 - 10^4	NA
	<i>Shigella</i>	10^0 - 10^2	NA
	<i>Salmonella</i>	10^2 - 10^4	NA
Protozoa	<i>Cryptosporidium</i> oocysts	10^1 - 10^3	1-10
	<i>Entamoeba</i> cysts	10^{-1} - 10^1	10-20
	<i>Giardia</i> cysts	10^3 - 10^4	<20
Helminths	Ova	10^1 - 10^3	NA
	<i>Ascaris lumbricoides</i>	NA	1-10
Viruses	Enteric Virus	10^3 - 10^4	1-10
	Coliphage	10^1 - 10^4	NA

(US EPA, 2002; Crites and Tchobanoglous, 1998; Anderson *et al.*, 1994; Brown *et al.*, 1980; Ziebell *et al.*, 1974). The most probable number (MPN) method is not an actual concentration, but a statistical estimate of concentration using serial dilutions. NA: not available

Table 4.2
Pathogenic Microorganisms Found in STE and Untreated Wastewater
(Lowe et al., 2007)

	Organism	Disease Caused	Symptoms
Bacteria	<i>Salmonella typhi</i>	Typhoid fever	High fever, diarrhea
	<i>Shigella</i>	Bacillary dysentery	Dysentery
	<i>Vibrio cholerae</i>	Cholera	Diarrhea, dehydration
	<i>Yersinia enterocolitica</i>	Gastroenteritis	Diarrhea
	<i>E. coli</i> (pathogenic)	Gastroenteritis	Diarrhea
	<i>Legionella pneumophila</i>	Legionnaires' disease	Malaise, acute respiratory illness
	<i>Leptospira</i> spp.	Weil's Disease	Jaundice, fever
	<i>Campylobacter jejuni</i>	Gastroenteritis	Diarrhea
Virus	Adenovirus	Respiratory disease	Diarrhea
	Enteroviruses	Gastroenteritis, meningitis, heart anomalies	Often no symptoms
	Poliovirus		
	Echovirus		
	Coxsackie virus		
	Hepatitis A	Infectious hepatitis	Jaundice, fever
	Norwalk	Gastroenteritis	Vomiting
	Parvovirus	Gastroenteritis	Diarrhea
	Rotavirus	Gastroenteritis	Diarrhea
	HIV	AIDS	
Protozoa	<i>Cryptosporidium parvum</i>	Cryptosporidiosis	Diarrhea, low-grade fever
	<i>Giardia lamblia</i>	Giardiasis	Diarrhea, nausea, indigestion
	<i>Balantidium coli</i>	Balantidiasis	Diarrhea, dysentery, intestinal ulcers
	<i>Entamoeba histolytica</i>	Amoebic dysentery	Diarrhea, dysentery
	<i>Cyclospora</i>	Cyclosporiasis	Severe diarrhea, nausea, vomiting, severe stomach cramps

Partially adapted from Bitton (1999) and from Crites and Tchobanoglous (1998)

Cold and Heat Stress Personnel will be monitored for heat stress during all field activities. The length of periods of active work without a break will be adjusted as the weather dictates. Anyone exhibiting signs or symptoms of heat-related illness will be removed to a controlled temperature location immediately.

O:\44237-001R011\Wpdocs\Report\F

Noise Hearing protection will be available for all field workers. Hearing protection is required at 85 decibels or above, on the A-weighted scale on a slow response scale as per American National Standards Institute (ANSI).

Electrical All temporary, 120V, single-phase, 15- and 10-ampere receptacles and cord sets will be protected by approved ground fault circuit interrupts (GFCIs) as prescribed in 29 CFR 1926.404(b)(ii). Prior to setting the drilling rig at location for piezometer installation, the field leader will determine the distance to electrical transmission lines. If the voltage of electrical transmission lines is unknown, a distance of 20 ft. will be maintained. If the voltage is known, the equipment will not be operated when any part enters a minimum radial distance of 10 ft. to electrical transmission lines as specified in 29 CFR 1910.181.

Other Physical Hazards Other physical hazards may be present. These hazards may include buried water lines; equipment movement; and equipment malfunctions. Improper lifting of heavy objects will be avoided. Tripping, slipping, and falling hazards and specific hazards pertaining to the operation of the drilling equipment will be evaluated. Equipment guards will be used on any mechanical equipment, as mandated by Occupational Safety and Health Administration (OSHA) regulations, to minimize personnel exposure to moving parts during piezometer installation. OSHA safety mandates and guidelines will be implemented by personnel that work near potentially dangerous drilling equipment.

The following are general health and safety standard operating procedures.

- 1) Wear designated PPE and safety equipment at all times while in the work area.
- 2) Do not eat, drink, chew gum or tobacco, smoke, or apply cosmetics in the work area.
- 3) Do not work with open wounds, including bandaged wounds, or other injuries that could provide a route of entry for possible microorganisms.
- 4) Prevent spillage. If a spill occurs, contain wastewater and dispose properly.
- 5) Practice good housekeeping. Keep everything orderly and out of potentially harmful situations.
- 6) Be familiar with the physical characteristics of the site, including:

- a. nearest emergency assistance;
 - b. accessibility to associates, equipment, and vehicles;
 - c. communication facilities at and near the site; and
 - d. site access and egress.
- 7) Keep the number of personnel and equipment in the work area to a minimum, but only to the extent consistent with work force requirements of safe site operation.
- 8) Dispose of all waste generated properly.
- 9) Report all injuries, no matter how minor, to the field leader.
- 10) Do not wear loose clothing and jewelry while working with or near drilling equipment.
- 11) If desired, wear gloves or other equipment for protection against physical hazards in addition to the above-mentioned PPE.
- 12) Be continually aware of potentially dangerous situations (e.g., presence of strong, irritating, or nauseating odors) and immediately take precautionary measures to ensure the safety of everyone.

4.2. Personal Protection Requirements

During Task B, the primary exposure risk is ingestion through splashes that contaminate food, drinks and/or hands (most common); inhalation of infectious agents or aerosols, and contact with unprotected cuts and abrasions. There is no airborne exposure pathway associated with the microbiological constituents present in residential STE or nitrified effluent. To mitigate these exposure routes for workers, eating, drinking or smoking will be prohibited in the field during monitoring. Good personal hygiene, such as avoiding touching the mouth, frequent hand washing, and use of disposable gloves (latex or nitrile), will be implemented. During routine field activities, personal protection equipment will include long pants, close-toed shoes, and appropriate gloves. Hard hats and safety glasses will be worn when equipment is being set up and when in the proximity of overhead hazards.

The primary potential public health risk associated with this project is the discharge of STE or nitrified effluent to the ground surface or groundwater underlying the site. To mitigate public exposure risk, all STE released to the environment will occur below ground;

there will be no surface application of wastewater effluent. In addition, access to the test site will be controlled (fencing, locking caps on monitoring points, etc.).

4.3 Emergency Response

The following procedures will be implemented in the event of an emergency during field activities. In case of emergency dial 911. The location of the nearest medical facility will be made available prior to field activities. Notify the Hazen and Sawyer project manager of any emergencies. Maps consisting of directions to the nearest medical facility and hospital will be posted at the job-site.

Section 5.0

References

- American Public Health Association (APHA) (2005). *Standard Methods for the Examination of Water and Wastewater*. 21st ed. A.D. Eaton, L.S. Clesceri, E.W. Rice, and A. E. Greenberg, eds. APHA-AWWA-WEF, Washington D.C.
- Anderson, D.L.; A.L. Lewis, and K.M. Sherman (1994). Human enterovirus monitoring at onsite sewage disposal systems in Florida. Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Systems, ASAE, St. Joseph, MI. pp: 94-104.
- Bicki, T.L.; R.B. Brown, M.E. Collins, R.S. Mansell, and D.F. Rothwell (1984). Impact of On-site Wastewater Disposal in Coastal Surface and Groundwater Quality. Soil Sci. Dept., Institute of Food and Agric. Sci. Univer. of Florida, Gainesville.
- Bitton, G. (1999). *Wastewater Microbiology*. New York, Wiley-Liss, Inc.
- Brown, K.W.; J.F. Slowey, and H.W. Wolf (1980). The movement of salts, nutrients, fecal coliform and virus below septic leach fields in three soils. Proceedings of the Second National Symposium on Individual and Small Community Sewage Systems, ASAE, St. Joseph, MI. pp:208-217.
- Crites, R.C. and G. Tchobanoglous (1998). *Small and Decentralized Wastewater Systems*. McGraw-Hill Publishing Company, Boston.
- Florida Department of Environmental Protection (2009). *Standard Operating Procedures*. Website accessed September 2009. <http://www.dep.state.fl.us/labs/qa/sops.htm>
- HACH (1998). *Water Analysis Handbook*. 2nd ed. HACH Chemical Company, Loveland, CO.
- Hazen & Sawyer (2009a). Literature Review of Nitrogen Reduction Technologies for Onsite Sewage Treatment Systems, FOSNRS Task A.2, Submitted to the Florida Department of Health, Tallahassee, Florida, August 2009.
- Hazen & Sawyer (2009b). Classification and Ranking of Technologies Final Report, FOSNRS Task A.7 and A.8, Submitted to the Florida Department of Health, Tallahassee, Florida, August 2009.
- Hazen & Sawyer (2009c). Classification, Ranking and Prioritization of Technologies Final Report, FOSNRS Task A.9, Submitted to the Florida Department of Health, Tallahassee, Florida, September 2009.

- Hazen & Sawyer (2009d). Passive Nitrogen Removal Study Final Report FOSNRS Task A.15, Submitted to the Florida Department of Health, Tallahassee, Florida, November 2009.
- Lowe, K.; N. Rothe, J. Tomaras, K. DeJong, M. Tucholke, J. Drewes, J. McCray, and J. Munakata-Marr (2009). Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Final Report. WERF, 04-DEC-1. PDF available at: www.werf.org
- Lowe, K.; N. Rothe, J. Tomaras, K. DeJong, M. Tucholke, J. Drewes, J. McCray, and J. Munakata-Marr (2007). Influent Constituent Characteristics of the Modern Waste Stream from Single Sources: Literature Review. WERF, 04-DEC-1. 89pg. PDF available at: www.ndwrcdp.org/publications
- Minitab, Inc. (2000). MINITAB Statistical Software, Release 13. State College, PA. 16801-3008.
- Selvakumar, A.; M. Borst, M. Boner, and P. Mallon (2004). Effects of sample holding time on concentrations of microorganisms in water samples. *Water Environment Research*. 76(1):67-72.
- Smith, D. (2009). Modular Nitrogen Removal in Distributed Sanitation Water Treatment Systems. Environmental Engineer, Spring, American Academy of Environmental Engineers, Annapolis, Maryland.
- Smith, D. (2008a). Florida Passive Nitrogen Removal Study Experimental Media Evaluation Final Report. Submitted to the Florida Department of Health, Tallahassee, Florida, April 28, 2008.
- Smith, D. (2008b). Florida Passive Nitrogen Removal Study Additional Monitoring. Submitted to the Florida Department of Health, Tallahassee, Florida, November 4, 2008.
- Smith, D., R. Otis, and M. Flint (2008). Florida Passive Nitrogen Removal Study Final Report. Submitted to Florida Department of Health, Tallahassee, Florida, May 26, 2008.
- Snedecor, G. W. and W. G. Cochran (1980). *Statistical Methods*, 7th Edition. Iowa State University Press.
- U.S. EPA (2002). *Onsite Wastewater Treatment Systems Manual*. Report No. 625/R-00/008. U.S. Environmental Protection Agency, Cincinnati, OH.
- Van Cuyk, S.; R. Siegrist, A. Logan, S. Masson, E. Fischer, and L. Figueroa (1999). Purification of wastewater in Soil Treatment Systems as Affected by Infiltrative Surface Character and Unsaturated Soil Depth. 72nd Water Environment Federation Exhibition and Technical Conference, October 9-13, 1999. New Orleans, LA.
- Ziebell, W.A.; D.H. Nero, J.F. Deininger, and E. McCoy (1974). Use of bacteria in assessing waste treatment and soil disposal systems. Proceedings of the First National Symposium on Individual and Small Community Sewage Systems, ASAE, St. Joseph, MI. pp:58-63.