Input needed from RRAC

A. Possible system selection strategies: Awaiting RRAC's Approval

1. Random Sampling based on all systems that have sufficient information to be located (addresses)
   Pros: this will give an overview of systems in general,
   Cons: limits comparisons between attributes. By getting many samples from common systems and counties with many installations but few of less common systems, differences between management approaches between systems or counties will be hard to detect.
2. Stratified Sampling by Manufacturer (based on all systems that have sufficient information to be located (addresses) and have manufacturer information
   Pros: By getting a minimum sample size of all manufacturers that exceed a minimum number of installations (e.g. 20), it will be possible to compare treatment technologies
   Cons: manufacturer information is not available for all records, so this approach would have to be either supplemented by additional random sampling, or risk losing information on systems with the management attribute "no manufacturer recorded"
3. Stratified Sampling by type of permit (ATU, PBTS, innovative, commercial vs. residential)
   Pros: The permit stands as a proxy for the type of management. Overall the management level is similar, though, with the exception of old experimental systems (no OP and ME) and commercial systems (no ME)
   Cons: little difference between ATU and PBTS expected because code is similar (requirement of ME). Commercial vs residential may be more interesting
4. Stratified Sampling by County (e.g. counties with few, many systems, or same number of samples per county)
   Pros: can gather comparative information on counties, even those with few systems
   Con: some counties have very few systems, so stratification could result in lots of information on a random small county, not better than random sampling. Approach also assumes that number of systems (rather than e.g. fraction of systems that have current operating permit) is a predictor of management
5. Stratification by Maintenance entity: Contact the Maintenance Entity and have them Identify systems that are in need of annual inspection or that is in need of frequently visits.

Pros: The Maintenance Entities are familiar with the systems and location of each sampling point (effluent or influent tanks)
Cons: We might be limited to only properly functioning systems. Information on maintenance entities is very limited in database, would need to be supplemented by random sampling

6. Contact County Health department and have them assist in the selection process.
Pros: Like the ME they should be familiar with the systems and would be able to provide additional information on the system.
Cons: They may not have the man power to devote to this project.

7. Visit all 67 counties and collect 9 samples per county.
Pros: This would be a true random sampling but, we would not have a parameter to judge or compare systems.
Cons: This would result in a time management discrepancy instead of 30 weeks it would take 67 weeks to complete this sampling event.

8. Select sites base on geographic location.
Pros: A representative group of systems would be selected with the same temperature and soil profiles. This could be used for further comparison through out the state.
Cons: While this may provide insights into temperature, it would provide no clear information on management, except by whatever locations happened to be picked. This would have a significant economic, as well as, time management disadvantage.

Draft Quality Assurance Project Plan For Assessment of Water Quality Protection by Advanced Onsite Sewage Treatment and Disposal Systems (OSTDS): Performance, Management, Monitoring

DEP Agreement No. G0239

Draft 2
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Prepared for:
State of Florida Department of Environmental Protection
3900 Commonwealth Boulevard
Tallahassee, FL 32399-3000

Prepared by:
Florida Department of Health
Bureau of Onsite Sewage Programs
4052 Bald Cypress Way BIN # A-08
Tallahassee, Fl 32399-1713

Approved: _____ Date: _____
FDEP Project Manager

Approved: _____ Date: _____
FDOH Contract Manager

Approved: _____ Date: _____
FDOH Engineer

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1.0 Overview

1.1 Project Purpose

To evaluate the performance of advanced systems throughout the State of Florida and identify best management practices with regards to compliance.

1.2 Background information

Onsite Sewage Treatment and Disposal Systems (OSTDS) are one of the nutrient sources in nutrient impaired watersheds. Estimates of the extent of their contribution to nitrogen loadings for different watersheds in Florida have ranged between less than five and 20%. Conventional OSTDS (septic tank-drainfields) have limited capacity to reduce nitrogen concentrations in water discharged to the drainfields. Because of this, residential density limitations have been used as one approach to meet the nitrate drinking water standard of 10 mg/L, which is not necessarily protective of ecological health. The phosphorus loading from OSTDS has been of most concern in the Florida Keys, where small lots, poor soils, and building practices increase the risks of impacts on surface water.

To achieve higher reductions of nutrient concentrations, additional treatment steps in OSTDS are necessary. Advanced OSTDS can utilize various approaches to improve treatment before discharge to a drainfield, or the drainfield itself can be modified. On occasion, engineers have included the drainfield as part of the treatment process, usually as means to achieve fecal coliform removal. In such cases, the engineer is required to include shallow groundwater monitoring wells in the monitoring plan.

The emphasis of this study will be on assessing the effectiveness of pretreatment before discharge to the drainfield. There are two large permitting categories in Florida onsite regulations that qualify as advanced treatment: Aerobic Treatment Units (ATUs) (Florida Administrative Code 64E-6.012), which are generally permitted based on certification by the National Sanitation Foundation; and performance-based treatment systems (PBTS) (Florida Administrative Code 64E-6, part IV), which are permitted based on design by an engineer experienced in wastewater. A third permitting category, rarely used, consists of engineer-designed alternative systems, such as sand filters.

Advanced systems have been required by local regulations, at least in part, with the objective to reduce nitrogen loading to sensitive areas (Florida Keys, St. George Island, Aucilla and Suwannee River floodplains, and Volusia County). In addition, Florida Administrative Code (FAC) 64E-6 requires advanced treatment, sometimes including nitrogen and fecal coliform removal, for lots where the usually required setback or authorized lot flow restrictions cannot be met.

Advanced systems differ in three aspects from conventional treatment systems that consist of a septic tank with drainfield. The design of advanced systems is more variable than the prescriptive approach for conventional systems. They need more frequent checkups and maintenance, which has been the reason for requiring operating permits for them. The performance expectations are more specific than absence of sewage on the ground surface, while failure definitions for advanced systems are vaguer. The first two issues have been challenges for the permitting process. Site specific performance specifications are not captured completely in the three databases that are used statewide for tracking permits, two that were developed for conventional system permitting for the state, and one that was developed for inspection tracking by Carmody, Inc. The third issue has made it hard to determine how well this aspect of Florida's onsite program is working. Until early 2001, operating permit fees allowed County Health Departments to perform limited sampling. In 2001, the legislature decided to limit operating permit fees. Since then, there has been no systematic statewide assessment of the management and performance of these systems. The proposed project aims to perform such a statewide assessment and develop improvements in the management of advanced systems where indicated.

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1.3 Sampling locations

The project is to be performed statewide. The specific sampling locations will be selected based upon one or more of the following criteria: system type, system age, geographic location, random sampling, and density of advanced systems. The systems will be selected based on the Task 2 project database. If manufacturer information and system type are available initially for at least half of the systems, the sampling will be stratified to assure proportional representation of manufacturers and system types. The final subgroup categories and sizes will be determined with input from the DOH Research Review and Advisory Committee (RRAC) and consideration of the results of Task 1.

Due to the wide range of sampling locations associated with this project, it is anticipated that several NELAP certified laboratories will be utilized. NELAP-certified laboratory services will be provided by DOH-labs, procured in a set of purchase orders with local labs, or by contract with regional labs.

1.4 Overview of project sampling plan

During phase 4 an estimated total of 600 systems will be tested for three of the five analytes (TSS,TN and CBOD) The samples will be collected from the effluent ports. Then 300 systems out of the 600 systems will be sampled from the effluent tank and tested for two of the five analytes (Fecal coliform and TP).

In additionally to the 600 systems selected 100 systems will be sampled from the influent tank and tested for all five analytes (TSS, TP, TN, CBOD and fecal Coliform)..

Upon completion of phase 4, a quarter sampling event (phase 5) requires the continuation of sampling for 70 systems; of which 35 systems shall be tested for TSS, TN, CBOD and remaining 35 systems shall be tested for TP and Fecal coliform.

The use of a single Laboratory or several different laboratories will be determined after input from the RRAC committee. To ensure holding requirement of 6 hours for the fecal coliform samples some local labs should be considered.

1.5 Project objectives

The objectives of the overall project are to quantify the reduced loading of contaminants from advanced Onsite Sewage Treatment and Disposal Systems (OSTDS) to the environment; assess the operational status of systems under the current management framework; survey perceptions of user groups regarding the management of such systems; validate elements of a monitoring protocol for consistent assessment of systems; document good management practices.

This Quality Assurance Project Plan (QAPP) lays out the methodologies, procedures and other requirements necessary for collecting data adequate to support the goals of the project. Subsequently, the water quality data gathered through the sampling will be used to assess the overall performance of these systems. The data will be used to recommend best management plans which will help ensure that advanced systems are performing as designed.

1.6 Definitions:

A. **Advanced system:** Includes aerobic treatment units (ATUs), performance-based treatment systems (PBTS), innovative systems, and sand or gravel filters.
B. **Carbonaceous Biochemical oxygen demand (CBOD5**): The concentration of oxygen (expressed as mg/l) utilized by microorganisms in the oxidation of organic matter during a five day period at a temperature of 20 Degrees Celsius or 68 degrees Fahrenheit.
C. **Data quality indicators:** Quantitative and qualitative measures of principal quality attributes, including precision, accuracy, representative-ness, comparability, completeness, and sensitivity employed as a means of specifying criteria which, if achieved, will provide an indication that the resulting data are expected to meet the data quality objectives of the standard.

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D. **Manufacturer:** The entity that develops, designs, and produces residential or commercial wastewater treatment systems.
E. **NELAP:** National Environmental Laboratory Accreditation Program
F. **Quality Assurance Project Plan (QAPP):** a written document that describes the implementation of quality assurance and quality control (QA/QC) activities during the life of the project.
G. **RRAC:** Research Review and Advisory Committee, Department of Health committee formed under F.S. 381.0065(4)(o).
H. **Total nitrogen:** The sum of the total Kjeldahl nitrogen (TKN), Nitrite (NO2), and Nitrate (NO3) in a sample, expressed as mg/L as N.
I. **Total suspended solids:** The quantity of solids (expressed as mg/L) readily removed from a well mixed sample with standard laboratory filtering procedures.
J. **Total Phosphorus:** are essential nutrient for plant growth.
K. **Fecal Coliform**: are bacteria mainly associated with the colon of animals (including humans) and which are excreted in feces.

2.0 Project Organization and Management:

2.1 Organization Chart of Key Personnel

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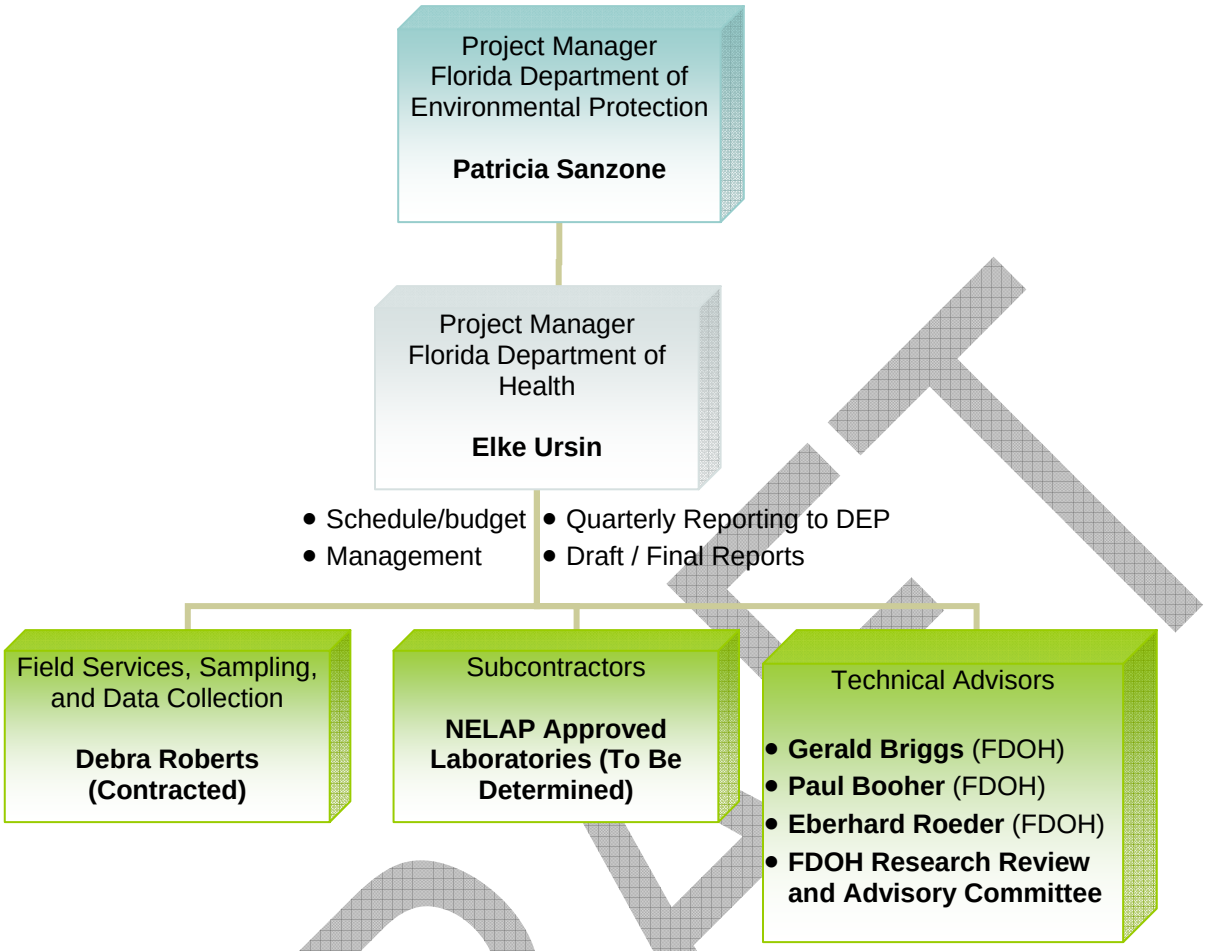

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2.2 Training Requirements and Certification

In accordance to the grant agreement individual performing sampling should obtain an OSTDS certification. An accelerated Training class will begin on December 7 thru December 11 of 2009. . Debra Roberts is enrolled and plans to obtain this certification.

The Department of Health licensed professional engineer, certified environmental health professionals, the Research Review and Advisory Committee, and other interested parties will be conducting draft and final report review.

Debra received her Bachelor of Science in 2001 from Florida A&M University major in Biology and minor in Chemistry. In addition she has worked as a QA Chemistry and Environmental Lab technician for General Dynamics, Chemist for Total Home Care Solutions and Quality Assurance Supervisor for Talecris Plasma Resources. The culmination of aforementationed employers has exposed her to an extensive knowledge of standard operating procedures with respects to handling samples, collection, preservation, transport and storage, documentation, chain of custody record completion, and communication with event coordinators and laboratory staff.

The selected laboratory will be NELAP certified according to EPA standards methods. Equipment probe numerical values will be obtained in accordance with manufacturers instructions.

3.0 Experimental Approach

3.1 General approach and testing conditions

The samples shall be collected and analyzed by a NELAP certified laboratory.

3.2 Experimental Design And Sampling Strategy

This experiment is designed to measure the overall performance of advanced systems. The sampling parameters include system type, system age, geographic location, random sampling, and density of advanced systems.

3.3 Sampling / Monitoring Points

A total of 600 sites will be selected for the sampling of effluent ports. Each site will be tested for TSS, TN and CBOD which will result in 1800 analytes tested from the effluent tanks. In addition to the 1800 analytes tested 600 will be collected from the effluent tank and tested for fecal coliform and TP. This will result in a net total of 2400 analytes tested from the effluent tanks.

While at the aforementioned sampling sites 100 will be selected for sample collection and tested for TSS, TN, TP, CBOD and Fecal coliform. This will result in a net total of 500 analytes tested from the influent tanks.

Additionally, 35 systems will be selected and tested on a quarterly basis for TSS, TN, CBOD and 35 systems will be tested for TP and Fecal coliform. This will result in the net total of 1400 analytes tested per year.

Field duplicates of both influent and effluent samples will be collected one duplicate for every twentieth samples.

An alternative 100 systems will be selected as a precautionary measure in the event that the original system does not produce an adequate amount of sample.

Depended on the laboratory selection an audit will be perform prior to sampling and then quarterly thereafter.

3.4 Frequency Of Sampling

The initial sampling timeline requires that 600 systems are sampled within the project period. An estimated amount between 5 to 10 systems will be sampled daily. Subsequently, a select number of 70 systems will be sampled on a quarterly basis thereafter.

3.5 Measurement and parameters of interest

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Obtaining access to property will serve as a limiting factor, however if a relationship with the associated system maintenance entity is developed this might aid in the process of gathering a larger number of samples. The basic project design is to sample a total of 700 ports which would serve as a representative population

4.0 Sample and audit plans

A total of 600 systems shall be selected for the sampling of effluent ports. Each system will be tested for TSS, TN and CBOD5 which will result in 1800 analytes tested from the effluent tanks. In addition to the 1800 analytes tested 600 will be collected from the effluent tank and tested for fecal coliform and TP. This will result in a net total of 2400 analytes tested from the effluent tanks.

While at the aforementioned sampling sites, 100 influent tanks will be selected for sample collection and tested for TSS, TN, TP, CBOD5, fecal coliform. This will result in a net total of 500 analytes tested from the influent tanks.

Depended on the laboratory selection an audit will be perform prior to sampling and then quarterly thereafter. If the laboratories are within driving range an initial audit of the facility will be conducted prior to first sample submission.

4.1 Significance of measuring analytes

4.1.1 Rationales for analytes to assess performance and operational status

The performance and operational status of a treatment system will be characterized by effluent concentration of several analytes. These will be indicators of a) how complete aerobic stabilization is; b) what the nutrient concentrations leaving the system are; c) the extent of treatment of a pathogen indicator; d) operational variables that are expected to be related to system functioning

A. CBOD5 test measures the oxygen utilized to oxidize organic material, inorganic material, and reduce forms of nitrogen in the sample. A change in levels away from acceptable ranges may interfere with aerobic processes, as well as, the decomposition of organic matter generates cell growth.

B. Total suspended Solids (TSS) measures the non filterable materials contained in the wastewater sample. The solids contained in a wastewater sample will accumulate over time thereby reducing the clear layer. If the clear layer is reduced, it causes the solids and liquid retention time to decreases. This will lead to an increase in the organic and solid matter leaving the tank.

C. Total Nitrogen measures dissolved inorganic nitrogen such as nitrites, nitrates and ammonia, as well as organic nitrogen. Excessive nitrogen in wastewater effluent can lead to eutrophication of receiving waters. Within wastewater treatment systems, nitrogen exists in a variety of forms; following nitrogen species through the wastewater treatment system can help to identify biological transformations. Different types of biological transformations occur under aerobic and anoxic conditions:

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Aerobic conditions:

***1. Hydrolysis*: Conversion of organic nitrogen into soluble ammonium**

***2. Nitrification*: Conversion of ammonium to nitrite and nitrate**

***3. Nitrogen assimilation*: Incorporation of nitrogen into biomass - cells are composed of approximately 12.4% nitrogen**

Anoxic conditions:

The main transformation is denitrification, where nitrite and nitrate are reduced to nitrogen gas, which evolves to the atmosphere.

Denitrification and nitrogen assimilation are the only ways to remove nitrogen from the system. All other processes are only transforming nitrogen from one dissolved species to another.

D. Total Phosphorus is a key nutrient for living organisms, and a key component of cell macromolecules such as RNA, phospholipids (cell membranes), and ATP. In aqueous solution, phosphorus is typically found as orthophosphate, polyphosphate, and organic phosphate.

1. Orthophosphates: (H_3PO_4) are readily available as nutrients.

2. Polyphosphates: which are chains of phosphorus-based molecules, must be converted to orthophosphates via hydrolysis prior to utilization as a nutrient.

3. Organic phosphates: must be converted to orthophosphate to be available as a nutrient. Cells are composed of approximately 2.5% phosphorus.

E. Fecal coliform are a good indicator of contamination from human or other animal waste products and they indicate greater risk of exposure to pathogenic organisms. Each person discharges from 100 to 400 billion fecal coliform organisms per day.

Total alkalinity is a measure of how much acid it can neutralize.

Alkalinity is significant in the treatment of wastewater, because it will influence treatment processes such as anaerobic digestion

Chlorine (only for systems with chlorination) is used as a disinfectant because it destroys targeted organisms by oxidizing cellular materials

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4.2 Preparations prior to sampling

4.2.1 Permit file review and coordination

Prior to sampling, the sampler will coordinate with the county health department for the respective systems. This will include review of the permitting files.
The following forms will be collected and maintained in a separate file: Engineer Schematics, Original permit, original soil evaluation, site plans, As built, latest Operating permit, latest ME inspection and latest CHD inspection.

The selected onsite systems will be tentatively sampled on Monday thru Thursday according to the following plan. Preparation for the following week sampling event shall occur on Friday.

A two hour window in between sites will allow for breakdown, transport and setup at the next location. This will vary based on the location of sample sites selected.

This will result in a yield of 5 systems sampled daily for approximately 30 weeks depending upon the weather and access to systems.

Fridays will designated to contacting system owners, ME and CHD to finalize the sampling time and date. Also this would be an opportunity to answer any questions that might arise.

The maintenance entity can assist identifying the component tanks and uncovering obstructed tanks.
The maintenance entity if possible could coordinate their inspection with the sampling events. While in the various counties, the local county health department shall be notified and can coordinate annually inspections accordingly. This would provide insight of their inspection process and best management practices.

4.3 Equipment preparations prior to sampling

4.3.1 Packing list

There are several tools and equipments required to complete a sampling event. An automatic sampler with sample container, crowbar, 500ml beaker, tubing, battery, coolers, Taylor test kit, 0.5 and 1.0 disposable pipette caps, 50 ml graduated cylinder , NIST-traceable thermometer, small table, YSI and sample bottles.

The supplies needed are as followed: powder free latex gloves, hand sanitizer, eye protection, plastic bags, garbage bags, liquinox detergent, hand lotion and ice.

Disposable powder free gloves are mandatory for sample collection to protect personnel who collect the samples and to assure the integrity of the samples. Disposable gloves will be changed and discarded at each sampling location.
Expose the sample points by removing any obstructions.

4.3.2 Equipment cleaning

When automatic sampler is deployed for extended time periods, clean the sampler using the following procedures when routine maintenance is performed. Inspect deployed samplers prior to each use. At a minimum, change the tubing if it has become discolored or has lost elasticity.

Clean the automatic sampler after each sampling event as followed: Wash the exterior and accessible interior portions of the automatic samplers (excluding the waterproof timing mechanisms) with laboratory detergent and rinse with de-ionized water. Next, clean the face of the timing case mechanisms with a clean, damp cloth. Then,

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check all tubing (sample intake and pump tubing). Change the tubing every six months or if it has become discolored (i.e., affected by mold and algae) or if it has lost its elasticity.

Disposable powder free gloves shall be mandatory for sample collection to protect personnel who collect the sample and to ensure the integrity of the samples. Disposable gloves will be changed and discarded at each sampling location.

4.4 Calibration of YSI devices

The YSI will be calibrated daily prior to sampling event. Then a verification calibration will be completed daily after the final sample collection.

Ph calibration will be completed by use of three buffers solutions. Prior to use and after opening buffer solution the date open will be annotated on the container. The expiration date of the buffers should not exceed one year after open date.

An air calibration will be completed on the dissolved oxygen probe and compared to the oxygen solubility table FT 1500-1 in FDEP's SOP FT 1500.

The temperature sensor will check against an NIST-traceable thermometer on bi-weekly intervals.

Table 1. Field Parameter

Parameter	Acceptable criteria	Units
Temperature	+/- 0.2	Celsius
Conductivity	+/- 5 % of solution value	mS/cm
Dissolved Oxygen (DO)	+/- 0.3 mg/L	DO%
Power of hydrogen (pH)	+/- 0.2	pH

If acceptable calibration standards are not meet a second attempt will be made to calibrate the YSI 556 instrument. After the second attempt to calibrate device proves to be unsuccessful a complete diagnosis by field personnel per manufacture instruction will be completed to ensure accuracy. A probe's reading will be qualified if calibrations are not within acceptable ranges.

4.5 Field testing equipment and calibration

In general electronic instruments for pH, DO and Turbidity are used to measure the properties of water or wastewater. As such, they are indirect methods of measurement, and must be calibrated. To calibrate probes/instruments, it is extremely important that the technology manufacturers SOP are carefully followed and documented. The operator, by complying with instructions will ensure that the equipment is operating as designed by the supplier and there is quality control of field data. Accurate field data is necessary in order to meet sampling protocol requirements Non-compliance with calibration and testing instruction will result in a lack of calibration and inaccurate measurements which will mask both treatment and effluent water quality problems and by violating sampling protocols will invalidate all data collected.

4.5.1 Temperature

The temperature will be measured using pH and dissolved oxygen meter, or thermometer.

4.5.2 PH

Measures the "acidity" of the water, measured using a pH meter.
This meter is used to measure the acidity of the water by comparing readings from a reference electrode and a sample electrode. To determine pH the output of these electrodes must be temperature-compensated, most pH meters also measure temperature.

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4.5.3 DO

The DO meter will measure dissolved oxygen, electrical conductivity, and salinity. DO is measured by the rate of consumption of oxygen at the tip of the probe, so it requires continual movement of water past the tip (an up-and-down motion seems to work best, keep the probe tip submerged). Stable readings are not possible while the temperature of the sample is changing.

4.6 Sample labeling

Sample container from the Laboratory are marked: influent grab CBOD5, influent grab TSS, influent grab TN, Influent grab TP, influent grab fecal coliform, effluent grab CBOD5 effluent grab TSS, effluent grab TN, effluent grab TP, effluent grab fecal coliform. The nomenclature of the sample will be.

The County coded+ unique Id from database will be annotated on the appropriate sample bottles label. If the sample collected is a blank the same county coded, unique Id and word blanks or equipment blanks will be used to identify the systems.
To ensure accuracy of the sample, label bottles with just prior to field uses.

Example of sample name:
01- Unique Id
01-Unique Id "blank"

Table 3. County and associated codes

County	Code	County	Code	County	Code	County	Code
Alachua	01	Flagler	18	Lake	35	Pinellas	52
Baker	02	Franklin	19	Lee	36	Polk	53
Bay	03	Gadsden	20	Leon	37	Putnam	54
Bradford	04	Gilchrist	21	Levy	38	Santa Rosa	55
Brevard	05	Glades	22	Liberty	39	Sarasota	56
Broward	06	Gulf	23	Madison	40	Seminole	57
Calhoun	07	Hamilton	24	Manatee	41	St. Johns	58
Charlotte	08	Hardee	25	Marion	42	St. Lucie	59
Citrus	09	Hendry	26	Martin	43	Sumter	60
Clay	10	Hernando	27	Monroe	44	Suwannee	61
Collier	11	Highlands	28	Nassau	45	Taylor	62
Columbia	12	Hillsborough	29	Okaloosa	46	Union	63
Dade	13	Holmes	30	Okeechobee	47	Volusia	64
Desoto	14	Indian Rivers	31	Orange	48	Wakulla	65
Dixie	15	Jackson	32	Osceola	49	Walton	66
Duval	16	Jefferson	33	Palm Beach	50	Washington	67
Escambia	17	Lafayette	34	Pasco	51		

4.7 Notification

4.7.1 Initial system observation

One day prior to the field sampling, a telephone call will be made to the homeowner. At this time if there are any questions, comments or concern the homeowner will have an opportunity to ask prior to staff arrival. During this phase the homeowner should be informed that there will be no retaliatory action or disruption to property upon arrival.

Upon arrival to the site location, knock on the door so that the homeowner is aware of your presents. Evaluate the property for dangers that may impede your ability to collect samples.

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4.7.2 Sampler setup

Prepare the site by removing the sampling equipment. Ensure that the effluent and influent tanks are easily differentiated by using the schematics provided by the local County Health Department. Place an automatic sampler near the effluent sampling point and a different automatic sampler near the influent sampling point when applicable. Ensure that all wires and tubing connections are properly connected and the battery is fully charged**.**

4.7.3 Preparing the site for sampling

4.7.3.1 Turbidity

The clarity of the water, measured using a portable turbid meter.
The turbid meter measures the light transmittance of a sample in NTU's (Nephelometric Turbidity Units, a standard measure). It needs no field calibration. Handle the sample vials only by their ends (preferably the lid) so as not to affect the transmittance; wipe any fingerprints, spots, etc. from the outside of the vial; and be sure to close the vial compartment lid when taking a measurement.

4.7.3.2 Collecting samples with auto-samplers

The sampler should be placed in an upright (it will not work if placed on its back or side. Open the sampler and remove the battery charge from the unit.
To secure the sample jug, screw the jug cap/float, place jug into the sampler enclosure, insert end of the peristaltic pump hose into the hole in jug cap and plug the float switch lead into the control panel. (Located under control panel enclosure).

If possible, secure the auto-sampler to a fixed point, such as a tree or fence post to prevent theft. The sampling unit is water resistant, not water proof. Avoid submerging the unit.
Insert the hose into the sample port and submerge the strainer under water but avoid the water surface or tank bottom. The samples should be collected at depth between 40% and 60% of the total depth where the turbulence is maximized.
Set the collection volume to appropriate volume and start collection process. Note: If the unit does not start the sample cycle press the pump test button to initiate a sample.
Label bottles with time and date of sample collection and note time on the chain of custody form.
The global Water WS700 wastewater sampler will function only if the battery plug is securely fastened into the battery socket on the control panel and the floater sensor plug is inserted into its socket.
Cap and invert the sample collecting jug 5 times to obtain a homogenous mixture then pour to contents into the respective sample bottle.

The remaining wastewater shall be used to determine visual/olfactory and Taylor chlorination test for chlorinated systems only.

Example of Automatic Sampler:
Composite and Discrete Samplers.

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FEATURES:
Ideal for wastewater, industrial and environmental sampling
CE Certified
Does composite, or discrete sampling
Simple to operate – no programming required
Output provided for use with optional data logger
Lightweight and easy to carry
Rugged construction for harsh environments
Meets federal, state and local wastewater regulations
Timed and external flow pulsed samples
Adjustable and repeatable sample volume
Peristaltic pump prevents sample contamination
Automatic back flush clears pickup strainer and hose
Rechargeable battery or AC powered
Refrigerated/cooler options available
The easiest and most reliable method for collecting water quality samples

4.8 Duplicates, fields and equipment blanks

Field duplicates of both influent and effluent samples shall be collected at a frequency of one duplicate after the twentieth samples.

Field blanks will be collected with the use of tap water and equipment blanks with distilled water after the twentieth sample collection.

Additionally, the laboratory will provide a sample bottle designated QC lab bottles. The chain of custody form will be annotated whether the field blank was tap water or distilled water.

4.8.1 Duplicates

A duplicate sample will be collected and tested for all five analytes after every twentieth sample collection.
4.8.1.1 Collect enough wastewater to fill 2 sets of sample bottles.
4.8.1.2 Fill the sample bottles
4.8.1.3 Label the bottles with time of sample collection and annotate “Duplicate” on appropriate sample bottles.

4.8.2 Field blanks

The field blank will be obtained by pouring clean water taken from distilled water container. The frequencies of field blank collection will occur after every twenty samples. If an analyte is detected in a blank at greater than the detection limit and/or 10 percent of a quantified project sample, a reanalysis will be required.

4.8.3 Equipment blanks

The equipment blanks will be collected by pouring distilled water into a 500 ml beaker. Then the autosampler hose will be inserted into the 500 ml beaker and cycle through the equipment. A sample collecting bottle will be placed in the autosampler to collect the equipment blank.

4.9 Field assessments and testing

4.9.1 Visual/Olfactory protocols

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It is important that the sample collector conduct a visual examination of the wastewater. In most cases this visual examination will immediately provide the sample collector with an understanding of the status of treatment. The sample collector's field inspection should include an evaluation of the color of the wastewater in the treatment unit, odors from the unit and finally the solid content of the effluent. The following are the items that need inspections:

1. Wastewater Color: no color __ brown___ clear___ turbid ____ other_____
2. Wastewater Odor: musty____ earthy ____ moldy ___offensive____
3. Effluent Solids: no___ some___ turbid_____

This information shall be recorded on the chain of custody form.

4.9.2 Alkalinity (use Taylor test kit)

1. Rinse and fill large comparator tube to 25 ml make with water to be tested.
2. Add 2 drops R-0007. Swirl to mix
3. Add 5 drops R-0008. Swirl to mix. Sample should turn green
4. Add R-0009 dropwise. After each drop, count and swirl to mix until color changes from green to red.
5. Multiple drops in step 4 by 10.Then, record as part per million (ppm) total alkalinity as calcium carbonate.

* When high TA is anticipated, this procedure may be used: Use 10ml sample, 1 drops R-0007, 3 drops R-0008 and multiply drops in step 4 by 25.

4.9.3 Chlorine test (Use Taylor test kit) (only for systems including chlorination)

1. Rinse and fill large comparator to desired mark with water to be tested.

Note: for 1 drop=0.2ppm, use 25 mls sample. For 1 drop=0.5ppm, use 10 mls sample.

2. Add 2 dipper R-0870. Swirl until dissolved. Sample will turn pink if chlorine is present.

Note: If pink color disappears, add R-0870 until color turns pink.

3. Add R-0871 dropwise, swirling and counting after each drop, until color change from pink to colorless.
4. Multiply drops in step 3 by drop equivalence (Step1). Record as part per million free chlorine (FC).
5. Add 5 drops R-0003. Swirl to mix. Sample will turn pink if combined chlorine is present.
6. Add R-0871 dropwise, swirling and counting after each drop, until color change from pink to colorless.
7. Multiply drops in step 6 by drop equivalent (Step 1). Record as ppm combined chlorine (CC).

4.9.4 Ph Test (if pH meter is not calibrated and occasional to check consistency)

1. Rinse and fill large comparator tube to 44mls mark with water to be tested.
2. Add 5 drops R-0004. Cap and invert to mix.
3. Match color with color standard. Then, record as pH units and save sample if pH needs adjustment. If sample color is between two values, pH is average of the two. To lower pH: go to acid demand test. To raise pH: Go to base demand test.

Acid Demand Test:
Use treated sample from pH test.
Add R-0005 dropwise. After each drop, count, mix and compare with pH color standards unit desired pH is matched. See treatment table to continue.
Base Demand Test:
Use treated sample form pH test.
Add R-0006 dropwise. After each drop, count, mix and compare with color standard until desired pH is matched. See treatment tables to continue.

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5.0 Data management

5.1 Chain of Custody Forms

The appropriate chain of custody form shall be used for all sample collections. Samplers shall sign when the cooler is relinquished to the shipper. The laboratory attendant shall sign when the cooler is delivered by the shipping agent. The Chain of Custody Form insures accountability for sample integrity. Copies of the chain of custody forms shall be retained during the period of sampling and analysis.

The approved laboratory shall provide a chain of custody form which includes the name of analytes, time of sample collection, time of receipt at lab, laboratory address, sample type, temperature upon arrival to the lab ect…

5.2 Laboratory methods

This grant agreement requires that the selected laboratory is NELAP certified. To verify that selected laboratory meets these requirements a current certification number will be obtained from each lab and documented on appropriate chain of custody.

The laboratory methodology numbers will be determined by selected lab and identified on the chain of custody form.

Depending on laboratory analyses results an alkalinity sample may be collected and tested. If an analyte is detected at greater than the detection limit and/or 10 percent of a quantified project sample, a reanalysis will be required.

This will not be a routine test and will be subjected to approval from DEP and the RRAC committee.

5.2.1 Transport *samples to the Laboratory*

Prior to collecting sample ice will be purchased and periodically throughout the day to ensure adequate cooling temperature is maintained.

The influent and effluent grab sample shall be sent to be analyzed for the following analytes: CBOD5, TSS, TN, TP, and Fecal Coliform.

If contract lab is within 30-50 miles, all samples will be transported to there. If a lab for fecal coliform is readily accessible (e.g. within 20 miles), fecal coliform samples will be transported to there to ensure holding time requirement of 6 hours for the fecal coliform. Other samples will be shipped to the contract lab.

The laboratories will provide a cooler kit which includes the following: sample bottles with affixed labels, approved additives, chain of custody and appropriate ice cooler.

Additionally, the affixed label from the lab should include the following annotation:
Influent/ effluent
Grab sample
Duplicate
Field blank
Sampling date and time

Table 2. Laboratory Parameters

Parameter	Method	Method Detection Limit	Laboratory	Holding time	Preservative
CBOD5	SM 5210B	2.0 mg/L	Various	48 hours	none
TSS	EPA 160.2	2.0 mg/L	Various	7 days	none
TN	Calculated	1.0 mg/L	Various	28 days	H2SO4
TP	EPA 365.4	0.15 mg/L	Various	28 days	H2SO4
Fecal Coliform	SM 9222D	10CFU/100mL	Various	6 hours	Na2S2O3

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5.2.2 Laboratory Submissions

The influent and effluent grab sample shall be sent to be analyzed for CBOD5, TSS, TN, TP, and Fecal Coliform. Additional samples of alkalinity shall be submitted to the laboratory for analyses base on the discretions of the RRAC committee. The chain of custody forms will be annotated with the machines serial number.

6.0 Data Quality Objectives and Criteria for Measurement Data

Data Quality Objectives (DQOs) are the quantitative and qualitative terms used to describe how well the data need to be in order to meet the project's objectives. DQOs for measurement data (also known as data quality indicators) are precision, accuracy, representativeness, completeness and comparability. The overall QA objective for analytical data is to ensure that data of known and acceptable quality are provided. These are necessary attributes to ensure that analytical data are reliable, scientifically sound and defensible.

6.1 Precision

Analytical precision is a measurement of how far an individual measurement may deviate from a mean of replicate measurements. Precision is evaluated from analysis of field and laboratory duplicates and spiked duplicates. The standard deviation (SD), relative standard deviation (RSD), and/or relative percent difference (RPD) recorded from sample analyses are methods used to quantify precision. RPD should be <20% or better. RPD is calculated by the following formula:

$$RPD= [(C1-C2])/ (C1+C2)/ 2] X 100\%$$

Where: C1= concentration of compound or element in the sample
C2= concentration of compound or element in the duplicate

Field duplicates of both influent and effluent samples will be collected one duplicate for every ten samples. The laboratory will run duplicate samples as part of the laboratory QA program.

6.2 Accuracy

Accuracy is the degree of agreement of measured value with the true or expected value of the quantity of concern. To ensure field accuracy instruments will be calibrated in accordance to manufacture suggestion, chemical used will be checked for expiration date, completion of chain of custody.

During the verification test, the laboratory will run matrix spike samples at a frequency of one spiked sample from every 10 samples analyzed. The laboratory will run an analysis on the laboratory control prior to testing samples.

6.3 Comparability

Comparability is a qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decisions to be made. Comparability shall be ensured by using standard sample collection, preparation and handling procedures. EPA-approved analytical methods and holding time, and by following QA/QC protocols. The data will be compared to determine the degree of differences in data being collected at these selected sites.

6.4 Representativeness

Representativeness is the degree to which data accurately and precisely represent a characteristic population, parameter at a sampling point, a process condition, or an environmental condition. The sampling location for the samples will be designed for easy access to help ensure that a representative sample of flow is obtained in each grab sample bottle. The laboratory will follow the set procedures in accordance to the good laboratory practices for homogenous mixing of grab container contents prior to sub-sampling in order to ensure a homogenous mix.

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and observation of the sample collection and review of operating logs maintained at the site

6.5 Completeness

Completeness is the percentage of valid results obtained compared to the total number of samples taken for a parameter. Completeness will be measured by tracking the number of valid data results against the specific requirements in the test plan. The anticipated number for valid result from analyses should be equal to or better than 85%.

7.0 DATA MANAGEMENT

7.1 Documentation and Records

Required documentation will include:
Registration of sample site in *approved* Access database
Chain of custody records for sample
Lab analysis report as filed by contracted laboratory manager

Copies of chain of custody records, laboratory reports, and other documentation will be submitted to the FDOH project manager for archiving. Upon completion of the review, a final report, including lab reports and chain of custody records will be archived at 4052 Bald Cypress Way Bin# A-08, Tallahassee, FL 32399 and submitted to the FDEP project manager.

7.2 Data Entry into MS-Access Database

A newly created statewide MS-Access database was created for this project. This database will be maintained on a server accessible to the Bureau of Onsite Sewage Programs. The database will be made available to the FDEP project manager at the end of the project, or as requested.

Information needed for data entry will be gathered from the laboratory results and field notes. Data entry for each sample event will be doubled checked by the project Technical Advisors or their assignees for accuracy and comparison. Any changes done during the quality check will be noted in the database.

Additionally, notes will be taken for each location and documented in a field notebook titled “319 Project”. A schematic of actual system installation will be drawn and a copy will be placed in the folder created for each system sampled. If unusual events are noted at a location they will be documented in the comment section of the database.

8.0 Testing and Measurement Protocols

8.1 Data Review

All data collected by this project is subject to review. This will allow for individuals or groups to determine if the data meet the Quality Assurance Project Plan (QAPP) objectives.

8.2 Data Integrity

Sampling chain of custody sheet must be filled at the time prior to delivery to the lab. Upon receipt, the lab will document the arrival time. This will ensure compliance with holding time requirements.

8.3 Data Entry

Data is then entered into the database described in section 5.2 which is designed to flag any values which fall outside of the expected range for each parameter.

9.0 Assessment/Oversight

9.1 Schedule of Audits

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The Research Review and Advisory Committee will review this QAPP and overall project design and may suggest procedural refinements or additional testing procedures. Any such change will be subjected to approval by the FDEP Project Manager and FDOH Project Manager. At least one lab audit will be performed during the testing by the FDOH representative.

9.2 Corrective Action

After initial review by the FDOH and the RRAC, a preliminary draft report will be provided to FDEP Project Manager. Any corrections to sampling locations, sample results, or collection information will be made to update the report. The corrected report shall be submitted to the RRAC and posted on the FDOH website.

Electronic copies of the lab reports, chain of custody records, field reports, and the final report from the sampling event shall be stored on FDOH data servers.

10.0 References

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16. YSI 556 MPS instruction Manual, retrieved from the worldwide web on November 13, 2009
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Appendix 1
Form 1-2 Operational Checklists: System evaluation (SE)

(This form is used for identification of the system design flow and to gather the operational checklists needed for conducting an O&M service visit.)

A. Client Contact Information

Name of owner:_____ System ref. #:_____Site address/County:_____

B. System Evaluation

2. Observation and assessment of the site (on lot and in neighborhood)
a. Evaluate presence of odor within 10 ft of perimeter of system:
☐ None ☐ Mild ☐ Strong ☐ Chemical ☐ Sour
i) Source of odor, if present: _____
b. Any surfacing or breakouts. Yes ___ No____
c. Any construction, utility work, or changes in drainage patterns. Yes ___ No____
d. Are all components present and not modified? Yes ___ No____
e. Are all lids at grade or on risers present and secure? Yes ___ No____
f. Traffic on onsite wastewater system. Yes ___ No____

3. Site status at conclusion of O&M service visit:
☐ Verify that controls are set on the appropriate mode.
☐ Power is on to all components.
☐ Revisit all components to verify lids are secure.
☐ Gather all tools for removal from the site.
☐ Verify that no sewage is on the ground surface.
☐ Service notification.
5.Alarm(s)
a. Alarm(s) present. Yes____No_____
b. Audio alarm operational. N.A.___Yes____No_____
c. Visual alarm operational. N.A.___Yes____No_____
d. Remote telemetry operational. N.A.___Yes____No_____
e. Electronic monitoring operational. N.A.___Yes____No_____

4. Comments:

5. Overall system condition:
☐ Acceptable ☐ Maintenance needed
☐ Unacceptable ☐ Maintenance performed
☐ Mitigation required

Company name: _____
Agreement period from: _____to _____

This report indicates the condition of the above onsite wastewater treatment system at the time of the O&M service visit. It does not guarantee that it will continue to function satisfactorily.

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Appendix 2

Form D-1 Residential evaluation survey (RES)

Name: _____ Date: _____ Time:_____

Address: _____ Phone: _____

Parcel #: _____ PM phone: _____

Designer: _____ Installer: _____

Home/Residents

1. Is this your first home with an on-site wastewater treatment system? YES / NO
2. Did you receive any septic system user information? YES / NO
3. Did you receive the as-built drawing for the system? YES / NO
4. Type of use: Permanent / Seasonal If seasonal, number of months used _____
   a. Number of people living in the home: Adults: ____ M ____ F
   b. Children: ____ M ____ F Teenagers: ____ M ____ F

c. Number of bedrooms: _____ Number of bathrooms: _____

5. Water supply: Private well / centralized system / other supply
6. Do you have an in-home business? YES / NO

f "yes", what type? _____

7. Is any resident using long term prescription drugs or antibiotics? YES / NO

ype _____

_____

_____

8. Do you use bath/skin oil/moisturizer? YES / NO

Use: _____times/week.

Do you use septic system additives?

YES / NO

If "yes", what products? _____

Appliances and cleaning products

10.Home equipped with water conserving fixtures/appliances? YES / NO

11.Garbage disposal? YES / NO Use: _____ times/day _____ times/week

12. Dishwasher used? YES / NO Use: _____ times/day _____ times/week

13.Laundry: Maximum _____ loads per day consecutive loads: YES / NO

Total _____ loads/week

a. Brand of laundry detergents used? _____ powder / liquid

b. Bleach used? YES / NO powder / liquid Use: _____ cups/load _____ loads/week

c. Hot or cold water used? _____

14.Whirlpool tub? YES / NO Use: _____ times/day _____ times/week

15.Is a drain cleaner used? YES / NO

Type: _____

Frequency of use: _____

16.Hand-washing soap brand? _____

Antibacterial? YES / NO

17.Number of rolls of toilet paper used per week? _____

18.Toilet cleaning product brand? _____

Cleanings/month _____

Continuous cleaner used in toilet tank?

YES / NO

19.Please list commonly used cleaning supplies:

Shower _____ Kitchen _____

Floors _____ Other: _____

20. Please list any antibacterial products:_____

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21. Water treatment device:
YES / NO
a. Is a water softener used? YES / NO
Back flushes to: _____
b. Reverse osmosis? YES / NO
Discharges to: _____

22. Air conditioner unit(s)? YES / NO
Condensate drains to: _____
23.Commercial ice machine? YES / NO
Condensate drains to: _____
24. Footing drains or basement sump pumps connected into the system? YES / NO
25. Is the pump working?
YES / NO
26.Chain of custody completed? YES / NO

Site Sketch (Sketch the system or attach record of construction (as-built)

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Scale 1” = _____ feet

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Appendix 3
Form 5-2 Operational Checklist: Septic, trash and processing tanks (STPT)

Service provided on: Date:_____ Time:_____ Reference #:_____
Service provided by: Company: _____ Employee:_____
Date of last service: _____ By: ☐ You ☐ Other:_____
Date of last inspection: _____

1. Type:
   ☐ Septic tank ☐ Trash tank
   ☐ Processing tank ☐ Pump vault present
2. Conditions at the tank
   a. Evaluate presence of odor within 10 ft of perimeter of system:
      ☐ None ☐ Mild ☐ Strong ☐ Chemical ☐ Sour
   b. Source of odor, if present: _____
3. Tank description
   a. Material: ☐ Concrete ☐ Fiberglass ☐ Plastic
   b. Capacity: _____gal
   c. Compartmented. Yes ____No_____
   d. Capacities for compartmented system: 1)_____ gal 2) _____ gal
4. Tank access
   a. Access location: ☐ Inlet ☐ Outlet ☐ Center
   b. Located at grade. Yes____No_____
   c. If 'No', how deep is lid buried. _____
   d. Risers on tank. Yes____No_____
   e. Evidence of infiltration in risers. Yes____No_____
   f. Lids securely fastened. Yes____No_____
   g. Lid in operable condition. Yes____No_____
5. Current tank operating conditions
   a. Liquid level relative to outlet: _____in
      ☐ At ☐ Above ☐ Below
   b. Maximum liquid level of tank (invert of inlet pipe):_____in
   c. Height at which alarm is activated as measured from invert of inlet: _____in
   d. Evidence liquid level has been higher. Yes____No_____
   e. Evidence liquid level dropped without pumping. Yes____No_____
   f. Evidence of continuous inflow. Yes____No_____
   g. Date of last pump out:_____
   h. Presence of flocculants in clear zone. Yes____No_____
   i. Evaluation of layers in tank:

Compartment Number	Scum (in)		Clear Zone (in)		Sludge (in)		Odor	Other
	Depth	Color*	Depth	Color	Depth	Color		
1								
2								

*Color Choices: ☐ Clear ☐ Flocced ☐ Milky ☐ Muddy ☐ Grainy
☐ Black ☐ Brown ☐ Mustard ☐ Gray ☐ White

6. Tank pumping recommended. Yes____No_____
Reference #:_____

7. Baffles currently structurally sound. Yes____No_____
a. Inlet baffle in place. Yes____No_____
   b. Outlet baffle in place. Yes____No_____
   c. Compartment baffle in place. N.A. _____ Yes____No_____
   d. Effluent screen. Yes____No_____

NOTES

2. ☐ Acceptable
   ☐ Unacceptable

4. ☐ Acceptable
   ☐ Unacceptable

5. ☐ Acceptable
   ☐ Unacceptable

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Manufacturer:_____Model:_____

e. Is screen accessible from ground surface? Yes____No_____
f. If screened, percent plugged: _____%
g. Was screen cleaned? Yes____No_____

8. Tank structural condition (evaluate if tank pumped): N.A._____
   a. Appears to be watertight (no visual leaks). Yes____No_____
   b. Rebar exposed. Yes____No_____
   c. Corrosion present. Yes____No_____
   d. Sapling present. Yes____No_____
   e. Cracks present. Yes____No_____
   f. Root intrusion. Yes____No_____
   g. Deflection noted. N.A.___Yes____No_____
9. Contractor responsible for pumping: _____
   a. Gal removed: _____ Date:_____
10. Lab samples collected for monitoring. Yes____No_____
    Types of analysis:_____
    _____
    _____

    f. Recirculation changed to:_____
    *If dam configuration, recirculation device cannot be inspected or cleaned
11. Additional tasks for trickling filters
    11.1 Clarification chamber
    a. Solids blanket below recirculation pump inlet. Yes____No_____*
    *If no, was system pumped out. Yes____No_____
    b. If screened inlet, was screen cleaned. Yes____No_____
    11.2 Sludge return
    a. Solids blanket slightly above return pump. Yes____No_____
    b. Changed solids return rate. Yes____No_____
       i) Pump: ☐ Off ☐ On
       ii) Changed from ____ min to ____min
12. Manufacturer's required maintenance performed. Yes____No_____
    (If 'Yes', attach Manufacturer Inspection form to this report, if supplied)
13. Lab samples collected for monitoring. Yes____No_____
    Types of analysis:_____
    _____
    _____

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Appendix 4

Form FD9000-8 **CALIBRATION LOG (FDEP SOP FT 1000-FT 1500, FD 1000-FD 400**

Project/Site: _____

Temperature (Quarterly) *For Date of Last Temperature Verification see* _____ *in log book* _____

Dissolved Oxygen	**DEP SOP FT 1500**	Initials	Date	Time	Probe Charge	Probe Gain
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						

Specific Conductance	**DEP SOP FT 1200**	Initials	Date	Time	Standard *µmhos/cm*	Exp. Date
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						

pH	**DEP SOP FT 1100**	Initials	Date	Time	Standard SU	Exp. Date
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						
CAL ICV CCV						

Maintenance: Weekly pH Slope: _____ Specific Conductance Probe Cleaned? Yes No Dissolved Oxygen

Notes:

Perform only in Calibrate Mode: **CAL** - Calibrate -

Perform only in **CCV** - Continuing

		Run Mode:	Calibration Verification
Perform only in Run Mode:	**ICV** - Initial Calibration Verification		

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Florida Department of Health
Bureau of Onsite Sewage Programs
Research Review and Advisory Committee Meeting

DATE AND TIME: **December 16, 2009 at 9 am**

PLACE: **via Conference Call:** 1-888-808-6959
Conference Code: 1454070#

Or
Florida Department of Health Southwood Complex
4042 Bald Cypress Way; Room 240 P
Tallahassee, FL 32399

This meeting is open to the public

AGENDA: FINAL

1. Introductions and Housekeeping
2. Review Minutes of Meeting September 10, 2009
3. Department's Interim Report on Nitrogen Reduction Strategies Study: Review, Comment, and Next Steps
4. Nitrogen Reduction Strategies Study: Comment on Deliverables and Next Steps
5. Section 319 Study Update: Comment on Proposed Sampling Plan
6. Manatee Springs Study: Comment on Final Report
7. Other Business
8. Public Comment
9. Closing Comments, Next Meeting, and Adjournment

Roeder, Eberhard

From: Roeder, Eberhard
Sent: Wednesday, December 09, 2009 12:54 PM
To: Roeder, Eberhard
Subject: Comments on technology classification, ranking and prioritization report
Attachments: 091207 Nitrogen Reduction.xls

From: Pio Lombardo [mailto:Pio@lombardoassociates.com]
Sent: Tuesday, December 08, 2009 3:41 PM
To: Roeder, Eberhard
Cc: Briggs, Gerald R; danderson@hazenandsawyer.com; Ursin, Elke; Booher, Paul W; soakley@csuchico.edu; jkreissl1@insightbb.com
Subject: RE: Next RRAC Meeting Announcement: December 16th

Eberhard

In reference to the attached Criteria 13 Stage of development, Heterotrophic Denitrification systems are permitted in the States of MA, FL, RI, MD, VA, NY, NC, CA, OR and AZ, so it should be classified as national use. Autotrophic denitrification should be classified as experimental. Again the opinions of other experts should be solicited

Also such a low, virtually meaningless weighing factor for Stage of Development should be revised upward significantly - at least by a factor of 10. It has a storing appearance that the authors are favoring ("stacking the deck") the system they originally proposed with their weighing factors

Furthermore, many of the scores for autotrophic systems are based upon extremely limited real world data vs the real world data of heterotrophic systems

Lastly, a category of environmental impact would be appropriate

Regards,

Pio

Pio Lombardo, P.E.

Lombardo Associates, Inc.
Environmental Engineers/Consultants

Tel: 617-964-2924
Cell: 617-529-4191
Fax: 617-332-5477
Email: Pio@LombardoAssociates.com

From: Pio Lombardo
Sent: Monday, December 07, 2009 03:47
To: 'Eberhard_Roeder@doh.state.fl.us'
Cc: Gerald_Briggs@doh.state.fl.us; danderson@hazenandsawyer.com; Elke_Ursin@doh.state.fl.us; Paul_Booher@doh.state.fl.us; soakley@csuchico.edu; jkreissl1@insightbb.com
Subject: RE: Next RRAC Meeting Announcement: December 16th

Thank you for your astute observations Eberhard

While Florida permitting may not have been a criterion definition, it is respectfully suggested that it should be at least noted which ones are already permitted, as there is no need to hide the information. Also the information assists in evaluating which options are "ready for prime time"

In my opinion there are inherent serious difficulties-weaknesses with ranking systems that have subjective scoring and subjective weighing factors. I am not a fan of them - as it is difficult to achieve transparency and reproducibility. Also the additional "optics" challenge exists with the highest ranked system being "developed" by the evaluators and is being pursued prior to the ranking.

Perhaps the ranking effort should be supplemented with evaluations by a select group of unaffiliated experienced, well respected practioners - a number of very competent people come to mind including Professor Stewart Oakley, Professor George Tchobanoglous and retired US EPA small flows technical specialist Jim Kreissl. There may be extensive disputes on weighing factors and criteria for points. In my opinion however subjective ranking tends to get overly academic and disassociated from the real world, which is driven predominately by treatment requirements and costs.

With the weighing factors used, the stage of development have such a meaningless impact on the ranking - while in reality it is critical in terms of risk & uncertainty elimination. As I have previously commented on many of the items and issues, I will not repeat them.

In terms of screening, the overwhelming preponderance of the evidence in other parts of the US and recent legal decisions for FL is that the stringent numeric TMDL requirements and then cost effectiveness should be the screening/ranking factors. This approach is totally objective, transparent and reproducible. While draft numeric effluent requirements are to be established in FL in the next 2+/- months, it is fairly obvious what they are likely to be based upon TMDL studies in other parts of the US and an understanding of FL water resources. Whatever placeholder values are used can be refined when the rules are issued.

1. Treatment Requirements

Water quality based

In environments similar to FL, on-site systems need to achieve extremely low TN levels comparable to enhanced nutrient removal central sewer systems, typically TN < 5 mg/l based upon TMDL requirements. In many New England areas, on-site systems are dismissed if they cannot achieve this performance requirement. So the ranking criteria should have TN < 5 mg/l as one of its reference points.

Drinking water aquifers

Require TN < 10 mg/l - even though some areas rely on dilution to achieve TN < 10 mg/l many areas simply require effluent TN < 10 mg/l

2. Cost effectiveness analysis

Life cycle Cost/lb-day N removed should be the ranking criteria. This is the standard engineering approach for optimizing cost effectiveness and has been used for comparing nitrogen removal technologies - including on-site systems in other parts of the US - especially Chesapeake Bay

Then only systems capable of achieving specified TN requirements would be ranked based upon cost effectiveness and then the other "soft" factors included in the ranking report. This approach then becomes very useful for political leaders, the public and practioners in determining which technologies are appropriate for areas with specific treatment requirements as well as where research opportunities exist - transparency and reproducibility then exists.

This approach is identical to what is performed for centralized wastewater treatment systems in which only technologies capable of achieving required levels are examined. One does not comingle technologies that do not have required performance capabilities with those that do. For example one does not place an extended aeration activated sludge plant in the same nitrogen removal category as a membrane bioreactor or biological nutrient removal process. Comingling obfuscates the important issues that need to be addressed

Additional comments below. Thank you for the opportunity to comment

Regards,

Pio

Pio Lombardo, P.E.

Lombardo Associates, Inc.
Environmental Engineers/Consultants

Tel: 617-964-2924

Cell: 617-529-4191
Fax: 617-332-5477
Email: Pio@LombardoAssociates.com

From: Eberhard_Roeder@doh.state.fl.us [mailto:Eberhard_Roeder@doh.state.fl.us]
Sent: Friday, December 04, 2009 04:02
To: Pio Lombardo
Cc: Gerald_Briggs@doh.state.fl.us; danderson@hazenandsawyer.com; Elke_Ursin@doh.state.fl.us; Paul_Booher@doh.state.fl.us
Subject: RE: Next RRAC Meeting Announcement: December 16th

Pio,

thank you for your comments.

It looks to me that there are two, not necessarily mutually exclusive, documents where your concerns could be discussed: The ranking report and the interim study report.

Within the ranking report, stage of technology development received a very low weighting factor, and the report's authors assigned the same score of "3" to hetero- and autotrophic denitrification 2-stage systems and the soil

infiltration with reactive barriers, and "5" to all other ranked technologies. Your argument appears to be at least in part that these scores don't reflect the differences in technology development that you see.

Absolutely, as the hetero-denitrification option is permitted in numerous states, has numerous installations that have been operating for years and has been evaluated by numerous independent parties - so it is well beyond demonstration. I know of no full scale operating systems for the autotrophic denitrification so it appears to be more experimental, as it has not been demonstrated in the real world yet. University of Massachusetts recent efforts in this regard have not proved fruitful as well as the environmental impact issue of sulfate additions with autotrophic denitrification to ground and surface waters is a serious matter taht should be an evaluation factor. Other researchers have opined to that issue being a fatal attribute of autotrophic denitrification

It is also apparent, and in agreement with the criterion definition, that Florida permitting considerations were not important in this approach.

So one question is how to bring the Florida-specific considerations into the discussion, and the other if and how broader agreement on scores can be achieved.

That seems like a good topic for the RRAC-meeting.

Damann's group may have some thoughts on that, too.

You are correct in reading that the test center experiments are anticipated to start before field testing at home sites. There could be some concurrency between the testing of home sites with ongoing test center experiments, details to be determined by the task B QAPP.

Regards,

Eberhard

From: Pio Lombardo [mailto:Pio@lombardoassociates.com]
Sent: Thursday, December 03, 2009 6:31 PM
To: Roeder, Eberhard
Cc: Briggs, Gerald R; danderson@hazenandsawyer.com
Subject: RE: Next RRAC Meeting Announcement: December 16th

Hello Eberhard,

It is respectfully suggested that Table 4.7 of Technologies Recommended for Testing in Task B of the Classification, Ranking and Prioritization Of Technologies Report (copy attached) include a column that indicates if the technology is currently approved in the State of Florida and if so permit information, and technology name - for the general populace

It is expected that non wastewater management professionals and the general public would want to know that information as it is expected that few will understand the generic terminology used. Also it is expected that it would help the Department and legislature to determine the status of technology development to decide where future funds would be best served.

As you and the project team know, of the two equivalently top ranked systems:

Type 1 Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) with Stage 2: Autotrophic denitrification with reactive media biofilter

- Top ranked system capable of meeting the lowest TN concentration standard. Suitable for new systems or retrofit

Type 2 Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) with Stage 2: Heterotrophic denitrification with reactive media biofilter

- Top ranked system capable of meeting the lowest TN concentration standard. Suitable for new systems or retrofit

The type 2 system is our FL DoH approved NitrexTM while, as I understand it, the Type 1 is the system developed in the earlier phases of the project and the technology has not been tested sufficiently to determine permit ability

Consequently we would naturally desire to have the Type 2 system will be field tested. As I have not been contacted in this regard and based upon my brief review of project documents, I am concerned that funds are solely being used to develop a technology, with risks, when one capable of achieving the study objectives already exists, is permitted in FL and has numerous real world installations operating for years.

Please advise. Am I misreading the documents and situation?

Sincerely,

Pio Lombardo, P.E., DEE

Lombardo Associates, Inc.
Environmental Engineers/Consultants
49 Edge Hill Road
Newton, MA 02467
Tel: 617-964-2924
Fax: 617-332-5477
Cell: 617-529-4191

Email: Pio@LombardoAssociates.com
Web Site www.LombardoAssociates.com

INTERIM STUDY AND REPORT ON NITROGEN REDUCTION STRATEGIES FOR ONSITE SEWAGE TREATMENT AND DISPOSAL SYSTEMS

Draft 12/03/2009
Target date February 1, 2010

By Eberhard Roeder

Bureau of Onsite Sewage Programs
Florida Department of Health

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EXECUTIVE SUMMARY

This report is submitted in compliance with Line Item 471 Section 3, Conference Report on Senate Bill 2600, General Appropriations Act for Fiscal Year 2009-2010. The item tasks the Florida Department of Health (FDOH) to continue and complete a study on passive strategies for nitrogen reduction that the legislature had authorized the previous year, and to submit an interim study and report on February 01, 2010, and a final study and report on May 01, 2010. The bill requires the report to include recommendations on passive strategies for nitrogen reduction that complement use of conventional onsite wastewater treatment systems.

The authorization in 2008 provided funding for Phase I of an anticipated 3-year project to develop passive strategies for nitrogen reduction that complement use of conventional onsite wastewater treatment systems. Within the task for the department, there were three particular areas of concern identified: (1) Quantification of life-cycle costs and cost effectiveness of passive nitrogen reduction treatment technologies in comparison to more active technologies and to conventional treatment systems. (2) Characterization of nitrogen removal from effluent in the soil underneath the drainfield and in shallow groundwater. (3) Development of simple models to describe the fate and transport of nitrogen from onsite sewage treatment and disposal systems.

FDOH and its Research Review and Advisory Committee (RRAC), with input from the general public, solicited proposals and selected a contractor in late 2008 and the contract was executed in January of 2009. As of late 2009, the contractor, in coordination with RRAC and FDOH, has completed literature reviews, developed criteria and prioritized nitrogen reduction technologies for field testing, designed test facilities for further development of passive technologies and plume monitoring, and prepared quality assurance documents for the anticipated subsequent work to be completed during the fiscal year 2009-2010. Installation of a test center for the evaluation of nitrogen reduction techniques and preparation for field sampling is planned for later in the fiscal year 2009-2010. Sampling and reporting of results would continue through subsequent years. Funding for fiscal year 2010-2011 is required to reap the benefits of this preparation. The report following summarizes the work completed.

Recommendations for passive strategies for nitrogen reduction have not been a strong focus of the completed work.

FDOH and its Research Review and Advisory Committee recommend the Legislature:

- Provide funding and budget authority to FDOH in the amount of $2 million for the fiscal year 2010-2011 for continuation of the contract and associated tasks.
- Allow FDOH to carry over any remaining funds from fiscal year 2009-2010 into fiscal year 2010-2011.

Comment: The following are for the purposes of discussion, and so far only my (E. Roeder) ideas.
While the technology evaluations are ongoing, the information to date appears sufficient to consider recommendations to address the following issues:

- in nitrogen sensitive areas, requiring lower sewage system densities or better treatment than currently allowed. For example, the current allowances for lots platted before 1972 provide for approximately five houses per acre for parcels served

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by private wells and eight houses per acre for parcels served by public water systems.

- allowing the use of performance-based treatment systems for establishments other than single family residences without the need for a variance.

- developing regulations for entities that operate and maintain shared treatment systems (clusters) treating sewage flows within the department's jurisdiction and/or serving an establishment on multiple parcels. This should include requirements for financial assurance, obligations of property owners, and rate setting.

- identifying funding and cost sharing mechanisms to implement inspection, maintenance or upgrade programs to existing onsite sewage systems

- establishing a task force for the study and development of water quality requirements, performance, approval, operation, maintenance and inspection standards for wastewater reuse treatment and waste separation systems, including those that would be constructed within buildings, and delineating the jurisdictional boundaries between the Building Authorities and the Department of Health for such systems.

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1 INTRODUCTION

1.1 Legislative Language

This report is submitted in compliance with Line Item 471 in Section 3, Conference Report on Senate Bill 2600, General Appropriations Act for Fiscal Year 2009-2010. The language instructs:

> "From the funds in Specific Appropriation 471, $540,000 from the Grants and Donations Trust Fund is provided to the department to continue and complete the study authorized in Specific Appropriation 1682 of chapater (sic) 2008-152, Laws of Florida. The report shall include recommendations on passive strategies for nitrogen reduction that complement use of conventional onsite wastewater treatment systems. The department shall submit an interim study and report on February 1, 2010, and a final study and report on May 1, 2010, to the Governor, the President of the Senate, and the Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities."

The instructions refer to a study that was previously authorized by the legislature. This study was based on budget language in 2008 that instructed:

> "…the Department of Health to further develop cost-effective nitrogen reduction strategies. The Department of Health shall contract, by request for proposal, for Phase I of an anticipated 3-year project to develop passive strategies for nitrogen reduction that complement use of conventional onsite wastewater treatment systems. The project shall be controlled by the Department of Health's research review and advisory committee and shall include the following components: 1) comprehensive review of existing or ongoing studies on passive technologies; 2) field-testing of nitrogen reducing technologies at actual home sites for comparison of conventional, passive technologies and performance-based treatment systems to determine nitrogen reduction performance; 3) documentation of all capital, energy and life-cycle costs of various technologies for nitrogen reduction; 4) evaluation of nitrogen reduction provided by soils and the shallow groundwater below and down gradient of various systems; and 5) development of a simple model for predicting nitrogen fate and transport from onsite wastewater systems. A progress report shall be presented to the Executive Office of the Governor, the President of the Senate and the Speaker of the House of Representatives on February 1, 2009, including recommendations for funding additional phases of the study."

Both instructions refer to nitrogen reduction and passive technologies or strategies for onsite sewage treatment and disposal systems. The following sections discuss several terms that are important for this study.

1.2 General Background

Protection of public health and the environment is the mission of the Onsite Sewage Program of the Florida Department of Health (FDOH). Onsite Sewage Treatment and Disposal Systems (OSTDS) are a permanent solution to wastewater treatment in many locations throughout the State of Florida. In Florida, an estimated 2.3 million OSTDS are in use statewide, serving approximately a third of the population. They create one of the largest artificial ground water

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recharge sources in the state. Ninety percent of the water used for drinking comes from ground water. It is necessary to protect this resource to protect public health and the environment.

Excessive nitrogen can have negative effects on public health and the environment. The primary impetus for this study is the increased level of nitrogen in the environment. Increased amounts of nitrogen in surface water bodies can cause eutrophication, which can lead to detrimental effects to sensitive aquatic ecosystems. Nitrogen sources to the environment include: atmospheric deposition; fertilizer from both agricultural and residential land uses; livestock wastewater; municipal wastewater treatment systems; onsite sewage treatment and disposal systems; and stormwater. The combination of these sources adds up to a cumulative nitrogen load to ground and surface waters. As land uses change and the population and the number of onsite systems increase, the relative contribution of onsite systems to nitrogen sources in an area may change.

Various investigators have evaluated the relative contribution of onsite systems to cumulative nitrogen impacts in specific watersheds and discussed opportunities to reduce this contribution. The department has been most involved in such efforts in the Wekiva Study Area and has provided reports on nitrogen and onsite systems to the Governor in 2004 and 2007. An increasing motivation for such evaluations is the need to maintain and restore water bodies to their designated uses, implemented through the total maximum daily load program of the Florida Department of Environmental Protection.

The 2008 legislative language addressed these concerns over the management of impacts from nitrogen from onsite systems on Florida's waters by providing initial funding for a research project. In the same line item, the legislature requested a report on an inspection program to address ongoing maintenance of conventional onsite systems and an inventory of onsite systems in Florida. The 2009 legislative language instructs the department to submit recommendations for passive strategies for nitrogen reduction based on the work accomplished during the project.

1.3 Discussion of Terms

Florida has been a leader in the field of onsite wastewater treatment and disposal system (OSTDS) practices. Conventionally, OSTDS consist of a septic tank and a drainfield. Onsite system construction and use standards in the State date from 1921. A major revision occurred in 1984 from which time onward all drainfields in new onsite system construction had to be installed to provide two feet of separation from groundwater. Figure 1-1 illustrates a conventional onsite system. Research in Florida and elsewhere has shown that OSTDS installed to these modern standards effectively reduce the concentration of pathogens found in normal wastewater, but that nitrogen levels are only reduced to a limited extent.

Mass vs. Concentration of Nitrogen

Mass and concentration of nitrogen in sewage will influence the working of a nitrogen reduction system. The mass of nitrogen to be treated by an onsite system depends on the diet, number, and life patterns of users. On a per capita basis, data allowing estimates of the annual mass of nitrogen leaving septic tanks in Florida have resulted in a range from 7 to 15 lbs of nitrogen per person, with a mid-range value of 11 lbs per capita and year. This estimate is also between the median and mean value of a recent national study including systems from Florida.

The concentration of nitrogen in sewage depends on the mass of nitrogen generated and the amount of water it is diluted with. The water usage is again variable and influenced by socioeconomic status. Studies in Florida in the 1980s and 1990s, on which current regulations

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are based, indicated that a typical total nitrogen concentration was just under 40 mg/L. Studies in the last few years suggest that typical concentrations have increased to 60 mg/L or even 80 mg/L.
While the concentrations appear to have increased, the mass loading of total nitrogen does not appear to have increased, which is consistent with water conservation as the main cause of the concentration increase. From the perspective of environmental impacts it appears more meaningful to refer to reductions in mass loading rather than particular concentration values, and most of this report does so.

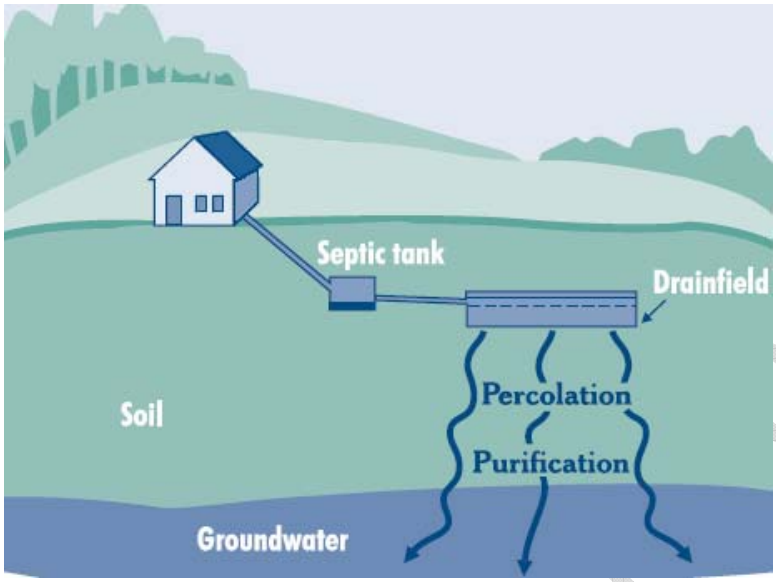

Figure1-1. Conventional onsite sewage treatment and disposal system (aka septic system) (from http://www.epa.gov/owm/septic/pubs/homeowner_guide_long.pdf)

"Advanced" Treatment Systems
Where local regulations require more treatment or where relatively small lots make it difficult to install a conventional system, more advanced treatment options exist. Aerobic treatment units add air to the sewage so that food can be digested before the sewage enters the drainfield. A more general permitting category is labeled performance-based treatment systems. For the purposes of this study the definition is a condensed version of the regulatory definition:

> **PBTS**: Performance Based Treatment System, a type of OSTDS that has been designed to meet specific performance criteria for certain wastewater constituents as defined by 64E-6.025(10) FAC

It should be noted that nitrogen is only one of the possible constituents in wastewater that can be addressed by performance-based treatment systems. Technologies used in a performance-based treatment system can have a range of complexity and energy intensity. Under current market conditions, most technologies used in performance-based treatment systems have been based on aerobic treatment units and include active aeration whereby air is blown into the sewage.

The department had undertaken in 2007-2008 a study on passive technologies for nitrogen removal. The definition used in that study and since then for "passive" is:

> **Passive**: A type of onsite sewage treatment and disposal system that excludes the use of aerator pumps and includes no more than one effluent dosing pump with mechanical and moving parts and uses a reactive media to assist in nitrogen removal.

Two elements are of significance in this definition: It excludes some approaches (aerator pumps) to achieving aeration, one of the processes included in sewage treatment; and it requires a particular approach (reactive media) for nitrogen removal, another process in the treatment of sewage. These elements are based on an understanding that nitrogen removal from wastewater generally occurs in two steps. In a first nitrification step associated with aeration, the nitrogen is converted to nitrate. In a second denitrification step, which occurs without air (anoxic conditions), the nitrate is converted to nitrogen gas that then leaves the sewage. Figure 1-2 illustrates the sequence of processes occurring in a passive system. The same processes can be achieved by other, less passive technological approaches, too. Table 1-1 characterizes the current relationships between conventional, performance-based treatment systems, and passive systems.

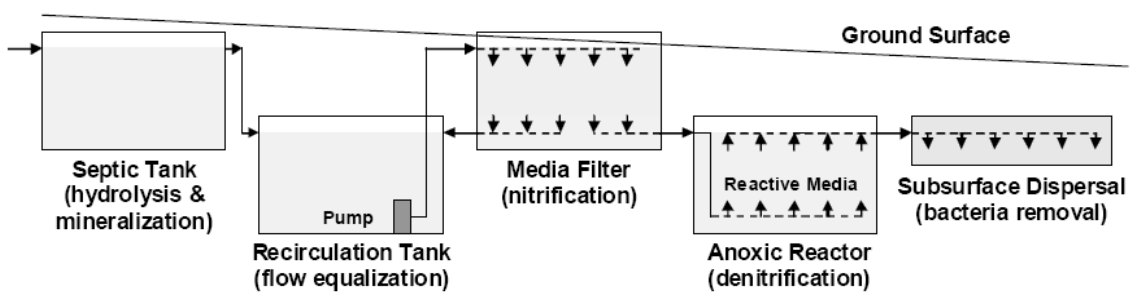

Figure 1-2. Sequence of processes in a passive system (Fig 4.9 of literature review for task A)

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Table 1- 1. Relationships between the terms conventional system, performance-based treatment system, and passive system for the purposes of this study.

Characteristic	**Conventional system**	**Performance-based treatment system**	
How important is nitrogen reduction in system?	Nitrogen reduction is coincidental	Nitrogen reduction is design goal	
Where does nitrogen reduction take place?	Nitrogen reduction limited in drainfield, site-specific	Denitrification integrated with aeration process	Additional, separate denitrification stage
What treatment processes beyond a conventional system are included?	Not included	Aeration by blowers	Not included
			Denitrification by dosing reactants
			Denitrification by reactive media
		Aeration by sewage flow over media	Not included
			Denitrification by dosing reactants
			Denitrification by reactive media

"passive system" for the purposes of this study

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2 PROGRESS OF THE MULTI-YEAR STUDY THROUGH NOVEMBER 2009

2.1 Contractor Selection

The legislation was passed and signed into law by the Governor on June 11, 2008. In cooperation with the RRAC, the department developed a request for proposals in the form of an invitation to negotiate (ITN) according to Florida Statute 287.054(3)(a). This ITN was advertised on September 26, 2008 as DOH 08-026 with the title "*Florida Onsite Sewage Nitrogen Reduction Strategies Study: Technology Evaluation, Characterization of Environmental Fate and Transport, and an Assessment of Costs*". Three teams submitted proposals. During the RRAC meeting on November 6, 2008 all proposals were ranked, and the proposal by the team led by Hazen and Sawyer was ranked highest.

The department invited the top-ranked team to begin negotiations. After several negotiation sessions during which aspects of the proposals were clarified and a more detailed scope of work defined, and review of the best and final offer, the department issued an intent to award letter on December 16, 2008, and the contract was executed on January 28, 2009.

The process from signing of the legislation to a completed agreement took approximately six months. This is comparable to the time requirements for soliciting and contracts for smaller projects in the past.

2.2 Summary of Scope and Status for the Multi-Year Study

The resulting contract for the study split the project into five main tasks:

- Task A: Technology Evaluation for Field Testing: Review, Prioritization, and Development
- Task B: Field Testing of Technologies and Cost Documentation
- Task C: Evaluation of Nitrogen Reduction Provided by Soils and Shallow Groundwater
- Task D: Nitrogen Fate and Transport Modeling
- Task E: Project Management, Coordination, and Meetings

For each of these tasks, the contract defines more detailed subtasks and their objectives. The contract anticipates progress by establishing particular milestones at which the gathered knowledge will be used to further refine subsequent work.

2.2.1 Task A: Technology Evaluation for Field Testing: Review, Prioritization, and Development

The objectives of Task A, Technology Evaluation for Field Testing: Review, Prioritization, and Development, are given in the following listing. Objectives that have been completely or partially accomplished are indicated in parentheses.

- Perform literature review to evaluate nitrogen reduction technologies (completed)
- Develop technology classification scheme (completed)
- Formulate criteria for ranking of nitrogen reducing technologies (completed)
- Rank and prioritize nitrogen reduction technologies for field testing (completed)
- Conduct technology ranking workshop with RRAC (completed)
- Prepare innovative systems applications
- Conduct Technology Development in Passive Nitrogen Removal Study II (50% design completed, quality assurance project plan draft completed)

2.2.2 Task B, Field Testing of Technologies and Cost Documentation

The objectives of Task B, Field Testing of Technologies and Cost Documentation, are:

- Indentify home sites and establish use agreements
- Establish vendor agreements
- Quality Assurance Project Plan
- Design and construct test facilities (50% design completed)
- Install field systems at test facilities and home sites
- Operate and monitor field systems
- Compile results in report format
- Provide technical description of nitrogen removal technologies
- Acceptance of systems by homeowners
- Conduct Life Cycle Cost Analyses
- Final Report for Task B

As these objectives build on the results of Task A, most of the work is anticipated for the future.

2.2.3 Task C, Evaluation of Nitrogen Reduction Provided by Soils and Shallow Groundwater

The objectives of Task C, Evaluation of Nitrogen Reduction Provided by Soils and Shallow Groundwater, are:

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- Critical characterization of nitrogen reduction in Florida soils and groundwater (completed)
- Develop Quality Assurance Project Plan (draft completed)
- Establish a controlled test facility (ongoing)
- Indentify home sites and make use agreements
- Instrument field systems at test facility and home sites (design of test facility 50% completed)
- Operate and monitor field systems
- Compile data in report format
- Close-out of home sites and controlled test facility
- Provide Final Report for Task C

2.2.4 Task D, Nitrogen Fate and Transport Modeling

The objectives of Task D, Nitrogen Fate and Transport Modeling, are:

- Literature review on fate and transport models (draft completed)
- Quality Assurance Project Plan
- Space time variable aquifer model with simplified soil treatment
- Development-scale aquifer model creation and calibration
- Space time variable model with complex soil treatment
- Development-scale model with aquifer and soil treatment
- Uncertainty analysis
- Validate and refine models using data from Task C
- Develop decision making framework
- Final Report for Task D

2.2.5 Task E, Project Management, Coordination and Meetings

The objectives of Task E, Project Management, Coordination and Meetings are:

- Conduct project kickoff meeting (completed)
- Prepare progress reports (four completed)
- Make presentations to Research Review and Adivisory Committee and Technical Review and Advisory Panel (one completed)
- Conduct Project Advisory Committee meetings

2.3 Expenditure Status

The proposed cumulative total funds anticipated to be spent on the contract with Hazen and Sawyer prior to the end of the 2009-2010 fiscal year are $760,000. Through October of 2009, Hazen and Sawyer has invoiced for deliverables valued at $312,000. The Department has spent about $25,000.through October of 2009 for four RRAC meetings in 2008 and five RRAC meetings in 2009, and other associated costs to discuss the scope of the project, to rank proposals, and to provide input into and updates on the project. It is anticipated at least quarterly RRAC meetings will be required to provide regular updates on the project.

2.4 Coordination with Advisory Committees of the Department

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Implementation of this study requires close cooperation with the department's Research Review and Advisory Committee (RRAC), which the legislature charged to control the study.

The Department's Research Review and Advisory Committee (RRAC) met first on July 30, 2008 in the Orlando area to discuss the project. One item of discussion was a clarification of roles between: the department that is to contract for the study, provide administrative support to the RRAC, review and accept the deliverables, and provide the report to the government; the RRAC which has been tasked with controlling the study; and the contractors that will perform the work, provide reports, and address comments. The RRAC voted unanimously that in controlling the study, RRAC will: rank proposals for contracts, review draft deliverables and provide comments, file a progress report, accept as completed the final report by contractors, and attach comments to the final report. The RRAC provided comments on the draft scope and directed department staff to proceed further with development of a solicitation.

Additional meetings of the RRAC took place on December 02, 2009, when the first progress report was discussed; January 5, 2009; February 3, 2009; May 27&28, 2009 when a workshop on prioritization of technologies for testing was held; July 1, 2009, September 10, 2009; and December 16, 2009

Department staff presented a status report on August 27, 2008 to the department's Technical Review and Advisory Panel (TRAP), which advises the department on onsite sewage rule making and policy per 381.0068 F.S. The TRAP voted to approve the project as presented to them and requested they be kept informed on the status of this project. The most recent update occurred at the TRAP meeting on August 27, 2009.

2.5 Anticipated Progress in Fiscal Year 2009/2010

The tasks associated with this project will have a significant amount of work completed prior to the end of the 2009-2010 fiscal year. The following paragraphs describe the anticipated progress.

For Task A, The design for the test facility has largely been completed and bidding, construction and beginning of testing are anticipated. The quality assurance project plan outlining details of this sub-project is currently being finalized.

For Task B, preparations for testing at individual homeowner sites will be dependent on anticipated funding in for subsequent years.

For Task C, A quality assurance project plan has been drafted to outline the monitoring framework for field sites and will be finalized. The monitoring approach takes a three-pronged approach: detailed monitoring, including of the vadose zone at small-scale drainfields at the test center; detailed monitoring of a large drainfield at the test center; monitoring of groundwater plume at home sites. The design for the test facility will be completed and monitoring commence. Home sites will be selected and agreements will be made with the homeowners. It is anticipated home sites will range across the State of Florida, including north Florida, central Florida (specifically the Wekiva area), and south Florida to capture diversity in site conditions. .

For Task D, a literature review of nitrogen fate and transport models will be finalized. A quality assurance project plan will be developed to outline steps required to develop a model capable of predicting nitrogen concentrations at a specified location downgradient from the wastewater

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source. A simple model of nitrogen transport from the drainfield through unsaturated soil to the groundwater will be developed. This model will likely use the approach of specifying removal fractions that are dependent on soil conditions and effluent quality.

3 SUMMARIES OF MAJOR COMPLETED MILESTONES OF STUDY

3.1 Task A Technology Evaluation for Field Testing: Review, Prioritization, and Development

A summary of the literature review findings and recommendations for application of nitrogen reduction strategies in Florida are provided in this section. Subsequent sections of this report include a technology classification scheme to allow comparisons of an array of technologies, a ranking scheme to allow relative rankings of technologies based on nitrogen reduction and treatment performance, system reliability and consistency, complexity of operation and maintenance, costs, aesthetics, and stage of development criteria, and a priority listing of the technologies for further testing and evaluation.

3.1.1 Literature Review (modified, edited and condensed from section 6 of literature review)

The goal of the *Florida Onsite Sewage Nitrogen Reduction Strategies Study* is to develop cost-effective strategies for nitrogen reduction by OSTDS. This literature review provides a review and critical assessment of available literature on nitrogen reduction practices, treatment processes and existing technologies that appear suitable for use in individual home and small commercial onsite sewage treatment and disposal systems (OSTDS). The review catalogued well over 600 papers, proceedings, reports, and manufacturers' technical materials regarding existing and emerging technologies.

3.1.1.1 Categories of Nitrogen Reducing Technologies

Many nitrogen reducing technologies are available for OSTDS applications. Available test results indicate that substantial variations exist between technologies. To simplify evaluation, the available technologies were grouped by the treatment processes used to achieve nitrogen reduction. Four major categories were identified: source separation, biological nitrification/denitrification, physical/chemical, and "natural systems". Each of these categories was broken down further based on distinct process variations within a group (see Figure 3-1). The most prevalent nitrogen reduction processes used for onsite sewage treatment were found to be biological nitrification/denitrification and natural systems. Significant overlap exists between these two process types.

Biological nitrification/denitrification treatment processes are typically contained in treatment vessels, which allow access to observe and modify operation.

"Natural systems" effect treatment from combinations of biochemical processes that occur within the soil matrix and vegetative uptake/evapotranspiration. Conventional onsite sewage treatment and disposal systems and constructed wetlands, which are designed based on mimicking ecological communities, are also included within this group.

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Physical/chemical processes, which do not rely on biological processes, are easier to control and are more consistent in treatment achieved but they require more operator attention and are more costly. Originally thought to be more effective for municipal treatment, they were mostly abandoned as biological processes became better understood and controlled.

Source separation on the other hand, is an emerging option for nitrogen removal. A promising practice is urine separation and recovery. Urine recovery can remove 70 to 80 percent of household generated nitrogen by installing urine separating toilets. If the infrastructure for urine collection and use as fertilizer is developed this offers an effective, reliable and easy to implement option that is low in cost compared to the other identified nitrogen reduction technologies. It also provides a readily available source of fertilizer rich in nitrogen and phosphorus.

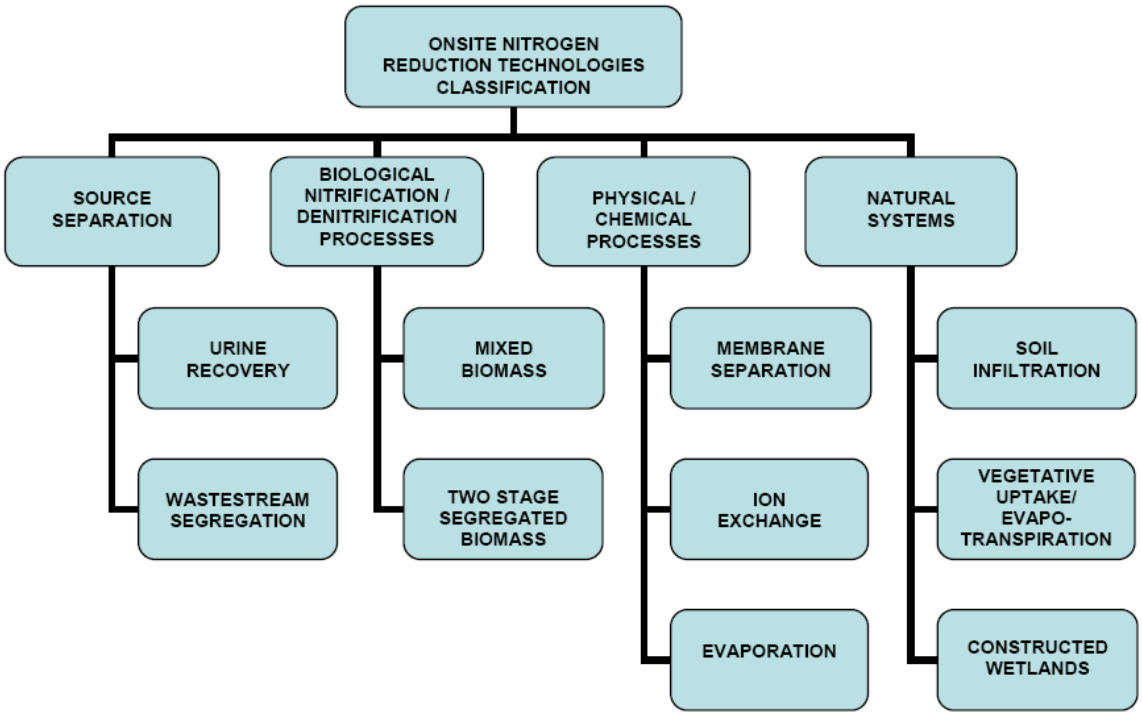

Figure 3-1. Categorization of treatment technologies for nitrogen reduction (Figure 4-1 of the literature review)

3.1.1.2 Process Performance

OSTDS technologies are available for most biological nitrification/denitrification and natural systems processes. The majority of technologies are proprietary but some public domain designs exist. Two large groupings of biological nitrification/denitrification processes are commonly used in these technologies; mixed biomass (single stage) and segregated biomass (two stage). The single stage process is the most frequently used process because it relies on organic carbon in the sewage to be the food or electron donor during denitrification as opposed to the two stage process, which requires an external source of food or electron donor. Nearly all of the treatment technologies designed for nitrogen removal can achieve close to 50 percent total nitrogen reduction but as removal requirements increase, fewer technologies are available. Figure 3-2 summarizes the performance capabilities.

The single stage process has been shown to achieve high removals of nitrogen in municipal wastewater treatment but for this process the amount of organic carbon reaching the denitrification stage in OSTDS appears to be limiting the amount of nitrogen reduction that can be achieved. This phenomenon can be seen in the performance of OSTDS that use different methods of carbon management in the system. Those nitrogen reducing OSTDS that rely on organic carbon released by dying microorganisms in the active biomass of the system typically achieve 40-60 percent total nitrogen removal while OSTDS that regularly recycle nitrified wastewater back to the anoxic septic tank to mix with organic carbon present in the raw wastewater typically achieve 60-80 percent total nitrogen reduction.

Segregated biomass or two stage processes, which do not rely on organic carbon in the system but rather add carbon or other food to the denitrification stage from an external source, can achieve nearly complete removal of nitrate by metering the carbon into the denitrification reactor based on the nitrate concentration it receives. Because of the intermittent flows and need for increased surveillance, a segregated biomass (two stage) biological nitrification/ denitrification process would be necessary where strict total nitrogen limits that require more than 70 percent removal prior to discharge to the soil.

Biological Denitrification Processes and Typical Nitrogen Reduction Limits of OSTDS

Process	Mixed Biomass (Simultaneous)	Mixed Biomass (with Recycle)	Segregated Biomass (Two Stage)
Electron Donor	Organic carbon from bacterial cells	Organic carbon from influent wastewater	External electron donor (Organic carbon; Ligno-cellulose; Sulfur; Iron, Other)
Typical N Reductions	40 to 65%	45 to 75%	70 – 96%
Typical Technologies	• Extended aeration[1] • Pulse aeration[2] • Recirculating media filters[3] • Sequencing batch reactors[4] • Reciprocating media beds[5] • Membrane bioreactor[6]	• Extended aeration with recycle back to septic tank • Recirculating media beds with recycle back to septic tank[7] • Moving bed bioreactor	• Heterotrophic suspended growth[8] • Heterotrophic packed bed fixed film • Autotrophic packed bed fixed film[9]

Figure 3-2. Biological Denitrification Processes and Typical Nitrogen Reduction Limits of OSTDS. (Table 5-3 of literature review)

Natural systems, which include the traditional OSTDS, also have inherent performance limitations. Application of septic tank effluent to unsaturated soil results in excellent cBOD and fecal coliform removals. However, nitrogen removals in conventional OSTDS are typically less than 40 percent. Soils with moderate to high hydraulic permeability with unsaturated (vadose) zones several feet deep below the system infiltrative surface are favored by the rules. Such soils are well aerated, which provide efficient and nearly complete nitrification of the influent nitrogen, but as the result of the aerobic soil atmosphere, the vadose zone is unable to retain organic carbon. If aerobic pretreatment and nitrification were to be provided upstream of the

infiltration system, slowly permeable soils, shallow organic soils, and soils with shallow perched saturated zones, which typically are restricted for OSTDS, would favor greater denitrification. Infiltration systems such as mound systems, which could be constructed above the ground surface with the soil's O and A horizons left intact, may provide nitrification through the sand fill and denitrification through the organic layers below, if anoxic.

Timed dosing of septic tank effluent with drip dispersal is a method that can enhance nitrogen reduction because of the wetting and drying cycles that occur below the drip emitters as a result of the intermittent dosing. The alternating aerobic and anoxic soil conditions in the presence of the carbon rich septic tank effluent results in nitrification and denitrification. However, if the timed dosing is set for the daily flow prescribed by rule rather than the actual daily flow, nitrogen reduction will be less. Soil infiltration systems, particularly those that use drip dispersal, can also be constructed to create large "footprints" parallel to the lot's contours, which reduce the mass of nitrogen loading per square foot of area to avoid unacceptable concentrations in the underlying groundwater. Like any of the natural systems though, carbon management is problematic and because the discharges are below the ground surface, compliance monitoring is difficult and costly. Therefore, OSTDS are usually only favored where strict nitrogen limits are not required.

3.1.1.3 Emerging Technologies

Few emerging technologies were identified in the literature. Most of those that were found have been variants to well-established processes. Others that could be considered new technologies for onsite treatment such as distillation or ion exchange are early in their development stages and are not yet proven effective.

The most promising new technology is urine recovery. This method of nitrogen reduction is already practiced in Scandinavia where urine separating toilets are commercially available. Implementation of this method of nitrogen reduction would be highly effective and far less costly if the necessary servicing and urine reuse infrastructure could be built and public objections to the idea of urine recovery could be overcome or avoided. In addition to ease of use and lower costs, urine recovery also has the added benefit of reducing phosphorus discharges.

3.1.1.4 Establishing Nitrogen Reduction Standards

The need for nitrogen reduction is not likely to be the same for all receiving environments. Therefore, because most nitrogen reduction options are more costly than traditional OSTDS, more complex, and require more attention to operate, the requirements for nitrogen reduction should be carefully considered. The considerations will result in the appropriate treatment requirement and the variations around that standard that will be allowed. Such an analysis should also consider the point of the standard's application. Several options exist. These include the end-of-pipe prior to discharge to the soil, the point below the system where the percolate enters the groundwater, at a property boundary, and/or at a point of use, e.g. a well, or a surface water. End-of-pipe points of application do not account for further treatment that might be attained in the soil. On the other hand, if the monitoring points are at poorly defined locations below the ground surface, compliance monitoring can be more costly and yield ambiguous results.

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3.1.1.5 Technology Selection

The variety of available nitrogen reduction technologies and performance capabilities allows selection of a system design that will best meet the particular site conditions and nitrogen reduction requirements established for the area. For example, where the density of housing is low and far from high value surface waters, natural systems, such as conventional OSTDS might be appropriate. In poorly drained soils or where the soil underlying the system contains organic matter, a component designed to nitrify the wastewater before discharging to the soil could be added. In areas where surface waters are not considered threatened but preventive measures are considered prudent, a technology using a mixed biomass nitrification/denitrification process that is capable of removing at least 50 percent might be most practical. In sensitive areas where protection of ground and surface waters is a high priority a two stage nitrification/denitrification process could be the only acceptable alternative.

3.1.1.6 Management and Enforcement

Implementation of nitrogen reduction technologies will expand the Department of Health's monitoring and enforcement operations and the owners' responsibilities toward their systems. Thought must be given to how nitrogen reduction standards are to be stated and how compliance monitoring is to be performed. Nitrogen reduction standards may be stated as concentration limits or as percent removals. Nitrogen reduction standards will require water quality sampling to confirm compliance. Alternatively, rather than water quality sampling, compliance could be based on proper technology section with processes that are known to meet the desired removal and routine maintenance and/or inspections to ensure the technology is functioning as intended. This latter approach to stating standards would likely be much less costly to monitor.

Monitoring of a sample of systems within the watershed rather than individual system monitoring to observe the aggregate impact of OSTDS on water resources could also be an effective alternative. Since impacts to watersheds have many sources and are tracked by multiple agencies, costs of monitoring could be shared between state and local water quality agencies.

Regardless of the choices made, system performance and maintenance tracking, inspections, monitoring and enforcement procedures should be available for deployment prior to permitting nitrogen reduction systems. Needed service provider qualifications and certification programs and sufficient service provider capacity also should be developed before system implementation. A public awareness program is also needed. Without these programs, requirements for nitrogen reduction systems are not likely to achieve the intended goals. In Florida, a regulatory framework developed for aerobic treatment units and performance based treatment systems exists already that addresses many of the needed requirements.

3.1.2 Technology Classification, Ranking and Prioritization of Technologies

(modified, edited and condensed based on A7/8/9 report)

3.1.2.1 Classification

The results of the literature review (discussed in section 3.1.1) led to development of a scheme for classifying nitrogen reduction technologies to allow comparisons between the many options that are available for use by onsite sewage treatment systems. This scheme consists of four categories for classification; source separation, biological treatment via nitrification/ denitrification, physical/chemical treatment, and natural systems (Figure 3-1). In most available onsite nitrogen reduction technologies, it is typical that more than one of these processes are operative in any given treatment

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system. The classification followed largely the pattern developed for the literature review (see figure 3-1).

3.1.2.2 Ranking Criteria

A simple numerical ranking system was developed to prioritize available nitrogen reduction systems based on thirteen selected criteria. Each criterion is scored against its particular attribute using a scale ranging from 1 to 5. To account for relative differences in significance of each of the criteria, the criteria are assigned weighting factors indicating relative importance, compared to the other criteria. The relative weights of the criteria were determined via a two stage process. First, each criterion was compared to every other criterion by the project team prior to the Technology Classification, Ranking and Prioritization Workshop and then by the RRAC at the workshop. Second, in order to reconcile the differences between the project team and RRAC weights, the weights for each criterion were averaged. Two criteria, construction and operational complexity, were added during the RRAC workshop. During subsequent discussions, RRAC concluded that the weight for energy requirements should be the same as for operation and maintenance cost.

The scoring systems were created with the full knowledge that data would not be universally available. Scores were made using the given criteria and good engineering judgment, based on the experience of the team where data was not available. Data available for classifications or groupings of technologies were gathered and reviewed by the project team. Given the wide variety of sources and scales, the resulting score was informed by the data but not necessarily based on a particular statistic (such as median or average) of the available data. In one particular way did the criteria depart from the results of the literature reviews: While the literature review summarized performance as a fraction of nitrogen removed, which accounts for the variability of nitrogen concentrations in untreated sewage, the ranking criterion focused on effluent concentrations regardless of the nitrogen concentrations in the influent of the treatment system.

More details on the individual criteria and how their scores were determined can be found in the report.

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Table 3-1. Ranking Criteria and Weighting Factors to evaluate technologies (Table 3-1 from classification, ranking, and prioritization report)

Ranking Criteria and Weighting Factors

Criterion Description	Maximum Score (S)	Weighting Factor (W)	Total Possible Score (S x W)
Effluent Total Nitrogen Concentration	5	11	55
Performance Reliability	5	10	50
Performance Consistency	5	9	45
Construction Cost	5	7.5	37.5
Operation and Maintenance Cost	5	7	35
Energy Requirements	5	7	35
Construction Complexity	5	5	25
Operation Complexity	5	5	25
Land Area Requirements	5	4.5	22.5
BOD/TSS Effluent Concentration	5	3.5	17.5
Restoration of Performance	5	3.5	17.5
System Aesthetics	5	2	10
Stage of Technology Development	5	0.5	2.5
			377.5

3.1.2.3 Ranking Results

A summary of the individual criterion scores for physical/chemical, biological, natural systems, and source separation technology classifications is presented in Tables 3.3. and 3.4 While the table encompasses the full range of possible systems contained in the classification, technology classifications that lacked sufficient data to make a criteria ranking determination were left blank. Technologies are summarized in broad categories. Scores for well established technologies reflect typical values from field installations, while scores for more experimental technologies tend to suggest the potential for the technology based on more controlled tests. In addition, the ranking of some of the technologies, in particular soil infiltration with reactive media, reflects the expectations of the project team extrapolated from other technologies more than available data.

The rankings did not include a conventional septic system. Such a system is likely to achieve a ranking slightly better than that of a dosed drainfield within the natural system category, based on lower construction and lower electrical costs.

Table 3-2. Score assignments for ranking criteria (Table 4-2 of report)

Criteria Number	Criteria	Score				
		1	2	3	4	5
1	Effluent Nitrogen Concentration (mg-N/L)	> 30	16 – 30	11 – 15	3 – 10	< 3
2	Performance Reliability	Monthly		Quarterly	Semi-Annually	Annually
3	Performance Consistency[1]	Activated Sludge Nite/Denite	IFAS[2]	MBR/IMB[3]	Fixed Film	Physical/ Chemical & Source Separation
4	Construction Cost[4] ($1,000's)	>20	16-20	11-15	5-10	<5
5	Operation and Maintenance Cost[5] ($/year)	>500	401-500	301-400	200-300	<200
6	Energy Requirement (kW-h/year)	>2500	1501-2500	1001-1500	500-1000	<500
7	Construction Complexity	Complex installation, specialized training, sophisticated electrical and controls knowledge req., master septic tank contractor		Some specialized knowledge and training required		Simple to install by any Contractor
8	Operation Complexity	Complex operation with operator training required; Scheduled visits by manufacturer's representative required > quarterly		Some specialized operator training required; Scheduled visits by manufacturer's representative required twice per year		Simple operation with limited operator requirements; annual scheduled visit
9	Land Area Required[6] (ft^2)	>2000	1001-2000	501-1000	250-500	<250
10	BOD/TSS Effluent Concentration (mg/L)	>50	30/30		20/20	10/10
11	Restoration of Performance[7]	Activated Sludge Nite/Denite	IFAS[2]	MBR/IMB[3]	Fixed Film	Physical/ Chemical & Source Separation
12	System Aesthetics	Not Acceptable		Perceived Nuisance/ Displeasing		Acceptable
13	Stage of Tech. Development	Conceptual	Experimental	Demonstration	State Use	National Use

The top ranked technology classifications (1 & 2) were biological systems with two stage segregated biomass employing autotrophic and heterotrophic denitrification. These systems are passive, require little operator attention, and provide high reliability. The total scores for autotrophic and heterotrophic denitrification technologies in two stage segregated biomass systems were sufficiently close that they were considered essentially equal. The third and fourth ranked technology classifications were mixed biomass fixed film biological systems with recycle and without recycle, respectively. The total scores for these systems were sufficiently close that they were considered essentially equal. These technology classifications have the stability advantages that are inherent in fixed film processes.

It is important to note that the natural systems should not be quantitatively compared, using these ranking criteria, to the groups of biological systems detailed in Tables 3.3 and 3.4. Primary among considerations supporting this division of technologies is the need to consider separately the elements, of each system, that perform treatment. The soil infiltration units utilize the soil's ecology and physical characteristics to perform treatment and all relevant data measures the treatment capacity within the soil pedon to reduce nitrogen. However, it must be kept in mind that the vast majority of biological systems also discharge to the soil. In order to be able to rank each technology fairly, only the nitrogen reduction components were considered. Moreover, management of non-soil based technologies, though more expensive, is simplified because the units can be operated effectively to adjust to varying conditions and serviced easily, which may not be the case with soil-based nitrogen reduction technologies. When malfunctions occur with soil-based technologies, repairs may be necessary and could lead to expensive reconstruction. When the latter is necessary, available land area can become a severe constraint. Finally, while soils provide good treatment over a broad range of conditions, variability of characteristics among soil units can be large creating significant uncertainty in predicting a soil's nitrogen reduction capacity.

The top ranked natural system was soil infiltration with reactive barriers. The second ranked natural system is traditional trench drainfield with timed dosing of septic tank effluent. However, this system received the lowest treatment score. Application of our ranking system to certain kinds of natural systems can be misleading from a purely quantitative perspective: in this instance, the score is high because of its passive characteristics and low operating costs, but does not address the difficulty of performance monitoring and the costs associated with correcting poor performance

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Table 3-3. Scores for pre-disposal treatment technologies based on ranking criteria (Tables 4-3 and 4-5 of report)

Technology Classification	Criteria													Total Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	
	Effluent TN Conc. (mg/L)	Performance Reliability	Performance Consistency	Construction Costs ($1000)	O&M Cost	Energy Req. (kW-h/yr)	Construction Complexity	Operation Complexity	Land Area Req. (ft^2)	BOD/TSS Effluent Conc (mg/L)	Restoration of Performance	System Aesthetics	Stage of Technology Development	
Weighting Factor[1]	11.0	10.0	9.0	7.5	7.0	7.0	5.0	5.0	4.5	3.5	3.5	2.0	0.5	
Physical/Chemical														
Membrane Separation	Not Enough Available Data to Score													
Ion Exchange	Not Enough Available Data to Score													
Evaporation	Not Enough Available Data to Score													
Biological														
Mixed Biomass														
Suspended Growth	3	3	1	2	2	2	3	3	3	4	1	5	5	188.5
Fixed Film														
Fixed Film with recycle	2	4	4	2	3	2	3	3	3	5	4	5	5	235.5
Fixed Film without recycle	1	4	4	2	4	3	3	3	3	4	4	5	5	235
Integrated Fixed Film Activated Sludge	2	3	2	2	2	1	3	3	3	4	2	5	5	183
Two Stage (Segregated Biomass)														
Heterotrophic Denitrification	4	5	4	2	3	2	3	5	3	4	4	5	3	273[2]
Autotrophic Denitrification	4	5	4	2	3	2	3	5	3	5	4	5	3	276.5[2]
Source Separation Systems														
Urine Recovery	Not Enough Available Data to Score													
Wastes Segregation	Not Enough Available Data to Score													

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Table 3-4. Scores for "natural system" technologies based on ranking criteria (Table 4-5 of report)

Technology Classification	Criteria													Total Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	
	Effluent of TN Conc. (mg/L)	Performance Reliability	Performance Consistency	Construction Costs ($1000)	O&M Cost	Energy Req. (kW-h/yr)	Construction Complexity	Operation Complexity	Land Area Req. (ft^2)	BOD/TSS Effluent Conc (mg/L)	Restoration of Performance	System Aesthetics	Stage of Technology Development	
Weighting Factor[1]	11.0	10.0	9.0	7.5	7.0	7.0	5.0	5.0	4.5	3.5	3.5	2.0	0.5	
Natural Systems														
Soil Infiltration														
With dosing	1	5	4	5	4	5	5	5	3	5	4	5	5	305
With reactive barriers	5	5	4	3	3	5	3	4	5	5	4	5	3	320
With drip dispersal	2	4	4	4	3	5	3	3	3	5	4	5	5	271.5
Annamox	Not Enough Available Data to Score													
Constructed Wetlands														
Subsurface flow with pre-nitrification	3	5	4	2	4	5	3	3	3	3	3	5	5	274

3.1.2.4 Recommendations for Testing

The top ranked technology classifications (1 & 2) were biological systems with two stage segregated biomass employing autotrophic and heterotrophic denitrification. These systems are passive and expected to require little operator attention and provide high reliability. The total scores for autotrophic and heterotrophic denitrification technologies in two stage segregated biomass systems were sufficiently close that they were considered essentially equal. The first stage of each is a mixed biomass recirculating biofilter through which nitrification occurs. Significant denitrification also occurs due to the recirculation. The biofilters can employ a variety of fixed film media, many of which are in current use and are described in the literature review. PNRS II testing will provide additional data for biofiltration with recycle using clinoptilolite, expanded clay, and polystyrene. The best performing media from PNRS II testing will be recommended for Task B testing. Stage 2 of these hybrid systems will employ autotrophic denitrification (System 1) and heterotrophic denitrification (System 2). The hybrid mixed biomass/separate biomass Systems 1 & 2 can be employed for new installations or inserted between primary treatment (i.e. septic tank) and soil dispersal in existing systems.

System 3 is a natural system that uses drip dispersal into the soil of settled or secondary effluent. The design of this system will be based on the results of PNRS II, in which variants of this basic system will be evaluated to determine the design that results

in the best nitrogen reduction performance. To enhance denitrification, an in-situ reactive media barrier will be constructed below the drip dispersal tubing. Effluent is dispersed within the root zone and percolates downward through the reactive media barrier containing high water retention materials such as expanded clay and lignocellulosic or elemental sulfur electron donors to support heterotrophic or autotrophic denitrification. This system would meet the FDOH definition of passive technology and has the potential to be a low cost in-situ system that can be applied for new installations or retrofits.

System 4 is a natural system using drip dispersal of settled or secondary effluent into the soil. By dosing septic tank effluent into the soil on timed cycles alternating aerobic and anoxic conditions are created in the soil near each emitter, which creates the necessary conditions for nitrification/denitrification to occur. This intermittent dosing of septic tank effluent has been shown by several studies to reduce the total nitrogen that migrates downward from the point of application.

Systems 5 and 6 are similar to Systems 1 and 2, in that they are hybrid mixed/segregated biomass systems with a first stage fixed film bioreactor with or without recycle, followed by a heterotrophic (System 5) or autotrophic (System 6) denitrification filter. While Systems 1 and 2 utilize various widely available media, System 5 and 6 will use a combination of different proprietary and non-proprietary media systems. Systems 5 will include recycling around the first stage aerobic biofilter to enhance predenitrification and lessen the nitrate loading to the Stage 2 denitrification filter. Systems 5 and 6 expand the evaluation of the hybrid mixed/segregated biomass systems over that provided by Systems 1 and 2 alone.

Systems 7 and 8 are IFAS (Integrated Fixed-Film Activated Sludge) systems. They combine elements of both fixed film and suspended growth microbial communities, resulting in relatively stable treatment processes that achieve more reliable and consistent performance than other mixed biomass processes.

System 9 is a suspended growth system, specifically a Sequencing Batch Reactor (SBR). Theoretically, SBR's should be able to control the loss of carbon better than other mixed biomass systems.

System 10 is a membrane bioreactor (MBR) which combines suspended growth with a membrane filtration unit. MBR has been applied for onsite treatment of multifamily residential wastewater and is an emerging treatment option for single family home systems.

Systems 11 and 12 are source separation systems. Source separation is an emerging onsite wastewater management option, and may become increasingly prevalent in the future in keeping with needs for sustainability and resource recovery. With regard to nitrogen removal, source separation has the potential to be a particularly efficient option since 50 to 75% of household waste nitrogen is from urine. Accordingly, separating the waste streams allows for more efficient, dedicated treatment options for individual components of the wastewater stream.

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Table 3-5. Recommendations for technologies to be tested at the test center and in field installations (Table 4.7 of the report)

System	Technology	Comment
1	Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) Stage 2: Autotrophic denitrification with reactive media biofilter	• 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	• Top ranked system capable of meeting the lowest TN concentration standard • Suitable for new systems or retrofit
3	Natural system: Septic tank/Mound with in-situ reactive media layer	• 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: Settled or secondary effluent with drip dispersal	• Suitable for reducing TN impacts on groundwater through enhanced TN removal and reduced TN loading on soil • Suitable for new systems or retrofit
5	Mixed biomass fixed film system with recycle followed by a heterotrophic denitrification with reactive media biofilter	• 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	• 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	• High performance aerobic treatment • Suitable for new systems or nitrogen reduction upgrades
8	Mixed biomass integrated fixed film activated sludge system: Moving bed bioreactor	• 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	• Aerobic treatment • Suitable for new systems or nitrogen reduction upgrades
10	Membrane process system: Membrane bioreactor (MBR)	• Suitable for new systems or nitrogen reduction upgrades
11	Source separation system: Dry toilet (evaporative or composting)	• Eliminates liquid disposal of wastes
12	Source separation system: Urine separating (recovery) toilet	• Innovative system that is capable of removing 70-80% of the household TN at little capital cost • Provides potential for sustainable recovery of nutrients

3.1.3 Test Facility Selection

Two sites were evaluated by the provider: the University of South Florida Lysimeter Facility property and the University of Florida's Gulf Coast Research and Education Center (GCREC) near Wimauma, FL. Salient issues included space availability, site access, wastewater source of sufficient quantity and quality, subsurface hydrology, power supply and security.

Summary (from GCREC memo by provider)
Based on the cost and time associated with rehabilitating the USF facility, it has become apparent that proceeding with construction of two test facility sites will be costly and time consuming. The current budget in the FOSNRS contract for construction of a test facility at USF does not appear to be sufficient for both the rehabilitation work and the testing facility construction. In addition, the USF Lysimeter station can only be used for pilot tests of treatment technologies and unsaturated zone work, since the water table is extremely deep at the site (>25 ft.) and sufficient area for plume delineation and monitoring is not available. Management of two facilities once operational will also be more difficult and expensive in future phases of the project.
The preliminary soils assessment, wastewater (STE) quality, and preliminary GW assessment appear to be conducive to performing the proposed work. While the flatwoods type soils at the site have a shallow groundwater that may be more likely to support *in-situ* denitrification, the soils of the Florida flatwoods land resource area make up approximately 55% of the area of the state, over 60% if the Everglades land resource area is excluded. In contrast, soils of the central Florida ridge land resource area make up approximately 17% of the area of the state (Ayres Associates, 1987). Also, a site conducive to *in-situ* denitrification is desirable from a groundwater modeling perspective. To include denitrification in the models developed in Task D, a study site where denitrification can be measured will be more likely to provide the needed inputs and calibration data for model development. If the mechanisms of *in-situ* denitrification can be identified at the site, then the models developed should be able to predict whether such denitrification is likely to occur at any given site. Additionally, the individual home field sites for Task C will be chosen to include soils of different types, including well drained fine sands typical of the central Florida ridge recharge areas, and the models developed will be tested at these sites.
Treatment technology pilot testing and both the saturated & unsaturated zone investigations could be performed at the GCREC. Therefore, the Project Team recommendation is to conduct all test facility work at the GCREC.

3.1.4 Passive Nitrogen Reduction Study II (Test Center Technology Development and Testing)

The purpose of the PNRS II study is to extend and expand into field pilot testing the previous experimental studies of the two-stage biofiltration process that were conducted in a previous study for the Department. PNRS II will perform field testing of prototype passive nitrogen reduction treatment systems using a variety of candidate biofiltration media. The results of PNRS II may be used to develop and implement subsequent evaluations of full-scale systems that will be conducted under Task B of this project. The pilot test systems will consist of various configurations of in-tank biofilters and passive in-situ systems. In-tank systems will primarily employ variants of the two-stage biofiltration concepts elucidated in PNRS I. In-situ technology evaluation will include a drip irrigation system for effluent dosing, with emitters located in shallow root zones

<u>Two-stage biofiltration evaluation</u>

Candidate media for evaluation in Stage 1 (unsaturated) biofilters and Stage 2 (saturated) biofilters are listed in Table 3-6 and 3-7, with physical properties and their sources. Included are media with high water retention and porosity. Stage 1 media includes expanded clay and clinoptilolite. These have greater than 45% porosity and high water retention. Clinoptilite also contains high ion exchange capacity to retain ammonia ions for enhanced ammonia removal under non-steady flows and higher loading rates. Livlite is an expanded clay with high water retention characteristics. Expanded polystyrene is a very lightweight, readily available and low cost material that appears to be quite suitable as a biofilter media for aerobic treatment.

The Stage 2 electron donor media are elemental sulfur, which will result in an autotrophic denitrification process in the anoxic biofilter; lignocellulosic materials, such as woodchips, which support heterotrophic denitrification, and glycerol, a readily available carbon source for heterotrophic denitrification.

Crushed oyster shell or sodium sesquicarbonate will be used as alkalinity sources in sulfur-based denitrification biofilters, as auto trophic sulfur-based denitrification will consume alkalinity. Expanded shale may be included as a Stage 2 option for its anion exchange capacity to enhance nitrate removal performance.

The biofilter systems will be operated over a twelve month period, dependent on additional funding, during which eight monitoring events will be conducted. A detailed description of analyses is included in the QAPP document. As outlined in Table A.1, there are 42 sampling points and a monitoring analyses structure that employs four analytical tiers.

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Table 3-6. Materials for Stage 1 Filters (Table 3.3 of QAPP)

Stage 1 Vertical Unsaturated Biofilter Configuration and Initial Operation

Unsaturated Biofilters (Stage 1)					
No.	**Media**	**Biofilter**	**Media Depth (Inches)**	**Flow Regime**	**Recycle Ratio (α)**
1	Expanded Clay	UNSAT-EC-1	15	Single Pass	-
2		UNSAT-EC-2		Recycle	3
3		UNSAT-EC-3	30	Single Pass	-
4		UNSAT-EC-4		Recycle	3
5	Clinoptilolite	UNSAT-CL-1	15	Single Pass	-
6		UNSAT-CL-2		Recycle	3
7		UNSAT-CL-3	30	Single Pass	-
8		UNSAT-CL-4		Recycle	3
9	Polystyrene	UNSAT-PS-1	30 (NS)	Single Pass	-
10	Upper: Filter Sand	UNSAT-IS-1	12	Single Pass	-
11	Lower: Expanded Clay, Lignocellulosic, Sulfur	UNSAT-IS-2	12	Single Pass	-

EC: expanded clay, CL: clinoptilolite, PS: polystyrene, SU: sulfur, α: recycle flowrate/forward flowrate, NS: non-stratified

Table 3-7. Denitrification filter material (Table 3.6 in QAPP)

Stage 2 Saturated Denitrification Biofilter Configuration and Initial Operation

No.	Electron Donor	Biofilter	Media Composition (by volume)	Initial Surface Loading Rate, gal/day-ft^2	Stage 1 Filter
1[1]	Elemental sulfur	DENIT-SU-1	80% SU 20% OS	10.0	2,4,6,8
2[1]		DENIT-SU-2	80% SU 20% NS	10.0	2,4,6,8
3[2]		DENIT-SU-3	80% SU 20% OS	4.7	1
4[2]		DENIT-SU-4	80% SU 20% NS	4.7	7
5[1]	Lignocellulosic	DENIT-LS-1	70% LS 30% EC	10.0	2,4,6,8
6[2]		DENIT-LS-2	70% LS 30% EC	4.7	3
7[2]		DENIT-LS-3	50% LS 60% EC	4.7	5
8[2]		DENIT-LS-4	30% LS 70% EC	4.7	9
9[1]	Glycerol	DENIT-GL-1	100% EC	10	2,4,6,8

SU: elemental sulfur, LS: lignocellulosic, GL: glycerol, OS: oyster shell, NS: sodium sesquicarbonate, EC: expanded clay

1. Fed from common Stage 1 effluent collection tank.

2. Directly connected to Stage 1 unsaturated biofilter

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Experimental in-situ simulators

In-situ testing will be conducted using in-situ simulators as shown in Figure 3-2. The simulators will consist of subsurface drip irrigation application to the root zone of surface vegetation, followed by downward transport through a 12 in. layer of filter sand. Underlying the filter sand is a 12 in. layer of engineered media containing electron donor which is in turn underlain by natural soil. The test matrix consists of subsurface drip irrigation emitter dosing of primary effluent (i.e. septic tank effluent) or nitrified effluent into the root zone of St. Augustine grass. Other than the pumping of effluent by subsurface irrigation, the in-situ simulators are completely passive systems. An innovative feature of the in-situ simulator design is the use of mixed media in unsaturated mode that contains both a high water retention media (expanded clay) and heterotrophic and autotrophic electron donor This potential for insitu treatment systems, including plant-assisted nitrogen transformations, has not been examined in Florida with innovative systems of this type but is of potentially high significance.

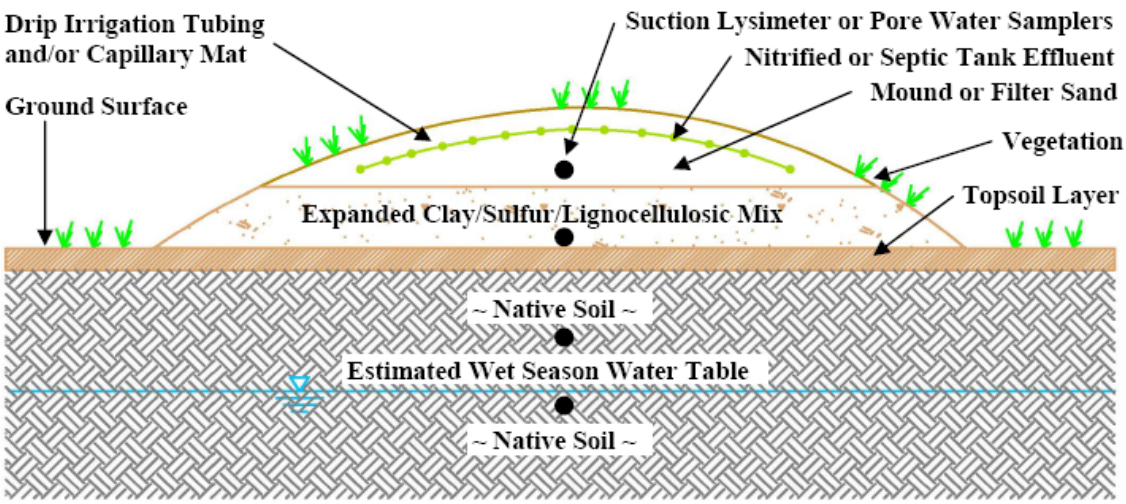

Figure 3-3. Conceptual drawing of in-situ simulators with engineered nitrogen reduction media (Figure 3-2. of QAPP)

3.2 Task C Evaluation of Nitrogen Reduction in Soil and Shallow Groundwater

3.2.1 Literature Review

The literature review revealed numerous factors that may influence nitrogen impacts to groundwater resulting from the use of OSTDS. Transport and fate processes that are present in the OSTDS, vadose zone, and saturated zone all will influence the extent of nitrogen impacts to groundwater. Furthermore, these factors, along with factors related to groundwater/surface water interactions will also determine if nearby surface water bodies are adversely affected. In doing site assessments, it is therefore important to develop sampling plans that can collect data for a majority of the factors described in the literature. Also, predictive efforts and efforts aimed at reduction of impacts should also consider the findings of the literature review. A brief summary of important points is as follows:

- Some studies identified lot size and location of water supply wells in relation to OSTDS as important factors in determining nitrate contamination to groundwater.
- OSTDS loading rate can significantly impact the performance of the soil and ultimately nitrogen concentrations in the aquifer.
- In certain cases, water table fluctuations may be a larger factor than loading rate of nitrogen on the overall OSTDS performance.
- Nitrogen reduction in the vadose zone is an important determining factor for nitrate concentrations in the groundwater. This is a complex process dependent on numerous factors that need to be studied in depth.
- Nitrification can be influenced by soil type and appropriate loading of an OSTDS. Some literature indicates that coarse-textured strongly-aggregated soils favor nitrification while finer textured soils lead to the development of anaerobic conditions and inhibit the process.
- Sandy soil aquifers are particularly susceptible to nitrate contamination, particularly in the case of low carbon content aquifers with relatively high groundwater velocities. In these cases, high concentrations and large areas of impact may be expected due to the lack of transformation and the distance nitrate can travel in a short time period.

- Denitrification occurs largely in anoxic soils and groundwaters with adequate carbon sources. In the soil column, denitrification may occur in systems with high or fluctuating water tables that allow the creation of anoxic conditions, providing the organic carbon content of the soil is adequate. In groundwater, dilution is often seen as the dominant mechanism for the reduction of nitrate, although some studies identify denitrification as the dominant factor. This is highly dependent on site-specific characteristics.
- Denitrification, while being a well-understood process is poorly quantified and not correlated with other site characteristics especially when considering the saturated zone. This should be a significant topic of further study.
- Some studies identified the relatively high denitrification capacity of river bed sediments, particularly if they contained high levels of organic carbon. This is especially relevant if the protection of adjacent surface water bodies is a key concern.

The literature review suggests reductions in groundwater nitrogen impacts associated with OSTDS are achievable with a few steps. Nitrate is highly mobile in groundwater and the only significant methods of natural attenuation is denitrification, a process that the review indicates is not always present in natural aquifers (however, it should be noted that saturated zone denitrification can be enhanced with amendments as a potential treatment process). Therefore, reduction of nitrate contamination may be most efficiently approached in the design and installation processes when considering OSTDS as a treatment alternative. Appropriate land planning and density of OSTDS in new developments is a first step. OSTDS should be placed within protective distance of downgradient groundwater and surface water resources. Additionally, recognizing the importance of dilution for nitrate concentration reductions, appropriate lot size should be in the design to allow adequate dilution from recharge water. Within the design of OSTDS, appropriate loading rates and an understanding of OSTDS effluent can achieve lower levels of nitrogen entering the subsurface.

Lastly, the review indicates the performance value of appropriate treatment units can improve effluent quality by reducing nitrogen prior to infiltration. Additional optimization can be achieved by a thorough understanding of site characteristics and how these may influence OSTDS performance and ultimately nitrogen concentrations in groundwater. Certain water table conditions, soil types, and other subsurface characteristics such as pH or temperature can have an effect on the treatment ability of OSTDS by varying oxygen content and redox conditions. If detrimental conditions are seen at a site being considered for OSTDS, other methods of wastewater treatment may be appropriate. This can also be true for areas identified as “high-risk,” such as areas adjacent to a protected water body. Alternatively, it may be possible to amend the site conditions or use an effluent pre-treatment method to improve OSTDS performance. Future work may be needed to examine the data in such studies and make attempts to correlate hydraulic and reactive parameters to observed nitrogen impacts.

3.2.2 Quality Assurance Project Plan for Field Work

A three-pronged approach is anticipated for the field work.
Detailed monitoring, including of the vadose zone under very controlled conditions will be performed to obtain a side-by-side comparison of drip and low-pressure dosed drainfields that are loaded with either nitrified or septic tank effluent. The in-situ simulators from task A will be monitored in the same way. Table 3-8 shows the experimental design, and Figure 3- 4 shows the cross section of the anticipated drainfields and their monitoring equipment.

Monitoring of a test center effluent plume in groundwater will be initially performed at a large mound on the test center. The test center provides somewhat controlled conditions and the size

of the mound will make it easier to find the plume and gather insights on the effects of size. Elements of the groundwater monitoring are outlined in table 3-9. The location at the test center where monitoring will take place is shown in figure 3-5.

Monitoring of effluent plumes in groundwater at individual home site will utilize the same methodology as the monitoring of the mound at the test center.

Table 3-8. Experimental design of soil and shallow groundwater monitoring (table 2.2 of draft QAPP)

Test Area ID	Effluent Quality	Design HLR (gpd/ft^2)	Soil Treatment Unit Design
TA1	STE	0.8	pressure dosed mound
TA2	STE	0.8	shallow drip dispersal
TA3	nitrified effluent	0.8	pressure dosed mound
TA4	nitrified effluent	0.8	shallow drip dispersal
TA5	in situ nitrified effluent (Task A)	from PNRS II pilots	mounded drip dispersal over denitrification media
TA6	in situ STE effluent (Task A)	from PNRS II pilots	mounded drip dispersal over denitrification media

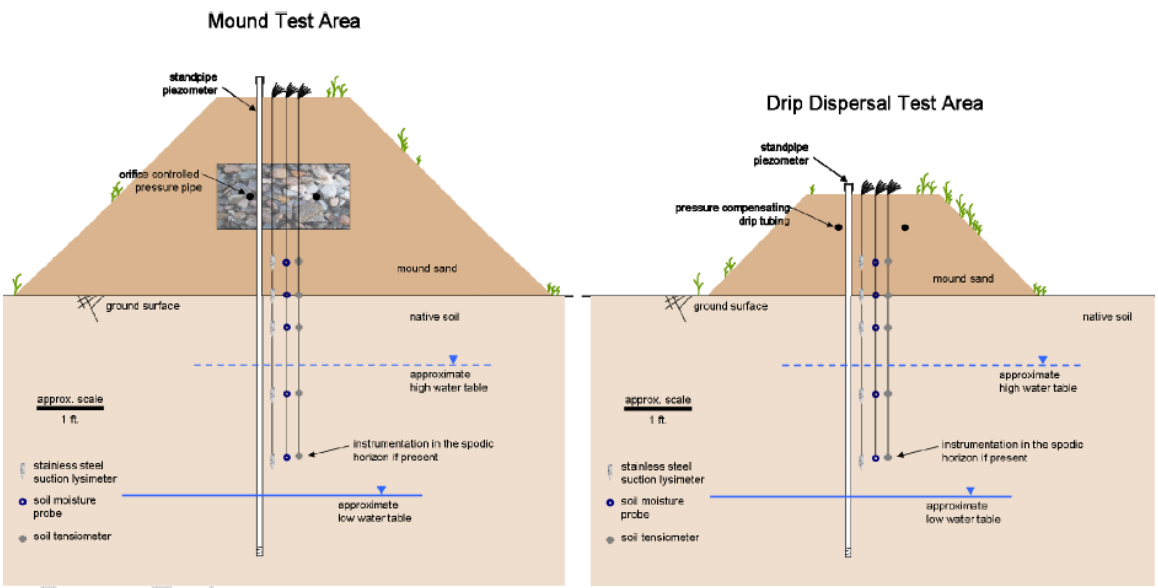

Figure 3-4. Conceptual cross sections of drainfields to evaluate soil nitrogen reduction (figure 2-2 of draft QAPP)

Table 3-9. Steps in monitoring the effluent plume of an OSTDS (Table 2-3 of draft QAPP)

Step	Purpose	Approach	Data to be Collected
1	Plume identification	sampling grid for groundwater screening	in-field measurements of groundwater specific conductance
2	Instrumentation	install multi-level drive point piezometers and shallow standpipe piezometers	soil properties determined from soil borings during standpipe piezometer installation
3	Aquifer characterization	conduct pump test and slug tests on standpipe piezometers	hydraulic gradient, saturated hydraulic conductivity
		baseline tracer test	establish groundwater velocity, dispersivity coefficients, and groundwater dilution
4	Routine monitoring	effluent quality, groundwater concentrations, water levels, climatic conditions	water quality parameters as necessary to determine nitrogen reduction
5	Additional instrumentation, testing, and/or monitoring	as warranted	refine denitrification rates, aquifer properties

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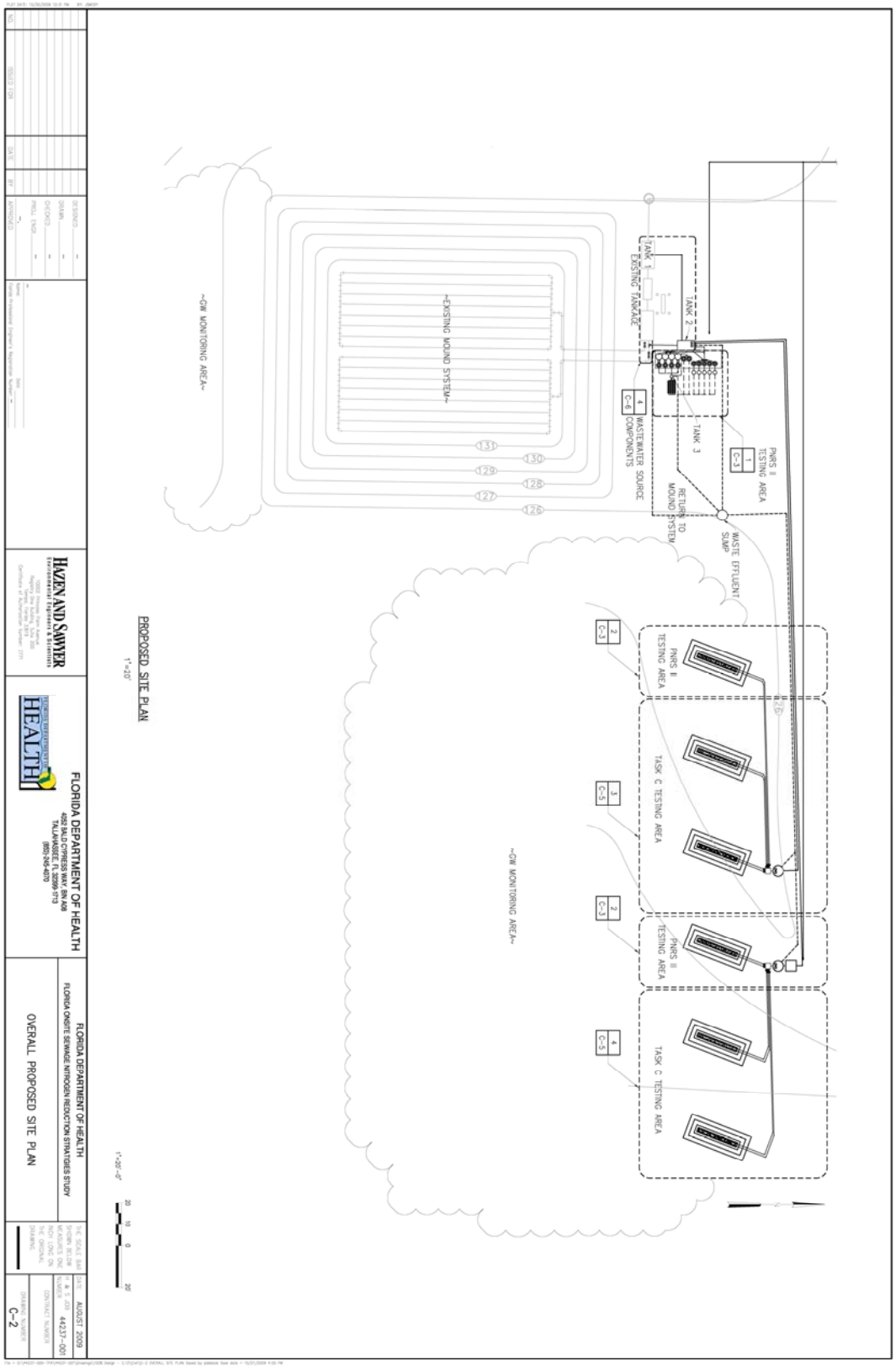

Figure 3-5. Outlay of the groundwater monitoring area at the test center. (Appendix B of the QAPP)

3.3 Task D, Nitrogen Fate and Transport Modeling

(edited from conclusions of the draft literature review)

A review of the literature, the conceptual understanding of the transport of nitrogen as related to OWTS, and the goals of the project are all taken into consideration when beginning to describe the tool that will be developed. From this, several conclusions and some suggestions for the modeling tool can be developed. The literature review was intended to identify the state-of-knowledge of nitrate fate and transport modeling, identify past models that may have provide good templates for the model developed by the FOSNRS Study, and assist in identifying key parameters and processes that need to be represented in a predictive tool.

As with any model development project, the appropriate approach can depend on numerous factors. When conceptualizing a model, several key questions need to be posed, such as:

- Will this model be constructed to represent a specific site of interest or be a predictive tool with broad applicability to a variety of sites?
- What is the desired output?
- What is the most appropriate method of calculating the output?
- Will this model require calibration to existing data sets?
- What, if any, regulatory requirements constrain the model choice?

The modeling tool that is being developed to simulate nitrate fate and transport will require certain features, some of which include:

- ease-of-use;
- ability to simulate time-variable OWTS inputs;
- simulation of transport and fate in both the vadose zone and saturated zones;
- representation of the numerous advective-dispersive and transformative processes that affect nitrate transport;
- simulation of temporal and spatial concentrations and mass loading downgradi-ent of the source;
- include the impacts of seasonal rainfall variation on the source function; and
- incorporate critical OWTS operating characteristics that strongly influence nitro-gen reduction.

Based on the above questions and objectives, many conclusions about the models and model types in the research summary can be made. No simple model (analytical or mass-balance) identified in the literature can currently achieve all of the above-described goals. Also, numerical models are generally not considered a useful tool for system de-sign or regulatory compliance where broad applicability is desired. Thus, development of a new modeling tool is likely required and rigorous numerical modeling may be needed as a first step to determine the most important parameters to include.

A strictly mass-balance modeling approach will likely be inappropriate, as it either does not consider the known physical processes that influence nitrate transport or makes simplifying assumptions about these processes. Furthermore, the output will not satisfy the objectives of the model (time-variable estimations of concentrations at specific spatial points). Nonetheless, these approaches have value in the conceptualization of model inputs and should not be ignored.

Transfer function models have not been widely applied and will likely encounter regulatory resistance, since they are based strictly on probabili-ties and do not directly consider measured site characteristics.

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Both analytical and numerical modeling methods are the most promising approaches when considering the FOSNRS Study model to be developed. These approaches will have wide applicability, regulatory acceptance, and are capable of estimating the important hydrogeochemical properties associated with nitrate fate and transport.

The modeling tool will need to consider transport and transformation (chemical and physical) in the vadose zone, because the Nitrogen transformations that occur in this zone have considerable influence on the mass-flux input into the underlying aquifer. This can be a numerical one-dimensional solution of the Richards' Equation. A one-dimensional formulation can likely be implemented in a spreadsheet. Additionally, the modeling will need to consider temporally and spatially variable inputs for multiple OSTDS, as would be found in a community development. This could be addressed through a series of one-dimensional vadose zone models that could provide input to a multi-dimensional groundwater flow and transport model. Both of these studies use the horizontal plane source model or some variation and are also capable of transient simulations. However, the models likely will not be capable of interacting with each other in the vadose zone (i.e., strictly vertical flow is assumed). Nonetheless, the value of including these model features is important when simulating the areal distribution of OSTDS in a potential housing development and the temporal variation of source input due to changes in wastewater input rate and precipitation recharge. These combined models can likely be implemented in a spreadsheet or using Fortran or C++ programming while maintaining simple and straight-forward input requirements. Of course, no similar model is available to our knowledge, so considerable model research and development must be achieved by this project.

The literature review has suggested the most likely processes and parameters that will need to be considered when developing the modeling tool. The fate and transport of nitrogen products is a result of advective movement, retardation via adsorption, and the transformative processes of nitrification and denitrification. These processes are to be calculated in the model tool via the solutions of the appropriate equations using the necessary parameters, described below. Key parameters to consider for simulation should consist of:

- physical parameters of the media such as bulk density, water content, and soil characteristics;
- advective-dispersive parameters such as hydraulic conductivity, hydraulic gradient, porosity (or groundwater velocities), and dispersivity values;
- retardation factor values for ammonium sorption; and
- rate coefficients for transformative reactions, typically first-order rate constants

A majority of the parameter values needed for model input can be collected during site characterization. In a previous study by members of this project team we utilized CFD's for the estimation of initial parameter values if utilizing literature values but the approach results in an uncertain model output where the degree of uncertainty must be quantified.
Additionally, many analytical models were found in the literature review (nitrate-specific and general analytical solutions) that are appropriate for the modeling tool, since these can be programmed into a spreadsheet and can be user-friendly.

4 RECOMMENDATIONS FOR FUNDING ADDITIONAL PHASES OF THE STUDY

Activities in fiscal year 2008-2009 will prepare the framework for rapid implementation of a field sampling program in fiscal year 2009-2010. Funding for fiscal year 2009-2010 is required to reap the benefits of this preparation. Funding for the first phase of this project is already appropriated and the associated activities are described above. The remaining years of the project still require funding in order to complete the goals of this project. For the 2010-2011 budget year $2-million dollars is required to fund the continuation of this study.

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During the 2010-2011 fiscal year, the tasks associated with this project are anticipated to include a significant amount of construction and sampling. For Task A, the test facility will have been installed and pilot testing will continue for various passive nitrogen removal technologies. For Task B, onsite systems will be installed at home locations throughout the State of Florida, and monitoring of the performance of these systems in the field will begin. The report on the life cycle cost analysis will be submitted based on actual purchase prices, installation cost estimates, and operational costs records. For Task C, instrumentation of home sites that have been selected to evaluate nitrogen movement in the soil and groundwater will occur and monitoring will begin. The installation of a facility to allow side-by-side evaluation of multiple drainfield configurations and the resulting nitrogen groundwater fate and transport in a common environment will have been completed and monitoring will continue. For Task D, an initial simple model will have been developed, and more complex models that allow evaluation of multiple OSTDS, such as on a development scale, will be developed. An alternative, more complex soil transport model that incorporates a more detailed analysis of transport through unsaturated soil will be developed and integrated with the groundwater transport models. These models will in subsequent years be compared to the data obtained during this project.

The results of this project will help refine strategies for cost-effective nitrogen reduction from onsite sewage treatment systems that will protect our environment, as well as, provide cost effective options for citizens of this state.

5 CONCLUSION

This report is submitted in compliance with Line Item 471 Section 3, Conference Report on Senate Bill 2600, General Appropriations Act for Fiscal Year 2009-2010. This progress report identifies the progress that has been made, what immediate progress is proposed, as well as a recommendation for funding additional phases of the study.

The department and its Research Review and Advisory Committee recommend the legislature:

- Provide funding and budget authority to the department in the amount of $2 million for the fiscal year 2010-2011 for continuation of the contract and associated tasks.
- Allow the department to carry over any remaining funds from fiscal year from fiscal year 2009-2010 into 2010-2011.

Continued support for this project will ultimately benefit Florida's onsite system owners and will improve environmental and public health protection.

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Revised

FINAL REPORT

Draft 12/10/2009

Reducing Onsite Sewage Treatment System Impacts in the Suwannee River Basin

for

Assistance ID No. MX – 97450302 – 6

U.S. Environmental Protection Agency
Gulf of Mexico Program

Prepared by

Harmon Harden[1], Eberhard Roeder[2], Jeffery Chanton[3], and Elke L. Ursin[4]

DRAFT Dec 2009

[1] Harmon Harden, M.S. Assistant in Research, Florida State University, Department of Oceanography, 117 N. Woodward Avenue, Room 102, Tallahassee, FL 32306-4320. Harden@ocean.fsu.edu

[2] Eberhard Roeder, PhD., P.E., Professional Engineer III, Florida Department of Health, 4052 Bald Cypress Way, Bin #A-08, Tallahassee, FL 32399-1713. Eberhard_Roeder@doh.state.fl.us

[3] Jeffery Chanton, PhD., Distinguished Research Professor, Florida State University, Department of Oceanography, 117 N. Woodward Avenue, Room 102, Tallahassee, FL 32306-4320. Chanton@ocean.fsu.edu

[4] Elke L. Ursin, Environmental Health Program Consultant, Florida Department of Health, 4052 Bald Cypress Way, Bin #A-08, Tallahassee, FL 32399-1713. Elke_Ursin@doh.state.fl.us

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EXECUTIVE SUMMARY

Phase I of this study, Manatee Springs Onsite Sewage Treatment and Disposal System Study, demonstrated rapid transport of nutrients to the groundwater from the conventional septic systems located at Manatee Springs State Park. The objectives of Phase II of the study were to retrofit the two onsite systems investigated in Phase I with nitrogen reducing treatment systems (NRTS) and evaluate their performance and effect on groundwater. The performance evaluation is documented in Chapter I. The history of the system modifications both by the State Park and in implementation of this project and additional data gathered from operating records and sampling events done prior to the performance evaluation is documented in Chapter II.

This study was complicated by three factors. Delays resulted in finalizing the two NRTS until March 2009, well into the proposed sampling period. A June deadline for completion of the project caused the sampling to occur in a more limited period of time than was initially planned, and in a period of time when the campground was under-utilized. Flooding of the Suwannee River closed the campgrounds from April 13 to 28, 2009. A similar event had occurred in 2003 during Phase I of this study. The floodwaters covered the Magnolia II wells for days and significantly raised the levels in the wells at Hickory campground, likely having a flushing effect on the soils and ground water. After reopening following the flood, visitation was significantly reduced from May through early June due to less than optimum conditions at the Park. This reduction in visitation resulted in a lower water use in the bathhouses studied than might otherwise have been the case. Therefore, additional sampling was completed in September of 2009.

1. The NRTS at Magnolia II, designed with a *Hydro-Action* aerobic treatment unit (ATU) and using the original septic tank as a trash tank was installed in 2004. Drainfield reconfiguration of the system was finalized and became operational on March 09, 2009. Through June 2009, twelve grab samples and four 24 hour composite samples of both the septic tank effluent (STE) flowing out of the trash tank and the effluent following treatment (EFT) downstream of the treatment area exhibited total nitrogen (TN) reduction ranging from 60 to 88%, n=12.

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2. The installation of the NRTS at Hickory, designed with a *MicroFAST* ATU and also using the original septic tank as a trash tank, was complicated by site restrictions causing design and installation delays. The system installation began in 2004 and was finalized on March 23, 2009 just prior to the start of sampling of the system. Through June 2009, eleven grab samples and four 24 hour composite samples of the original STE and the EFT (effluent following treatment) exhibited TN reduction ranging from 22 to 75%, n=11. The nitrogen reduction of 22% is calculated from the composite samples taken during the performance assessment. This may not be an accurate reflection of performance as the 9 grab samples taken during the same time period indicated nitrogen reduction of 55%. Not including the composite samples or the 03/27/09 event (37% TN reduction), the NRTS at Hickory reduced total nitrogen from 55% to 75%.
3. Since the sampling event on 03/26/09 was just after the NRTS were fully operational and the other two sampling events on 05/11/09 and 06/04/09 were impacted by flooding, another sampling event on 09/10/09 was added to the study to capture more typical conditions at the sites. The STE and EFT samples of the NRTS at Hickory indicate a nitrogen reduction on 59%. At Magnolia II, the NRTS apparently was not functioning properly as the EFT value was 138 mg-N/L, near the STE value.
4. Groundwater samples collected from wells were lower in nitrogen species in the Phase II portion of this study, following the installation of the NRTS systems, relative to concentrations in Phase I. However, interpretation of this result is somewhat tentative. The first sampling even (in January 2009) was intended to give nutrient concentrations in the groundwater prior to the effluent being re-directed to the original drainfields; however untreated effluent had been intermittently diverted to the drainfields in the vicinity of those wells at Hickory through May of 2008 and at Magnolia II through October 2008. Thus the January 2009 sampling event captured a residual impact on the groundwater prior to the beginning of operation of the NRTS units which were initiated in March 2009. The flooding that occurred in the middle of the study also complicated the interpretation of the groundwater data as both campgrounds were closed and the Magnolia II well field submerged. Following reopening of the campgrounds, visitation at the park was very light. However we were able to compare groundwater data in 2009 to a similar flooded period at the Park in 2003. The groundwater nitrate concentrations in

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2009 were much lower than those observed post flood in 2003, consistent with the hypothesis that the NRTS would reduce N-loading to the subsurface aquifer. All groundwater samples collected after operation of the NRTS were lower than all previous values observed indicating that NRTS units reduce N input to the subsurface.

5. Since the sampling event on 03/26/09 was just after the NRTS were fully operational and the other two sampling events on 05/11/09 and 06/04/09 were impacted by flooding, another sampling event on 09/10/09 was added to the study to capture more typical conditions at the sites. The nitrate levels in the monitoring wells observed on 09/10/09 at Hickory were similar to the data collected during the background event on 01/14/09 and at Magnolia II, the concentrations were lower on 09/10/09 than on 01/14/09. This gives further evidence that installation of the NRTS significantly reduces N-loading in the subsurface.

The following are some additional observations and conclusions:

1. This study benefited from and was influenced by upgrades the State Park implemented concurrently at the two bathhouses. Two changes relative to Phase I stemming from these upgrades were the use of low-flow fixtures in the bathhouses and the use of lift-dosing instead of gravity to feed the monitored drainfields. The use of low-flow fixtures has likely increased the concentration of nitrogen in the effluent, but is not expected to have changed the mass of nitrogen discharged in the sewage.
2. The treatment technologies eventually selected for this project represented the two approaches currently outlined in state law for the protection of the Suwannee River flood plain: an aerobic treatment unit with combined activated sludge/fixed film technology that has extensive documentation on its nitrogen reduction capability available and has been commonly installed as a performance-based treatment system for this purpose, and an extended aeration aerobic treatment unit that is lacking such documentation.
3. Retrofitting of the existing systems had to contend with site constraints based on prior construction. The use of existing old drainfields was part of the design of the study to allow comparison to Phase I. The reuse of the existing septic tanks as trash compartments for the treatment units resulted in trash tanks that are about twice as large

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as would usually be the case for new system construction. There was no indication that the trash tanks resulted in a lack of food for the aerobic treatment units, though, and the experience over the course of the project suggested that campground bathhouses generate a large amount of solids appropriate for a larger trash tank.

4. A first attempt to install a treatment unit in the first chamber of the existing tank did not result in successful treatment. At least for situations such as those encountered in this study, retrofitting for additional treatment appears to require at least an additional tank for the treatment unit.
5. Thorough maintenance appears key to ensuring effective treatment by at least the extended aeration treatment unit at Magnolia II. Samples taken on three occasions in 2006 and 2007 showed that total nitrogen in the ATU-effluent ranged from 73 to 120 mg/L and were similar to septic tank effluent samples taken at the same, which ranged from 71 to 150 mg/L total nitrogen. On these occasions, there was also little evidence of cBOD5 and TSS removal, and nitrification relative to septic tank effluent. Two of three other aerobic treatment units by the same manufacturer that were installed at park restrooms were sampled in 2007 and showed a similar lack of nitrification. In contrast, a sample taken in January 2009 at Magnolia II, after a thorough maintenance visit in June 2008 that addressed the functioning of air diffusers, showed nearly complete nitrification and a total nitrogen concentration of 66 mg/L. The sampling event in September 2009 indicated loss of nitrification function again at the Magnolia II treatment unit.
6. A more thorough inspection and possibly training protocol that is shared between the owner of the system, the maintenance entity and the regulatory agency may help to detect sub-optimal performance more quickly. The lack of treatment discussed in the previous point occurred even though the aerobic treatment unit appeared to be working, as indicated by the running of the aerator, except for some overheating problems observed by park staff.
7. Outside the direct scope of this project, park management reported and DOH staff observed a variety of problems related to the functioning of the pressure dosing system installed as part of the park service-initiated upgrade. Some of these problems appeared unique to the size and design of the particular systems involved.

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8. For the continued operation of the bathhouses it proved useful to have the research project drainfields remaining as a gravity-fed backup to the pressure-dosed systems. This benefit has to be considered against the lack of treatment obtained during periods when the pressure-dosed system is not functional. In addition, the continued intermittent use of the old existing drainfield resulted in residual nitrogen concentrations in the monitoring wells that had the potential to confound an evaluation of the treatment effect.
9. Septic tank effluent contained nearly exclusively reduced forms of nitrogen (TKN) with 56 to 95% of that concentration being present as ammonia-nitrogen.
10. Nitrogen concentrations in septic tank effluent from the two systems frequently exceeded Florida's limit of 100 mg/L TKN for domestic sewage and was by a factor of two to four higher than average values in domestic sewage found in prior Florida studies. In part this high concentration is due to the use of low-flow fixtures and may indicate a broader change in domestic sewage composition. Total phosphorus concentrations ranged from 0.5 to 33 mg/L with most being below 10 mg/L. cBOD5, ranging from 25 to 220 mg/L, and TSS, ranging from 38 to 126 mg/L indicated that septic tanks retain their effectiveness for the reduction of these parameters with more concentrated sewage.

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CHAPTER I: Performance Evaluation Study on Nutrient Removal in Onsite Sewage Treatment and Disposal Systems in Karst Areas

Prepared by:

Harmon Harden and Jeff Chanton
Department of Oceanography
Florida State University
Tallahassee, Florida 32306-4320
Phone 850-644-6700

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1. Executive Summary

Phase I of this study, Manatee Springs Onsite Sewage Treatment and Disposal System Study, demonstrated rapid transport of nutrients to the groundwater from the conventional septic systems located at Manatee Springs State Park. The two conventional septic systems studied in Phase I were replaced by Nutrient Reducing Treatment Systems (NRTS) for Phase II. This study was complicated by 3 factors. Delays resulted in finalizing the two NRTS until March 2009, well into the proposed sampling period. Flooding of the Suwannee River closed the campgrounds from April 13 to 28, 2009. A June deadline for completion of the project caused the sampling to occur in a more limited period of time than was initially planned, and in a period of time when the campground was under-utilized. The floodwaters covered the Magnolia II wells for days and significantly raised the levels in the wells at Hickory campground, likely having a flushing effect of the soils and ground water. After reopening following the flood, visitation was significantly reduced from May through early June due to less than optimum conditions at the Park. This reduction in visitation significantly reduced the typical daily influent loading of the system. Therefore, additional sampling was completed in September of 2009.

1. The NRTS at Magnolia II, designed with a *Hydro-Action* aerobic treatment unit (ATU) and using the original septic tank as a trash tank was installed in 2004. Drainfield reconfiguration of the system was finalized and became operational on March 09, 2009. Through June 2009, twelve grab samples and four 24 hour composite samples of both the septic tank effluent (STE) flowing out of the trash tank and the effluent following

treatment (EFT) downstream of the treatment area exhibited total nitrogen (TN) reduction ranging from 60 to 88%, n=12.

2. The installation of the NRTS at Hickory, designed with a *MicroFAST* ATU and also using the original septic tank as a trash tank, was complicated by site restrictions causing design and installation delays. The system installation began in 2004 and was finalized on March 23, 2009 just prior to the start of sampling of the system. Through June 2009, eleven grab samples and four 24 hour composite samples of the original STE and the EFT (effluent following treatment) exhibited TN reduction ranging from 22 to 75%, n=11. The nitrogen reduction of 22% is calculated from the composite samples taken during the performance assessment. This may not be an accurate reflection of performance as the 9 grab samples taken during the same time period indicated nitrogen reduction of 55%. Not including the composite samples or the 03/27/09 event (37% TN reduction), the NRTS at Hickory reduced total nitrogen from 55% to 75%.
3. Since the sampling event on 03/26/09 was just after the NRTS were fully operational and the other two sampling events on 05/11/09 and 06/04/09 were impacted by flooding, another sampling event on 09/10/09 was added to the study to capture more typical conditions at the sites. The STE and EFT samples of the NRTS at Hickory indicate a nitrogen reduction on 59%. At Magnolia II, the NRTS apparently was not functioning properly as the EFT value was 138 mg-N/L, near the STE value.
4. Groundwater samples collected from wells were lower in nitrogen species in the Phase II portion of this study, following the installation of the NRTS systems, relative to concentrations in Phase I. However, interpretation of this result is somewhat tentative. The first sampling even (in January 2009) was intended to give nutrient concentrations in the groundwater prior to the effluent being re-directed to the original drainfields; however untreated effluent had been diverted to the drainfields in the vicinity of those wells at Hickory through May of 2008 and at Magnolia II through October 2008. Thus the January 2009 sampling event captured a residual impact on the groundwater prior to the beginning of operation of the NRTS units which were initiated in March 2009. The flooding that occurred in the middle of the study also complicated the interpretation of the groundwater data as both campgrounds were closed and the Magnolia II well field submerged. Following reopening of the campgrounds, visitation at the park was very

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light. However we were able to compare groundwater data in 2009 to a similar flooded period at the Park in 2003. The groundwater nitrate concentrations in 2009 were much lower than those observed post flood in 2003, consistent with the hypothesis that the NRTS would reduce N-loading to the subsurface aquifer. All groundwater samples collected after operation of the NRTS were lower than all previous values observed indicating that NRTS units reduce N input to the subsurface.

5. Since the sampling event on 03/26/09 was just after the NRTS were fully operational and the other two sampling events on 05/11/09 and 06/04/09 were impacted by flooding, another sampling event on 09/10/09 was added to the study to capture more typical conditions at the sites. The nitrate levels in the monitoring wells observed on 09/10/09 at Hickory were similar to the data collected during the background event on 01/14/09 and at Magnolia II, the concentrations were lower on 09/10/09 than on 01/14/09. This gives further evidence that installation of the NRTS significantly reduces N-loading in the subsurface.

2. Introduction

Onsite sewage treatment and disposal systems (OSTDS) are an important part of Florida's wastewater infrastructure, serving about a quarter of the state's households (Social Science Data Analysis Network, undated; FDOH, 2007b). The proportion of homes served by OSTDS units is much higher in the rapidly growing, formerly rural areas of central and north Florida. In these areas, karst features, such as large springs, sinkholes and caves have formed in shallow limestone layers. Karst features have been shown to rapidly transport contaminants to the underlying groundwater (e.g. Paul et al., 2000; Price, 1988; Dillon et al., 1999, 2000). Recent work done in the Wakulla Springs drainage basin, with a similar karst topography to that found near Manatee Springs, indicates that approximately half of the TN concentration observed in effluent from conventional OSTDS (STE) is found in the groundwater directly below the drainfield (Katz, et al., in review).

Springs in most areas, except in national forests, have experienced degradation in water quality, particularly exhibiting elevated nitrogen concentrations (Florida Springs Task Force, 2006).

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While other sources, such as fertilizer use, stormwater runoff, atmospheric deposition, and wastewater treatment plant discharge are large contributors to nutrient loading of groundwater, the effects of conventional onsite sewage systems, consisting of a septic tank with a drainfield, have become of concern (Katz et al, 1999). The EPA has stated "alternative systems may be necessary in karst areas" (EPA, 2006). In Florida, nutrient reduction is required for permanent onsite systems installed in the Florida Keys, where limestone is at the surface, lots are small, and allowable discharge methods include well injection (64E-6 Florida Administrative Code). In other karst areas of Florida, a larger drainfield is required when discontinuous limestone is encountered during site evaluation (FDOH, 1999). Wakulla County in North Florida has an ordinance mandating Performance Based Treatment Systems (PBTS) implemented with the goal of reducing nitrogen inputs from OSTDS to groundwater, Wakulla Springs and other local springs and water bodies (Wakulla County Ordinance, 2007).

Phase I of this study, completed in 2004, demonstrated the rapid transport of nitrogen to the groundwater from the conventional septic systems located at two bath houses in campgrounds at Manatee Springs State Park (FDOH 2004, Harden et al, 2008).
Tracer tests employing fluorescein dye and sulfur hexafluoride gas established the connectivity between the two septic drainfields and the groundwater. At Magnolia II campground, high to intermediate concentrations of tracers were observed in 8 of the 10 wells and at Hickory campground, 3 of the 10 wells. The average of the peak TN concentrations in the 11 wells with significant tracer concentration was 47.8 ± 14.9 (n=11) mg/L nitrate-N. Total N concentrations higher than 50 mg/L were observed in 7 of the 11 wells (FDOH, 2004; Harden et al, 2008).

The primary goal of this study is to assess the performance of two NRTS. A secondary goal is to establish the relationship between the observed nutrient concentrations in the groundwater to the effluent concentrations from the NRTS and to compare these results with those from Phase I. Since karst conditions occur throughout most of Florida, the results of the study will help shed light on the effectiveness of NRTS in much of the state. We tested the hypothesis that the NRTS units would reduce N loading to the groundwater which would result in reduced groundwater nitrate concentrations.

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3. Study Background

The two conventional systems studied in Phase I were replaced with onsite NRTS for Phase II. Both systems consist of three tanks. The systems used the original septic tank as the trash tank, and had an ATU treatment tank, and a pump tank. There was no recirculation from the treatment of pump tanks back to the trash tank. In this study we refer to effluent from the trash tank as septic tank effluent (STE). This water represents the nutrient load released from a typical septic tank without an ATU. Treated water was collected from the pump tank. This water is referred to as Effluent Following Treatment (EFT). The degree of N-reduction is compared between the treated water in the pump tank effluent (EFT) and the untreated septic tank effluent (STE). The treatment tank, containing the ATU, provides oxygen to convert the TKN, mostly ammonia, into nitrate (NO_3) and nitrite (NO_2) with most NO_2 converting rapidly to NO_3. Once the nitrogen is converted into NO_3 and NO_2, denitrification may occur with N_2 gas as the end nitrogen species. The aerated effluent then flows into a pump tank where denitrification may also occur depending on dissolved oxygen (DO) level and organic carbon source concentrations. The aerated effluent from the treatment tank temporarily raises DO in the effluent in the pump tank. After a dosing of aerated effluent, the pump tank effluent DO concentrations rapidly decrease. Similar systems designed for residential use have been shown to reduce nitrogen by 50-70% when operating as designed (FDOH, 2007a, unpublished FDEP).

At Magnolia II, the ATU installed was a Hydro-Action and at Hickory a MicroFAST ATU was installed. The MicroFAST ATU has a fixed media in the treatment tank for the nitrifying bacteria to attach to and grow upon, while in the Hydro-Action system, the nitrifying bacteria grow in suspension without any fixed support. Details of the installation process are described in Chapter II. The installation of the systems at both campgrounds began in 2004. At Magnolia II the ATU began operation in 2004. Drainfield reconfiguration of the system was finalized and became operational on March 09, 2009. The installation and design of the system at the Hickory campground was complicated and delayed by site limitations and was not finalized until March 23, 2009, well into the study period. These delays postponed the first of the 3 “post-operational” sampling events until March 26-27, 2009, severely restricting the scheduling of sampling events,

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which were required to be completed by mid June, 2009. An additional sampling event occurred in September 2009.

New drainfields were installed away from both study sites in less environmentally sensitive areas of the park. Plumbing was installed with a valve to direct the effluent back to the original drainfields used in Phase I of the study (Harden et al., 2008) and also in case issues arose with the new drainfields and pumps. The study plan was to direct the effluent to the original drainfields after the ATU units were installed, and to compare the nutrient concentrations in the wells to the Phase I results. The new drainfield for the Magnolia II campground is located further from the river and is less likely to experience flooding. The new drainfield at Hickory is located between the main parking lot and the Magnolia II campground (Figure 1).

Sampling for this study started in January, 2009 with a sampling event that was intended to collect background data, before the treated effluent was diverted back to the original (Phase I) drainfields. However due to issues with effluent pumping to the new drainfields, both sites had experienced some periods of untreated effluent flow to the original drainfields during the time between installation of the systems and system finalization. The last such events appeared to have occurred in October 2008 at Magnolia II and in May 2009 at Hickory. **Thus the January 2009 sampling event captured a residual impact of septic tank effluent on the groundwater prior to the beginning of operation of the ATU's which were initiated in March 2009.** At Magnolia II, the effluent was re-directed back to the original drainfield on February 24, 2009. On March 31, 2009 FDOH staff reported that the pump tank appeared to be leaking and the pumps appeared not to be switching to the on position properly. The floats were repaired within 3 days, but it is unclear if the pump tank is still leaking (personal communications, Park Manager), which would rather complicate the analysis of the monitoring well nutrient data. If the pump tank is leaking as reported, then effluent is entering the water table without going through the drainfield. At Hickory, the effluent was redirected to the original drainfield on March 23, 2009 (personal communications, Park Manger). The timing of the redirection of effluent back to the original drainfield is crucial to understanding the connection of the loading of nutrients by the NRTS and nutrient data from the respective monitoring wells.

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A further complication was the flooding that occurred at the Park during the study period. The Suwannee River was above the 10-ft flood stage at Manatee Springs from April 18 to April 22, 2009, cresting on April 20, 2009 (SRWMD website, 2009). The flooding submerged the wells at Magnolia II and raised the water levels significantly in the Hickory site wells. This flooding had two effects. First, it flushed the groundwater in the wells, impacting the water quality most likely lowering nutrient levels in the well fields. Second, the park campgrounds were closed from April 13 to April 29, 2009 resulting in no influent loading into the septic systems, which were not in use during this period. Swimming at the Park was not reopened until May 7th; therefore even following reopening of the campground, visitation at the park was very light compared to normal attendance during much of the study. During our June sampling event and 4 day intensive NRTS sampling, the campgrounds were only about half full (field observation). The period of inactivity due to the flood and lower than normal bathhouse usage may have influenced the performance of the NRTS. The June 30 completion date for the study necessitated sampling under less than optimum conditions. **However, we were able to compare groundwater data in 2009 to a similar flooded period in 2003.**

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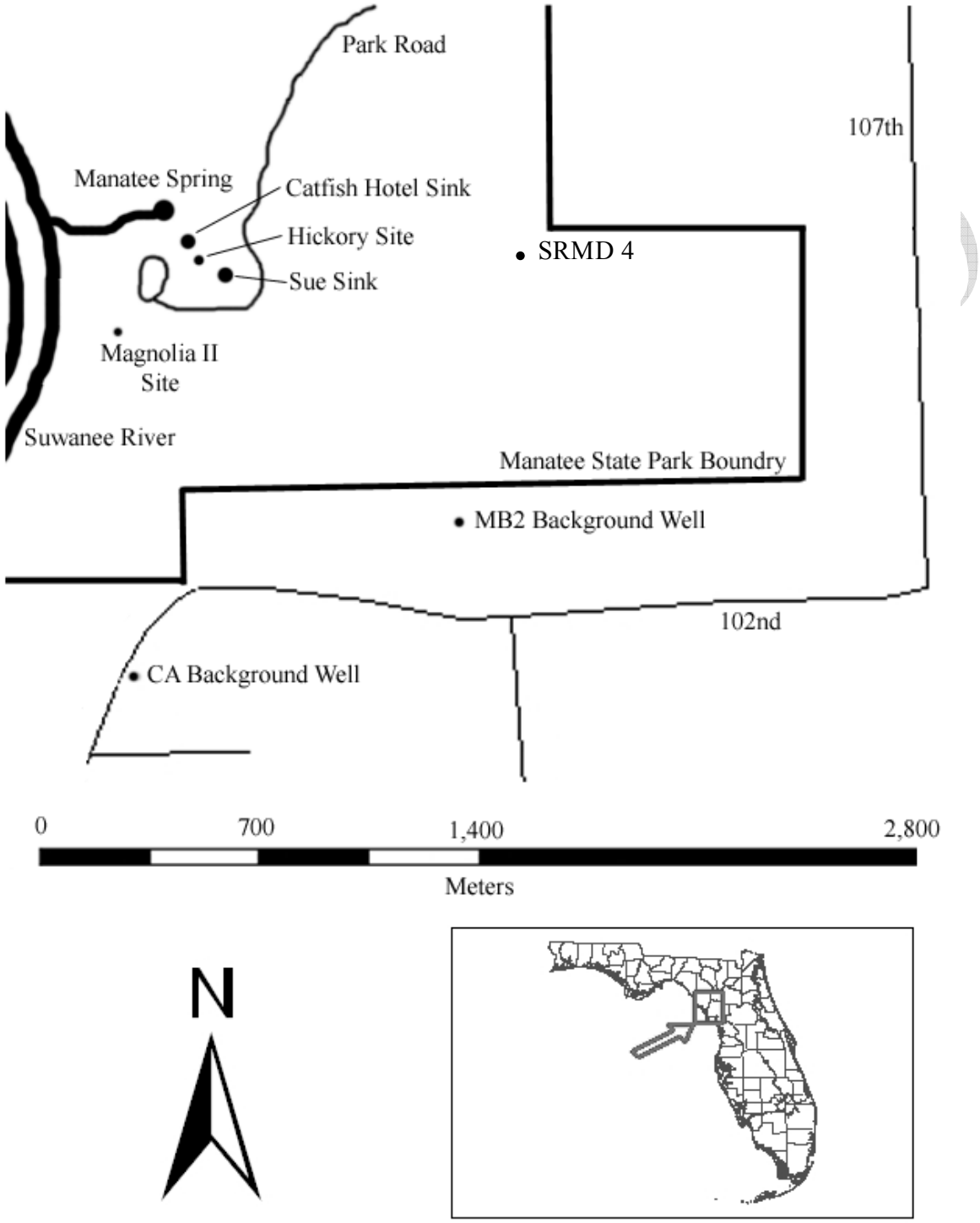
Figure 1. Map of study site. Background wells in Phase II are CA and SRMD 4.



4. Methods

4.1. *Study Design*

Environmental sampling

The conventional septic systems at Hickory and Magnolia II were replaced by NRTS and the effluent pumped to new drainfields. A valve was installed so that the effluent could be re-directed to the original drainfields for this study. The first sampling event in January 2009 sampled the wells before the NRTS units were brought on line. Three more sampling events were planned through June 2009 after the units were operational. An additional sampling event occurred in September 2009. The same parameters measured in Phase I (nitrite, nitrate, ammonia, TKN, total phosphorus and fecal coliforms) were measured in this study. Additionally, an YSI Model 63 field instrument was used to collect field water quality data, including dissolved oxygen, conductibility, pH, oxidation/reduction potential and salinity. The tracers released in Phase I were analyzed in samples from the first two sampling events occurring after the systems were finalized.

At Magnolia II, 8 wells were sampled, with two wells M4 and M10 from Phase I being omitted (Figure 2). These wells were shown by the nutrient and tracer data to be outside the septic plume in Phase I (Harden et al, 2008). At Hickory 5 of the 10 monitoring wells were sampled. C6, one of the wells shown to have elevated nitrate concentrations in Phase I, was damaged during construction of the new septic system. The 5 wells with the highest average nitrate concentrations in Phase I (S1, S2, C3, C4 and C5) were sampled in this study (Figure 3). The nitrate concentrations had averaged less than 0.5 mg/L in the other 4 wells in Phase I (Harden et al., 2008). One background well from Phase I (Camp Azalea) was sampled in this study. The other background well from Phase I, MB2, was shown to have elevated nitrate levels and therefore not an appropriate background sampling station (FDOH, 2004). The second background well from Phase I was substituted by SRWMD #4 for this study. In addition to the groundwater samples, influent and effluent samples were taken from the two NRTS.

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Figure 2. Magnolia II site behind the Magnolia II campground bathhouse, showing OSTDS. Well M1 is in the lower portion of the drain mound slope. Wells M10, M4, M6 are just in front of the cypress marsh adjacent to the Suwannee River.

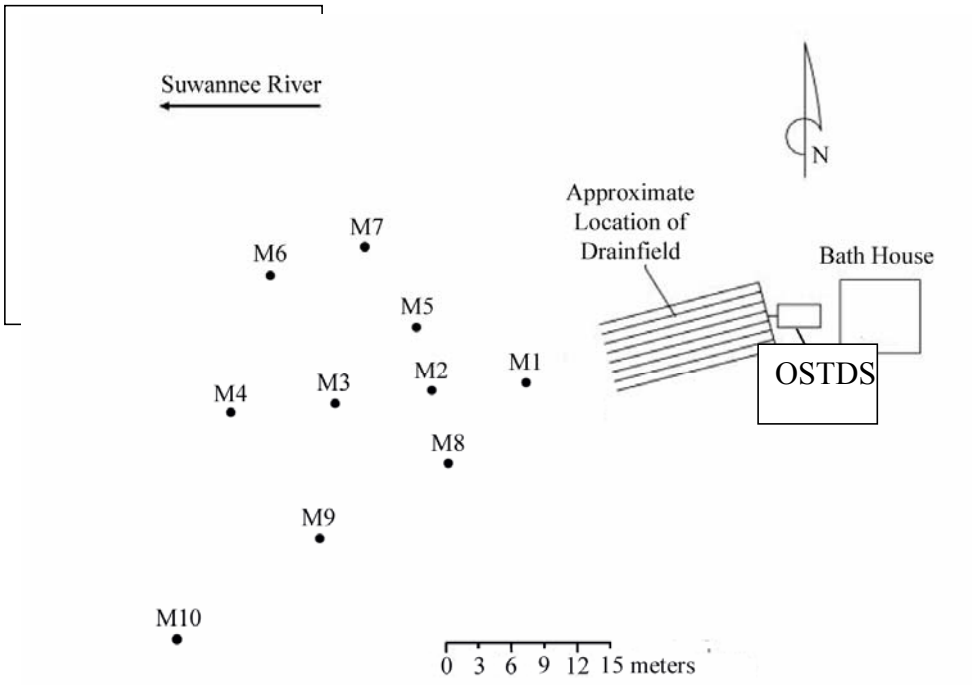

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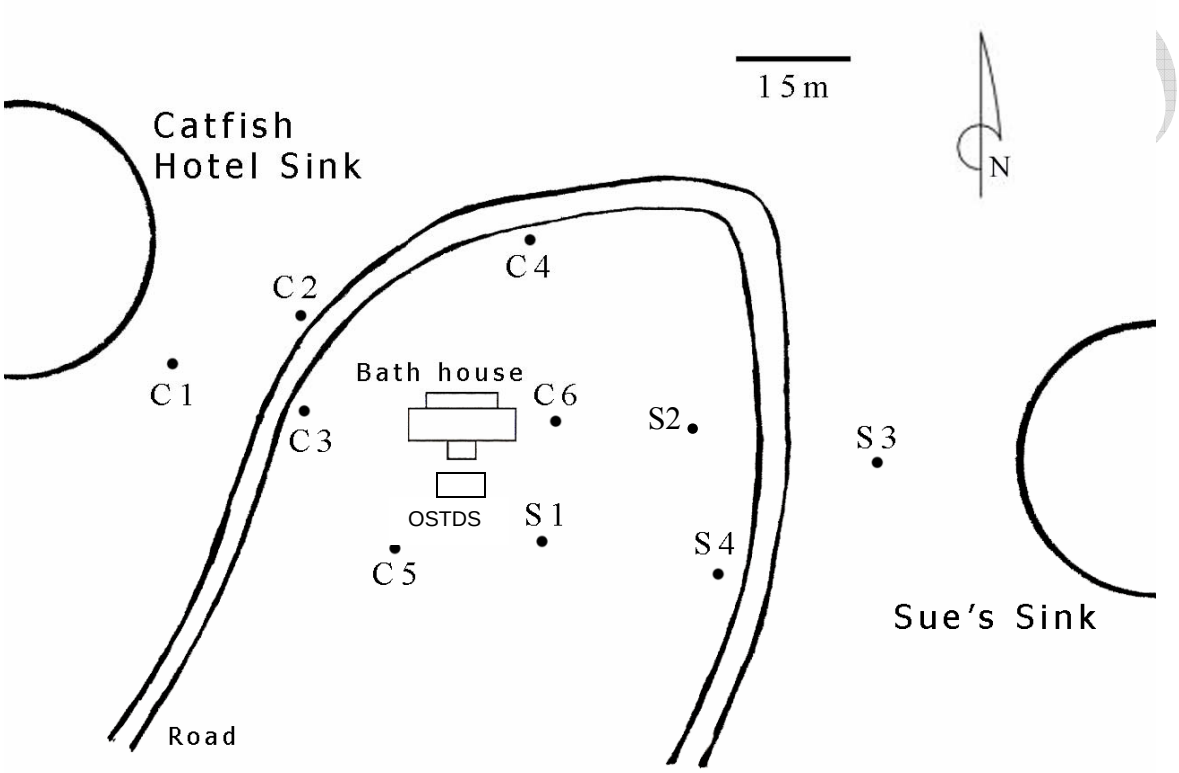
Figure 3. Study site at Hickory campground. Well S1 is installed in a Paleo-sink hole as determined by the ground penetrating radar study in Phase I. The original drainfield was due South of the bathhouse, with multiple lines running near C5, S1, S4. S2 was installed at the end of a drainfield line. Wells S1, S2, C3, C4 and C5 were sampled in this study. Current NRTS is located between wells S1 and C5.



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Performance assessment

To assess diurnal and daily variability of performance, multiple samples of the influents and effluents were taken over a period of four consecutive days from 16:55 May 31 to 16:14 June 4, 2009, consisting of 8 grab and four 24 hour time composite samples. The last environmental sampling event occurred on the last day of the performance assessment. The field parameters dissolved oxygen, conductivity, pH, oxidation reduction potential, and salinity were measured using an YSI Model 63 field probe in addition to the same nutrients analyzed in the ground water samples.

4.2. *Monitoring Well Sample Collection*

All samples were collected using a submersible purge pump. At least three well volumes were pumped prior to any sampling. Samples for nutrients and fecal coliforms were collected from the wells in containers provided by the analytical laboratory. Sulfur hexafluoride samples were collected in 30-mL serum vials. The vial was allowed to overflow for at least three bottle volumes, and was then sealed with a rubber septum and a crimp cap. Fluorescein samples were collected and stored in 100-mL amber polycarbonate containers.

4.3. *Septic System Sample Collection*

Samples representing the pre-advanced treatment of the influent were taken from the outlet filter of the first tank of the two systems, also known as a trash tank, and are designated STE as they are the same as effluent for a conventional septic tank. At each campground, the original conventional septic tank served as the trash tank for the NRTS. A tube was placed in the outlet filter chamber at the trash tank outflow pipe prior to the treatment tank containing the ATU to obtain these samples.

Effluent following treatment (EFT) was sampled from a clean out between the pump tank and the drainfield at the Hickory site. To take a sample, the pump was manually turned on and a sample vessel was used to catch the flowing water. YSI measurements were taken by

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placing the probe into a collection vessel either immediately before of after the sample was taken. At the Magnolia II site, the EFT was sampled directly from the pump tank, as no cleanout was available post pump tank. A peristaltic pump was used to take the sample through weighted tubing placed several inches below the effluent surface.

Only two automatic composite samplers were available at the time of the performance assessment. The other two composite samples consisted of 4 sub composite samples taken every 6 hours, held on ice and combined to make a 24-hour composite sample.

4.4. *Nutrient and Fecal Coliform Analysis*

Samples were transported on ice to the laboratory and analyzed for fecal coliforms (SM9222D), total phosphorus (EPA 365.3), total ammonia (EPA 350.2), total Kjeldahl nitrogen (TKN) (EPA 351.3), nitrite-nitrogen (SM 4500NO2B), and nitrate-nitrogen (EPA 353.3).

4.5. *Sulfur Hexafluoride Sample Analysis*

Sulfur hexafluoride samples were extracted as described by Dillon et al. (1999) and Harden et al. (2003). A small headspace of 4 mL of ultra-high purity nitrogen was added to the samples using a syringe. Simultaneously, 3 mL of water from the sample was removed and discarded to allow room for the headspace. The serum vials were slightly over-pressurized with 1 cc of nitrogen to allow for several injection volumes (100 uL or less) for the gas chromatograph (GC). After shaking for at least two minutes, this method extracts 95+% of the SF_6 from a water sample. The lower limit of this technique is 0.1 pM (Dillon et al., 2000). Samples were analyzed with a Shimadzu model 8A gas chromatograph equipped with an electron capture detector as described in Harden et al. (2003). Headspace concentrations in ppmv (parts per million by volume, = μL/L) of SF_6 were determined by reference to a 1.04 ppmv standard (Scott Specialty Gases). Headspace concentrations were converted to dissolved concentrations in pM.

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4.6. *Fluorescein Dye Analysis*

The fluorescein samples were analyzed using a Turner Designs TD-700 Fluorometer, which provides exact concentrations after calibration. The fluorometer used a 10-089 blue mercury vapor lamp, 10-105 excitation filter (486 nm), and 10-109R-C emission filter (510-700 nm), as specified by the manufacturer. The fluorometer was initially calibrated using fluorescein standards made using DI water in the laboratory with a lower detection limit of 0.0005 mg/L. Calibration was checked several times daily by use of solid-state standards.

4. Results

4.1. *Environmental Monitoring*

Magnolia II Campground

In wells M1, M2, M5 and M6 the highest concentrations were observed on the first sampling event, 01/14/09 and then concentrations decreased over the next three sampling events. In well M2, the nitrate concentrations observed on the last two sampling events were below the levels in the background wells (shown in Fig 7). Well M6, nitrate concentrations was also below background levels on the last sampling event on 6/4/09 (Figure 4).

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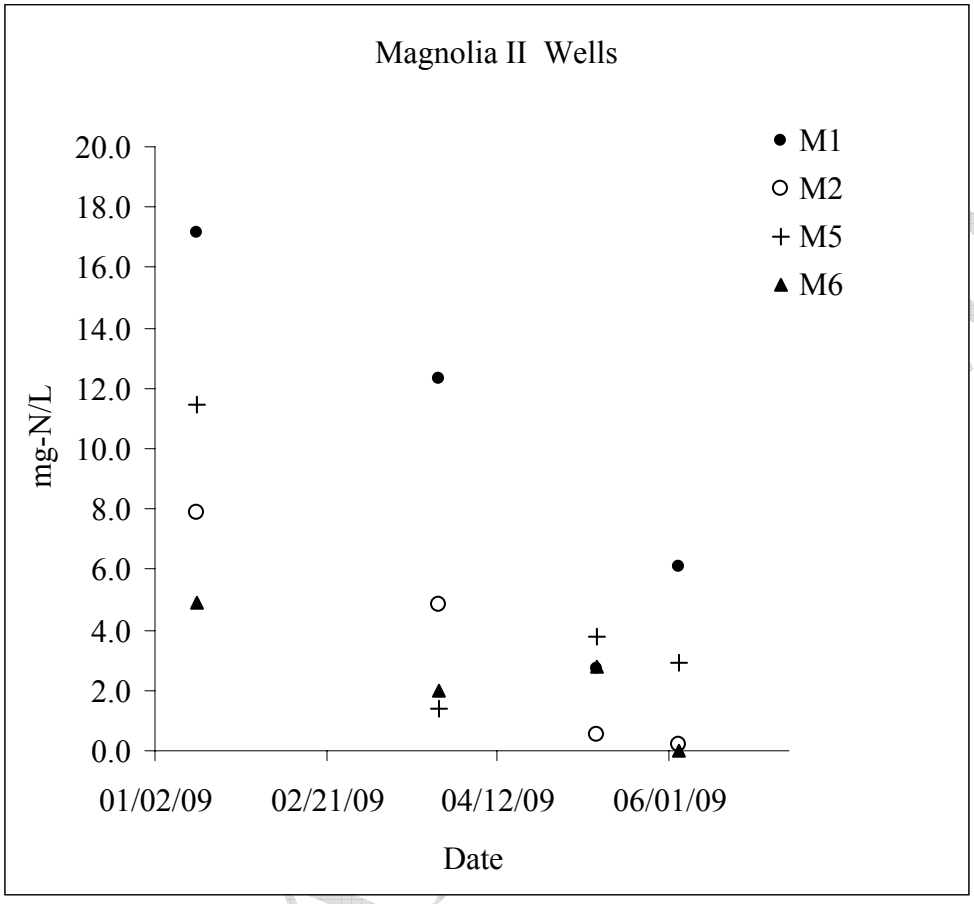
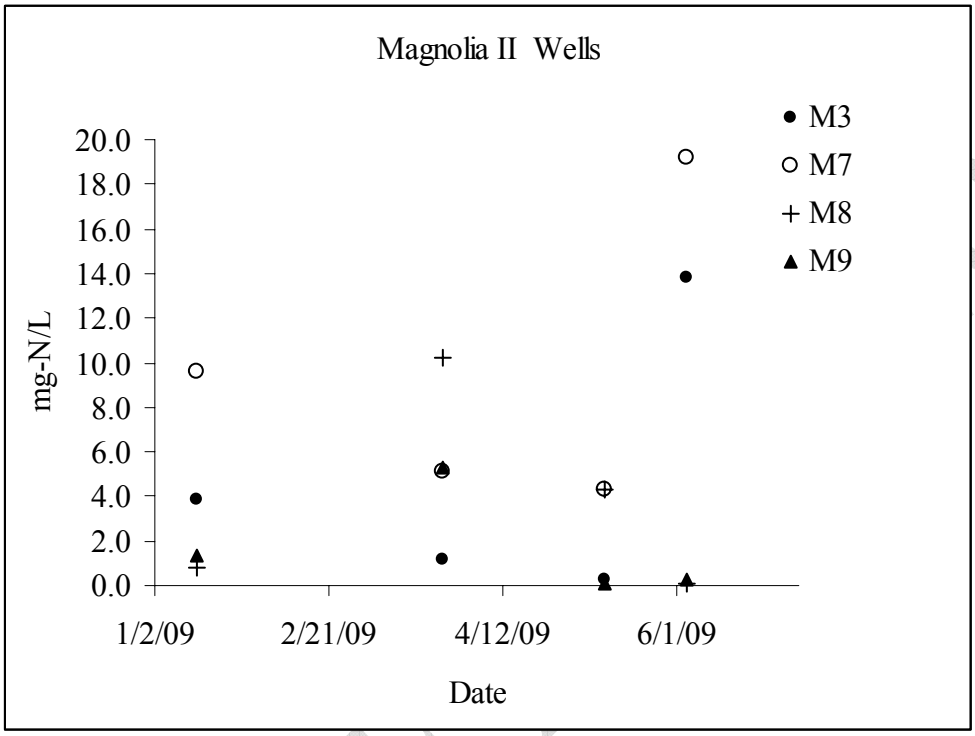
Figure 4. Nitrate concentrations from wells M1, M2, M5 and M6 sampled on 01/14/09, 3/26/09, 05/11/09 and 06/04/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29 and submerging the wells at Magnolia II.



On 01/14/09, nitrate levels observed in wells M3 and M7 were above background well concentrations, and wells M8 (0.77 mg-N/L) and M9 (1.36 mg-N/L) were near background levels (shown in Fig 7). On 3/26/09, the nitrate concentrations in M8 and M9 increased and decreased in wells M3 and M7 to near background concentrations. On 05/11/09, concentrations of nitrate decreased to near background levels in wells M3 and M10, and also decreased in M7 and M8 but were well above background well concentrations. The highest concentrations of nitrate in wells M7 and M3 were observed on 06/04/09 and concentrations in M8 and M9 were below background well concentrations (Figure 5).

Figure 5. Nitrate concentrations from wells M3, M7, M8 and M9 were taken on 01/14/09, 3/26/09, 05/11/09 and 06/04/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29 and submerging the wells at Magnolia II.



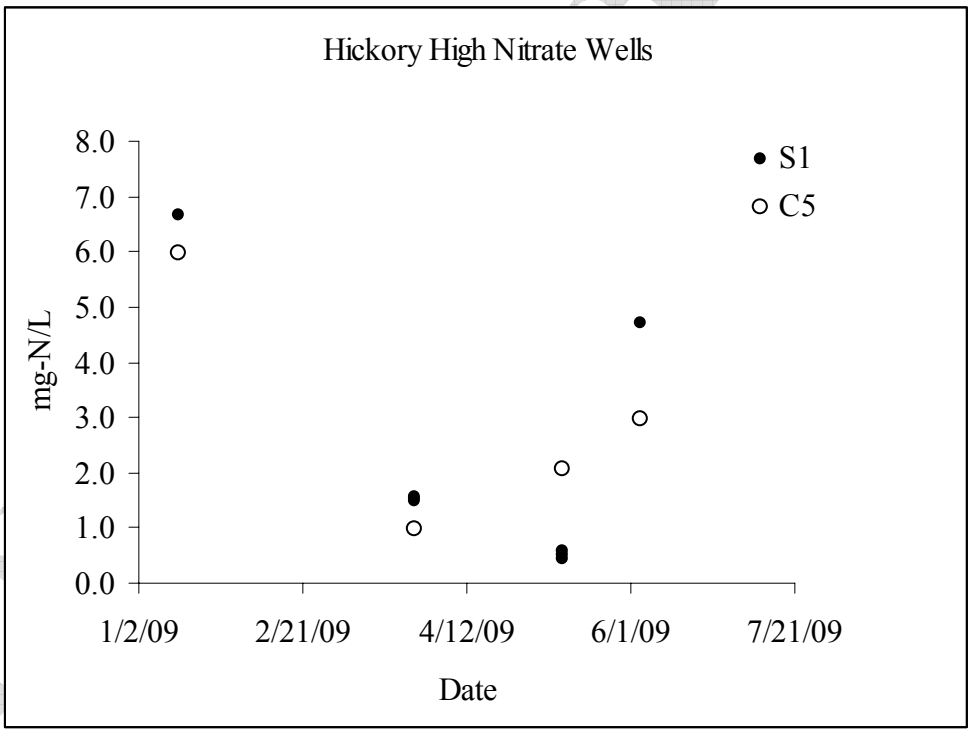
Total phosphorus in the wells at Magnolia II were between a low of 0.09 ± 0.03 mg-P/L (n=4) in well M9 to a high of 0.34 ± 0.04 mg-P/L (n=4) in well M2. All wells, except M9, were above the concentrations observed in the background wells, 0.13 ± 0.14 mg-P/L (n=8).

Fecal coliform was found sporadically throughout the well field. All wells had zero colonies in at least one of the four sampling events. The highest counts were 93 colonies/100 mL in M9, 67 and 32 colonies/100 mL in M2, and 32 colonies/100 mL in well M6. No fecal coliform colonies were found in the background wells.

Hickory Campground

In all 5 wells at Hickory campground the highest nitrate levels were observed in samples from the first sampling event on 01/14/09. This sampling event was intended to indicate the water quality surrounding the drainfields before the effluent was re-directed. Unfortunately, issues with the new systems required the old drainfields to be used during repairs prior to the start of the study. Wells S1 and C5 had the highest observed nitrate concentrations observed at the Hickory site. Nitrate concentrations were lower in the next two sampling events on 3/24/09 and 05/11/09. On the last sampling event on 06/04/09, the concentrations increased again (Figure 6).

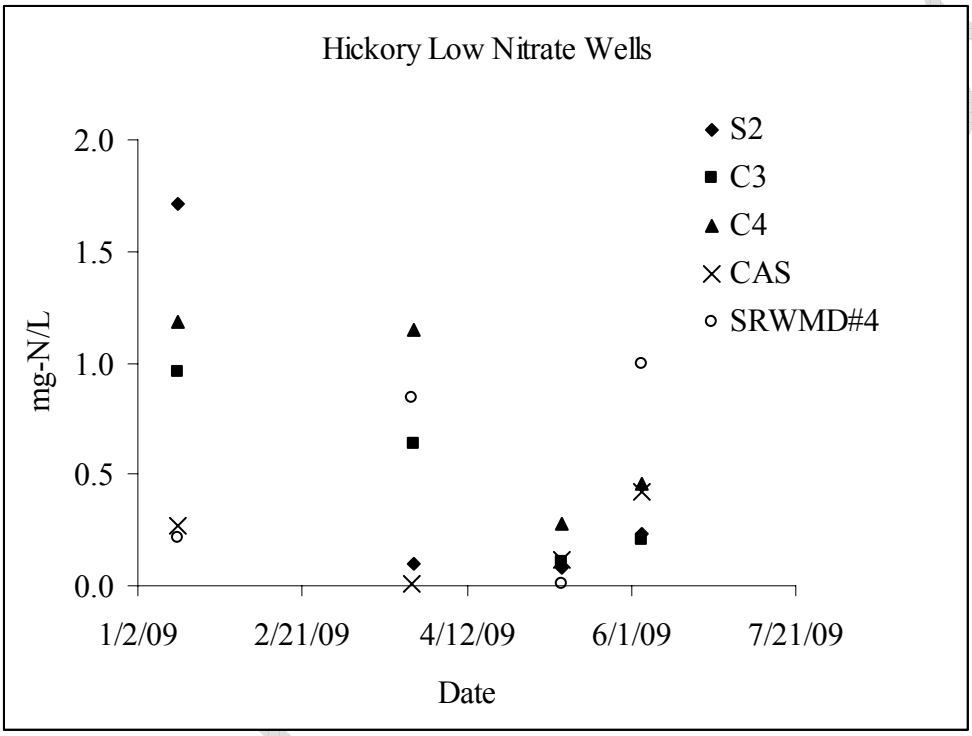
Figure 6. Nitrate concentrations from wells S1 and C5 taken on 01/14/09, 3/27/09, 05/11/09 and 06/04/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29.



On 01/14/09, the nitrate concentrations in wells S2, C3, and C4 were above the levels found in the two background wells, 0.20 ± 0.18 mg-N/L in CAS and 0.52 ± 0.48 mg-N/L in SRWMD #4, yet much lower than S1 and C5 (Figure 6). Concentrations decreased on 3/27/09, but were still above background levels in wells C3 and C4. In the last two

sampling events on 5/11/09 and 6/4/09 wells S2, C3, and C4 were near or below back ground well concentrations (Figure 7).

Figure 7. Nitrate concentrations from wells S2, C3, C4 and background wells CA and SRWMD #4 taken on 01/14/09, 3/27/09, 05/11/09 and 06/04/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29.



Total phosphorus in wells S2, C3, C4, and C5 were less than half the concentration of 0.13 ± 0.14 mg-N/L (n=8) observed in the two background wells. The total phosphorus observed in well S1 was 0.76 ± 0.40 mg-N/L (n=4). The highest concentration of 1.32 mg-N/L was the only sample above background levels.

Fecal coliform was found sporadically throughout the well field. All wells had zero colonies in two of the four sampling events. The highest counts were 120 colonies/100 mL in C5, 76 colonies/100 mL in C4, and 18 and 25 colonies/100 mL in well S2. No fecal coliform colonies were found in the background wells.

Tracers

Samples for tracers released in Phase I were collected during the sampling events of 03/26-27/09 and 05/11/09. Neither tracer was detected in any of the samples, indicating that the tracers are likely no longer present in the groundwater.

Water Use

Water meter data at both bath houses clearly indicate the period of inactivity at the park during and after the flood (Fig 8).

Figure 8a. Park staff records weekly water meter readings at both bathhouses and the water meters were read during sampling events.

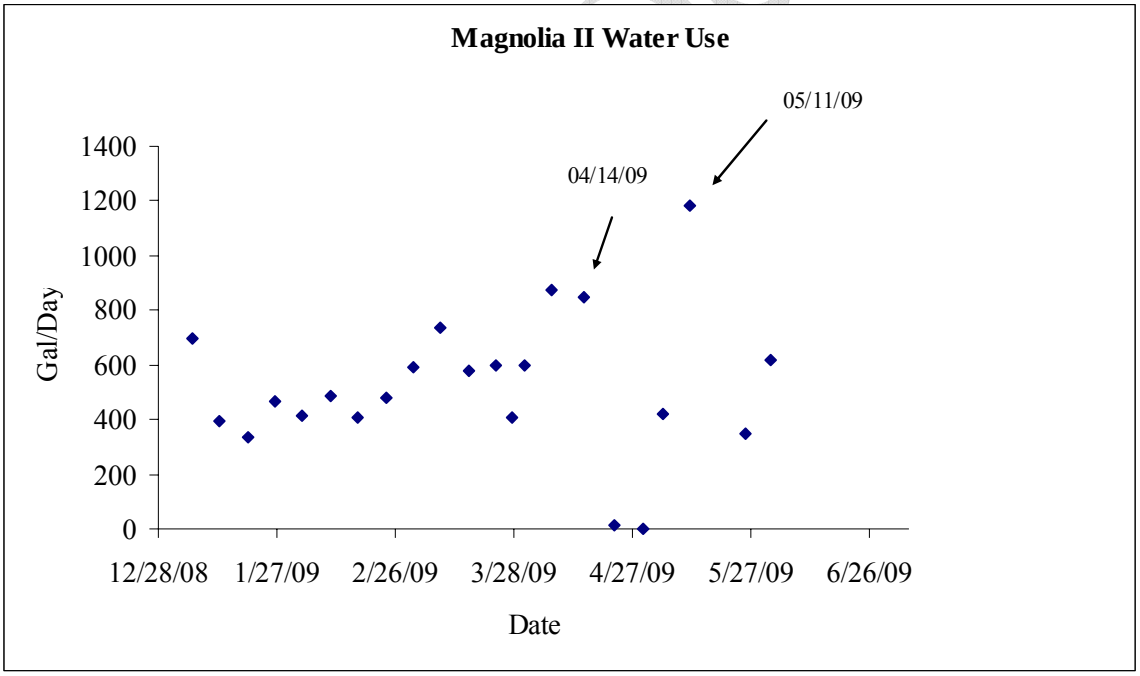
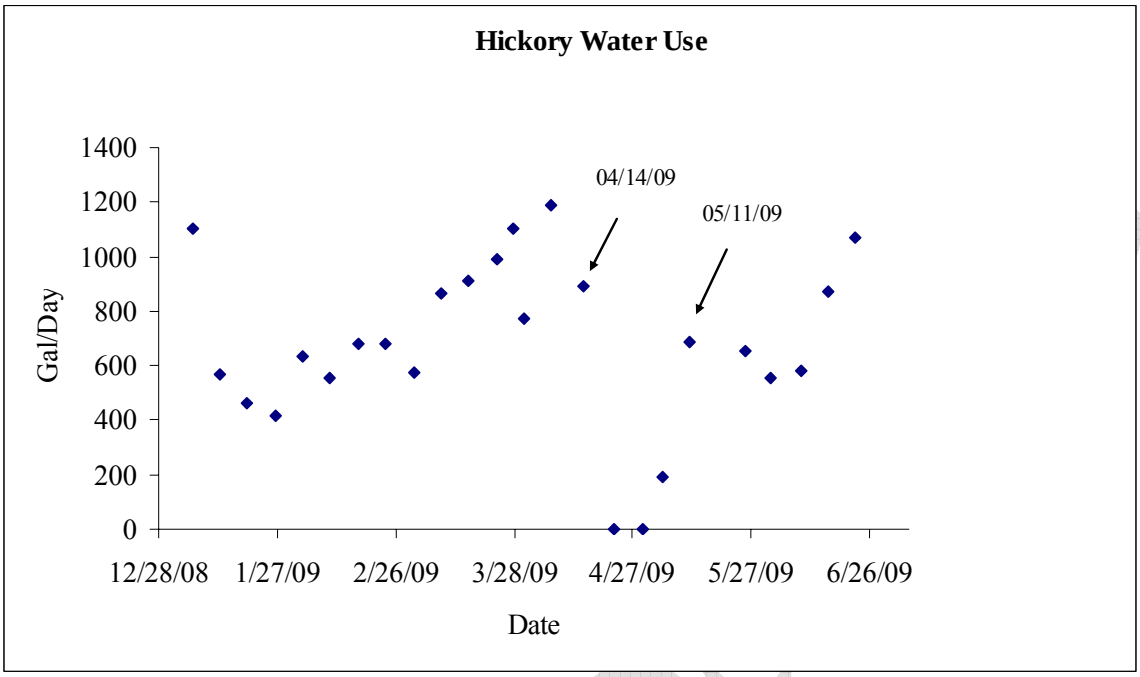


Figure 8b. Park staff records weekly water meter readings at both bathhouses and the water meters were read during sampling events.



4.2. *Septic System Performance Assessment*

The performance assessment sampling occurred on five days, from the afternoon of Sunday May 31, 2009 through the afternoon of Thursday, June 04, 2009. The septic influent was sampled from a tube placed in the outlet filter chamber, so it was representative of the effluent flowing out of the first tank in the system, known as the trash tank. At Magnolia II the four trash tank composite samples were taken using an automatic sampler. The first composite trash tank sample at Hickory employed a composite sampler. The automatic composite sampler took a sample every three hours for 24 hours. Composite trash tank samples 2-4 at Hickory were manually combined and consisted of four 100 mL samples, each taken 6 hours apart and stored on ice. Pump tank effluent was sampled directly from the pump tank at Magnolia II, with the first composite sample being manually combined and the remaining three composite samples were sampled with an automatic sampler. At Hickory, the EFT was sampled from a cleanout between the pump and drainfield. All Hickory composite EFT samples were manually combined. In addition to the composite samples, 2 grab samples were taken during each 24 hour period over the 4 days. At the end

of the last 24-hour period, the final environmental sampling event was performed, which included an additional grab sample from each septic sampling station.

Average water use over the four days of performance sampling was 473 gpd at Hickory and 408 gpd at Magnolia II, in both cases about 40% of the design hydraulic capacity. The weekly water readings conducted by park staff on Monday mornings indicate that the average daily water use during the week ending at the beginning of the performance sampling at Hickory was 530 gpd and 420 gpd at Magnolia II. The average weekly water use during the week that included three of the performance sampling days was 610 gpd at Hickory and 370 gpd at Magnolia II. This indicates that Hickory experienced more use during weekends and that the sampling monitored the transition from higher use conditions during the weekend to lower use during weekdays. Comparison of these flow data with figures 8a and 8b indicates that the use during the performance assessment was typical for the study period.

At Magnolia II, composite and grab sample results were very similar. The Magnolia II STE samples had total N values of 143.33 ± 25.27 mg-N/L (n=4) for the composite samples and for the grab samples 141.61 ± 27.89 mg-N/L (n=9). The EFT values for total N at Hickory were also in close agreement between the four composite samples (44.52 ± 12.53 mg-N/L) and the nine grab samples (42.49 ± 8.24 mg-N/L). The % reduction of total nitrogen calculated from the composite samples was 68.9% and from the grab samples is was 70.0%.

Higher TN concentrations were observed in the STE at Magnolia II on the environmental sampling events of 03/26/09 and 05/11/09, yet the EFT samples were lower, yielding higher % reduction of TN (Table 1).

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Table 1. Both the influent (STE) and effluent (EFT) nutrient results from the performance assessment composite and grab samples at Magnolia II campground. The composite samples are 24 hour samples. The grab sample average of 5/31 to 6/4 includes the third environmental sample taken on 06/04/09. The composite samples are 24 hour samples taken over a 4 day period from 05/31/09 to 06/04/09. The % N reduction by the system is reported by the different sampling dates. Campground usage was still below normal on the 05/11/09 and 06/04/09 sampling events.

			Nitrate+Nitrite	Ammonia	TKN	TN	Total P
5/31 to 6/4			mg/L	mg/L	mg/L	mg/L	mg/L
Mag STE	**Comp**	**Ave.**	**6.45**	**97.27**	**136.88**	**143.33**	**4.05**
		Stdev	12.60	20.91	27.38	25.27	0.30
Mag EFT	**Comp**	**Ave.**	**18.39**	**21.38**	**26.13**	**44.52**	**3.47**
		Stdev	15.07	5.31	4.20	12.53	0.39
				% TN Reduction		***68.9***	
5/31 to 6/4							
Mag STE	**Grab**	**Ave.**	**3.59**	**103.31**	**138.02**	**141.61**	**3.85**
		Stdev	*6.99*	*21.30*	*31.16*	*27.89*	*0.38*
Mag EFT	**Grab**	**Ave.**	**12.95**	**22.17**	**29.54**	**42.49**	**3.66**
		Stdev	*10.18*	*6.56*	*14.74*	*8.24*	*0.30*
				% TN Reduction		***70.0***	
Environmental sampling							
Mag EFT	**01/14/09**		**63.48**	**2.02**	**3.00**	**66.49**	**20.80**
Mag STE	**03/26/09**		**7.76**	**83.64**	**202.89**	**210.65**	**0.13**
Mag EFT	**03/26/09**		**12.24**	**1.68**	**14.16**	**26.40**	**0.11**
				% TN Reduction		***87.5***	
Mag STE	**05/11/09**		**0.06**	**39.56**	**177.88**	**177.94**	**1.50**
Mag EFT	**05/11/09**		**6.94**	**10.70**	**12.92**	**19.86**	**1.75**
				% TN Reduction		***88.8***	

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At Hickory campground the difference between composite samples and grab samples was more pronounced. The trash tank composite samples had total nitrogen concentrations of 79.83 ± 17.64 (n=4), while the total nitrogen concentration in the grab samples, 110.68 ± 31.83 mg-N/L (n=9), were in the same range, but more variable. The EFT total nitrogen concentrations of the composite samples, 61.34 ± 9.97 mg-N/L (n=4) and grab samples, 50.09 ± 20.79 mg-N/L (n=9) were in good agreement. The percent reduction of nitrogen by the system was less clear for the composite samples than the grab samples. The grab samples indicate a total nitrogen reduction of 54.7%. The percent reduction of total nitrogen calculated from composite samples was less clear as the second set of composite samples yielded a higher effluent total nitrogen (61.0 mg-N/L) value than the influent total nitrogen (52.5 mg-N/L), yielding a negative % reduction (Table 2). Note that this system was only installed on March 23, 2009.

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Table 2. Nutrient results from the performance assessment composite and grab samples at Hickory campground. The composite samples are 24 hour samples. The grab sample average of 5/31 to 6/4 includes the environmental sample taken on 06/04/09 (third environmental event). The second set of composite samples, Comp #2, had higher TN in the ETF sample than the STE, yielding a negative % reduction.

			Nitrate+Nitrite	Ammonia	TKN	TN	Total P
5/31 to 6/4			mg/L	mg/L	mg/L	mg/L	mg/L
Hick STE	**Comp**	**Ave.**	**0.52**	**65.85**	**78.41**	**78.93**	**3.50**
		Stdev	*0.37*	*18.63*	*18.00*	*17.64*	*0.38*
Hick EFT	**Comp**	**Ave.**	**34.26**	**27.90**	**27.08**	**61.34**	**3.35**
		Stdev	*18.79*	*17.04*	*15.44*	*9.91*	*0.42*
Four day Average				***% TN Reduction***		***22.3%***	*n=4*
			Without Comp #2	***% TN Reduction***		***30.7%***	*n=3*
5/31 to 6/4							
Hick STE	**Grab**	**Ave.**	**3.08**	**80.54**	**107.60**	**110.68**	**4.05**
		Stdev	*8.03*	*28.46*	*30.54*	*31.83*	*1.25*
Hick EFT	**Grab**	**Ave.**	**22.50**	**25.20**	**27.59**	**50.09**	**3.29**
		Stdev	*21.41*	*16.92*	*19.40*	*20.79*	*0.32*
Four day Average				***% TN Reduction***		***54.7%***	*n=4*
Hick STE	**03/27/09**		**0.12**	**61.70**	**173.31**	**173.43**	**13.50**
Hick EFT	**03/27/09**		**2.42**	**42.34**	**106.70**	**109.13**	**12.99**
				% TN Reduction		***37.1%***	
Hick STE	**05/11/09**		**0.09**	**59.41**	**235.16**	**235.25**	**2.92**
Hick EFT	**05/11/09**		**6.31**	**33.60**	**52.54**	**58.84**	**2.73**
				% TN Reduction		***75.0%***	

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The field parameters measured with an YSI probe were very consistent over the course of the performance assessment. The influent trash tank samples were characterized by a high conductivity, low dissolved oxygen, and a highly negative oxidation/reduction potential compared to the STE samples with lower conductivity, higher dissolved oxygen, and a positive oxidation/reduction potential (Table 3).

Table 3. Field parameters from the performance assessment of the septic systems conducted from 05/31/09 to 6/4/09.

Site	Calc	Water T	COND	COND	Salinity	%SAT	DO	PH	ORP
		Celsius	µS/cm	mS/cm	ppt	%	mg/L	mg/L	mg/L
Hick STE	**Ave.**	**25.62**	**1312.67**	**1.33**	**0.65**	**9.07**	**0.74**	**6.94**	**-141.55**
	Stdev	0.16	23.77	0.03	0.01	7.37	0.60	0.13	28.04
Hick EFT	**Ave.**	**25.46**	**972.56**	**0.98**	**0.48**	**36.08**	**2.90**	**7.74**	**26.36**
	Stdev	0.49	82.65	0.09	0.04	10.73	0.85	0.21	17.69
Mag STE	**Ave.**	**27.15**	**1469.79**	**1.53**	**0.73**	**8.26**	**0.65**	**6.92**	**-142.48**
	Stdev	0.13	7.46	0.01	0.00	5.48	0.43	0.22	22.05
Mag EFT	**Ave.**	**26.72**	**1123.13**	**1.16**	**0.55**	**41.64**	**3.32**	**6.82**	**19.53**
	Stdev	0.22	16.89	0.02	0.01	7.84	0.62	0.36	26.75

4.3. *Nitrification and De-nitrification in Septic Systems*

Nitrification occurs in the treatment tank of the NRTS by the addition of air into the septic effluent. In the two STE grab samples on 03/27/09 and 05/11/09 and the first five grab samples of the performance assessment indicate that nitrification is limited, as the TKN values are greater than the nitrite + nitrate concentrations (Figure 9). .Note that the system had only been running 3 days when the first sample was collected on 3/27. Additionally, the

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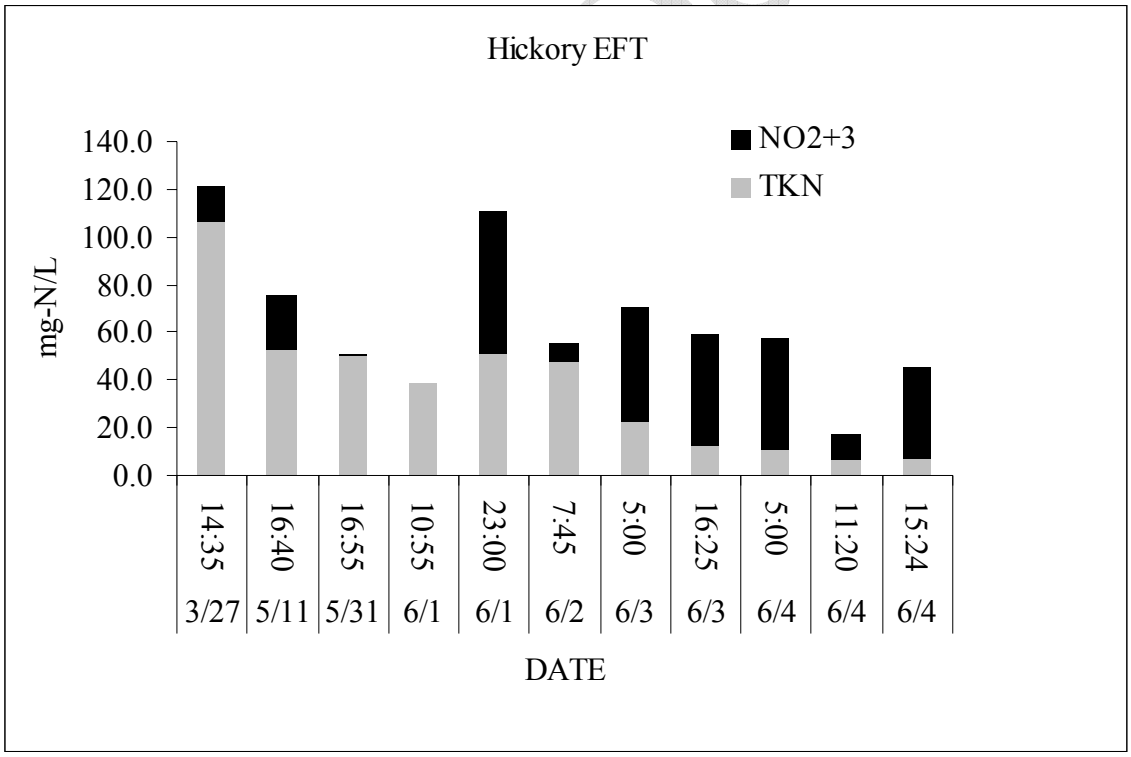
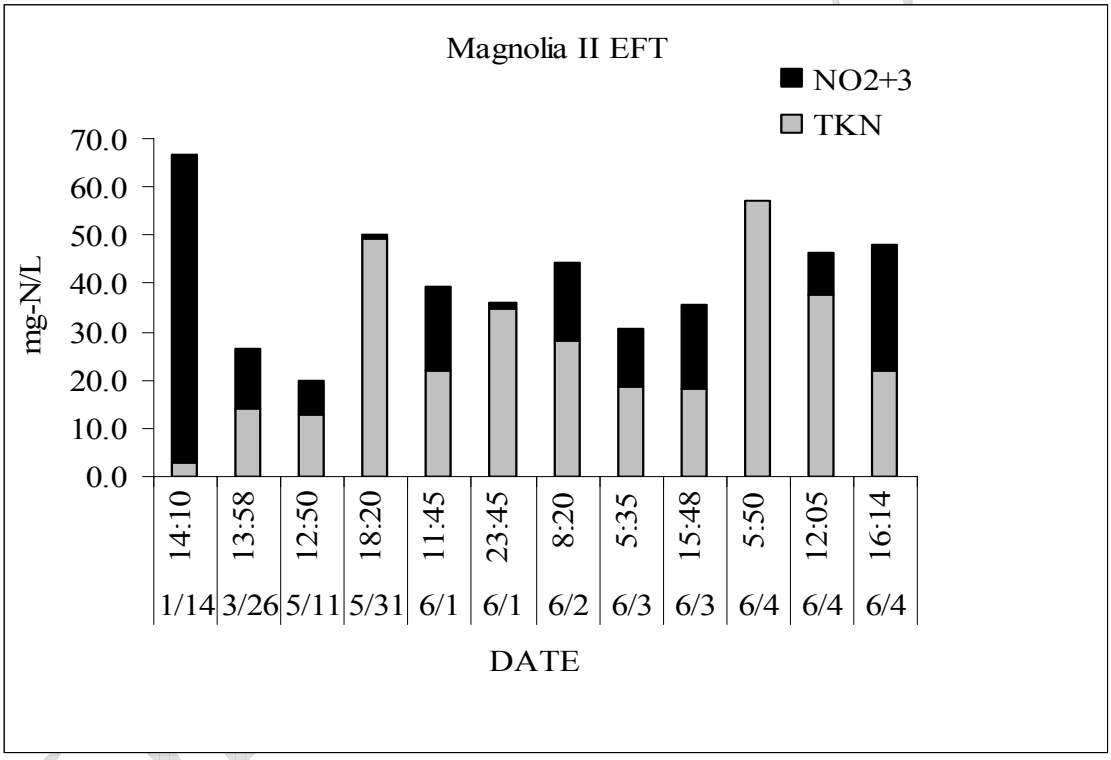
campground was closed from April 13th to the 29th and usage was below normal as swimming was reopened at the spring on May 7th. The data from 03/27/09 and 05/11/09 may be more representative of start-up conditions for the system. When a system is first started or re-started after a period of disuse, the nitrifying bacterial colonies are reestablishing and growing, thus limiting nitrification. By the time of the four day performance assessment, starting on May 31st, the system should have been past any start up period. The last four grab samples of the performance assessment indicate that the majority of the TKN had been converted to nitrate. Note the trend in the data towards lower TN values and more oxidized forms of nitrogen in Figure 9, with nitrate concentrations increased relative to TKN.

Figure 9. TKN and NO_3 + NO_2 are given for the EFT grab samples at Hickory campground. In samples with more TKN than NO_3 + NO_2, nitrification is limited, or else the nitrate was removed by denitrification. Note the trend in the data towards lower TN values and more oxidized forms of TN. Nitrate concentration increase relative to TKN



At Magnolia II, nitrate seems to be limited in many of the samples, with TKN being the major N species in the effluent. A notable exception is the STE sample taken on 01/14/09, which is mostly nitrite + nitrate (Figure 10). This may be due to limitation of nitrification (nitrate formation) or it could have been due to consumption of nitrate (denitrification).

Figure 10. TKN and nitrite + nitrate are given for the EFT grab samples at Magnolia II campground. In samples with more TKN than nitrite + nitrate, nitrification is limited, or the else the nitrate was removed by denitrification.



The significant reduction in total nitrogen during treatment, strongly suggests that de-nitrification is occurring (Figures 11 and 12). The dissolved oxygen values in the STE of approximately 40% saturation (Table 3) are not favorable for de-nitrification to occur in bulk solution, however, micro-environments are likely to be present which allow for de-nitrification.

Figure 11. Total nitrogen concentrations of influent samples (STE) and effluent samples (EFT) at Hickory campground. E designates grab samples from the environmental monitoring and G are grab samples from the performance assessment. Note that in every instance the STE bar is higher in concentration than the EFT bar it is paired with. The amount of this decrease is the % N reduction in the system as reported in Table 3.

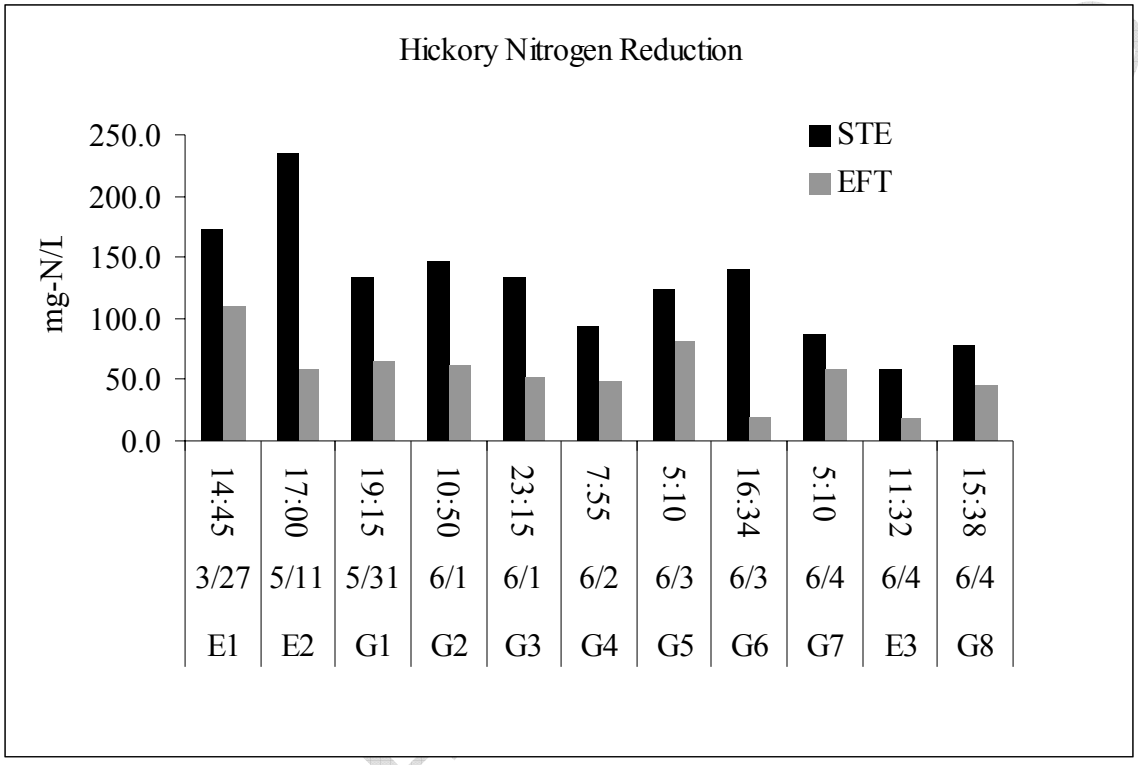


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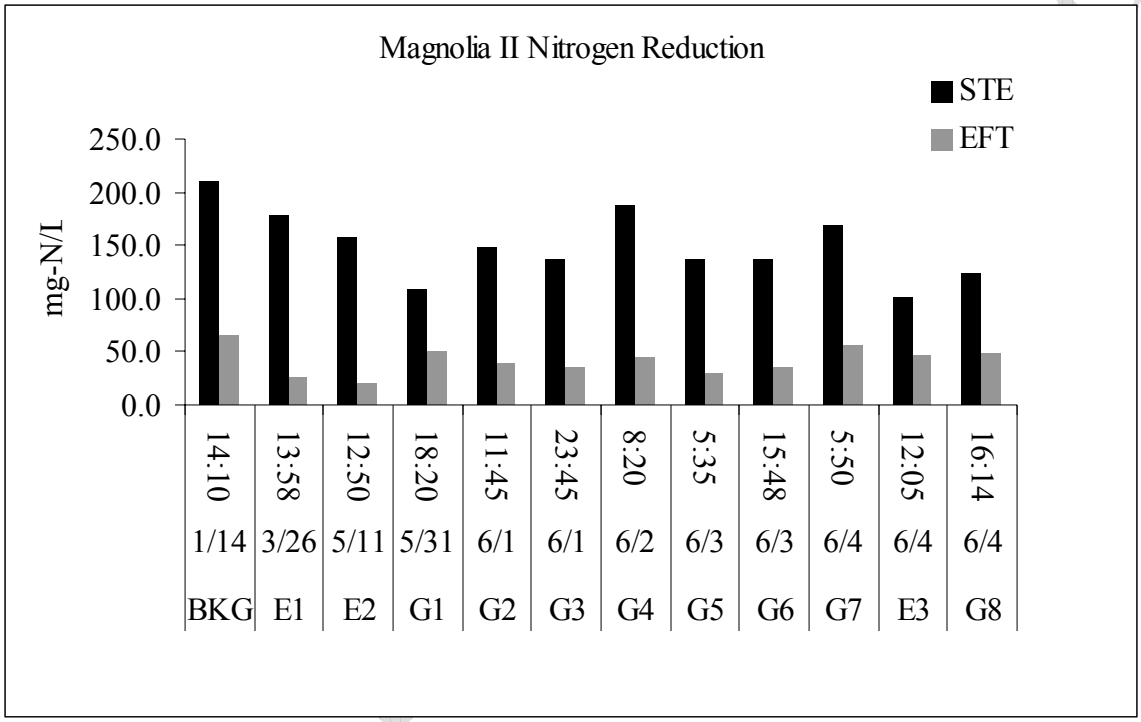
Figure 12. Total nitrogen concentrations of influent samples (STE) and effluent samples (EFT) at Magnolia II campground. E designates grab samples from the environmental monitoring and G are grab samples from the performance assessment. Note that in every instance the STE bar is higher in concentration than the EFT bar it is paired with. The amount of this decrease is the % N reduction in the system as reported in Table 3.



4.4. *Field Duplicates and Lab Replicates*

One field duplicate well sample was taken during each sampling event and laboratory replicates were analyzed from the march, 2009 sampling event. Table 4 summarizes the field duplicates and lab replicates. All errors were less than 10%, except for sample S1 on 05/11/09 which had an error of 12% for nitrate and 11% for TN. The values for nitrate (0.51 ± 0.06 mg-N/L) and TN (0.58 ± 0.06 mg-N/L) were low and range of error was acceptable.

Table 4a. Duplicates (F) and lab replicates (L) for well samples on each sampling date. The bold value is the average of the two duplicate or replicate and the italized value is the ½ the range of the values.

ID	Date		F Coli Cts/100ml	Nitrite mg/L	NO_2+NO_3 mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	TN mg/L	T P mg/L
S1	03/27/09	L	**1**	**0.01**	**1.53**	**1.53**	**0.01**	**0.05**	**1.58**	**0.39**
			0	*0.00*	*0.03*	*0.03*	*0.00*	*0.00*	*0.03*	*0.00*
S1	05/11/09	F	**0**	**0.01**	**0.51**	**0.51**	**0.04**	**0.07**	**0.58**	**0.56**
			0	*0.00*	*0.06*	*0.06*	*0.00*	*0.00*	*0.06*	*0.01*
M1	03/26/09	F	**8**	**0.01**	**12.31**	**12.30**	**0.12**	**0.35**	**12.66**	**0.13**
			1	*0.00*	*0.94*	*0.94*	*0.00*	*0.01*	*0.94*	*0.00*
M2	1/14/09	F	**67**	**0.00**	**7.92**	**7.91**	**0.13**	**0.15**	**8.06**	**0.35**
			0	*0.00*	*0.24*	*0.24*	*0.00*	*0.01*	*0.23*	*0.02*
M9	03/26/09	L	**93**	**0.05**	**5.33**	**5.28**	**0.01**	**0.21**	**5.54**	**0.12**
			3	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*
M9	06/04/09	F	**2**	**0.02**	**0.27**	**0.25**	**0.41**	**0.52**	**0.78**	**0.11**
			0	*0.00*	*0.03*	*0.03*	*0.01*	*0.05*	*0.02*	*0.05*

The field duplicates of the influent and effluent of the NRTS were less precise than the well samples. This observation is likely due to the nature of the wastewater being sampled. STE is the wastewater flowing out of the trash tank. This wastewater is likely not homogeneous and inputs from the bathhouse during or just prior to sampling would increase the heterogeneity The EFT or wastewater exiting the NRTS is from the pump tank. The wastewater would likely be better mixed than the trash tank wastewater, but would be influenced by inputs from the treatment tank during or just prior to sampling. The TN values for all septic samples were greater than 10% precision ,except for sample 06/02/09 Magnolia II EFT and sample 03/27/09 Hickory EFT which both had an error of 12%. The Hickory EFT sample on 06/03/09 is interesting that both the nitrite and nitrate concentrations had errors greater than 50%, yet the TN values were within 1% of each other (Table 4b).

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Table 4b. Field duplicates for septic samples during the environmental monitoring and the NRTS performance assessment. The bold value is the average of the two duplicate or replicate and the vitalized value is the ½ the range of the values. Some samples were analyzed fro NO2 + NO3 together, instead of separately. Not all septic samples had fecal coliform analyzes.

ID	Date	F Coli Cts/100ml	Nitrite mg/L	NO_2+NO_3 mg/L	Nitrate mg/L	Ammonia mg/L	TKN mg/L	TN mg/L	TP mg/L
Mag STE	05/11/09	**12965**	**0.07**	**0.06**	**0.00**	**39.56**	**177.88**	**177.94**	**1.50**
		555	*0.00*	*0.01*	*0.00*	*0.84*	*8.89*	*8.90*	*0.35*
Mag STE	06/03/09		**0.17**	**0.18**	**0.02**	**87.94**	**137.09**	**137.28**	**3.66**
			0.01	*0.03*	*0.02*	*1.38*	*6.40*	*6.37*	*0.14*
Hick STE	06/01/09			**0.40**		**80.74**	**87.59**	**87.99**	**3.74**
				0.00		*4.11*	*3.58*	*3.58*	*0.00*
Hick STE	06/04/09		**0.11**	**0.40**	**0.29**	**48.83**	**85.86**	**86.26**	**3.08**
			0.00	*0.00*	*0.00*	*7.20*	*7.70*	*7.70*	*0.32*
Mag EFT	05/11/09	**7805**	**1.67**	**6.94**	**5.28**	**10.70**	**12.92**	**19.86**	**1.75**
		195	*0.15*	*0.00*	*0.15*	*0.51*	*0.24*	*0.24*	*0.01*
Mag EFT	06/02/09			**11.06**		**23.51**	**29.84**	**40.90**	**3.96**
				1.03		*4.02*	*3.69*	*4.72*	*0.07*
Mag EFT	06/04/09	**8700**	**1.51**	**25.17**	**23.66**	**11.79**	**15.72**	**40.89**	**3.42**
		2000	*1.49*	*0.16*	*1.65*	*0.06*	*1.32*	*1.15*	*0.11*
Hick EFT	03/27/09	**7410**	**0.13**	**2.42**	**2.30**	**42.34**	**106.70**	**109.13**	**12.99**
		650	*0.00*	*2.18*	*2.18*	*2.30*	*9.68*	*11.86*	*0.20*
Hick EFT	06/03/09		**18.43**	**47.54**	**29.11**	**12.46**	**10.55**	**58.10**	**3.09**
			14.88	*0.67*	*15.55*	*0.19*	*0.21*	*0.46*	*0.11*
Hick EFT	06/04/09		**0.49**	**60.72**	**60.23**	**10.74**	**12.49**	**73.21**	**3.18**
			0.09	*1.61*	*1.52*	*0.05*	*1.15*	*0.46*	*0.22*

5. Discussion

5.1. *Septic Tank Effluent*

In this study, the STE samples are considered influent or input into the NRTS. A recent study of *residential* conventional OSTDS report the raw sewage (pre-treatment) has TN concentrations that are very similar to the STE concentrations flowing into the drainfield

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pipe, indicating little N attenuation in a residential septic tank (Lowe et al, 2009). The influent TN concentrations (131.9 ± 43.4 mg-N/L) found in this study were much higher than those concentrations observed in residential septic tank effluent during recent research in the Wakulla Springs Basin by both FDEP and the Colorado School of Mines, ≈70 mg-N/L (Lowe et al, 2009; FDEP, unpublished). This finding is not unexpected when the usage pattern differences of a residence are compared to state park bathhouse. Bathhouse influent consists almost exclusively of toilet use, hand washing, teeth brushing and showering. At a person's home, other activities such as clothes and dish washing would be a large component of the influent. These two activities account for much less of the TN inputs of influent, than other nutrient rich activities such as toilet use.

One weakness of the Phase I research approach was that STE concentrations were not measured for nutrient loading calculations of the drainfield. Both NRTS use the original septic system as a trash tank. After Phase I, both bathhouses were refurbished with low flow plumbing fixtures. The lower water use from the new plumbing would result in a more concentrated sewage with higher TN concentrations than with the original plumbing in Phase I. At Hickory, the trash tank was pumped on March 9, 2009 and the first STE sample taken less than three weeks afterwards. This is reported as another difference in the sites resulting from the different time period between system finalization and the first environmental sampling event on March 27, 2009. It is unclear whether the pump-out affected the STE at Hickory or was inconsequential.

5.2. *Total Nitrogen reduction by the Nutrient Reducing Treatment Drainfields*

In Wakulla County, Florida approximately half of the TN concentration in STE from conventional residential septic systems was found in the groundwater directly under the drainfields (Katz, et al, in review). Presumably the soil at Manatee Springs State Park would behave in a similar fashion.

5.3. *Monitoring Well Data*

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Comparison with Phase I

The nitrate concentrations found in this study were less than the concentrations observed in Phase I (Table 5). At Hickory campground the wells most impacted by the septic system in Phase I, S1 and C5, had the highest nitrate concentrations in Phase II. The concentrations in these wells were much lower in Phase II than in Phase I. The concentrations in wells S2, C3, and C4 had nitrate concentrations that were very similar to those in Phase I and the background wells. At Magnolia II campground, the nitrate concentrations were much lower in Phase II than in Phase I (Table 5).

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Table 5. The high and average NO_3 (mg-N/L)concentrations from both Phase I and Phase II at Hickory and Magnolia II campgrounds. The high NO_3 concentrations in Phase I all occurred on 08/22/2003. Nitrate concentrations are given in mg-N/L. The background well SRWMD #4 in Phase II was substituted for MB2 from Phase I, although NO3 concentrations are higher than some of the wells in Hickory. Note that concentrations were greater in Phase I of the study The samples from 01/14/09 were higher than the other samples in Phase II except in wells M3, M7, M8, and M9..

Well ID	High NO_3 **Phase I**	Average NO3 **Phase I**	NO_3 **01/04/09**	High NO_3 **Phase II**	Average NO3 **Phase II**
	Background				
CA	0.15	0.07 ± 0.06		0.42	0.20 ± 0.18
MB2	1.61	0.61 ± 0.74	SRWMD# 4	1.00	0.52 ± 0.48
	Hickory				
S1	56.1	21.9 ± 16.1	6.67	4.71	2.25 ± 2.19
S2	1.1	0.58 ± 0.38	1.71	0.23	0.14 ± 0.08
C3	1.1	0.59 ± 0.30	0.96	0.64	0.32 ± 0.29
C4	1.23	0.71 ± 0.33	1.18	1.15	0.63 ± 0.46
C5	41.3	11.7 ± 14.7	5.96	2.96	2.00 ± 0.99
	Magnolia II				
M1	49.8 ± 18.8	29.4 ± 9.8	17.14	13.2	7.02 ± 4.87
M2	63.2	22.8 ± 17.5	7.91	4.83	1.84 ± 2.60
M3	33.9	14.9 ± 11.2	3.88	13.8	5.05 ± 7.57
M5	62.6	26.1 ± 15.2	11.47	3.78	2.69 ± 1.22
M6	51.4	17.5 ± 14.5	4.92	2.80	1.59 ± 1.44
M7	63.3	19.4 ± 17.7	9.57	19.2	9.53 ± 8.41
M8	54.6 ± 14.7	30.1 ± 17.1	0.77	10.26	4.90 ± 5.10
M9	35.9	6.9 ± 12.6	1.36	5.28	1.88 ± 2.95

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Three weeks prior to the sampling event of 05/11/09, the well field was flooded from the Suwannee River. The Suwannee River was above the 10-ft flood stage at Manatee Springs from April 18 to April 22, 2009, cresting on April 20, 2009 (SRWMD website, 2009). At the 10-ft flood stage the wells at Magnolia II are submerged. Swimming at the Park was not reopened until May 7th due flooding impact on the water quality of the spring. In sampling following the flooding, we observed relatively low nitrate concentrations compared to the other sampling events. On 06/04/09, concentrations are again higher in many wells, especially M7and M3 at Magnolia II (Figure 5) and wells S1 and C5 at Hickory (Figure 6). This indicates that these wells are most affected by the septic system at Magnolia II and Hickory.

The flushing effect after flooding was also shown in the data from Phase I, due to a period of high water from March 10th to May 6th, 2003 (Figure 13). The May 20, 2003 TN concentrations were lower than the TN concentrations observed in May 10th, 2004, when there was no preceding flood (Table 6).

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Figure 13. River stage at Manatee Springs State Park for 2003 to 2005 (Phase I) and 2009 (Phase II). Sample dates given in Table 6 are indicated (SRWMD, 2009).

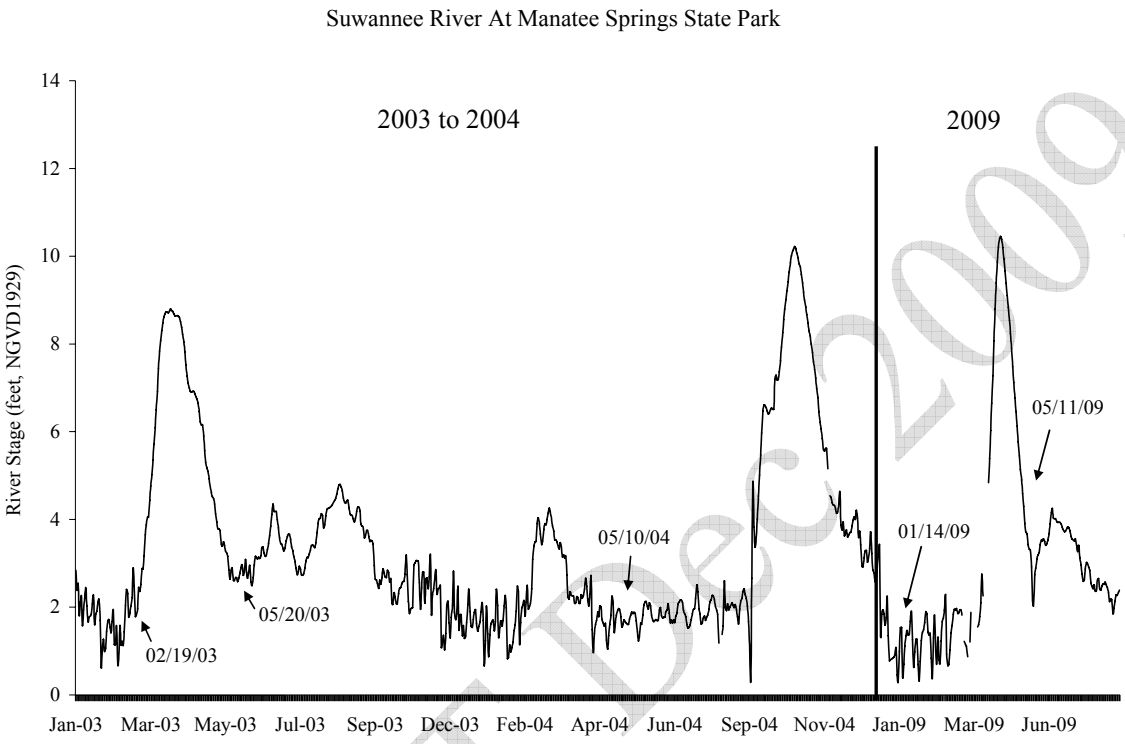

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Table 6. The nitrate concentrations (mg-N/L) from both Phase I and Phase II at Hickory and Magnolia II campground wells are given before and after flooding in 2003 and 2009, as well as May 2004 when no flooding occurred. Nitrate concentrations are given in mg-N/L. The background well SRWMD #4 in Phase II was substituted for MB2 from Phase I, although NO3 concentrations are higher than some of the wells in Hickory.

Well ID	Pre Flood NO_3 02/20/2003 Phase I	Post Flood NO_3 05/20/2003 Phase I	No Flood NO_3 05/10/2004 Phase I	Pre Flood NO_3 01/14/09 Phase II	Post Flood NO_3 05/11/2009 Phase II
Background					
CA	0.12	<0.01		0.42	0.11
MB2	<0.01	0.08	SRWMD# 4	1.00	0.01
Hickory					
S1	26.8	13.6	36.0 ± 3.3	6.67	0.51 ± 0.09
S2	0.92	0.27		1.71	0.23
C3	0.38	0.37		0.96	0.10
C4	0.44	0.60		1.18	0.28
C5	1.94	3.32	32.7	5.96	2.06
Magnolia II					
M1	18.2 ± 0.4	23.1	38.1	17.14	2.69
M2	22.0	7.70	25.8	7.91	0.51
M3	0.92	6.57	22.8	3.88	0.26
M5	21.9	15.3	30.8	11.47	3.78
M6	6.11	9.8 ± 1.99	14.8	4.92	2.80
M7	9.55	11.1	18.4	9.57	4.27
M8	19.6	5.9	38.1 ± 30.3	0.77	4.35
M9	0.96	0.30	35.9	1.36	0.11

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The flow of septic effluent was altered during Phase II. The septic effluent was pumped into the drainfield by the NRTS, in the conventional system the effluent was gravity fed, likely changing the dispersal pattern in the drainfield mound. .The pumps are designed for drainfields that are a good distance from the systems, It is likely the drainfields had a more frequent and lower volume dosing with gravity feed which occurs as water is used in the bathhouse than with pumping which is determined by floats in the pump tank and quickly reduces the tank volume until the float shuts off.

Additionally, during construction of the NRTS at Magnolia II the drainfield mound was re-shaped. This may help explain why the highest nitrate concentrations after the flood at Magnolia II were in wells M7 (20.0 mg-N/L) and M3 (14.5 mg-N/L) on 06/04/09 o, while in Phase I M8, M5 and M1 had the highest nitrate concentrations (Table 5). The highest TN concentrations in the other wells at Magnolia II were observed on 01/14/09 when the drainfield was still under gravity feed. In wells M8 (0.9 mg-N/L) and M9 (1.5 mg-N/L)observed on 01/04/09 had very low concentrations, once the pumps were activated the concentrations of TN rose to 10.4 mg-N/L in M8 and 5.5 mg-N/L in M9. The same pattern with higher nitrate concentrations is observed in wells M3 and M7, highest concentrations observed after the flood.

At Hickory only in wells S1 and C5 did the TN concentrations increased after the flooding in the 06/04/09 (Figure 6). These were also the most impacted wells from Phase I sampled in Phase II.

Groundwater samples collected after March 2009 were influence by two factors relative to previous samples. These factors were the flooding that occurred and the initiation of the ATUs at these sites. No doubt, groundwater TN and nitrate concentrations were lower following the initiation of advanced waste water treatment at the Park. But was this due to the flooding or the treatment? To address this question, we examined our 2003 data to discern the effect of flooding on groundwater nitrate concentrations (Figure 14).

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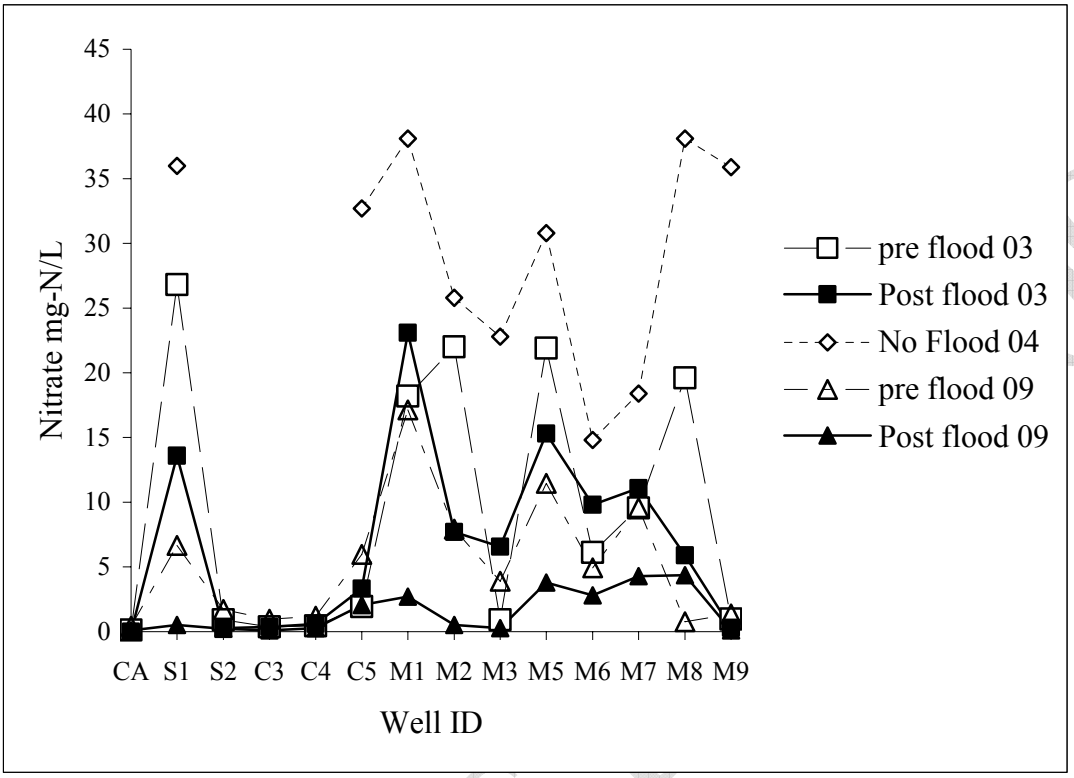
Figure 14. Nitrate levels pre and post flooding (2003 and 2009), and in the absence of flooding in May, 2004 (data graphed from Table 5 and 6).



The data indicate that in 2003, flooding reduced groundwater nitrate by only 10 to 30% while in 2009, the post-flood, post-treatment data are generally more reduced relative to the January 2009 pre-flood, pre-ATU treatment data. The results are corroborated by a comparison of average well nitrate data from Phase I, compared to the January 2009 sampling, and the average data from Phase II, following ATU treatment (Figure 15).

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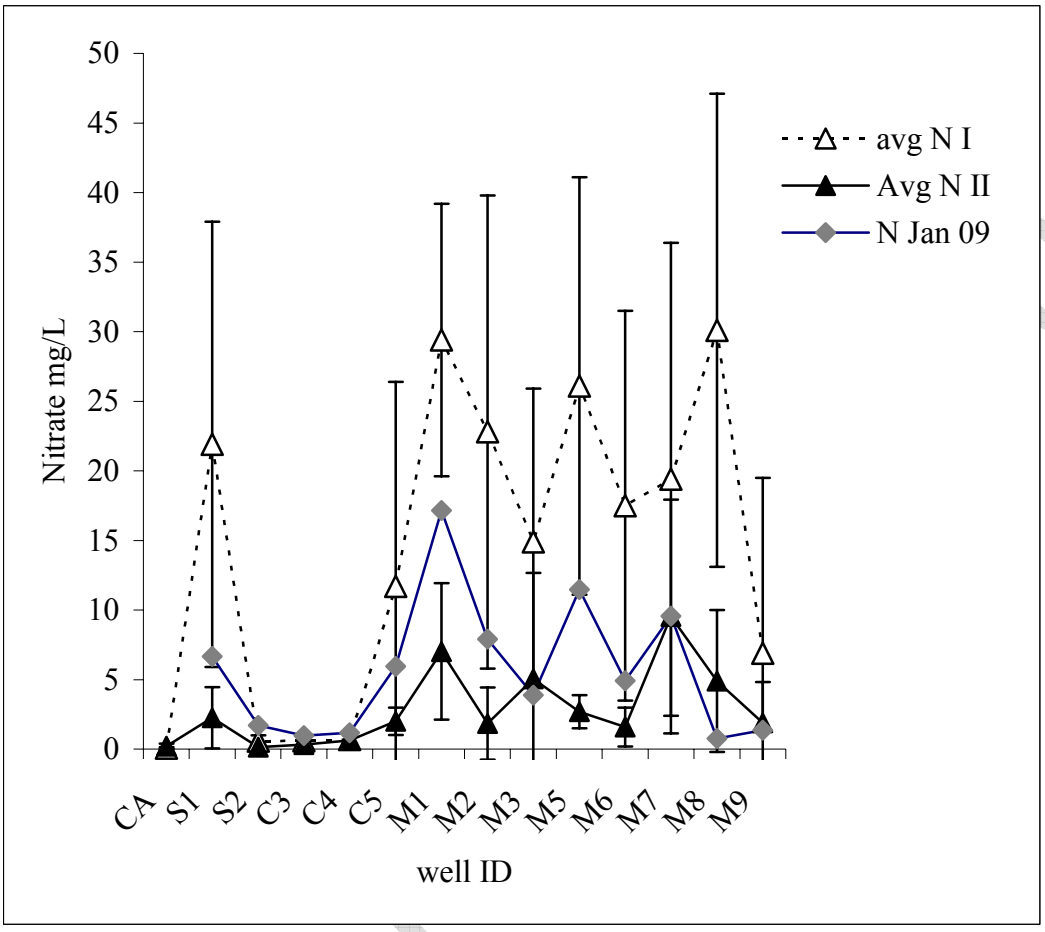
Figure 15. Average well nitrate data from Phase I sampling, Phase II sampling following ATU treatment of septic effluent and January 2009 data prior to ATU treatment.



Overall, the Phase II data appear to exhibit nitrate reduction relative to Phase I data and relative to January 2009 data prior to ATU treatment. The nitrate reduction is greater than observed for flooding alone in 2003. The data are consistent with the hypothesis that ATU treatment reduces groundwater nutrient concentrations.

6. Additional Sampling Event with No Flood Impact.

Since the sampling event on 03/26/09 was just after the NRTS were fully operational and the other two sampling events on 05/11/09 and 06/04/09 were impacted by flooding, another sampling event was scheduled to capture more typical conditions at the sites. The sampling event occurred on 09/10/09 when the park was at or above normal attendance, flow to the drainfields was reduced, and the river level was normal.

6.1. *Monitoring Well Data*

The monitoring wells and NRTS were sampled on 09/10/09 during conditions not impacted by flooding and with both NRTS operational for almost six months. At Hickory, wells S1 and C5 had similar nitrate concentrations as found on 01/14/09 (Figure 16). Although these wells continue to be impacted by the NRTS, the nitrate levels are significantly lower than observed in Phase I, 21.9 ± 16.1 mg-N/L.

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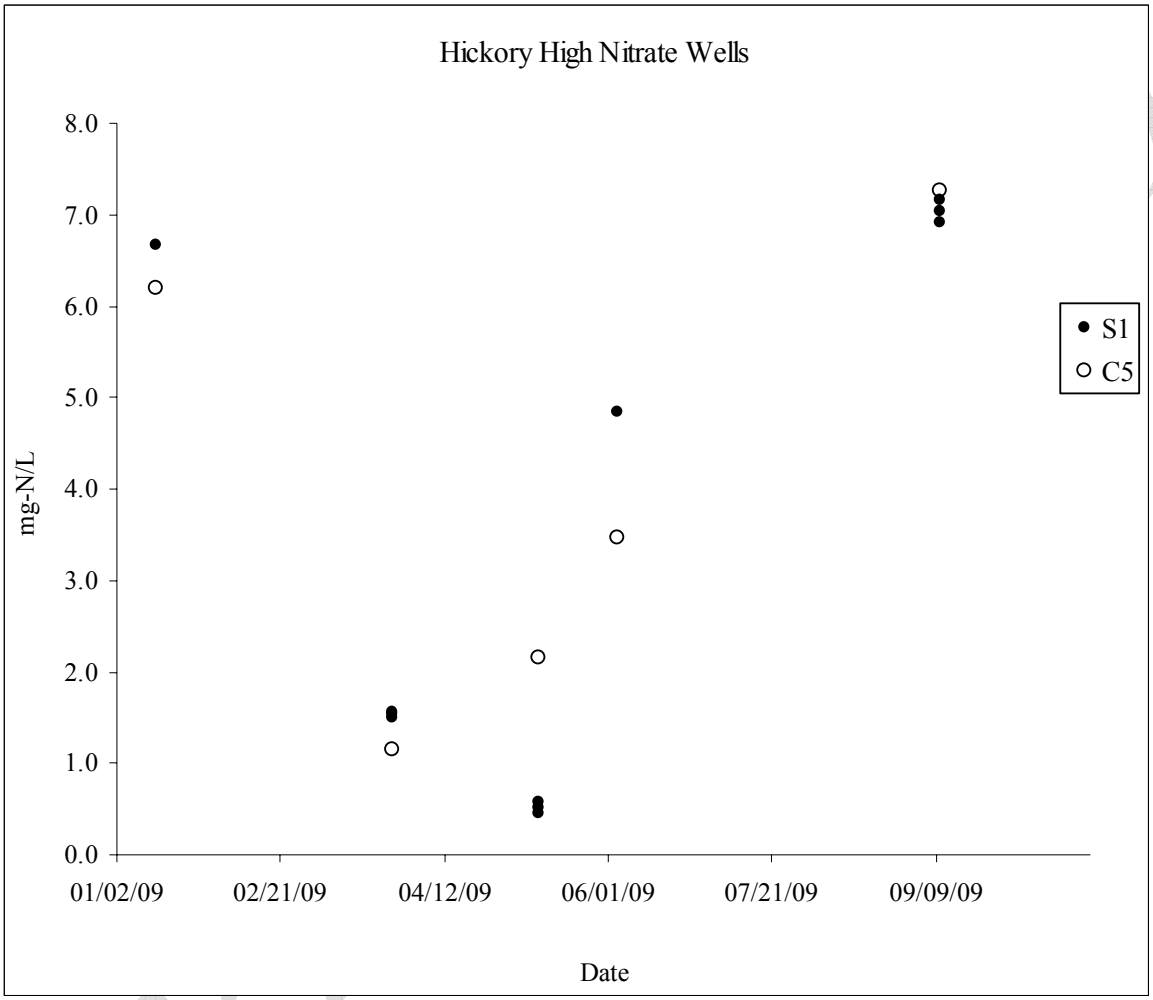
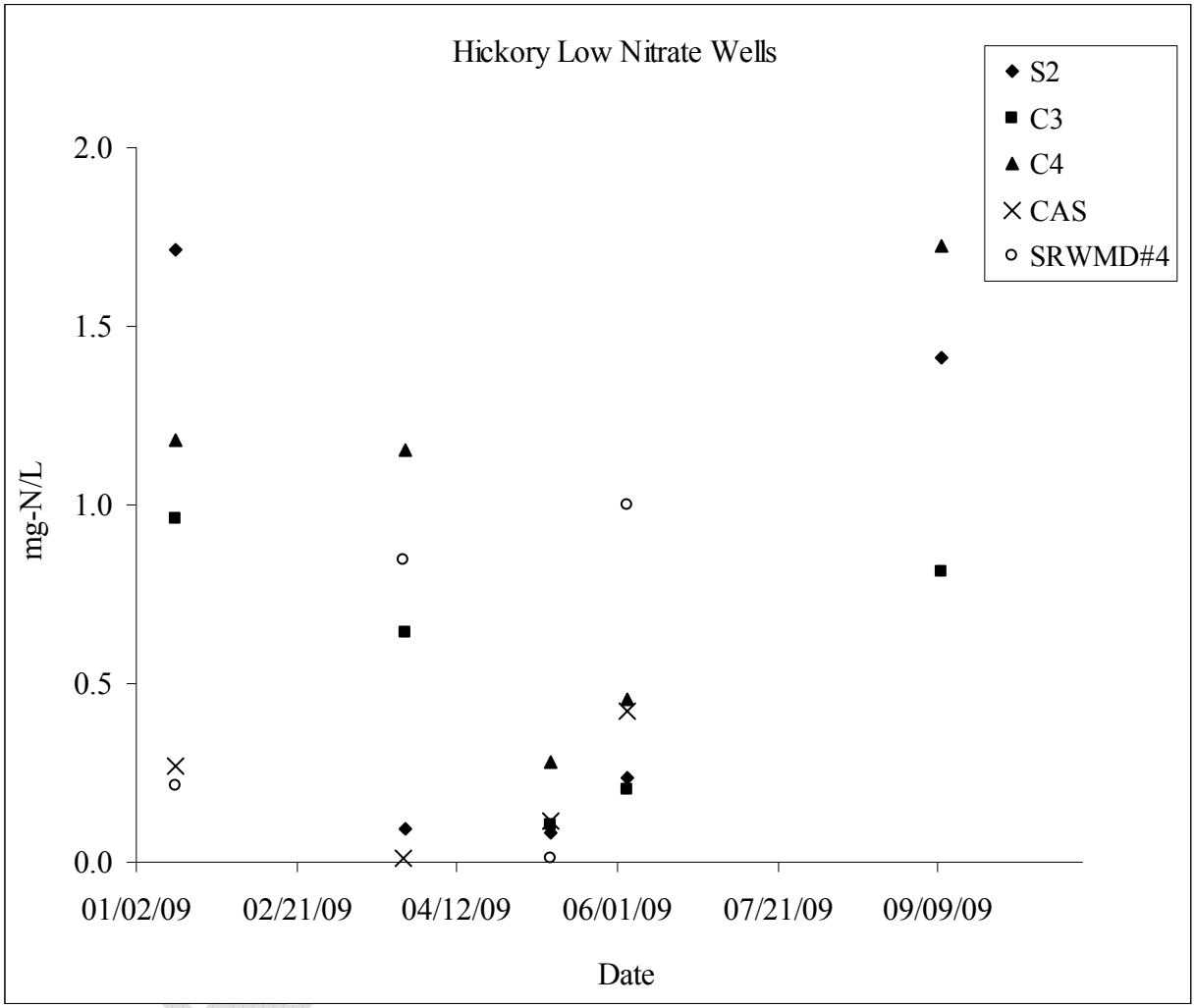
Figure 16. Nitrate concentrations from wells S1 and C5 taken on 01/14/09, 3/27/09, 05/11/09, 06/04/09 and 09/10/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29. The samples taken on 09/10/09 were not impacted by the flood.



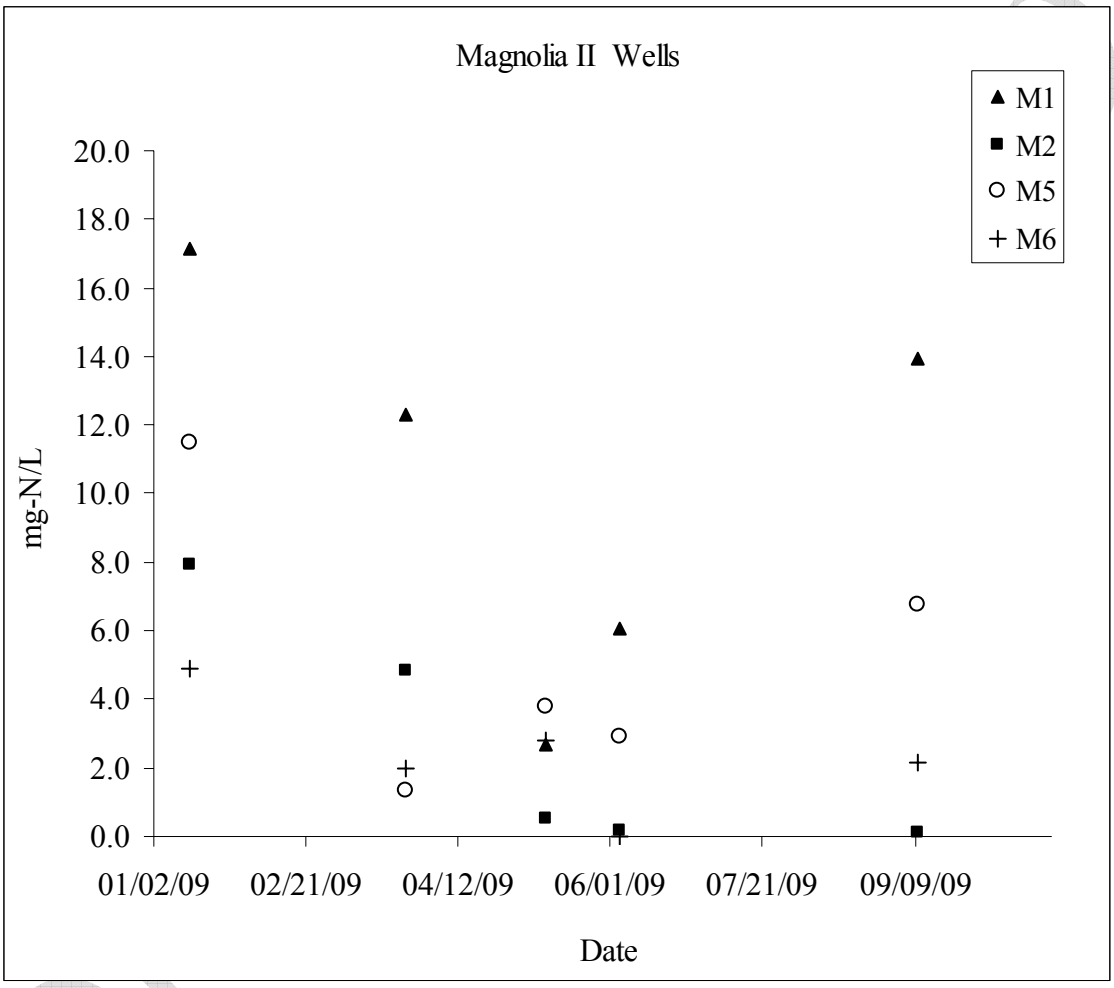
The nitrate concentrations in the other wells at Hickory were also similar to those observed on 01/14/09. The concentrations are above background levels and similar to those observed in Phase I (Table 5), but show these wells are less impacted than S1 and C5 (Figure 17).

Figure 17. Nitrate concentrations from wells S2, C3, C4 and background wells CA and SRWMD #4 taken on 01/14/09, 3/27/09, 05/11/09, 06/04/09 and 09/10/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29. The samples taken on 09/10/09 were not impacted by the flood.



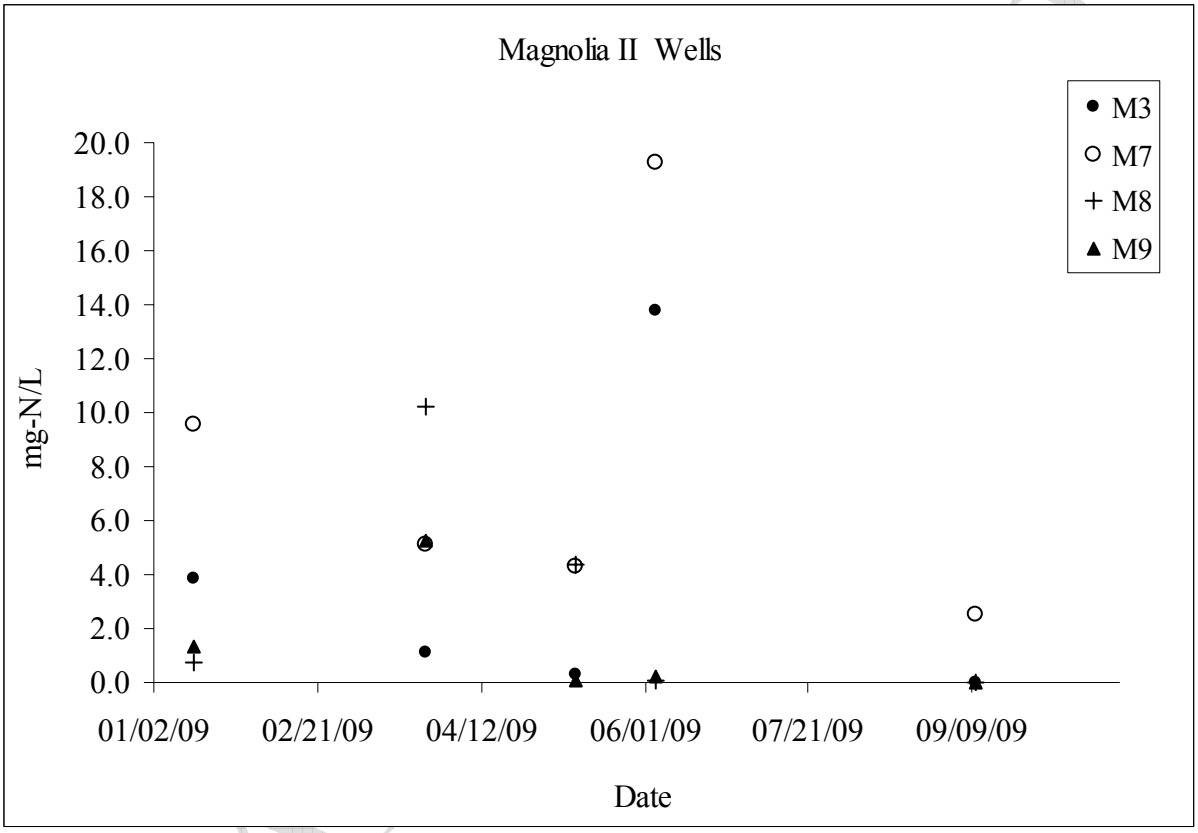
At Magnolia II, M1 and M5 had the highest nitrate concentrations and were the only wells in which nitrate increased relative to the first 3 sampling events, but they did not surpass the concentrations observed on 01/14/09. Well M6 had a concentration similar to the earlier sampling events (Figure 18).

Figure 18. Nitrate concentrations from wells M1, M2, M5 and M6 sampled on 01/14/09, 3/26/09, 05/11/09, 06/04/09 and 09/10/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29 and submerging the wells at Magnolia II. The samples taken on 09/10/09 were not impacted by the flood.



At the remaining wells at Magnolia II (M2, M3, M7, M8, M9), the nitrate concentrations observed on 09/10/09 were the lowest measured in the study. (Figure 19).

Figure 19. Nitrate concentrations from wells M3, M7, M8 and M9 were taken on 01/14/09, 3/26/09, 05/11/09, 06/04/09 and 09/10/09. The Suwannee River was above flood stage April 18-22, closing the State Park campgrounds from April 13 to April 29 and submerging the wells at Magnolia II. The samples taken on 09/10/09 were not impacted by the flood and were the lowest measured in the study.



6.2. ***NRTS Data***

Hickory

Both the STE and EFT from the NRTS at Hickory campground was similar to the other grab samples in this study. The TN in the STE on 09/10/09 was 140.04 mg-N/L, within the range of the other grab samples, 127.7 ± 49.37.2, n=.11 The EFT TN value of 57.3 mg-N/L was also similar to the other grab sample values, 56.5 ± 23.5. The percent reduction of nitrogen by the NRTS on 09/10/09 was calculated to be 59.2%. During this sampling event, TSS, BOD and cBOD5 were also measured. The NRTS reduced the TSS from 47.2 mg/L in the

STE to 4.8 mg/L in the EFT. BOD was reduced from 48.5 mg/L in the STE to 12.3 mg/L in the EFT and cBOD5 from 24.5 mg/L to 10.5 mg/L, respectively.

Magnolia II

The NRTS at Magnolia II appears to not have been functioning properly during the sampling on 09/10/09. The STE TN value of 149.2 mg-N/L was very similar to the other grab samples in the study, 151.2 ± 33.6 mg-N/L, n=11. The TN EFT value of 138.1 mg-N/L measured on 09/10/09 was much higher than the other EFT grab samples, 48.7 ± 29.6 mg-N/L and closer to values for STE. The calculated percent reduction of total nitrogen is 7.5% and indicates that the system is not operating properly. The EFT was approximately 30% nitrate and nitrite and 70% TKN (Appendix G), indicating incomplete nitrification in the ATU portion of the system. The NRTS did reduce the TSS from 90.0 mg/L in the STE to 6.2 mg/L in the EFT and cBOD5 from 60.5 mg/L in the STE to 2.5 /L in the EFT. The BOD results are unclear; the EFT value of 88.5 mg/L is larger than the STE value of 66.5 mg/L.

7. Conclusions

Significant reduction of total nitrogen is occurring in both NRTS studied, greatly reducing the nutrient loading of the groundwater by the effluent from the two bath houses. At Magnolia II, the reduction in TN ranged from 69 to 88% except during the 09/10/09 sampling event when only a 7.5% reduction was observed. At Hickory it nitrogen reduction ranged from 22 to 75%. The nitrogen reduction of 22% is calculated from the composite samples taken during the performance assessment. This may not be an accurate reflection of performance as the 9 grab samples taken during the same time period indicated nitrogen reduction of 55%. The Hickory site was problematic in its installation due to site limitations, and was finalized on 3/23/09, just prior to the 03/27/09 sampling event, which indicated a nitrogen reduction of 37 %. This sampling period included the start-up period during which the nitrifying and denitrifying bacterial colonies may have been premature to evaluate the system at Hickory. Not including the composite samples or the 03/27/09 event, the NRTS at Hickory reduced total nitrogen from 55% to 75%. When functioning properly, both NRTS reduce N-loading more than 50%.

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Groundwater samples collected from wells were lower in TN in the Phase II portion of this study following the installation of the NRTS systems, relative to concentrations in Phase I and relative to concentrations in January prior to the introduction of the NRTS systems. This finding is consistent with the hypothesis that NRTS will reduce inputs of nutrients to groundwater.

8. Recommendations

More work needs to be done to properly access the performance the NRTS installed at Magnolia II and Hickory campgrounds. The data from this study is influenced by the period of no usage during the flood and lower volume of sewage due to reduced park attendance. Additionally the first samples at Hickory were taken just four days after the finalization of the system. More grab and composite samples need to be taken when the campgrounds have normal attendance and both systems are well established. Another worthwhile study would be to continue sampling influent and effluent of the NRTS from Phase II and add other NRTS or similar systems that are in Manatee Springs State Park, Fanning Springs State Park as well as other parks in Florida.

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CHAPTER II: Activities in Support of the Study

Prepared by:

Eberhard Roeder
Florida Department of Health
Division of Environmental Health
Bureau of Onsite Sewage Programs
4052 Bald Cypress Way, Bin #A08
Tallahassee, Florida 32399-1713

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1. Executive Summary

This chapter presents additional background information on the project sites and a summary of activities and observations during the project period leading up to the environmental and performance sampling described in Chapter I.

The objectives of the study were to retrofit the two onsite systems investigated in Phase I of this study with nitrogen reducing systems and evaluate their performance and effect on groundwater. Performance evaluation is documented in Chapter I. The following are some additional observations and conclusions:

1. This study benefited from and was influenced by upgrades the State Park implemented concurrently at the two bathhouses. Two changes relative to Phase I stemming from these upgrades were the use of low-flow fixtures in the bathhouses and the use of lift-dosing instead of gravity to feed the monitored drainfields. The use of low-flow fixtures has likely increased the concentration of nitrogen in the effluent, but is not expected to have changed the mass of nitrogen discharged in the sewage.
2. The treatment technologies eventually selected for this project represented the two approaches currently outlined in state law for the protection of the Suwannee River flood plain: an aerobic treatment unit with combined activated sludge/fixed film technology that has extensive documentation on its nitrogen reduction capability available and has been commonly installed as a performance-based treatment system

for this purpose, and an extended aeration aerobic treatment unit that is lacking such documentation.

3. Retrofitting of the existing systems had to contend with site constraints based on prior construction. The use of existing old drainfields was part of the design of the study to allow comparison to Phase I. The reuse of the existing septic tanks as trash compartments for the treatment units resulted in trash tanks that are about twice as large as would usually be the case for new system construction. There was no indication that the trash tanks resulted in a lack of food for the aerobic treatment units, though, and the experience over the course of the project suggested that campground bathhouses generate a large amount of solids appropriate for a larger trash tank.
4. A first attempt to install a treatment unit in the first chamber of the existing tank did not result in successful treatment. At least for situations such as those encountered in this study, retrofitting for additional treatment appears to require at least an additional tank for the treatment unit.
5. Thorough maintenance appears key to ensuring effective treatment by at least the extended aeration treatment unit at Magnolia II. Samples taken on three occasions in 2006 and 2007 showed that total nitrogen in the ATU-effluent ranged from 73 to 120 mg/L and were similar to septic tank effluent samples taken at the same, which ranged from 71 to 150 mg/L total nitrogen. On these occasions, there was also little evidence of cBOD5 and TSS removal, and nitrification relative to septic tank effluent. Two of three other aerobic treatment units by the same manufacturer that were installed at park restrooms were sampled in 2007 and showed a similar lack of nitrification. In contrast, a sample taken in January 2009 at Magnolia II, after a thorough maintenance visit in June 2008 that addressed the functioning of air diffusers, showed nearly complete nitrification and a total nitrogen concentration of 66 mg/L. The sampling event in September 2009 indicated loss of nitrification function again at the Magnolia II treatment unit.
6. A more thorough inspection and possibly training protocol that is shared between the owner of the system, the maintenance entity and the regulatory agency may help to detect sub-optimal performance more quickly. The lack of treatment discussed in the previous point occurred even though the aerobic treatment unit appeared to be

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working, as indicated by the running of the aerator, except for some overheating problems observed by park staff.

7. Outside the direct scope of this project, park management reported and DOH staff observed a variety of problems related to the functioning of the pressure dosing system installed as part of the park service-initiated upgrade. Some of these problems appeared unique to the size and design of the particular systems involved.
8. For the continued operation of the bathhouses it proved useful to have the research project drainfields remaining as a gravity-fed backup to the pressure-dosed systems. This benefit has to be considered against the lack of treatment obtained during periods when the pressure-dosed system is not functional. In addition, the continued intermittent use of the old existing drainfield resulted in residual nitrogen concentrations in the monitoring wells that had the potential to confound an evaluation of the treatment effect.
9. Septic tank effluent contained nearly exclusively reduced forms of nitrogen (TKN) with 56 to 95% of that concentration being present as ammonia-nitrogen.
10. Nitrogen concentrations in septic tank effluent from the two systems frequently exceeded Florida's limit of 100 mg/L TKN for domestic sewage and was by a factor of two to four higher than average values in domestic sewage found in prior Florida studies. In part this high concentration is due to the use of low-flow fixtures and may indicate a broader change in domestic sewage composition. Total phosphorus concentrations ranged from 0.5 to 33 mg/L with most being below 10 mg/L. cBOD5, ranging from 25 to 220 mg/L, and TSS, ranging from 38 to 126 mg/L indicated that septic tanks retain their effectiveness for the reduction of these parameters with more concentrated sewage.

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2. Introduction

The first phase of this study had investigated the impacts on groundwater quality by conventional onsite sewage treatment and disposal systems (OSTDS), consisting of a septic tank and drainfield, in a karst environment. Karst is characterized by the presence of solution channels, sinkholes and springs in limestone bedrock. A layer of sand frequently covers the bedrock. The

first phase confirmed that this environment allowed rapid transport of sewage effluent tracers between the onsite sewage treatment and disposal system and groundwater and resulted in particular in elevated nitrogen concentrations in the monitoring wells (Harden et al, 2008). Figure 1 shows the location of the study sites, two bathhouses within Manatee Springs State Park on the eastern side of the Suwannee River. Both bathhouses are just outside of the 10-year flood plain of the Suwannee.

Current laws governing the installation of new OSTDSs in the 10-year floodway of the Suwannee River already require that improved treatment techniques be used. Common methods of complying with this provision is to install either an aerobic treatment unit (ATU) or a performance based treatment system (PBTS) that is designed to remove at least 50% of the nitrogen prior to the drainfield of the onsite sewage treatment and disposal system. Similarly, Corbett et al. (2002) recommended based on a study on a barrier Island that aerobic treatment units, combined with a 3-ft separation to the water table, would likely provide efficient treatment before introducing contaminants to groundwater.

More recently, water quality investigations in the Suwannee River have culminated in the development of a total maximum daily load (TMDL) report for the Florida Department of Environmental Protection (FDEP) (Hallas and Magley, 2008). The report summarizes existing water quantity and quality data and establishes an average monthly concentration of 0.35 mg/L nitrate-nitrogen as the target appropriate for the assimilative capacity of the river. Compared to conditions during the evaluation period, this target represents a 58% reduction for the lower Suwannee River where Manatee Springs is located, and a 79% reduction for Manatee Springs itself (Hallas and Magley, 2008). The 58% required nitrogen reduction for the Lower Suwannee River is similar in magnitude to the reduction specified in onsite regulations for the Suwannee flood plain. The TMDL report as well as an earlier study by the US Geological Survey (Katz et al. 2007) identified OSTDS as one of the sources of nitrate in the Suwannee River basin. Pittman et al. (1995) had found that for base flow conditions, springs and groundwater were important transport pathways for nitrates to the Suwannee river.

The purpose of this project was to conduct treatment performance and environmental monitoring to compare the nutrient loading of a conventional OSTDS to one that is retrofitted with nutrient

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reducing technology. In order avoid an additional confounding factor in this comparison and to save costs, the project concept was based on using the existing monitoring wells and existing drainfields, even though these were not in conformance with current construction practices for new onsite systems. Secondary objectives were to gather information on the installation, operation and maintenance of such systems, and to assess the variability of performance.

The project proceeded in roughly six steps:

1. Upgrades to existing system by the Park Service
2. Selection of nitrogen reducing technologies
3. Initial retrofitting of the existing systems with technologies
4. Collection of data on operation and water quality
5. Final modifications to the onsite systems
6. Performance and environmental sampling (Chapter I)

In the following text, activities related to Tasks 1 through 5 are described.

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3. Upgrades to Existing Systems by the Park Service

Towards the end of Phase I of the case study in 2003 and 2004, the Park Service initiated upgrades and modifications to the bathhouses and onsite systems under study. The bathhouses were refurbished and replaced and received low-flush fixtures as discussed below. The onsite systems received new drainfields away from cave systems and the flood plain, additional treatment tanks, and pump tanks and pumps to transfer the sewage to the new drainfields. The construction measures retained connections to the old existing drainfields to allow continuation of this study.

3.1. *Description of Bathhouses and Sites*

The bathhouse at Hickory was originally established around 1962/63. It and the campground it serves are located on a slight rise between two sinkholes, Sue's Sink and Catfish Hotel,

over the main conduit feeding Manatee Springs. The elevations of the top of well casings, roughly at ground surface level, at Hickory were surveyed by DOH staff to be between 14 and 17 feet (NGVD 1929). The bathhouse at Hickory serves 25 campsites, each equipped with electricity and a supply of potable water. The design flow, or estimated sewage flow per Florida onsite sewage regulations, is 1,250 gallons per day (gpd). Figure 2 shows the monitoring wells, bathhouse and onsite system as they were surveyed in 2002 during Phase I.

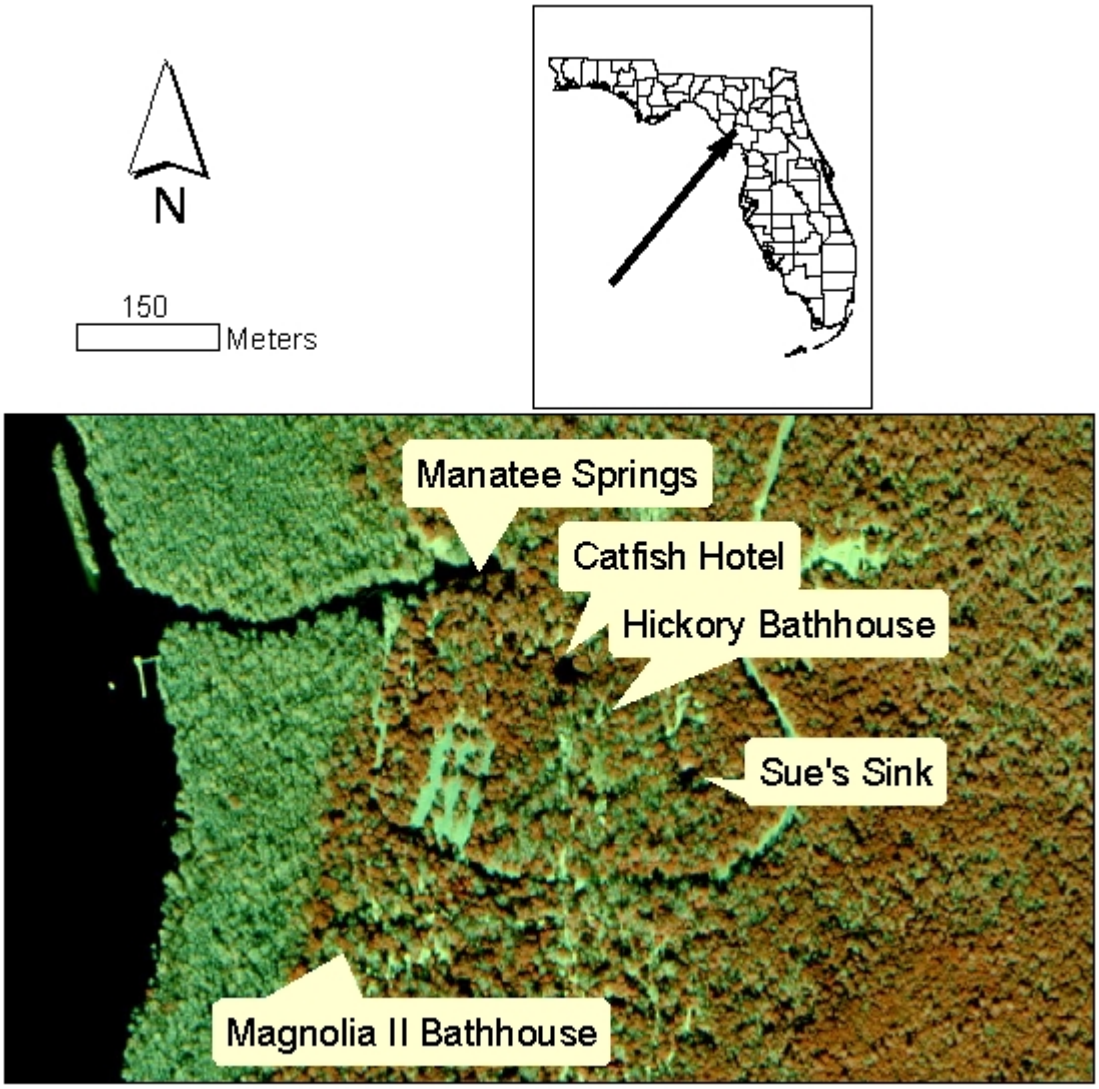

Figure 1. Location of Study Site. Shown is part of Manatee Springs State Park with the Spring and Spring Run.

The bathhouse at Magnolia II was likely established in the early 1970s (Mark Hooks, personal communication 10/1/2004, based on information provided to him by Bill Roberson, assistant park manager). It, and the campground it serves, are at the edge of the 10-year flood plain, which likely was the reason for building the bathhouse and the associated onsite sewage system on an artificial hill that reaches an elevation of 15-ft. The monitoring wells were installed towards the river side of the hill in what appeared to be natural ground. The elevations of the tops of well casings at Magnolia II were surveyed by DOH staff to be between 6.5 and 10.3 feet (NGVD 1929). For comparison, the Suwannee River flood elevations at Manatee Springs are 7-ft for the two-year flood; 13-ft for the 10-year flood, and 16-ft for the 100-yr flood (SRWMD, 2004). The bathhouse at Magnolia II serves 20 campsites, each equipped with electricity and a supply of potable water. The design flow, or estimated sewage flow, of the bathhouse per current Florida onsite sewage regulations is 1,000 gpd. Figure 3 shows the monitoring wells, bathhouse and onsite system as they were surveyed in 2002 during Phase I

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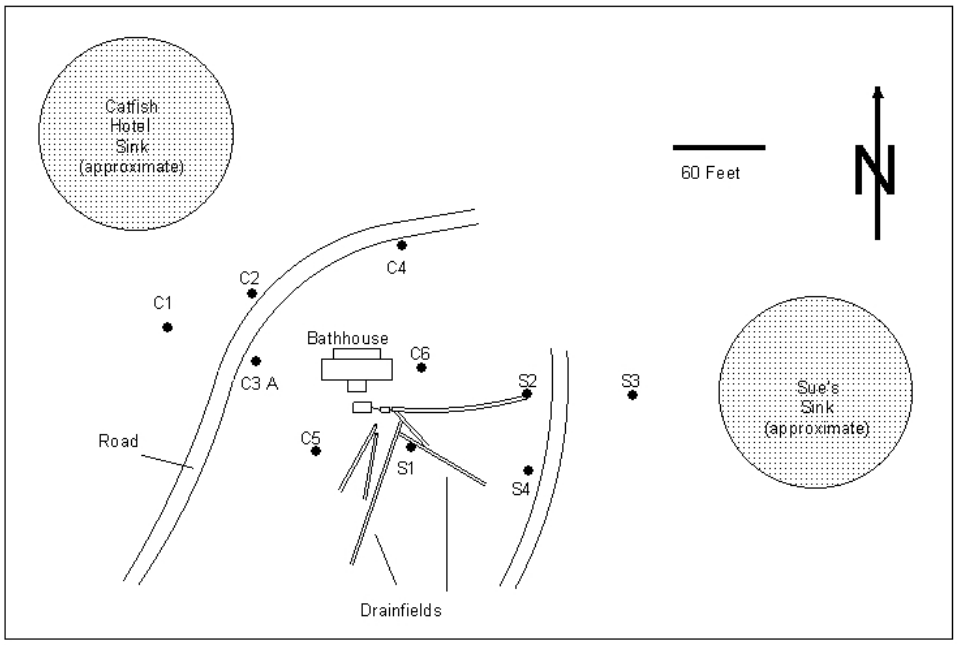

Figure 2. Site plan of Hickory during Phase I.

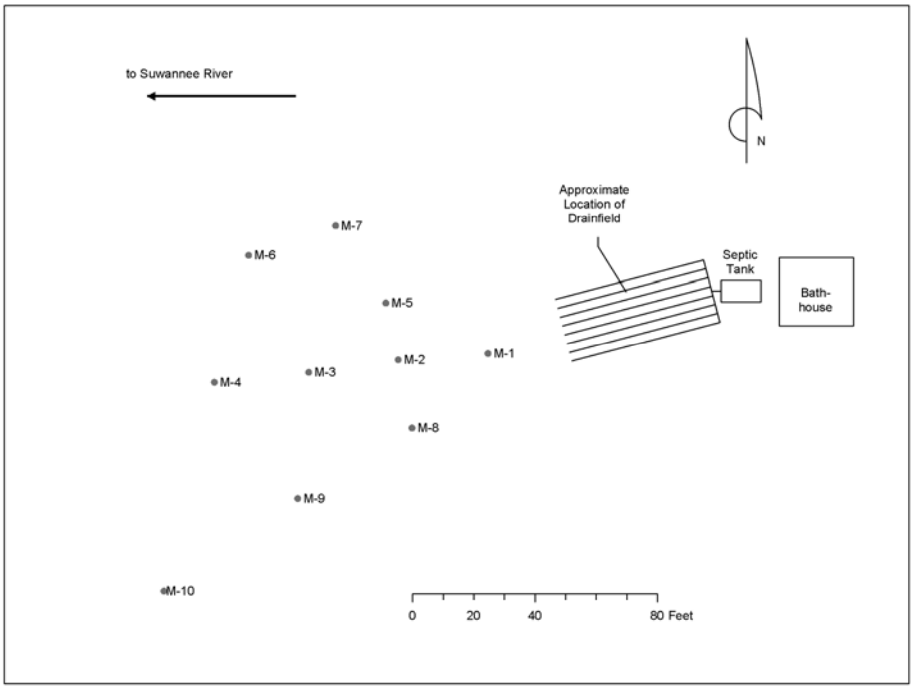

Figure 3. Site plan of Magnolia II during Phase I.

3.2. *Renovations of Bathhouses*

The Florida Park Service initiated renovations of the Magnolia II house and a replacement of the bathhouse at Hickory independent of this project. These constructions occurred from 09/04/2003 - 05/02/2004 at Hickory and from 4/19/2004 through September 2004 at Magnolia II. Subsequently sometime in 2005, the initially installed waterless urinals were replaced with low-flush urinals, so that the two bathhouses had the following configurations for the performance sampling in 2009:

The Hickory bathhouse includes four showers, four sinks, four toilets, and two ADA compartments, which each includes a shower, sink, and toilet. It also includes an outside faucet on the septic tank side of the building and a drinking fountain, which was not operable during the sampling in 2009. The Hickory campground host site is located next to the bathhouse and the 2003/2004 renovations included providing a sewer connection for this site directly into the septic tank. During the construction activities, monitoring well C-6 became damaged and unoperable for the remainder of the study.

The bathhouse at Magnolia II includes four showers, four sinks, and four low-flush toilets. A water meter is installed about 50-yards to the north of the bathhouse. The water meter measures flow to an outside faucet in front of the bathhouse in addition to the bathhouse usage. This faucet was rarely used based on observations during site visits, and appears to contribute an insignificant amount to the water usage.

3.3. *Hickory Onsite System Upgrades*

The onsite system monitored in Phase I of this study had consisted of a 2300 gallon dual compartment septic tank with outlet filter that discharged by gravity to a network of trenches in the vicinity of the bathhouse and on top of the cave feeding Manatee Springs. The connections, or lack thereof, between trenches beyond a distribution box were not

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established. The septic tank had been installed as part of Phase I between the building sewer and the distribution box to replace a previous tank.

The upgrades initiated by the Park Service in 2003 included a new drainfield about 100 yards south, across an access road and near to the Magnolia II campground. This drainfield serves to dispose of effluent away from the cave system feeding Manatee Springs. The drainfield is a low-pressure dosed mound and was permitted according to 2003 current onsite sewage regulations.

In order to facilitate the pumping to the mound drainfield, a 1250 gallon pump tank with alternating pumps was installed. For unknown reasons, this tank included a compartment wall, and the two pumps were installed in the second compartment while the control floats were installed in the first compartment. With the intention to assist in the execution of this project, the Park Service project also included a 750 gallon tank between the septic tank and the treatment tank for uses in future nitrogen reduction upgrades. Both of these new tanks were installed in the location where a prior survey had indicated the existence of a, likely unconnected, trench.

Figure 4 shows a view from the pump line north toward the new tanks and bathhouse. There was an outside sink that was later removed and only a hose faucet was present for 2009 performance monitoring.

To allow continuation of this study, the park service project installed a branch-off with valves after the septic tank that allowed gravity flow either to the old drainfield or to the intermediate tank and pump tank for pumping to the new mound drainfield.

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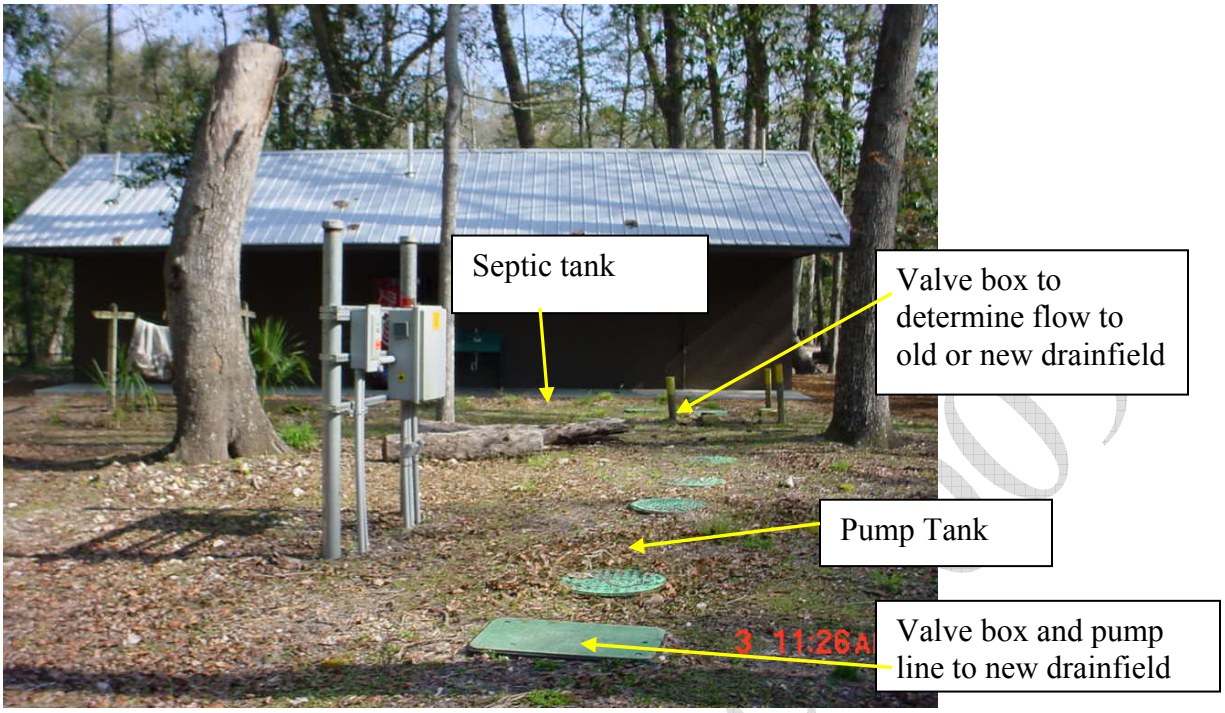

Figure 4. Hickory bathhouse on 03/03/2006. Pump tank with two round manhole covers in front, septic tank behind.

3.4. *Magnolia II Onsite System Upgrades*

The Magnolia II onsite system monitored in Phase I of this study had consisted of a large septic tank with outlet filter that discharged by gravity to a distribution box connected to three lines of drainfield. As part of their continuing efforts to improve onsite sewage treatment within the state park system, the Park Service added in 2004 an aerobic treatment unit with a treatment capacity of 1000 gpd and a 1050 gallon single compartment pump tank. Both tanks consist of fiberglass and the pump tank is a two-piece tank with a mid-seam. The pump tank was equipped with two alternating pumps to move effluent to a new mound drainfield about a hundred yards to the southeast that is further removed from the flood plain.

With these additions, the existing septic tank began to serve as a trash tank to the aerobic treatment unit. To facilitate this project, as in the case of Hickory, this installation provided a branch-off with valves to allow flow from the old septic tank by gravity either to the old drainfield studied in Phase I and II or to the new ATU. Figure 5 illustrates the location of the additional tanks that were surrounded by a fence.

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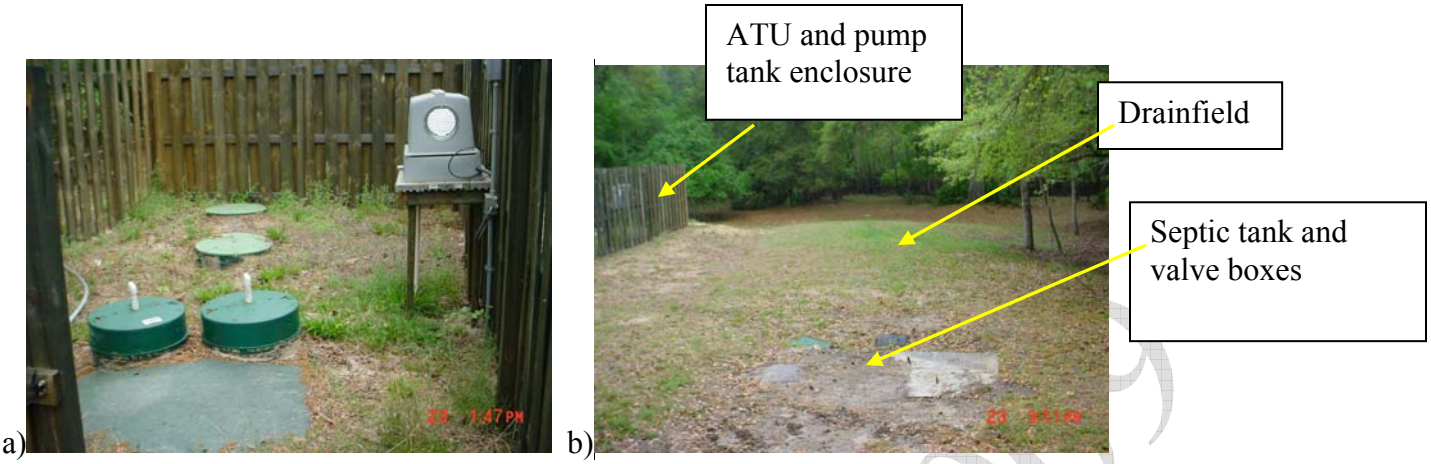

Figure 5. Additions to Magnolia II on 03/23/2006: a) ATU with air supply and pump tank. b) View across the septic tank, valve boxes and old drainfield towards the monitoring wells and the Suwannee River

4. Selection of Nitrogen Reducing Technologies

The treatment technologies eventually selected for this project represented the two approaches currently outlined in state law for the protection of the Suwannee River flood plain: an aerobic treatment unit with combined activated sludge/fixed film technology that has extensive documentation on its nitrogen reduction capability available and has been commonly installed throughout the State of Florida as a performance-based treatment system for this purpose, and an extended aeration aerobic treatment unit that is lacking such documentation.

4.1. *Hickory*

While the modifications implemented by the Park Service in 2003/2004 had provided an additional tank for use in future treatment, no nitrogen-reducing treatment was included. DOH solicited proposals by engineers for a treatment system for this site in 2005. The solicitation for a proposal for this project emphasized the need to reuse the existing tank upstream of the branch-off in order to facilitate dispersal in the old drainfield within a limited budget. The only proposal by an engineer received by DOH proposed the installation of a combined activated sludge/fixed film kit (Micro-Fast) with a treatment capacity of 1500 gpd in the first compartment of the septic tank for nitrogen reduction and a phosphorus absorbing media into the second compartment. A single family residence size version of the nitrogen

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reducing module had been part of side-by-side evaluations in the Florida Keys, where it had achieved nitrogen concentration reductions by roughly 70% to about 10 mg/L.

Usually, such a nitrogen-reducing treatment system is installed in a compartment following a trash compartment or tank. The constraints of the site included the presence of a concrete pad over the building sewer lines that precluded installation of an additional trash tank upstream of the large existing septic tank and the existence of a 750 gallon tank that was too small to install the kit. On the other hand, some earlier installations of such a kit had not included a separate trash compartment and the engineer judged them to be functioning, and the close contact between raw sewage reaching the first compartment and the aeration unit in it could possibly be expected to maximize the use of carbon for denitrification. An additional potential benefit was the possibility that such a configuration would allow a retrofit without the installation of an additional tank. Therefore, the configuration was installed as proposed by the engineer.

Based on the observations and experiences discussed in subsequent sections, the configuration did not perform well and the engineer proposed a modified design, which is discussed in more detail at the end of this chapter, which was installed and then evaluated during the performance assessment of Chapter I. The final site configuration is shown in Figure 9.

4.2. *Magnolia II*

The modifications implemented by the Park Service had resulted in the availability of an extended aeration aerobic treatment unit (Hydro-Action) at this site. While this treatment unit has been certified by NSF under the standard NSF-40 for removal of cBOD5 and TSS, no data on nitrogen reduction were available.

Initial treatment concepts developed by DOH staff for this system envisioned the use of recirculation from the ATU to the septic tank. This treatment concept progressed through detailed design calculations based on wastewater engineering literature. Eventually, this approach was abandoned in favor of simply testing the performance of the aerobic treatment

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unit. This decision was influenced by further review of Florida studies that suggested that a combination of aerobic treatment unit and drainfield could possibly be sufficient as nutrient reducing treatment. The same concept is also included in statutory language for the Suwannee River flood plain. Furthermore, the site-specific design and configuration would have had very limited applicability to other aerobic treatment systems, was based on literature values rather than test data, and there was no means of assessing the benefit from the additional design and construction effort relative to simply using the aerobic treatment unit. Therefore, these considerations concluded with a design that allowed the effluent from the ATU to be lift-dosed into the old drainfield instead of being discharged into the new drainfield. The final configuration is shown in Figure 13.

5. Initial Retrofitting of the Existing Systems with Technologies

5.1. *Hickory*

In early March of 2006, the combined activated sludge/fixed film kit for nitrogen reduction was installed in the first compartment of the septic tank in the presence of the design engineer (Figure 6). Aeration was activated on April 14, 2006, following sampling of the pump tank without the effect of aeration on March 23, 2006. Initial operational and clogging problems at the inlet end did not reoccur once aeration was established and the treatment unit operated continuously. The phosphorus absorbing media were added to the second compartment in June of 2006. The treatment unit continued to operate until modifications to implement the final design were installed in March of 2009.

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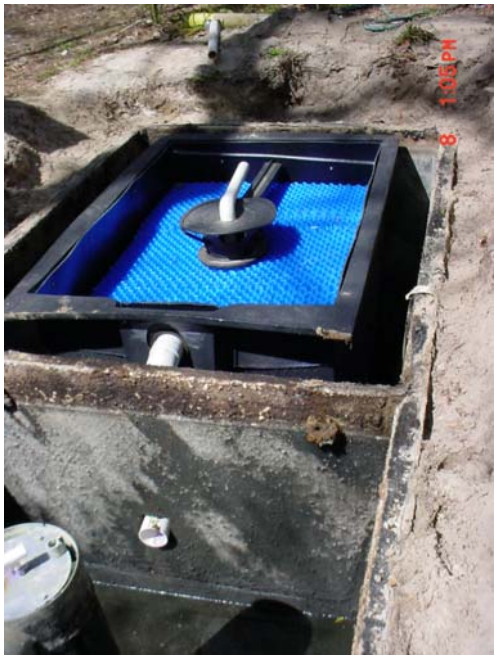

Figure 6. Initial installation of the Hickory nitrogen reducing system. 03/08/2006.

5.2. *Magnolia II*

At the Magnolia II site, the upgrades implemented by the Park Service consisting of a large septic tank followed by an extended aeration treatment unit and a pump tank, became the initial retrofit. The treatment unit either operated when the pumping to the new drainfield was functioning or was bypassed when pumps did not function and valves were switched to allow gravity flow from the septic tank to the old drainfield.

In February of 2009 a modification was installed that allowed the pumping of effluent from the aerobic treatment unit to the old drainfield, in order to monitor the effect of effluent on the monitoring wells.

6. Collection of Data on Operation and Water Quality

DOH staff collected data and recorded observations during site visits by DOH staff, from a log by the Park Manager on maintenance activities by outside contractors, and from updates provided to DOH staff by the Park Manager on problems encountered and resolved. Of particular value was a logging system that the Park Manager instituted in 2004 to record staff

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observations during weekly maintenance visits. State Park staff performs approximately weekly maintenance visits of the onsite systems installed in the park. During these visits, the staff usually washes off the outlet filters, checks the pump functioning, and records elapsed pump times and water meter readings. These records provided the most finely resolved data on the operation of the systems.

7. Operation of Treatment Systems

7.1. *Hickory*

Manatee Springs State Park has all onsite systems pumped out annually during the summer as a matter of routine maintenance. During these annual tank pumpouts in 2007 and 2008, following the installation of the initial system in 2006, it was evident from excessive accumulation of solids on and in the nitrogen reduction kit that the system as installed was not capable of treating the wastewater completely. At least in part this appeared to be due to lack of storage space for the large amount of indigestible solids received by the treatment system. DOH-staff also observed that the kit was submerged deeper in the sewage than designed, which initially suggested a clogging problem between the unit and the drainfield. It was only during subsequent construction in 2009 that the installer discovered that the septic tank was sloping upward by three inches, which contributed to the presence of the water level above the inlet invert. Subsequent review of photographs of the 2006 installation showed that the upward sloping was present already then. This suggests that the tank was either originally not installed level or that construction in 2003/2004 resulted in some movement of the tank.

The aeration system worked continuously and no problems were noted. In particular during the initial days of starting the system up in 2006 there was some odor noticed by campground residents, when what had been septic sewage was aerated.

7.2. *Magnolia II*

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State Park staff noticed that the aerators of several of the aerobic treatment units installed in Manatee and Fanning Springs State Park experienced an overheating problem that the maintenance entity was not able to resolve. After pursuing a variety of options to find a resolution, the contractor who had originally installed most of the systems in the Park visited the site in June of 2008. During this visit the function of air diffusers was restored and the aerators were provided with openings in their housing to allow better heat dissipation.

8. Operation of Pumping Systems and Resulting Drainfield Use

An approximate time line of the operation of the pumping system and resulting drainfield use at each system was reconstructed based on comments and annotations found in the weekly OSTDS maintenance visits by park staff; a history of maintenance events and observations recorded by the park ranger; notes in communications between park and DOH staff, and observations during field visits by DOH staff.

For the continued operation of the bathhouses it proved useful to have the research project drainfields remaining as a gravity-fed backup to the pressure-dosed systems. This benefit has to be considered against the lack of treatment obtained during such periods. In addition, the continued use of the old existing drainfield resulted in residual nitrogen concentrations in the monitoring wells that had the potential to confound an evaluation of the treatment effect.

8.1. *Hickory*

During the project period the system had recurrent problems with the pump system, mainly floats and pumps, but also one line break. An important cause for the problems appeared to be the installation of float controls in the first compartment and pumps in the second compartment of the pump tank. This resulted on occasion in continuous running of a pump due to the limited vertical movement possible for the off-float. Maintenance actions by the maintenance entity or additional contractors resolved issues temporarily until the spring of 2009, when additional work on the floats appeared to results in the pump system working properly continuously.

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Whenever the pumping system ceased to deliver effluent to the new drainfield, an available option was to switch the valves to gravity flow from the first tank to the old drainfield. This has lead to intermittent use of the old drainfield.

At the Hickory site, the bathhouse was closed from 09/04/2003 through 05/02/2004 for renovations to the bathhouse and installation of a pump tank to a low-pressure dosed drainfield some distance away. Pump time readings show pumping to the new drainfield from 07/26/2004 - 07/25/2005 with the exception of closing for hurricanes from 09/02/2004 to 10/04/2004. From 07/25/2005 through 08/29/2005 the old drainfield was used during repairs to the pressure line to the new drainfield. From 08/29/2005 to some time between August 2006 and May 2007 the new drainfield was used. The old drainfield was then used through 05/30/2008. From then on, the new drainfield was used, with possible short periods of interruptions to accommodate work on the pumps.

After installation of the final modifications the valves were switched to direct the effluent predominantly to the old drainfield on 03/23/2009. From 04/13/2009 through 04/27/2009 the park was closed due to flooding. Around 06/08/2009 park staff adjusted the valves to distribute flow both to the old and the new drainfield.

8.2. *Magnolia II*

During the project period this pump system, too, experienced intermittent problems. Whenever the pumping system ceased to deliver effluent to the new drainfield, an available option was to switch the valves to gravity flow from the first tank to the old drainfield. This has lead to intermittent use of the old drainfield, so that effluent from the septic tank rather than the aerobic treatment unit has from time to time discharged to the gravity-fed drainfield studied during Phase I.

At the Magnolia II site, bathhouse renovations began on 04/19/2004. This renovation included installation of an aerobic treatment unit and a pump tank to serve a low pressure dosed drainfield some distance away. From 9/02/2004 to 10/04/2004 the park was closed due to hurricanes. Pump timer readings indicate that the old drainfield was predominantly

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used through January 2006, with the exception of 10/11/2004 through 01/03/2005 when the new drainfield was used. Issues relating to the control panel for the pump station and finding a replacement for a specific pump resulted in intermittent use of the new drainfields from then on. From 02/2006 to 04/10/2006 the new drainfield was used, followed by a period of time through 08/17/2006 when the old drainfield was used. In the beginning of 2007, one pump became operational and effluent was discharged to the new drainfield. New drainfield use continued through at least June 2007, but the old drainfield was then used for a period before 3/3/2008, and continued to be used from sometime between 03/11/2008 and 5/5/2008 through 10/14/2008.

From 10/14/2008 through 03/09/2009 the new drainfield was used, at which time the modifications for the final configuration had been completed and the treated effluent flow was predominantly directed to the old drainfield. In contrast to prior years, observations on arrival at the site on 03/23, 3/26 and 3/31/2009 showed the same water level in the pump tank. On 03/31/2009 it was discovered that the on-float for the pump controls was not working properly and a water tightness test indicated that the pump tank was leaking. The observations were consistent with leaking at the level of the the mid-seam of the pump tank. This would have resulted in a release of effluent from the pump tank into the subsurface immediately surrounding it instead of effluent flowing to the designated drainfield. Around 04/02/2009, the pump floats were repaired to ensure operation of the pumps at a water level below the mid-seam to provide flow to the drainfields. From 04/13/2009 through 04/27/2009 the park was closed due to flooding. Around 06/08/2009 park staff adjusted the valves to distribute effluent flow both to the old and the new drainfield.

9. Water Quality Measurements

Water and effluent samples were obtained on several occasions by DOH staff, the Department's contractor for sampling, and Suwannee River Water Management District staff, as detailed below. Two laboratories analyzed samples for this project. In Phase 1 of the study and through 2008, Ackuritlabs (A) in Tallahassee analyzed the samples. Late in 2008, the contractor for sampling in this study began to utilize McGlynn Laboratories (M) in Tallahassee. Both

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laboratories were NELAC-certified for the methods used. The slight variations in methods applied are shown in Table 1.

Table 1. Laboratory analytes and methods used by the two laboratories providing data for this study.

Analyte	Units	Ackuritlabs, Inc. (A)	McGlynn Laboratories (M)
Fecal Coliform	cfu/100 mL	SM 9222D	SM 9222D
Nitrite-N	mg/L	SM 4500NO2B	EPA 354.1
Nitrite+Nitrate-N	mg/L	n/a	EPA 353.3
Nitrate-N	mg/L	EPA 353.3	calc
Ammonia-N	mg/L	EPA 350.2	EPA 350.3
TIN	mg/L	n/a	calc
TKN	mg/L	EPA 351.3	EPA 351.4
organic N (calc)	mg/L	n/a	calc
TN	mg/L	Calculated	Calculated
TP	mg/L	EPA 365.3	EPA 365.2
Ortho-Phosphorus	mg/L	EPA 365.3	n/a
cBOD5	mg/L	SM 5210 B	n/a
TSS	mg/L	EPA 160.2	n/a
Alkalinity	mg/L as CaCO3	EPA 310.1	n/a

9.1. *OSTDS Water Quality Measurements*

Concentrations of effluent leaving the existing septic tanks, representing the influent to the aerobic treatment units, and out of the aerobic treatment units were measured on several occasions. The occasions can be grouped together as follows:

1. During the first phase of the nutrient reducing design, treatment in both onsite sewage systems was envisioned to effect the most upgradient tank compartment. In the case of Hickory the treatment kit was going to be installed in the existing septic tank. In the case of Magnolia II, a recirculation of ATU-effluent into the septic tank was envisioned. Without a separate tank, there would be no raw sewage to measure influent concentrations in order to characterize performance. To accommodate this, concentrations in the outlet filters of the septic tanks were measured, as well as concentrations in effluent at other points, such as within the pump tank or from the

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distribution box at the Hickory drainfield. These sampling events were funded by the DOH and performed by DOH staff. They occurred on 03/23/2006, 05/15/2007, and 06/04/2007.

2. In 2007, the park management obtained funding from the Florida Department of Environmental Protection for lab analyses of a one-time sampling event of multiple aerobic treatment units and arranged with DOH staff to take the samples in combination with sampling the treatment systems under study as discussed before. These samples were taken on 05/15/2007 and 06/04/2007, mostly by means of an intermediate container that was held under free-flowing effluent into pump tanks. On these occasions field parameters (pH, specific conductance, salinity, dissolved oxygen concentration and saturation, oxygen reduction potential (ORP), and temperature) were obtained with a YSI 556 in addition to laboratory results.
3. On two occasions DOH's contractor for sampling also obtained samples from onsite systems in association with a well monitoring sampling event. Several locations were sampled on 01/10/2006. The pump tank at Magnolia II was sampled on 01/14/2009.

Samples were either obtained with an intermediate container that was rinsed with effluent before taking the sample, or by means of the pumping equipment of a Global Water automatic sampling device, which included flushing the line before taking a sample. Samples indicated in the following tables were taken from within the effluent filter compartment. They were obtained by removing the effluent filter, letting turbidity settle, and taking a sample from within the frame of the effluent filter. The following Tables 2 – 7 show the results of the sampling.

Except for TSS, agreement between duplicate samples was usually within 10%. There appeared to be no consistent difference between taking a sample with an intermediate container and pumping it. Effluent filter sampling at Hickory on 5/15/2009 showed that raising the effluent filter to gain access to the effluent can introduce sufficient turbulence to entrain solids. During the performance sampling (Chapter I) this problem was addressed by lifting the effluent filter only briefly and a short distance and inserting the top of the peristaltic tubing inside.

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Readings for the YSI 556 probe were taken usually after two to four minutes stabilization time by either submerging the probe in the water to about the top of the probe housing, or by measuring in the intermediate container after laboratory samples had been obtained. Dissolved oxygen measurement for septic tanks tended to still be drifting downward at the time of measurement. The probe began to malfunction in summer of 2007 and was repaired in November 2007. Probe readings are summarized in Table 8.

Thorough maintenance appears key to ensuring effective treatment by at least the extended aeration treatment unit at Magnolia II. Samples taken on three occasions in 2006 and 2007 showed that total nitrogen in the ATU-effluent ranged from 73 to 120 mg/L was similar to septic tank effluent concentrations ranging from 71 to 150 mg/L total nitrogen at the same times. On these occasions, there was also little evidence of cBOD5 and TSS removal, and nitrification relative to septic tank effluent (Table 3 and 6). Two of three other aerobic treatment units of the same manufacturer that were installed at park restrooms were sampled in 2007 and showed a similar lack of nitrification (Table 5). In contrast, a sample taken at Magnolia II after a more thorough maintenance visit in June 2008 that addressed the functioning of air diffusers showed nearly complete nitrification and a total nitrogen concentration of 66 mg/L (Table 3).

This initial lack of treatment occurred even though the aerobic treatment unit appeared to be working as indicated by the running of the aerator, except for some overheating problems observed by park staff.

Septic tank effluent contained nearly exclusively reduced forms of nitrogen (TKN) with 56 to 95% of that concentration being present as ammonia-nitrogen. Total nitrogen concentrations in septic tank effluent from the two systems frequently exceeded Florida's limit of 100 mg/L TKN for domestic sewage and was by a factor of two to four higher than average values in domestic sewage found in prior Florida studies. In part, this high concentration is due to the use of low-flow fixtures and may indicate a broader change in domestic sewage composition. Total phosphorus concentrations ranged from 9 to 33 mg/L and showed some elevation relative to previous study results. cBOD5, ranging from 92 to 220 mg/L, and TSS, ranging

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from 38 to 126 mg/L did not show a similar increase, indicating that septic tanks retain their effectiveness for the reduction of these parameters with more concentrated sewage.

9.2. *Additional Well Monitoring Data*

The Department's contractor for sampling was tasked with additional sampling to maintain a record of the development of concentrations over time until the modifications to the treatment systems were accomplished. These sampling events followed the same procedures as the regular sampling for this project, and were funded by the Department. Such sampling events occurred on 05/10/2004, 11/23/2004, 1/26/2006, and 1/14/2009. Tables 9 and 10 show the results. On May 20, 2008, in combination with the pump-out of tanks for preparation of permitting, DOH staff used the YSI 556 probe to measure field parameters in the monitoring wells. The wells were not purged prior to measuring on this occasion. These data are included in Table 8.

9.3. *Additional Background Water Quality Monitoring Data*

The water quality of the potable water supply was determined by three grab samples from the faucet before the Magnolia II bathhouse. The potable water supply for all of Manatee Springs Park stems from a well upgradient of the bathhouses. The raw water is then treated and supplied to the bathhouses and campgrounds.

Grab samples were also taken once from catfish hotel and from Manatee Springs. On the occasion of well sampling at the two bathhouses, water samples were also obtained from monitoring wells operated by the Suwannee River Water Management District. These wells are equipped with pumps. These samples were only analyzed for fecal coliform and nutrients.

One equipment blank of the auto sampler pumping equipment was taken by taking a sample from a DI water bottle.

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The results for fecal coliform and nutrients are shown in Table 11. The results for cBOD5, TSS and alkalinity are shown in Table 12.

9.4. *Oxygen reduction potential as field indicator of nitrogen status.*

The lack of nitrification in many tank samples raises the question if there are quantifiable field parameters that could be used to assess the status of a treatment system. Dissolved oxygen and oxygen reduction potential (ORP) are two field parameters that provide information on the availability of oxygen (for oxidation) and the activity of electrons (involved in oxidation-reduction reactions). The two are somewhat related as indicated by the observation that four of five measurements with the highest ORP showed also dissolved oxygen concentrations above three mg/L. In contrast, ORP did appear to provide a better indication of the presence and completeness of nitrification. All six treatment effluent samples with an ORP above -300 mV had considerable amounts of oxidized nitrogen. Only one of eleven samples with an ORP below -300 mV had higher concentrations than 1 mg/L NOx. This observation would be consistent with ongoing but limited denitrification. To assess the extent of nitrification and its large range from zero to complete, the ratio of NOx to TKN was calculated and log-transformed as log(0.001+NOx/TKN). The correlation coefficient between this parameter and ORP (R) was 0.81. Further observations and validations will be necessary to determine the applicability of this approach.

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Table 2. Magnolia II nutrient and fecal coliform data for septic tank effluent and ATU effluent.

Effluent Type	Effluent Location	Sampling	Dups	Date	Sampler	Lab	Fecal Coliform	Nitrite -N	Nitrate -N	Nitrite+ Nitrate-N	Ammonia -N	TKN	TN	TP
							cfu/ 100 mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Septic	In effluent filter			1/10/2006	HH	A	50000	0.012U	0.367		68.9	70.4	70.8	31.3
Septic	In effluent filter	int. cont.		3/23/2006	ER	A		0.012U	0.012U		79.9	133	133	10.9
Septic	In effluent filter	int. cont.	dup	3/23/2006	ER	A		0.012U	0.012U		82.6	110	110	12.2
Septic	In effluent filter	pump		3/23/2006	ER	A		0.012U	0.012U		83.4	148	148	11.8
Septic	In effluent filter	pump	dup	3/23/2006	ER	A		0.012U	0.012U		90	148	148	10.8
Septic	In effluent filter	pump		5/15/2007	ER	A				0.012U	62.4	70.6	70.6	11.8
Septic	In effluent filter	pump		6/4/2007	ER	A				0.165	104	107	107.2	14.7
ATU	Pump tank	pump		3/23/2006	ER	A		0.012U	0.012U		92	96.7	96.7	12.3
ATU	Pump tank	pump		3/23/2006	ER	A		0.012U	0.012U		92.8	116	116	10.2
ATU	after ATU	free fall		5/15/2007	ER	A				0.012U	67	73.4	73.4	13.1
ATU	after ATU	free fall		6/4/2007	ER	A				0.193	92.6	101	101.2	15
ATU	Pump tank	pump		6/4/2007	ER	A				0.143	94.2	99.6	99.7	14.3
ATU	Pump tank	Pump		1/14/2009	HH	M	3780	0.371	63.113	63.484	2.025	3.003	66.487	20.802

Note: int. cont.=intermediate container; Dups =duplicate; HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

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Table 3. Hickory nutrient and fecal coliform data for septic tank effluent and ATU effluent and treatment compartment.

Effluent Type	Effluent Location	Sampling	Date	Sampler	Lab	Fecal Coliform	Nitrite-N	Nitrate-N	Nitrite+ Nitrate-N	Ammonia-N	TKN	TN	TP	Ortho-P
						cfu/ 100 mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Septic	in effluent filter	int. cont.	1/10/2006	HH	A	280000	0.012U	0.351		90.2	95.7	96.1	18.1	
Septic	Pump tank	int. cont.	1/10/2006	HH	A	150000	0.012U	0.389		92.2	110	110	19	
Septic	in effluent filter	Pump	3/23/2006	ER	A		0.012U	0.012U		104	109	109	9.38	0.014U
Septic	Pump tank	int. cont.	3/23/2006	ER	A		0.012U	0.012U		104	115	115	10	0.014U
Septic	Pump tank	Pump	3/23/2006	ER	A		0.012U	0.012U		101	121	121	8.53	0.014U
ATU	in effluent filter	Pump	5/15/2007	ER	A				0.012U	79.8	80.4	80.4	13.5	
ATU	in effluent filter	Pump	6/4/2007	ER	A				63	40.8	46.2	109.2	12.2	
ATU	D-box	Pump	6/4/2007	ER	A				61.5	37.5	44.2	105.7	12.5	
ATU-related	on treatment unit	Pump	5/15/2007	ER	A				17.5	61	67	84.5	14	
ATU-related	on treatment unit	Pump	6/4/2007	ER	A				59.5	34.2	37.6	97.1	12.4	
ATU-related	in effluent filter, stirred, contained solids	Pump	5/15/2007	ER	A				0.575	83.9	559	560	15.2	

Note: int. cont.=intermediate container; Dups =duplicate; HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

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Table 4. Nutrient and fecal coliform data for ATU effluent of other bathhouse/restroom systems and a dumping station within Manatee/Fanning Springs State Park.

System	Effluent Location	Sampling	Date	Samp.	Lab	Fecal Coliform	Nitrite -N	Nitrate -N	Nitrite+ Nitrate-N	Ammonia -N	TKN	TN	TP	Ortho -P
						cfu/ 100 mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Manatee Concession	After ATU	free fall	5/15/2007	ER	A	53600 B,L			0.012U	80.2	94.2	94.2	12.7	
Fanning Springside	After ATU	free fall	5/15/2007	ER	A	630 B			22.7	4.03	4.48	27.2	2.44	
Fanning Springside	After ATU	free fall	6/4/2007	ER	A	31600			56	65	65.8	121.8	11	
Fanning Wayside	After ATU	free fall	6/4/2007	ER	A	170000			0.198	162	168	168.2	11.3	
Manatee Dumping Station	dosing tank	Pump	3/23/2006	ER	A		0.012 U	0.012U		772	785	785	57.5	0.014 U

Note: int. cont.=intermediate container; HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

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Table 5. Magnolia II cBOD5, TSS and alkalinity data for septic tank effluent and ATU effluent.

Effluent Type	Effluent Location	Sampling	Dups	Date	cBOD5	TSS	Alkalinity,
					mg/L	mg/L	mg/L as CaCO3
Septic	in effluent filter	int. cont.		3/23/2006	112	118	672
Septic	in effluent filter	int. cont.	Dup	3/23/2006	100	68	624
Septic	in effluent filter	pump		3/23/2006	128	66	596
Septic	in effluent filter	pump	Dup	3/23/2006	129	126	608
Septic	in effluent filter	pump		5/15/2007	220	54	510
Septic	in effluent filter	pump		6/4/2007	164	38	750
ATU	pump tank	pump		3/23/2006	80.4	52	596
ATU	pump tank	pump		3/23/2006	88.9	52	580
ATU	after ATU	free fall		5/15/2007	139	34	510
ATU	after ATU	free fall		6/4/2007	146	28	730
ATU	pump tank	pump		6/4/2007	111	18	640

Note: int. cont.=intermediate container; Dups =duplicate;

Table 6. Hickory cBOD5, TSS and Alkalinity data for septic tank effluent and ATU effluent and treatment compartment.

Effluent Type	Effluent Location	Sampling	Date	cBOD5	TSS	Alkalinity,
				mg/L	mg/L	mg/L as CaCO3
Septic	in effluent filter	pump	3/23/2006	149	164	520
Septic	pump tank	int. cont.	3/23/2006	91.5	46	584
Septic	pump tank	pump	3/23/2006	100	58	540
ATU	in effluent filter	pump	5/15/2007	239	92	570
ATU	in effluent filter	pump	6/4/2007	73.8	50	320
ATU	D-box	pump	6/4/2007	70.7	22	320
ATU-related	on treatment unit	pump	5/15/2007	161	122	420
ATU-related	on treatment unit	pump	6/4/2007	83.8	30	290
ATU-related	in effluent filter, stirred, contained solids	pump	5/15/2007	1363	10510	800

Note: int. cont.=intermediate container

Table 7. cBOD5, TSS and alkalinity data for ATU effluent of other bathhouse/restroom systems and a dumping station within Fanning/Manatee Springs State Park.

System	Date	cBOD5	TSS	Alkalinity,
		mg/L	mg/L	mg/L as CaCO3
Manatee Concession	5/15/2007	176	50	600
Fanning Springside	5/15/2007	5.4	4	147
Fanning Springside	6/4/2007	51.5	12	
Fanning Wayside	6/4/2007	118	28	
Manatee Dumping Station	3/23/2006	507	810	2500

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Table 8. Field parameters measured with a YSI 556 probe

SampleType	Sample Location	Date	Samp -ler	Temp-erature	Specific Conduct-ivity	Salin -ity	DO	DO sat.	pH	ORP
				deg C	uS/cm	ppt	mg/L	%	su	mV
Magnolia II										
Septic	effluent filter	03/23/2006	ER	24.66	1680	0.85	1.31	15.8	8.32	-396.3
Septic	effluent filter	5/15/2007	ER	25.35	1620	0.81	0.15	2.10	8.53	-406.9
Septic	effluent filter	6/4/2007	ER	26.32	1695	0.85	1.52	19.0	8.21	-384.7
ATU	pump tank	03/23/2006	ER	22.66	1644	0.83	0.36	4.2	8.73	-389.7
ATU	after ATU	5/15/2007	ER	25.15	1664	0.84	1.78	21.50	8.53	-382.0
ATU	pump tank	5/15/2007	ER	25.10	1637	0.82	0.50	59.0	9.09	-422.1
ATU	after ATU	6/4/2007	ER	26.09	1684	0.85	-0.02*	-0.2*	8.18	-393.0
ATU	pump tank	6/4/2007	ER	26.23	1666	0.84	-0.02*	-0.2*	8.33	-407.0
ATU	pump tank	1/14/2009	ER	18.5	1136	0.57	3.8	40.7	6.79	163.3
Hickory										
ATU	D-box	5/15/2007	ER	24.81	1613	0.81	0.63	7.6	8.72	-428.0
ATU	effluent filter	5/15/2007	ER	24.40	1632	0.82	0.01*	-0.2*	8.60	-445.7
ATU	D-box	6/4/2007	ER	24.97	1306	0.65	1.49	18.2	8.25	-274.0
ATU	effluent filter	6/4/2007	ER	25.03	1196	0.59	1.23	14.9	8.57	-394.0
ATU	effluent filter	5/20/2008	ER	25.45	19.13*	0.97	0.33	4.0	6.87	-130.0
ATU-related	on treatment unit	5/15/2007	ER	24.99	1559	0.78	0.00	0.4	8.08	4.2
ATU-related	on treatment unit	6/4/2007	ER	25.19	1282	0.64	5.11	62.3	7.88	-25.9
Other ATUs										
Manatee Concession	after ATU	5/15/2007	ER	23.50	1850	0.94	2.72	31.2	9.60	-426.0
Fanning Springside	after ATU	5/15/2007	ER	24.03	562	0.27	3.03	36.00	7.85	1.0
Fanning Springside	after ATU	6/4/2007	ER	25.52	1046	0.52	-0.02*	-0.2*	8.30	-272.2
Fanning Wayside	after ATU	6/4/2007	ER	26.97	1557	0.78	1.73	22.5	8.72	-357.2
Tap Water	Magnolia II faucet	03/23/2006	ER	19.78	848	0.42	5.16	56.6	7.42	164.2
Wells										
C3A	Well	5/20/2008	ER	20.81	557	0.27	4.28	48.0	7.06	594.4
C4	Well	5/20/2008	ER	20.89	563	0.27	5.49	61.6	7.06	598.8
C5	Well	5/20/2008	ER	21.09	636	0.31	2.75	31.0	7.08	592.3
S1	Well	5/20/2008	ER	21.75	939	0.46	0.56	6.5	6.88	580.1
S2	Well	5/20/2008	ER	21.03	525	0.25	4.00	45.1	7.13	605.5
S3	Well	5/20/2008	ER	20.91	632	0.31	1.50	16.9	7.04	552.3
M1	Well	5/20/2008	ER	20.88	945	0.47	0.90	10.2	6.95	537.0
M2	Well	5/20/2008	ER	20.06	678	0.33	0.79	8.8	6.95	538.0
M3	Well	5/20/2008	ER	19.78	744	0.36	1.48	16.8	6.90	551.4
M4	Well	5/20/2008	ER	19.85	747	0.37	1.18	13.0	7.12	652.0
M5	Well	5/20/2008	ER	20.13	872	0.43	1.65	18.3	6.98	543.0
M6	Well	5/20/2008	ER	19.83	877	0.43	0.38	4.2	6.94	564.0
M7	Well	5/20/2008	ER	19.97	899	0.44	1.84	20.3	6.90	556.6
M8	Well	5/20/2008	ER	19.76	757	0.37	0.75	8.3	6.99	551.0
M9	Well	5/20/2008	ER	19.80	794	0.39	0.55	6.0	7.20	675.0
M10	Well	5/20/2008	ER	19.80	480	0.23	0.95	10.5	7.26	564.0

Note: ER=Eberhard Roeder; *=likely recording or instrument error

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Table 9. Well nutrient and fecal coliform data at Magnolia II.

Well	Dups	Date	Sampler	Lab	Fecal Coliform	Nitrite-N	Nitrate-N	Ammonia-N	TKN	TN	TP
					Cfu/100 mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
M1		5/10/2004	HH	A	2U	0.012U	38.1	1.76	2.1	40.2	0.363
M1		11/23/2004	HH	A	2U	0.012U	17.2	0.834	0.878	18.1	0.295
M1		1/26/2006	HH	A	2U	0.018	19.8	0.401	0.784	20.6	0.28
M2		5/10/2004	HH	A	2U	0.012U	25.8	0.072	0.095	25.9	0.886
M2		11/23/2004	HH	A	2U	0.012U	4.5	0.142	0.146	4.65	0.282
M2		1/26/2006	HH	A	2U	0.012U	9.03	0.038	0.165	9.2	0.54
M2		1/26/2006	HH	A	2U	0.013	8.34	0.067U	0.118	8.46	0.542
M3		5/10/2004	HH	A	2U	0.036	22.8	0.074	0.087	22.9	0.458
M3		11/23/2004	HH	A	2U	0.031	2.03	0.165	0.264	2.29	0.014U
M3		1/26/2006	HH	A	2U	0.035	4.38	0.067U	0.163	4.54	0.308
M4		5/10/2004	HH	A	2U	0.012U	0.774	0.138	0.313	1.09	0.014U
M4		11/23/2004	HH	A	2U	0.012U	0.302	0.15	0.199	0.501	0.014U
M4		1/26/2006	HH	A	2U	0.012U	0.061	0.067U	2.06	2.12	0.014U
M5		5/10/2004	HH	A	2U	0.012U	30.8	0.59	0.66	31.5	0.076
M5		11/23/2004	HH	A	2	0.031	10.9	0.373	0.427	11.3	0.014U
M5		1/26/2006	HH	A	2U	0.012U	19.5	0.395	0.451	20	0.029
M6		5/10/2004	HH	A	2U	0.012	14.8	0.18	0.213	15	0.014U
M6		11/23/2004	HH	A	2U	0.014	9.47	0.248	0.256	9.73	0.014U
M6		1/26/2006	HH	A	2U	0.066	16	0.259	0.357	16.4	0.014U
M7		5/10/2004	HH	A	2U	0.012U	18.4	0.143	0.203	18.6	0.107
M7		11/23/2004	HH	A	2U	0.012U	10.6	0.157	0.187	10.8	0.014U
M7		1/26/2006	HH	A	2U	0.016	24.8	0.754	0.932	25.7	0.181
M8		5/10/2004	HH	A	2U	0.012U	37.9	0.962	0.965	38.9	1.36
M8	dup	5/10/2004	HH	A	2U	0.012U	38.3	0.933	1.01	39.3	1.28
M8		11/23/2004	HH	A	2U	0.031	1.49	0.155	0.157	1.65	0.046
M8	dup	11/23/2004	HH	A	2U	0.029	1.53	0.067	0.094	1.62	0.401
M8		1/26/2006	HH	A	2U	0.016	2.16	0.079	0.22	2.38	0.223
M9		5/10/2004	HH	A	2U	0.012U	35.9	0.219	0.273	36.2	0.014U
M9		11/23/2004	HH	A	2U	0.012U	0.405	0.172	0.19	0.595	0.014U
M9		1/26/2006	HH	A	2U	0.012U	0.207	0.067U	0.264	0.471	0.014U
M10		5/10/2004	HH	A	6	0.012U	0.012	0.083	0.481	0.481	0.014U
M10		11/23/2004	HH	A	54	0.012U	0.012	0.211	0.257	0.257	0.014U
M10		1/26/2006	HH	A	2U	0.012U	0.012U	0.07	0.263	0.263	0.014U

Note: Dups=duplicate ; HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

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Table 10. Well nutrient and fecal coliform data at Hickory.

Well	Dups	Date	Sampler	Lab	Fecal Coliform	Nitrite-N	Nitrate-N	Ammonia-N	TKN	TN	TP
					Cfu/100 mL	mg/L	mg/L	Mg/L	mg/L	mg/L	mg/L
C3a		1/26/2006	HH	A	2U	0.012U	1.09	0.197	0.265	1.36	0.014U
C5		5/10/2004	HH	A	2U	0.012U	32.7	0.067U	0.071U	32.8	0.014U
C5		11/23/2004	HH	A	2U	0.012U	6.72	0.118	0.128	6.85	0.014U
C5		1/26/2006	HH	A	2U	0.012U	8.36	0.067U	0.081	8.44	0.014U
S1		5/10/2004	HH	A	24	0.012U	33.6	0.147	0.197	33.8	0.452
S1	dup	5/10/2004	HH	A	22	0.012U	38.3	0.067U	0.08	38.4	0.485
S1		11/23/2004	HH	A	22	0.012U	5.44	0.422	0.469	5.91	0.15
S1	dup	11/23/2004	HH	A	2U	0.012U	4.38	0.378	0.406	4.79	0.182
S1		1/26/2006	HH	A	2U	0.012U	58.8	0.069	0.098	58.9	0.014U
S2		1/26/2006	HH	A	2U	0.012U	0.881	0.067U	0.098	0.979	0.014U
S3		11/23/2004	HH	A	2U	0.012U	0.021	0.067U	0.071U	0.021	0.014U
S4		11/23/2004	HH	A	2U	0.012U	0.1	0.094	0.1	0.2	0.014U
S4		1/26/2006	HH	A	2U	0.012U	0.17	0.067U	0.109	0.279	0.014U

Note: Dups=duplicate ; HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

Table 11. Nutrients and fecal coliform in tap water, surface water, background wells and an equipment blank.

Location	Date	Sampler	Lab	Fecal Coliform	Nitrite-N	Nitrate-N	Nitrite+ Nitrate-N	Ammonia-N	TKN	TN	TP
Tap water				cfu/100 mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Mag II	5/10/2004	HH	A		0.012U	0.054		0.067U	0.265	0.319	0.014U
Mag II	3/23/2006	ER	A		0.012U	0.012U		0.067U	0.14	0.14	0.259
Mag II	5/15/2007	ER	A				0.012U	0.067U	0.096	0.096	0.014U
Surface water											
Catfish Sink	11/23/2004	HH	A	8	0.012U	1.42		0.067U	0.071U	1.42	0.014U
Manatee Spring	11/23/2004	HH	A	6	0.012U	1.75		0.067U	0.071U	1.75	0.014U
Background Wells											
MB2	1/26/2006	HH	A	2U	0.012U	1.39		0.067U	0.091	1.39	0.014U
SRWMD #4	1/10/2006	HH	A	2U	0.012U	0.351		0.067U	0.103	0.478	0.014U
CA	1/26/2006	HH	A	2U	0.012U	0.264		0.067	0.264	0.264	0.014U
Equipment Blank	3/23/2006	ER	A		0.012U	0.012U		0.067U	0.071U	0.071U	0.014U

Note: HH=Harmon Harden; ER=Eberhard Roeder; A=Ackuritlabs; M= McGlynn Laboratories; U=below method detection limit

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Table 12. cBOD5, TSS and alkalinity in tap water and an equipment blank.

Location	Date	cBOD5	TSS	Alkalinity
		mg/L	mg/L	mg/L as CaCO3
Mag II	5/10/2004			174
Mag II	3/23/2006	2.0U	2.0U	185
Mag II	5/15/2007	2.0U	3	182
Equipment Blank	3/23/2006	2.0U	2.0U	10.0U

Note: U=below method detection limit

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10. Variability of Weekly Flows

During Phase I of this study, water use had not been measured. For this phase, water use was recorded to better characterize the operating conditions of the onsite sewage treatment system and the mass of nitrogen released from the onsite system. To assess the patterns of flow, two years of weekly maintenance logs were copied from park service records to assess the variability of observed flows, and compare observed flows relative to the design values. The two years were the periods from 1/17/2005, when water meter readings began to be included for the park's maintenance visits at Hickory, to 1/16/2006, and from 12/03/2007 to 12/01/2008. The observations were generally recorded weekly, with occasional deviations by up to three days and one instance each in which no record of one weekly visit existed, and one additional instance when a reading for the water meter at Magnolia II had not been recorded.

The water use records were used to calculate the average weekly, monthly, quarterly, and annual flows for each water meter and each of the two annual observation periods. These average values were then sorted to determine percentiles and cumulative distributions. Table 13 shows the statistical characteristics of water use. All four yearly series of observations show that the longer averaging periods have lower variability, as indicated by their standard deviations, than shorter averaging periods. Figures 7 and 8 show the distribution of weekly and monthly average water uses for the two sites. These figures illustrate that about a tenth of the time each there are particularly high or low water uses, but that most values fall within a steady continuum. Average water use in 2008 was somewhat higher than in 2005 for both systems. Average annual water

use was between about 40% and 50% of the estimated sewage flow. Maximum weekly water use exceeded the estimated sewage flow in three of four cases.

The water use data were obtained after the bath houses had been renovated and low-flush toilets been installed. Flows before these renovations during the work for Phase I of this study, while not measured, would therefore be expected to have been higher.

A characteristic that may be more generally applicable to the design of campground bathhouses than the absolute water usage data is the ratio between maximum and average flows, which is called the peaking factor. Such a peaking factor can be calculated for shorter periods of time, such as weeks and months. For each observation period and system a peaking factor was calculated as the maximum yearly value of an average flow condition divided by the annual average flow for that observation period and system. These data resulted in a peaking factor between 1.8 and 3.3 (average 2.4) for weekly water use; between 1.5 and 1.7 (average 1.6) for monthly water use, and between 1.1 and 1.2 (average 1.2) for quarterly water use. As mentioned before, longer averaging periods result in less variability and lower peaking factors relative to the annual observation period. While not enough daily water use data were collected to determine a peaking factor for the daily flow, the peaking factor for daily flow would be higher than the one for the weekly flow resulting in peak uses that could be by a factor of two or more above the design daily flow.

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Table 13. Summary of average water use data for the two bathhouses, based on approximately weekly recordings

Parameter	Hickory (estimated sewage flow 1250 gpd)						Magnolia II (estimated sewage flow 1000 gpd)					
	2005 (annual average=524 gpd)			2008 (annual average=637 gpd)			2005 (annual average=425 gpd)			2008 (annual average=507 gpd)		
	weekly	Monthly	quarterly	Weekly	monthly	quarterly	weekly	monthly	quarterly	weekly	monthly	quarterly
Average (gpd)	526	529	528	636	635	637	432	427	428	503	507	507
Stdev (gpd)	243	164	84	211	142	118	249	121	52	200	137	74
25-percentile (gdp)	379	431	491	501	547	567	287	329	399	374	458	459
Median (gpd)	513	453	515	619	625	626	423	414	431	448	473	514
75-percentile (gpd)	614	609	552	758	674	696	548	510	459	660	560	562
Maximum (gpd)	1255	899	641	1288	942	786	1395	630	485	917	798	579
Peaking factor (-)	2.4	1.7	1.2	2.0	1.5	1.2	3.3	1.5	1.1	1.8	1.6	1.1

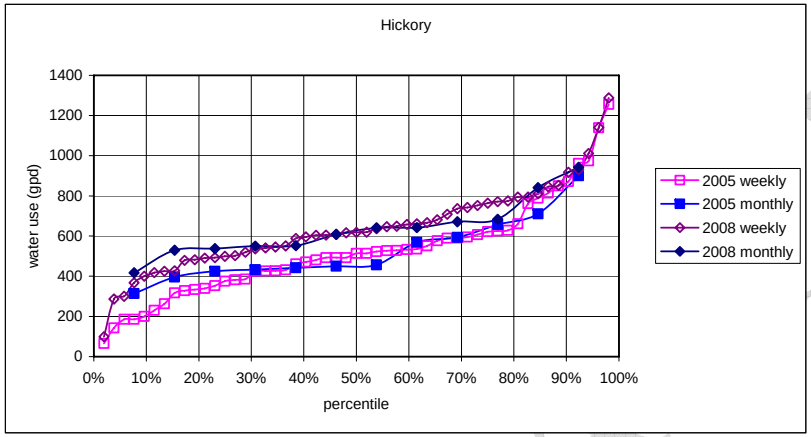

Figure 7. Cumulative distributions of weekly and monthly water use data for the Hickory bath house (design flow =1250 gpd)

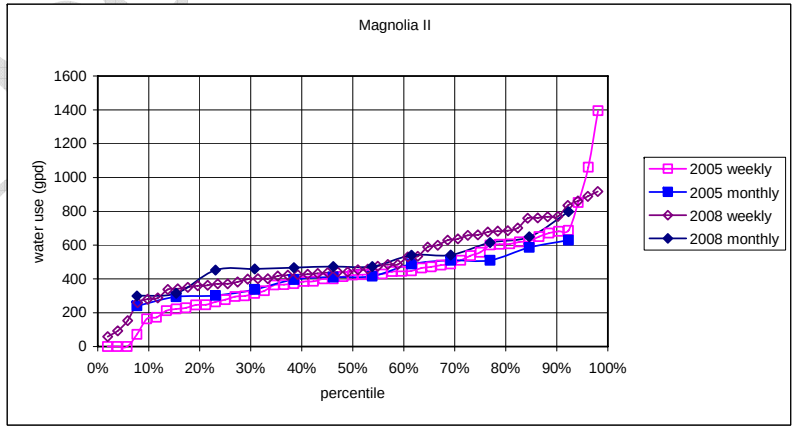

Figure 8. Cumulative distributions of weekly and monthly water use data for the Magnolia II bath house (design flow =1000 gpd)

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11. Final Modifications to the Onsite Systems

11.1. *Hickory*

Concurrently with the 2008 annual maintenance pumpouts, the tanks were certified by a septic tank contractor and a site evaluation was completed in preparation for further modifications. The site evaluator discovered an additional drain line.

The constraints of the site, including the presence of a concrete pad over the building sewer lines precluded installation of an additional trash tank upstream of the treatment tank. The engineer who had provided the original design developed a revised design that did not include phosphorus absorption and replaced the intermediate 750 gallon tank with a 1138 gallon tank large enough to hold the treatment kit. With this design, gravity flow of treated effluent into the old drainfield could not be accomplished. The design therefore utilized a branch-off with valves from the existing low-pressure dosing lines coming out of the existing pump tank to return the effluent to the old drainfield. In this way, the old drainfield is not gravity-fed but lift dosed. Figure 9 shows the final configuration of the Hickory site.

During replacement of the 750 gallon treatment tank with the larger new treatment tank, the installers intercepted a drainline that was oriented in southerly direction. The drainline consisted of gravel with corrugated pipe.

The initial plan had been to simply move the treatment kit from the first to the second tank. During construction the walls and treatment media of the old kit were damaged (Figure 10) due to the accumulation of solids, and only the aeration pipe and splash plate piece could be reused in the new kit that was installed in the new treatment tank (Figure 11). The treatment tank was initially filled with tap water to facilitate the start of aeration. The construction was finally completed on March 23, 2009 (Figure 12), the aeration activated and the effluent flow was directed to the old drainfield. The valves were adjusted to a flow that appeared small enough so that the existing trench network could safely accommodate it.

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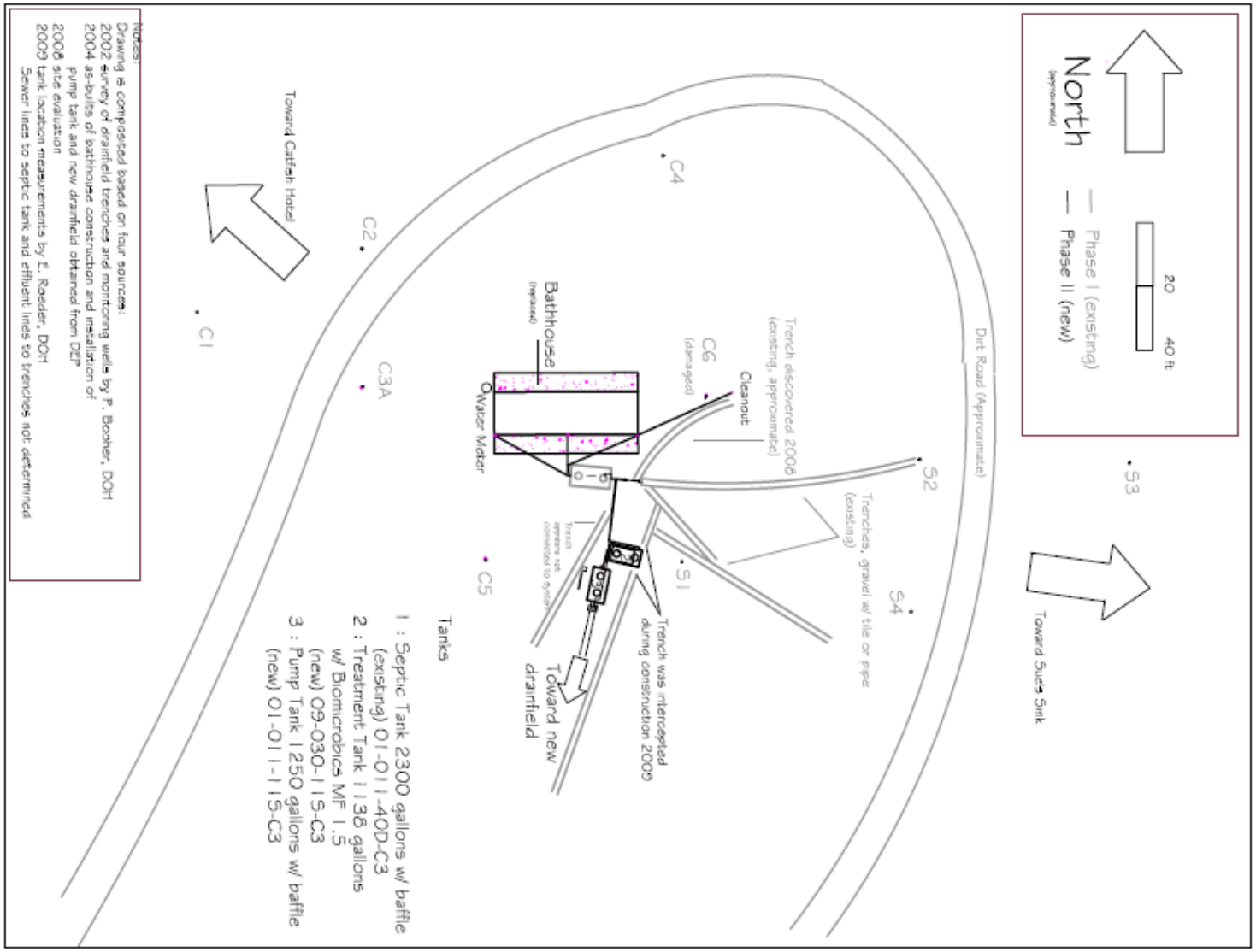

Figure 9. Hickory bathhouse with final treatment system configuration and monitoring wells.

Figure 10. Broken treatment kit, due to increased weight from solids accumulation (note textiles) (March 2009)

Figure 11. New treatment tank with treatment kit installed March 23, 2009. Small diameter pipe in front of the tank is the return line to the old drainfield.

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Figure 12. Post-installation site condition March 23, 2009.

11.2. *Magnolia II*

In preparation of the final modifications at this site, a site evaluation was completed in May 2008. All tanks were pumped and certified as structurally sound and all drainfields were evaluated according to DOH standards. This information was a necessary component of the septic modification permit. Figure 13 shows the final configuration of the Magnolia II site.

The modifications to the system as previously existing were the following (Figure 14):

- Install piping to allow drainfield lift-dosing from the existing ATU to either the old existing drainfield for the duration of the research project or to the new existing drainfield
- Install an inspection port to monitor quality of effluent going into the old drainfield
- Replace the existing distribution box and piping between the distribution box and the proposed inspection port

The modifications were made in February 2009, and on March 09, 2009, the ATU-effluent was directed toward the monitored drainfield after verification that the old drainfield was not pressurized by a dose of effluent. Figure 15 shows the condition of the drainfield during this time. During this work concerns about float functioning arose and on March 31, further

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observations suggested that the on-float was not working properly, and that leakage through the mid-seam of the pump tank might be occurring. On April 02, 2009, the float was replaced and set to trigger pumping below the water level reaches the mid-seam.

Figure 13. Magnolia II: Installing the return line from the ATU to the old drainfield, 02/24/2009.

Figure 14. Magnolia II: old drainfield on 02/24/2009 and 03/31/2009, prior to consistent dosing of the old drainfield.

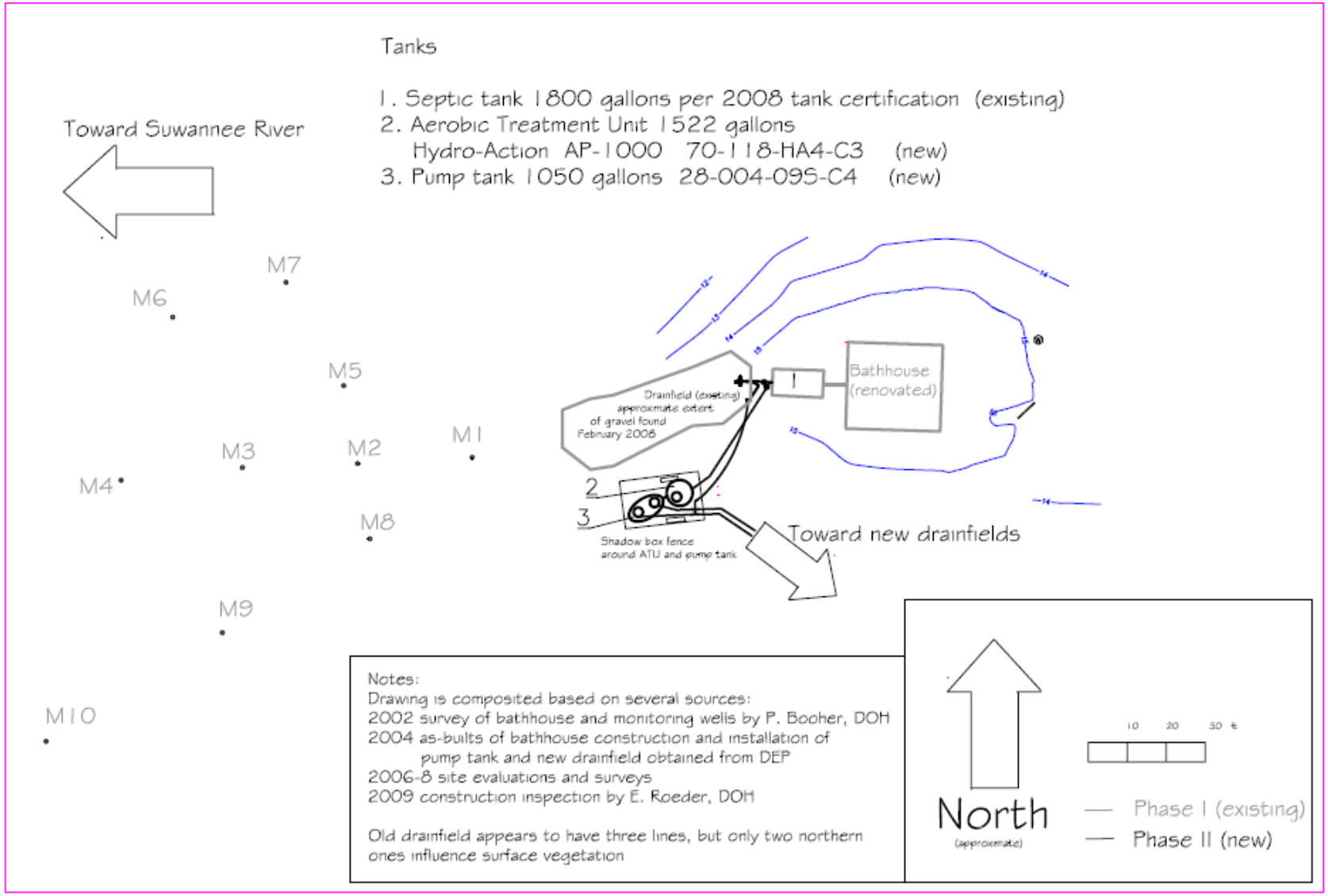

Figure 15. Magnolia II bathhouse with final treatment system configuration and monitoring wells.

12. Conclusions

The objectives of the study were to retrofit the two onsite systems investigated in Phase I of this study with nitrogen reducing systems and evaluate their performance and effect on groundwater. The following are some additional observations and conclusions:

1. This study benefited from and was influenced by upgrades the State Park implemented concurrently at the two bathhouses. Two changes relative to Phase I stemming from these upgrades were the use of low-flow fixtures in the bathhouses and the use of lift-dosing instead of gravity to feed the monitored drainfields. The use of low-flow fixtures has likely increased the concentration of nitrogen in the effluent, but is not expected to have changed the mass of nitrogen discharged in the sewage.
2. The treatment technologies eventually selected for this project represented the two approaches currently outlined in state law for the protection of the Suwannee River flood plain: an aerobic treatment unit with combined activated sludge/fixed film technology that has extensive documentation on its nitrogen reduction capability available and has been commonly installed as a performance-based treatment system for this purpose, and an extended aeration aerobic treatment unit that is lacking such documentation.
3. Retrofitting of the existing systems had to contend with site constraints based on prior construction. The use of existing old drainfields was part of the design of the study to allow comparison to Phase I. The reuse of the existing septic tanks as trash compartments for the treatment units resulted in trash tanks that are about twice as large as would usually be the case for new system construction. There was no indication that the trash tanks resulted in a lack of food for the aerobic treatment units, though, and the experience over the course of the project suggested that campground bathhouses generate a large amount of solids appropriate for a larger trash tank.
4. A first attempt to install a treatment unit in the first chamber of the existing tank did not result in successful treatment. At least for situations such as those encountered in this

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study, retrofitting for additional treatment appears to require at least an additional tank for the treatment unit.

5. Thorough maintenance appears key to ensuring effective treatment by at least the extended aeration treatment unit at Magnolia II. Samples taken on three occasions in 2006 and 2007 showed that total nitrogen in the ATU-effluent ranged from 73 to 120 mg/L and were similar to septic tank effluent samples taken at the same, which ranged from 71 to 150 mg/L total nitrogen. On these occasions, there was also little evidence of cBOD5 and TSS removal, and nitrification relative to septic tank effluent. Two of three other aerobic treatment units by the same manufacturer that were installed at park restrooms were sampled in 2007 and showed a similar lack of nitrification. In contrast, a sample taken in January 2009 at Magnolia II, after a thorough maintenance visit in June 2008 that addressed the functioning of air diffusers, showed nearly complete nitrification and a total nitrogen concentration of 66 mg/L. The sampling event in September 2009 indicated loss of nitrification function again at the Magnolia II treatment unit.
6. A more thorough inspection and possibly training protocol that is shared between the owner of the system, the maintenance entity and the regulatory agency may help to detect sub-optimal performance more quickly. The lack of treatment discussed in the previous point occurred even though the aerobic treatment unit appeared to be working, as indicated by the running of the aerator, except for some overheating problems observed by park staff.
7. Outside the direct scope of this project, park management reported and DOH staff observed a variety of problems related to the functioning of the pressure dosing system installed as part of the park service-initiated upgrade. Some of these problems appeared unique to the size and design of the particular systems involved.
8. For the continued operation of the bathhouses it proved useful to have the research project drainfields remaining as a gravity-fed backup to the pressure-dosed systems. This benefit has to be considered against the lack of treatment obtained during periods when the pressure-dosed system is not functional. In addition, the continued intermittent use of the old existing drainfield resulted in residual nitrogen concentrations in the monitoring wells that had the potential to confound an evaluation of the treatment effect.

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9. Septic tank effluent contained nearly exclusively reduced forms of nitrogen (TKN) with 56 to 95% of that concentration being present as ammonia-nitrogen.
10. Nitrogen concentrations in septic tank effluent from the two systems frequently exceeded Florida's limit of 100 mg/L TKN for domestic sewage and was by a factor of two to four higher than average values in domestic sewage found in prior Florida studies. In part this high concentration is due to the use of low-flow fixtures and may indicate a broader change in domestic sewage composition. Total phosphorus concentrations ranged from 0.5 to 33 mg/L with most being below 10 mg/L. cBOD5, ranging from 25 to 220 mg/L, and TSS, ranging from 38 to 126 mg/L indicated that septic tanks retain their effectiveness for the reduction of these parameters with more concentrated sewage.

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We would like to thank the State Park Service for the permission to research their sewage. Thanks to the park manager and both present and past staff of Manatee Springs State Park for the assistance provided and patience with this project. We appreciate the assistance and documentation made available by the staff in the Bureau of Design and Construction.

We would like to thank the following people for their hard work and valuable insight on this project: the FDOH Research Review and Advisory Committee; staff at the Levy County Health Department; and the many other people that contributed. Their assistance was invaluable.

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COMMUNITY EDUCATION

The report and the brochure developed from Phase I results have prompted much interest. FSU submitted a journal manuscript about the results of Phase I to the *Journal of Hydrology* in November of 2006. The manuscript was first redirected and then returned back for revisions. DOH presented results of Phase I at the 2005 National Conference of the National Onsite Wastewater Recycling Association, and a comparison of tracer transport in this environment with a wetland environment study at the 2006 National Conference of the National Onsite Wastewater Recycling Association. DOH staff is continuing to analyze tracer data in more detail. Florida State University provided a revised draft Phase I report on June 19, 2007. FSU submitted a journal manuscript titled "Evaluation of Onsite Sewage Treatment and Disposal Systems in Shallow Karst Terrain" to Water Research on August 21, 2007. Comments were received regarding the manuscript, and FSU and FDOH addressed these comments. The manuscript was accepted for publication in Water Research and was published in issue 42(2008) 2585-2597. The draft final report from the provider and the draft report on the work performed by DOH were submitted to the department's Research Review and Advisory Committee for review and comment. This committee consists of representatives from 10 different interest groups (home builders, engineers, state university system, Department of Health, environmental interest group, consumers, local government, real estate industry, restaurant industry, and septic tank industry). The final project report will be posted on the department's research website: http://www.doh.state.fl.us/environment/ostds/research/index.html.

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APPENDIX A: Chapter I Appendix NRTS Performance Assessment and Periodic Sampling

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A.1 NRTS Performance Assessment and Periodic Sampling Field Data

Station	Date	Time *YSI*	Water T *YSI* Celsius	COND *YSI* µS/cm	COND *YSI* mS/cm	Salinity *YSI* ppt	DO %SAT *YSI* %	DO *YSI* mg/L	PH *YSI* mg/L	ORP *YSI* mg/L	PH *Probe* units
Hick EFT	5/31/2009	17:06	27.13	1077	1.121	0.53	43.3	3.03	8.02	50.2	8.0
Hick EFT	5/31/2009	22:56	25.48	1094	1.104	0.54	43.3	3.48	7.60	38.0	8.0
Hick EFT	6/1/2009	4:55									7.7
Hick EFT	6/1/2009	5:07	25.29	1117	1.124	0.55	44.2	3.36	7.15	13.0	7.7
Hick EFT	6/1/2009	11:00	25.58	1076	1.088	0.53	49.3	3.98	7.07	63.1	8.1
Hick EFT	6/1/2009	17:02	25.53	1053	1.064	0.52	53.7	4.39	7.99	59.1	8.0
Hick EFT	6/1/2009	23:07	25.37	1015	1.022	0.50	39.1	3.19	8.09	29.9	7.9
Hick EFT	6/2/2009	7:49	25.14	1003	1.006	0.49	32.1	2.64	8.29	14.9	7.3
Hick EFT	6/2/2009	11:04	25.50	982	0.991	0.48	36.2	2.96	8.40	18.4	
Hick EFT	6/2/2009	17:04	25.51	967	0.976	0.47	33.5	2.72	8.17	43.8	7.7
Hick EFT	6/2/2009	23:03	25.43	944	0.951	0.46	38.2	3.12	8.20	10.3	7.7
Hick EFT	6/3/2009	5:05	25.03	935	0.934	0.46	25.7	2.12	8.34	10.7	7.7
Hick EFT	6/3/2009	11:03	25.73	922	0.935	0.45	21.6	1.75	8.57	8.5	7.6
Hick EFT	6/3/2009	16:28	25.49	902	0.910	0.44	39.3	3.21	8.05	20.9	7.6
Hick EFT	6/3/2009	17:03	25.44	900	0.908	0.44	29.9	2.44	8.14	6.4	7.6
Hick EFT	6/3/2009	23:02	25.50	885	0.894	0.43	42.3	3.45	8.05	24.3	7.6
Hick EFT	6/4/2009	5:07	24.62	885	0.879	0.43	15.5	1.27	7.93	26.0	
Hick EFT	6/4/2009	11:24	25.41	874	0.881	0.43	45.0	3.68	7.77	26.3	
Hick EFT	6/4/2009	15:30	25.15	875	0.878	0.43	17.2	1.42	7.70	10.6	7.6
	average		**25.46**	**972.56**	**0.98**	**0.48**	**36.08**	**2.90**	**7.97**	**26.36**	**7.74**
	stdev		*0.49*	*82.65*	*0.09*	*0.04*	*10.73*	*0.85*	*0.40*	*17.69*	*0.21*
Hick EFT	05/11/09	16:44	25.96	1403	1.429	0.7	52.6	4.28	4.44	37.2	
Hick EFT	09/10/09	14:56	27.03	920	0.955	0.45	50.3	3.96	12.42	30.6	7.4

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A.1 NRTS Performance Assessment and Periodic Sampling Field Data (continued)

Station	Date	Time *YSI*	Water T *YSI* Celsius	COND *YSI* µS/cm	COND *YSI* mS/cm	Salinity *YSI* ppt	DO %SAT *YSI* %	DO *YSI* mg/L	PH *YSI* mg/L	ORP *YSI* mg/L	PH *Probe* units
Hick STE	5/31/2009	17:23	25.62	1335	1.351	0.66	3.9	0.32	7.16	-203.0	7.2
Hick STE	5/31/2009	19:26	25.50	1330	1.342	0.66	4.0	0.33	6.98	-159.0	7.1
Hick STE	5/31/2009	22:37	25.51	1312	1.324	0.65	4.3	0.34	6.74	-177.8	7.1
Hick STE	6/1/2009	10:49	25.72	1271	1.289	0.63	2.9	0.24	7.00	-190.0	
Hick STE	6/1/2009	17:13	25.53	1261	1.275	0.63	2.9	0.24	7.03	-108.9	7.1
Hick STE	6/1/2009	23:18	25.39	1266	1.275	0.63	7.8	0.64	7.16	-139.0	6.9
Hick STE	6/2/2009	7:58	25.38	1295	1.304	0.64	4.1	0.33	7.51	-125.2	7.0
Hick STE	6/2/2009	11:15	25.58	1340	1.355	0.67	25.5	2.08	7.45	-130.6	
Hick STE	6/2/2009	17:13	25.54	1332	1.346	0.66	8.2	0.66	7.32	-136.2	6.9
Hick STE	6/2/2009	23:12	25.51	1324	1.337	0.66	6.8	0.55	7.28	-121.7	6.8
Hick STE	6/3/2009	5:13	25.40	1326	1.336	0.66	8.0	0.64	7.54	-119.0	6.9
Hick STE	6/3/2009	11:08	25.86	1323	1.345	0.66	4.3	0.35	7.55	-113.9	6.9
Hick STE	6/3/2009	16:42	25.73	1319	1.338	0.66	11.3	0.92	7.42	-116.0	6.9
Hick STE	6/3/2009	17:13	25.76	1323	1.342	0.66	9.2	0.75	7.44	-112.3	6.9
Hick STE	6/3/2009	23:15	25.86	1317	1.339	0.66	17.5	1.42	7.40	-164.0	6.8
Hick STE	6/4/2009	5:15	25.81	1323	1.343	0.66	11.4	0.93	7.23	-156.8	
Hick STE	6/4/2009	11:31	25.85	1309	1.330	0.65	27.4	2.22	6.98	-146.8	6.8
Hick STE	6/4/2009	15:36	25.63	1322	1.339	0.66	3.8	0.31	6.97	-127.7	6.8
	average		**25.62**	**1312.67**	**1.33**	**0.65**	**9.07**	**0.74**	**7.23**	**-141.55**	**6.94**
	stdev		*0.16*	*23.77*	*0.03*	*0.01*	*7.37*	*0.60*	*0.24*	*28.04*	*0.13*
Hick STE	03/27/09	14:45	23.29	1087	1.051	1	2.2				
Hick STE	05/11/09	16:59	25.91	1611	1.639	0.81	8.9	0.72	4.40	-241.2	
Hick STE	09/10/09	15:06	26.81	1444	1.494	0.72	4.3	0.34	12.15	-350.9	6.9

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A.1 NRTS Performance Assessment and Periodic Sampling Field Data (continued)

Station	Date	Time *YSI*	Water T *YSI* Celsius	COND *YSI* µS/cm	COND *YSI* mS/cm	Salinity *YSI* ppt	DO %SAT *YSI* %	DO *YSI* mg/L	PH *YSI* mg/L	ORP *YSI* mg/L	PH *Probe* units
Mag EFT	5/31/2009	18:07	26.73	1168	1.207	0.58	30.8	2.45	6.72	79.6	
Mag EFT	5/31/2009	23:48	26.90	1146	1.189	0.57	43.0	3.44	6.27	31.3	7.0
Mag EFT	6/1/2009	5:48	26.65	1142	1.178	0.56	32.1	2.56	6.41	10.9	
Mag EFT	6/1/2009	5:55									7.2
Mag EFT	6/1/2009	11:56	26.61	1132	1.166	0.56	39.6	3.08	6.07	42.4	7.2
Mag EFT	6/1/2009	18:02	26.85	1124	1.164	0.55	34.9	2.79	6.87	55.1	7.1
Mag EFT	6/1/2009	23:46	26.76	1120	1.158	0.55	36.9	2.95	6.88	-2.9	7.1
Mag EFT	6/2/2009	8:21	26.58	1117	1.151	0.55	40.0	3.21	7.26	3.6	7.0
Mag EFT	6/2/2009	15:14	27.15	1112	1.158	0.55	57.7	4.56	7.00	24.4	
Mag EFT	6/2/2009	16:10									7.2
Mag EFT	6/2/2009	18:02	27.18	1111	1.157	0.55	48.9	3.86	6.74	48.9	6.6
Mag EFT	6/3/2009	5:34	26.74	1111	1.147	0.55	46.0	3.68	6.94	-3.3	6.6
Mag EFT	6/3/2009	15:51	26.56	1110	1.143	0.55	34.7	2.77	6.88	16.7	6.5
Mag EFT	6/3/2009	16:10									7.0
Mag EFT	6/3/2009	18:25	26.70	1111	1.148	0.55	41.2	3.29	6.87	5.0	6.5
Mag EFT	6/4/2009	5:50	26.49	1114	1.146	0.55	41.9	3.36	6.41	-10.4	6.3
Mag EFT	06/04/09	12:04	26.50	1113	1.145	0.55	55.7	4.47	6.21	-2.5	6.2
Mag EFT	6/4/2009	16:13	26.41	1116	1.146	0.55	41.2	3.3	6.31	-5.9	
Mag EFT	**average**		**26.72**	**1123.13**	**1.16**	**0.55**	**41.64**	**3.32**	**6.66**	**19.53**	**6.82**
	stdev		**0.22**	**16.89**	**0.02**	**0.01**	**7.84**	**0.62**	**0.35**	**26.75**	**0.36**
Mag EFT	01/14/09	14:10	18.50	1136	0.996	0.570	40.7	3.80	6.79	163.30	
Mag EFT	05/11/09	12:48	26.15	1237	1.264	0.61	9.9	0.8	3.78	55.3	
Mag EFT	09/10/09	15:31	27.49	1049	1.098	0.52	33.9	2.67	12.7	-11.8	7.7

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A.1 NRTS Performance Assessment and Periodic Sampling Field Data (continued)

Station	Date	Time *YSI*	Water T *YSI* Celsius	COND *YSI* µS/cm	COND *YSI* mS/cm	Salinity *YSI* ppt	DO %SAT *YSI* %	DO *YSI* mg/L	PH *YSI* mg/L	ORP *YSI* mg/L	PH *Probe* units
Mag STE	5/31/2009	18:44	27.46	1458	1.527	0.73	1.8	0.14	6.93	-177.0	7.2
Mag STE	5/31/2009	23:23	27.39	1473	1.537	0.73	6.2	0.46	6.21	-176.9	7.1
Mag STE	6/1/2009	12:07	27.23	1472	1.535	0.73	3.2	0.25	5.78	-179.9	7.0
Mag STE	6/1/2009	18:12	27.13	1471	1.530	0.73	4.9	0.38	6.76	-137.6	6.9
Mag STE	6/1/2009	23:59	27.10	1465	1.524	0.73	3.5	0.28	6.77	-140.6	7.0
Mag STE	6/2/2009	8:33	27.04	1465	1.522	0.73	4.7	0.39	7.18	6.-126.9	6.9
Mag STE	6/2/2009	15:22	27.13	1473	1.533	0.74	15.6	1.23	7.13	-150.7	
Mag STE	6/2/2009	16:15									7.3
Mag STE	6/2/2009	18:15	27.09	1481	1.541	0.74	19.6	1.54	6.95	-134.6	6.7
Mag STE	6/3/2009	5:44	27.16	1477	1.538	0.74	6.8	0.54	7.09	-115.4	6.7
Mag STE	6/3/2009	15:40	27.11	1464	1.523	0.73	5.7	0.45	7.24	-128.8	6.7
Mag STE	6/3/2009	16:05									7.2
Mag STE	6/3/2009	18:13	27.05	1473	1.531	0.74	7.7	0.62	7.36	-130.6	6.7
Mag STE	06/04/09	11:54	27.07	1463	1.521	0.73	16.5	1.30	6.94	-125.9	6.7
Mag STE	6/4/2009	5:42	27.18	1460	1.521	0.73	11.8	0.93	6.97	-134.1	6.8
Mag STE	6/4/2009	15:58	26.96	1482	1.538	0.74	7.7	0.61	6.89	-120.2	
Mag STE	**average**		**27.15**	**1469.79**	**1.53**	**0.73**	**8.26**	**0.65**	**6.87**	**-142.48**	**6.92**
	stdev		**0.13**	**7.46**	**0.01**	**0.00**	**5.48**	**0.43**	**0.42**	**22.05**	**0.22**
Mag STE	05/11/09	13:07	26.91	1430	1.482	0.71	1.6	0.11	3.78	-249.4	
Mag STE	09/10/09	15:43	28.41	1459	1.555	0.73	7.3	0.55	11.74	-279.9	6.8

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A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
				MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Hick EFT	C1	06/01/09	11:30	1			17.006		48.684	45.222	62.228	3.712
Hick EFT	C2	06/02/09	12:30	1			26.526		34.401	34.423	60.949	3.659
Hick EFT	C3	06/03/09	12:00	1		2.695	32.794	30.099	17.775	16.175	48.969	2.836
Hick EFT	C4	06/04/09	13:30	1		0.583	62.333	61.749	10.685	11.341	73.674	2.958
Hick EFT	C4	06/04/09	13:35	F2		0.398	59.103	58.704	10.790	13.646	72.749	3.396
Hick EFT	C4	06/04/09	13:35	Ave			60.718		10.737	12.494	73.212	3.177
		Average	**n=4**				**34.261**		**27.899**	**27.078**	**61.339**	**3.346**
		St Dev					*18.794*		*17.042*	*15.435*	*9.915*	*0.417*
Hick EFT	G1	05/31/09	16:55	1			14.917		40.114	50.612	65.529	3.535
Hick EFT	G2	06/01/09	10:55	1			23.271		41.359	38.587	61.857	3.364
Hick EFT	G3	06/01/09	23:00	1			0.608		33.511	51.175	51.783	3.489
Hick EFT	G4	06/02/09	7:45	1			0.211		52.014	48.029	48.240	3.676
Hick EFT	G5	06/03/09	5:00	1		3.069	59.643	56.575	20.328	22.583	82.227	3.162
Hick EFT	G6	06/03/09	16:25	1		3.848	7.140	3.292	14.535	12.977	20.116	3.071
Hick EFT	G7	06/03/09	5:00	1		3.556	48.217	44.661	12.654	10.342	58.558	3.198
Hick EFT	G7	06/03/09	5:00	F2		33.314	46.872	13.558	12.264	10.764	57.637	2.981
Hick EFT	G7	06/04/09	5:00	Ave		18.435	47.544	29.110	12.459	10.553	58.097	3.089
Hick EFT	E3	06/04/09	11:20	1	6200	4.607	10.785	6.179	5.759	6.783	17.569	2.668
Hick EFT	G8	06/04/09	15:24	1		0.146	38.381	38.234	6.729	7.010	45.391	3.541
		Average	**n=9**				**22.500**		**25.201**	**27.590**	**50.090**	**3.288**
		St Dev					*21.408*		*16.921*	*19.398*	*20.791*	*0.318*

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A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data (continued)

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
				MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Hick EFT	E1	03/27/09	14:35	1	8060	0.125	4.600	4.475	44.640	116.386	120.986	12.789
Hick EFT	E1	03/27/09	14:35	F2	6760	0.129	0.248	0.119	40.043	97.017	97.265	13.193
Hick EFT	E1	03/27/09	14:35	Ave	7410	0.127	2.424	2.297	42.341	106.701	109.125	12.991
Hick EFT	E2	05/11/09	16:40	1	3350	1.327	6.307	4.979	33.595	52.537	58.844	2.731
Hick EFT	E4	09/10/09	14:55	1		3.283	43.079	39.796	9.733	14.945	58.024	3.068
Hick EFT	E4	09/10/09	14:55	F2		3.294	42.590	39.295	10.266	13.934	56.524	2.923
Hick EFT	E4	09/10/09	14:55	Ave		3.288	42.834	39.546	10.000	14.440	57.274	2.996
		Average	**n=3**			**1.581**	**17.188**	**15.607**	**28.646**	**57.893**	**75.081**	**6.239**
		St Dev				*1.596*	*22.295*	*20.775*	*16.729*	*46.363*	*29.493*	*5.848*
Hick STE	C1	06/01/09	14:30	1			0.400		76.632	91.178	91.578	3.733
Hick STE	C1	06/01/09	14:30	F2			0.400		84.853	84.009	84.408	3.741
Hick STE	C1	06/01/09	14:30	Ave			0.400		80.742	87.593	87.993	3.737
Hick STE	C2	06/02/09	12:45	1			1.052		50.668	51.474	52.526	3.896
Hick STE	C3	06/03/09	11:50	1		0.135	0.211	0.076	83.149	88.735	88.946	3.270
Hick STE	C4	06/04/09	13:14	1		0.117	0.401	0.283	56.022	93.552	93.953	2.759
Hick STE	C4	06/04/09	13:20	F2		0.112	0.401	0.289	41.630	78.160	78.561	3.409
Hick STE	C4	06/04/09	13:20	Ave			0.401		48.826	85.856	86.257	3.084
		Average	**n=4**				**0.516**		**65.846**	**78.415**	**78.931**	**3.497**
		St Dev					*0.368*		*18.631*	*17.999*	*17.638*	*0.383*

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A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data (continued)

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
				MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Hick STE	G1	05/31/09	19:15	1			0.226		27.374	133.164	133.390	4.311
Hick STE	G2	06/01/09	10:50	1			0.878		129.518	146.016	146.895	3.959
Hick STE	G3	06/01/09	23:15	1			24.464		95.909	110.214	134.677	3.786
Hick STE	G4	06/02/09	7:55	1			0.665		64.654	91.979	92.644	7.259
Hick STE	G5	06/03/09	5:10	1		0.135	0.155	0.020	82.778	124.724	124.878	3.397
Hick STE	G6	06/03/09	16:34	1		0.151	0.161	0.010	96.803	139.712	139.873	3.397
Hick STE	G7	06/04/09	5:10	1		0.135	0.068	0.000	90.928	86.397	86.465	3.325
Hick STE	E3	06/04/09	11:32	1	15400	0.115	0.099	0.000	61.506	58.459	58.558	3.321
Hick STE	G8	06/04/09	15:38	1		0.137	0.984	0.847	75.388	77.748	78.732	3.661
		Average	**n=9**				**3.078**		**80.540**	**107.601**	**110.679**	**4.046**
		St Dev					*8.027*		*28.461*	*30.537*	*31.831*	*1.250*
Hick STE	E1	03/27/09	14:45	1	26000	0.054	0.116	0.063	61.696	173.313	173.429	13.496
Hick STE	E2	05/11/09	17:00	1	60000	0.062	0.092	0.031	59.414	235.162	235.254	2.919
Hick STE	E4	09/10/09	15:05	1		0.101	6.244	6.143	88.158	134.116	140.361	0.479
		Average	**n=3**				**2.151**		**69.756**	**180.864**	**183.015**	**5.632**
		St Dev					*3.545*		*15.977*	*50.944*	*48.168*	*6.920*

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A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data (continued)

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
				MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Mag EFT	C1	06/01/09	12:40	1			9.697		28.513	26.151	35.848	3.066
Mag EFT	C2	06/02/09	16:10	1			12.090		19.490	33.525	45.615	4.037
Mag EFT	C2	06/02/09	15:35	F2			10.028		27.528	26.149	36.176	3.888
Mag EFT	C2	06/02/09	16:10	Ave			11.059		23.509	29.837	40.896	3.962
Mag EFT	C3	06/03/09	16:10	1		3.069	6.356	3.287	18.177	27.590	33.946	3.470
Mag EFT	C4	06/04/09	16:30	1		0.000	46.455	46.455	15.318	20.942	67.397	3.396
		Average	**n=4**				**18.392**		**21.379**	**26.130**	**44.522**	**3.473**
		St Dev					*18.813*		*5.843*	*3.777*	*15.530*	*0.370*
Mag EFT	G1	05/31/09	18:20	1		11.717	0.806		24.848	49.333	50.139	3.864
Mag EFT	G2	06/01/09	11:45	1			17.528		28.368	21.862	39.390	4.002
Mag EFT	G3	06/01/09	23:45	1			1.023		27.169	34.973	35.997	3.676
Mag EFT	G4	06/02/09	8:20	1			16.214		22.027	28.009	44.223	3.964
Mag EFT	G5	06/03/09	5:35	1		3.556	12.181	8.625	17.305	18.609	30.790	3.307
Mag EFT	G6	06/03/09	15:48	1		4.156	17.559	13.402	14.931	18.240	35.798	3.252
Mag EFT	G7	06/04/09	5:50	1		0.117	0.068	0.000	31.648	57.116	57.183	3.488
Mag EFT	E3	06/04/09	12:05	1	6700	3.000	25.002	22.003	11.734	17.042	42.044	3.535
Mag EFT	E3	06/04/09	12:05	F2	10700	0.022	25.330	25.308	11.848	14.407	39.737	3.314
Mag EFT	E3	06/04/09	12:05	Ave	8700	1.511	25.166	23.656	11.791	15.724	40.891	3.424
Mag EFT	G8	06/04/09	16:14	1		0.002	26.000	25.998	21.432	21.962	47.962	3.966
		Average	**n=9**				**12.949**		**22.169**	**29.536**	**42.486**	**3.660**
		St Dev					*10.178*		*6.565*	*14.742*	*8.241*	*0.300*

DRAFT Dec 2009

A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data (continued)

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event Sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
	BKG	Background Sample		MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Mag EFT	BKG	01/14/09	14:10	1	3780	0.371	63.484	63.113	2.025	3.003	66.487	20.802
Mag EFT	E1	03/26/09	13:58	1	2100	1.184	12.242	11.058	1.675	14.161	26.403	0.113
Mag EFT	E2	05/11/09	12:50	1	8000	1.512	6.943	5.431	10.199	13.160	20.102	1.743
Mag EFT	E2	05/11/09	12:50	F2	7610	1.819	6.943	5.124	11.211	12.675	19.618	1.763
Mag EFT	E2	05/11/09	12:50	Ave			6.943		10.705	12.918	19.860	1.753
Mag EFT	E4	09/10/09	15:30	1		3.984	41.448	37.464	28.164	96.604	138.052	1.981
		Average	**n=3**				**31.029**		**10.642**	**31.671**	**62.701**	**6.162**
		St Dev					*26.426*		*12.405*	*43.575*	*54.298*	*9.796*
Mag STE	C1	06/01/09	15:25	1			25.359		95.403	120.824	146.183	4.481
Mag STE	C2	06/02/09	16:15	1			0.039		77.420	121.218	121.257	3.820
Mag STE	C3	06/03/09	16:05	1		0.087	0.130	0.043	89.717	177.664	177.794	3.886
Mag STE	C4	06/04/09	16:20	1		0.072	0.289	0.216	126.541	127.799	128.088	3.992
		Average	**n=4**				**6.454**		**97.270**	**136.876**	**143.330**	**4.045**
		St Dev					*12.604*		*20.907*	*27.380*	*25.268*	*0.299*

DRAFT Dec 2000

A.2 NRTS Performance Assessment and Periodic Sampling Nutrient Data (continued)

	C	Composite sample			**F Coli**	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
	G	Grab Sample			SM	EPA	EPA	calc	EPA	EPA		EPA
	E	Event Sample			9222D	354.1	353.3		350.3	351.4	calc	365.2
	BKG	Background Sample		MDL	*1*	*0.003*	*0.006*	*0.006*	*0.022*	*0.056*	*0.056*	*0.004*
				PQL	*4*	*0.012*	*0.024*	*0.024*	*0.088*	*0.224*	*0.224*	*0.016*
Station	**ID**	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Mag STE	G1	05/31/09	18:35	1			0.168		97.367	156.863	157.031	4.215
Mag STE	G2	06/01/09	12:05	1			20.138		76.243	89.330	109.468	4.567
Mag STE	G3	06/01/09	23:55	1			10.028		138.813	139.081	149.108	4.100
Mag STE	G4	06/02/09	8:30	1			0.909		84.492	135.452	136.361	3.477
Mag STE	G5	06/03/09	5:42	1		0.151	0.173	0.022	94.663	188.665	188.839	3.669
Mag STE	G6	06/03/09	15:35	1		0.175	0.214	0.038	86.564	130.690	130.904	3.524
Mag STE	G6	06/03/09	15:35	F2		0.161	0.155	0.000	89.316	143.493	143.647	3.796
Mag STE	G6	06/03/09	15:35	Avg			0.184		87.940	137.091	137.276	3.660
Mag STE	G7	06/04/09	5:40	1		0.118	0.068	0.000	127.163	169.553	169.621	3.597
Mag STE	E3	06/04/09	11:55	1	102100	0.115	0.075	0.000	100.784	102.330	102.405	3.435
Mag STE	G8	06/04/09	16:00	1		0.109	0.588	0.479	122.302	123.809	124.396	3.913
		Average	**n=9**				**3.592**		**103.307**	**138.020**	**141.612**	**3.848**
		St Dev					*6.993*		*21.300*	*31.164*	*27.888*	*0.380*
Mag STE	E1	03/26/09	14:20	1	10500	0.127	7.761	7.634	83.644	202.893	210.654	0.128
Mag STE	E2	05/11/09	13:10	1	13520	0.071	0.055	0.000	38.718	168.989	169.045	1.842
Mag STE	E2	05/11/09	13:10	F2	12410	0.070	0.070	0.000	40.402	186.769	186.839	1.150
Mag STE	E2	05/11/09	13:10	Ave	12965	0	0.063	0.000	39.560	177.879	177.942	1.496
Mag Ste	E4	09/10/09	15:42	1		0.101	6.306	6.205	82.947	142.937	149.242	1.621
		Average	**n=3**				**4.710**		**68.717**	**174.570**	**179.279**	**1.082**
		St Dev					*4.090*		*25.253*	*30.115*	*30.728*	*0.828*

DRAFT Dec 2009

APPENDIX B: Chapter I Appendix Environmental Monitoring

DRAFT Dec 2009

B 1. Environmental Monitoring Field Data

Station	Date	**Well**	**Time**	**Water T**	**COND**	**COND**	**Salinity**	**DO %SAT**	**DO**	**PH**	**ORP**	**PH**
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
Background												
CAS	01/14/09	3.40	12:14	21.65	41.83			27.4	2.21	8.06		
CAS	03/26/09	6.40	13:31	21.00	41.83			27.4	2.2	8.06		
CAS	05/11/09	2.52	12:35	20.83	53				1.65	3.48		
CAS	06/04/09	2.79	11:04	21.33	277				2.19	4.48		
	average	**n=4**		**21.20**	**103.42**				**2.07**	**6.02**		
	stdev			*0.36*	*115.84*				*0.28*	*2.39*		
SRWMD #4	01/14/09	5.46	12:56	22.21	157.9			14.9	0.60	7.71		
SRWMD #4	03/26/09	6.77	13:12	22.21	157.9			14.9	0.6	7.71		
SRWMD #4	05/11/09	4.61	12:59	21.37	299				1.39	3.36		
SRWMD #4	06/04/09	4.90	11:43	21.48	206				1.45	8.46		
	average	**n=4**		**21.82**	**205.20**				**1.01**	**6.81**		
	stdev			*0.46*	*66.52*				*0.47*	*2.33*		

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B 1. Environmental Monitoring Field Data (continued)

Station	Date	Well Depth	Time	Water T	COND	COND	Salinity	DO %SAT	DO	PH	ORP	PH
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
Hickory												
S1	01/14/09	4.36	9:44	21.86	634	0.596	0.31	21.7	1.89	7.57	219.1	
S1	03/27/09	4.20	14:20	21.96	589.00	0.555	0.29	28.2	2.46	6.75	101.9	
S1	05/11/09	3.75	16:19	21.57	645	0.602	0.31	5.6	0.49	4.00	36.3	
S1	06/4/09	3.73	11:09	21.62	660	0.618	0.32	3.2	0.29	7.37	29.7	7.2
S1	09/10/09	4.16	14:37	22.80	656	0.628	0.32	5.9	0.51	12.59	22.6	7.1
	average	**n=5**		**21.96**	**636.80**	**0.60**	**0.31**	**12.92**	**1.13**	**7.66**	**81.92**	
	stdev			*0.50*	*28.58*	*0.03*	*0.01*	*11.27*	*0.98*	*3.11*	*82.98*	
S2	01/14/09	4.26	10:05	21.58	553	0.518	0.27	39.3	3.47	7.47	218.2	
S2	03/27/09	4.08	12:15	21.32	536	0.499	0.26	46.9	4.15	5.79	108.5	
S2	05/11/09	3.45	14:18	21.22	548	0.508	0.27	11.6	1.02	4.13	12.9	
S2	06/4/09	3.64	10:12	21.13	532	0.493	0.26	4.8	0.43	7.51	33.4	7.3
S2	09/10/09	4.03	13:17	22.1	552	0.521	0.27	11.5	1.01	12.7	30.6	7.1
	average	**n=5**		**21.47**	**544.20**	**0.51**	**0.27**	**22.82**	**2.02**	**7.52**	**80.72**	
	stdev			*0.39*	*9.60*	*0.01*	*0.01*	*18.91*	*1.67*	*3.21*	*85.18*	

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B 1. Environmental Monitoring Field Data (continued)

Station	Date	Well Depth	Time	Water T	COND	COND	Salinity	DO %SAT	DO	PH	ORP	PH
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
C3	01/14/09	4.30	10:55	21.46	588	0.548	0.29	57.0	5.03	7.34	243.7	
C3	03/27/09	4.12	13:30	21.07	566	0.523	0.27	62.1	5.51	6.60	105.0	
C3	05/11/09	3.475	15:24	20.85	555	0.511	0.27	31.3	2.79	4.03	35.6	
C3	06/4/09	3.66	10:44	20.83	550	0.506	0.27	27.0	2.50	7.41	32.6	7.2
C3	09/10/09	4.055	13:56	22.04	566	0.534	0.27	24.2	2.11	12.67	32.3	7.1
	average	**n=5**		**21.25**	**565.00**	**0.52**	**0.27**	**40.32**	**3.59**	**7.61**	**89.84**	
	stdev			*0.51*	*14.63*	*0.02*	*0.01*	*17.83*	*1.56*	*3.14*	*91.42*	
C4	01/14/09	4.37	11:12	21.33	573	0.533	0.27	69.7	6.16	7.31	250.1	
C4	03/27/09	4.18	12:45	20.98	563	0.520	0.27	70.1	6.25	6.43	107.5	
C4	05/11/09	3.54	14:59	20:57	541	0.495	0.26	36.3	3.26	4.08	33.1	
C4	06/4/09	3.73	10:32	20.96	542	0.500	0.26	30.6	2.71	7.49	32.6	7.2
C4	09/10/09	4.115	13:39	22.17	571	0.54	0.28	32.5	2.86	12.64	34.4	7.1
	average	**n=5**		**17.26**	**558.00**	**0.52**	**0.27**	**47.84**	**4.25**	**7.59**	**91.54**	
	stdev			*9.18*	*15.52*	*0.02*	*0.01*	*20.24*	*1.80*	*3.13*	*94.27*	
C5	01/14/09	4.30	10:35	21.91	696	0.655	0.34	40.6	3.55	7.39	240.8	
C5	03/27/09	4.13	13:50	21.86	639	0.600	0.31	28.1	2.46	6.67	96.6	
C5	05/11/09	3.475	15:50	21.33	641	0.596	0.31	10.9	0.96	4.00	34.7	
C5	06/4/09	3.66	10:59	21.41	658	0.613	0.32	32.4	2.87	7.38	31.7	7.2
C5	09/10/09	4.07	14:17	22.35	615	0.584	0.3	13.1	1.13	12.66	27	7.1
	average	**n=5**		**21.77**	**649.80**	**0.61**	**0.32**	**25.02**	**2.19**	**7.62**	**86.16**	
	stdev			*0.41*	*30.03*	*0.03*	*0.02*	*12.73*	*1.12*	*3.14*	*91.02*	

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B 1. Environmental Monitoring Field Data (continued)

Station	Date	Well Depth	Time	Water T	COND	COND	Salinity	DO %SAT	DO	PH	ORP	PH
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
M1	01/14/09	2.52	13:44	21.88	959	0.897	0.47	7.2	0.63	7.11	158.9	
M1	03/26/09	2.50										
M1	05/11/09	1.41	12:34	21.52	827	0.773	0.41	5.6	0.49	3.94	43.5	
M1	06/04/09	1.97	14:54	21.16	839	0.778	0.41	2.3	0.21	7.33	13.7	7.1
M1	09/10/09	2.31	12:47	22.33	748	0.71	0.37	2.9	0.25	12.6	18.6	7.1
	average	**n=4**		**21.72**	**843.25**	**0.79**	**0.42**	**4.50**	**0.40**	**7.75**	**58.68**	
	stdev			*0.50*	*87.09*	*0.08*	*0.04*	*2.30*	*0.20*	*3.59*	*68.08*	
M2	01/14/09	2.04	13:12	19.64	719	0.645	0.35	18.0	1.64	7.09	165.7	
M2	03/26/09	2.04										
M2	05/11/09	0.93	12:04	19.95	492	0.445	0.24	5.4	0.49	3.98	23.1	
M2	06/04/09	1.45	14:31	21.04	616	0.569	0.3	3.3	0.29	7.48	10.3	7.1
M2	09/10/09	1.84	12:20	23.85	536	0.524	0.26	4.1	0.34	12.43	-20.9	7.1
	average	**n=4**		**21.12**	**590.75**	**0.55**	**0.29**	**7.70**	**0.69**	**7.75**	**44.55**	
	stdev			*1.92*	*99.72*	*0.08*	*0.05*	*6.92*	*0.64*	*3.49*	*82.85*	
M3	01/14/09	1.70	12:16	20.45	763	0.697	0.37	7.4	0.66	7.20	178.6	
M3	03/26/09	1.69										
M3	05/11/09	0.62	10:55	19:55	619	0.554	0.3	6.5	0.6	3.97	43.6	
M3	06/04/09	1.12	12:28	20.03	663	0.600	0.32	4.0	0.36	7.35	10.2	7.2
M3	09/10/09	1.495	11:12	22.31	611	0.579	0.3	7.0	0.6	12.51	-21.2	7.1
	average	**n=4**		**15.90**	**664.00**	**0.61**	**0.32**	**6.23**	**0.56**	**7.76**	**52.80**	
	stdev			*10.10*	*69.85*	*0.06*	*0.03*	*1.53*	*0.13*	*3.53*	*87.94*	

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B 1. Environmental Monitoring Field Data (continued)

Station	**Date**	**Well Depth**	**Time**	**Water T**	**COND**	**COND**	**Salinity**	**DO %SAT**	**DO**	**PH**	**ORP**	**PH**
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
M5	01/14/09	2.00	13:00	21.36	886	0.824	0.44	8.0	0.71	7.10	163.8	
M5	03/26/09	1.98										
M5	05/11/09	0.91	11:54	20.64	748	0.686	0.37	4.2	0.38	3.93	43.0	
M5	06/04/09	1.39	14:21	20.59	745	0.682	0.36	4.9	0.44	7.76	14.0	7.2
M5	09/10/09	1.79	11:59	21.45	750	0.699	0.37	2.8	0.25	12.66	20.2	7.1
	average	**n=4**		**21.01**	**782.25**	**0.72**	**0.39**	**4.98**	**0.45**	**7.86**	**60.25**	
	stdev			*0.46*	*69.20*	*0.07*	*0.04*	*2.20*	*0.19*	*3.61*	*70.15*	
M6	01/14/09	1.44	12:32	20.93	869	0.801	0.43	5.6	0.51	7.15	172.3	
M6	03/26/09	1.94										
M6	05/11/09	0.41	11:20	20.49	805	0.73	0.4	2	0.17	3.86	45.7	
M6	06/04/09	0.82	12:35	20.39	778	0.710	0.38	3.7	0.33	7.26	11.6	7.2
M6	09/10/09	1.25	11:31	21.36	775	0.721	0.38	5.3	0.46	12.62	20.9	7.0
	average	**n=45**		**20.79**	**806.75**	**0.74**	**0.40**	**4.15**	**0.37**	**7.72**	**62.63**	
	stdev			*0.45*	*43.64*	*0.04*	*0.02*	*1.66*	*0.15*	*3.63*	*74.52*	
M7	01/14/09	1.63	12:46	21.36	894	0.832	0.44	7.1	0.63	7.12	165.8	
M7	03/26/09	1.61										
M7	05/11/09	0.57	11:37	20.32	810	0.738	0.4	2.7	0.24	3.80	43.4	
M7	06/04/09	1.03	12:43	20.57	744	0.681	0.36	4.3	0.37	7.33	11.5	7.2
M7	09/10/09	1.415	11:44	24.4	773	0.72	0.38	4.3	0.37	12.63	21.4	7.1
	average	**n=4**		**21.66**	**805.25**	**0.74**	**0.40**	**4.60**	**0.40**	**7.72**	**60.53**	
	stdev			*1.88*	*65.04*	*0.06*	*0.03*	*1.83*	*0.16*	*3.65*	*71.44*	

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B 1. Environmental Monitoring Field Data (continued)

Station	Date	Well Depth	Time	Water T	COND	COND	Salinity	DO %SAT	DO	PH	ORP	PH
		FSU	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*YSI*	*Probe*
		(m)		Celsius	µS/cm	mS/cm	ppt	%	mg/L	units	mg/L	units
M8	01/14/09	1.98	13:28	21.02	715	0.660	0.35	5.9	0.53	7.17	159.6	
M8	03/26/09	1.96										
M8	05/11/09	0.87	12:14	19.89	667	0.602	0.33	4.3	0.39	4.00	33.8	
M8	06/04/09	1.38	14:43	20.24	638	0.580	0.32	2.5	0.23	7.47	13.3	7.2
M8	09/10/09	1.77	12:33	21.82	631	0.592	0.31	2.6	0.23	12.66	16.5	7.1
	average	**n=4**		**20.74**	**662.75**	**0.61**	**0.33**	**3.83**	**0.35**	**7.83**	**55.80**	
	stdev			*0.86*	*38.16*	*0.04*	*0.02*	*1.61*	*0.14*	*3.59*	*69.78*	
M9	01/14/09	1.84	11:50	20.67	689	0.633	0.34	11.3	1.02	7.39	180.7	
M9	03/26/09	1.82										
M9	05/11/09	0.74	10:44	19.65	562	0.505	0.27	6.9	0.63	4.12	42.6	
M9	06/04/09	1.24	12:11	20.22	566	0.515	0.27	4.0	0.36	7.46	9.9	7.1
M9	09/10/09	1.62	10:49	21.63	588	0.551	0.29	4.4	0.39	12.65	15.6	7.2
	average	**n=4**		**20.54**	**601.25**	**0.55**	**0.29**	**6.65**	**0.60**	**7.91**	**62.19**	
	stdev			*0.84*	*59.61*	*0.06*	*0.03*	*3.36*	*0.30*	*3.53*	*80.28*	

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B 2. Environmental Monitoring Nutrient Data

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
CAS	01/14/09	12:14	1	0	0.041	0.310	0.27	0.120	0.448	0.76	0.01
CAS	03/26/09	13:31	1	0	0.131	0.139	0.01	0.012	0.172	0.31	0.01
CAS	05/11/09	12:35	1	0	0.042	0.155	0.11	0.053	0.073	0.23	0.32
CAS	06/04/09	11:00	1	0	0.052	0.476	0.42	0.407	0.832	1.31	0.10
	average	**n=4**			**0.067**	**0.270**	**0.20**	**0.148**	**0.381**	**0.65**	**0.11**
	stdev				*0.043*	*0.157*	*0.18*	*0.178*	*0.340*	*0.50*	*0.15*
SRWMD #4	01/14/09	12:56	1	0	0.010	0.226	0.22	0.123	0.088	0.31	0.01
SRWMD #4	03/26/09	13:12	1	4	0.019	0.863	0.84	0.014	0.130	0.99	0.01
SRWMD #4	05/11/09	12:59	1	0	0.009	0.020	0.01	0.045	0.095	0.11	0.27
SRWMD #4	06/04/09	11:30	1	0	0.033	1.032	1.00	0.466	0.655	1.69	0.29
	average	**n=4**			**0.018**	**0.535**	**0.52**	**0.162**	**0.242**	**0.78**	**0.14**
	stdev				*0.011*	*0.488*	*0.48*	*0.208*	*0.276*	*0.71*	*0.15*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
S1	01/14/09	9:44	1	7	0.001	6.670	6.67	0.134	0.096	6.77	1.32
S1	03/27/09	14:20	1	1	0.006	1.504	1.50	0.006	0.048	1.55	0.39
S1	03/27/09	14:20	F2	1	0.006	1.562	1.56	0.006	0.053	1.61	0.39
S1	03/27/09	14:20	Ave	1	0.006	1.533	1.53	0.006	0.050	1.58	0.39
S1	05/11/09	16:10	1	0	0.005	0.575	0.57	0.041	0.072	0.65	0.57
S1	05/11/09	16:10	F2	0	0.006	0.453	0.45	0.040	0.069	0.52	0.55
S1	05/11/09	16:10	Ave	0	0.006	0.514	0.51	0.041	0.070	0.58	0.56
S1	06/04/09	11:10	1	0	0.133	4.841	4.71	0.264	0.565	5.41	0.78
S1	09/10/09	14:44	1		0.001	7.165	7.164	0.093	0.239	7.40	0.040
S1	09/10/09	14:44	F2		0.002	6.920	6.918	0.146	0.172	7.09	0.051
S1	09/10/09	14:44	Ave		0.002	7.043	7.04	0.120	0.206	7.25	0.05
	Average	**n=5**			**0.03**	**4.12**	**4.09**	**0.11**	**0.20**	**4.32**	**0.62**
	St Dev				*0.06*	*2.97*	*2.96*	*0.10*	*0.21*	*3.05*	*0.47*
S2	01/14/09	10:05		0	0.000	1.713	1.71	0.132	0.081	1.79	0.05
S2	03/27/09	12:15		18	0.009	0.104	0.10	0.008	0.169	0.27	0.07
S2	05/11/09	14:20		25	0.000	0.085	0.08	0.047	0.061	0.15	0.06
S2	06/04/09	10:14		0	0.010	0.245	0.23	0.335	0.445	0.69	0.02
S2	09/10/09	13:15			0.000	1.413	1.414	0.162	0.226	1.639	0.352
	Average	**n=5**			**0.004**	**0.537**	**0.53**	**0.131**	**0.189**	**0.73**	**0.05**
	St Dev				*0.005*	*0.788*	*0.79*	*0.146*	*0.177*	*0.75*	*0.02*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
C3A	01/14/09	10:55	1	8	0.000	0.963	0.96	0.108	0.072	1.04	0.01
C3A	03/27/09	13:30	1	0	0.008	0.649	0.64	0.007	0.079	0.73	0.05
C3A	05/11/09	15:25	1	0	0.004	0.109	0.10	0.041	0.110	0.22	0.03
C3A	06/04/09	10:46	1	4	0.004	0.208	0.20	0.405	0.367	0.58	0.02
C3A	09/10/09	13:55	1		0.011	0.822	0.811	0.092	0.145	0.967	0.042
	average	**n=5**			**0.006**	**0.550**	**0.545**	**0.130**	**0.155**	**0.705**	**0.032**
	stdev				*0.004*	*0.376*	*0.376*	*0.159*	*0.122*	*0.328*	*0.016*
C4	01/14/09	11:12	1	0	0.000	1.180	1.18	0.109	0.084	1.26	0.02
C4	03/27/09	12:45	1	7	0.004	1.156	1.15	0.007	0.120	1.28	0.05
C4	05/11/09	15:05	1	0	0.001	0.281	0.28	0.044	0.113	0.39	0.05
C4	06/04/09	10:34	1	76	0.008	0.467	0.46	0.304	0.450	0.92	0.08
C4	09/10/09	13:34	1		0.000	1.724	1.725	0.089	0.166	1.890	0.058
	average	**n=5**			**0.003**	**0.961**	**0.959**	**0.111**	**0.186**	**1.148**	**0.050**
	stdev				*0.003*	*0.586*	*0.588*	*0.115*	*0.150*	*0.548*	*0.023*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
C5	01/14/09	10:35	1	120	0.026	5.984	5.96	0.118	0.220	6.20	0.03
C5	03/27/09	13:50	1	10	0.035	1.019	0.98	0.008	0.133	1.15	0.03
C5	05/11/09	15:50	1	0	0.003	2.064	2.06	0.040	0.081	2.15	0.05
C5	06/04/09	11:00	1	0	0.021	2.982	2.96	0.585	0.485	3.47	0.03
C5	09/10/09	14:15	1		0.013	7.019	7.006	0.114	0.241	7.260	0.037
	average	**n=5**			**0.02**	**3.81**	**3.79**	**0.17**	**0.23**	**4.05**	**0.04**
	stdev				*0.01*	*2.58*	*2.58*	*0.24*	*0.16*	*2.61*	*0.01*
M1	01/14/09	13:44	1	10	0.011	17.155	17.14	0.483	0.232	17.39	0.19
M1	03/26/09	13:40	1	7 *	0.006	13.243	13.24	0.116	0.361	13.60	0.13
M1	03/26/09	13:42	F2	8 *	0.008	11.372	11.36	0.117	0.348	11.72	0.14
M1	03/26/09	13:42	Ave	8	0.007	12.307	12.30	0.117	0.355	12.66	0.13
M1	05/11/09	12:38	1	0	0.008	2.698	2.69	0.050	0.120	2.82	0.39
M1	06/04/09	14:56	1	0	0.005	6.083	6.08	0.044	0.989	7.07	0.20
M1	09/10/09	12:45	1		0.005	13.922	13.918	0.085	0.355	14.278	0.326
	Average	**n=5**			**0.01**	**10.43**	**10.43**	**0.16**	**0.41**	**10.84**	**0.25**
	St Dev				*0.00*	*5.91*	*5.91*	*0.19*	*0.34*	*5.84*	*0.11*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
M2	01/14/09	13:12	1	67	0.005	8.157	8.15	0.127	0.136	8.29	0.37
M2	01/14/09	13:12	F2	67	0.005	7.674	7.67	0.128	0.155	7.83	0.33
M2	01/14/09	13:12	Ave	67	0.005	7.915	7.91	0.127	0.145	8.06	0.35
M2	03/26/09	12:45	1	32	0.013	4.846	4.83	0.016	0.161	5.01	0.34
M2	05/11/09	12:05	1	8	0.005	0.514	0.51	0.051	0.149	0.66	0.38
M2	06/04/09	14:32	1	0	0.004	0.184	0.18	0.042	0.665	0.85	0.29
M2	09/10/09	12:15	1		0.000	0.099	0.099	0.090	0.321	0.420	1.203
M2	09/10/09	12:15	F2		0.001	0.083	0.083	0.087	0.444	0.527	1.235
M2	09/10/09	12:15	Ave		0.000	0.091	0.09	0.088	0.383	0.47	1.22
	Average	**n=5**			**0.005**	**2.710**	**2.705**	**0.065**	**0.301**	**3.011**	**0.517**
	St Dev				*0.005*	*3.526*	*3.523*	*0.043*	*0.227*	*3.395*	*0.394*
M3	01/14/09	12:16	1	0	0.023	3.899	3.88	0.125	0.237	4.14	0.38
M3	03/26/09	11:30	1	20	0.027	1.148	1.12	0.052	0.251	1.40	0.04
M3	05/11/09	11:00	1	5	0.002	0.266	0.26	0.042	0.109	0.38	0.25
M3	06/04/09	12:30	1	4	0.178	13.957	13.78	0.544	0.524	14.48	0.20
M3	09/10/09	11:10	1		0.001	0.032	0.032	0.103	0.295	0.328	0.400
	Average	**n=5**			**0.046**	**3.861**	**3.814**	**0.173**	**0.283**	**4.144**	**0.253**
	St Dev				*0.075*	*5.850*	*5.776*	*0.210*	*0.151*	*5.982*	*0.147*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
M5	01/14/09	13:00	1	0	0.006	11.474	11.47	0.124	0.127	11.60	0.42
M5	03/26/09	12:30	1	7	0.055	1.424	1.37	0.069	0.310	1.73	0.27
M5	05/11/09	11:55	1	0	0.003	3.787	3.78	0.051	0.138	3.92	0.18
M5	06/04/09	14:22	1	4	0.016	2.943	2.93	0.068	0.751	3.69	0.15
M5	09/10/09	12:00	1		0.023	6.815	6.792	0.082	0.311	7.126	0.195
M5	09/10/09	12:00	F2		0.023	6.917	6.894	0.080	0.338	7.255	0.162
M5	09/10/09	12:00	Ave		0.023	6.866	6.84	0.081	0.324	7.19	0.18
	Average	**n=5**			**0.021**	**5.299**	**5.278**	**0.079**	**0.330**	**5.629**	**0.237**
	St Dev				*0.021*	*3.982*	*3.994*	*0.028*	*0.253*	*3.870*	*0.110*
M6	01/14/09	12:32	1	0	0.081	5.005	4.92	0.125	0.333	5.34	0.09
M6	03/26/09	11:50	1	10	0.093	2.062	1.97	0.037	0.229	2.29	0.03
M6	05/11/09	12:50	1	5	0.064	2.864	2.80	0.051	0.112	2.98	0.58
M6	06/04/09	12:36	1	32	2.626	1.415	0.00	0.359	0.686	2.10	0.06
M6	09/10/09	11:30	1		0.099	2.229	2.130	0.104	0.288	2.517	0.106
	Average	**n=5**			**0.593**	**2.715**	**2.365**	**0.135**	**0.330**	**3.045**	**0.171**
	St Dev				*1.137*	*1.380*	*1.771*	*0.130*	*0.216*	*1.323*	*0.229*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
M7	01/14/09	12:46	1	0	0.022	9.593	9.57	0.124	0.161	9.75	0.48
M7	03/26/09	12:15	1	29	0.063	5.151	5.09	0.037	0.229	5.38	0.09
M7	05/11/09	11:40	1	3	0.011	4.284	4.27	0.052	0.140	4.42	0.35
M7	06/04/09	12:45	1	14	0.202	19.425	19.22	0.373	0.562	19.99	0.22
M7	09/10/09	11:45	1		0.097	2.585	2.489	0.104	0.323	2.908	0.262
	Average	**n=5**			**0.079**	**8.208**	**8.129**	**0.138**	**0.283**	**8.491**	**0.281**
	St Dev				*0.077*	*6.784*	*6.728*	*0.136*	*0.172*	*6.913*	*0.145*
M8	01/14/09	13:28	1	0	0.020	0.786	0.77	0.126	0.077	0.86	0.31
M8	03/26/09	13:20	1	2 *	0.026	10.284	10.26	0.015	0.157	10.44	0.09
M8	05/11/09	12:15	1	0	0.003	4.351	4.35	0.053	0.142	4.49	0.24
M8	06/04/09	14:44	1	0	0.002	0.102	0.10	0.036	0.705	0.81	0.17
M8	09/10/09	12:32	1		0.000	0.032	0.033	0.112	0.331	0.364	1.299
	Average	**n=5**			**0.010**	**3.111**	**3.101**	**0.069**	**0.282**	**3.393**	**0.423**
	St Dev				*0.012*	*4.386*	*4.378*	*0.048*	*0.254*	*4.277*	*0.497*

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B 2. Environmental Monitoring Nutrient Data (continued)

				F Coli	**Nitrite**	**Nitrate+Nitrite**	**Nitrate**	**Ammonia**	**TKN**	**TN**	**Total P**
				SM	EPA	EPA	calc	EPA	EPA	calc	EPA
				9222D	354.1	353.3		350.3	351.4		365.20
			MDL	*1*	*0.003*	*0.006*	*0.01*	*0.022*	*0.056*	*0.06*	*0.00*
			PQL	*4*	*0.012*	*0.024*	*0.02*	*0.088*	*0.224*	*0.22*	*0.02*
Station	**Date**	**Time**	**Rep**	**Cts/100ml**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
M9	01/14/09	11:50	1	13	0.009	1.370	1.36	0.110	0.127	1.50	0.08
M9	03/26/09	10:55	1	96	0.048	5.332	5.28	0.014	0.216	5.55	0.12
M9	03/26/09	10:55	F2	90	0.049	5.325	5.28	0.014	0.209	5.53	0.12
M9	03/26/09	10:55	Ave	93	0.049	5.329	5.28	0.014	0.213	5.54	0.12
M9	05/11/09	10:50	1	0	0.002	0.111	0.11	0.035	0.151	0.26	0.05
M9	06/04/09	12:15	1	2	0.017	0.239	0.22	0.419	0.562	0.80	0.16
M9	06/04/09	12:15	F2	2	0.019	0.297	0.28	0.401	0.471	0.77	0.06
M9	06/04/09	12:15	Ave	2	0.018	0.268	0.25	0.410	0.517	0.78	0.11
M9	09/10/09	10:50	1		0.000	0.032	0.033	0.094	0.483	0.515	0.325
	Average	**n=5**			**0.016**	**1.422**	**1.406**	**0.133**	**0.298**	**1.720**	**0.137**
	St Dev				*0.020*	*2.250*	*2.231*	*0.160*	*0.187*	*2.185*	*0.109*

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Appendix C Water meter data

Date and time	Hickory meter	gal/day	Date/Time	Magnolia meter	gal/day	
12/29/08 12:00	1013882		12/29/08 12:00	763991		Park staff, no time
1/5/09 12:00	1021590	1101	1/5/09 12:00	768874	698	Park staff, no time
1/12/09 12:00	1025574	569	1/12/09 12:00	771642	395	Park staff, no time
1/19/09 12:00	1028820	464	1/19/09 12:00	773974	333	Park staff, no time
1/26/09 12:00	1031736	417	1/26/09 12:00	777227	465	Park staff, no time
January 2009		638			473	
2/2/09 12:00	1036175		2/2/09 12:00	780145		Park staff, no time
2/9/09 12:00	1040051	554	2/9/09 12:00	783547	486	Park staff, no time
2/16/09 12:00	1044820	681	2/16/09 12:00	786390	406	Park staff, no time
2/23/09 12:00	1049580	680	2/23/09 12:00	789736	478	Park staff, no time
February 2009		638			457	
3/2/09 12:00	1053595		3/2/09 12:00	793866		Park staff, no time
3/9/09 12:00	1059670	868	3/9/09 12:00	799027	737	Park staff, no time
3/16/09 12:00	1066030	909	3/16/09 12:00	803084	580	Park staff, no time
3/23/09 12:00	1072963	990	3/23/09 12:00	807278	599	Park staff, no time
3/27/09 14:55	1077512	1104	3/26/09 10:00	808471	409	FSU
3/30/09 12:00	1079730	771	3/30/09 12:00	810920	600	Park staff, no time
March 2009		933			609	

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Appendix C Water meter data
(continued)

Date and time	Hickory meter	gal/day	Date/Time	Magnolia meter	gal/day	
4/6/09 12:00	1088049		4/6/09 12:00	817026		Park staff, no time
4/14/09 12:00	1095200	894	4/14/09 12:00	823783	845	Park staff, no time
4/22/09 12:00	1095200	0	4/22/09 12:00	823900	15	Park staff, no time
April 2009		447			430	
5/4/09 12:00	1097500		5/4/09 12:00	826000		Park staff, no time
5/11/09 12:00	1102320	689	5/11/09 13:20	834365	1186	FSU
5/11/09 17:10	1102463	664	5/11/09 14:00	834440	2700	Park staff, no time
5/25/09 12:00	1111500	656	5/25/09 12:00	839262	346	Park staff, no time
5/31/09 16:30	1114825	537	5/31/09 18:30	841188	307	FDOH
5/31/09 19:30	1114900	600	5/31/09 19:06	841213	1000	FDOH
5/31/09 22:30	1115085	1480	5/31/09 23:30	842078	4718	FDOH
May 2009		641			585	
6/1/09 12:00	1115200		6/1/09 12:00	842200		Park staff, no time
6/4/09 15:28	1116695	475	6/4/09 16:11	842781	183	FSU
6/8/09 12:00	1119500	728	6/8/09 12:00	844820	533	Park staff, no time
6/15/09 12:00	1125600	871	6/15/09 12:00	849130	616	Park staff, no time
6/22/09 12:00	1133100	1071	6/22/09 12:00	854000	696	Park staff, no time
June 2009		852			562	
9/10/09 14:55	1208134	937	9/10/09 15:50	899203	564	FSU
Total cumulative		**761**			**530**	

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Appendix C Water meter data during performance assessment.

Performance Assessment

Date and time	Hickory meter	gal/hr	Date / time	Magnolia meter	gal/hr	
5/31/09 16:30	1114825		5/31/09 18:30	841188		FDOH
5/31/09 19:30	1114900	25	5/31/09 19:06	841213	42	FDOH
5/31/09 22:30	1115085	62	5/31/09 23:30	842078	197	FDOH
6/1/09 5:10	1115188	15	6/1/09 5:43	842085	1	FSU
6/1/09 10:46	1115195	1	6/1/09 11:47	842160	12	FSU
6/1/09 11:00	1115202	30	6/1/09 12:07	842160	0	FSU
6/1/09 12:30	1115242	27	6/1/09 15:02	842176	5	FSU
6/1/09 17:01	1115293	11	6/1/09 15:18	842199	86	FSU
6/1/09 17:11	1115296	18	6/1/09 18:00	842206	3	FSU
6/1/09 23:04	1115517	38	6/1/09 18:10	842206	0	FSU
6/1/09 23:16	1115530	65	6/1/09 23:46	842288	15	FSU
6/2/09 5:05	1115616	15	6/1/09 23:59	842288	0	FSU
6/2/09 7:45	1115690	28	6/2/09 8:18	842305	2	FSU
6/2/09 7:55	1115692	12	6/2/09 8:21	842305	0	FSU
6/2/09 11:02	1115747	18	6/2/09 8:33	842320	75	FSU
6/2/09 11:15	1115754	32	6/2/09 15:11	842372	8	FSU
6/2/09 17:02	1115828	13	6/2/09 15:20	842379	47	FSU
6/2/09 17:11	1115830	13	6/2/09 16:10	842382	4	FSU
6/2/09 23:01	1116012	31	6/2/09 17:58	842398	9	FSU
6/2/09 23:12	1116020	44	6/2/09 18:13	842398	0	FSU
6/3/09 5:03	1116053	6	6/3/09 5:32	842521	11	FSU
6/3/09 5:13	1116053	0	6/3/09 15:38	842566	4	FSU
6/3/09 11:03	1116257	35	6/3/09 15:49	842566	0	FSU
6/3/09 11:16	1116258	5	6/3/08 18:10	842608	0	FSU
6/3/09 16:26	1116328	14	6/3/09 18:20	842624	0	FSU
6/3/09 16:42	1116329	4	6/3/09 18:29	842632	53	FSU
6/3/09 17:01	1116335	19	6/4/09 5:38	842711	7	FSU
6/3/09 17:09	1116335	0	6/4/09 5:50	842711	0	FSU
6/3/09 23:02	1116453	20	6/4/09 11:52	842766	9	FSU
6/3/09 23:10	1116453	0	6/4/09 12:02	842766	0	FSU
6/4/09 5:05	1116459	1	6/4/09 15:56	842781	4	FSU
6/4/09 5:13	1116459	0	6/4/09 16:11	842781	0	FSU
6/4/09 11:22	1116649	31				FSU
6/4/09 11:29	1116658	77				FSU
6/4/09 15:28	1116695	9				FSU
Performance	**gal/hr**	**20**			**17**	
Performance	**gal/day**	**473**			**408**	

DRAFT Dec 2009

DRAFT Dec 2009

Research Review and Advisory Committee for the Bureau of Onsite Sewage Programs

Approved Minutes of the Meeting held at the Southwood Office Complex, Tallahassee, FL
December 16, 2009
Approved by the RRAC March 23, 2010

In attendance:

- **Committee Membership and Alternates**:
  - **In person:** Anthony Gaudio (vice chairman, member, Septic Tank Industry); Bill Melton (member, Consumer); Jim Oskowis (member, Local Government)
  - **Via teleconference:** David Carter (chairman, member, Home Building Industry); Kim Dove (member, Division of Environmental Health); John Dryden (alternate, State University System); Eanix Poole (alternate, Consumer); Patti Sanzone (member, Environmental Interest Group); John Schert (member, State University System); Vince Seibold (alternate, Local Government); Clay Tappan (member, Professional Engineer); and Pam Tucker (member, Real Estate Profession)
- **Not represented**: Restaurant Industry
- **Visitors**:
  - In person: Bruce French (York)
  - Via teleconference: Damann Anderson (Hazen and Sawyer); Quentin (Bob) Beitel (Markham Woods Association); Fred Brummer (Orange County Commissioner); Josefin Edeback (Hazen and Sawyer); Keith Hetrick (Florida Home Builders Association); Bruce Higginbotham; Dick Otis (Otis Environmental); Daniel Smith (Applied Environmental Technologies)
- **Department of Health (DOH), Bureau of Onsite Sewage Programs**:
  - Paul Booher; Kara Loewe; Debra Roberts; Eberhard Roeder; and Elke Ursin

1. **Introductions:** Nine out of ten groups were present, representing a quorum. Chairman Carter called the meeting to order at 9:07 a.m. Introductions were made and some housekeeping issues were discussed.

2. **Review of Previous Meeting Minutes**: The committee recommended that the approval of the minutes from the September 10th meeting be postponed until the next RRAC meeting due to the delay in getting the minutes out to the committee members. This will be included on the agenda for the next meeting.

3. **Department's Interim Report on Nitrogen Reduction Strategies Study: Review, Comment, and Next Steps -** David Carter introduced the report and stated that the report appears to be a summary of what has been done to date. The committee is to consider the report and make comments now prior to it going to the legislature. Eberhard Roeder asked for specific feedback on the following points:
   - Does the committee want recommendations in the report now or in final report that is due in March?
   - Does the committee want to add a discussion of technologies currently available in Florida in comparison to prioritization results?

- Add background on evidence requirements to become an “innovative system” in Florida, and innovative system permitting?

David Carter asked whether the ranking discussed during the prioritization workshop with Hazen and Sawyer would need to be changed based on the interim report and Eberhard Roeder stated that the original report would not need to be changed. RRAC developed the prioritization scheme and then the contract provider put the available information into the scheme to calculate the results. Damann Anderson stated that the ranking workshop was to look at available technologies and how to rank them for testing. The ranking report is not a report for the public to use to decide what technologies to use now, it’s to help with the testing which, when completed, will hopefully provide information that the public can use. Anthony Gaudio stated that the ranking process was designed by the contractor. He noted at that meeting that he thought the process was flawed and the results appeared to be skewed. He indicated he did not want to participate in the vote because he did not agree with the weighting of the items, particularly the stage of technical development which he thought was one of the more important issues had the lowest weighting. Eanix Poole suggested rewording the report so that it is not so heavy on the rankings and not so detailed. Several people were in agreement that the report could be confusing with regards to the rankings. It could be misconstrued that the rankings are for which systems are the best systems rather than ranking for testing. The interim report will be revised so that this is clearer.

There was much discussion on the report and several suggestions were made on how to wordsmith the document. Eberhard Roeder edited the report live on the WebEx web conference.

There was a discussion on the process forward for how to get the report edited and approved by the RRAC, and the following motion was passed:

> **Anthony Gaudio made a motion, seconded by Bill Melton, for staff to take the comments made during the meeting, rewrite the Executive Summary and other parts of the Interim Report, email the revised document to the RRAC for review and comment, then Department staff will submit the report as per the appropriation. All were in favor with none opposed and the motion passed unanimously.**

Jim Oskowis stated that the report needs to be stronger in the recommendations and conclusions to show that the project is on schedule and on budget. He stated that it is important to mention the nationwide focus to reduce nutrients in wastewater and the environment and to reiterate the purpose of the study. Keith Hetrick mentioned that the report should mention that this is one project that is looking at developing technologies to come up with solutions. The report will be updated to include the most recent status of the project. There was a discussion on the tanks located at the test facility and the repairs and testing that will be done to assure that the tanks are not taking in the surrounding groundwater. There was also a discussion on the importance of management and enforcement and how the county health departments may not currently have the capability to adequately manage these more complex systems within the current existing framework (not enough manpower or funding). Pam Tucker stated that the Wekiva seasonal variability study needs to be more prominent in the report. Patti Sanzone made several comments on the report and will submit written comments to the department after the meeting. Quentin Beitel stated that it is important to note that all of this stems from the Wekiva issue. There was a discussion on the recommendations and whether they should be included in this

interim report or wait until the final report. There was a general consensus from the RRAC that the recommendations should be delayed and considered for the final report due in May. RRAC directed staff to check with the DOH legal staff to see if recommendations are required in the interim report per the appropriation language. Eberhard Roeder stated that the contract amendment will include a task for the provider to draft the final report due in May and then RRAC and DOH can review prior to routing.

4. **Nitrogen Reduction Strategies Study: Comment on Deliverables and Next Steps:** An overview was given outlining what has happened since the last meeting. Numerous reports have been submitted and reviewed by RRAC and DOH:
   - Passive nitrogen removal study phase II quality assurance project plan
   - Classification, ranking, and prioritization of technologies
   - Literature review of nitrogen reduction by soils and shallow groundwater
   - Nitrogen reduction by soils and shallow groundwater quality assurance project plan
   - Test Center initial design
   - Literature review on nitrogen fate and transport modeling

   The draft contract amendment, as recommended at July meeting, is currently being reviewed by provider. This amendment will update payment schedules, costs, and tasks associated with the project now that some of the finer details have been fleshed out. Eberhard Roeder provided a summary of the QAPP for Task C and there was some discussion on some of the details in this report. The 50% design documents and the literature review for Task C were also discussed. Pam Tucker stated that it is important to make sure that the draft interim report and the Task C QAPP are consistent.

5. **Section 319 Study Update: Comment on Proposed Sampling Plan:** For the database task, data has been gathered from the state database (from two sources: construction permits and operating permits), any county specific databases, and from Carmody. The data fields and database structure have been discussed and sketched. There was a discussion on the review of data from operating permits that has been gathered from the various sources and how there is limited overlap of the data. The Carmody system can contain records for systems that are also found in the state database, and for many systems in the state database there would be both a construction permit as well as an operating permit, so there is the potential for duplicate records. Much time has been spent trying to locate and eliminate duplicate records in this new database so that there is one comprehensive list of all advanced systems in the state for the purposes of pulling addresses to send the survey and also to locate properties for sampling. The issues with gathering this data show some of the management issues as they relate to data management.

   The Florida State University Survey Research Laboratory was selected to perform the user-group perceptions survey task, and they have completed development of the surveys and they will be sent out after the holidays.

   A revised draft of the Quality Assurance Project Plan for the sampling task has been submitted to the RRAC, and comments are due in the near future.

   There was a discussion on what criteria should be used to select systems for sampling. Should there be a purely random sample taken or should the criteria be stratified? If it is stratified, what criteria should be used (i.e. type of permit (ATU vs. PBTS, commercial vs. residential), by counties (counties with many systems vs. counties with few systems), treatment technology /

manufacturer, maintenance history)? Bill Melton stated that his understanding is that the intent of the sampling is not to look at how extended aeration compares with fixed media but instead to look at how systems are operating throughout the state. Eb Roeder agreed with this: that this project is looking both at how systems operate (for example: whether they meet the permitted constituent levels) as well as how the management is working (for example: whether a well maintained system works better than a poorly maintained system). There was a discussion on whether to sample those systems that are turned off or in some way obviously not working as designed. Several RRAC members suggested just noting those systems when performing the site inspection but not sampling them and still others felt that gathering the sample results would be good information to have. After the discussion the RRAC recommended that the information should be noted and a percentage of those systems should be sampled but not all of them. It was recommended that staff members create a flowchart showing how to make the decision on which systems to sample. There was some discussion of selecting systems to allow distinction between treatment technologies, such as aeration approach. It was also recommended to get with the manufacturers on how to take grab samples and to include the maintenance entity and county health department when going out to sample the systems. Bruce French stated that there is a regulatory process for compliance enforcement and that the maintenance entity is to routinely provide a report to the department. Anthony Gaudio suggested first running some statistics on the overall sample population and then running a random sample and evaluating the results to eliminate some of the over or under represented systems. There were lots of pros and cons from the system selection strategies list that RRAC discussed, DOH will sift through the comments and send a strategy back to RRAC for comment.

6. **Manatee Springs Study: Comment on Final Report:** The original contracted sampling work has been completed. The final report on the entire project was submitted to EPA at the end of September. An additional sampling event occurred on September 10th during non-flood conditions. The final report that was sent to EPA has been amended with the new information and a draft of this report has been sent to the RRAC for review and comment. There are a couple of additional sections to the end of the Phase I report and some additions to the executive summary. The average septic tank effluent concentrations were about the same for total nitrogen. For both sampled sites there was about a 60-82% nitrogen removal. Eanix Poole asked whether the conclusions of this study were reliable and Eberhard Roeder stated that the groundwater data were more influenced by the flooding but that the effluent sampling showed a decline in nitrogen after the nitrogen reducing systems were installed. If the RRAC have any comments they would be appreciated so that they can be incorporated into the final report prior to sending to EPA.

7. **Updates on other projects:** [the following items were listed on the slide presentation but were not verbally discussed during the meeting]

    a. **Town of Suwannee Study** – At the last RRAC meeting the committee voted to renew the contract with the contract provider to replicate the sampling effort during November and December of 2009. This contract renewal was completed and the sampling began in November.

    b. **Monroe County Performance Based Treatment System Performance Assessment** – Quality control of existing data is ongoing. All sampling has been completed. A report summarizing this project is being written.

c. **Optical Wastewater Tracers Study**: The final report on this project was submitted to EPA at the end of October.

8. **Upcoming Projects** [the following item was listed on the slide presentation but was not verbally discussed during the meeting]

   a. **Columbia County Nitrogen Well Sampling Study**: The first step for this project is to obtain a purchase order with a lab that is able to do the sample analysis. Private labs will be contacted to see if they might be able to do the analysis. The Columbia County Health Department staff is interested in collecting the samples.

9. **Other Business** – Bill Melton mentioned that at the last RRAC meeting he had suggested that someone come to the next RRAC meeting to discuss getting information off the permitting database regarding alternative drainfield products. Kara Loewe stated that this will be addressed at the next meeting.

10. **Public Comment** - The public were allowed to comment throughout the meeting. There was no public comment.

11. **Next Meeting** – The next meeting will be scheduled for sometime in March. The meeting location has not been determined but may be at the Gulf Coast Research Facility and/or via teleconference. The focus of the next meeting will be to discuss the final report on the Nitrogen Reduction Strategies Study as well as discuss current and proposed research projects.

Bill Melton made a motion to adjourn, seconded by Pam Tucker, and the meeting adjourned at 2:04 p.m.

FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task A.15

Passive Nitrogen Removal Study II Quality Assurance Project Plan

Final Report

November 2009

4423-001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK A.15
FINAL REPORT

Passive Nitrogen Removal Study II
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

November 2009

Prepared by:

HAZEN AND SAWYER
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Applied Environmental Technology

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Section 1.0
Project Organization and Management

The Florida Department of Health has contracted to continue the study of passive nitrogen removal (PNRS II) under Task A of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS). PNRS II is a follow up to the previous experimental evaluations of passive nitrogen removal technologies conducted under Contract CORY (Passive Nitrogen Removal Study I). The Passive Nitrogen Removal Study II (PNRS II) will be conducted by Hazen and Sawyer and Applied Environmental Technology, who will perform overall project management, establish and conduct the pilot studies, and who will deliver samples for water quality analyses to an approved analytical laboratory. The contractors will review and interpret the resulting data, adjust the pilot testing program as warranted, and generate a summary report and recommendations. Prudent project management will help minimize changes, ensure project continuity, and avoid delays in the project schedule. This type of project is highly specialized, requiring unusual equipment and services. Therefore it is crucial that adequate project management be used to ensure the success of the project. Figure 1-1 depicts the organization chart for PNRS II.

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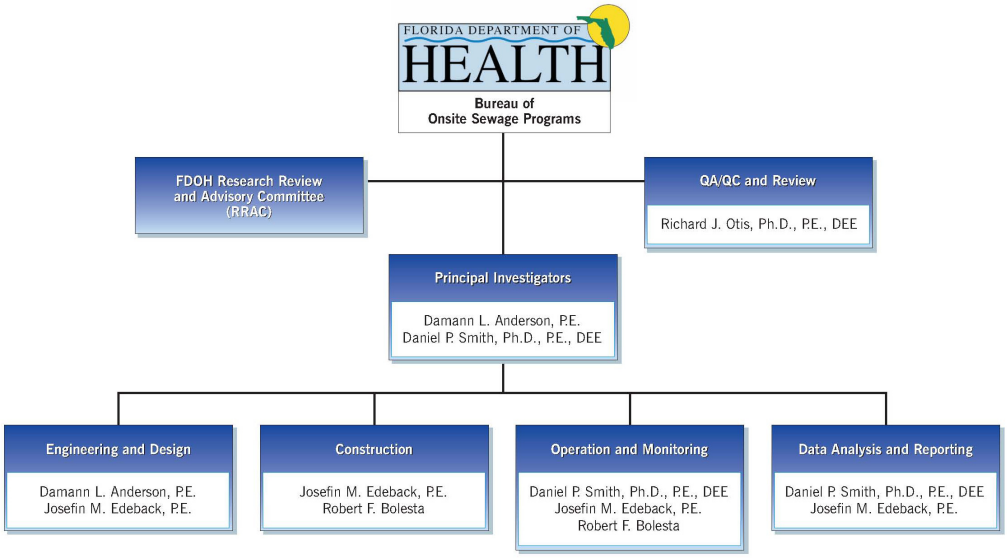

Figure 1-1: Organization Chart for PNRS II

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Section 2.0
Problem Definition and Background

2.1 Project Background

The Florida Department of Health (FDOH) has provided funding to evaluate methods that can be used to enhance nitrogen removal in onsite wastewater systems in a passive and cost effective manner. The Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) Passive Nitrogen Removal Study II (PNRS II) QAPP entails formulating a pilot testing plan to evaluate candidate technologies that can be used to remove nitrogen from septic tank effluent with more passive systems. The purpose of the PNRS II study is to extend and expand into field pilot testing the previous experimental studies of the two-stage biofiltration process that were conducted in PNRS I. PNRS II will perform field testing of passive nitrogen reduction treatment systems using a variety of candidate biofiltration media. Pilot test systems will consist of various configurations of in-tank biofilters and passive in-situ systems. The results of PNRS II may be used to develop and implement subsequent evaluations of full-scale systems that will be conducted under Task B of this project.

The *Florida Passive Nitrogen Removal Study Literature Review and Database* proposed the development of a two stage biofilter system for passive removal of total nitrogen from septic tank effluent (Smith et al., 2008). The two stage system consisted of an initial unsaturated media biofilter for ammonification and nitrification, followed in series by a saturated anoxic denitrification biofilter. The system would be deployed between the septic tank and the soil treatment unit (drainfield) or soil dispersal system of new or existing facilities. Nitrogen in septic tank effluent would be substantially removed before wastewater was directed to the soil for treatment or dispersal. Results from the previous experimental studies conducted in PNRS I provided the proof of concept of the two-stage passive nitrogen reduction system.

To perform PNRS II testing, it is desired to conduct studies in a manner that more closely resembles the functioning of actual onsite systems. Actual candidate media will be used, and placed in appropriate layers and depths distribution. Continuously operated biofilter operation will be employed, where microbial populations will establish their metabolic activities and perform desired biochemical transformations in response to conditions similar to an operating system. In addition, in-situ testing will be conducted using in-situ simulators consisting of subsurface drip irrigation application to the root zone of

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surface vegetation, followed by downward transport through a layer of filter sand and engineered media. The use of actual septic tank effluent (STE) as feed source is deemed preferable to use of a synthetic analog STE. This Quality Assurance Project Plan (QAPP) describes the methods and procedures that will be used to conduct the passive nitrogen removal evaluations.

2.2 Candidate Study Site

A candidate site, the University of Florida Gulf Coast Research and Education Center (GCREC), has been identified and arrangements are being sought for its use. The acceptability of the site has been established. The chosen site has a source of actual septic tank effluent or primary effluent, a power supply to pump STE to test biofilters, and power for operation of equipment. The site location is isolated from public access and would cause minimal disruption to any activity, and it has reasonable security. The site is located in Hillsborough County, Florida.

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Section 3.0
Project Description

3.1 Project Purpose

To evaluate candidate media and treatment processes for development of more passive nitrogen removal systems for onsite wastewater treatment.

3.2 Project Objectives

The objective is to establish pilot passive nitrogen removal systems to evaluate the effectiveness of various media and two-stage biofilter designs in removing total nitrogen from septic tank effluent. The pilot test systems will consist of various configurations of in-tank biofilters and passive in-situ systems. In-tank systems will primarily employ variants of the two-stage biofiltration concepts elucidated in PNRS I. In-situ technology evaluation will include a drip irrigation system for effluent dosing, with emitters located in shallow root zones.

In the two-stage biofilter process, a first stage unsaturated biofilter is followed in series by a second stage biofilter operated in a water saturated mode. Septic tank effluent will be applied to the top of the first stage media, resulting in a downward percolation of wastewater over and through the media biofilter bed. The unsaturated pore spaces in the first stage media will allow air to reach microorganisms attached to the media surfaces, enabling aerobic biochemical reactions to occur. The significant target reactions are aerobic heterotrophic oxidation (by microorganisms that oxidize organic material and reduce biochemical oxygen demand), hydrolysis and ammonification (releasing ammonia), and nitrification (biochemical conversion of ammonia to nitrate and nitrite). Of particular interest are the organic and ammonia nitrogen concentrations in first stage effluent, as well as nitrate and nitrite.

Effluent from the bottom of the first stage biofilter is passed through a saturated anoxic biofilter that contains a reactive media that supplies electron donor for denitrification (reduction of nitrate and nitrite to N_2 gas). The biofiltration systems will be operated over a twelve month period, if funding is available, and monitored for nitrogen species and other water quality parameters. Of particular interest are the concentrations of ammonia in first stage effluent and nitrate, nitrite and total nitrogen in the second stage effluent.

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The interaction of media with applied wastewater governs the treatment process. Key features affecting nitrogen removal performance include:

1. The effects of hydraulic and nitrogen loading rates, on average daily and per dose basis, on first stage effluent nitrogen concentrations.

2. The effects of first stage media on effluent nitrogen levels.

3. Alkalinity consumption in the first stage and its possible effects on nitrification.

4. The effects of hydraulic and nitrogen loading rates, on average daily basis, on second stage effluent nitrogen concentrations.

5. The effects of second stage media on effluent nitrogen levels.

6. Second stage effluent total nitrogen concentrations and speciation into organic, ammonia, and oxidized nitrogen forms.

7. Alkalinity consumption or restoration in the second stage and its possible effects on denitrification.

8. Use of first stage recycle.

3.3 Project Tasks and Timeline

Project tasks and preliminary timeline are shown in Table 3.1. The start dates and tasks are contingent upon Recommendations for Process Forward (FOSNRS Task A.14) and may be altered based on the results of Task A.14. The task descriptions provide a template by which the project team will conduct the PNRS II project. The nature of technology demonstration projects will necessitate system and testing modifications during the course of the study. It is important to recognize that operational adaptation is a central feature of pilot testing and process optimization. A typical example is a modification in operation as a result of assessment of performance data, where a higher loading rate is applied to a well functioning system to evaluate performance over a wider loading envelope. The QAPP establishes initial loading rates for PNRS II systems that may be adjusted as the study progresses, based on ongoing results and the professional judgment of the project team. A degree of discretion must be afforded to the project team to make modifications as warranted. Additionally, longer term operation of successful onsite treatment systems is warranted but dependent on future funding. All substantive modifications will be fully communicated to FDOH.

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Table 3.1
Project Tasks and Timeline

Task/Activity	Start	Projected Completion
Task 1 PNRS II infrastructure design	Week 1	Week 4
Task 2 Procurement of materials and media	Week 4	Week 8
Task 3 Construction of test facility and pilot systems	Week 6	Week 10
Task 4 Operation and monitoring of pilot systems	Week 12	Week 64
Task 5 Preparation of draft report	Week 68	Week 74
Task 6 Preparation of final report	Week 76	Week 80

Task 1: PNRS II Infrastructure Design

A final testing site will be established based on the acceptability of wastewater sources, use of the site for other FOSNRS work elements in Tasks B and C, and establishing site use arrangements. Once test facility infrastructure is designed (Tasks A.17 through A.19), the design of PNRS II infrastructure can begin and will be integrated into the test facility design. The design documents will define the needed materials and construction of the PNRS II testing component.

Task 2: Procurement of Materials and Media

Candidate media for evaluation in Stage 1 (unsaturated) biofilters and Stage 2 (saturated) biofilters are listed in Table 3.2, with physical properties and their sources. Included are media with high water retention and porosity, and the clinoptilolite additionally provides ion exchange capacity. Media will be procured from vendors for use (Table 3.2). Stage 1 media includes expanded clay and clinoptilolite. These have greater than 45% porosity and high water retention. Characteristics of hydrous sodium aluminosilicates, clinoptilolites, include cation exchange capacities of 1.5 to 1.8 meq/g, high specific surface area generally 40 m^2/gram, and will act to retain ammonia ions for enhanced ammonia removal under non-steady flows and higher loading rates. Livlite is an expanded clay with high water retention characteristics. Expanded polystyrene is a very lightweight, readily available and low cost material that appears to be quite suitable as a biofilter media for aerobic treatment.

The Stage 2 electron donor media are elemental sulfur, which will result in an autotrophic denitrification process in the anoxic biofilter; lignocellulosic materials, such as woodchips, which support heterotrophic denitrification, and glycerol, a readily available carbon source for heterotrophic denitrification. Crushed oyster shell and sodium sesquicarbonate will be used as alkalinity sources in sulfur-based denitrification biofilters, as auto-

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trophic sulfur-based denitrification will consume alkalinity. Expanded shale may be included as a Stage 2 option for its anion exchange capacity to enhance nitrate removal performance. Stage 2 biofilters will be monitored for sulfate and CBOD which will characterize concentration and indicate the reduction achieved prior to soil infiltration following the systems.

Table 3.2
Biofilter Media

Material	Bulk density, lb/ft^3	Typical Particle Size Range as Supplied	Supplier
Zeo-Pure AMZ 8/20 Clinoptilolite	55	0.8 – 2.3 mm	Ash Meadows, Armagose, NV
Livlite (expanded clay)	41	3 to 5 mm	Big River, Alpharetta, GA
Expanded Polystyrene	0.34 – 1.5	2.2 – 3.6 mm	JSP
Elemental sulfur	77	2 – 4 mm	Georgia Sulfur, Valdosta, GA
Oyster shell	82	3 – 15 mm	Misc. Locations, FL
Sodium Sesquicarbonate T-50	69	1 – 3 mm	Solvay
Lignocellulosic material (woodchips, sawdust)	20 – 28	1 to 5 mm	Robbins Products, Tarrytown, FL
Glycerol	79	-	Greenhunter Energy
ACT-MS ESF-450 Utelite (expanded shale)	54	0.4 – 4.5 mm	ES Filter, Ogden, UT

Task 3: Construction of Test Facility and Pilot Systems

A test facility will be constructed that will provide a source of primary effluent (i.e. septic tank effluent) to the PNRS II systems, as well as dosing regimes, sampling ports, and effluent collection. Design of the test facility will be conducted under FOSNRS Tasks A.17 through A.19. Two types of testing systems will be constructed:

A. Vertical/Horizontal Two-Stage Biological Filtration

B. In-Situ Vegetation/Media Simulators

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A. Vertical/Horizontal Two-Stage Biological Filtration

The two-stage biofiltration systems consist of a vertical unsaturated biofilter followed by a saturated denitrification biofilter. The general concept of a typical two-stage biofiltration process is illustrated in Figure 3-1. Primary effluent (i.e. septic tank effluent) is dosed to the upper surface of the Stage 1 biofilter, trickles through the unsaturated media, and then flows by gravity through the saturated horizontal denitrification biofilter. In PNRS II pilot testing, multiple Stage 1 biofilters will be operated in parallel on the same primary effluent, and multiple Stage 2 biofilters will be operated in parallel on Stage 1 effluent.

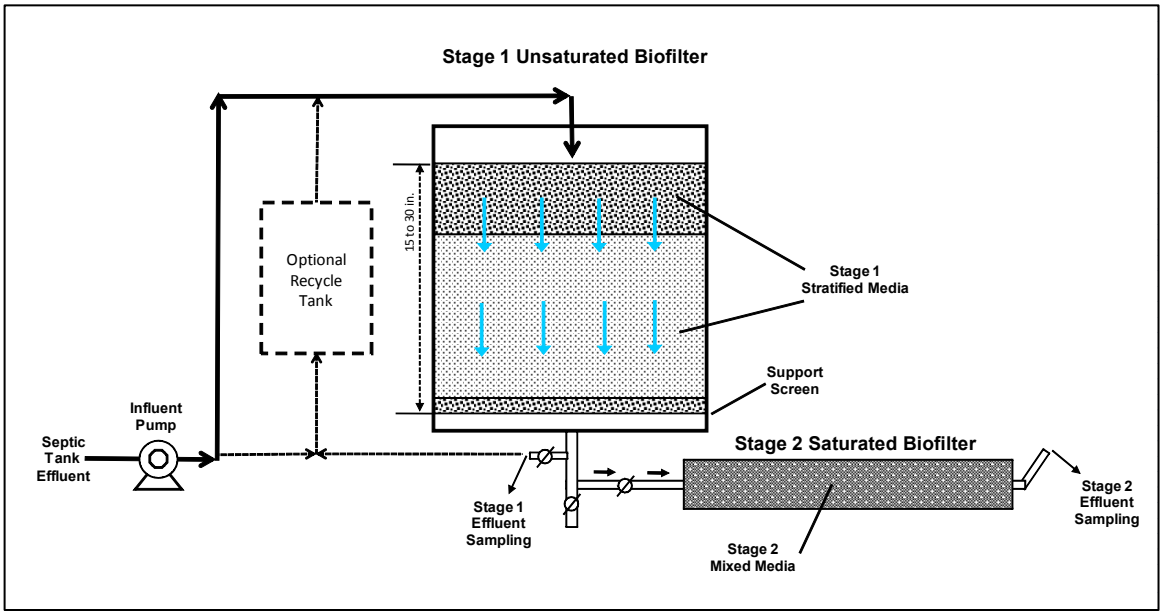

Figure 3-1: Schematic of Vertical/Horizontal Two-Stage Biofiltration Concept

An illustration of different configurations of the Stage 1 unsaturated biofilters is shown in Table 3.3. Three biofilter media will be examined in PNRS II pilot studies: expanded clay and clinoptilolite, both of which were evaluated in PNRS I, and expanded polystyrene, a readily available low cost and light weight material. Design of the expanded clay and clinoptilolite pilot biofilters will be guided by the results of PNRS I. Expanded clay and clinoptilolite biofilters will each be evaluated in 2^2, or 4 units. The 2^2 test matrix consists of two media depths (15 and 30 inch) and single pass and recycle operation (Table 3.3). All expanded clay and clinoptilolite biofilters will employ a two layer stratified design for particle size (Table 3.4). The expanded polystyrene biofilter will be evaluated in single pass operation (Table 3.3). All pilot Stage 1 biofilters (Systems 1 through 11 in Table 3.3) will be dosed at a 30 to 60 minute interval (24 to 48 doses/day), which is similar to the dos-

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ing regime that was employed successfully in PNRS I. Systems 10 and 11 in Table 3.3 are in-situ simulators that consist of simulated dosing by drip irrigation tubing into filter sand media underlain by an engineered media with expanded clay, lignocellulosic and sulfur electron donor.

The initial hydraulic loading rate to Stage 1 biofilters 1 through 9 will be 3 gallon/ft^2-day. As performance data is gathered over the course of the study, it is expected that this loading rate will be progressively increased. The PNRS II pilot studies will include recycle systems to delineate total nitrogen removal by pre-denitrification, and the use of two media size stratification and different media depths than were applied in PNRS I. These factors have direct technological and cost savings implications as they would affect the size of the treatment biofilters.

Stratification of media based on particle size is based on the expected progression of biochemical reactions within the biofilter. The processes in the upper coarse media layer include adsorption of wastewater particulates and colloids, hydrolysis and release of soluble organics, aerobic utilization of soluble organics, and biomass synthesis. In the upper layer, the biochemical processing of organic matter between doses must keep pace with the newly applied wastewater constituents from each dose. The greatest accumulation of organic and inorganic mass will occur in the upper layer, and the use of larger particle size media will provide greater space for accumulation of solids. Stratified media should enhance the potential for long term operation while maintaining treatment efficiency. The use of finer particle sizes in the lower media depths will provide greater surface area for microbial attachment and physical filtration, the later which could improve removal of pathogens and other wastewater constituents. The coarser sized particles in the upper layer will also filter out larger particulates and protect the underlying finer media. The two layer media size stratification (Table 3.4) is a simplification of the 3 layer design employed in PNRS I; the two layer design will simplify construction and reduce costs.

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Table 3.3
Stage 1 Vertical Unsaturated Biofilter Configuration and Initial Operation

Unsaturated Biofilters (Stage 1)					
No.	**Media**	**Biofilter**	**Media Depth (Inches)**	**Flow Regime**	**Recycle Ratio (α)**
1	Expanded Clay	UNSAT-EC-1	15	Single Pass	-
2		UNSAT-EC-2		Recycle	3
3		UNSAT-EC-3	30	Single Pass	-
4		UNSAT-EC-4		Recycle	3
5	Clinoptilolite	UNSAT-CL-1	15	Single Pass	-
6		UNSAT-CL-2		Recycle	3
7		UNSAT-CL-3	30	Single Pass	-
8		UNSAT-CL-4		Recycle	3
9	Polystyrene	UNSAT-PS-1	30 (NS)	Single Pass	-
10	Upper: Filter Sand	UNSAT-IS-1	12	Single Pass	-
11	Lower: Expanded Clay, Lignocellulosic, Sulfur	UNSAT-IS-2	12	Single Pass	-

EC: expanded clay, CL: clinoptilolite, PS: polystyrene, SU: sulfur, α: recycle flowrate/forward flowrate, NS: non-stratified

Specification of pilot hydraulic loading rates was guided by the results of PNRS I. Unsaturated expanded clay and clinoptilolite biofilters both exhibited exceptional performance at 3 gallon/ft^2-day. The PNRS I results suggest that the potential of these media was not fully utilized. The PNRS II pilot study will delineate treatment performance under real world conditions at the PNRS I loading rate of 3 gallon/ft^2-day and at higher loading rates. Higher loading rates translate into a smaller footprint for Stage 2 biofilters and significantly lower construction costs. The general experimental progression will be to establish performance at the initial hydraulic loading rate of 3 gallon/ft^2-day, characterize performance at that loading rate for at least 3 months of operation, and if that operation is consistent, to modify operation to a fixed, higher hydraulic loading rate and characterize performance at that new operating condition.

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Table 3.4
Stage 1 Vertical Unsaturated
Biofilter Media Depth and Stratification

Total media depth, inch	Layer	Media layer depth, inch	Particle diameter, mm
15	Upper	5	1.5 – 2.5
	Lower	10	0.3 – 0.6
30	Upper	10	1.5 – 2.5
	Lower	20	0.3 – 0.6

The Stage 1 biofilters will be supplied with septic tank effluent with a timed dosing of once per one half hour to one hour (24 to 48 doses/day), as was employed in PNRS I. A centrally located dosing system will be used to distribute primary effluent over the surface of the media of each Stage 1 biofilter. Water will percolate downward through the Stage 1 media, through the support screen, and into a line that conveys biofilter effluent to either the directly connected Stage 2 biofilter or the common Stage 1 effluent collection chamber. The water elevation in the line below the Stage 1 biofilter will provide hydraulic head for passive movement of water to the common collection chamber. A valve and sample port (with another valve) will be located in the line below the Stage 1 biofilter. In normal biofilter operation, the sample port valve will be closed and the valve leading to the effluent collection chamber will be open. The design of the biofilter system will minimize internal volumes within the connecting piping. At 48 doses per day and 3 gallon/ft^2-day, a single dose will add a volume that is approximately 6% of the water retained within the Stage 1 biofilter bed of a single pass system (Smith et al., 2008).

Unsaturated biofilter Systems 10 and 11 in Table 3.3 will be in-tank analogs of the in-situ simulators that will be placed in the ground as described in Section 3.3 Task 3B. The media configuration of Systems 10 and 11 is shown in Table 3.5. Biofilter Systems 10 and 11 have two significant media differences from the in-situ simulators that will be placed in the ground: they will not include plants at the upper surface, and will not include natural soil horizons. System 10 will receive septic tank effluent and System 11 will receive nitrified effluent supplied over a capillary seepage mat. Systems 10 and 11 will both be dosed at 0.8 gal/ft^2-day and will not be subject to rainfall inputs at the surface. Sample ports will be provided at 4 inch increments along the depth of the biofilter, which will enable six point longitudinal profiling of nitrogen species and other water quality parameters. The design of the in-tank in-situ simulators will enable quantification of liquid volumes exiting the filter.

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Table 3.5
In-Situ Biofilter Media Depth and Stratification

Total media depth, inch	Layer	Media layer depth, inch	Particle diameter, mm
24	Upper – Sand	12	1.5 – 2.5 (medium-coarse sand)
	Lower - Engineered Media	12	0.5 – 1.0

Configuration of the Stage 2 saturated denitrification biofilters is shown in Table 3.6. The Stage 2 biofilters will be constructed with unstratified mixed media containing elemental sulfur, crushed oyster shell, sodium sesquicarbonate, lignocellulosic materials, and expanded clay (Table 3.6). The use of elemental sulfur with oyster shell was successfully demonstrated in PNRS I. Sodium sesquicarbonate will provide alkalinity supply which will not release calcium and reduce the potential for calcium carbonate precipitation. The use of lignocellulosic materials as a source of organics in denitrification filters was reviewed in the PNRS I literature review. Expanded clay was also evaluated as microbial attachment medium in PNRS I. Glycerol is a low cost fermentable substrate which serves as a denitrification electron donor. Glycerol will be added by dosing pump or other methods.

Stage 2 biofilters will employ non-stratified mixed media of 1 to 2 mm particle size. The configuration of the Stage 2 biofilters that are supplied by the common Stage 1 STE effluent (i.e. Nos. 1, 2, 5, and 9 in Table 3.6) is as 6 inch diameter columns of 72 inch length. Sample ports will be provided at 12 inch increments along the length of the biofilter, which will enable six point longitudinal profiling of nitrogen species and other water quality parameters. The configuration of the Stage 2 biofilters that are directly connected to Stage 1 biofilters (i.e. Nos. 3, 4, 6, 7, and 8 in Table 3.6) is as 22 inch diameter circular upflow filters of 30 inch media depth. Sample ports will be provided at 6 inch increments along the depth of the biofilter, which will enable five point longitudinal profiling of nitrogen species and other water quality parameters. Detailed design will be conducted in Tasks A.16 through A.19.

Like PNRS I, the pilot PNRS II biofilter systems will be configured for simplicity of operation, minimal moving parts and passive gravity flow where possible. The same primary effluent (i.e. septic tank effluent) will be supplied to the surface of each of the Stage 1 vertical biofilters, which will be placed above ground to allow effluent to flow by gravity to either a directly connected Stage 2 denitrification filter or alternatively to a common Stage 1 effluent tank.

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In the initial configuration, the single pass Stage 1 biofilters will be directly connected to Stage 2 denitrification filters, and effluent from the Stage 1 biofilters with recycle will be routed to a Stage 1 effluent collection tank that will produce a common effluent. The Stage 2 denitrification filters that are not directly connected to single pass Stage 1 biofilters will receive effluent from the Stage 1 collection tank by pumps that provide independent flowrate control to each. Stage 2 biofilters will be maintained in saturated mode by the Stage 2 overflow elevation pipe. Stage 2 effluent will be collected via gravity into a Stage 2 collection tank, for management or disposal. Details of design and fabrication of pilot biofilter systems will be addressed in Tasks A.16 through A.19.

Monitoring sample points are septic tank effluent, Stage 1 effluents, the common Stage 2 influent, and Stage 2 effluents (Table A.1). For each monitoring point, separate samples will be collected for field analyses and for laboratory analyses. Field analyses will be performed immediately upon sample collection. Samples for laboratory analyses will be collected by directing samples directly into sample collection containers that are located within iced coolers and that contain any required sample preservatives. Influent and effluent samples will not have contact with any intermediate sample devices. Effluent samples will be maintained in iced coolers and transported to the lab within 24 hours of collection.

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Table 3.6
Stage 2 Saturated Denitrification Biofilter
Configuration and Initial Operation

No.	Electron Donor	Biofilter	Media Composition (by volume)	Initial Surface Loading Rate, gal/day-ft^2	Stage 1 Filter
1[1]	Elemental sulfur	DENIT-SU-1	80% SU 20% OS	10.0	2,4,6,8
2[1]		DENIT-SU-2	80% SU 20% NS	10.0	2,4,6,8
3[2]		DENIT-SU-3	80% SU 20% OS	4.7	1
4[2]		DENIT-SU-4	80% SU 20% NS	4.7	7
5[1]	Lignocellulosic	DENIT-LS-1	70% LS 30% EC	10.0	2,4,6,8
6[2]		DENIT-LS-2	70% LS 30% EC	4.7	3
7[2]		DENIT-LS-3	50% LS 60% EC	4.7	5
8[2]		DENIT-LS-4	30% LS 70% EC	4.7	9
9[1]	Glycerol	DENIT-GL-1	100% EC	10	2,4,6,8

SU: elemental sulfur, LS: lignocellulosic, GL: glycerol, OS: oyster shell, NS: sodium sesquicarbonate, EC: expanded clay

1. Fed from common Stage 1 effluent collection tank.

2. Directly connected to Stage 1 unsaturated biofilter

B. In-Situ Vegetative/Media Simulators

In-situ testing will be conducted using in-situ simulators as shown in Figure 3-2. The simulators will consist of subsurface drip irrigation application to the root zone of surface vegetation, followed by downward transport through a 12 in. layer of filter sand. Underlying the filter sand is a 12 in. layer of engineered media containing electron donor which is in turn underlain by natural soil.

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The configuration of the in-situ simulators is shown in Table 3.7. The 2^1 test matrix consists of subsurface drip irrigation emitter dosing of primary effluent (i.e. septic tank effluent) or nitrified effluent into the root zone of St. Augustine grass. The in-situ simulators will receive an average hydraulic application rate of 0.80 gallon/ft^2-day on an aerial basis applied at 6 doses/day. Drip emitters will be placed at 12 inch spacings. Other than the pumping of effluent by subsurface irrigation, the in-situ simulators are completely passive systems.

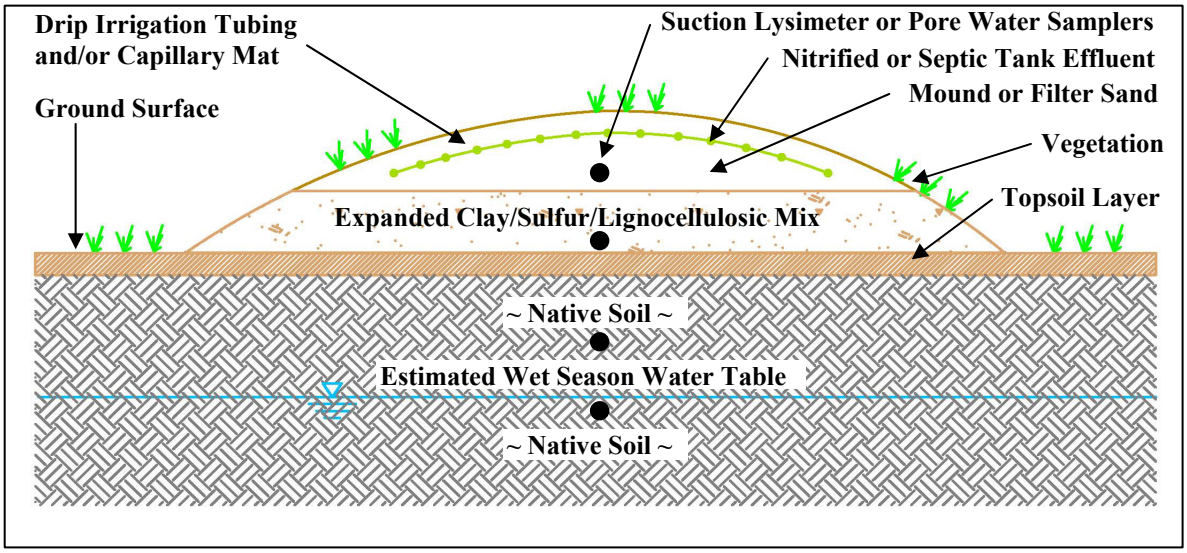

Figure 3-2: Cross-Section Schematic of In-Situ Vegetative Denite - Media Treatment System

In the INSITU-1 simulator, primary effluent (i.e. septic tank effluent) will be applied by subsurface drip irrigation to a near surface location, such that STE will interact with the active root zone of plantings, trickle downward through the sand layer and a 12 in. zone containing electron donor media, and then pass through an underlying zone of natural undisturbed soil (Figure 3-2).

In INSITU-2, primary effluent will first be nitrified and then applied to a near surface location by drip irrigation and using an innovative application of a capillary seepage mat that has been developed for irrigation of agricultural plants by scientists at the University of Florida Gulf Coast Research and Education Center (GCREC). Nitrified effluent will interact with the active root zone of plantings, trickle downward through the sand layer and a 12 in. zone of engineered media, and then pass through an underlying zone of natural undisturbed soil (Figure 3-2).

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An innovative feature of the in-situ simulator design is the use of mixed media in unsaturated mode that contains both a high water retention media (expanded clay) and heterotrophic and autotrophic electron donor (Table 3.7). The media mix will provide three electron donor source options for denitrification: wastewater organics, lignocellulosics, and elemental sulfur. The use of solid electron donor media in an unsaturated operational mode will facilitate both aerobic processes (i.e. nitrification) and denitrification. This design will provide conditions for both nitrification and denitrification, with an additional supply of electron donor over that which would be available from with wastewater organics or endogenous carbon sources alone.

The goal of this testing is to quantify nitrogen reduction in systems where STE or nitrified effluent is applied with subsurface drip emitter tubing or capillary mat to shallow locations within the subsurface which contain plant root zones, unsaturated media, and electron donor media for enhanced denitrification. Timed dosing to shallow application points in the subsurface could be capable of affecting nitrogen reduction. This potential for in-situ treatment systems, including plant-assisted nitrogen transformations, has not been examined in Florida with innovative systems of this type but is of potentially high significance.

Issues that may affect nitrogen reduction are average daily hydraulic application rate, horizontal emitter spacing, doses per day, volume per dose, and the depth at which the bottom of emitter tubes is placed. Emitter tubing is available with spacings of as little as 12 in., which are preferred to typical 24 in. emitter spacings and will be used in this study. The lower emitter spacing results in lower effluent volume per dose at each emitter that are spread more uniformly over the plan area of the dosing zone, thereby increasing the effectiveness of utilization of the total plan area of the receiving surface. Hydraulic application rate affects volume per dose for any given dosing schedule, as interrelated to dosing frequency. As the average daily hydraulic application rate increases, the vegetative/media system will be increasingly challenged to assimilate nitrogen in the applied STE and limit downward nitrogen migration. The depth of emitters and the relationship of emitted effluent to surface vegetation root zones is an ostensibly significant factor affecting total nitrogen reduction. A dosing event can lead to water saturation in a temporally and spatially limited zone that creates oxygen limited conditions that favor denitrification. After saturated conditions end, microenvironments with limited DO can persist and provide continued denitrification. When bulk pore spaces are filled with air, conditions can favor nitrification. Plant roots can exude organic carbon and provide an electron donor rich region. The combination of the supply of organic carbon and reduced nitrogen in the applied STE, the varying saturation and oxygen levels resulting from the dosing regime, and the characteristics of the plant root zone can affect sequential nitrification and denitrification reactions. Downward advective transport of organic carbon and

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nitrate can create a biologically active denitrification zone of some vertical extent. The interaction of all of these factors will determine the extent to which total nitrogen reduction can be affected by drip application of STE into plant/media systems and the significance of plant processes on overall nitrogen reduction. Another factor is downward migration of exudates from the in-situ treatment processes, including biochemical oxygen demand and sulfate that will result from the electron donor media in the engineered layer of the drainfield. These will be monitored, but the small scale of this research study will not require consideration of the additives rule due to the limited mass that could potentially enter the groundwater. Detailed design of in-situ simulators will be conducted in Tasks A.16 through A.19.

For all PNRS II pilot units, system shakedown will proceed following fabrication and set up. System integrity and hydraulics will be fully evaluated with clean water. Basic features of system integrity and hydraulic conveyance will be examined, including system leaks, gravity flow conveyance where applicable, operation of pumps and valves, and sample access functionality. Media will be pre-screened where needed, washed at least three times to remove fines, and placed to appropriate depths in the biofilters. Denitrification biofilters will be initially filled with a clean water source which will be displaced upon commencement of operation. Operation on wastewater will proceed and flow monitoring will be commenced.

Table 3.7
In-Situ Vegetation/Media Simulator Configuration and Operation

No.	In-Situ Simulator	Influent	Flow Application	Unsaturated Media	Saturated Media	Hydraulic Loading Rate, Plan Area Basis, gallon/ft^2-day	Dosing Regime
1	INSITU-1	Primary effluent	Subsurface Drip Irrigation Tubing	12 in. filter sand 1.5-2.5 mm 12 in. 0.5-1 mm 40% EC 30% LS 30% SU	Native soil	0.80	6/day
2	INSITU-2	Nitrified effluent	Subsurface Drip Irrigation Tubing	12 in. filter sand 1.5-2.5 mm 12 in. 0.5-1 mm 40% EC 30% LS 30% SU			

SU: elemental sulfur LS: lignocellulosic EC: expanded clay

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Task 4: Operation and Monitoring of Pilot Systems

The biofilter systems will be operated over a twelve month period, dependent on additional funding, during which eight monitoring events will be conducted. The analytical template is shown in Table 3.8. A detailed analytical description is included in Appendix A. As outlined in Table A.1, there are 42 sampling points and a monitoring analyses structure that employs four analytical tiers. Tier 1 analytes include field and laboratory parameters that will be monitored at each sample point (up to 42) and at each sample event. Potential monitoring points are STE (1), Stage 1 effluents (11), Stage 2 influent (1), and horizontal Stage 2 effluents (9). In addition, the in-situ soil/vegetative simulator effluents will be monitored at two sampling points within each mound at 5 depths each (20). Tier 1 analytes include field parameters (temperature, pH, dissolved oxygen (DO), and oxidation reduction potential (ORP); the nitrogen series (laboratory parameters) of total kjeldahl nitrogen (TKN), ammonia (NH_3), and oxidized nitrogen (NO_x); five day carbonaceous biochemical oxygen demand (C-BOD_5) and total suspended solids (TSS). Tier 2 analytes are supporting parameters that will be monitored at much reduced frequency at all sample points. Tier 3 parameters will be conducted only on sulfur-based denitrification biofilter sample points. Tier 4 analyte is fecal coliform which will be monitored at a much reduced frequency at all sample points (Table 3.8).

Table 3.8
Analyses Template

Analysis Tier	Number of events	Sample points	Analytes	Total number of analyses
1	4/8	42 (all)	Temperature	296
			pH	296
			DO	296
			ORP	296
			Alkalinity	296
			TKN	296
			NH_3-N	296
			(NO_3+NO_2)-N	296
			C-BOD_5	296
			TSS	296
2	1 – 4	42 (all)	COD	78
			Total phosphorus	48
3	2 – 8	26 (sulfur systems)	Sulfate	176
			H_2S	84
4	2/3	42 (all)	Fecal Coliform	116

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Task 5: Preparation of Draft Report

A draft report will be prepared describing pilot testing methods and procedures, results of the research, discussion and conclusions, and all monitoring data. The draft report will be submitted to FDOH for review and comment.

Task 6: Preparation of Final Report

A final report will be prepared based on comments from reviewers of the draft report.

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Section 4.0
Quality Objectives and Criteria

The objective of this monitoring program is to evaluate media for passive nitrogen removal from septic tank effluent. The following summarizes the work to be performed:

- Two stage biofilters and passive in-situ systems will be constructed and operated on primary effluent over a twelve month period.
- The flowrates to each biofilter system provide a range of hydraulic loading rates.
- First stage recycle will be employed to evaluate pre-denitrification.
- Monitoring will be conducted for septic tank effluent, effluent from the Stage 1 (unsaturated) biofilters and effluent from the Stage 2 (saturated) biofilters.
- Field parameters will be monitored at the site. Samples will be collected and transported to the laboratory for analysis of nitrogen species, sulfate and other wet chemistry parameters.
- Operation or configuration of the biofilters will be modified based on analysis of results and adaptive management.
- In-situ soil/vegetative evaluations will be conducted using subsurface drip irrigation technology with emitters located in root zone and monitoring to develop nitrogen concentrations and vertical nitrogen flux.

The monitoring data will be used to calculate:

1. average concentrations and standard deviations of water parameters in septic tank effluent, Stage 1 effluent and Stage 2 effluents;
2. percent removal nitrogen and nitrogen species in Stage 1 biofilters, Stage 2 biofilters and two stage biofilter systems;
3. changes to dissolved oxygen, pH, oxidation reduction potential and alkalinity through biofiltration treatment stages;

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4. average applied hydraulic loading rate, applied loading rates of total nitrogen and nitrogen species; and

5. vertical nitrogen flux in in-situ soil/vegetative systems.

4.1 Precision and Accuracy

Precision describes the reproducibility of results. Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy will be evaluated through the analysis of surrogate spikes, Laboratory Control Samples (LCS), Laboratory Control Sample Duplicates (LCSD), matrix spike samples (MS/MSD) and laboratory internal blind audit samples. Precision and accuracy information is tracked by the laboratory, with acceptable ranges updated periodically. NELAC requirements include the analysis of proficiency test samples to evaluate precision and accuracy. Analytical methods, precision and accuracy, method detection limits and practical quantification limits are shown in Table 4.1 for parameters which will be measured as part of the base monitoring program, as well as other potential parameters of interest. GCREC is not a NELAC certified laboratory; however, GCREC staff includes trained and qualified professionals with extensive experience in NELAC procedures and quality control who will insure that NELAC requirements are fully met.

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Table 4.1
Aqueous Methodology, Precision and Accuracy, Detection Limits

Analyte	Method	Precision (%)	Accuracy (%)	MDL (ppm)	PQL (ppm)
pH	SM4500H+B	20	NA	0.1 pH units	0.1 pH units
Turbidity	180.1	20	90-110	0.2 NTU	0.2 NTU
Alkalinity	SM2320 B	20	90-110	5.0	5.0
C-BOD_5	SM5210 B	20	85-115	2.0	2.0
COD	410.4	20	90-110	12.09452	25
TOC	SM5310 B	20	90-110	0.14778	1.0
TSS	SM2540 D	20	90-110	5.0	5.0
TKN	351.2	20	90-110	0.07121	0.5
NH_3-N	350.1	20	90-110	0.02	0.05
(NO_3+NO_2)-N	353.2	20	90-110	0.02541	0.05
Total Phosphorus	365.1	20	90-110	0.0094	0.0376
Sulfate	300.0	20	90-110	0.05523	0.5
H_2S	SM4500S-E	20	80-120	1.0	1.0
Fecal coliforms	SM9222 B or SM9222 D	20	NA	1.0	1.0
Total coliforms	SM9222 B	20	NA	1.0	1.0
Escherichia coli	SM9222 B	20	NA	1.0	1.0

MDL = method detection limit

PQL = practical quantitation limit

4.2 Representativeness

Representativeness refers to the relationship of a sample taken from a site to be analyzed to the remainder of the sample matrix at the site. The samples will be taken directly from the influents and effluent of the biofilters and will provide representativeness.

4.3 Comparability

The use of NELAC approved procedures and consistent approved methodologies ensure the comparability of data sets generated by different laboratories.

4.4 Completeness

Completeness is defined as a measure of the extent to which the data fulfill the data quality objectives of the project. The completeness of the data will be determined during the data validation and verification process.

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Section 5.0
Documentation and Records

All documentation archives will be kept for a minimum of 5 years after the date of project completion as outlined in Table 5.1. Reports and deliverables will be submitted in Word or Excel format.

Table 5.1
Documentation and Records Storage

Document/Record	Location	Retention Time	Format
QAPP and revisions	Hazen and Sawyer, AET	5 years after project completion	Paper, electronic
Field notes	Hazen and Sawyer	5 years after project completion	Paper
Chain of custody	Hazen and Sawyer, Lab	5 years after project completion	Paper
Laboratory QA manual	Lab	5 years after project completion	Paper, electronic
Laboratory SOPs	Lab	5 years after project completion	Paper, electronic
Laboratory data reports	Hazen and Sawyer, Lab	5 years after project completion	Paper, electronic
Laboratory equipment maintenance logs	Lab	5 years after project completion	Paper
Laboratory calibration records	Lab	5 years after project completion	Paper, electronic

5.1 Field Documentation

1. Field Notes
   Field notes will be documented and maintained by field staff.

2. Field Parameters
   Field staff will record specific sample point, date and time of sample collection, parameter name, result and units

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3. Sample Collection, Preservation and Transport
   Chain of custody forms and sample tags attached to sample bottles will be supplied by the laboratory. Figure 5-1 depicts a typical chain of custody form. Legal or evidentiary chain of custody as defined in the NELAC standards will be executed.

CHAIN OF CUSTODY RECORD No. E Page ____ of ____

(INSTRUCTIONS ON BACK OF THIS FORM)

FOR LAB USE ONLY
Temp. of Contents:_____°C (or Received on Ice, ROI)
Condition of Contents: _____
Condition of Seals: _____

FOR LAB USE ONLY
Submission No.

1. Client: (Company or Individual)
Address: 13097 N Telecom Parkway
City: Tampa State: FL Zip Code:
Phone: ( )
Fax: ( )

2. Report to: (if different from above)
Address:
City State Zip Code
Phone: ( )
Fax: ( )

18. Report Type:
Routine
Standard QC
Data Package

19. Turnaround Time
Standard
Rush : __/__/__

3. Client Project Name: Baffle Box Research Project
4. Client Project No.:
5. P.O. No.:
6. Custody Seal No.:
7. Sampled By: Daniel Smith
8. Shipping Method:

Water Sample Codes (for Item 13)	Container Codes (for Item 16)
DW = Drinking Water	V = VOA vial
GW = Ground Water	G = glass
SW = Surface Water	P = plastic
PW = Processed Water	M = micro bag/cup
WW = Waste Water	O = other

14. 15. Preservatives
16. Containers
17. NH3 TKN NOx TP COD CBOD5 TSS PO4

Preservative Codes (for Item 15)
C = Cool Only
H = Hydrochloric Acid
M = Monochloroacetic Acid
N = Nitric Acid
OH = Sodium Hydroxide
S = Sulfuric Acid
T = Sodium Thiosulfate

Item	9. Sample ID or No.	10. Sample Description	11. Date	11. Time	12. Comp.	12. Grab	13. Water	13. Air	13. Soil	13. Sludge	13. Other	20. REMARK	LAB USE ONLY LAB SAMPLE NO.
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													

	21. RELINQUISHED BY	DATE	TIME	22. RECEIVED BY	DATE	TIME
1						
2						
3						
4						

FOR LAB USE ONLY
Sampling Fee: _____ Hrs.
Equipment Rental Fee:_____
Profile No.: Quote No.:

DISTRIBUTION: White with report; Blue, Green, Yellow to labs; Gold to submitter Revised:

Figure 5-1: Typical Chain of Custody Form

5.2 Laboratory Documentation and Reporting

Laboratory deliverables will be submitted in Word or Excel format. Laboratory reports will be issued in accordance with NELAC requirements. Certificates from vendors will be retained, whether from a laboratory or commercial vendor. Records of the lot numbers of reagents and other cleaning supplies, with the inclusive dates for use, will be recorded. Pre-cleaned container packing slips, lot numbers of shipments, and certification statements provided by the vendor will be retained by laboratories. All local, state and federal requirements pertaining to waste storage and disposal will be followed.

5.3 Archival of Electronically Stored Data

Analytical reports generated will be retained by Hazen and Sawyer and the laboratories performing the analyses.

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Section 6.0
Sampling Process Methodology

6.1 Site Location

The project will be conducted at the Gulf Coast Research and Education Center in Hillsborough County as discussed in Section 2B.

6.2 Monitoring and Sampling Frequency and Duration

The biofilter systems will be monitored eight times, dependent on future funding, over a twelve month period.

6.3 Number of Samples and Matrices

All sampling will be aqueous samples. On each monitoring date, samples will be collected for septic tank effluent, the effluents from Stage 1 biofilters, and the effluents from Stage 2 biofilters. Field analysis will be performed upon sample collection. Aqueous samples for laboratory analysis will be collected in sample containers prepared by the laboratories, maintained in an iced cooler during collection and transport, and transported to the laboratory. Samples will arrive at laboratories within twenty four hours after the completion of collection activities, or as needed for shorter sample hold times. Field analysis will be performed on the same date and for the sample locations taken for aqueous laboratory samples. Samples for field analyses will be collected in separate containers from laboratory samples. Stage 1 and 2 field parameter analyses will be measured in-situ by placing probes directly into collected samples or directly into effluent pipes. Shipping coolers will be supplied and decontaminated by the laboratories. Sample preservation and holding times are provided in Table 6.1 for parameters which will be measured as part of the base monitoring program, as well as other potential parameters of interest. The laboratories will follow all local, state and federal requirements pertaining to waste storage and disposal. No equipment except the sample container will be used to collect the samples, and the sampling equipment will be certified clean by the laboratory providing the equipment. A field blank will be collected for TKN, NH_3 and NO_3+NO_2 for a minimum of 5% of samples collected over the life of the project using distilled water supplied by the laboratories. As a part of its QC, laboratories will perform sample duplicates for a minimum of 5% of samples. Laboratory QC will also include matrix spikes, percent recovery on QC standards, and method blanks.

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Table 6.1
Aqueous Matrix Containers, Preservation and Holding Times

Analyte	Method	Minimum Sample Volume	Holding Time	Container Type	Sample Preservation	Preservative Dosage
Physical and Inorganic Parameters						
Alkalinity as CaCO3	310.1/SM2320B	100 mL	14 days	250 mL	4° C	n/a
Ammonia	350.1	25 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
BOD / cBOD	SM5210B/405.1	1 L	48 hours	1 L Plastic	4° C	n/a
Chloride	300	50 mL	28 days	250 mL	4° C	n/a
COD	410.4	50 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Hydrogen Sulfide	376.1	500 mL	7 days	500 mL Plastic	Zinc Acetate / NaOH	.1 / .5 gm/ 500 mL
Nitrate/Nitrite-N (NO_X)	SM4500	50 mL	28 days	250 mL	1:1 H_2SO_4 / 4 ° C	I mL/ 250 mL
Nitrate-N	SM4500	50 mL	48 hours	250 mL	4° C	n/a
Nitrite-N	SM4500	50 mL	48 hours	250 mL	4° C	n/a
Organic Nitrogen (calculation)	350.1/351.2	100 mL	28 days	500 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Ortho Phosphorus	365.4/9056/300.0	25 mL	48 hours	250 mL	4° C	n/a
pH	SM4500HB	50 mL	24 hours	250 mL	4° C	n/a
Sulfate	300	10 mL	28 days	250 mL	4° C	n/a
Sulfide	376.1/9030/9034	500 mL	7 days	500 ml	NaOH + Zn Acetate	1 mL/ 500 mL
TKN	351.2	100 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Nitrogen (calculation)	300.0/351.2	100 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Organic Carbon (TOC)	415.1/SM5310B	25 mL	28 days	125 mL Plastic	HCl to pH < 2 / 4 ° C	.5 mL/ 125 mL
Total Phosphorus	365.2/365.4	50 mL	28 days	250 mL	1:1 H_2SO_4 to pH < 2	1 mL/ 250 mL
Total Suspended Solids	160.2	300 mL	7 days	1 L Plastic	4° C	n/a
Turbidity	180.1	30 mL	48 hours	125 mL Plastic	4° C	n/a

Table 6.1
Aqueous Matrix Containers, Preservation and Holding Times

Analyte	Method	Minimum Sample Volume	Holding Time	Container Type	Sample Preservation	Preservative Dosage
Microbiological Parameters						
Total Coliform (MMO-Mug)	SM9223	100 mL	30 hours	Micro-cup	4° C	n/a
Total Coliform (MF)	SM9222	100 mL	6 hours	Micro-cup	4° C	n/a
Fecal Coliform (MF)	SM9222	100 mL	6 hours	Micro-cup	4° C	n/a
Standard Plate Count	SM9222	100 mL	8 hours (DW)	Micro-cup	4° C	n/a
Standard Plate Count	SM9222	100 mL	6 hours (WW)	Micro-cup	4° C	n/a
Fecal Coliform (MPN)	SM9221	100 g.	24 hours	Micro-cup	4° C	n/a

Short hold times

Minimum volume does not include sample volume needed to perform required quality control parameters

6.4 Inspection/Acceptance of Supplies and Consumables

1. Sample Containers
   To be provided by the laboratory prior to each sampling event.

2. Sample Coolers
   To be provided by the laboratory prior to each sampling event.

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Section 7.0
Data Review, Verification and Validation

7.1 Data Verification

Data verification is the process for evaluating the completeness, correctness, and conformance of the data set against the methodology. This evaluation is integral to the final report. Verification will check that the data were complete, that sampling and analysis matched QAPP requirements, and that Standard Operating Procedures (SOPs) were followed. Verification of data compiled for a sampling event will be the responsibility of the Task Leader.

7.2 Data Validation

Data validation is an analyte and sample specific process that determines the quality of the data set relative to the end use. The entire set of data collected from individual biofilters and from the total set of biofilters operated during PNRS II will be entered into spreadsheets to enable global evaluation of individual parameters, trend analysis, quality of the overall data sets, and assessment of suitability for end use. In this process, outliers and data discrepancies will be identified. Any data deemed to be unusable for the stated objectives will be identified as such in the final report.

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Section 8.0
References

References

Smith, D., R. Otis, and M. Flint (2008) Florida Passive Nitrogen Removal Study Final Report. Submitted to the Florida Department of Health, Tallahassee, Florida, June 26, 2008.

Smith, D. (2008) Florida Passive Nitrogen Removal Study Additional Monitoring. Submitted to the Florida Department of Health, Tallahassee, Florida, November 4, 2008.

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Appendix A
Analytical Schedule

Table A.1
Estimated Number of Analyses at each Monitoring Point for each Sampling Event

Sample point	Influent (STE)	Vertical non-sulfur Stage 1 effluent	Vertical sulfur Stage 1 effluent	Stage 2 influent	Horizontal sulfur Stage 2 effluent	Horizontal non-sulfur Stage 2 effluent	In-situ vegetative/ media simulator SP#1	In-situ vegetative/ media simulator SP#2
No. of sample points	1	9	2	1	4	5	10	10
Analyses	No. of Sample Events							
Temp	8	8	8	8	8	8	8	4
pH	8	8	8	8	8	8	8	4
DO	8	8	8	8	8	8	8	4
ORP	8	8	8	8	8	8	8	4
Alkalinity	8	8	8	8	8	8	8	4
TKN	8	8	8	8	8	8	8	4
NH_3	8	8	8	8	8	8	8	4
NO_x	8	8	8	8	8	8	8	4
C-BOD_5	8	8	8	8	8	8	8	4
TSS	8	8	8	8	8	8	8	4
COD	4	2	2	4	2	2	2	1
Total P	4	1	1	4	1	1	1	1
SO_4	0	0	8	8	8	0	8	4
H_2S	0	0	4	0	4	0	4	2
Fecal	3	3	3	3	3	3	3	2

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Table A.2
Estimated Total Number of Analyses
at each Monitoring Point over PNRS II Study

	Influent (STE)	Vertical non-sulfur Stage 1 effluent	Vertical sulfur Stage 1 effluent	Stage 2 influent	Horizontal sulfur Stage 2 effluent	Horizontal non-sulfur Stage 2 effluent	In-situ vegetative/ media simulators SP#1	In-situ vegetative/ media simulators SP#2	
	1	9	2	1	4	5	10	10	
Analyses	No. of Samples								Total Samples
Temp	8	72	16	8	32	40	80	40	296
pH	8	72	16	8	32	40	80	40	296
DO	8	72	16	8	32	40	80	40	296
ORP	8	72	16	8	32	40	80	40	296
Alkalinity	8	72	16	8	32	40	80	40	296
TKN	8	72	16	8	32	40	80	40	296
NH_3	8	72	16	8	32	40	80	40	296
NO_x	8	72	16	8	32	40	80	40	296
C-BOD_5	8	72	16	8	32	40	80	40	296
TSS	8	72	16	8	32	40	80	40	296
COD	4	18	4	4	8	10	20	10	78
Total P	4	9	2	4	4	5	10	10	48
SO_4	0	0	16	8	32	0	80	40	176
H_2S	0	0	8	0	16	0	40	20	84
Fecal	3	27	6	3	12	15	30	20	116

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FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task A.7, A.8 and A.9

Classification, Ranking and Prioritization of Technologies

Final Report

September 2009

4423-001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK A.7, A.8 AND A.9
FINAL REPORT

Classification, Ranking and Prioritization Of Technologies

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

September 2009

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

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Applied Environmental Technology

Otis Environmental Consultants, LLC

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Section 1.0
Introduction

The Florida Department of Health has contracted with Hazen and Sawyer, P.C. to conduct the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study to evaluate technologies and develop strategies to reduce nitrogen loading from onsite wastewater treatment systems in Florida. This multi-year, multi-disciplinary study consists of four main areas of work, as summarized below.

Task A: Technology Evaluation for Field Testing: Review, Prioritization and Development

Task B: Field Testing of Technologies and Cost Documentation

Task C: Evaluation of Nitrogen Reduction Provided by Soils and Shallow Groundwater

Task D: Nitrogen Fate and Transport Modeling

This report covers preliminary work under FOSNRS Task A. This effort includes a multistep process to identify and evaluate available nitrogen reduction technologies for subsequent field testing in Task B. Task A includes an expansion and update to the literature review of nitrogen reduction technologies that was conducted under a previously completed FDOH project, the Passive Nitrogen Reduction Study (PNRS I). The literature review is presented as a separate report and was used as the basis for identifying and classifying available onsite sewage nitrogen reducing technologies in this report.

This report summarizes the results from the Technology Classification, Ranking and Prioritization Workshop (Task A) conducted with the FDOH Research Review and Advisory Committee (RRAC) on May 28, 2009. The following summarizes the contents of this report.

- ***Classification of Technologies (Task A.7)*** includes a classification system for nitrogen reduction technologies that includes major categories of source separation, physical/chemical treatment technologies, biological treatment technologies, and natural systems. The classification scheme was based on the literature review and consideration of fundamental principles of wastewater treatment unit processes.

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- ***Technology Ranking Criteria (Task A.8)*** presents important criteria for onsite nitrogen reduction technologies, defines the criteria attributes, and delineates numerical scores for each criterion. The criterion scores are combined with criteria weighing factors which can then be used to generate an overall score for each technology in Task A.9 technology prioritization for testing.

- ***Prioritization of Nitrogen Reduction Technologies (Task A.9)*** this portion of the report outlines the overall methodology by which technologies will be classified, ranked and evaluated in order to prioritize technologies for testing.

The Technology Classification, Ranking and Prioritization Workshop presented the nitrogen reduction technology classifications, ranking criteria, and weighting factors recommended by the project team in the draft report, and sought input from the stakeholders on the RRAC. The objectives of the workshop were to gain consensus on the methods that will be used to rank and prioritize technologies for subsequent field testing. Based on input from the workshop and review comments, this is the final Technology Classification, Ranking and Prioritization Report.

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Section 2.0
Classification of Nitrogen Reduction Technologies (Task A.7)

The results of the literature review (Task A.2) led to development of a scheme for classifying nitrogen reduction technologies to allow comparisons between the many options that are available for use by onsite sewage treatment systems. This scheme consists of four categories for classification; source separation, biological treatment via nitrification/denitrification, physical/chemical treatment, and natural systems (Figure 2-1). In most available onsite nitrogen reduction technologies, it is typical that more than one of these processes are operative in any given treatment system.

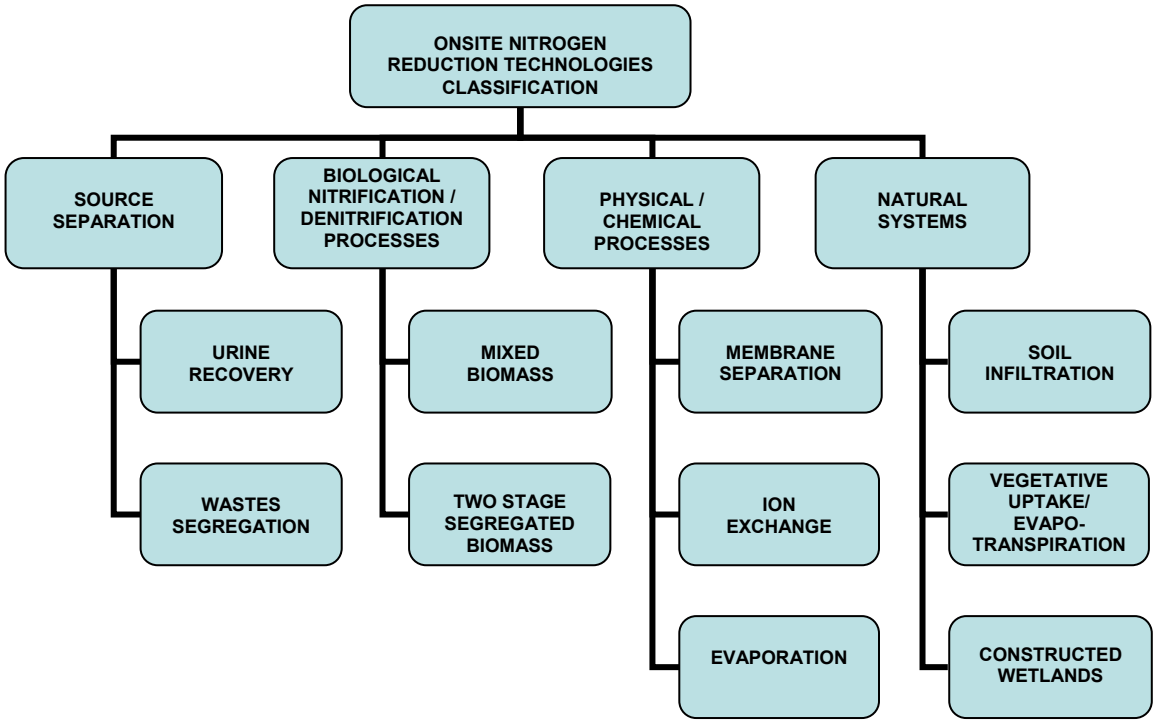

Figure 2-1: Options for Reducing Nitrogen in Household Sewage

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2.1 Source Separation

Source separation options are shown in Figure 2-2. The primary source separation options include: 1) urine recovery and 2) separation of domestic wastewater into greywater and black water waste streams. Toilets are the source of approximately 80% of all nitrogen discharged in household waste streams making urine recovery or wastes segregation significant nitrogen reduction options. Segregation of waste streams also would allow for treatment of the more concentrated, nitrogen-laden waste streams separately via nitrification/denitrification and would result in less waste volume for treatment.

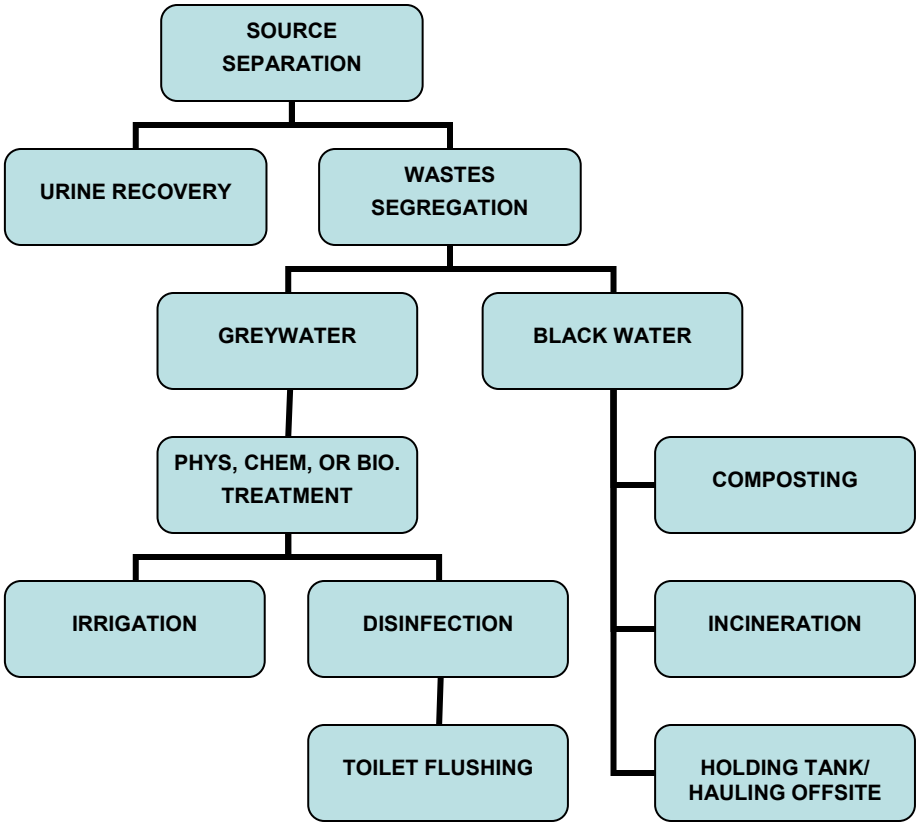

Figure 2-2: Source Separation Options

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2.2 Physical / Chemical Treatment

Physical / chemical treatment processes do not rely on biological processes and therefore are typically more stable and consistent in their performance. However, as a consequence their operation and maintenance can be more intensive. Figure 2-3 illustrates the classification of these processes for nitrogen removal.

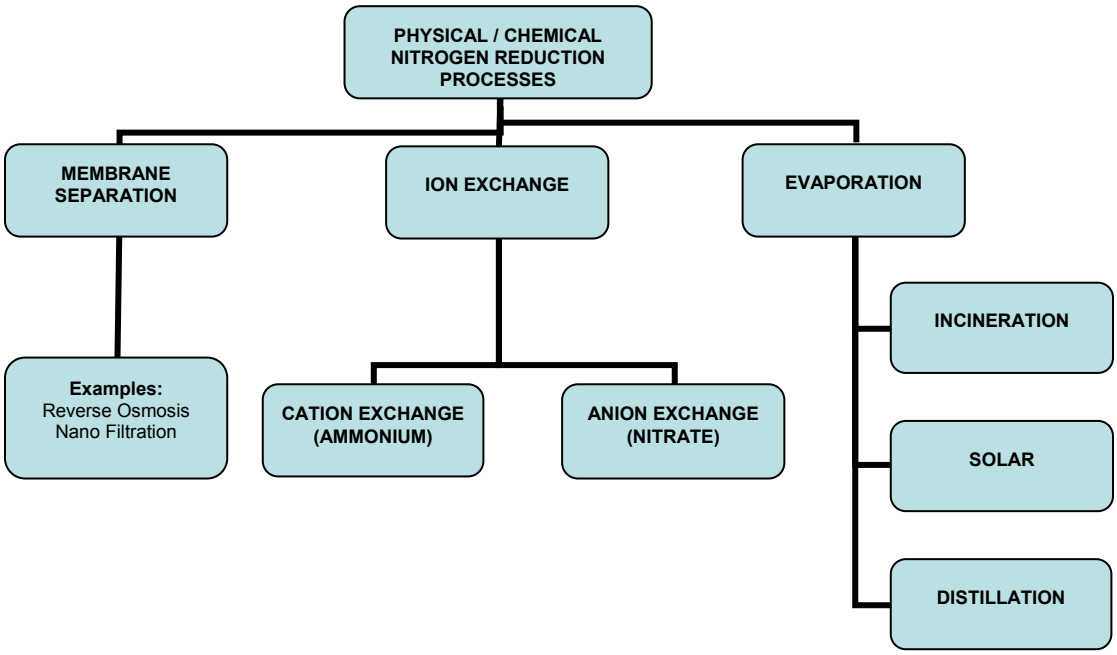

Figure 2-3: Physical / Chemical Nitrogen Reduction Categories

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2.3 Biological Nitrification / Denitrification

Biological nitrification / denitrification processes are the most commonly used methods for reduction of nitrogen in wastewater. The two that are the most practical for onsite sewage treatment are mixed biomass and segregated biomass processes. The mixed biomass process includes suspended growth, fixed film, and integrated fixed film activated sludge technologies as shown in Figure 2-4. The segregated biomass technologies use various external organic carbon sources or elemental chemicals in place of the mixed biomass process' complete reliance on wastewater organic carbon as the electron donors necessary for microbial metabolism to reduce nitrate nitrogen. The segregated biomass systems require a highly nitrified influent to achieve nitrogen reduction goals.

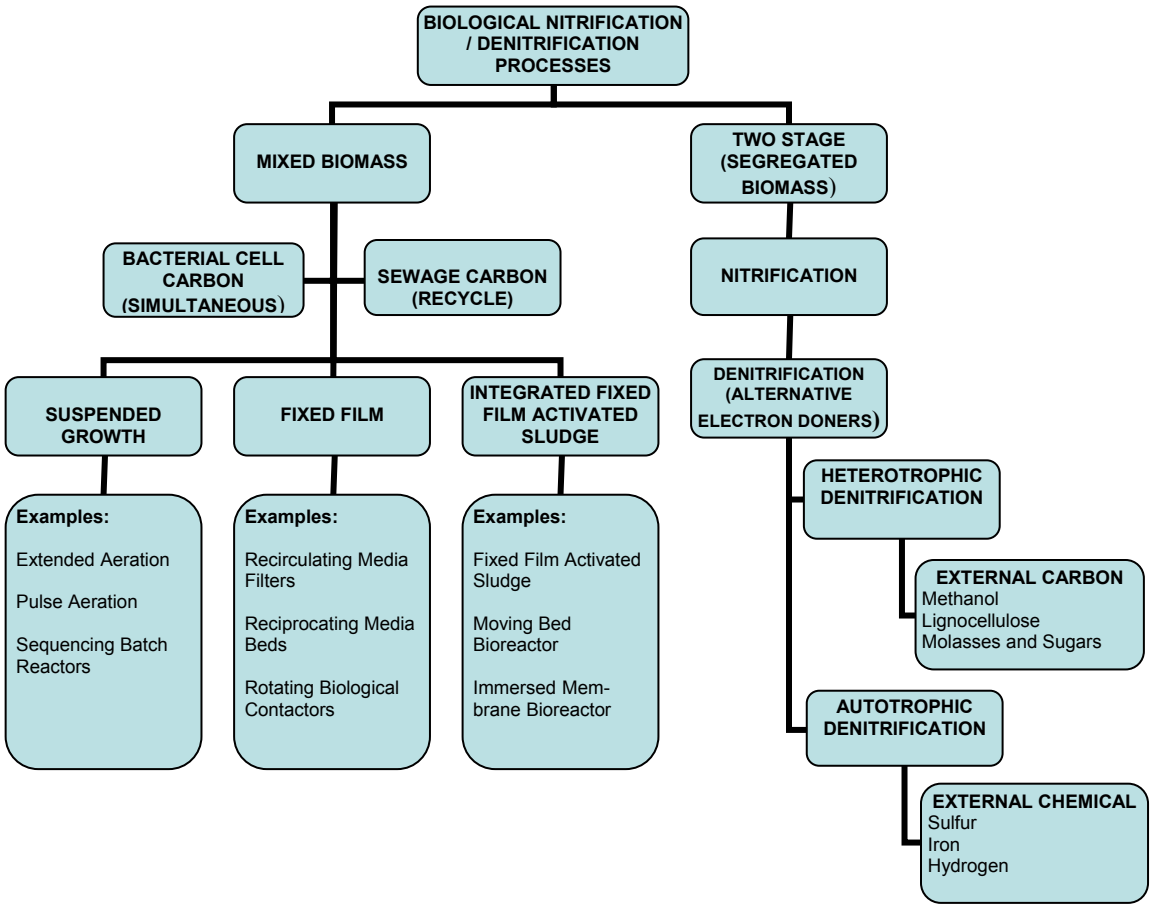

Figure 2-4: Biological Nitrification / Denitrification Technology Classifications

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Table 2.1 provides a summary of the various biological denitrification processes and their typical treatment limits for onsite wastewater systems. These denitrification processes can be linked to any source of nitrified wastewater to provide nitrogen reduction by converting nitrate nitrogen to gaseous nitrogen. Figure 2-5 illustrates the relative system complexity for biological nitrogen reduction systems in relation to the process used.

Table 2.1
Biological Denitrification Processes and Typical Nitrogen Reduction Limits of OSTDS

Process	Mixed Biomass (Simultaneous)	Mixed Biomass (with Recycle)	Segregated Biomass (Two Stage)
Electron Donor	Organic carbon from bacterial cells and influent wastewater	Organic carbon from influent wastewater and bacterial cells	External electron donor (Organic carbon; Ligno-cellulose; Sulfur; Iron, Other)
Typical N Reductions	40 to 65%	45 to 75%	70 – 96%
Typical Technologies	• Extended aeration[1] • Pulse aeration[2] • Recirculating media filters[3] • Sequencing batch reactors[4] • Reciprocating media beds[5] • Membrane bioreactor[6]	• Extended aeration with recycle back to septic tank • Recirculating media beds with recycle back to septic tank[7] • Moving bed bioreactor	• Heterotrophic suspended growth[8] • Heterotrophic packed bed fixed film • Autotrophic packed bed fixed film[9]

[1] *Leverenz, et al., (2002); USEPA (2002)*
[2] *California State Water Resources Control Board (2002)*
[3] *USEPA (2002)*
[4] *Ayres Associates (1998)*
[5] *Behrends, et al. (2007)*
[6] *Abbeggen, et al., (2008); Sarioglu, et al. (2009)*
[7] *Ronayne, et al. (1982); Gold, et al. (1992); Piluk and Peters (1994); Roy and Dube (1994) California Regional Water Quality Control Board (1997); Ayres Associates (1998); Louden et al. (2005)*
[8] *USEPA, (1993)*
[9] *Rich (2007); Heufelder et al. (2008)*

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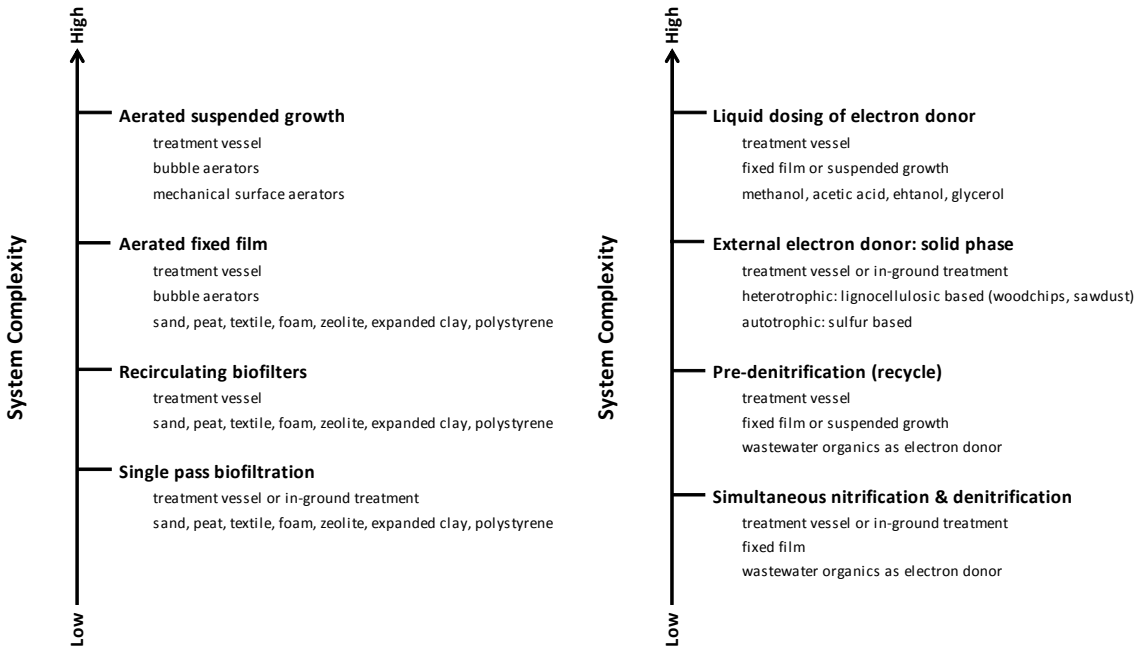

Figure 2-5: Generic System Complexity for Biological Nitrogen Reduction Systems

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2.4 Natural Systems

Natural systems include soil infiltration, vegetative uptake, evapotranspiration and constructed wetlands as shown in Figure 2-6. These technologies use a variety of physical, chemical and biological processes to effect treatment. The reason they are listed in a separate category is that they are typically passive systems that depend more on natural, ecological processes within the receiving environment where process control is severely limited.

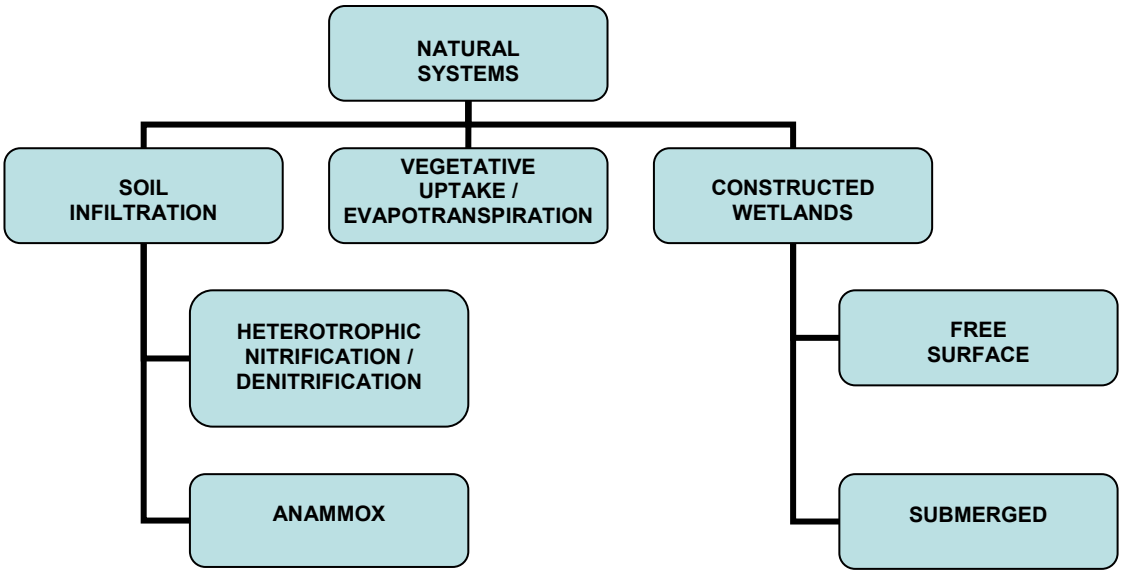

Figure 2-6: Natural Systems Categories

2.5 Treatment Technologies for Wastestream Components

As developed in the Task A literature review report, the domestic sewage from individual households can be divided into 4 individual waste streams:

A – Greywater
B – Kitchen waste
C – Fecal waste
D – Urine

Separation of these waste streams at the source can be utilized to reduce the nitrogen content of the remaining wastewater. Since toilet wastes contribute approximately 80% of the nitrogen to household sewage, with urine the principal contributor, separation of

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toilet wastes or urine from the waste stream could significantly reduce the nitrogen content of household wastewater. However, the separated waste streams must still be treated and reused or discharged for soil infiltration.

Nitrogen reduction technology selection would be guided by the flow and constituent concentrations in the waste stream, the intended application of the final liquid effluent, and the degree of nitrogen reduction required in the final effluent. Greywater separation removes over half of the water volume and concentrates the constituent mass, while urine separation removes substantial nitrogen content while having little effect on total volume. Effluent from in-vessel nitrogen reduction systems may be applied to natural systems for irrigation use or for soil dispersal or subjected to disinfection treatment for indoor reuse.

Greywater may be made suitable for irrigation or indoor use with appropriate treatment. Aerobic biological treatment stabilizes biodegradable organics in the greywater stream and maintains oxidizing conditions; these enable storage for on demand reuse of the water and nutrient values while reducing possible odors. Treated greywater may be directly applied for irrigation, or recycled for indoor toilet flushing after disinfection. Ultraviolet disinfection is one candidate onsite technology.

Separation of urine is a candidate technology with potential benefit for both onsite nitrogen reduction and beneficial use of nitrogen contained in the urine stream. One year's urine production from a typical household could be captured in a single 500 gallon tank, removed annually and processed for recovery using struvite precipitation or other nitrogen and phosphorus recovery techniques. However, onsite urine recovery systems are not likely to become widespread in the near future. The service and recovery infrastructure is not currently in place in the U.S., and may take considerable time to be developed.

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Section 3.0
Technology Ranking Criteria (Task A.8)

3.1 General Description of the Ranking System

A simple numerical ranking system was developed to prioritize available nitrogen reduction systems based on thirteen selected criteria. Each criterion is scored against its particular attribute using a scale ranging from 1 to 5. To account for relative differences in significance of each of the criteria, the criteria are assigned weighting factors indicating relative importance, compared to the other criteria. The priority ranking for a technology is determined by its total score, which is the sum of the products of the individual criterion scores times the weighting factors for each criterion. The highest score represents the highest priority ranking.

3.2 Criteria Selection and Relative Significance Comparison

Thirteen ranking criteria were selected based on priority concerns regarding their influence on the performance, costs, and acceptance of the available nitrogen reduction technologies. The selected criteria are listed in Table 3.1, which also provides how the relative significance of each criterion was weighted.

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Table 3.1
Ranking Criteria and Weighting Factors

Criterion Description	Maximum Score (S)	Weighting Factor (W)	Total Possible Score (S x W)
Effluent Total Nitrogen Concentration	5	11	55
Performance Reliability	5	10	50
Performance Consistency	5	9	45
Construction Cost	5	7.5	37.5
Operation and Maintenance Cost	5	7	35
Energy Requirements	5	7	35
Construction Complexity	5	5	25
Operation Complexity	5	5	25
Land Area Requirements	5	4.5	22.5
BOD/TSS Effluent Concentration	5	3.5	17.5
Restoration of Performance	5	3.5	17.5
System Aesthetics	5	2	10
Stage of Technology Development	5	0.5	2.5
			377.5

The relative weights of the criteria were determined via a two stage process. First, each criterion was compared to every other criterion by the project team prior to the Technology Classification, Ranking and Prioritization Workshop and then by the RRAC at the workshop. If the criterion in a given column was considered to be more important than the criterion in a given row, then a “0” was entered into the box at the intersection of the column and row. If the criterion in the row was considered more important, then a “1” was entered into the box. The totals for each row established the relative rankings of each criterion with the highest score receiving the highest rank. Second, in order to reconcile the differences between the project team and RRAC weights, the weights for each criterion were averaged. Two criteria, construction and operational complexity, were added during the RRAC workshop. During subsequent discussions, RRAC concluded that the weight for energy requirements should be the same as for Operation and Maintenance Cost. Table 3.2 lists the weighting factor assigned to each criterion based on this process.

The scoring systems were created with the full knowledge that data would not be universally available. Scores were made using the given criteria and good engineering judgment, based on the experience of the team where data was not available. Generally, nitrogen concentration, performance reliability, construction costs, energy requirements, BOD/TSS concentration and stage of technology development data were generally easy

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to find for most systems. Performance consistency, O&M cost, land area, system aesthetics, and restoration of performance data were harder to come by and more frequently required judgment.

Table 3.2
Selected Ranking Criteria and Weighting Factor Determination

	Effluent Nitrogen Concentration	Performance Consistency	Performance Reliability	Construction Cost	Operation and Maintenance Cost	Land Area Required	Energy Requirement	System Aesthetics	BOD/TSS Effluent Concentration	Restoration of Performance	Stage of Technology Development	Construction Complexity	Operation Complexity	RRAC Relative Rank Score	H&S Relative Rank Score	Average
Effluent Nitrogen Concentration		1	1	1	1	1	1	1	1	1	1	1	1	12	10	11
Performance Consistency	0		0	1	1	1	1	1	1	1	1	1	1	10	8	9
Performance Reliability	0	1		1	1	1	1	1	1	1	1	1	1	11	9	10
Construction Cost	0	0	0		1	1	1	1	1	1	1	1	1	9	6	7.5
Operation and Maintenance Cost	0	0	0	0		1	1	1	1	1	1	1	1	8	6	7
Land Area Required	0	0	0	0	0		1	1	0	0	1	0	0	3	6	4.5
Energy Requirement	0	0	0	0	0	0		1	0	0	1	0	0	2	4	7
System Aesthetics	0	0	0	0	0	0	0		0	0	1	0	0	1	3	2
BOD/TSS Effluent Concentration	0	0	0	0	0	1	1	1		1	1	0	1	6	1	3.5
Restoration of Performance	0	0	0	0	0	1	1	1	0		1	1	1	6	1	3.5
Stage of Technology Development	0	0	0	0	0	0	0	0	0	0		0	0	0	1	0.5
Construction Complexity	0	0	0	0	0	1	1	1	1	0	1		0	5		5
Operation Complexity	0	0	0	0	0	1	1	1	0	0	1	1		5		5

3.3 Criteria Descriptions and Values

A description of each criterion is presented below together with the attributes for the criterion and the value scores that are the basis for scoring of individual technologies.

3.3.1 Effluent Total Nitrogen Concentration

The attribute of this criterion is the concentration of total nitrogen in the final effluent that is achieved under suitable conditions with proper and adequate operation and maintenance. Effluent total nitrogen concentration is assigned a weighting factor of 11. The criterion values for total nitrogen effluent concentration are listed in Table 3.3. Total nitrogen values used to score a given technology were based on an average of values from various sources, ranging from peer reviewed publications with systems data to manufacturers' websites. The scores in the prioritization report represent what the project team determined to be accurate reflections of the system potentials.

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Table 3.3
Criterion Values for
Total Nitrogen in Effluent

Effluent TN (mg/L)	Score
< 3	5
3 – 10	4
11 – 15	3
16 – 30	2
> 30	1

3.3.2 Performance Reliability

The attributes of the reliability criterion is expressed as the "mean time between unscheduled service calls". The frequency of routine service and unscheduled call-outs provides a measure of the reliability of a technology. Unscheduled service calls exclude inspections required by the FDOH rule. Factors that can increase the need for service include a high number of mechanical components (pumps, aerators, mechanical mixers), complexity of electrical systems, complexity of design, components prone to failure, and complex equipment that requires specialized parts and training of personnel. The reliability of onsite nitrogen reduction is assigned a weighting factor of 10. The categories for performance reliability are listed in Table 3.4.

Table 3.4
Criterion Values for
Performance Reliability

Mean Time Between Unscheduled Service Calls	Score
Annually	5
Semi-annually	4
Quarterly	3
Monthly	1

3.3.3 Performance Consistency

The consistency of performance is defined here as the sensitivity of the treatment system to upset. The sensitivity of a system is heavily influenced by the treatment process used. Therefore the attribute of the performance consistency criterion is the type of treatment process used, based on a review of wastewater treatment design guidelines and onsite wastewater treatment performance. Performance consistency is assigned a weighting factor of 9. The categories for performance consistency are listed in Table 3.5.

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Table 3.5
Criterion Values for
Performance Consistency

System Type	Score
Physical/Chemical & Source Separation	5
Fixed Film	4
MBR / IMB*	3
IFAS**	2
Activated Sludge Nite/Denite	1

**MBR/IMB: Membrane Bioreactor / Immersed Membrane Bioreactor*

***IFAS: Integrated Fixed-Film Activated Sludge*

3.3.4 Construction Cost

The attribute of this criterion is the total capital cost of system installation, including septic tank and drain field where necessary. Available data on construction costs can be found in the technology database that accompanies this report. However, available data was not always complete, and therefore engineering judgment and cross-study comparisons were used to attempt to compare costs between technologies. Construction cost is assigned a weighting factor of 7.5. The categories for construction costs are listed in Table 3.6.

Table 3.6
Criterion Values for
Construction Cost

Construction Cost ($1000)	Score
< 5	5
5 - 10	4
10 – 15	3
15 – 20	2
> 20	1

3.3.5 Operation and Maintenance Cost

The attribute of this criterion is the cost of routine or recommended operation and maintenance, excluding power costs, that is needed to ensure that the treatment system meets its performance objectives. Operation and maintenance cost data obtained during this study is summarized in the technology database that accompanies this report. While the number of service calls would likely be a key factor in the operation and maintenance cost, data typically only included a total cost or estimate, and did not specify details of the various cost components. Operation and maintenance cost is assigned a

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weighting factor of 7. The categories for operation and maintenance are listed in Table 3.7. Operation and maintenance costs typically included the costs of equipment servicing and consumable materials (reactive filter media, chemicals, etc.) but not the replacement cost of primary treatment components such as tanks. Notably, this criterion does not include energy costs, which are accounted for separately. The operation and maintenance costs are calculated as the present value of these costs over the useful life of the system.

Table 3.7
Criterion Values for Required Operation and Maintenance Costs

O&M Annual Cost ($/year)	Score
<200	5
200 - 300	4
301 - 400	3
401 - 500	2
> 500	1

3.3.6 Energy Requirements

The attribute of this criterion is the annual energy usage of the entire treatment system, including pumps, aerators, and mixing devices. The annual energy requirement is the sum of all energy requiring components or the rate of energy usage in operating the component multiplied by the component operating time. Energy requirement is assigned a weighting factor of 7. Criterion values for energy requirements are listed in Table 3.8. Greater energy use is associated with more “active” technologies that employ greater numbers of liquid pumps, aeration pumps, and mechanical mixing, whereas unsaturated granular media filters that employ passive aeration would consume less energy.

Table 3.8
Criterion Values for Energy Requirements

Energy Req. (kW-hr/year)	Score
< 500	5
500 – 1,000	4
1,001 – 1,500	3
1,501 – 2,500	2
> 2,500	1

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3.3.7 Construction Complexity

The attribute of this criterion is the degree of difficulty necessary to install the system in question. High scoring systems will be simple to install even by an untrained contractor or installer – put it in the ground, plug it in, and it works. Low scoring systems will require substantial training and require an extensive installation process. Construction complexity is assigned a weighting factor of 5. Criterion values for construction complexity are qualitative, and are listed in Table 3.9. Data for this criterion was generally unavailable, and engineering judgment was therefore used to score the various technologies based on knowledge of system components and the perceived difficulty of installation.

Table 3.9
Criterion Values for
Construction Complexity

Description	Score
Simple to install by any contractor	5
Some specialized knowledge and training required	3
Complex installation, specialized training, sophisticated electrical and controls knowledge req., master septic tank contractor	1

3.3.8 Operation Complexity

The attribute of this criterion is the degree of complexity required to operate the system in question. High scoring systems will allow operation by the homeowner with little or no effort or training, while low scoring systems will not. Operation complexity is assigned a weighting factor of 5. Criterion values for operation complexity are qualitative, and are listed in Table 3.10. Data for this criterion was generally unavailable, and engineering judgment was therefore used to score the various technologies based on the knowledge of the process utilized and perceived difficulty in maintaining treatment performance.

Table 3.10
Criterion Values for
Operation Complexity

Description	Score
Simple operation with limiter operator requirements annual scheduled visit	5
Some specialized operator training required; Scheduled visits by manufacturer's representative required twice per year	3
Complex operation with operator training required; Scheduled visits by manufacturer's representative required > quarterly	1

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3.3.9 Land Area Requirements

The attribute of this criterion is the plan area or the size of the footprint required for the treatment system, including the drain field, nitrogen reducing component, and septic tank where required. Available data for this criterion can be found in the technology database accompanying this report. However, data was limited and significant judgment was required to compare relative land area requirements between technologies. Land area required is assigned a weighting factor of 4.5. Criterion values for land area required are the footprint area in square feet, and are listed in Table 3.11.

Table 3.11
Criterion Values for
Land Area Requirements

Land Area Req. (ft^2)	Score
< 250	5
250-500	4
501-1000	3
1001-2000	2
> 2000	1

3.3.10 Effluent cBOD/TSS Concentrations

The attribute of this criterion are the final effluent concentrations of five day carbonaceous biochemical oxygen demand ($cBOD_5$) and total suspended solids (TSS) under suitable conditions with proper and adequate operation and maintenance. BOD and TSS effluent concentration is assigned a weighting factor of 3.5. Categories for BOD and TSS effluent concentration are listed in Table 3.12.

Table 3.12
Criterion Values for
cBOD/TSS Effluent Concentrations

Effluent cBOD/TSS (mg/L)	Score
10 / 10	5
20 / 20	4
30 / 30	2
> 50	1

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3.3.11 Performance Restoration

Treatment technologies occasionally will fail to achieve their performance expectations. Such upsets may be due to electrical or mechanical problems or a process upset. The time needed to restore treatment is an important criterion in preventing harm to the environment. The consequences of an operational failure are much less significant if treatment efficacy is restored rapidly. Data was generally unavailable for this criterion, so scoring was based on engineering judgment related to the treatment process utilized by a given technology, as noted in Table 3.13. Performance restoration is assigned a weighting factor of 3.5. The categories for performance restoration are listed in Table 3.13.

Table 3.13
Criterion Values for
Performance Restoration

System Type	Score
Physical/Chemical & Source Separation	5
Fixed Film	4
MBR/IMB*	3
IFAS**	2
Activated Sludge Nite/Denite	1

**MBR/IMB: Membrane Bioreactor / Immersed Membrane Bioreactor*

***IFAS: Integrated Fixed-Film Activated Sludge*

3.3.12 System Aesthetics

The attribute of this criterion is a general judgment of the aesthetic perception of the system when it is properly and adequately operated and maintained. System Aesthetics is assigned a weighting factor of 2. Categories for system aesthetics are listed in Table 3.14.

Table 3.14
Criterion Values for System Aesthetics

System Aesthetics	Score
Acceptable	5
Perceived nuisance/displeasing	3
Not acceptable	1

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3.3.13 Stage of Technology Development

The attribute of this criterion is the stage in development of the nitrogen reduction technology. Stage of technology development is assigned a weighting factor of 0.5. Criterion values for stage of technology development are listed in Table 3.15. Systems used nationwide, or thoroughly tested by NSF or MASSTC will be assigned the highest ranking, while the lower rankings allow room for consideration of meritorious ideas that have not yet been tested. This would include "experimental" systems, such as those tested in PNRS I, or "conceptual" system ideas based on processes, components, or operational strategies that have yet to be tested.

Table 3.15
Criterion Values for Stage of Technology Development

Stage of Development	Score
National use	5
State use	4
Demonstration	3
Experimental	2
Conceptual	1

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Section 4.0
Prioritization of Nitrogen Reduction Technologies (Task A.9)

Prioritization of nitrogen reduction technologies was based on systematic application of the ranking criteria to the technologies identified in the literature review. Technologies were grouped according to the classification scheme developed in Task A.7. Each technology classification received individual scores for the separate evaluation criterion, and the weighting criteria were used to generate the total score for the technology classification. The technologies within each classification were prioritized according to their total score.

4.1 List of Technologies

The literature review and survey of manufacturers indicated that many processes and commercial systems are available for onsite wastewater treatment. The technology database is comprised of available onsite nitrogen reduction technologies from manufacturers and the literature review. The identified technologies were sorted according to the major classifications developed in Task A.7: source separation, biological treatment, physical/chemical treatment and natural systems. The basis for assignment of classification was the principal nitrogen reduction process of the technology. The systems within the major groupings were then further grouped into the process variations within each major classification.

4.2 Technology Evaluation Criteria

The technology evaluation criteria were individually discussed and edited, and a final consensus list of criteria was agreed to and adopted during the Technology Classification, Ranking and Prioritization Workshop held with the Research Review and Advisory Committee on May 28, 2009. Also agreed to and adopted at that meeting were the weighting factors for each individual criterion. The finalized criteria and weighting factors are listed in Table 4.1.

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Table 4.1
Technology Criteria and Weighting Factor

Criteria	Weighting Factor
Effluent Nitrogen Concentration	11
Performance Reliability	10
Performance Consistency	9
Construction Cost	7.5
Operation and Maintenance Cost	7
Energy Requirement	7
Construction Complexity	5
Operation Complexity	5
Land Area Required	4.5
BOD/TSS Effluent Concentration	3.5
Restoration of Performance	3.5
System Aesthetics	2
Stage of Technology Development	0.5

For each of the individual technologies identified within the literature review, data were acquired from a wide variety of sources focusing on the ranking criteria. Manufacturer's information and third party test results such as the NSF International (NSF) Standard 40 Protocol, EPA Environmental Technology Verification Program (ETV), or field and/or laboratory evaluations reported in the technical literature were utilized to develop the technology database. Some performance data were available only as manufacturer's claims, other data as a range of removal percentages from field installations, and some data included detailed analytical results with statistical ranges. Results were averaged because sufficient data was generally not available to distinguish between differences in scale, number of experiments and control of influent variability. Nitrogen effluent data were generally available while nitrogen influent data were not. The attributes of the performance consistency and performance reliability criteria were based on the type of treatment process used. Construction cost was estimated for a newly installed, complete treatment system for a three-bedroom home in Florida, and included primary treatment (i.e. septic tank) and a conventional drainfield. Performance reliability data were available for a few systems for which frequency of maintenance visits recorded were available, and estimated for the remainder. Energy use data (kW-h/day or kW-h/year) were available for a few systems that detailed a cost per month or cost per year, and estimated for the others. For energy use, a conversion to uniform data values was obtained by using an assumption of $0.10 per kW-h. Operation and maintenance cost estimates, land area required, constructional complexity, operational complexity, and system aesthetics data

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were very limited, so professional judgment was used to assign scores for individual criteria to the technology classifications. Data which was available was referenced and summarized in the technology database provided with this report. Assumptions used in the scoring process are footnoted below the criteria scoring tables that follow.

4.3 Criteria Scores

For each of the thirteen criteria, scores were established based on cost and/or non-cost attributes. Table 4.2 presents a summary of score assignments for each criterion. The criterion assignments were the basis for scoring and ranking of the technology classifications.

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Table 4.2
Criteria Scores

Criteria Number	Criteria	Score				
		1	2	3	4	5
1	Effluent Nitrogen Concentration (mg-N/L)	> 30	16 – 30	11 – 15	3 – 10	< 3
2	Performance Reliability	Monthly		Quarterly	Semi-Annually	Annually
3	Performance Consistency[1]	Activated Sludge Nite/Denite	IFAS[2]	MBR/IMB[3]	Fixed Film	Physical/ Chemical & Source Separation
4	Construction Cost[4] ($1,000's)	>20	16-20	11-15	5-10	<5
5	Operation and Maintenance Cost[5] ($/year)	>500	401-500	301-400	200-300	<200
6	Energy Requirement (kW-h/year)	>2500	1501-2500	1001-1500	500-1000	<500
7	Construction Complexity	Complex installation, specialized training, sophisticated electrical and controls knowledge req., master septic tank contractor		Some specialized knowledge and training required		Simple to install by any Contractor

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Table 4.2 (continued)
Criteria Scores

Criteria Number	Criteria	Score				
		1	2	3	4	5
8	Operation Complexity	Complex operation with operator training required; Scheduled visits by manufacturer's representative required > quarterly		Some specialized operator training required; Scheduled visits by manufactur-er's repre-sentative re-quired twice per year		Simple operation with limited operator require-ments; annual scheduled visit
9	Land Area Required[6] (ft^2)	>2000	1001-2000	501-1000	250-500	<250
10	BOD/TSS Effluent Concentration (mg/L)	>50	30/30		20/20	10/10
11	Restoration of Performance[7]	Activated Sludge Nite/Denite	IFAS[2]	MBR/IMB[3]	Fixed Film	Physical/ Chemical & Source Separation
12	System Aesthetics	Not Acceptable		Perceived Nuisance/ Displeasing		Acceptable
13	Stage of Tech. Development	Conceptual	Experimental	Demonstra-tion	State Use	National Use

1. *Since most of the natural systems include fixed film, the natural systems received a score of "4".*
2. *Integrated Fixed-Film Activated Sludge*
3. *Membrane Bioreactor / Immersed Membrane Bioreactor*
4. *Construction cost assumes a standard septic tank cost of $2000 and drainfield cost of $4500 installed.*
5. *Operation and maintenance cost includes inspections, annual operating permit fee ($100), and maintenance entity, but it does not include power costs.*
6. *Land area is for a new entire system, and assumed standard septic tank 50 SF and drainfield 400 SF.*
7. *Since soil infiltration is fixed film, a score of "4" was used for the natural soil infiltration classifications. The constructed wetlands subsurface flow is not quite comparable; therefore it received a score of "3".*

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The criteria were developed with the full knowledge that data for many of the criteria would be sparse and difficult to attain. Good engineering judgment and experience with various types of systems were used to develop technology ranking scores when data were not available.

4.3.1 Criteria Scores for Physical/Chemical and Biological Technology Classifications

A summary of the individual criterion scores for physical/chemical and biological technology classifications is presented in Table 4.3. While the table encompasses the full range of possible systems contained in our classification, technology classifications that lacked sufficient data to make a criteria ranking determination were left blank. Natural and source separation systems need to be considered separately and are therefore summarized in Table 4.5.

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Table 4.3
Criteria Scores for Physical/Chemical and Biological Technology Classifications

Technology Classification	Criteria													Total Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	
	Effluent TN Conc. (mg/L)	Performance Reliability	Performance Consistency	Construction Costs ($1000)	O&M Cost	Energy Req. (kW-h/yr)	Construction Complexity	Operation Complexity	Land Area Req. (ft^2)	BOD/TSS Effluent Conc (mg/L)	Restoration of Performance	System Aesthetics	Stage of Technology Development	
Weighting Factor[1]	11.0	10.0	9.0	7.5	7.0	7.0	5.0	5.0	4.5	3.5	3.5	2.0	0.5	
Physical/Chemical														
Membrane Separation	Not Enough Available Data to Score													
Ion Exchange	Not Enough Available Data to Score													
Evaporation	Not Enough Available Data to Score													
Biological														
Mixed Biomass														
Suspended Growth	3	3	1	2	2	2	3	3	3	4	1	5	5	188.5
Fixed Film														
Fixed Film with recycle	2	4	4	2	3	2	3	3	3	5	4	5	5	235.5
Fixed Film without recycle	1	4	4	2	4	3	3	3	3	4	4	5	5	235
Integrated Fixed Film Activated Sludge	2	3	2	2	2	1	3	3	3	4	2	5	5	183
Two Stage (Segregated Biomass)														
Heterotrophic Denitrification	4	5	4	2	3	2	3	5	3	4	4	5	3	273[2]
Autotrophic Denitrification	4	5	4	2	3	2	3	5	3	5	4	5	3	276.5[2]

1. *See Section 3.0 for how weighting factors were developed.*
2. *Criteria score pertains to a fixed film (Stage 2) denitrification biofilter and fixed film aerobic (Stage 1) process. For other types of Stage 1 systems, the criteria score for the two stage system would be the criteria score for the Stage 1 system (e.g. activated sludge, IFAS).*

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For each technology classification, the criterion scores (Table 4.3) were multiplied by the weighting factor (Table 4.1) and summed to generate a total score. The total score was used to rank technology classifications. Total scores for biological technology classifications are listed in Table 4.4 and plotted in Figure 4-1.

Table 4.4
Biological Technology Classification Overall Ranking

Technology Classification	Total Score	Overall Ranking
Two Stage (Segregated Biomass) – Autotrophic Denitrification	276.5[1]	1
Two Stage (Segregated Biomass) – Heterotrophic Denitrification	273.0[1]	2
Mixed Biomass – Fixed Film with Recycle	235.5	3
Mixed Biomass – Fixed Film without Recycle	235.0	4
Mixed Biomass – Suspended Growth	188.5	5
Mixed Biomass – Integrated Fixed Film Activated Sludge	183.0	6

1. *Criteria score pertains to a fixed film (Stage 2) denitrification biofilter and fixed film aerobic (Stage 1) process. For other types of Stage 1 systems, the criteria score for the two stage system would be the criteria score for the Stage 1 system (e.g. activated sludge, IFAS).*

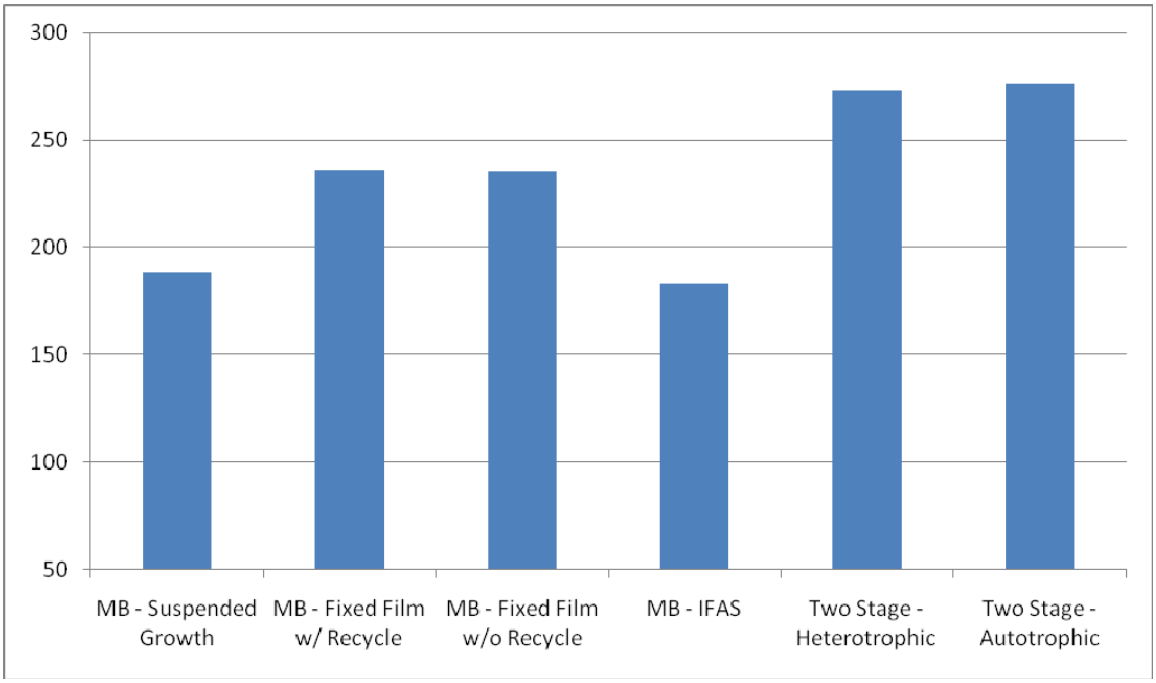

Figure 4-1: Overall Ranking of Biological Technology Classifications

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The top ranked technology classifications (1 & 2) were biological systems with two stage segregated biomass employing autotrophic and heterotrophic denitrification. These systems are passive, require little operator attention, and provide high reliability. The total scores for autotrophic and heterotrophic denitrification technologies in two stage segregated biomass systems were sufficiently close that they were considered essentially equal.

The third and fourth ranked technology classifications were mixed biomass fixed film biological systems with recycle and without recycle, respectively. The total scores for these systems were sufficiently close that they were considered essentially equal. These technology classifications have the stability advantages that are inherent in fixed film processes.

Mixed biomass suspended growth systems were the fifth ranked technology classification and mixed biomass integrated fixed film systems were the sixth. These systems employ suspended growth basins and exhibit higher effluent nitrogen concentrations and lower performance consistency and reliability.

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4.3.2 Criteria Scores for Natural and Source Separation Technology Classifications

Table 4.5
Criteria Scores for Natural and Source Separation System Technology Classifications

Technology Classification	Criteria													Total Score
	1	2	3	4	5	6	7	8	9	10	11	12	13	
	Effluent of TN Conc. (mg/L)	Performance Reliability	Performance Consistency	Construction Costs ($1000)	O&M Cost	Energy Req. (kW-h/yr)	Construction Complexity	Operation Complexity	Land Area Req. (ft^2)	BOD/TSS Effluent Conc (mg/L)	Restoration of Performance	System Aesthetics	Stage of Technology Development	
Weighting Factor[1]	11.0	10.0	9.0	7.5	7.0	7.0	5.0	5.0	4.5	3.5	3.5	2.0	0.5	
Natural Systems														
Soil Infiltration														
With dosing	1	5	4	5	4	5	5	5	3	5	4	5	5	305
With reactive barriers	5	5	4	3	3	5	3	4	5	5	4	5	3	320
With drip dispersal	2	4	4	4	3	5	3	3	3	5	4	5	5	271.5
Annamox	Not Enough Available Data to Score													
Constructed Wetlands														
Subsurface flow with pre-nitrification	3	5	4	2	4	5	3	3	3	3	3	5	5	274
Source Separation Systems														
Urine Recovery	Not Enough Available Data to Score													
Wastes Segregation	Not Enough Available Data to Score													

1. *See Section 3.0 for how weighting factors were developed.*

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Table 4.6
Natural System Technology Classification Overall Ranking

Technology Classification	Total Score	Overall Ranking
Soil Infiltration with reactive barriers	320.0	1
Soil Infiltration with dosing	305.0	2
Constructed Wetlands subsurface flow with pre-nitrification	274.0	3
Soil Infiltration with drip dispersal	271.5	4

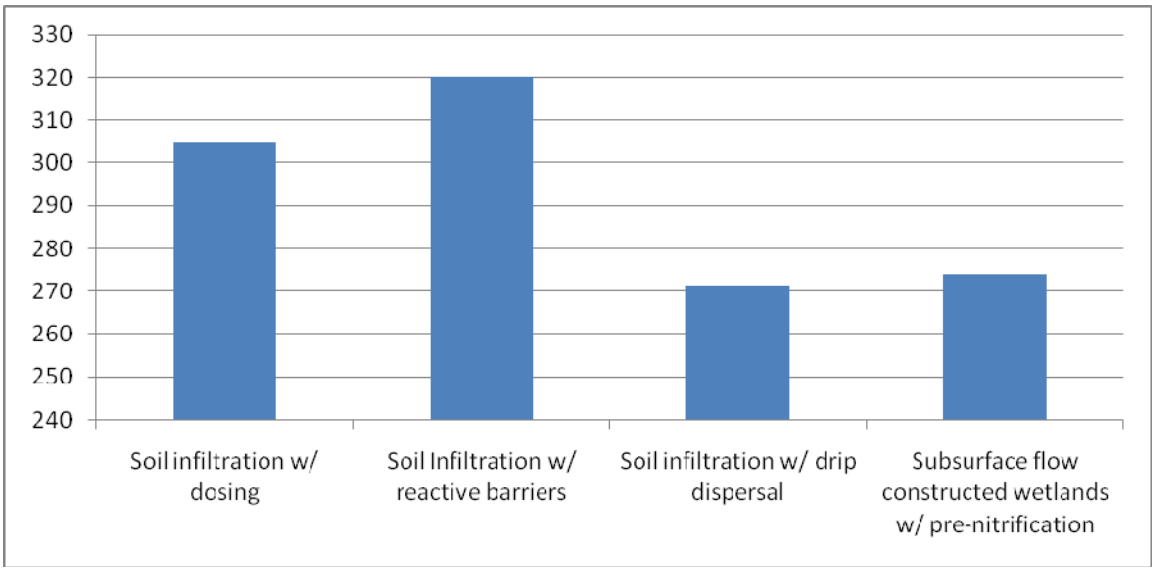

Figure 4-2: Overall Ranking of Natural System Technology Classifications

The top ranked natural system was soil infiltration with reactive barriers. The second ranked natural system is traditional trench drainfield with timed dosing of septic tank effluent. However, this system received the lowest treatment score. Application of our ranking system to certain kinds of natural systems can be misleading from a purely quantitative perspective: in this instance, the score is high because of its passive characteristics and low operating costs, but does not address the difficulty of performance monitoring and the costs associated with correcting poor performance.

Subsurface-flow constructed wetlands with pre-nitrification and drip dispersal of septic tank effluent to soil infiltration technologies ranked within 1% of each other. The constructed wetlands can achieve more complete nitrification and denitrification than soil infiltration with drip dispersal, but drip dispersal offers much greater control of perfor-

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mance and repairs of malfunctions are less costly and easier to perform. Aesthetically, the systems scored the same, but the acceptance could be quite different among property owners.

It is important to note that the natural systems should not be quantitatively compared, using these ranking criteria, to the groups of proprietary and non-proprietary biological systems detailed in Tables 4.3 and 4.4, and Figure 4-1. Primary among considerations supporting this division of technologies is the need to consider separately the elements, of each system, that perform treatment. The soil infiltration units utilize the soil's ecology and physical characteristics to perform treatment and all relevant data measures the treatment capacity within the soil pedon to reduce nitrogen. However, it must be kept in mind that the vast majority of proprietary systems also discharge to the soil. In order to be able to rank each technology fairly, only the nitrogen reduction components were considered. Moreover, management of non-soil based technologies, though more expensive, is simplified because the units can be operated effectively to adjust to varying conditions and serviced easily, which may not be the case with soil-based nitrogen reduction technologies. When malfunctions occur with soil-based technologies, repairs may be necessary and could lead to expensive reconstruction. When the latter is necessary, available land area can become a severe constraint. Finally, while soils provide good treatment over a broad range of conditions, variability of characteristics among soil units can be large creating significant uncertainty in predicting a soil's nitrogen reduction capacity.

4.4 Recommendations for Testing

The technology classification ranking provides the basis from which to formulate recommendations for the field testing to be conducted in Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study. The criteria used to consider in establishing priorities for testing include representation of several technology classifications, nitrogen effluent performance data, similarity of technologies, and maturity level of technologies. The purpose of prioritization is to select the more promising technologies that may not have sufficient prior testing or may be differently configured to improve performance, and to avoid duplicate testing where substantial experience already exists. The priority list for Task B testing is listed in Table 4.7. The recommended technologies include mixed biomass, two stage segregated biomass biofiltration systems, natural systems with and without external sources of electron donors for denitrification, fixed film and integrated fixed film activated sludge processes, denitrification filters with reactive media as post-treatment to commercial aerobic treatment processes, onsite elimination of urine effluent, and urine separation and recovery.

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Table 4.7
Technologies Recommended for Testing in Task B

System	Technology	Comment
1	Two stage (segregated biomass) system: Stage 1: Biofiltration with recycle (nitrification) Stage 2: Autotrophic denitrification with reactive media biofilter	• 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	• Top ranked system capable of meeting the lowest TN concentration standard • Suitable for new systems or retrofit
3	Natural system: Septic tank/Mound with in-situ reactive media layer	• 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: Settled or secondary effluent with drip dispersal	• Suitable for reducing TN impacts on groundwater through enhanced TN removal and reduced TN loading on soil • Suitable for new systems or retrofit
5	Mixed biomass fixed film system with recycle followed by a heterotrophic denitrification with reactive media biofilter	• 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	• 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	• High performance aerobic treatment • Suitable for new systems or nitrogen reduction upgrades

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Table 4.7 (continued)
Technologies Recommended for Testing in Task B

System	Technology	Comment
8	Mixed biomass integrated fixed film activated sludge system: Moving bed bioreactor	• 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	• Aerobic treatment • Suitable for new systems or nitrogen reduction upgrades
10	Membrane process system: Membrane bioreactor (MBR)	• Suitable for new systems or nitrogen reduction upgrades
11	Source separation system: Dry toilet (evaporative or composting)	• Eliminates liquid disposal of wastes
12	Source separation system: Urine separating (recovery) toilet	• Innovative system that is capable of removing 70-80% of the household TN at little capital cost • Provides potential for sustainable recovery of nutrients

The first two technologies listed in Table 1.7 are hybrid mixed biomass/segregated biomass systems. The first stage of each is a mixed biomass recirculating biofilter through which nitrification occurs. Significant denitrification also occurs due to the recirculation. The biofilters can employ a variety of fixed film media, many of which are in current use and are described in the literature review. PNRS II testing will provide additional data for biofiltration with recycle using clinoptilolite, expanded clay, and polystyrene. The best performing media from PNRS II testing will be recommended for Task B testing. Stage 2 of these hybrid systems will employ autotrophic denitrification (System 1) and heterotrophic denitrification (System 2). The hybrid mixed biomass/separate biomass Systems 1 & 2 can be employed for new installations or inserted between primary treatment (i.e. septic tank) and soil dispersal in existing systems.

System 3 is a natural system that uses drip dispersal into the soil of settled or secondary effluent. The design of this system will be based on the results of PNRS II, in which variants of this basic system will be evaluated to determine the design that results in the best nitrogen reduction performance. To enhance denitrification, an in-situ reactive media barrier will be constructed below the drip dispersal tubing. Effluent is dispersed within the root zone and percolates downward through the reactive media barrier containing high water retention materials such as expanded clay and lignocellulosic or elemental sulfur electron donors to support heterotrophic or autotrophic denitrification. This system

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would meet the FDOH definition of passive technology and has the potential to be a low cost in-situ system that can be applied for new installations or retrofits.

System 4 is a natural system using drip dispersal of settled or secondary effluent into the soil. By dosing septic tank effluent into the soil on timed cycles alternating aerobic and anoxic conditions are created in the soil near each emitter, which creates the necessary conditions for nitrification/denitrification to occur. This intermittent dosing of septic tank effluent has been shown by several studies to reduce the total nitrogen that migrates downward from the point of application.

Systems 5 and 6 are similar to Systems 1 and 2, in that they are hybrid mixed/segregated biomass systems with a first stage fixed film bioreactor with or without recycle, followed by a heterotrophic (System 5) or autotrophic (System 6) denitrification filter. While Systems 1 and 2 utilize various widely available media, System 5 and 6 will use a combination of different proprietary and non-proprietary media systems. Systems 5 will include recycling around the first stage aerobic biofilter to enhance pre-denitrification and lessen the nitrate loading to the Stage 2 denitrification filter. Systems 5 and 6 expand the evaluation of the hybrid mixed/segregated biomass systems over that provided by Systems 1 and 2 alone.

Systems 7 and 8 are IFAS (Integrated Fixed-Film Activated Sludge) systems. They combine elements of both fixed film and suspended growth microbial communities, resulting in relatively stable treatment processes that achieve more reliable and consistent performance than other mixed biomass processes.

System 9 is a suspended growth system, specifically Sequencing Batch Reactors (SBR). Theoretically, SBR's should be able to control the loss of carbon better than other mixed biomass systems.

System 10 is a membrane bioreactor (MBR) which combines suspended growth with a membrane filtration unit. MBR has been applied for onsite treatment of multifamily residential wastewater and is an emerging treatment option for single family home systems.

Systems 11 and 12 are source separation systems. Source separation is an emerging onsite wastewater management option, and may become increasingly prevalent in the future in keeping with needs for sustainability and resource recovery. With regard to nitrogen removal, source separation has the potential to be a particularly efficient option since 50 to 75% of household waste nitrogen is from urine. Accordingly, separating the waste streams allows for more efficient, dedicated treatment options for individual components of the wastewater stream.

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Section 5
References

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Smith, D. (2008) Florida Passive Nitrogen Removal Study Additional Monitoring. Florida Department of Health, Tallahassee, Florida, November 4, 2008.**Task A:** Technology

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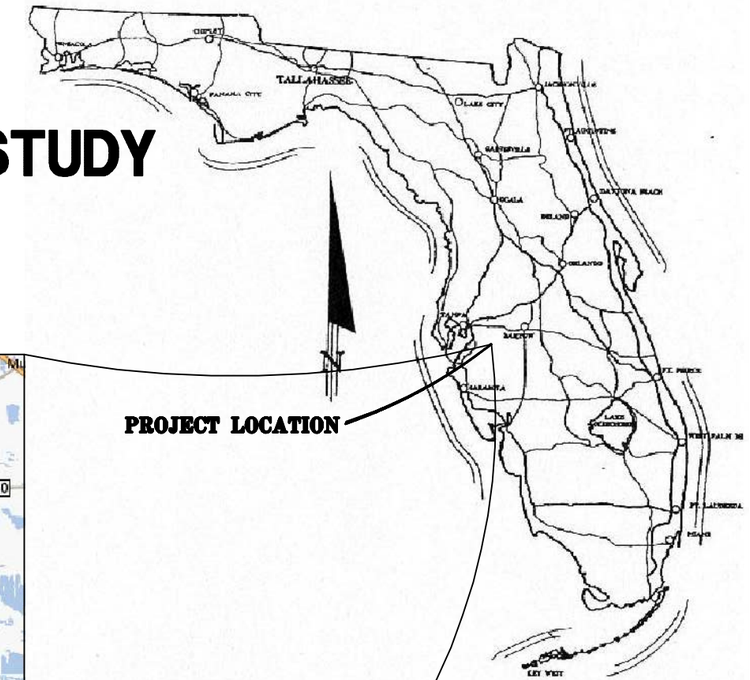
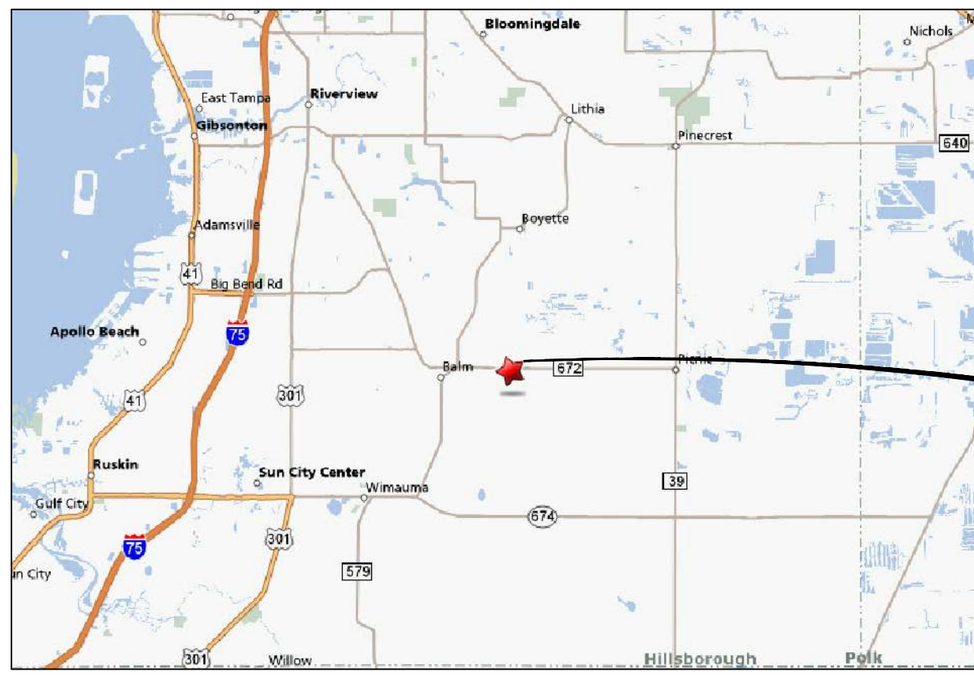
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATEGIES STUDY 50% DESIGN DOCUMENTS



LIST OF DRAWINGS

SHEET COUNT	SHEET NUMBER	SHEET TITLE
		GENERAL
1	G-1	COVER SHEET AND INDEX OF DRAWINGS
		CIVIL
2	C-1	EXISTING ONSITE SEPTIC TANK SYSTEM
3	C-2	PROPOSED OVERALL SITE PLAN
4	C-3	PNRS II DETAILS
5	C-4	PNRS II DETAILS
6	C-5	TASK C NITROGEN FATE OF TRANSPORT STUDY DETAILS
7	C-6	WASTEWATER SOURCE COMPONENTS DETAILS
8	C-7	MONITORING PLAN
		MECHANICAL
9	M-1	YARD PIPING PLAN
		ELECTRICAL
10	E-1	ELECTRICAL SITE PLAN



LOCATION MAP

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HAZEN AND SAWYER
Environmental Engineers & Scientists

10002 Princess Palm Ave., Suite 200
Tampa, Florida 33619
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4052 BALD CYPRESS WAY, BIN A08
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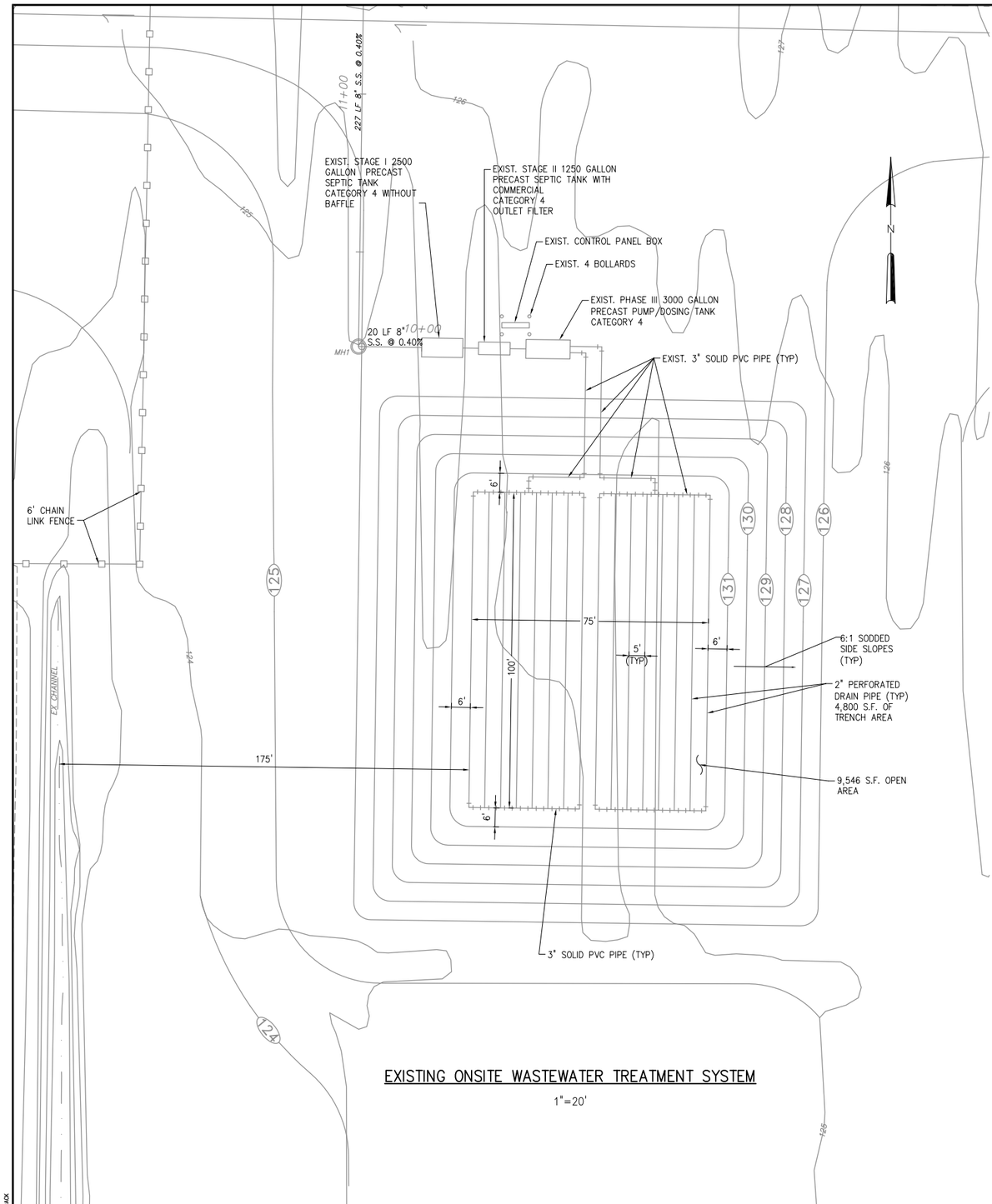


EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

1"=20'

EXISTING DRAIN FIELD CALCULATION

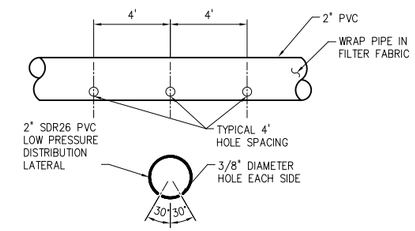
BASED ON UNSUITABLE SUBSURFACE CONDITIONS

LOAD RATE = 0.65
TRENCH AREA = 2828 GPD/0.65 = 4351 SF
OPEN AREA = 2 x 4351 SF = 8702 SF

EXISTING SYSTEM FLOW CALCULATION

DESIGN FLOW (PER 64E-6.008(1b) TABLE 1)

ADMIN/STAFF (100x15)	= 1500 GPD
SCHOOL [STUDENT BOARDING TYPE] (16 x 75 GPD)	= 1200 GPD
ADD FOR SHOWERS (16 x 4)	= 64 GPD
ADD FOR CAFETERIA (16 x 4)	= 64 GPD
TOTAL	= 2828 GPD



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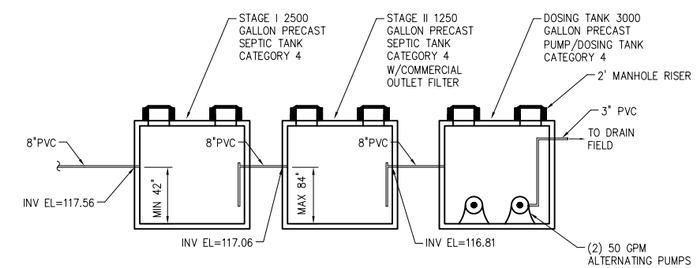

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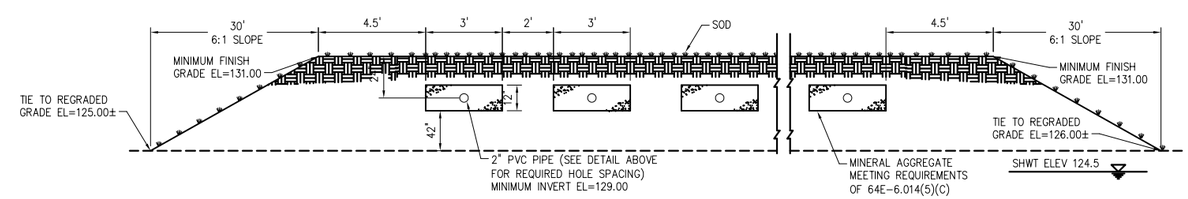

TYPICAL SECTION THRU EXISTING DRAIN FIELD

N.T.S.

1"=20'-0" 20 10 0 20'

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

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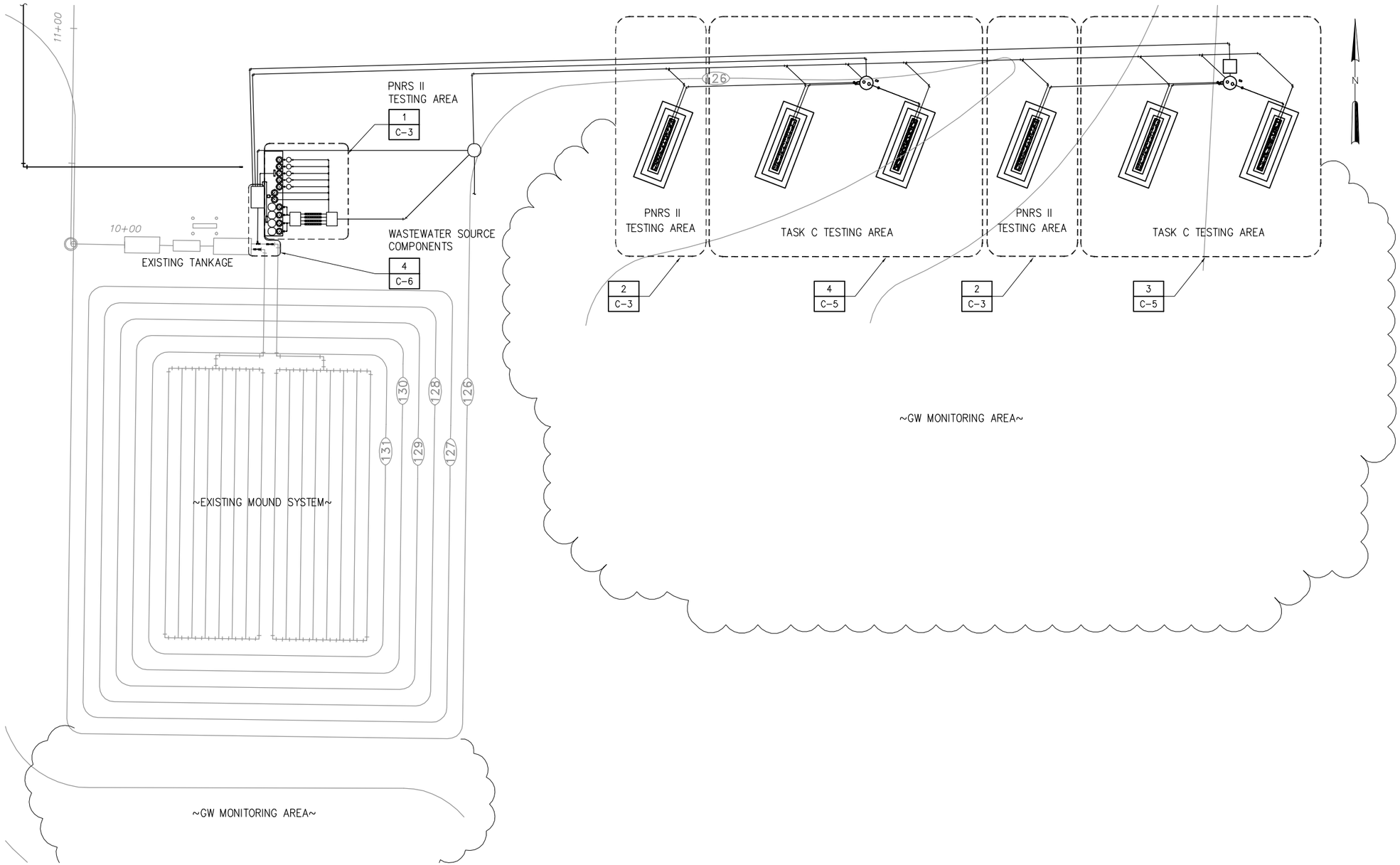

PROPOSED SITE PLAN

1"=20'

1"=20'-0"

20 10 0 20'

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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OVERALL PROPOSED SITE PLAN

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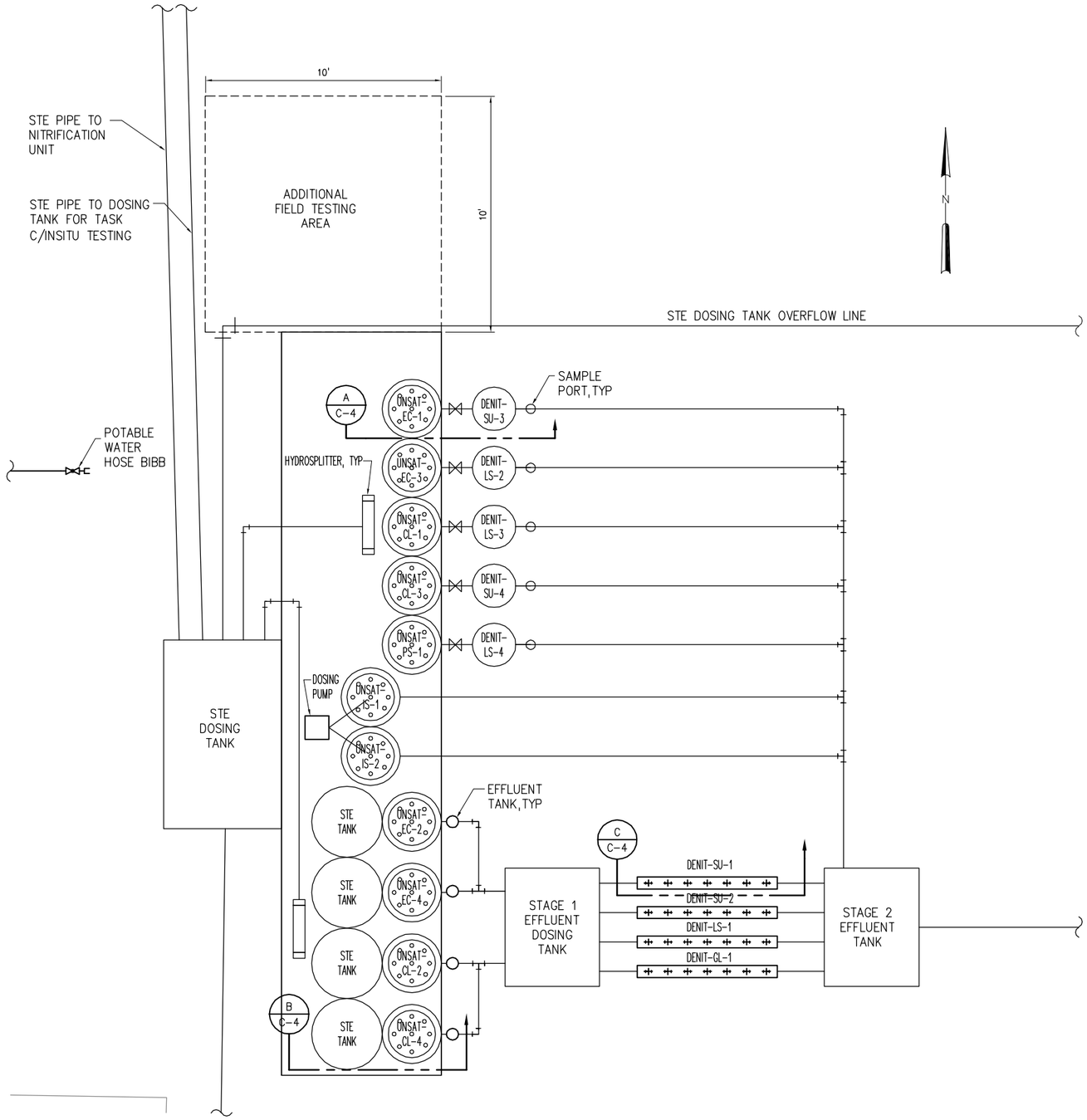

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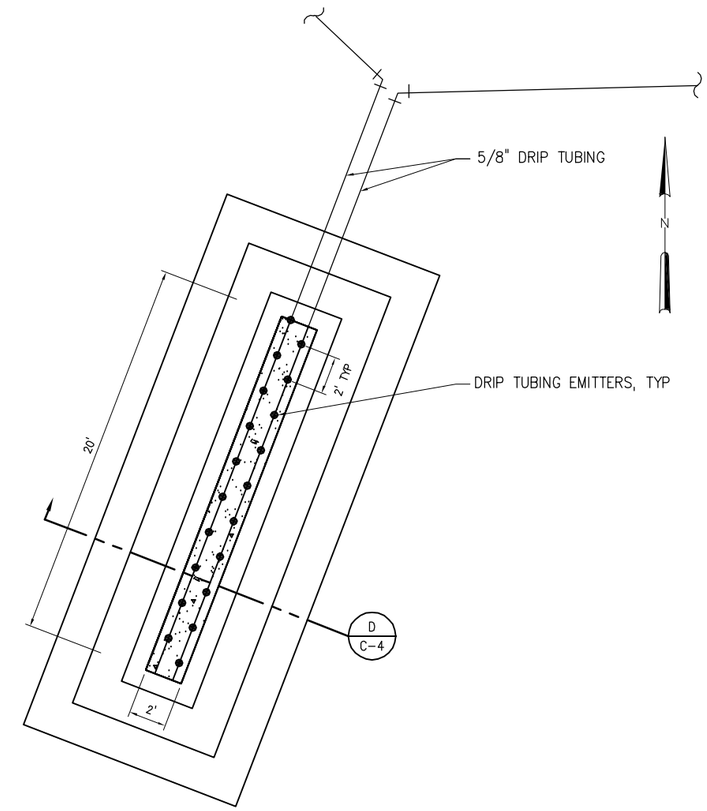

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DETAIL 2 / C-2
3/8"=1'-0"

3/8"=1'-0"

12" 0 1 2 4'

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

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4052 BALD CYPRESS WAY, BIN A08
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PNRS II DETAILS

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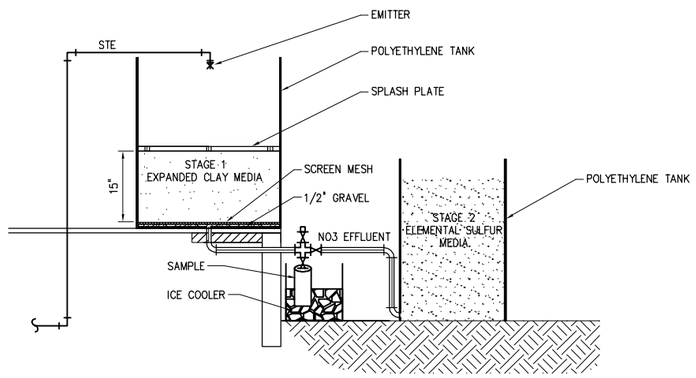

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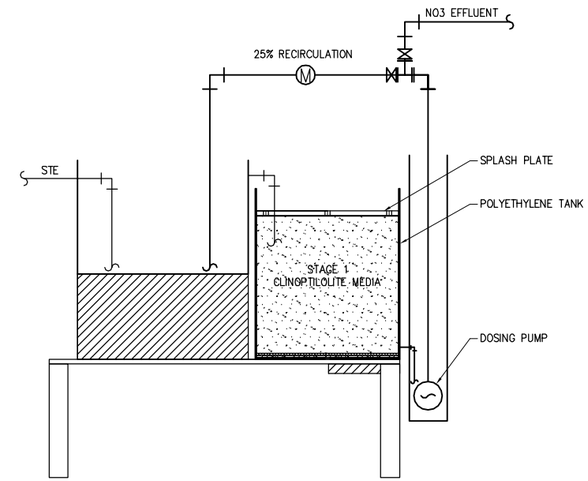

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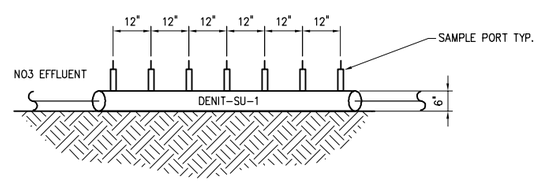

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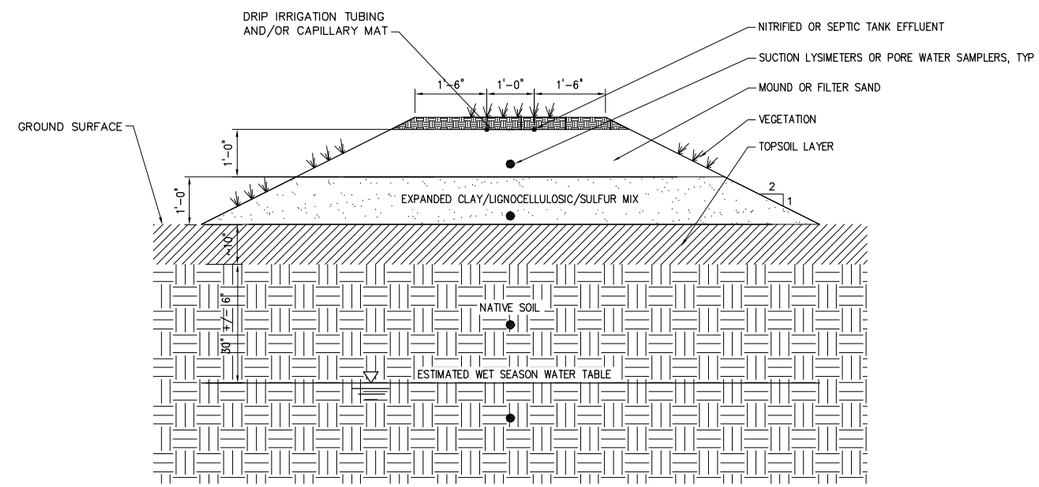

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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
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PNRS II DETAILS

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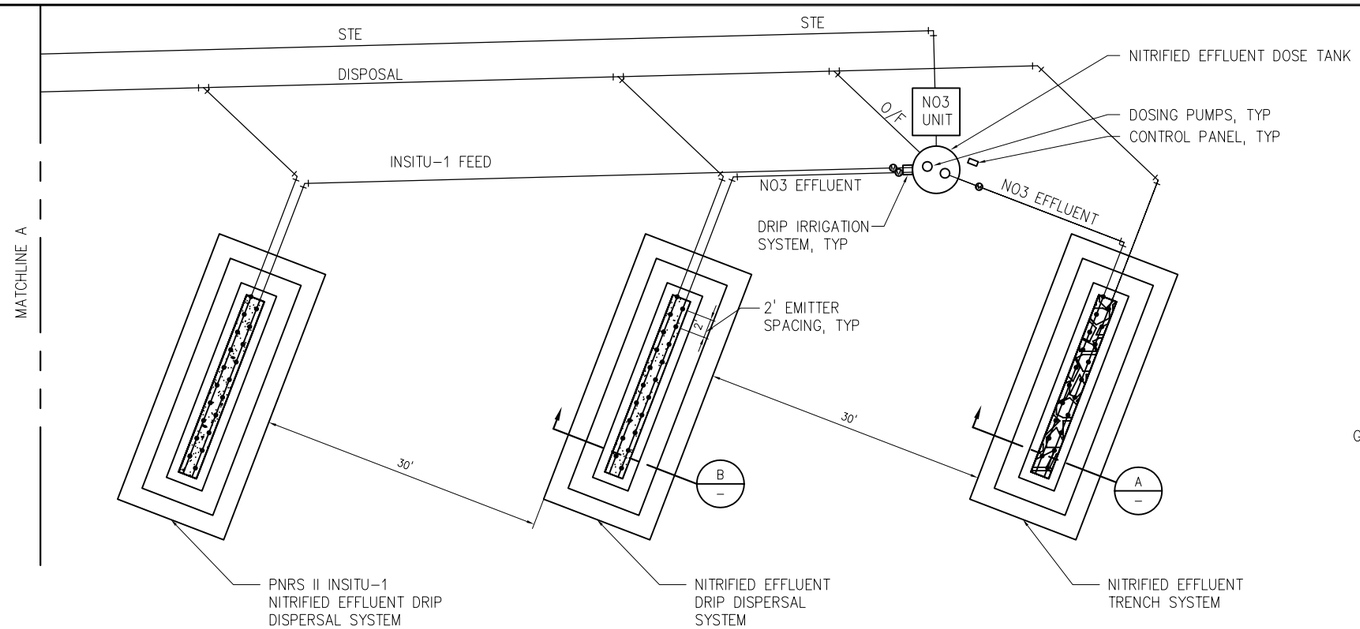

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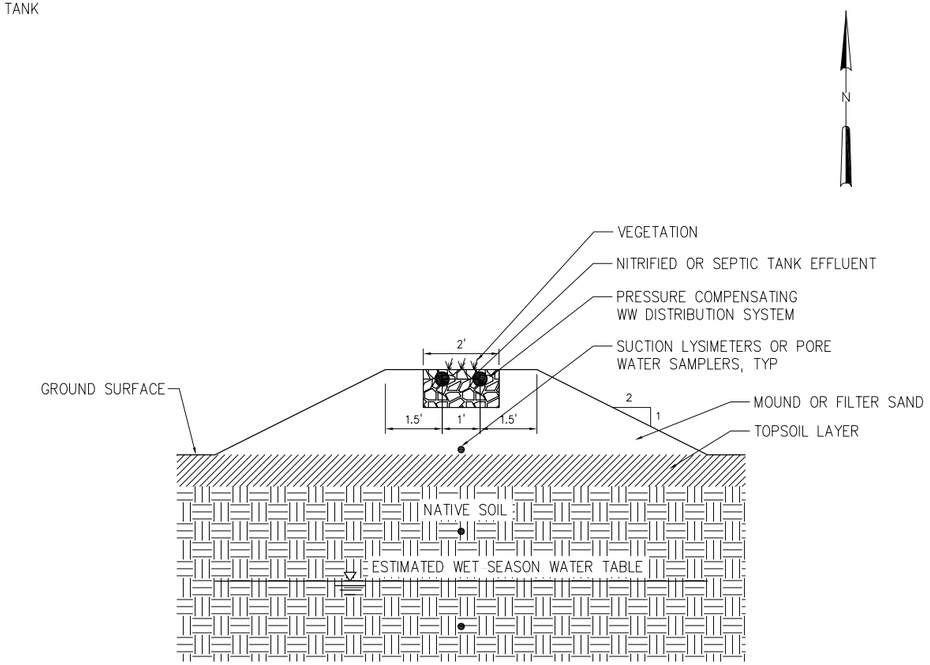

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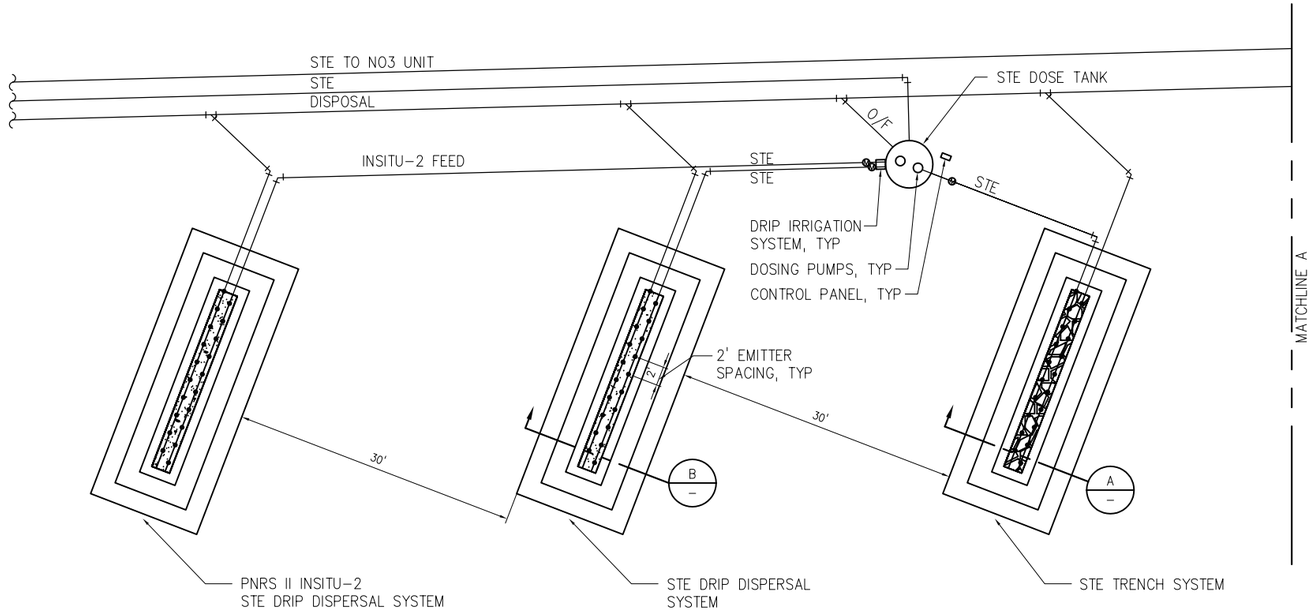

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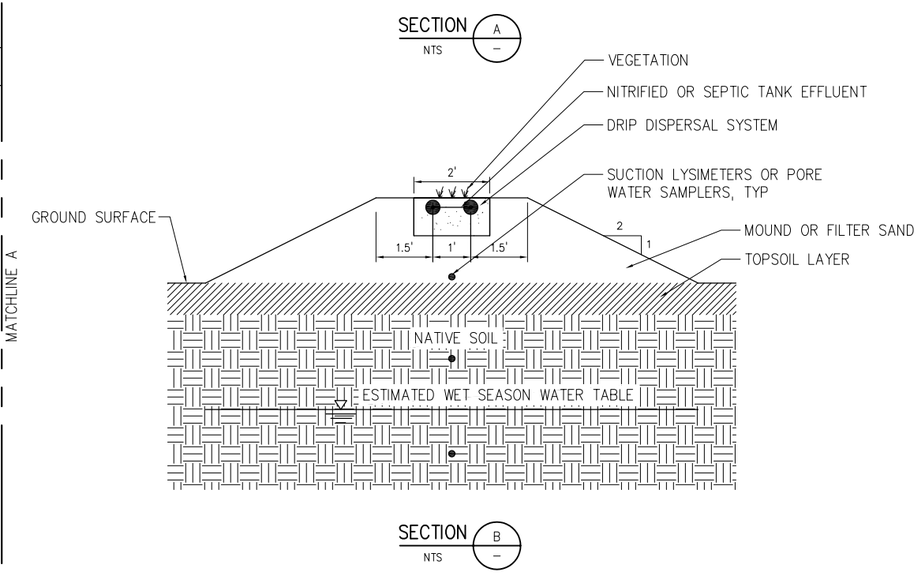

SECTION B
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10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

TASK C NITROGEN FATE & TRANSPORT STUDY
DETAILS

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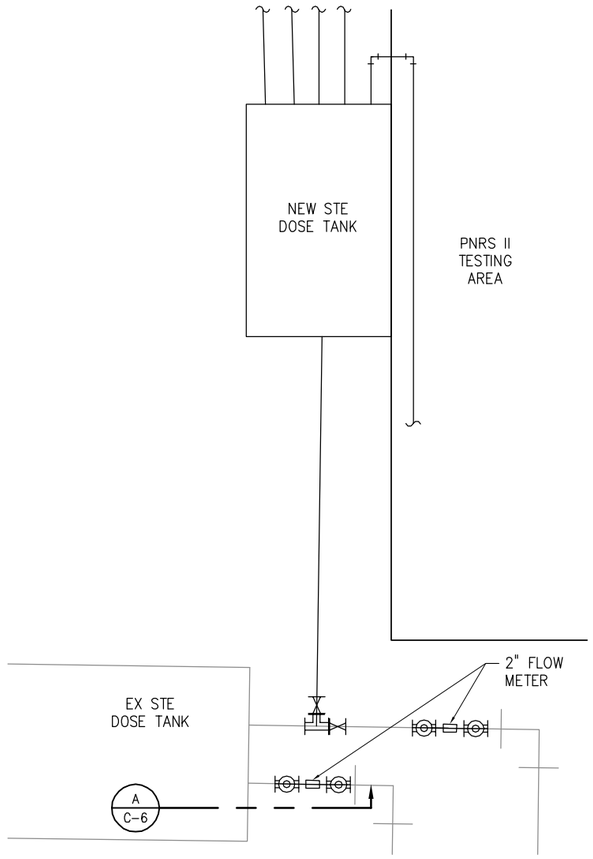

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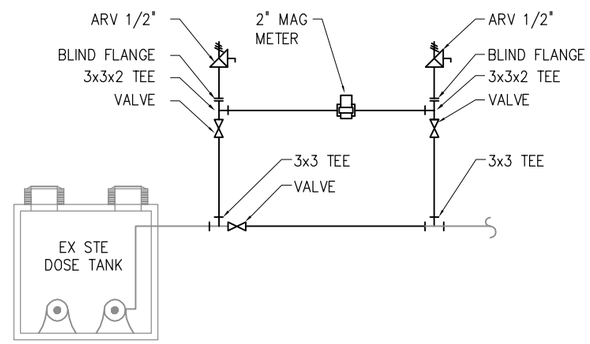

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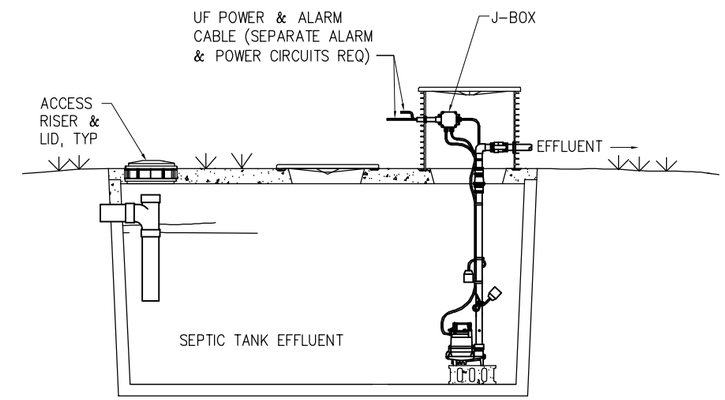

TYPICAL DOSE TANK

DETAIL 5 / M-1
NTS

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

WASTEWATER SOURCE COMPONENTS DETAILS

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CONTRACT NUMBER
DRAWING NUMBER C-6

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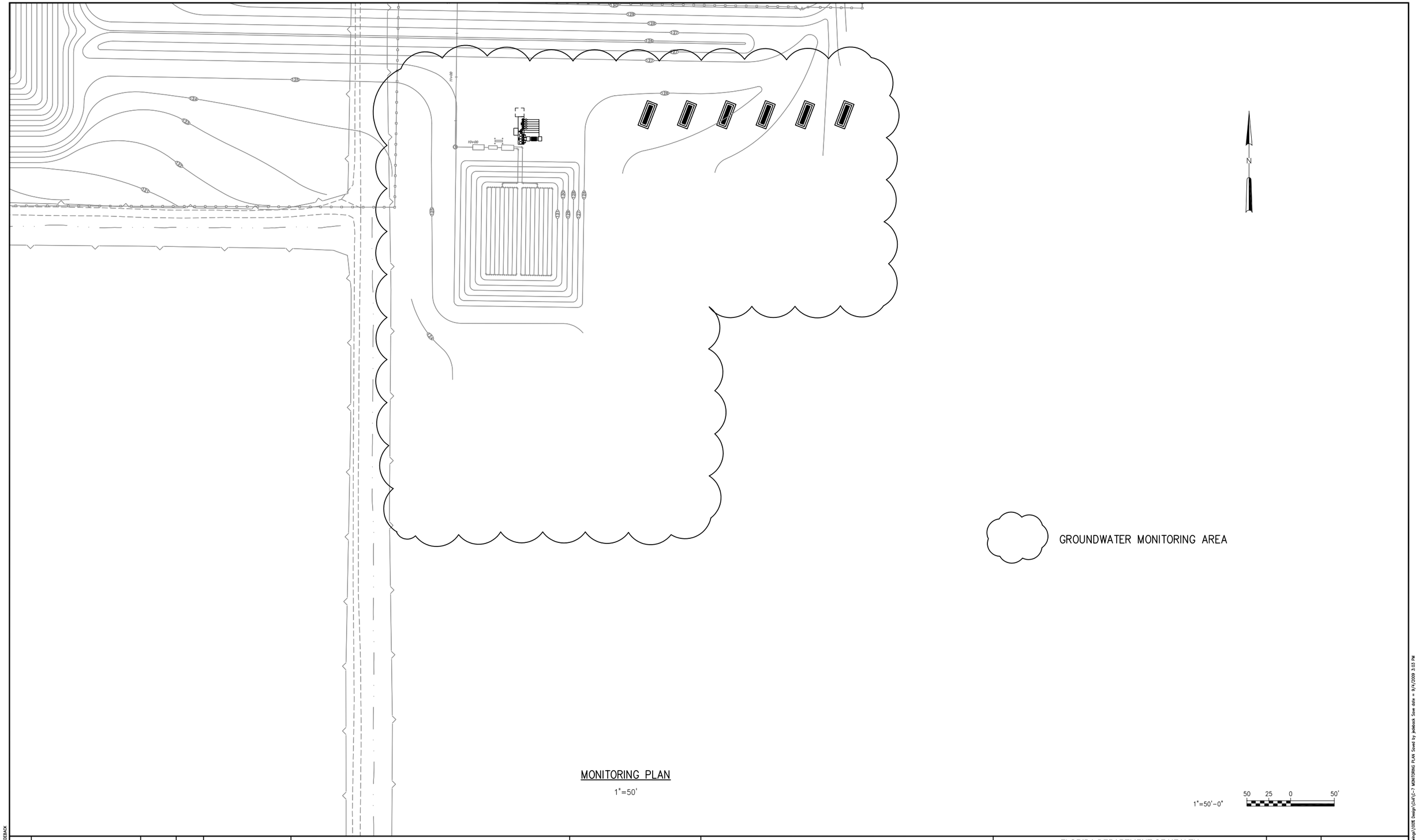

MONITORING PLAN

1"=50'

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Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

MONITORING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

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PLOT DATE: 9/4/2009 3:40 PM BY: JEDEBACK

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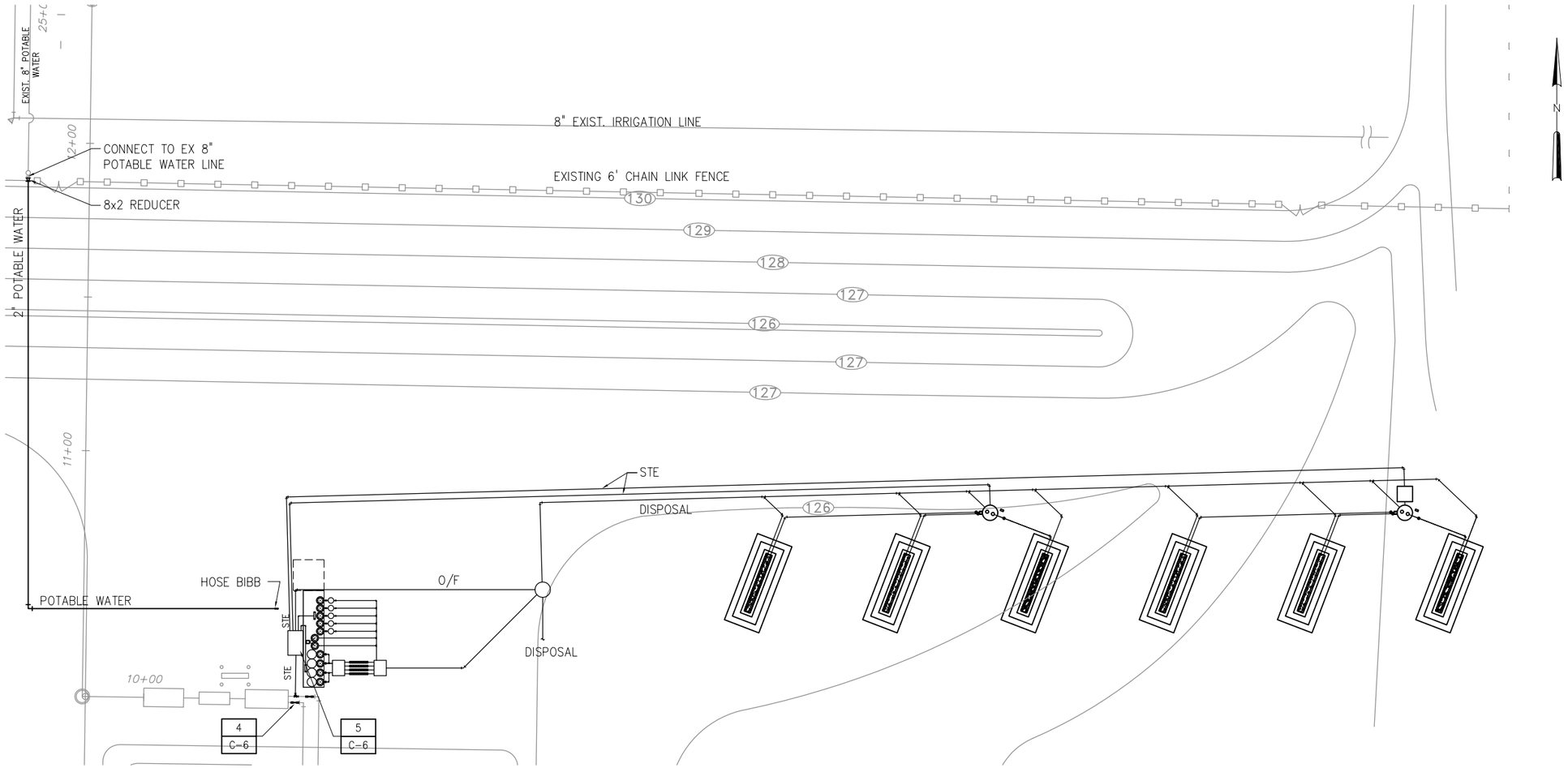

YARD PIPING PLAN

1"=20'

1"=20'-0" 20 10 0 20'

NO.	ISSUED FOR	DATE	BY

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

FLORIDA DEPARTMENT OF HEALTH
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

YARD PIPING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER M-1

PLOT DATE: 9/4/2009 2:37 PM BY: JEDSMUCK

File = G:\44237-001-TP\44237-001\Drawings\1035 Design\Mechanical\M-1 YARD PIPING PLAN Saved by jedsmuck Save date = 9/4/2009 11:35 AM

HEADHOUSE
5208
FFE=133.65

GREEN-HOUSE
FFE = 134.14
3,600 SF

FUTURE GREEN-HOUSE

5204 EQUIPMENT/CART STORAGE
FFE = 134.67

EXISTING PANEL 38A BREAKER

5207 FIELD STORAGE / PEST MIX
FFE = 133.67

1-24,300 SF
SHADEHOUSE
FFE = 131.80

3/4"C 2-#12, 1-#12G

EXISTING 6' CHAIN LINK FENCE

ADDITIONAL RECEPTACLE

EX POLE

EX DISCONNECT

NEW GFI WEATHERPROOF RECEPTACLE

ELECTRICAL SITE PLAN

1"=40'

1"=40'-0"

40 20 0 40'

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10002 Princess Palm Avenue
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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ELECTRICAL SITE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER E-1

PLOT DATE: 9/4/2009 2:50 PM BY: JEREBACK

File = Q:\44237-001-TPA\44237-001\Drawings\100% Design\Electrical\E-1 ELECTRICAL SITE PLAN.Saved by jeberback Save date = 9/4/2009 11:28 AM

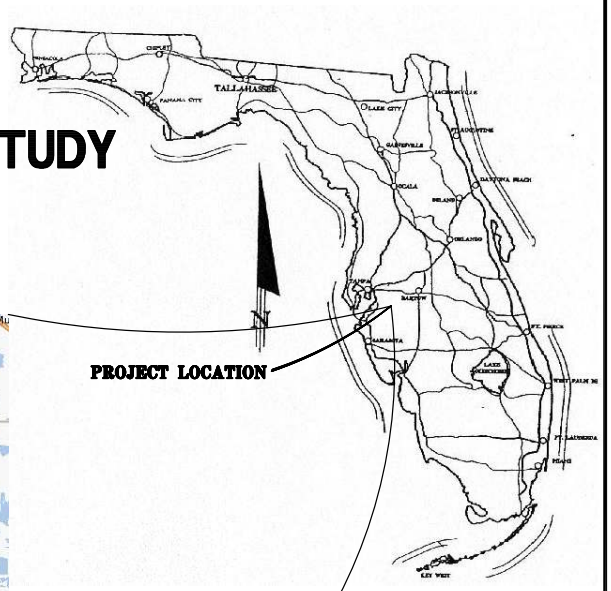
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATEGIES STUDY 50% DESIGN DOCUMENTS

LIST OF DRAWINGS

SHEET COUNT	SHEET NUMBER	SHEET TITLE
		GENERAL
1	G-1	COVER SHEET AND INDEX OF DRAWINGS
		CIVIL
2	C-1	EXISTING ONSITE SEPTIC TANK SYSTEM
3	C-2	PROPOSED OVERALL SITE PLAN
4	C-3	PNRS II DETAILS
5	C-4	PNRS II DETAILS
6	C-5	TASK C NITROGEN FATE OF TRANSPORT STUDY DETAILS
7	C-6	WASTEWATER SOURCE COMPONENTS DETAILS
8	C-7	MONITORING PLAN
		MECHANICAL
9	M-1	YARD PIPING PLAN
		ELECTRICAL
10	E-1	ELECTRICAL SITE PLAN

LOCATION MAP

N.T.S.



PROJECT LOCATION
UNIVERSITY OF FLORIDA
GULF COAST RESEARCH AND EDUCATION CENTER
WIMAUMA, FL.

HAZEN AND SAWYER
Environmental Engineers & Scientists

10002 Princess Palm Ave., Suite 200
Tampa, Florida 33619
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Summary of Comments on C:\Documents and Settings\cscott\My Documents\FDOH.dwf

Page: 1

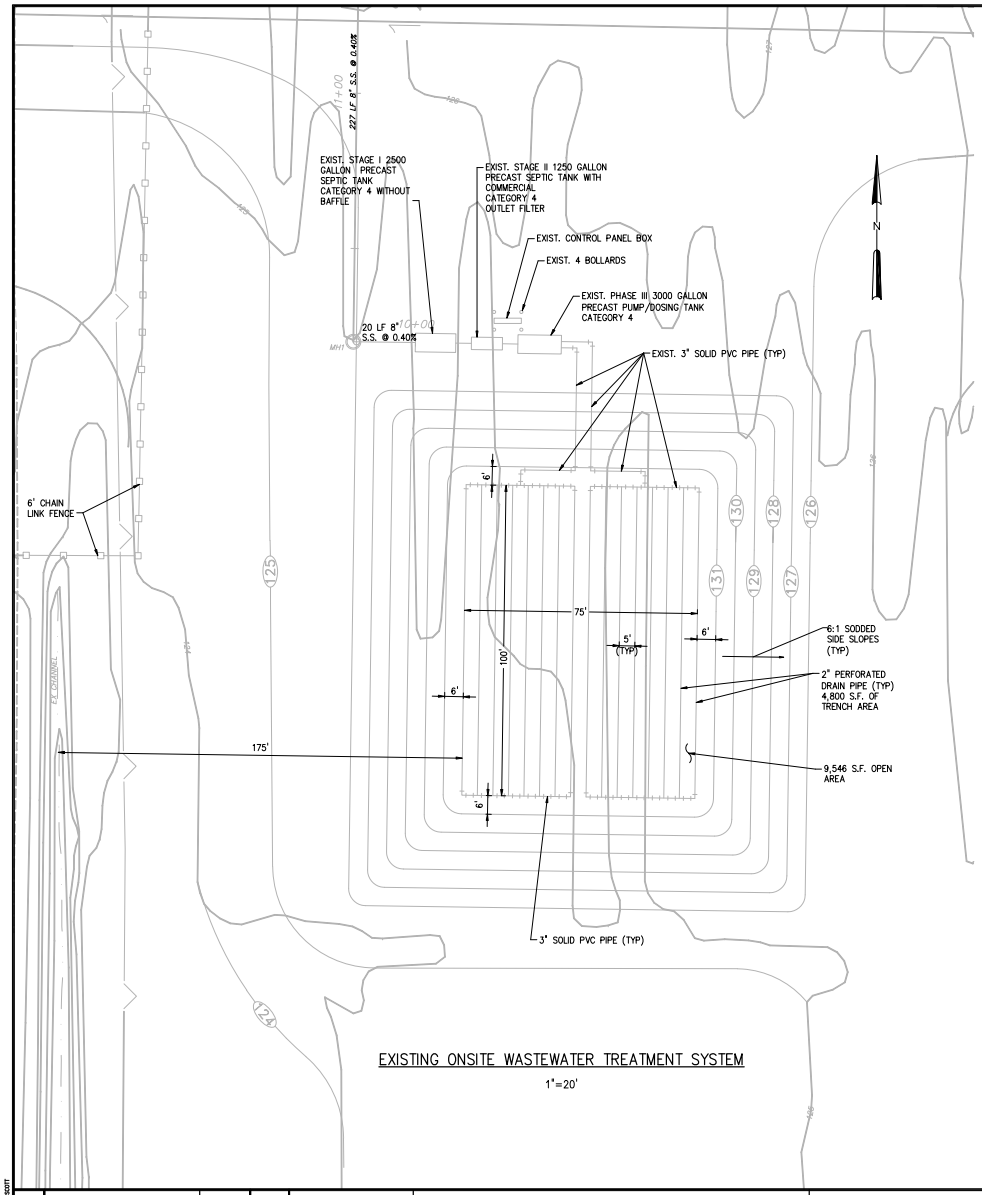
Number: 1 Author: UrsinEL Subject: Note Date: 8/26/2009 4:30:54 PM

Comments from Patti Sanzone:

Drawing No. C-3 – What does the line up the left side of the page and partially across the top go to or represent?
Drawing No. C-5 - What does the line, with what might be a valve on the end, up on the top left side of the page, seemingly not attached to anything, represent?
Drawing No. C-6 – Detail 5 / C-2 does not appear to have a corresponding notation of location on Drawing No. C-2.
Drawing No. C-7 – I presume that the groundwater movement in the area has been looked at sufficiently to assure that there will be no sideways movement toward the northwest of effluent from the farthest west test site and the background monitoring area north of the existing onsite system.
Drawing No. M-1 – What is the existing "line" that is shown toward the top, indicated with small squares across it? See Drawing No. E-1. Is this a fence? What is the dashed line representing?
Drawing No. E-1 – What are the tightly dashed lines as opposed to the other dashed line further to the south? Is the line with the squares along it a fence or something else?
Is there supposed to be a sheet showing the symbols to be used throughout the plan drawings? If not, shouldn't details that I noted be labeled?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:02:45 AM

Drawing C-3: This line is a line that transfers STE to the PNRS II Insitu and Task C testing area (see sheet M-1) for entire line, see new drawing C-2
Drawing C-5: That is a potable water line with a hose bib for the testing area (see sheet M-1)
Drawing C-6: Detail 5/C-2 should be Detail 5/M-1
Drawing C-7: We have installed 5 piezometers so far to monitor groundwater flow direction, and it appears to be from NE to SW
Drawing M-1: The line with small squares is a 6' chain link fence
Drawing E-1: We will label existing lines



EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

1"=20'

EXISTING DRAIN FIELD CALCULATION

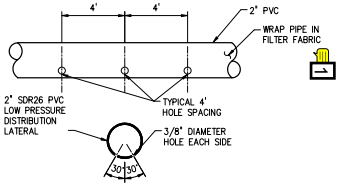
BASED ON UNSUITABLE SUBSURFACE CONDITIONS

LOAD RATE = 0.65
TRENCH AREA = 2828 GPD/0.65 = 4351 SF
OPEN AREA = 2 x 4351 SF = 8702 SF

EXISTING SYSTEM FLOW CALCULATION

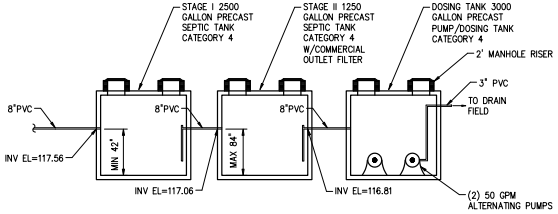
DESIGN FLOW (PER 64E-6.008(1b) TABLE 1)

ADMIN/STAFF (100x15)	= 1500 GPD
SCHOOL [STUDENT BOARDING TYPE] (16 x 75 GPD)	= 1200 GPD
ADD FOR SHOWERS (16 x 4)	= 64 GPD
ADD FOR CAFETERIA (16 x 4)	= 64 GPD
TOTAL	= 2828 GPD



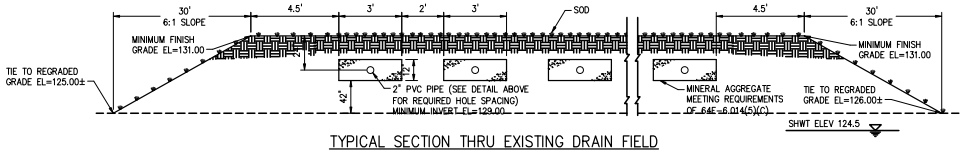
EXISTING HOLE SPACING DETAIL

N.T.S.



EXISTING SEPTIC TANK CROSS-SECTION

N.T.S.



TYPICAL SECTION THRU EXISTING DRAIN FIELD

N.T.S.

1"=20'-0" 20 10 0 20'

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Environmental Engineers & Scientists
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-1

PLOT DATE: 7/7/2009 11:46 AM BY: DCOTT

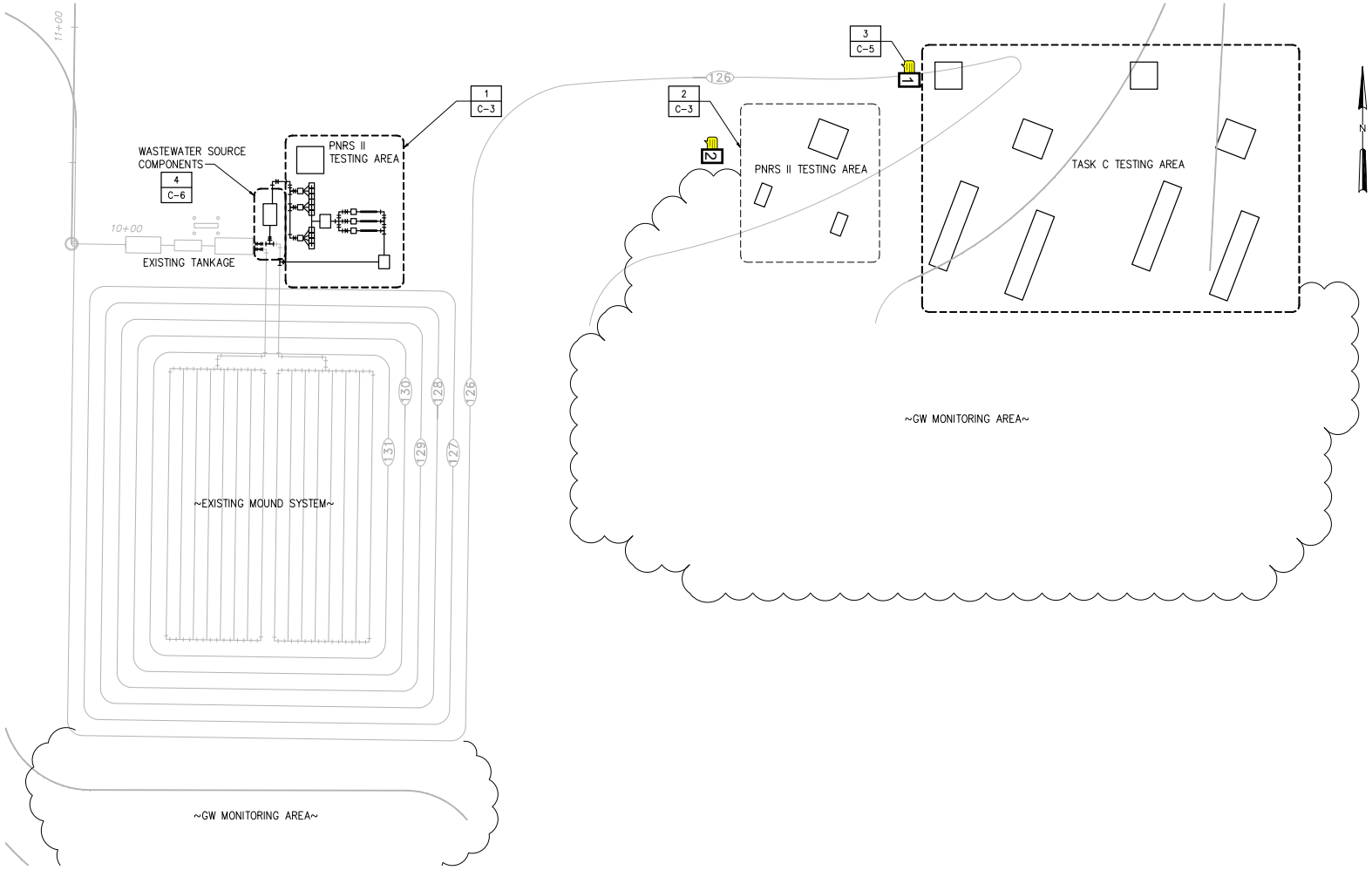
File = U:\44237-001-FH\44237-001\Drawings\Dwg\C-1 EXISTING SEPTIC TANK.DWG Saved by jackson.tom date = 6/29/2009 8:19 PM

Number: 1 Author: RoederEX Subject: Note Date: 9/1/2009 11:52:42 AM

Why is the dosing pipe wrapped in filter fabric? How did this come about?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:03:44 AM

This is from the existing mound system design details. Ask your local health department representative



PROPOSED SITE PLAN

1"=20'

1"=20'-0" 20 10 0 20'

NO.	ISSUED FOR	DATE	BY

DESIGNED —
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4052 BALD CYPRESS WAY, BIN A08
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OVERALL PROPOSED SITE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-2

Page: 3

Number: 1 Author: UrsinEL Subject: Note Date: 9/1/2009 11:57:14 AM

The Detail box #5 listed on C-6 is not shown on this plan.

Author: jedeback Subject: Sticky Note Date: 9/2/2009 1:45:00 PM

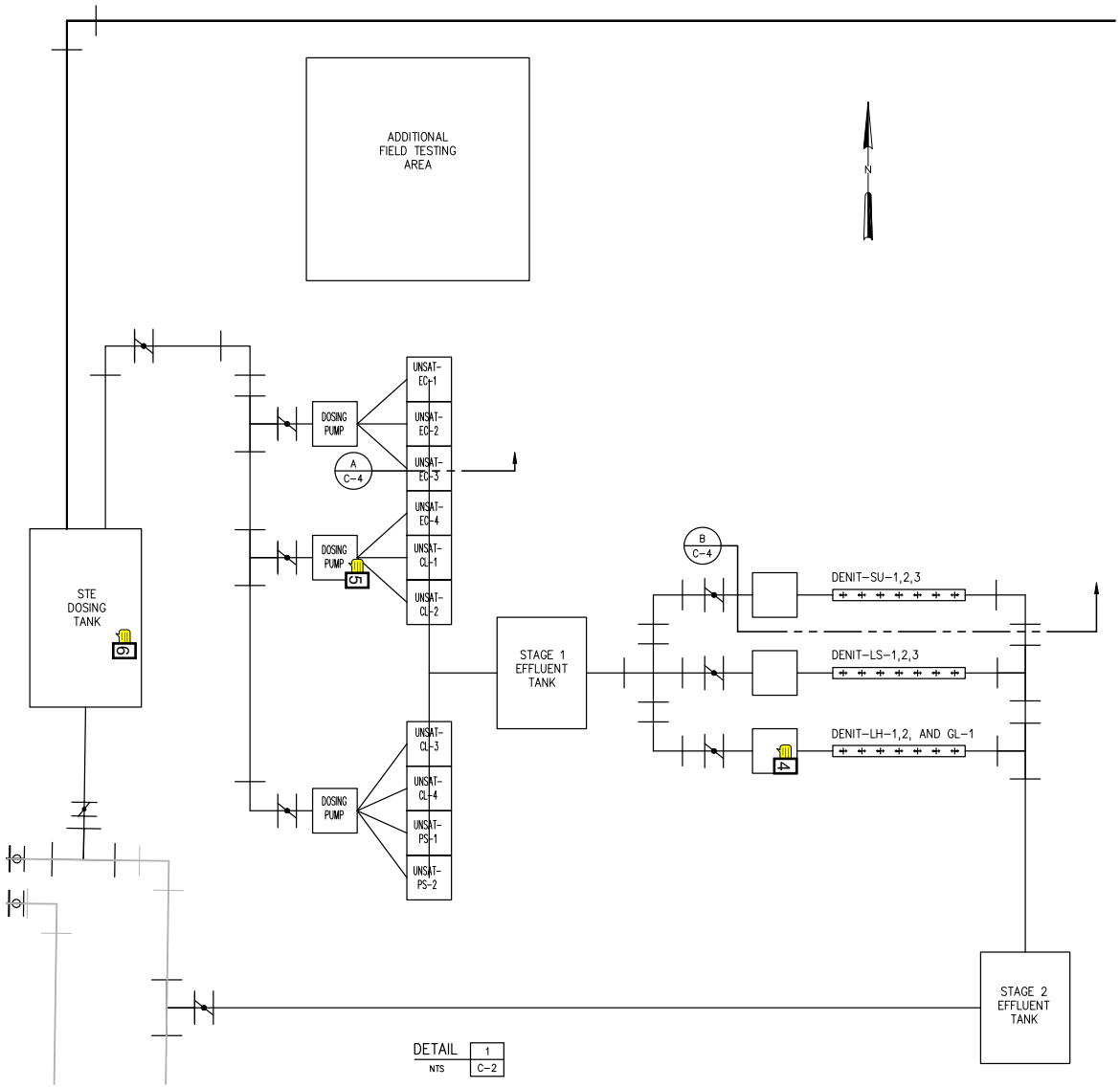
Incorrect call-out on sheet C-6, should be referencing M-1 not C-2

Number: 2 Author: UrsinEL Subject: Note Date: 9/1/2009 11:57:27 AM

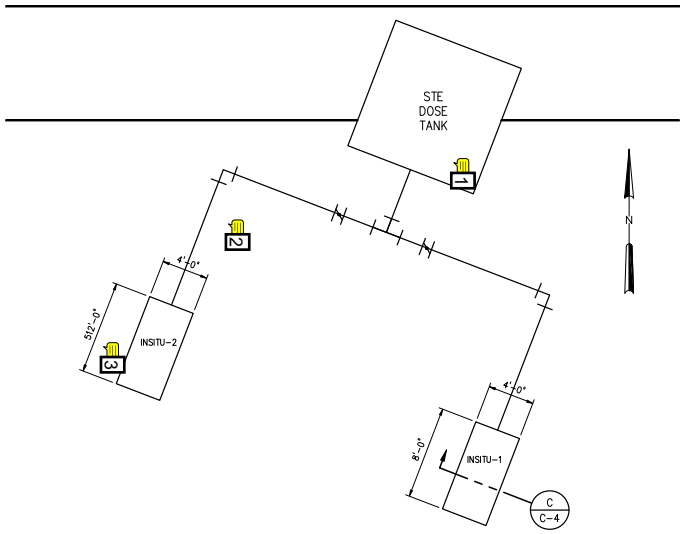
How does the effluent get to Part 2 of the PNRS II Testing Area and the Part 3 Task C area? I see that this is shown on M-1, but is there a way this could be shown here too?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:05:39 AM

Yes, we can include on this sheet as well. See new sheet C-2



DETAIL 1 / C-2
NTS



DETAIL 2 / C-2
NTS

NO.	ISSUED FOR	DATE	BY

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

PNRS II DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-3

Number: 1 Author: RoederEX Subject: Note Date: 9/1/2009 1:01:49 PM
Where is the nitrification unit to make nitrified effluent mentioned in the QAPP?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:06:17 AM
See new sheet C-5 which includes the nitrification unit

Number: 2 Author: RoederEX Subject: Note Date: 9/1/2009 1:07:23 PM
where are the recirculation/flushing lines?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:06:38 AM
Included on new sheets

Number: 3 Author: RoederEX Subject: Note Date: 9/1/2009 1:07:45 PM
512' seems long compared to the 8' on the other side.

What prompts this geometry of a narrow bed? This would be typically fed by two drip lines. Will this represent a bed or a trench?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:07:23 AM
Now revised to 20' long beds. New drawing includes two drip lines.

Number: 4 Author: RoederEX Subject: Note Date: 9/1/2009 12:11:18 PM
Does this represent three dosing pumps on top of each other?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:07:54 AM
New drawings show individual pumps.

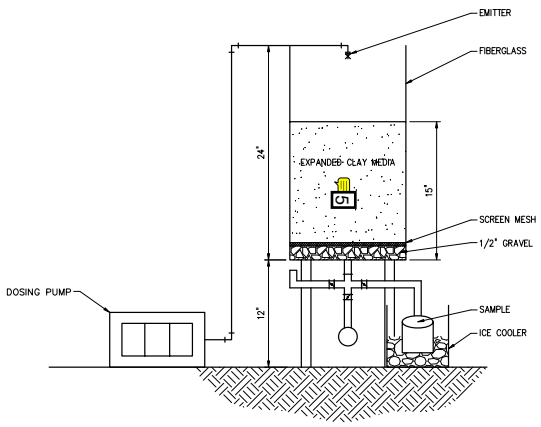
Number: 5 Author: RoederEX Subject: Note Date: 9/1/2009 12:12:07 PM
This does not allow for independent testing of the effect of recycle. There is not provision for recycling at all.

The setup could easily be expanded to address the "magic" mix that is proposed for the in-situ testing

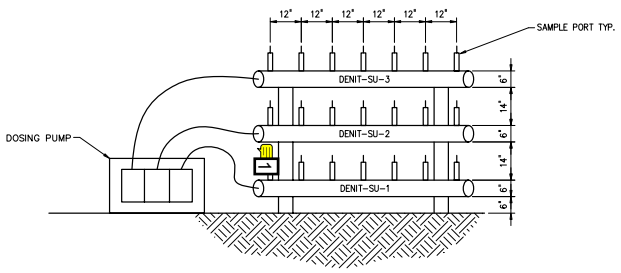
Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:09:37 AM
New drawing shows recycle set-up (see Section B sheet C-4) and two in-situ representations included (Detail 1 sheet C-3) UNSAT IS-1 and UNSAT IS-2.

Number: 6 Author: RoederEX Subject: Note Date: 9/1/2009 12:07:45 PM
What is the proposed residence time in this dosing tank? Will there be any food left?

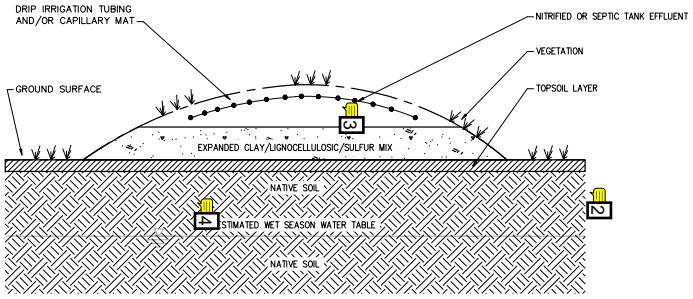
Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:10:07 AM
Will be sized for at the most 2-3 days of storage



SECTION A / C-3
NTS



SECTION B / C-3
NTS



SECTION C / C-3
NTS

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10002 Princess Palm Avenue
Registry One Building, Suite 200
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

PNRS II DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-4

PLOT DATE: 7/7/2009 11:48 AM BY: CSCOTT

Page: 5

Number: 1 Author: RoederEX Subject: Note Date: 9/1/2009 12:57:39 PM

draft QAPP proposed 15 variations (without duplicates and controls), the drawings show only 9. Where are the rest?

What will you use, in the absence of duplicate columns, to assess variability between columns.

Author: jedeback Subject: Sticky Note Date: 9/4/2009 12:07:14 PM

We have included 2 columns to mimic the Insitu testing and have eliminated 6 of stage 2 filters. The QAPP is being revised to reflect this. Currently designed to include (11) Stage 1 filter (2 being In-situ mix representations); (5) Stage 2 single pass; (4) Stage 2 with recirculation

Number: 2 Author: UrsinEL Subject: Note Date: 8/26/2009 4:35:37 PM

Address how Section C will be contained, or how effluent will comply with additives rule, etc.

Author: jedeback Subject: Sticky Note Date: 9/4/2009 12:07:26 PM

The sulfate that will result from the electron donor media in the engineered layer of the drainfield will be monitored, but we do not feel that the small scale of this research study should require consideration of the additives rule.

Number: 3 Author: RoederEX Subject: Note Date: 9/1/2009 12:56:03 PM

What are the specifications on this dome shaped geometry?

Author: jedeback Subject: Sticky Note Date: 9/2/2009 2:02:07 PM

This was just a representative drawing. They will be designed at a 2:1 slope.

Number: 4 Author: RoederEX Subject: Note Date: 9/1/2009 12:18:52 PM

What are the specified thicknesses and distances from water table?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:12:37 AM

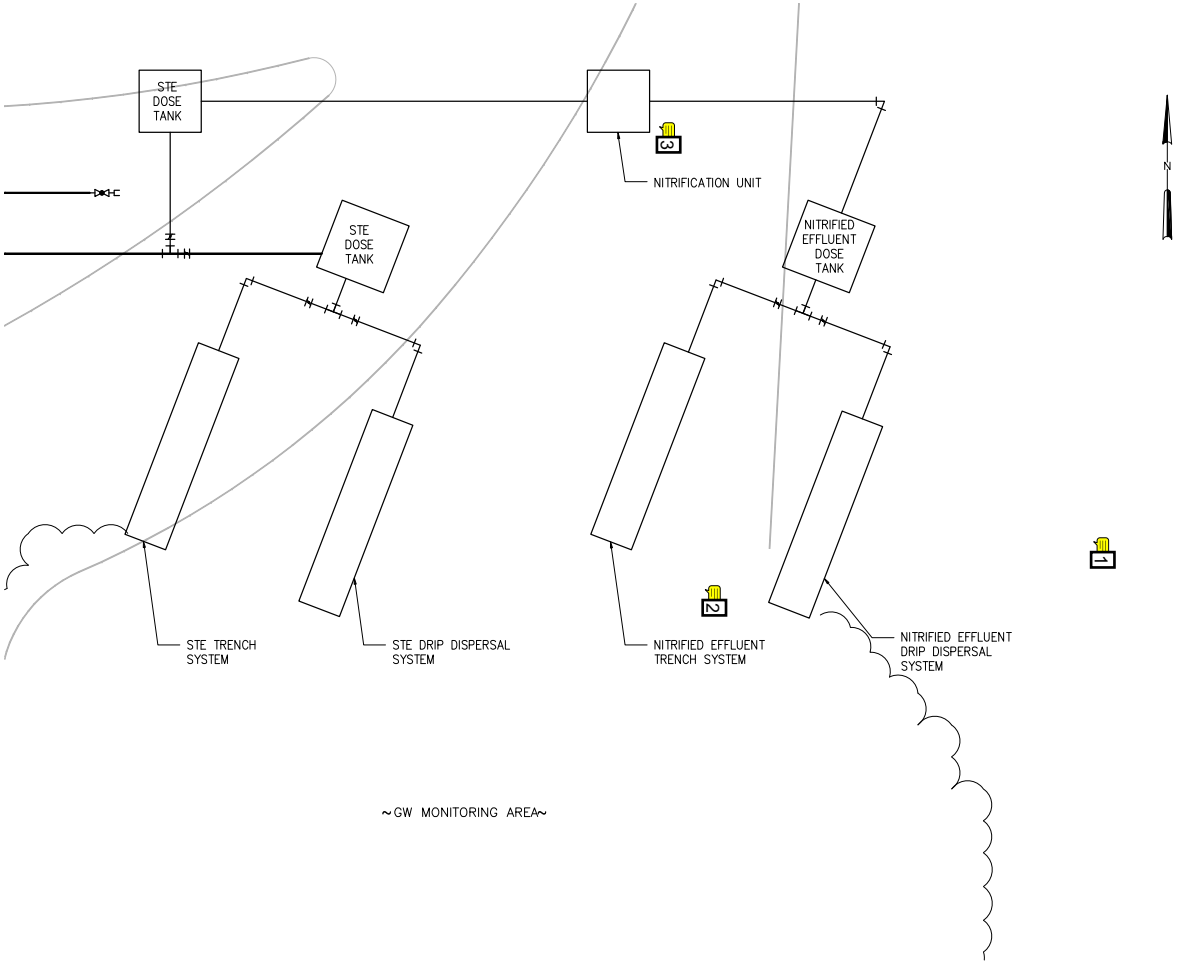
Shown on new drawing, see section D, sheet C-4

Number: 5 Author: RoederEX Subject: Note Date: 9/1/2009 12:59:26 PM

are these columns going to be circular? What diameter?

Author: jedeback Subject: Sticky Note Date: 9/2/2009 2:03:42 PM

Current design is 30" circular tanks



DETAIL 3 / C-2
NTS

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Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

TASK C NITROGEN FATE & TRANSPORT STUDY DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-5

Number: 1 Author: UrsinEL Subject: Note Date: 8/26/2009 4:36:21 PM

Should we see where the monitoring wells will be installed?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:13:20 AM

This will be addressed in the Task C QAPP

Number: 2 Author: RoederEX Subject: Note Date: 9/1/2009 12:55:51 PM

This is a 2x2 experimental design with no duplication. Could you check with Colorado School of Mines how they set up the drip testing. I recall that it had elements of duplication in it.
This approach is going to evaluate drip against what kind of trench material?

Monitoring equipment is missing!

Author: jedeback Subject: Sticky Note Date: 9/4/2009 12:07:56 PM

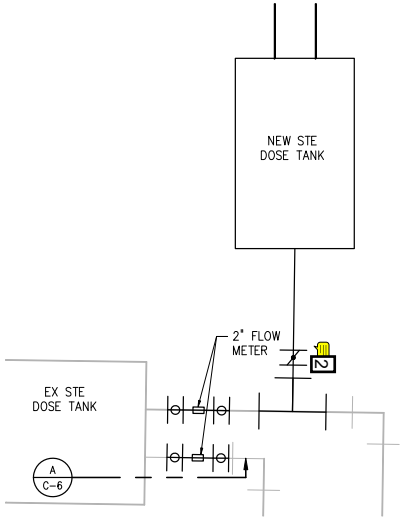
Yes, in a way it is a 2x2 experimental design with no duplication. This will be addressed in the Task C QAPP. The approach will evaluate drip against gravel trench material.

Number: 3 Author: RoederEX Subject: Note Date: 9/1/2009 12:21:58 PM

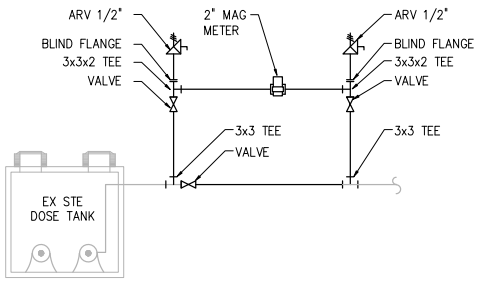
What is proposed as nitrification unit?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:15:10 AM

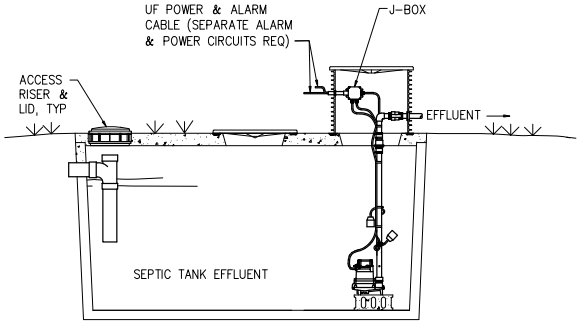
First company to donate one will be the one used



DETAIL 4 / C-2
NTS



SECTION A / C-6
NTS



TYPICAL DOSE TANK

DETAIL 5 / C-2
NTS

1

NO.	ISSUED FOR	DATE	BY

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DRAWN –
CHECKED –
PROJ. ENGR. –
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TALLAHASSEE, FL 32399-1713
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WASTEWATER SOURCE COMPONENTS DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-6

Page: 7

Number: 1 Author: UrsinEL Subject: Note Date: 8/26/2009 4:37:42 PM

Only proposing to mess with dosing lines AFTER they leave the tank, right? There is no proposal to put extra holes in the tank, right?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:15:24 AM

Correct

Number: 2 Author: RoederEX Subject: Note Date: 9/1/2009 12:35:42 PM

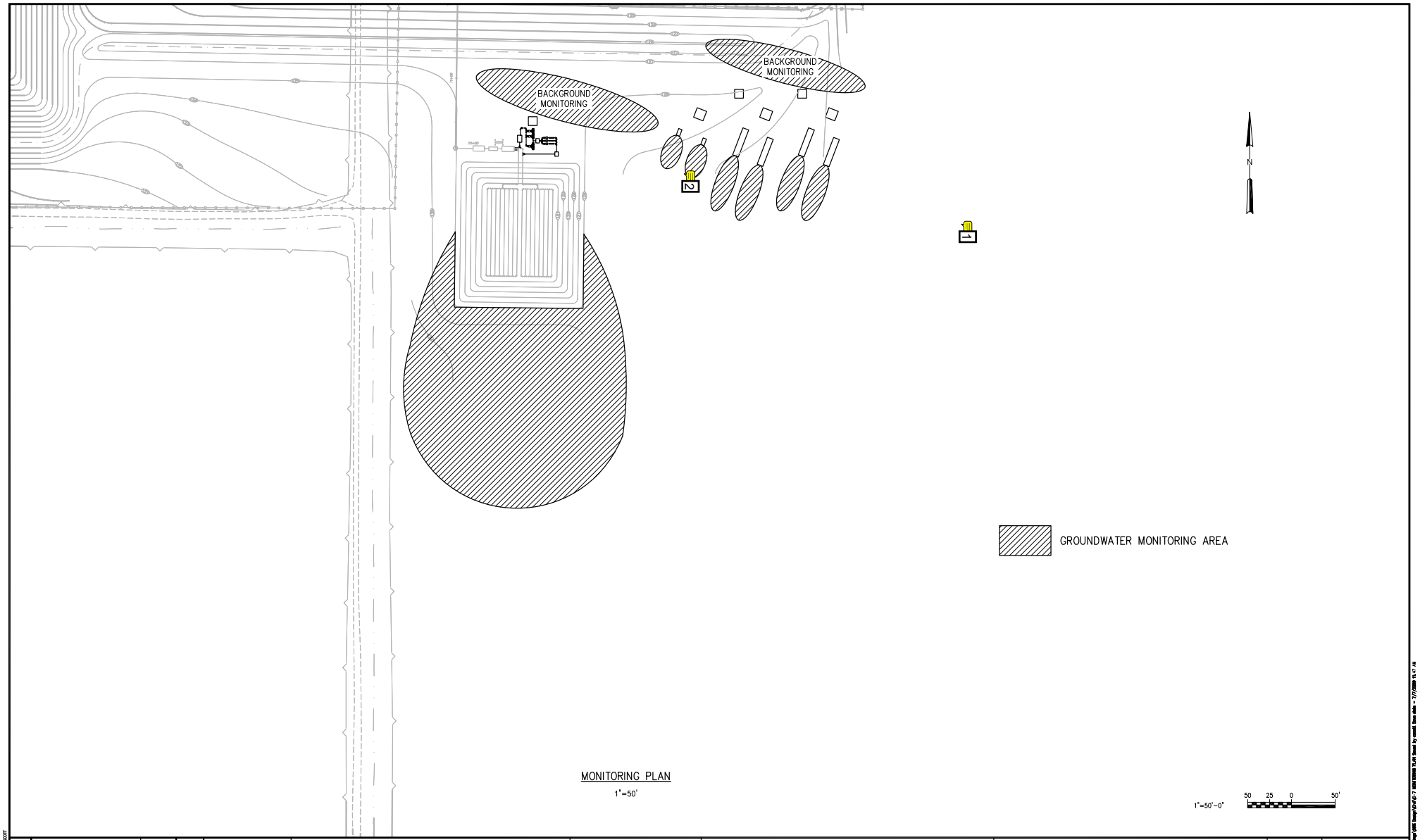
So, the experiment will be fed by one of the existing pumps, so you have a design flow of about 1400 gpd to work with. You need about 30-300 gpd (depending on the diameter of the experimental cells) for the PNRSII columns.

How will you decide how much to bleed off to the existing drainfield? It looks like you just have some valves to adjust.

How big will the new dosing tank be?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:16:24 AM

Yes, valves will be used to adjust. Approximately 2-3 days of storage.



MONITORING PLAN

1"=50'

NO.	ISSUED FOR	DATE	BY

DESIGNED —
DRAWN —
CHECKED —
PROJ. ENGR. —
— APPROVED

Name: Date:
Florida Professional Engineer's Registration Number: —

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

MONITORING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-7

PLOT DATE: 7/7/2009 11:30 AM BY: CCOTT

Page: 8

Number: 1 Author: UrsinEL Subject: Note Date: 8/26/2009 4:36:35 PM

Should we see where the monitoring wells will be installed?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:16:52 AM

This will be addressed in the Task C QAPP

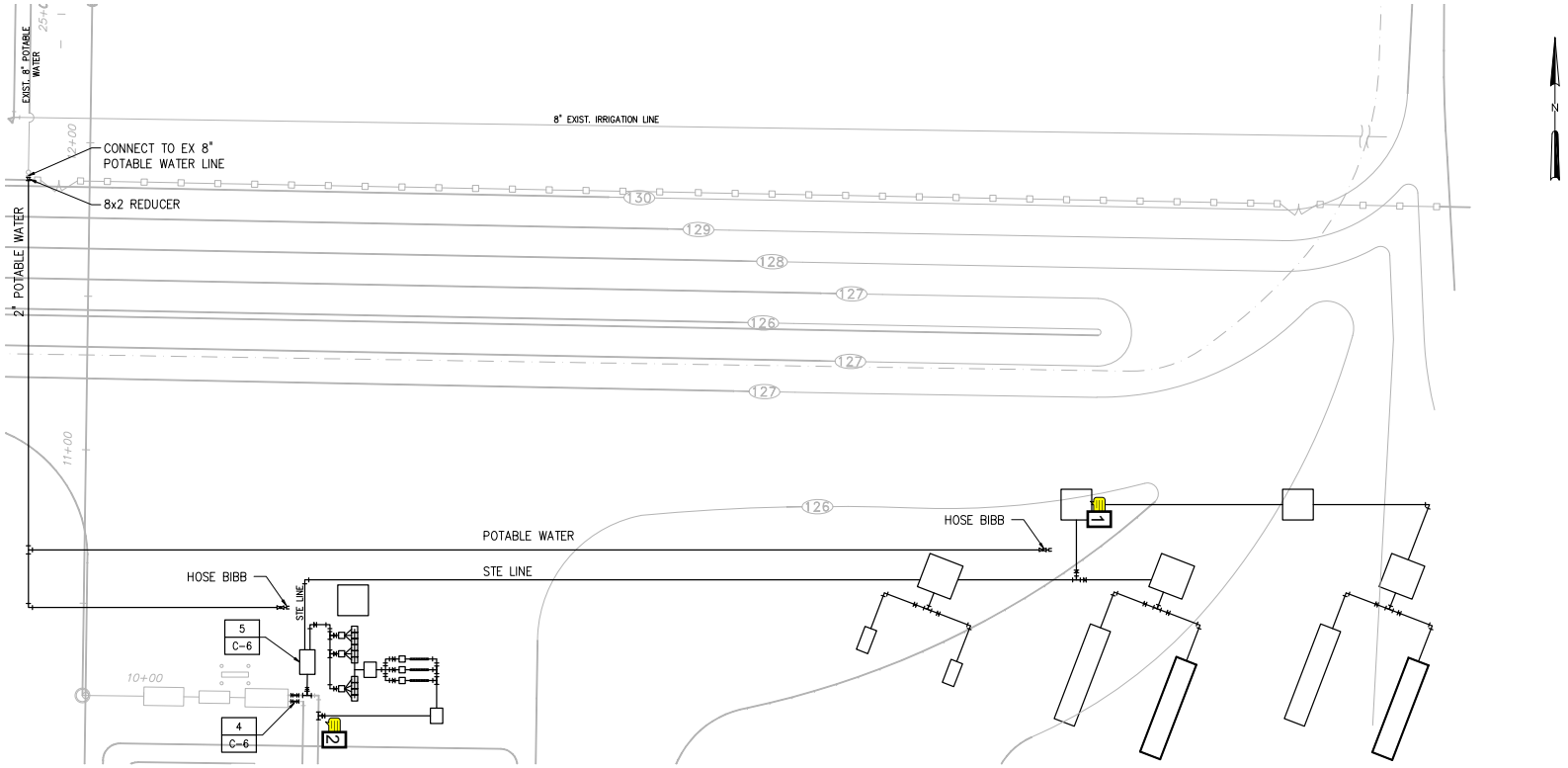
Number: 2 Author: RoederEX Subject: Note Date: 9/1/2009 12:53:46 PM

Looks like one more reason to set this up differently is to allow a better tie-in with task C.

Soil and Groundwater monitoring is not addressed in these drawings

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:17:39 AM

New drawings show these rearranged so that we could better tie in Task C.



YARD PIPING PLAN

1"=20'

1"=20'-0"

20 10 0 20'

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APPROVED —

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Florida Professional Engineer's Registration Number: —

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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YARD PIPING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER M-1

PLOT DATE: 7/7/2009 11:30 AM BY: CCOTT

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Page: 9

Number: 1 Author: RoederEX Subject: Note Date: 9/1/2009 12:45:37 PM

This is the sixth tank that sewage has to pass through. What will it's characteristics be?

An alternative could be to insert several pumps into one dosing tank, so you would have to sample only that one.

Author: jedeback Subject: Sticky Note Date: 9/2/2009 2:07:39 PM

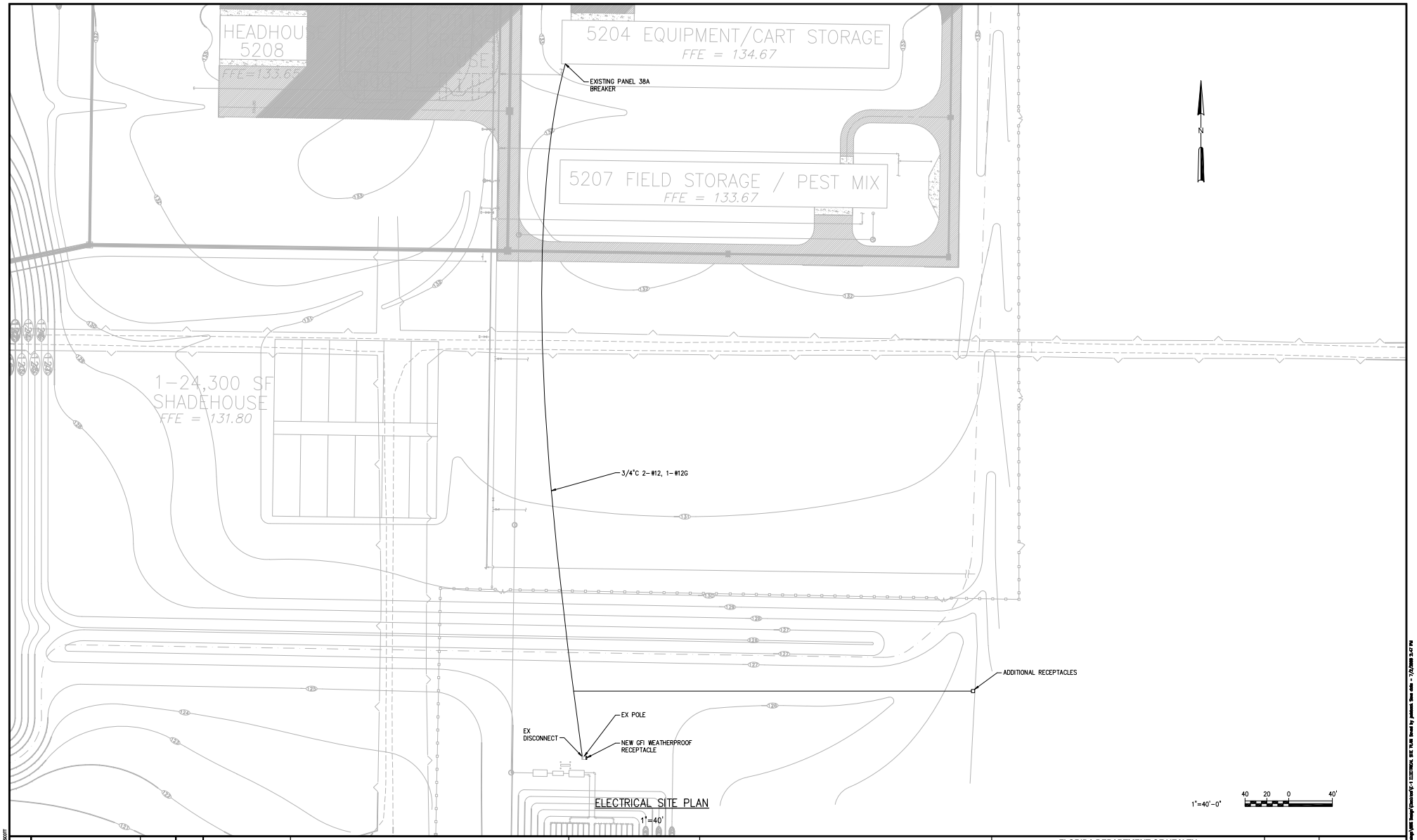
This tank has been removed

Number: 2 Author: RoederEX Subject: Note Date: 9/1/2009 12:42:54 PM

is this a check valve? Is the effluent collector still high enough for gravity flow?

Author: jedeback Subject: Sticky Note Date: 9/4/2009 11:17:52 AM

Revised in new drawings



ELECTRICAL SITE PLAN
1"=40'

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DESIGNED —
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CHECKED —
PROJ. ENGR. —
APPROVED —

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Florida Professional Engineer's Registration Number: —

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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ELECTRICAL SITE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE JUNE 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER E-1

This page contains no comments

FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task C.2

Literature Review of Nitrogen Reduction by Soils and Shallow Groundwater

Final Report

October 2009

4423-001

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK C.2
FINAL REPORT

Literature Review of Nitrogen Reduction by Soils and Shallow Groundwater

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 2009

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

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Section 1.0
Introduction

1.1 Project Background

As a result of the widespread impacts of nitrogen on groundwater and surface waters in Florida, the management of nitrogen sources, including onsite sewage treatment and disposal systems (OSTDS), is of paramount concern for the protection of the environment. As part of Task C of the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study, a review of available research related to the fate and transport of nitrogen is being developed. The primary objectives of this review are to:

- Assess the current available information on nitrogen treatment in soils and the effects to the receiving groundwater;
- Develop a searchable database of available literature concerning nitrogen groundwater contamination and OSTDS;
- Assist in the conceptual understanding of the fate and transport processes that influence distribution of nitrogen in groundwater; and
- Guide future field evaluation efforts and provide additional information to the development of a modeling tool for simulation of nitrogen in groundwater (Task D).

The following presents a literature review to assess the current state-of-knowledge regarding the fate and transport of nitrogen and its movement and distribution in groundwater related to OSTDS. The review will identify existing studies and reports that examine the influence of OSTDS-derived nitrogen inputs, the transformative processes that impact nitrate distribution, and the key factors that result in a significant effect to groundwater quality from OSTDSs. As part of the literature review, a database of the references was developed in conjunction with this summary report. This database (see separate Excel file “Nitrogen Soil-GW Studies”) includes a summary table of the relevant features and parameters of each modeling study. As a result of the large number of identified sources, some studies that were deemed as not valuable to this effort and are mentioned in this report, but are not described in detail and the reader is directed to the database for further information.

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1.2 Nitrogen in Ground Water; Conceptual Considerations

Nitrogen is an important concern for water quality and nitrates represent perhaps the most common groundwater pollutant. Animals, crops, ecosystems, and human health can be adversely impacted by the presence of nitrogen in water supplies. Of these concerns, nitrate impacts to human health have been a primary consideration. The consumption of nitrates has been linked to various illnesses, including cyanosis in infants and some forms of cancer. As a result, in the United States, a maximum allowable nitrate concentration of 10 mg/L as N has been established as protective of human health (Canter, 1996). Other agencies around the world have also established such standards for nitrates in groundwater.

Also of concern are the environmental effects on groundwater and surface water that can result from nitrogen impacts. The degradation of groundwater quality 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).

A survey of community service wells and private domestic wells performed by the U.S. Environmental Protection Agency (EPA) indicated that over half of these water supply wells contained detectable levels of nitrate (Canter, 1996). The sources of this contamination are various, and include agricultural and domestic fertilizer applications, natural sources, wastewater treatment applications, and the use of OSTDS. The last category is often of concern, as nearly 25% of the population in the U.S. and 30% of all new development utilize OSTDS (Lowe et al., 2007). In Florida, nearly a third of all house-holds are serviced by OSTDS and 92% of water supplies come from groundwater (Briggs et al., 2007; Lowe et al., 2007).

Due to the unique features of the geology and hydrogeology, the groundwater systems and ultimately ecological systems and human health may be adversely impacted by nitrogen contamination of groundwater. The geology in Florida is characterized by the presence of sinkholes and fractures that develop in the karst limestone prevalent in many areas (Briggs, Roeder et al., 2007). These features tend to act as preferential flowpaths that can contribute to widespread groundwater contamination and potentially can impact protected surface waters.

Nitrogen transport in the subsurface is a complex process, especially when considering the nitrogen inputs from OSTDS. Meeting the objectives of the FOSNRS project there-

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fore requires the development of a conceptual understanding that includes the relevant fate and transport processes, parameters, and simulation approaches that will appropriately achieve the goals of the project. Figure 1-1 summarizes the conceptual understanding of the inputs of nitrogen and the transformative and advective processes that lead to nitrogen contamination of groundwater. The FOSNRS project should result in tools that will consist of the adequate level of complexity to represent these processes to accurately simulate the fate and transport of nitrogen species.

Proper OSTDS design, installation, operation, and management are essential to ensure protection of the water quality and the public served by that water source. Assuming soils and site conditions are judged suitable, a wide variety of OSTDS are designed and installed (U.S. EPA, 1997, 2002; Crites and Tchobanoglous, 1998; Siegrist, 2001). Conventional OSTDS rely on septic tanks for the primary digestion of raw wastewater followed by discharge of septic tank effluent (STE) to the subsurface soils for eventual recharge to underlying groundwater (Crites and Tchobanoglous, 1998; Metcalf and Eddy, 1991; U.S. EPA, 2002). However, increasing uses of alternative OSTDS rely on additional treatment of the STE prior to discharge to the environment in sensitive areas (e.g., aerobic filter) or in some designs may eliminate use of a septic tank altogether (e.g., membrane bioreactor).

Conventional septic tanks are anaerobic and have long solids retention times (e.g., years) that can enable digestion resulting in a reduction of sludge volume (40%), biochemical oxygen demand (60%), suspended solids (70%) and conversion of much of the organic nitrogen to ammonium (Reneau et al., 2001). Septic tanks are also important as they attenuate instantaneous peak flows from the dwelling unit or establishment. The effluent discharged from the septic tank (i.e., septic tank effluent or STE) then flows to subsequent treatment (e.g., aerobic treatment unit) or directly to the soil treatment unit where the processes of soil adsorption, filtration, and transformation (biological and chemical) occur.

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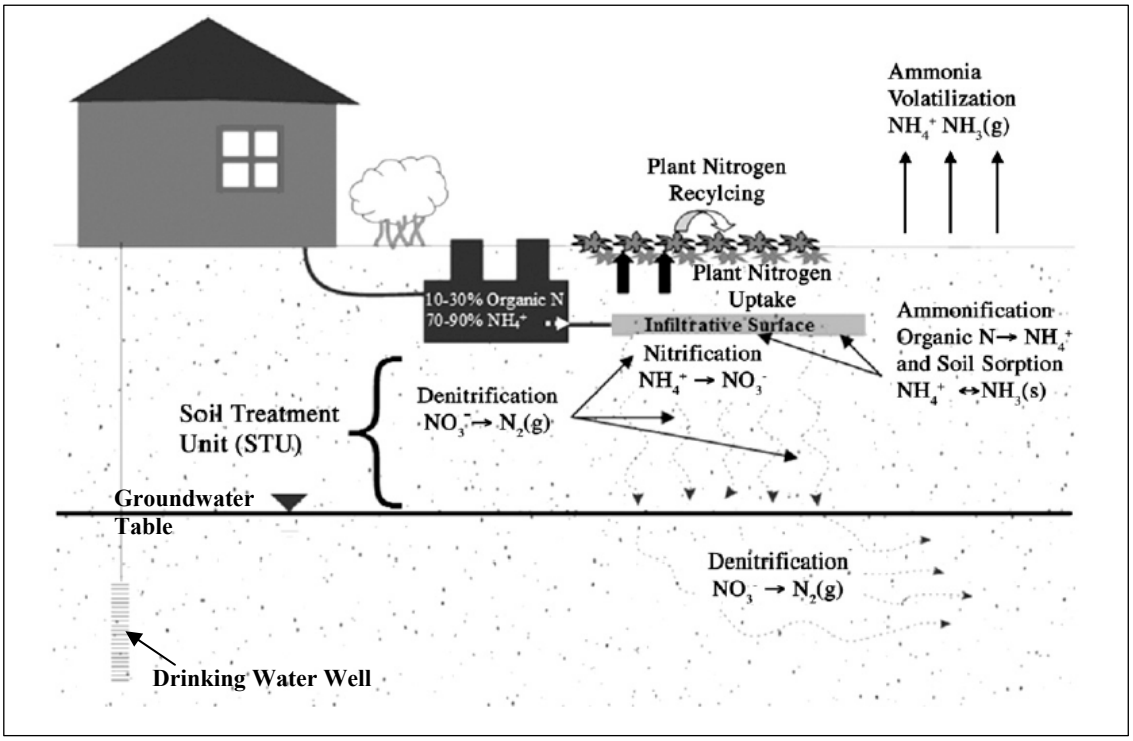

Figure 1-1: Nitrogen Processes Occurring in a Typical OSTDS (adapted from Heatwole and McCray, 2007)

Nitrogen waste products are a considerable component of septic tank effluent. Total nitrogen, composed primarily of organic nitrogen products and ammonium-nitrogen, is typically assumed to range between 20-190 mg-N/L in untreated waste water, and 26-125 mg-N/L in STE (Canter, 1996; Crites and Tchobanoglous, 1998; Lowe et al., 2009). Furthermore, in a recent study that evaluated the composition of raw wastewater and STE, the median total nitrogen concentration in STE specific to Florida was determined to be 65 mg-N/L (average = 61 mg-N/L) (Lowe et al., 2009). In terms of mass loading to the subsurface, the median loading rate was determined to be 10 g-N/capita/d (average = 13.3 g-N/capita/d) (Lowe et al., 2009). McCray et al. (2005) suggested that an average subdivision can generate up to 2880 kg/km^2 annually. While this value is significantly higher than estimates of naturally generated deposition (600-1,200 kg/km^2 annually), it is much lower than the loading that results from fertilizer application (10,000-20,000 kg/km^2 annually). Nonetheless, OSTDS should be considered a potential contributor to groundwater nitrogen concentrations.

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The first stages of nitrogen transformation related to OSTDS occur in the septic tank. Organic nitrogen is mineralized to the inorganic form (ammonia) via the process of ammonification, followed by volatilization to ammonium ions.

$$NH_3(aq) + H_2O \rightarrow NH_4^+ + OH^- \qquad \text{(equation 1)}$$

Once the liquid portion of the wastewater enters the drainfield through the subsurface infiltration system, nitrogen species (specifically ammonium and nitrate) are further transformed in the soil by nitrification and denitrification. Nitrification is a two step process by which ammonium is converted first to nitrite than to nitrate via biological oxidation.

$$NH_4^+ + O_2 \rightarrow NO_2^- + O_2 \rightarrow NO_3^- \qquad \text{(equation 2)}$$

Although a two step process, it can be assumed to be a one step process since the conversion of nitrite to nitrate is relatively rapid. Nitrification is either described as a zero-order or first-order reaction or via Monod kinetics. This particular reaction is of importance, as it represents the transformation from the relatively immobile nitrogen form (ammonium) to the highly mobile form (nitrate). Most studies of OSTDS with suitable unsaturated soil have indicated that little ammonium reaches the underlying groundwater and that most impacts to groundwater from nitrogen are in the nitrate form. Nitrate behaves essentially as a conservative solute, with virtually no sorption or retardation processes affecting its movement in the aquifer. It is, however, subject to transformative processes.

Denitrification is the transformation of nitrate to N_2 gas.

$$5(CH_2O) + 4NO_3 + 4H^+ \rightarrow 5CO_2 + 2N_2 + 7H_2O \qquad \text{(equation 3)}$$

Denitrification occurs in oxygen-free conditions, and is therefore seen in anoxic zones in the soil and groundwater. This reaction is typically described as first-order. However, nitrogen transformations are probably best modeled using Monod kinetics, which result in zero-order rate constants for concentrations typical of nitrate-impacted groundwater. The process, while studied extensively, is not well understood or well quantified.

Understanding denitrification in the saturated zone, while receiving much less focus in the literature, is nonetheless a potentially valuable topic. Korom (1982) provides a thorough review of denitrification in the saturated zone. Although not specific to OSTDS impacts, aquifer denitrification can naturally reduce nitrate concentrations, and can be potentially enhanced via the addition of *in situ* amendments such as sucrose or methanol. This review goes on to include data and estimated denitrification rates found in both la-

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boratory and field studies. In order to assess the contribution denitrification makes to nitrate reductions, researchers will often use the ratio of non-reactive solute (typically chloride) to nitrate along the plume flowpath. Any relative reduction in nitrate can be attributed to denitrification, since a reduction due to mixing with ambient groundwater would not change the ratio. Depending on the aquifer conditions, previous studies concerning the reduction of nitrate concentrations specifically from OSTDS identify denitrification rates as relatively small, and that most reductions occur as a result of mixing with ambient groundwater (see Reneau et al., 1989). A small number of studies however indicate that denitrification may be the dominant process, perhaps characterizing aquifers with low groundwater flux (see Hantzche and Finnemore, 1992).

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Section 2.0
Literature Review

The following presents a summary of available research related to the treatment of nitrogen in soils and the subsequent fate and transport of nitrogen in groundwater.

2.1 OSTDS Performance – Laboratory and Field Studies

A number of studies have looked at the performance of either experimental or conventional OSTDS in terms of the treatment of nitrogen wastes depends on the effluent quality dispersed into the environment and subsequent soil treatment, both of which have a significant influence on the resulting impacts to groundwater. These types of studies are valuable in that they can indicate which factors influence the transformative processes and how various loading rates, soil types, and geochemical parameters may lead to excessive nitrogen concentrations. Furthermore, these studies suggest ways of improving the performance of older or failing OSTDS. A large body of research has been dedicated to this topic and is important for assessing nitrogen in groundwater; however, a full discussion on this topic is beyond the scope of this review, and therefore only a few relevant studies are indicated below.

An in-depth review of the fate and transport of contaminants from on-site systems is provided by Reneau et al. (1989). This study considers multiple factors, including soil type, loading rates, effluent quality, and carbon content. In this review the author describes the important mechanisms related to OSTDS performance. Firstly, he describes the importance of conditions conducive to nitrification, namely coarse-textured soils in which aerobic conditions are dominant. This is even true in fine-grained clay soils as long as unsaturated conditions are present. Denitrification in soils utilized for OSTDS is expected to be minimal except in anaerobic microsites. However, soils that are influenced by fluctuating water tables in which saturated conditions can occur will see increases in denitrification rates. For groundwater, sites which are ideal for OSTDS are often the most vulnerable to nitrate impacts, since they are often well drained soils with limited capacity for denitrification. In this case, often the most important mechanism for nitrate reduction is dilution by ambient groundwater.

Cogger and Carlile (1984) looked at the performance of 15 conventional and alternative OSTDSs to determine their performance in soils with high water tables in North Carolina. The alternative methods included low-pressure pipe systems, soil replacement systems,

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and pressure-dosed mounds. At the study site, shallow groundwater wells were installed around the systems and monitored monthly for nitrogen species. The study found in general that nitrogen species concentrations were markedly influenced by seasonal variations in the water table, although some systems experienced continuous saturation. Those systems that were continually saturated had the poorest performance, as well as those with the heaviest effluent loadings. Additionally, transport of nitrogen products was facilitated by those systems located in areas with high gradients and continuous soil saturation. The low-pressure pipe systems, designed to distribute the effluent of the entire adsorption field and provide occasional dosing rest periods, performed the best in spite of any level of saturation from the water table. The mound system did not perform well, however the authors indicate the pumps feeding the system were not operating correctly and the dosing recommendations were being exceeded. The soil replacement systems showed no improved performance over the conventional systems.

Similarly, Costa (2002) conducted a series of experiments comparing the nitrogen removal capabilities of a conventional system, two proprietary nitrogen removal systems (the Waterloo Biofilter and the MicroFAST Model), and a recirculating sand filter (RSF) system. “Nitrogen losses” are described as reduction in nitrogen from the septic tank effluent to the groundwater. Measurements were conducted over an 18 month period. Results indicate that the conventional system removed 21-25%, the Waterloo 60%, the MicroFAST removed 55%, and the RSF removed 41%.

Cogger et al. (1988) examined the performance of an OSTDS on a coastal barrier island. The study considered loading rate and water table as the primarily influences on OSTDS performance. Two absorption fields were constructed and sampled biweekly for a period of 18 months. Three loading rates (one, four, and six cm/day) were applied in a random fashion. Loading rate was identified as significant. Additionally, periods with a high water table in the early part of the year resulted in anaerobic conditions which inhibited nitrification. Redox conditions were generally considered low. However, in drier conditions, aerobic conditions dominated and more nitrification resulted with corresponding increases in redox parameters. The authors concluded that although loading was a factor, the fluctuations in the water table were more influential in determining the rates of transformation.

Various loading rates were applied and the resulting leaching of nitrogen compounds in an OSTDS were measured (Uebler, 1984). Loading rates of 7.5, 11.3 and 15 L m^{-2} d^{-1} were tested. Additionally, soil amendments (cement and lime) were also part of the experiment. Transformation of ammonium to nitrate was enhanced by the soil amendments, particularly the cement amendment when water levels were higher. Interestingly, the nitrate concentrations were highest with the lowest loading rate, particularly during

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high water table conditions. This observation suggests that water table level influences the production of nitrate more than the loading rate.

Lowe and Seigrist (2008) describe a pilot-scale study to evaluate the effects of infiltrative surface architectures (ISA) and hydraulic loading rates (HLR) on soil treatment of septic tank effluent. A test site was established in Golden, Colorado with three different ISAs (open, stone, and synthetic) and with two different HLRs (four and eight cm/day). Monitoring was done over a two-year period to evaluate the infiltration capacity and purification performance of the different conditions. Results indicate improved infiltration using the higher HLR and using the open ISA. The higher HLR resulted in increased nitrogen mass removal (42%) compared to the lower HLR. No significant difference was reported for the different ISAs. The data suggests that improved purification can be achieved by applying higher HLRs to a portion of the soil treatment area rather than a low HLR over the entire area.

In another study, Lowe et al. (2007 and 2008) describes a large field-scale study examining the soil treatment performance receiving three different effluent qualities: septic tank effluent, textile filter unit effluent and membrane bioreactor effluent. The different units were operated over a period of 16 to 28 months, with water quality monitoring for different parameters including nitrogen. Results showed an improved performance for both the MBR and TFU over the conventional septic tank, with a 30% and 61% nitrogen removal rate for the TFU and MBR, respectively (compared to the conventional septic tank only). The systems including a textile filter or membrane bioreactor, generally performed better with respect to nitrogen removal and were less affected by hydraulic loading rate than the system comprised of only a septic tank and soil treatment.

2.2 Vadose Zone Processes and Impacts to Groundwater

Soil treatment of nitrogen from OSTDS in the vadose zone can also have a significant influence on the resulting nitrogen concentrations in the aquifer. The transformations and reactions of sorption, nitrification, and denitrification described earlier are present in this zone. Nitrogen that is present as ammonium is subject to adsorption to negatively charged soil particles, plant uptake, or microbial bioaccumulation. Nitrate, on the other hand, is mobile in the vadose zone but can be subject to denitrification. It is therefore important to quantify the vadose zone processes to assess nitrogen attenuation prior to entering the saturated zone.

Otis (2007) estimated the nitrogen loadings to groundwater from OWTS located within the Wekiva Study Area. Because most literature data lacked accurate wastewater flow data, mass loadings could not be determined from existing data and a range of percent removals were estimated based on the factors that affect biological denitrification (soil

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drainage, depth to water table, and organic soil matter content). While the study did not address nitrogen in groundwater, it did provide conservative estimates for nitrogen removal for soil types specific to the Wekiva Study Area. In another study conducted by the project team members, a summary of the available literature related to nitrogen attenuation in the soil treatment unit (STU) was done to identify the parameters that influenced transformations and reactions (McCray, et al., 2008). Data from available literature was collected and tabulated for nitrogen concentration vs. depth, vadose zone characteristics, and soil type. Additional data was collected considering wastewater type, hydraulic loading rates, and source type characterization. Data analysis was performed to indicate the correlation between nitrogen attenuation and the various parameters. Initial analysis indicated no significant relationship existed between expected nitrogen concentrations and depth, soil type, or HLR. A more in-depth analysis found that the data variability was most related to HLR, suggesting that this parameter may be more influential than soil type when considering nitrogen attenuation. However, the study also indicates that different soil types will have different hydraulic properties and this can influence nitrogen attenuation.

Ammonium that is not immobilized can be converted to nitrate via nitrification. This form of nitrogen, as mentioned before, is highly mobile and can impact aquifers under OSTDS. Within the vadose zone, the pathway of nitrate reduction is denitrification. In the vadose zone, denitrification is the dominant process affecting nitrate concentrations below the absorption field (Wilhelm, Schiff et al., 1998) and is therefore a key process in estimating the resultant nitrate loading to the aquifer. A body of research has been involved with understanding and quantifying denitrification in the vadose zone.

Ritter and Eastburn (1988) provide a summary of available literature related to denitrification and OSTDS. Based on their review of available literature, several factors which may influence nitrogen attenuation are:

- adequate supply of a carbon source;
- infiltrative surface biozones (the biozone has been shown to improve denitrification);
- OSTDS with high water tables (potentially insignificant dentrification due to lack of conditions conducive to nitrification);
- dosing (likely to improve denitrification); and
- recirculating sand filters (and other aerobic treatment units may improve denitrification).

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Degen (1991) conducted a study that considered multiple factors that could potentially influence denitrification processes including effluent loading rates, effluent type, dosing rates, and temperature. This study included both experiments on soil cores in the laboratory and field sampling and measurements on sites in Virginia. The predominant soil types consisted mainly of silt loams collected in Blacksburg, Virginia. Soil cores collected for the laboratory experiments were subjected to a variety of effluent dosing rates and effluent types in order to quantify the response in a more controlled environment. The study attempted to quantify the denitrification via a number of methods, including nitrate/chloride ratios, soil chemical analyses, and microbial activity analyses. Field studies used similar analyses. Additionally, an attempt was made to model the expected denitrification in the field based on the lab results. The study made several key conclusions as follows:

- Carbon content was the limiting factor for denitrification.
- Applications every 48 hours (i.e., one dose every 48 hours) doubled the denitrification rates compared to applications every 24 hours.
- The model was not useful for predicting denitrification in the field, likely due to the more favorable anaerobic conditions present in the field study.

Tucholke (2006) provides an analysis for relating denitrification rates in the vadose zone with soil type. The study consisted primarily of identifying studies that measured denitrification rates and described the soil characteristics of the study site with the hypothesis that predictions of denitrification could be made based on soil type. While the data did not support the hypothesis, it did show that denitrification varied significantly with soil type. However, the study concluded that denitrification is a process dependent on many variables, such as organic carbon content, soil temperature, water content, and soil pH. This conclusion was verified by statistical analysis that demonstrated that data variability was dependent on the variability in the various parameters.

One of the major research concerns with quantifying denitrification is the wide variation in measured rates in different studies. This issue makes correlation of site characteristics and denitrification difficult. Tucholke et al. (2007) provides a review discussing the variability seen in the literature. This variation is attributed to variations in measurement method and wide variations observed spatially and temporally in the field. For example, rates determined in the laboratory as compared to the field varied widely, as did rates determined by isotope analysis as compared to other methods. Also, site heterogeneities in limiting factors such as water content and pH also impacted the rate determination.

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Nitrogen in the vadose zone that results from OSTDS is subject to various transformations and reactions which are dependent on numerous factors within the soil and from the source. Attenuation of nitrogen is accomplished via sorption, plant uptake, bioaccumulation, or conversion of nitrate to nitrogen gas (denitrification). No single dominant process or parameter can be identified; rather, an interconnected complex of factors will ultimately influence the nitrogen attenuation. Due to the complexity of the issue, more research is required in the future to relate all of the processes and variables to observed changes in nitrogen concentration from the source to the groundwater.

2.3 Land Planning and OSTDS Density

While a large number of studies consider lot size or OSTDS density to be important factors, two studies were identified that examined these as primary characteristics for estimating potential groundwater impacts from OSTDS. Ultimately consideration of lot size or septic tank density will play a key role in land planning and developments considering OSTDS as the primary method of wastewater disposal.

A method of determining lot size and density related to land development in Pennsylvania was developed by Taylor that assumes the reduction of nitrate is primarily via groundwater dilution (Taylor, 2003). The author reiterates the discussion of whether or not denitrification is a significant process in groundwater, and ultimately concludes that land planning must consider dilution as the primary factor in nitrate reduction, since this approach is both conservative and simple. Also, the author indicates denitrification is a poorly understood process and should not be relied on for nitrate reductions.

Similarly, Yates concludes in her study of OSTDS distribution in various watersheds in the United States that the most important factor in limiting OSTDS impacts is restricting system density (Yates, 1985). The author looks at nitrate impacted areas in New Mexico, Colorado, New York, Massachusetts, Delaware, and North Carolina. The study cites other research in these areas that quantifies the number of septic tanks in a particular watershed and the level of nitrate impacts. However, little quantitative analysis is provided and no significant conclusions that specify lot size or density of septic tanks and how that relates to high nitrate concentrations in groundwater are given.

2.4 Groundwater Denitrification

An important component of the nitrogen cycle in the subsurface is denitrification in groundwater. This reaction, as described earlier, is essentially the conversion of nitrate to nitrogen gas. This transformative process is of particular importance when considering the reduction of impacts from OSTDS, since this is the primary pathway of nitrate reduction other than dilution by ambient groundwater. Most research on this topic has been

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focused on the nitrate impacts from agricultural activities or aquifer impacts that are not attributed to a specific source; therefore limited research directly related to OSTDS has been identified. However the body of research available is nonetheless valuable as the factors influencing denitrification are not exclusive to agricultural subsurface environments and can be applied when considering reductions related to OSTDS impacts. During this review, 47 references related to denitrification in groundwater were identified. The following summarizes natural denitrification in groundwater and provides an examination of the rates and processes described in deep and shallow aquifers and in riparian (streambed) environments. Additionally, the key factors identified as the most influential on the denitrification process are described.

In the literature review, studies by Hiscock et al. (1991), Korom (1992), Hill (1996), and Rivett et al. (2008) were reviews and discussions of the state-of-knowledge of the denitrification process in saturated subsurface environments. Hiscock et al. (1991) reviewed not only natural processes, but provided additional information on the progress of methods intended to enhance the denitrification process *in situ.* Korom (1992) provided a background of the denitrification process, a historical perspective on denitrification research, published rates of denitrification in the field and laboratory, and made recommendations for further research. The review done by Hill (1996) looked at the process of denitrification in the riparian zones of the stream/groundwater interface. Rivett et al. (2008) looked primarily at the biogeochemical factors and processes related to denitrification. This study was mainly focused on the limiting factors such as electron donor availability and attempts to identify the influence of chemical and physical factors. Since the organization and material presented in these four papers is generally similar, a summary of their findings is provided below to give a summary of the current understanding of the denitrification process.

Denitrification is generally accepted as the most significant pathway to nitrate attenuation in groundwater (Rivett et al., 2008; Korom, 1992). This process requires four key components for denitrification to occur (from Korom, 1992):

- N oxides (N_2O, NO_3^-, NO_2^- NO) as terminal electron acceptors;
- Bacteria with the appropriate metabolic capacity;
- Suitable electron donors; and
- Anaerobic conditions.

In general, the species of bacteria are fairly common in a variety of aquifer environments (Rivett et al., 2008). They can be found in shallow aquifers and at great depths. Bacterial species capable of denitrification have been found in clayey sands to 489 meters as well as deep limestone and granite aquifers. These bacteria either derive their energy

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through the oxidation of organic carbon or certain inorganic compounds. This distinction leads to the classification of the denitrification pathways available described below.

Depending on the electron donor used by the bacteria, denitrification can be classified as either heterotrophic or autotrophic. Heterotrophic denitrification utilizes organic carbon as an electron donor, whereas autotrophic denitrification utilizes reduced inorganic compounds such as sulfate or ferrous iron (Korom, 1992). Furthermore, autotrophic processes can follow heterotrophic processes in aquifers with both types of electron donors present when concentrations of nitrate become limited. Most researchers identified by Korom indicate the presence of either heterotrophic or autotrophic denitrification occurring but not both; however, most aquifers have both types of electron donors present. The review by Hiscock et al. (1991) also describes studies that identify the pathway of denitrification based on electron donors, but not in great detail.

Rivett et al. (2008) provides additional detail when considering the heterotrophic pathway to denitrification in terms of limiting factors. Their review indicates that in the case of the heterotrophic pathway, the rate of denitrification is most limited by the concentration of dissolved organic carbon in the pore water. Reseach indicates that the distinction between DOC and the total fraction of organic carbon (f_{oc}) or organic carbon present in soils is important based on bioavailability; soil organic carbon is generally not available to the microbial species that facilitate denitrification. Furthermore, studies are identified that correlate the rate of denitrification to the concentration of DOC in a given aquifer and since most aquifers have relatively low DOC concentrations, it is therefore critical to the occurrence of denitrification.

The review by Hill (1996) describing the denitrification process in riparian zones confirms the importance of organic carbon in the heterotrophic pathway. Organic carbon concentrations in these zones are typically high when compared to those found in aquifers and riparian zones often display complete reductions in nitrate. Also, Hiscock et al. (1991) describes methods, both above-ground and *in situ*, that attempt to enhance the denitrification process by the addition of organic carbon, usually in the form of methanol, ethanol, or sucrose. In most cases, an improved rate of denitrification was observed in the studies cited.

Temperature can also be an important factor. Hiscock et al. (1991) states that denitrification decreases markedly below 5°C, and generally, a doubling of denitrification occurs with each 10°C increase in temperature, other factors being equal. The temperature range for denitrification identified by Rivett et al. (2008) is from 2 - 50°C, however, their review indicates that the optimum temperature for denitrification is between 25 and 35°C. Thus, denitrification rates in Florida soils and groundwater should be higher than

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in cooler regions, as temperatures are typically near the lower end of this optimum range.

Rivett et al. (2008) indicate that the autotrophic process is less understood and Hiscock et al. (1996) describes autotrophic denitrification as “uncommon.” Both Rivett et al. (2008) and Korom (1992) cite studies that show that groundwater with high concentrations of ferrous iron typically do not contain nitrate. They also cite references that describe denitrification via reduced sulfure and pyrite, as does the Hiscock et al. (1991) review. As this process is not well understood, little detail describing how it proceeds and the limiting factors is provided, except to say that the desired endpoints may be less stable and the reaction can be pH dependent. Rivett et al. (2008) also indicates that using inorganic substrates from a remedial perspective may result in undesirable impacts to groundwater in terms of water hardness, corrosion to well materials and the formation of sulfate plumes.

Rivett et al. (2008) also looks at the influence of a number of biogeochemical factors that may influence denitrification. Nutrients and micronutrients such as phosphorus, boron, copper, and zinc are all important to the growth of denitrifying bacteria. In general, most aquifers have adequate concentrations of these nutrients, but they may be lacking in certain oligotrophic aquifers. Denitrifying bacteria prefer a pH range between 5.5 and 8, but the influence of pH is typically site-specific due to adaptive behaviors of the bacteria. Salinity, toxic substances, and small pore space that prevent the development of bacterial colonies are all identified as factors that may limit, but not prevent, denitrification. Based on the review, while these factors may influence the rate of denitrification but are not considered limiting factors as to whether denitrification occurs.

The review by Rivett et al. (2008) and Korom (1992) also describe an alternative pathway for nitrate in groundwater, dissimilatory nitrate reduction to ammonium (DNRA). In this case, it has been theorized in systems where nitrate supplies to the bacteria are limiting; however, this pathway is less common, mainly because the bacteria that facilitate this process cannot occupy as much substrate as those that facilitate denitrification. Though not common in the literature, some studies have identified DNRA process in aquifers. The main concern would be the cycling of ammonium back to nitrate in cases with a fluctuating water table that result in aerobic and anaerobic conditions.

Beyond the general review of research that these studies provide are research projects that collect field data from aquifers in an effort to characterize the nitrate reduction processes, if any exist. The descriptions of the studies represent a diverse collection of research in terms of site characteristics, aquifer type, and methods of determining whether or not denitrification is occurring. The value of the following material lies in this diversity of research as the material presented gives insight into how denitrification

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works in a variety of aquifer materials and which factors present in these materials may influence the reduction of nitrate.

Numerous studies considered the reduction of nitrate in shallow or unconfined aquifers, a relevant environment when considering the nitrate impacts that result from OSTDS. As stated earlier, a majority of the studies are field-scale studies that consider agricultural environments, but the processes and components that influence the denitrification reaction can be applied to nitrate plumes that result from OSTDS. The benefit is a developed understanding of the subsurface conditions that most influence the denitrification reaction and therefore source composition and orientation does not need to be considered. In fact, Anderson (1998) reviewed denitrification rates from some of the studies described here and identified the relevant factors for denitrification. Furthermore, the study then applied a statistically-generated regression to apply the rates to denitrificaiton related to an OSTDS site in Florida. Based on mass-balance calculations, the regression-derived rate indicated successfully that the nitrate reduction in this system was due to denitrification.

Over 20 studies were found during the review of the literature. Many of the studies are similar in their methodology and conclusions so a complete summary of each study is not warranted. Also, several studies looked to measure nitrate attenuation without consideration of the key parameters or pathway. Therefore, the following summarizes the important findings of the studies and highlights those that are the most relevant.

Many of the studies indicate heterotrophic denitrification as the dominant pathway in nitrate attenuation. This is likely due to the heterotrophic reaction being thermodynamically preferred. However, organic carbon concentration is often a limiting factor and in many cases natural levels of dissolved organic carbon are low. Bradley et al. (1992) show in their study of aquifer sediments collected in Tampa Bay, Florida that the levels of organic carbon limit the denitrification rate. They compared the natural *in situ* rates with those amended with organic carbon in the laboratory and found a significant difference in the results. Additionally, the heterotrophic pathway is strongly influenced by bioavailability of the organic carbon. In fact, many studies that indicate autotrophic reductions indicate that the carbon source present is not available to the bacteria in the aquifer. Siemens et al. (2003) describe an aquifer system that has relatively high concentrations of organic matter in the form of dissolved organic matter, but the matter is not spatially distributed to favor attenuation of nitrate and bioavailability is low.

Although numerous studies describe heterotrophic denitrification as the more dominant pathway, a surprisingly large number of studies identify autotrophic denitrification as the nitrate reduction pathway. These include the studies done by Robertson et al. (1996), Postma et al. (1991), Kolle et al. (1985), Pauwels et al. (1998), and Boettcher et al.

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(1991). Robertson et al. (1996) look at nitrate attenuation in aquitard sediments in southern Ontario, Canada. The spatial relationship between reduced nitrate concentrations and a sulfur reservoir in the silty aquitard sediments suggest that sulfur is being used as the electron donor in this case. The authors conclude that similar silty or clayey materials, due to their relatively high concentrations of sulfur when compared to surrounding aquifer sands, have high potential for autotrophic denitrification. Boettcher et al. (1991) similarly conclude that sulfur is the dominant electron donor in the Fuhrberger aquifer in Germany due to mass balance calculations that correlate reductions in nitrate to increases in sulfate concentrations. The preference towards autotrophic denitrification is attributed to the lack of bioavailability of organic carbon in this aquifer.

Postma et al. (1991) look at denitrification in a sandy, unconfined aquifer in Denmark. Their findings indicate that pyrite is the dominant electron donor in spite of the fact that the aquifer has abundant amounts of organic carbon. While this observation seems contradictory, in this case the source of the organic carbon is brown coal fragments, and given the short residence time of the groundwater, cannot contribute enough to provide adequate bioavailability to the bacterial populations. Pauwels et al. (1998) describe autotrophic nitrate attenuation also due to pyrite oxidation in an aquifer in France characterized by silts, clays and sandstones with large amounts of pyrite. As with the previous study, the autotrophic reaction is favored; in this case, organic carbon concentrations are low and cannot contribute to nitrate reduction.

Some studies considered the denitrification processes that occur in deep or confined aquifers. These aquifers are typically characterized by sandstones, claystones, or limestones, and are typically fractured aquifer systems. Additionally, some systems in these studies consider the source of nitrate to be natural. Morris et al. (1988) examined deep coastal sediments in South Carolina to look for the occurrence of denitrification. Cores up to 185 meters in a silty and clay aquifer were sampled at discrete intervals, and samples were amended with 1 mM nitrate. Evidence of denitrification was seen at all the intervals, however the highest rates were observed in the near-surface sediments. The researchers suggest the rate is limited by the concentration of nitrate; however, they did not sample sediments for organic carbon, but they describe carbon as a limiting factor.

Two studies (Rivett et al., 2008; Wilson et al., 1990) looked for evidence of denitrification in limestone aquifers in England. The two studies result in contradictory evidence. Rivett et al. (2008), in taking a look at the hydrogeochemical conditions present in the major confined aquifers of England, have a pessimistic view of the potential for significant reductions in nitrate concentrations from denitrification. Although the conditions are anoxic, the bioavailability of organic carbon and the small pore space which can restrict bacterial colony growth are not favorable for denitrification. However, Wilson et al. (1990) in collecting aquifer data and comparing noble gas ratios, show evidence of significant denitri-

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fication in the Lincolnshire Limestone aquifer. As the objective of the study is to show evidence of denitrification, no data was collected concerning possible factors that could enhance or limit the nitrate reductions observed. The authors also do not indicate whether or not this observed reduction would have a significant impact on water quality. Both studies describe the need for further research in this aquifer types to determine denitrification potential in deep, confined aquifers in England.

Vogel et al. (1981) studied a deep confined sandstone aquifer in the Kalahari Desert. The nitrate in this groundwater system is from natural sources, but the study wanted to assess the rate of denitrification in such a system. Their findings, using noble gas ratios, indicate the denitrification rate is extremely slow and is essentially non-existent. This is attributed to the very low organic carbon content of the water.

Studies were found that examine denitrification in riparian zones (also known as buffer zones) and the results indicate that these regions have high potential for reduction of nitrate concentrations. In many cases, this can be attributed to the high organic carbon content of streambed sediments. However, heterotrophic reduction pathways are not the exclusive pathway in riparian zones, as the literature review revealed. Rather, a combination of biogeochemical factors in these zones seems to contribute to the ability to attenuate nitrate. Studies focused on this topic include Bohlke et al. (2002), Burt et al. (1999), Christensen et al. (1989), Devito et al. (2000), and Hill (1996). The study by Hill is a review of the current understanding of denitrification in these zones and is described earlier. Burt et al. (1999) studied the denitrification of riparian zones in England. Based on measurements of nitrogen gases that would be indicative of denitrification, the riparian zone showed very high potential for significant nitrate reductions, provided the water table adjacent to the buffer zone stayed adequately high to maintain anaerobic conditions. Also, the authors note that the silts and clays with the highest potential for reductions were often bypassed as groundwater flowed through gravel lenses above and below the lower permeability areas. Bohlke et al. (2002) conducted a similar study in a riparian zone on a stream in Minnesota. Nitrate concentrations were measured as well as other major groundwater chemistry parameters to determine the fate of agricultural nitrate contamination. Interestingly, the riparian zone in this case, which significantly reduced nitrate concentrations, was rich in pyrite and therefore the autotrophic pathway was favored. Organic carbon is present, but is in a form that is not biologically available. Christensen et al. (1989) conduct a study of denitrification in a riparian zone along three streams in Denmark. Significant reductions in nitrate were observed, however the authors do not attribute this to any factor such as organic carbon or pyrite minerals present in the sediments.

The researchers, as a result of the data collected in these studies, identify key factors in the process of denitrification which can be indicators of the occurrence of nitrate reduc-

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tion. Although a precise correlation may not be identified, the presence or absence of certain groundwater components in the appropriate concentrations can, in some cases, lead to complete reduction of nitrate. Among the key findings related to denitrification in groundwater are the following:

- The primary limiting factor is most often related to the electron donor, whether it is organic carbon, ferrous iron, or sulfur compounds.
- The heterotrophic pathway, though thermodynamically favorable, is considerably dependent on the bioavailability of the organic carbon.
- It is important to consider both pathways of denitrification when assessing a particular aquifer as the conditions for both pathways may be present and may be active once a particular electron donor is depleted.
- Although there are optimal pH levels and temperatures for denitrification, the range is relatively wide when considering most aquifers and therefore they are generally not limiting. Soil and groundwater temperatures in Florida, however, are near optimum for denitrification. Therefore, denitrification rates should be higher than in cooler regions, other factors being equal.
- Certain limestone or sandstone environments are not favorable for the growth of bacterial colonies that can facilitate denitrification; however, given the typical aquifer environment common to OSTDS, this may not be relevant.

The factors influencing the denitrification reaction are various, as are the resultant rates of reduction. Studies that calculated or measured denitrification rates report values that vary by several orders of magnitude. This variability is indicative of not only the heterogeneity of the aquifers studied, but the importance of the identified biogeochemical factors observed in the research. Denitrification can occur in a variety of aquifers and utilize different pathways to achieve significant reductions of nitrate in groundwater. This results in a potential dichotomy; on one side, the process of denitrification may be fairly ubiquitous in most aquifer settings. On the other side, determining if it is actually occurring, at what rate, and what biogeochemical factors are driving the process may be difficult. Nonetheless, based on the literature review, a number of suggestions can guide sampling and assessment of natural denitrification in groundwater:

- Groundwater sampling directed at determining denitrification parameters can be focused on measurements of nitrate concentrations, denitrification end products, dissolved organic carbon, ferrous iron, pyrite minerals, and sulfur compounds.

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- Groffman et al. (2006) describe several methods for the direct measurement of denitrification *in situ.* These methods should warrant further investigation and possibly lead to actual implementation in the field.

- Measurement of denitrification rates should be done in the context of other transport parameters. Smith et al. (2004) indicate that although the aquifer in their study had measurable rates of denitrification, these rates could not attenuate nitrate enough to overcome the transport rate and a large nitrate plume still resulted.

2.5 Groundwater Monitoring Studies and Reports

A relatively large number of studies and reports were found that considered nitrate distribution, plume delineation, and estimates of the source contribution of OSTDS. Generally these are characterized by various levels of groundwater sampling, and usually some effort to make conclusions as to the nature of the nitrogen impacts based on the results of the sampling. In some cases the studies or reports are quite simple, considering only nitrate concentrations. Others are highly detailed, considering not only nitrogen species concentrations, but a variety of hydraulic and geochemical parameters. Typically the more complex studies draw more conclusions as to the transport and transformative processes at work at the various sites. However, this level of complexity does not always correspond with superior results; in some cases, the simple study addresses the objectives and can make some significant conclusions related to nitrogen impacts.

A study in Helena, Montana, examined the change in groundwater nitrate distribution as correlated with the increase in population in the area (Drake and Bauder, 2005). The study indicates a potential relationship between the increase in observed nitrate concentrations and the increased use of OSTDS between 1971 and 2003. The study compiled data for aquifer nitrate concentrations from 10 publicly funded investigations in the defined time period. From this data, trend analysis with statistical significance methods was applied to identify any trend between the increasing population and nitrate concentration trends. Additionally, the data was plotted geographically for spatial trend analysis. The area surrounding Helena experienced a 17% increase in population and a 68% increase in septic tank use in the decade between 1990 and 2000. The statistical analysis confirmed a correlation between nitrate concentrations and increasing population. The geographical analysis also indicated a spatial trend, showing the highest increases occurred in rural areas. This was especially the case in areas overlying bedrock aquifers and areas with high density and unpermitted OSTDS.

A similar study summarized the overall impacts due to OSTDS in New Mexico that also considered nitrate distribution (McQuillan, 2004). In this study, data was compiled in a

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similar fashion to the study described above. The study compared the level of nitrate impacts of aquifers with largely oxic conditions to aquifers with anoxic conditions. Also, data results from geochemical isotopic fingerprinting are provided, to identify the source of nitrate contamination. Figure 2-1 shows the results using isotopic fingerprinting. This study indicated that areas with more significant nitrate concentrations occur in aquifers with oxic conditions, whereas aquifers with anoxic conditions have lower impacts due to conditions not being favorable for the transformation of ammonium to nitrate. The results of the study also indicated that isotopic fingerprinting can be a useful tool for identifying nitrate sources, which can be useful for targeting primary nitrate sources.

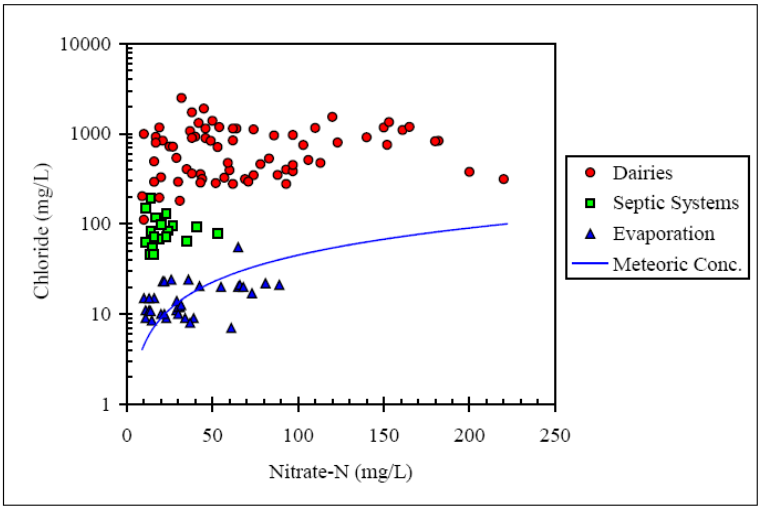

Figure 2-1: Nitrate Sources as Determined from Isotope Fingerprinting (McQuillan, 2004)

A study of the Darling Plateau region near Perth, West Australia also examined the nitrate contributions from OSTDS in a populated area served almost exclusively by individual OSTDS (Gerritse, Adeney et al., 1995). It was estimated in this study that nearly 80% of the nitrogen in the subsurface could be attributed to OSTDS source contributions. This study specifically looked at impacts of a neighboring surface water body approximately 70 meters downgradient. Monitoring of nitrogen species and bromide tracers showed significant decreases in inorganic nitrogen as the groundwater approached the creek. Interestingly, the surface water body had relatively high background concentrations of nitrate, but the study showed no significant contribution from this soil treatment unit.

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Lapointe et al. (1990) conducted a study to relate groundwater impacts to nearby marine surface waters via tidally-influenced groundwater recharge in the Florida Keys. The area in the study is characterized by typical tropical wet and dry seasons, with most of the precipitation falling between June and October. The subsurface is a highly porous and permeable limestone that allows for rapid lateral groundwater flow. For sampling, networks of monitoring wells were established on seven residences using OSTDS and one control site in a neighboring wildlife refuge. Wells were sampled monthly for approximately one year for nitrogen species and other biogeochemical factors. Groundwater flow was measured directly using an *in situ* flow meter. Surface water was also sampled. The results indicated that the contribution of nitrogen to the groundwater by OSTDS was significant in this area, in some cases as much as two orders of magnitude higher than when compared to control groundwater. Ammonium was the dominant species, the result of the largely unfavorable conditions for nitrification. Surface water showed a seasonal variation, with the highest concentrations occurring in the summer months. The study also concluded that seasonal variations in tides and groundwater levels result in significant contributions from OSTDS to surface waters in the Florida Keys.

A series of reports have been previously completed for assessment of OSTDS contributions to nitrate contamination of groundwater and surrounding surface waters in the Wekiva watershed in Florida. This includes reports prepared by: Anderson (2006); Briggs, Roeder et al. (2007); MACTEC (2007); Otis (2007); and Young (2007). The study was initiated to protect the Wekiva river system which had been assigned protection under the Wekiva River Protection Act. The watershed occupies roughly 304,000 acres and includes parts of Lake, Orange, and Seminole counties in central Florida. The project has been performed over a number of years and includes a series of tasks in order to assess the contribution to groundwater impacts from OSTDS and ultimately strategies to reduce these impacts. The tasks included:

- Field sampling for watershed characteristics, nitrogen concentrations, and OSTDS loading estimates.
- A literature review for refining estimates of OSTDS loading.
- Integrating these estimates with estimates of other source contributions.
- Development and discussion of alternatives for reducing OTWS contributions.

Three sites were selected for sampling that met the criteria and were deemed suitable for assessment of the desired data. After completion of the tasks, a number of conclusions were reached. For example, an average home with 2.6 people on average contributes 18 pounds of nitrogen to the groundwater annually with the main nitrogen contribu-

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tor attributed to fertilizer use. This is slightly higher than reported by Lowe et al. (2008) of approximately 14 pounds of nitrogen annually (excluding outdoor residential nitrogen sources). The studies also concluded that OSTDS contribution to shallow groundwater contamination was similar in terms of intensity to atmospheric deposition, however, due to the areal distribution, nitrate impacts from OSTDS were approximately an order of magnitude higher and distinct plumes could be delineated. Furthermore, OSTDS tended to be in high-vulnerability areas and did not have effective nitrogen removal as compared to centralized wastewater methods. Figure 2-2 shows the estimated relative contributions for medium density residential land uses.

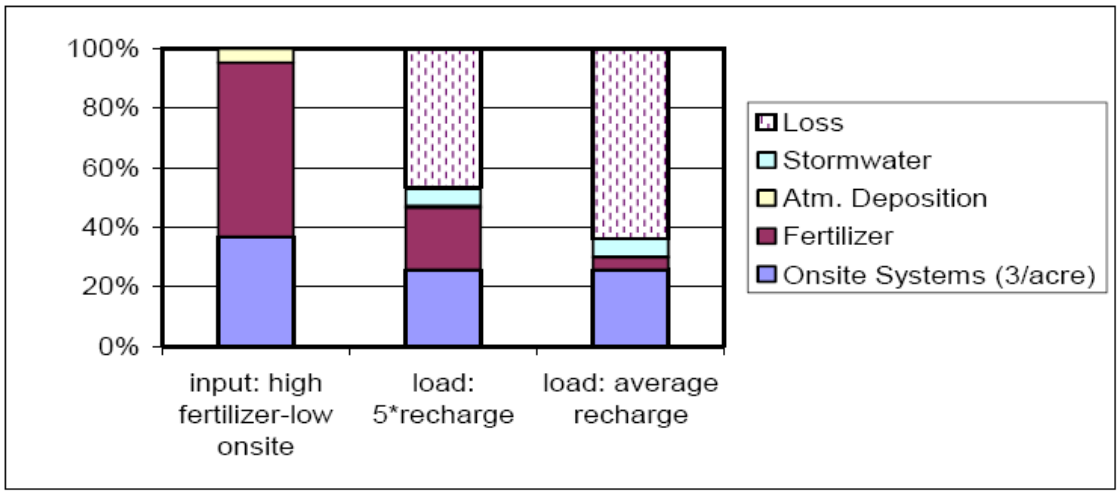

Figure 2-2: Source Contribution to Nitrate Impacts (Briggs, Roeder et al., 2007)

Other aspects of the study considered transport and transformation of nitrogen. Two factors were identified that influenced nitrogen entering the drainfield; the amount of nitrogen present in the effluent, and the level of pre-treatment prior to discharge. In the event pre-treatment was present then ammonia is converted to nitrate. However, nitrification will be limited in soils with high water tables. After discharge, if there is adequate organic carbon present, the nitrate can be denitrified to nitrogen gas.

Soils with moderate to poor drainage, fine loamy texture with clay, shallow water tables, and some organic matter have the highest potential for denitrification.

Ultimately the study found that contributions from OSTDS could be effectively minimized by reduced loading and improving OSTDS performance with pre-treatment methods and

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improvement of subsurface characteristics, especially considering high water table areas.

Andreadakis (1987) performed laboratory simulations of an alternative OSTDS in Greece to estimate the effectiveness of the system for nitrogen removal. The system consisted of a septic tank, gravel filter, two sand filters operated alternatively, and two soil absorption trenches operated alternatively. The study found the system could achieve approximately 70% nitrogen removal. The factors that influenced the effectiveness were the compaction characteristics of the filters and soil, loading rates, and variability in saturated/unsaturated conditions.

Reneau (1977) conducted a study of changes in inorganic nitrogen compound concentrations from a septic tank in a soil with a fluctuating water table in Virginia coastal plain area. Samples were collected and analyzed for nitrate, nitrite, and ammonium ions over a three year period. The relationship between nitrate and ammonium and distance is demonstrated by the ratio of these constituents to chloride (Cl^-). Assuming that chloride undergoes no significant transformations or adsorption, any variation in the ratio can be the result of either adsorption or transformation. In this case, the ratio of ammonium to chloride decreased with depth, indicating that at higher points anaerobic conditions dominated and nitrification could not take place. Following this trend, decreases in the nitrate to chloride ratio suggested that in some areas denitrification could take place due to the rising water table.

Arnade (1999) examined the relationship between nitrate well contamination and distance from OSTDS as related to seasonal variations in water level in Palm Bay, Florida. The study area experiences high precipitation during the summer months and results in high water tables in sandy soils that cause septic tank overflows and ultimately groundwater contamination. Results indicated that during the wet season, nitrate concentrations tended to be higher as distance increased as compared to the dry season, although the opposite was true closer to the OSTDS. The reasons provided for this observation were perhaps dilution, plant uptake, or enhanced transformation. This reasoning seems suspect, as if dilution is a factor in reduced concentrations, then concentrations should follow the same pattern throughout the flow path.

Walker et al. (1973a and b) describes two studies that look at nitrogen transformations of septic tank effluent in sands. The first study focused on transformations in sand while the second study examined transformations related to groundwater quality. Research was done at the field scale at five separate locations in Wisconsin. In all cases, effluent was ponded near the surface due to the formation of a “crust” (aka, the biozone) which was the result of biological processes. As a result, unsaturated flow rates were extremely low (8 cm/day). The biozone conditions were favorable for nitrification where groundwater

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was not present. Most of the sites showed complete nitrification was possible at six centimeters below the biozone. One site had a high water table and as a result nitrification did not occur unless seasonal variations resulted in a lowering of the water table. Denitrification was identified in an underlying clay layer at some of the sites, although this was not the case if the site had an underlying sandy layer. In the groundwater, the dominant process reducing the nitrate concentrations were dilution with ambient groundwater and not denitrification due to the nature of the well-aerated sandy soils and the low carbon content of the groundwater. The authors concluded that in order to minimize impacts from OSTDS in such aquifers, considerable land size is necessary in order to maximize the effects of dilution from clean water.

Harman et al. (1996) looked at the groundwater impacts resulting from an OSTDS at a school in Langton, Ontario, Canada. In this community, over 30% of the water supply wells exceeded the standard for nitrate. Multiple sources, primarily from OSTDS use and agricultural practices contributed to the high nitrate concentrations. The study aquifer in question was characterized by fine to medium sands and has a relatively high groundwater velocity (170 meters/year). The wastewater from the facility was largely from washrooms, as the site had no laundry facilities present. The effluent was primarily ammonium. At the site over 400 samples were collected at 45 multilevel monitoring points at various locations downgradient of the OSTDS. Samples were collected for all major ions, DOC, alkalinity, pH, and dissolved oxygen. The results found high nitrate concentrations were observed (20-120 mg/L) and extended over 100 meters downgradient owing to the high groundwater velocity. Vadose zone residence time was one to two weeks but did not appear to allow for complete conversion of ammonium to nitrate. However, geochemical analyses indicated reduced ammonium and organic carbon concentrations coinciding with increases in nitrate which suggest that nitrification was occurring. Denitrification was limited and isolated due to low levels of organic carbon and aerobic conditions. It appeared that most of the reduction of nitrate along the plume extent was likely due to natural dilution; denitrification was limited by low levels of organic carbon and aerobic conditions.

Robertson et al. (1991) studied the OSTDS impact to sand aquifer from two single-family homes in Ontario, Canada. The first site was a home in Cambridge, Ontario. The surficial aquifer was characterized as a coarse sand overlying a low permeability silt. The home was occupied by four people. The second site in Bracebridge, Ontario was situated on a fine sand aquifer with a household occupied by two people. Major ion geochemistry and typical septic tank nutrients were sampled. Bromide tracer tests were also performed. Both sites showed evidence of nitrification due to high concentrations of nitrate, and low concentrations of dissolved organic carbon and ammonium. High concentrations of nitrate were observed more than 130 meters downgradient from the sources which suggested little or no denitrification was occurring and that aquifer conditions were

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favorable for considerable nitrate migration. However, almost complete denitrification was observed in the carbon rich river sediments downgradient. In this aquifer, it was concluded that due to the low dispersive nature of this type of aquifer, current minimum distance to well regulations may not be protective. This was verified by natural-gradient bromide tracer tests.

Another study conducted looked at water sampling from domestic supply wells in five unsewered subdivisions in Wisconsin (Tinker, 1991). The objective of the study was to identify the sources of nitrate impacts to drinking water. Water samples were collected on two separate occasions from supply wells in five subdivisions and tested for nitrate concentrations. Sources of nitrate impacts were assessed by the location of the OSTDS and the water supply well in relation to the groundwater flow direction and comparison of the results of three mass-balance models. The combination of methods resulted in a good correlation between the locations and the groundwater flow, as well as the results of the mass-balance modeling. The author concluded that elevated nitrate concentrations could be attributed to lot size (from the mass-balance modeling) and locations of water supply wells and OSTDS.

Reay (2004) examined the impacts from OSTDS to near shore areas along Chesapeake Bay. Due to the sandy characteristics of the aquifer and the shallow water table, significant nitrate impacts to near shore sediments were observed. Multiple characteristics were analyze at three separate sites in Virginia considered representative of the Virginia coastal plains. Among the characteristics were depth to water, aquifer thickness, soil characteristics, lot size, and persons per household. Groundwater was sampled for nitrogen species and phosphorus as was neighboring surface waters. The author noted the lot size and relatively high loading rates contributed to the observed concentrations. Furthermore, the sites showed potentially high nitrification rates are likely present due to the observed concentrations of nitrate versus ammonium, and that very little denitrification was occurring, which led to significant nitrate impacts to nearby surface waters.

A sampling study to quantify the nitrogen impacts from OSTDSs was performed for a community in Nevada (Rosen et al., 2006). This study combined field data and a mass-balance approach to assess the nitrogen impacts attributed to OSTDS. The area under study was a densely populated area north of Reno, Nevada. In this area, 2,070 septic tanks were in use. Annual precipitation was low (20-25 cm/year) and recharge water to the aquifer also came from irrigation ditches (54%) and septic tank effluent (17%). Four separate sites were sampled monthly for one year. No geochemical or hydraulic parameters were collected. The final results of the estimates indicated that 25-30 metric tons of nitrogen in the groundwater could be the result of OSTDS use, although the authors concede that considerable error is possible and that future studies considering more parameters will be needed.

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2.6 OSTDS Plume Geochemistry

A number of researchers went beyond the approach of considering nitrate concentrations only and considered numerous factors of OSTDS-generated nitrate plumes to delineate the important parameters that may affect nitrate transport and transformation. In most cases, the study collected samples related to all major ions present in groundwater (K^+, Cl^-, NO_3^-, SO_4^{-2}, Ca^{+2}, Na^+, Mg^{+2}, PO_4^{-3}), field parameters such as pH, conductivity, alkalinity, dissolved oxygen, and other factors such as dissolved organic carbon. Additionally, complete characterization of the aquifer parameters were collected, such as those related to soil type and groundwater flow and velocity. These studies were often performed at the field scale, although some laboratory experiments were done as well. The value of these studies is the opportunity to understand how the aquifer responds to transformative processes in terms of changes to other constituents and physical characteristics, and provide a rationale for the extent of impacts observed.

Wilhelm et al. (1998) looked at changes in geochemistry for two operating OSTDS in a sandy aquifer in Ontario for evidence of nitrate transformation. The objective of the study was to confirm a conceptual model that indicated the transformative processes related to nitrogen would result in the creation of redox zones. Changes in geochemical parameters could be measured to confirm the presences of these zones. Sampling was performed along the wastewater flow path at two sites from 1987 to 1990. In the septic tanks themselves a primarily anaerobic environment existed, with low concentrations of nitrate and high concentrations of ammonium and carbon. Aerobic conditions dominated below the discharge pipes. The research indicated that nitrification zones could be identified in areas with decreases in pH and alkalinity, whereas zones of denitrification were characterized by increases in both parameters. Differences in the sediment composition led to different behaviors of nitrate in the groundwater. For example, the plume at the second site entered carbon-rich sediments near a river bed, ultimately leading to complete denitrification and an increase in alkalinity.

Another study looked primarily at changes in inorganic nitrogen compounds related to septic tank effluents, but also looked at subsequent changes in pH and Eh (redox potentials) in a groundwater system in Virginia (Reneau, 1979a). The objective of the study was to relate changes in concentrations as related to distance traveled, soil properties, and seasonal variation. At three different sites, rows of sampling wells were established at 1.5, 5, 10, and 13.5 meters downgradient and sampled semi-monthly for phosphate, nitrogen species, Eh, and pH. Sampling occurred over a two-year period. For nitrate, concentrations reached a maximum (average values ranging from 2.7 to 3.9 mg/L) at the five meter sampling points then decreased with distance. This was attributed to nitrification of ammonium and the subsequent denitrification of nitrate to a relatively large degree. This was accompanied by a drop in pH and a slight increase in Eh values.

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A study conducted in Ontario, Canada examined multiple geochemical factors which can be related to OSTDS impacts (Ptacek, 1998). Temperature, pH, dissolved organic carbon redox conditions and nitrogen species concentrations were all sampled. The original OSTDS effluent contained 98 mg/L of nitrogen as ammonium. Nitrate concentrations were high in the shallow portions of the aquifer, along with diminishing concentrations of DOC downgradient. pH stayed near neutral which was attributed to the buffering capacity of the aquifer due to carbonate content. Nitrate concentrations were low, which may suggest low rates of denitrification.

Robertson and Blowes (1995) observed nitrate concentrations in an acidic OSTDS plume. The study site was again located in Ontario, Canada at a location using an OSTDS for wastewater at a seasonal-use cottage. Sampling was performed at 38 piezometers adjacent to and underneath the infiltration bed. Major ion geochemistry samples were collected. Subsurface soil characteristics were various, from clays to silts to sands. The water table was generally consistent (1.5 meters below the field tiles), but became much shallower during the off-season winter months. In this system, background pH was naturally low; however, more acidic conditions existed within the plume core. Ammonium levels dropped substantially suggesting nitrification was occurring. The authors suggest that changes in nitrate concentrations downgradient were due to denitrification that was facilitated by relatively high levels of dissolved organic carbon and anaerobic conditions. Furthermore, at greater depths in the groundwater, high levels of sulfate coinciding with drops in nitrate concentrations suggested an alternative pathway for consumption of nitrate via sulphur oxidation.

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Section 3.0
Discussion and Analysis

The literature review revealed important conceptual information for the assessment of nitrogen impacts in groundwater due to OSTDS. One of the primary objectives of the review was to examine the current state-of-knowledge related to the primary influences on the fate and transport of nitrogen following the initial loading into the soil from the use of OSTDS. A cascade of processes and factors contribute to nitrogen contamination. These include loading rate, OSTDS density, soil characteristics, oxygen content, aquifer recharge, and water table elevation and fluctuation. Primary factors that can lead to significant nitrogen concentrations are found in both the septic tank and the vadose zone and an understanding of the processes within these is important rather than just considering processes in the aquifer.

The transformative processes of nitrification and denitrification require further study and quantification, especially when considering septic tank performance and processes within the vadose zone. Additionally, an understanding of the aquifer characteristics, such as groundwater velocity and flux estimates can greatly improve the quantification of dilution for reduction of nitrate. Nitrification can be inhibited by high water tables and overloading of OSTDS. Likewise, heterotrophic denitrification, is an important process in the reduction of nitrate in groundwater, requires anoxic conditions in the presence of adequate carbon sources.

An improved understanding and assessment of field conditions prior to septic tank design can improve performance and result in reduced impacts from OSTDS. A large number of reports have been generated that are essentially monitoring reports describing nitrogen levels in observation wells. In some cases, these reports considered factors beyond nitrogen concentrations and included multiple geochemical factors as well. These studies have immense value in the light of other studies, in which the influence of important factors for nitrogen contamination can be quantified in real field-scale studies. Specifically, these studies provide quantitative data concerning:

- Downgradient and cross gradient nitrogen concentrations in groundwater which provides plume delineation spatially and in some cases temporally;
- Site-specific subsurface characterization such as soil type and distribution;

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- Groundwater measurements that provide data concerning groundwater flow paths, velocities, and fluxes which can strongly influence the extent of the impacts in terms of concentrations and distance from the OSTDS;

- Total nitrogen loading rates at the source, which when compared to downgradient nitrogen concentrations provide data concerning OSTDS performance, and nitrogen conversion rates; and

- In some cases, surface water sampling which may indicate the level of groundwater/surface water interaction and/or transformative processes present at the groundwater /surface water interface.

The conclusions reached using the data in these studies can then be applied for nitrogen impact estimates in future studies and how to appropriately monitor and sample a site that will utilize OSTDS. Furthermore, these studies can be examples for assisting in OSTDS design and installation to minimize nitrogen in groundwater. Lastly, data from these studies can be applied to the further study of the OSTDS and vadose zone processes affecting nitrogen transport and fate in groundwater and lead to better predictive methods for estimating nitrogen impacts.

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Section 4.0
Conclusions

The literature review revealed numerous factors that may influence nitrogen impacts to groundwater resulting from the use of OSTDS. Transport and fate processes that are present in the OSTDS, vadose zone, and saturated zone all will influence the extent of nitrogen impacts to groundwater. Furthermore, these factors, along with factors related to groundwater/surface water interactions will also determine if nearby surface water bodies are adversely affected. In doing site assessments, it is therefore important to develop sampling plans that can collect data for a majority of the factors described in the literature. Also, predictive efforts and efforts aimed at reduction of impacts should also consider the findings of the literature review. A brief summary of important points is as follows:

- Some studies identified lot size and location of water supply wells in relation to OSTDS as important factors in determining nitrate contamination to groundwater.
- OSTDS loading rate can significantly impact the performance of the soil and ultimately nitrogen concentrations in the aquifer.
- In certain cases, water table fluctuations may be a larger factor than loading rate of nitrogen on the overall OSTDS performance.
- Nitrogen reduction in the vadose zone is an important determining factor for nitrate concentrations in the groundwater. This is a complex process dependent on numerous factors that need to be studied in depth.
- Nitrification can be influenced by soil type and appropriate loading of an OSTDS. Sikora and Corey (1976) indicate that coarse-textured strongly-aggregated soils favor nitrification while finer textured soils lead to the development of anaerobic conditions and inhibit the process.
- Sandy soil aquifers are particularly susceptible to nitrate contamination, particularly in the case of low carbon content aquifers with relatively high groundwater velocities. In these cases, high concentrations and large areas of impact may be expected due to the lack of transformation and the distance nitrate can travel in a short time period.

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- Denitrification occurs largely in anoxic soils and groundwaters with adequate carbon sources. In the soil column, denitrification may occur in systems with high or fluctuating water tables that allow the creation of anoxic conditions, providing the organic carbon content of the soil is adequate. In groundwater, dilution is often seen as the dominant mechanism for the reduction of nitrate, although some studies identify denitrification as the dominant factor. This is highly dependent on site-specific characteristics.

- Denitrification, while being a well-understood process is poorly quantified and not correlated with other site characteristics especially when considering the saturated zone. This should be a significant topic of further study.

- Some studies identified the relatively high denitrification capacity of river bed sediments, particularly if they contained high levels of organic carbon. This is especially relevant if the protection of adjacent surface water bodies is a key concern.

The literature review suggests reductions in groundwater nitrogen impacts associated with OSTDS are achievable with a few steps. Nitrate is highly mobile in groundwater and the only significant methods of natural attenuation is denitrification, a process that the review indicates is not always present in natural aquifers (however, it should be noted that saturated zone denitrification can be enhanced with amendments as a potential treatment process, see Korom (1992)). Therefore, reduction of nitrate contamination may be most efficiently approached in the design and installation processes when considering OSTDS as a treatment alternative. Appropriate land planning and density of OSTDS in new developments is a first step. OSTDS should be placed within protective distance of downgradient groundwater and surface water resources. Additionally, recognizing the importance of dilution for nitrate concentration reductions, appropriate lot size should be in the design to allow adequate dilution from recharge water. Within the design of OSTDS, appropriate loading rates and an understanding of OSTDS effluent can achieve lower levels of nitrogen entering the subsurface. Lastly, the review indicates the performance value of appropriate treatment units can improve effluent quality by reducing nitrogen prior to infiltration.

Additional optimization can be achieved by a thorough understanding of site characteristics and how these may influence OSTDS performance and ultimately nitrogen concentrations in groundwater. Numerous studies were identified that have data related to existing systems and their performance within the framework of the characteristics of the site. Certain water table conditions, soil types, and other subsurface characteristics such as pH or temperature can have an effect on the treatment ability of OSTDS by varying oxygen content and redox conditions. If detrimental conditions are seen at a site being considered for OSTDS, other methods of wastewater treatment may be appropriate. This

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can also be true for areas identified as “high-risk,” such as areas adjacent to a protected water body. Alternatively, it may be possible to amend the site conditions or use an effluent pre-treatment method to improve OSTDS performance. Future work may be needed to examine the data in such studies and make attempts to correlate hydraulic and reactive parameters to observed nitrogen impacts.

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Section 5.0
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FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task C

Quality Assurance Project Plan

Draft Report

October 2009

HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK C
DRAFT REPORT

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 2009

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

SCHOOL OF MINES
1874
COLORADO

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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).

Nitrogen transport in the subsurface is a complex process, especially when considering the nitrogen inputs from onsite sewage treatment and disposal systems (OSTDS). Figure 1-1 summarizes the conceptual understanding of the inputs of nitrogen and the transformative and advective processes that lead to nitrogen contamination of groundwater. Additional discussion regarding the fate and transport of nitrogen and its movement and distribution in groundwater related to OSTDS was presented in the Task C Literature Review.

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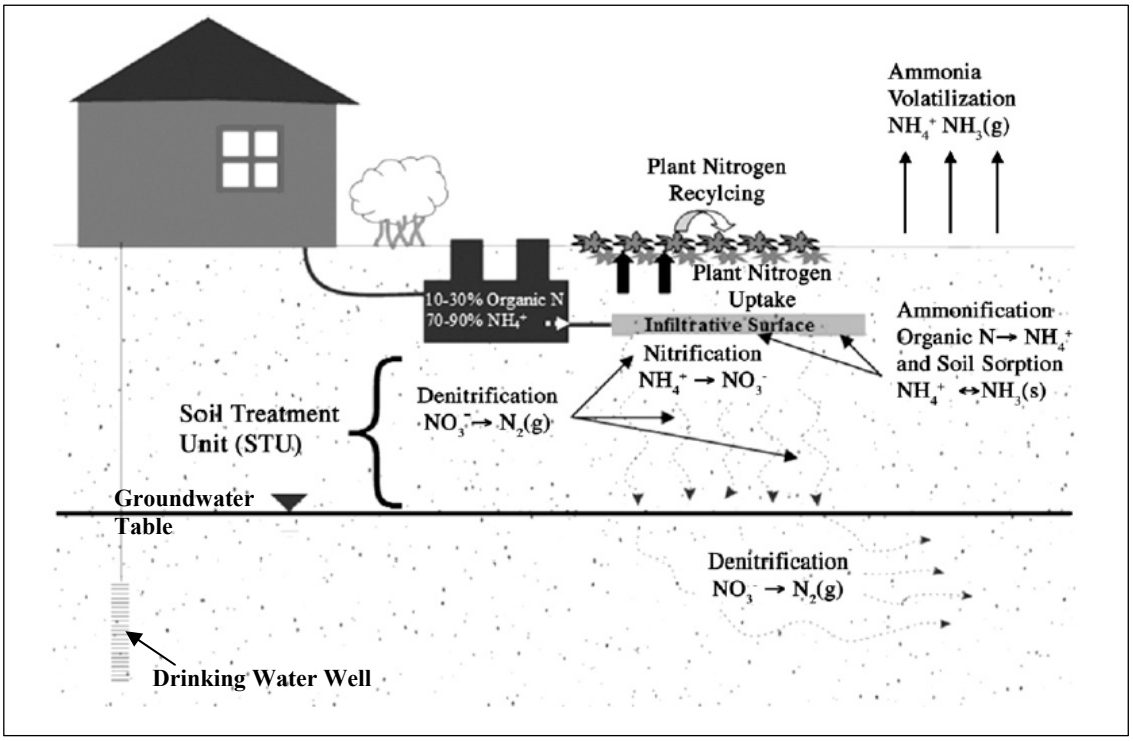

Figure 1-1: Nitrogen Processes Occurring in a Typical OSTDS (after Heatwole and McCray, 2007)

As a result of the widespread impacts of nitrogen on groundwater and surface waters in Florida, the management of nitrogen sources, including OSTDS, is of paramount concern for the protection of the environment. As part of Task C of the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study, field testing related to nitrogen fate and transport will be conducted at the University of Florida Gulf Coast Research and Education Center (GCREC) and individual residential home sites to evaluate expected full-scale performance and produce data required for calibration and validation of fate and transport models developed in Task D.

1.2 Project Scope and Purpose

The overall goal of Task C is to critically characterize nitrogen reduction in Florida soils and groundwater. To accomplish this goal several objectives are identified:

- determine the cumulative mass loading of N to the soil and groundwater (i.e., at the GCREC),

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- identify how currently designed and implemented OSTDS perform (i.e., home sites),
- understand treatment processes involved, and
- obtain/refine model parameter inputs (e.g., denitrification rates).

To meet these objectives a combination of controlled field testing and field monitoring at home sites is planned. Controlled field testing will be conducted at the GCREC. Home sites will be selected from three regions: north Florida, central Florida, and south Florida. Monitoring at each site will include effluent quality, hydraulic loading rate to the soil, soil properties, groundwater properties, groundwater concentrations, and climate/weather conditions. The project approach is described in detail in Section 2.0.

1.3 Project Organization

Task C is comprised of several interrelated subtasks that fall within four primary categories:

1) literature review and work plan development,
2) controlled pilot-scale testing,
3) field monitoring, and
4) reporting.

The literature review and work plan development are the first tasks to be completed. This Quality Assurance Project Plan (QAPP) describes the proposed testing and field monitoring framework building off of the existing knowledge of OSTDS performance. The literature review has been previously submitted to the Florida Department of Health (FDOH) and the Research Review and Advisory Committee (RRAC) for review (Task C.1). Supplemental plans to this QAPP will include the homeowner agreement (Task C.6), home site installation reports (Task C.7), and the test facility design and construction (Tasks C.11 – C.18). The work described in this QAPP encompasses the entire scope of the 5 year project. However, efforts to be completed in subsequent years will build off of the previous findings using the observational method, and will be dependent on future project funding.

Controlled pilot-scale testing will be conducted at GCREC to characterize nitrogen fate and transport under a variety of typical operating conditions. The test area will be highly monitored in the both the unsaturated and saturated zones to enable definition of key

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treatment processes. Tracer tests are also planned to determine groundwater velocity and enable assessment of the groundwater dilution that occurs in an OSTDS. Each test area will be monitored to delineate effluent quality, hydraulic and nitrogen loading rates to the soil, nitrogen transformation in the vadose zone, and potential groundwater impacts. Sufficient temporary piezometers will be used to enable hydrogeologic characterization.

Field monitoring will be conducted at residential home sites in Florida to evaluate current nitrogen reduction in soil and groundwater. The nitrogen mass loading to the environment and the resulting groundwater concentrations will provide input for parameter selection as well as validation of the simple models developed in Task D. Each site will be monitored to delineate the OSTDS effluent quality, hydraulic and nitrogen loading rates to the soil, and potential groundwater impacts. Sufficient temporary piezometers will be used to enable hydrogeologic characterization.

Reporting of Task C results and findings will be through submittal of routine monitoring reports. A final report summarizing the results of Task C will be provided at the completion of the overall project.

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Section 2.0
Task C Description

Controlled field testing will be conducted during the first phase of Task C with field monitoring at individual home sites conducted in subsequent phases. This approach will enable more efficient instrumentation and monitoring of home sites by applying what has been learned from the controlled field testing to the monitoring framework at each home. For example, if it is determined through controlled field testing that treatment in the unsaturated zone is very similar for each operating condition (e.g., 30% removal in 2 feet of soil), then the number of monitoring points in the unsaturated zone at the homes sites can be minimized. Alternatively, monitoring at the controlled field test areas may suggest that specific conditions are critical to capture (e.g., significant rainfall events) and the frequency of monitoring may be modified to ensure key operational stages or conditions are sufficiently characterized. The following sections describe the field activities that will be conducted during the controlled field testing and outline the field activities anticipated during the individual home field monitoring.

2.1 Description of Activities

The work scope described in this section is consistent with the scope of work and deliverables in the FOSNRS contract. The following description of activities provides detail related to the controlled field testing and field monitoring including the test area design, operating conditions, number and location of monitoring points, sample collection and analyses, and data handling.

The overall goal of Task C is to critically characterize nitrogen reduction in Florida soils and groundwater. To accomplish this goal several objectives are identified:

2.1.1 Controlled Field Testing at GCREC

Controlled pilot-scale testing will be conducted at the GCREC to characterize nitrogen fate and transport under a variety of typical operating conditions.

2.1.1.1 GCREC Site Conditions

The GREC facility is located at 14625 County Road 672, Wimauma, Florida. The facility is situated on 475 acres of land that were donated by Hillsborough County government. A preliminary soils assessment conducted by the United States Department of Agricul-

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ture (USDA) Natural Resources Conservation Service (NRCS) identified the soils in the area to be used for this project as primarily Seffner fine sand and Zolfo fine sand, with a limited area of Myakka fine sand (Figure 2-1). The Zolfo fine sand in the northeastern portion of the project area gradually transitions to Seffner find sand in the southwestern portion of the project area. These soils are somewhat poorly to poorly drained and are typical of the Florida flatwoods land resource area. A well developed spodic horizon was identified between 54 and 58 inches in the northeastern portion of the project area. Selected key soil properties of the soils in the project area are summarized in Table 2.1. The Test Facility Site Evaluation with soils information is provided in Appendix A for reference.

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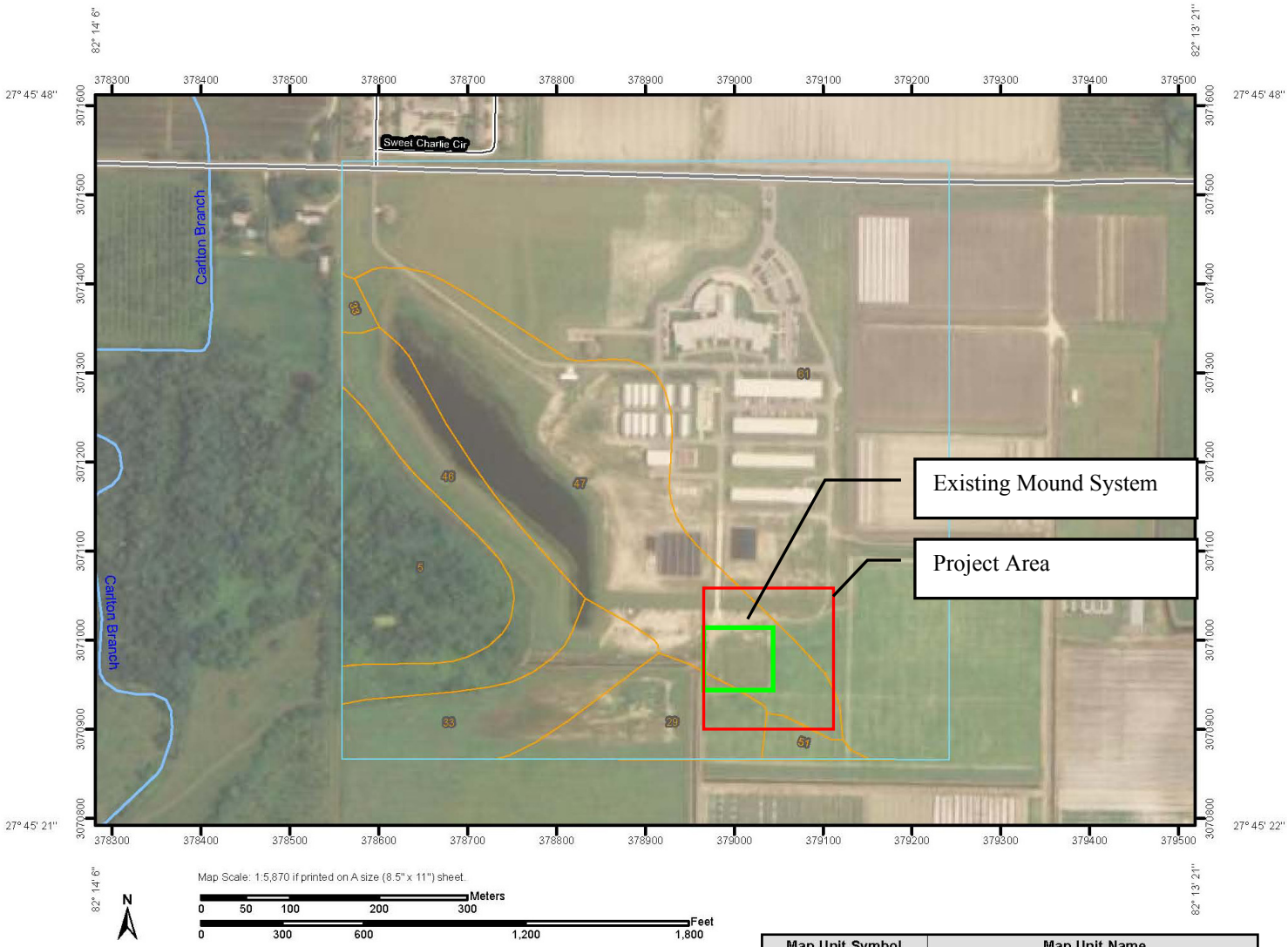

Map Unit Symbol	Map Unit Name
5	Basinger, Holopaw, and Samsula soils, depressional
29	Myakka fine sand
33	Ona fine sand
46	St. Johns fine sand
47	Seffner fine sand
51	Haplaquents, clayey
61	Zolfo fine sand

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Figure 2-1: GCREC Facility Soil Survey (NRCS, 2009)

Table 2.1
Selected Soil Properties of Soils Identified at the GCREC Facility[1]

Soil Name	Depth (in.)	USDA Texture	Moist Bulk Density (g/cm^3)	Organic Matter (%)	Cation Exchange Capacity (meq/100g)
Seffner fine sand	0-13	fine sand	1.35 – 1.45	0 – 2.9	1.2 – 7.6
	13-21	fine sand, sand	1.35 – 1.45	0 – 2.9	0.7 – 5.6
	21-80	fine sand, sand	1.50 – 1.60	0 – 2.9	0.7 – 5.6
Zolfo fine sand	0-3	fine sand	1.35 – 1.55	0 – 2.9	1.0 – 3.8
	3-60	fine sand, sand	1.30 – 1.60	0 – 2.9	0.8 – 3.6
	60-80	fine sand, sand	1.50 – 1.70	0 – 2.9	--
Myakka fine sand	0-5	fine sand	1.35 – 1.45	0.5 – 2.0	--
	5-20	fine sand, sand	1.45 – 1.60	0 – 1.0	--
	20-30	fine sand, sand, loamy fine sand	1.45 – 1.60	1.0 – 6.0	--
	30-80	fine sand, sand	1.45 – 1.70	0 – 0.8	--

[1] *Typical soil properties from "Soil Survey of Hillsborough County, FL", NRCS*

Seasonal high water table indicators were found between 24 and 39 inches. Water level measurements were obtained from existing piezometers in the project area in March, June and July 2009. Based on these water level measurements depth to groundwater ranged from approximately 3 ft to 6 ft below ground surface. It should be noted that the 6 ft depth to groundwater was measured in March 2009 after a three-year drought in the area. The regional groundwater gradient in the project area is from northeast to south-west.

Wastewater from the GCREC research offices and onsite dormitories flow to an existing OSTDS. Wastewater from Facility laboratories is not directed to the OSTDS. This existing OSTDS consists of a pressure dosed mound system designed for 2,850 gallons per day. Two septic tanks (2,500 and 1,250 gallons) provide primary treatment followed by a dosing tank (3,000 gallons). The mound drainfield has 4,351 ft^2 of infiltrative area (design hydraulic loading rate of 0.65 gpd/ft^2) with each half of the drainfield receiving alternating doses. As part of this project, a flow meter will be installed to monitor the actual daily flow to the drainfield.

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2.1.1.2 Test Area Design

Test areas representative of typical mounded OSTDS will be established at the GCREC to enable controlled testing and evaluation of nitrogen reduction in soil and groundwater. Four test areas will be established receiving either septic tank effluent (STE) or nitrified effluent delivered to the soil via a pressure dosed mound or a shallow drip dispersal system (Table 2.2). Effluent will be delivered to the soil at the maximum allowable rate for the sandy soils of 0.8 gpd/ft^2. The combination of STE at the maximum hydraulic loading rate represents the highest allowable mass loading rate to the soil and is therefore expected to provide the most conservative nitrogen removal resulting in the highest expected concentrations of nitrogen reaching the groundwater. However, it is also recognized that many systems in Florida employ an aerobic treatment unit (ATU) which results in delivery of a nitrified effluent to the soil treatment unit (aka, drainfield). Delivery of both STE and nitrified effluent to the soil will enable comparison of the groundwater plumes and evaluation of the benefits (or lack of) of nitrogen transformation and/or reduction prior to groundwater recharge. These two effluents will be delivered to the soil via conventional pressure dosed mound systems or shallow subsurface drip dispersal systems (mounded as required to meet groundwater separation). The drip dispersal system is designed to optimize nitrogen removal through plant uptake and reduce the mobile nitrate-nitrogen fraction that recharges the groundwater. A more detailed description of nitrogen uptake in drip dispersal systems can be found in Parzen (2007).

Table 2.2
Study Design Conditions for Test Areas

Test Area ID	Effluent Quality	Design HLR (gpd/ft^2)	Soil Treatment Unit Design
TA1	STE	0.8	pressure dosed mound
TA2	STE	0.8	shallow drip dispersal
TA3	nitrified effluent	0.8	pressure dosed mound
TA4	nitrified effluent	0.8	shallow drip dispersal
TA5	in situ nitrified effluent (Task A)	from PNRS II pilots	mounded drip dispersal over denitrification media
TA6	in situ STE effluent (Task A)	from PNRS II pilots	mounded drip dispersal over denitrification media

STE will be pumped from the first GCREC septic tank to a holding tank near the test areas. Excess effluent will be returned to the existing GCREC mound to prevent effluent from discharging to the ground and to minimize the holding tank residence time. A portion of the STE from this holding tank will be directed to an approved aerobic treatment unit (e.g., textile filter, single pass sand filter, or other) with the treated effluent held in a

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separate tank as the source of the nitrified effluent. The aerobic treatment unit will be operated in accordance to approved manufacturer specifications and allowed to begin nitrifying (10 to 30 days from start-up) prior to delivery to the soil.

Test areas TA1 – TA4 will have an infiltrative surface of 40 ft^2 (20 ft long and 2 ft wide) and receive effluent in 6 equal doses of 5.33 gallons/dose each day. Equal distribution of effluent to the soil will enable replicate monitoring locations along the length of each test area. Orifice controlled pressure distribution, with orifices located at 1 ft intervals, will be used to deliver the effluent to the mound test areas. This delivery approach will ensure that effluent is equally distributed along the length of the mound. Effluent will be delivered via commercial pressure tubing with pressure compensating emitters located at 1 ft intervals in the drip dispersal systems.

Mound test areas will be constructed using two rows of orifice controlled pressure distribution piping placed 1 ft apart in the center of a 20 ft long, 2 ft wide, and 1 ft thick gravel (mineral aggregate meeting requirements of 64E-6.014(5)(C)) infiltrative surface. One ft of mound or filter sand will underlie the gravel and be placed on the ground surface, providing at least 2 ft of unsaturated separation during high water tables and 3 or more ft of unsaturated separation during low water tables. Native soil will be placed over the gravel with vegetation to minimize erosion. Sides of the mound will be graded to a slope of 2:1 (horizontal:vertical). Additional detail is illustrated on the 50% Test Facility Design drawings (Task C.12) provided in Appendix B for reference.

Drip dispersal test areas will be constructed in 1.5 ft of mound or filter sand placed on the ground surface, again providing at least 2 ft of unsaturated separation during high water tables and 3 or more ft of unsaturated separation during low water tables. Two rows of commercially available drip tubing will be placed 4 to 6 inches deep and 1 ft apart. Turf grass will be placed on the drip dispersal area to replicate a typical residential installation. Additional detail is illustrated on the 50% Test Facility Design drawings (Task C.12) provided in Appendix B for reference.

Test areas will be separated by 20 to 30 ft to minimize potential plume interactions between each test area. In addition, prior to test area construction, vertical and horizontal groundwater gradients will be determined. Test areas will be oriented with the 20 ft dimension in line with the horizontal gradient to further minimize potential plume interactions and enable groundwater plume characterization with fewer monitoring points.

2.1.1.3 Monitoring Framework

Each test area will be monitored for operational conditions, unsaturated and saturated nitrogen concentrations, soil properties, groundwater properties, and weather conditions.

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Operational conditions include effluent quality, hydraulic loading rate to the soil, and ponding on the soil infiltrative surface. The STE and nitrified effluent quality will be monitored weekly for the first month and then bi-monthly for the duration of testing. Due to the multiple wastewater sources to the septic tank, the STE quality is expected to be relatively consistent (compared to typical single family residential homes). The sampling frequency will be further reduced, if indeed the effluent quality is consistent, but the frequency will remain sufficient to estimate nitrogen mass loading rates to the soil. Effluent samples will be analyzed for temperature, specific conductance, pH, dissolved oxygen (DO), total kjeldahl nitrogen (TKN), nitrate-nitrogen, ammonium-nitrogen, and chloride. In addition, half of the samples will also be analyzed for pH, alkalinity, 5-day carbonaceous biochemical oxygen demand ($cBOD_5$), total phosphorus, total solids (TS), total suspended solids (TSS), fecal coliform and *E.coli*. Up to 10% of the samples will also be analyzed for anions and cations. Sample collection, handling and analysis methods will be in accordance with Florida Department of Environmental Protection (FDEP) standard operating procedures (SOPs) and are discussed in Section 3.0. The hydraulic loading rate to the soil will be monitored by recording the delivery pump cycles and with a flow meter for each test area. Should ponding develop within the gravel of the mound test areas, the ponding height will be recorded with water level indicators (+/- 1/32 in. ponding) and visual observations.

The center of test areas TA1 – TA4 will be equipped with unsaturated and shallow saturated zone monitoring instrumentation. Up to two sets of such monitoring equipment will be placed in each of the four test areas. This instrumentation will include stainless steel suction lysimeters, soil moisture probes, and tensiometers. Suction lysimeters, soil moisture probes, and tensiometers will be located at 0.5, 1.0, 1.5, 2.5, and 3.5 ft below the bottom of the gravel or below the drip emitter. During installation, the depth intervals may be adjusted to capture the transition between soil layers (e.g., spodic horizon noted in Soil Survey) and the capillary zone of the low water table. At least four soil moisture probe depth intervals will be located in the unsaturated zone to ensure adequate parameter estimation during inverse modeling (Ritter et al. 2004). Installation methods are discussed in Section 3.0. Figure 2-2 provides general schematics illustrating the locations of the unsaturated zone instrumentation.

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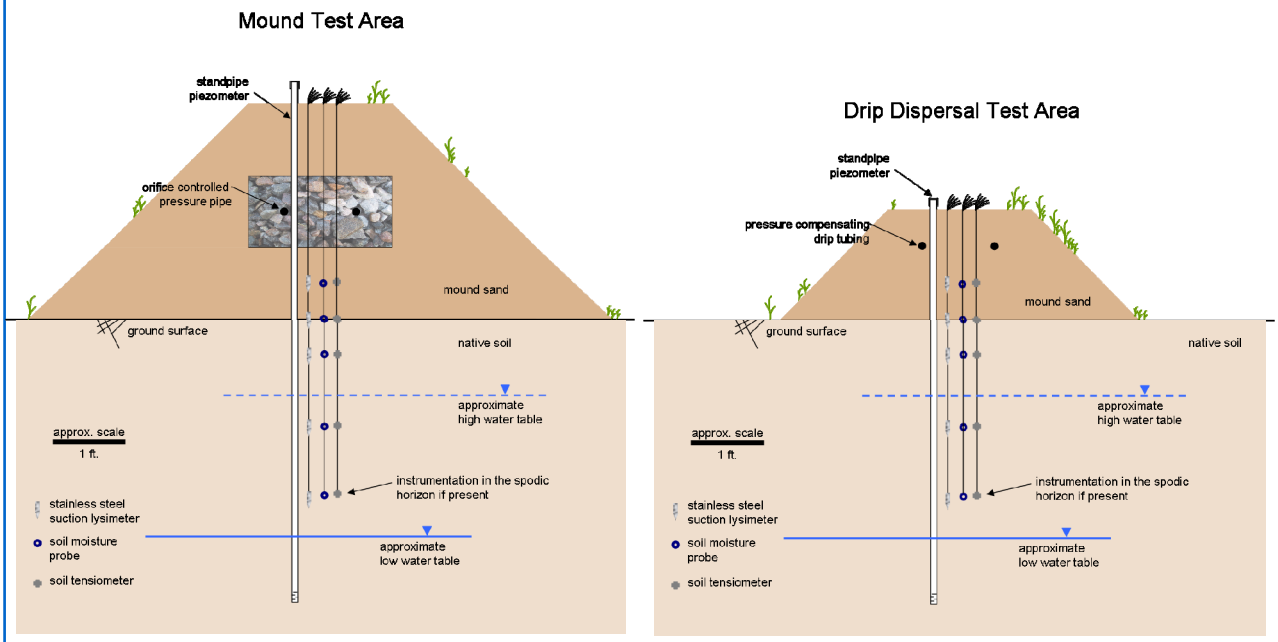

Figure 2-2: General Schematic of Unsaturated Zone Monitoring Framework at the GCREC

Suction lysimeter samples will be collected at 1, 3, 5, 7, 9, and 11 months after effluent delivery. All unsaturated zone solution samples will be analyzed for temperature, pH, specific conductance, DO, TKN, nitrate-nitrogen, ammonium-nitrogen, and chloride. In addition, half of the samples will also be analyzed for alkalinity, chemical oxygen demand (COD), and total phosphorus. COD is a measure of the oxygen equivalent of the organic matter content that is susceptible to oxidation by a strong chemical oxidant and can be empirically related to $cBOD_5$. Because $cBOD_5$ is expected to be at very low concentrations in soil moisture and groundwater samples and is time consuming to measure, COD will be analyzed instead of $cBOD_5$. Up to 10% of the samples will also be analyzed for dissolved organic carbon (DOC), anions, and cations. Note the 0.2 micron nominal pore size of the suction lysimeter precludes total organic carbon (TOC), solids, and microorganism sample analyses. Sample handling and analysis methods will be in accordance with FDEP SOPs and are discussed in Section 3.0. Sample frequency may be increased or decreased to capture seasonal trends and/or changes in system performance as the biozone is developed. Previous work at CSM with suction lysimeter sampling suggests changes in treatment performance within a mature soil treatment unit are adequately captured with samples collected at intervals up to 2 to 3 months (Tillotson, 2009). In addition, samples collected daily over 2 weeks showed relative percent difference (RPD) in soil pore water concentrations of only 13% for ammonium, 11% for

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nitrate, and 10% for chloride. Rather than discrete time intervals, it is more important to capture changes in operating conditions (e.g., start-up vs. mature system) and seasonal changes (rainy season vs. dry season, hot periods vs. cool periods, etc.). Soil moisture content will be collected at least hourly through an automated data logging system. During selected intervals, soil moisture content may be collected every minute to provide high resolution data for short time periods such as capturing effluent movement between doses. Soil tension will be measured at selected time periods to obtain sufficient data resolution to correlate with soil moisture measurements and for parameter estimation during Task D.

Saturated zone monitoring will include groundwater quality, depth of groundwater table, and gradient (i.e., water level). Groundwater will be monitored through two types of piezometers: small diameter standpipe piezometers and drive point piezometers (Figure 2-3). Standpipe piezometers are 0.75 to 1.0 inch diameter wells for groundwater sampling, water levels, and hydraulic testing (e.g., pump tests, slug tests, etc.). Drive point piezometers are stainless steel drive points attach to polyethylene tubing and will be used to locate and define groundwater plumes and enable collection of groundwater samples. Installation methods are described in Section 3.0. Initially up to 12 drive point piezometers will be installed along 2 or 3 transects perpendicular to groundwater flow. Seven or more multi-level piezometers will be installed within the project area (encompassing all four test areas) to monitor vertical gradients, horizontal gradients, and nitrogen flux. One standpipe piezometer will be located at the center of the test area adjacent to the unsaturated zone instrumentation. Two additional standpipe piezometers will be installed down gradient of the test area. These downgradient standpipe piezometers may not be installed until a groundwater plume is identified and additional hydrogeologic information is required.

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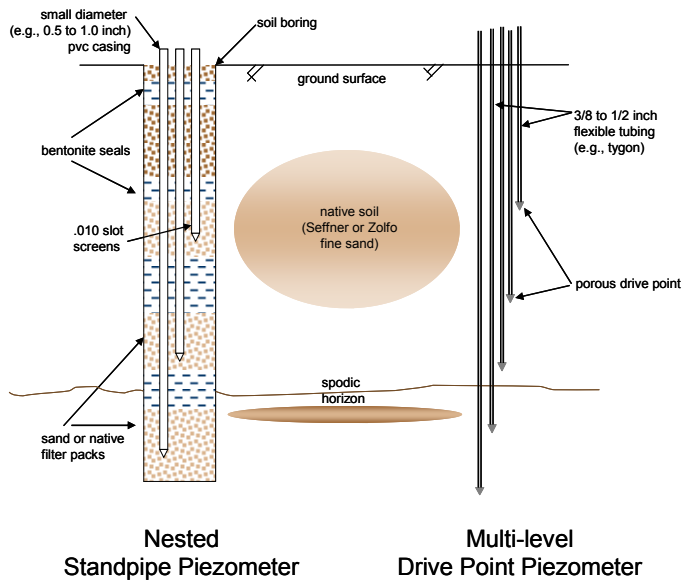

Figure 2-3: Illustration of Standpipe and Drive Point Piezometers

Water level measurements will be taken from all piezometers monthly. Initially, specific conductance, nitrate, and chloride will be monitored monthly, at a minimum, to identify development of a groundwater plume from each test area. After development of a groundwater plume, groundwater samples will be collected at the same frequency and for the same analytes as the soil suction lysimeter samples described above. In addition, all groundwater samples will be analyzed for specific conductance, DO, and chloride. The location of the groundwater samples will be based on groundwater quality field screening (specific conductance). Sufficient groundwater samples will be collected to delineate the groundwater plume (horizontal and vertical) and determine denitrification rates.

2.1.1.4 Tracer Testing

Tracer tests will be conducted at two time points during test area operation; prior to effluent delivery and after six months or more of effluent delivery. Bromide (Br^-) will be used as a conservative tracer (added to clean water or effluent as potassium bromide) representative of the water movement through soil, although some diffusion from mobile to immobile water may occur. The first tracer test, prior to effluent delivery to the test areas, will enable characterization of the background groundwater velocity and dilution. The second test will be conducted after a groundwater plume has been defined and enable comparison of the subsurface changes attributed to effluent delivery. During this

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second tracer test, a nitrogen isotope tracer (^{15}N ammonium chloride) may be added to assess concentration, movement and species partitioning of nitrogen in the effluent delivered to the soil. Tracer test methods are described in Section 3.0.

2.1.2 Field Monitoring at Home Sites

Field monitoring will be conducted at residential home sites in Florida to evaluate current nitrogen reduction in soil and groundwater, to assess groundwater impacts due to conventional and nitrogen removal systems, and to provide data for parameter estimation, and verification and validation of models developed in Task D. Field monitoring will be conducted in subsequent phases of this project and are dependent on continued funding. However, the existing OSTDS at the GCREC will be monitored during this first phase allowing for methodology refinement for future home site monitoring.

2.1.2.1 Site Selection

Up to 8 home sites from three geographical regions (north, central, and south Florida) will be selected for inclusion in this study. Six of these home sites will be monitored. The remaining two sites will enable quick replacement of a home site if it is subsequently deemed inappropriate after monitoring has begun (i.e., unplanned extended absence of the homeowner, homeowner withdraws, etc.).

Home sites located in Wakulla County will serve as representative homes of northern Florida. Wakulla County covers approximately 607 square miles and is predominantly rural (~51 people per square mile). Home sites in Wakulla County are currently being monitored by project team members (Water Research Consulting, LLC) to assess nitrogen in groundwater from performance-based treatment systems. Selected locations within the soil treatment unit have been monitored, but the full extent of the groundwater plume has not been delineated. Leveraging monitoring at these sites will provide historical information beneficial to understanding longer-term behavior and performance. For central Florida, home sites will be located in the Wekiva Study Area, and for southern Florida, home sites will be located near the Gulf Coast in Charlotte County. The Wekiva Study Area covers approximately 300,000 acres within Seminole, Lake and Orange Counties, and is the subject of considerable recent study and proposed nitrogen reduction regulations pertaining to OSTDS. Home sites in the Wekiva Study Area have also been previously monitored by project team members (Mechling Engineering & Consultants, Inc.) to assess fate and transport of nitrogen in highly vulnerable aquifers. Leveraging monitoring at these sites will build off of a large existing knowledge base and again provide understanding of longer-term behavior and performance. Charlotte County covers approximately 694 square miles and is predominantly urban in the eastern portions of the county and rural in the western portions (~216 people per square mile). FDOH permit information will be gathered for each candidate site and a system inspec-

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tion and evaluation will be conducted at the selected sites. If suitable home sites with willing home owners cannot be identified in these locations, the search for sites will be broadened to include additional Counties.

Factors that will be considered during site selection will encompass a range of conditions affecting nitrogen mass loading to the soil and resulting groundwater concentrations. It is not the intent of this study to monitor older OSTDS which do not meet recent or current code requirements. Rather, only approved and permitted sites will be considered ranging in system age from 5 to 10 years old. To enable comparison of the findings with the controlled testing at GCREC, one conventional OSTDS (i.e., STE) and one approved ATU or nitrogen reducing OSTDS (i.e., nitrified effluent) will be monitored in each geographic location. Key factors to be considered also include homeowner amenability, site access, occupancy, and daily household flow. Homeowner amenability is critical. Field monitoring will include installation of numerous instruments which the homeowner must be comfortable with. After potential candidate sites are selected based on FDOH permit review, project team members will meet with prospective homeowners to discuss the project goals and scope. An agreement will be established with the homeowner if identified for inclusion in this study. Site access is also a critical factor. Only sites with readily accessible OSTDS will be selected (no landscape interferences, nearby power and clean water). Candidate sites will have two or more occupants residing in the home year round. To the extent possible, home sites with daily household flow within typical ranges (e.g., 50 – 70 gallons per capita per day) will be selected. After selection, each home site will be equipped with a flow meter. Should daily household flow rates be significantly outside the typical range, the site will be removed from the study and an alternate site included. While numerous subtleties exist between individual OWS, monitoring these key conditions and factors will enable comparison of sites between the three geographical regions and determination of the relative impact of mass loading and nitrogen reduction based on hydraulic loading rate, effluent quality, and season.

2.1.2.2 Monitoring Framework

The existing OSTDS at the GCREC provides a unique opportunity to combine controlled field testing with field scale monitoring. Methods for field monitoring and refinement of the overall monitoring framework will be conducted here to enable development of the simple groundwater model in Task D and streamline future data collection at home sites. The following framework is specific to the existing OSTDS at the GCREC. Field monitoring at home sites will be patterned on the same framework with revisions to sample locations and frequency based on the findings at the GCREC site.

Field monitoring will follow 5 general steps as summarized in Table 2.3. First, the plume extent and location will be determined. Second, based on the delineation of the plume,

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the site will be instrumented with drive point and standpipe piezometers. Next the aquifer will be characterized to determine the groundwater gradient, hydraulic conductivity, and velocity. Following aquifer characterization, routine monitoring will be conducted for at least 12 months. Finally, based on each data collection event, the need for additional information and instrumentation will be assessed. Additional data will be collected as needed to refine the evaluation of nitrogen reduction from OSTDS (e.g., higher resolution of data collection for a short period of time to capture key conditions, additional tracer testing with ^{15}N isotope tracers to refine denitrification rates). Methods for field activities and laboratory analyses during each step are described in Section 3.0.

Table 2.3
Summary of Field Monitoring Framework

Step	Purpose	Approach	Data to be Collected
1	Plume identification	sampling grid for groundwater screening	in-field measurements of groundwater specific conductance
2	Instrumentation	install multi-level drive point piezometers and shallow standpipe piezometers	soil properties determined from soil borings during standpipe piezometer installation
3	Aquifer characterization	conduct pump test and slug tests on standpipe piezometers	hydraulic gradient, saturated hydraulic conductivity
		baseline tracer test	establish groundwater velocity, dispersivity coefficients, and groundwater dilution
4	Routine monitoring	effluent quality, groundwater concentrations, water levels, climatic conditions	water quality parameters as necessary to determine nitrogen reduction
5	Additional instrumentation, testing, and/or monitoring	as warranted	refine denitrification rates, aquifer properties

Initially a grid will be established downgradient of the soil treatment unit. A 25 ft by 25 ft grid will be marked (a smaller grid such as 10 ft by 10 ft will be used for home sites with smaller soil treatment units). Hand held methods (e.g., slide hammer, hand auger) will place a drive point connected to flexible tubing in the subsurface. The specific conductance of the groundwater at that location will be measured and recorded. The drive point will be advanced to additional depths, as feasible, to obtain a vertical conductivity profile at that location. Based on the groundwater specific conductivity, the general plume location and extent will be determined.

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After the groundwater plume has been identified, drive point and standpipe piezometers will be installed. Up to 20 multi-level (up to 5 depths) drive point piezometers will be installed based on the extent of the plume. This network of drive point piezometers will enable vertical and horizontal monitoring of nitrogen in groundwater. Four standpipe piezometers will also be installed: one upgradient of the plume and three within the plume downgradient of the soil treatment unit. These standpipe piezometers will enable aquifer characterization of the gradient and saturated hydraulic conductivity. Soil samples will be collected from the soil borings during standpipe installation to determine general soil properties (lithology, soil features, organic matter content, grain size, etc.). An installation report describing the monitoring system installed will be provided for each home site (Deliverable C.7).

Next the aquifer will be characterized through a pump test and slug tests to determine the saturated hydraulic conductivity and variability within the plume. A conservative tracer test will be conducted to determine groundwater velocity and the affect of aquifer dilution.

Routine groundwater and effluent quality monitoring will be conducted at least four times (i.e., seasonally) to capture the range of likely climatic conditions. Groundwater and effluent samples will be analyzed for temperature, pH, specific conductance, DO, TKN, nitrate-nitrogen, ammonium-nitrogen, and chloride. Effluent samples will also be analyzed for TS and TSS. In addition, half of the samples will also be analyzed for alkalinity, $cBOD_5$ or COD, total phosphorus, fecal coliform and *E.coli*. Up to 10% of the samples will also be analyzed for anions and cations. Sample collection, handling and analysis methods will be in accordance with FDEP SOPs and are discussed in Section 3.0. Higher frequency sample collection and additional sample analysis as needed for model development, calibration, and validation may be conducted based on the results from the GCREC OSTDS monitoring. Sufficient groundwater samples will be collected to delineate the groundwater plume (horizontal and vertical) and determine denitrification rates. A monitoring report describing the each monitoring event will be provided for each home site (see Section 3.4.3).

Finally, based on the field monitoring results, additional testing and/or instrumentation may be required. Additional testing and monitoring will be conducted as needed to ensure the data quality objectives (DQOs) are met or it is determined that the required data collection is not feasible (Section 3.1).

2.2 Performance Assessment

The performance assessment of Task C will be evaluated by the acquisition of sufficient data to:

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- delineate nitrogen reduction in the soil and groundwater at the selected sites, and
- calibrate and validate the simple model developed in Task D.

Successful completion of the first measure listed above will enable determination of the cumulative mass loading of N to the soil and groundwater, identify how currently designed and implemented OSTDS perform, and provide understanding of treatment processes occurring with OSTDS. The second measure will enable development of a simple, yet robust, model for nitrogen fate and transport in Florida subsurface environments in Task D. The combination of these two measures will provide an understanding of how Florida OSTDS perform and a user-friendly tool to predict nitrogen concentration at specified location downgradient of an OSTDS or the nitrogen loading / mass flux at a specified location.

2.3 Contingency Measures

The observational method for technical decision making will be employed during controlled field testing and home site monitoring. This method is a continuous, integrated, process of design, monitoring, and review that enables modifications to be incorporated into the field monitoring framework as appropriate. The observational method provides for initial design based on the most probable conditions rather than the most unfavorable. The gaps in the available information are then filled by observations (e.g., nitrogen concentrations, subsurface soil layers, daily flow rates, etc.) which aid in the assessment of the groundwater by modifying the monitoring framework based on these findings. This approach enables decisions in the field and can be described as a “learn as you go” method. For example, the observational method enables locating groundwater piezometers based on field screening of groundwater specific conductance rather than at preselected locations that may not capture the highest nitrogen concentrations (critical for being able to determine the denitrification rate and nitrogen fate and transport). Coupled with the observational method for this study are identification of additional home sites, in-field screening approaches, frequent data review and assessment, and flexibility in the number and location of sampling points as well as frequency of sample collection. This initial monitoring framework and observational method will be consistent with the Task C DQOs.

During Task C, corrective actions may be required for two 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 analysis, 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.

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Members of the field team will monitor ongoing work performance as a normal part of their daily responsibilities. All project personnel will promptly identify, report, and solicit approved correction for conditions adverse to quality. All findings and actions concerning equipment problems and nonconformance problems will be documented in field or office logbooks.

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.

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Section 3.0
Quality Assurance and Quality Control

3.1 Data Quality Objectives (DQOs)

The general quality assurance (QA) objective for Task C 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 (FDEP-SOP-001/01, FDEP-QA-002/02). Specific DQOs for Task C are to:

- ensure that the home sites selected for monitoring are sufficiently characterized to be representative of the target waste stream and of properly installed OSTDS in Florida;
- ensure that the groundwater contamination by nitrogen is defined and the nitrogen reduction that is occurring is quantified at the home sites and the controlled field test site;
- ensure that soil, soil pore water, and groundwater samples are of sufficient quality to assess the presence and concentration of nitrogen (TKN, ammonium-nitrogen, nitrate-nitrogen), pH, alkalinity, carbon (TOC/DOC, $cBOD_5$, COD), and fecal coliform bacteria;
- ensure sufficient sample resolution to assess the variability within home sites and at the controlled field test site; and
- ensure sufficient sample resolution to determine model input parameters required for Task D model calibration and verification for assessment of nitrogen removal.

Of key importance is to define the groundwater concentrations and areal extent of contamination. This data will enable development of model input parameters as well as field calibration and verification of the simple model developed in Task D. Ultimately the data collected during Task C will be used to make decisions on the behavior of groundwater plumes and the mechanisms contributing to nitrogen reduction (e.g., dilution, denitrification, aerobic treatment prior to soil dispersal). While some uncertainty in the groundwater concentrations is expected, sufficient sampling locations are required to define the groundwater plume (both vertical and horizontal extent) such that factors affecting nitrogen reduction can be assessed. For example, to determine nitrogen reduction (C/C_o),

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the maximum groundwater concentration is essential to determine the maximum reduction.

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 C activities that affect data quality include the sampling design, field collection methods, laboratory analysis, and data analysis. 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 both field and the laboratory are also described (e.g., data type, frequency of use, handling of failed QC measures).

3.2. Field Activities

The Task C 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 C. The SOPs will be kept on site and will be used by field personnel performing field work for the project.

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Table 3.1
List of FDEP SOPs (FDEP-SOP-001/01) for Task C

SOP	Description
FC 1000	Cleaning / Decontamination Procedures
FD 1000	Documentation Procedures
FQ 1000	Field Quality Control Requirements
FS 1000	General Sampling Procedures
FS 2200	Groundwater Sampling
FS 2400	Wastewater Sampling
FS 3000	Soil
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
FT 2000	Residual Chlorine

3.2.1.1 Sample Collection

As described in Section 2, several different types of samples will be collected in Task C including effluent samples, soil samples, groundwater samples, and soil pore moisture samples (see Section 3.2.3 for soil pore moisture samples). In addition, routine monitoring will include several field measurements including pH, temperature, specific conductance, dissolved oxygen, soil moisture content, and soil tension. Finally operating conditions and weather conditions will be monitored and recorded. Sampling methods will be in accordance with FDEP-SOPs (FS 1000). The sample collection methods and field measurement methods are described below and are summarized in Tables 3.2 and 3.3. Associated QC samples are summarized in Section 3.2.1.4.

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Table 3.2
Summary of Sample Collection

Type of Sample	Analysis	Frequency[a]	Sample Collection Method
Controlled Test Site (GCREC)			
Effluent	TKN, nitrate-nitrogen, ammonium-nitrogen	weekly during the first month of operation, then bimonthly	peristaltic pump grab sample
	pH, alkalinity, $cBOD_5$, total phosphorus, total solids, total suspended solids, fecal coliform and *E.coli*	50% of the samples	
	anions and cations	10% of the samples	
	TKN, nitrate-nitrogen, ammonium-nitrogen, pH, alkalinity, $cBOD_5$	to be determined	depth specific grab sample
Soil	lithology, soil features, organic matter content, grain size	1 ft intervals to the total depth and location of standpipe piezometers	direct push soil core
Groundwater	nitrate-nitrogen	monthly at drive point piezometer locations until plume is established	low flow peristaltic pump grab sample
	TKN, nitrate-nitrogen, ammonium-nitrogen	every 2 months at drive point piezometer locations after plume is established	
	pH, alkalinity, COD, total phosphorus	50% of the samples	
	anions and cations	10% of the samples	
Soil moisture	TKN, nitrate-nitrogen, ammonium-nitrogen	1, 3, 5, 7, 9, and 11 months after effluent delivery	in situ suction lysimeter
	pH, alkalinity, COD, total phosphorus	50% of the samples	
	anions and cations	10% of the samples	

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Table 3.2 continued
Summary of Sample Collection

Type of Sample	Analysis	Frequency[a]	Sample Collection Method
Home Sites[b]			
Effluent	TKN, nitrate-nitrogen, ammonium-nitrogen	four times	peristaltic pump grab sample
	pH, alkalinity, $cBOD_5$, total phosphorus, total solids, total suspended solids, fecal coliform and *E.coli*	50% of the samples	
	anions and cations	10% of the samples	
Soil	lithology, soil features, organic matter content, grain size	1 ft intervals to the total depth and location of standpipe piezometers	direct push soil core
Groundwater	water level	monthly	water level indicator
	TKN, nitrate-nitrogen, ammonium-nitrogen,	four times	low flow peristaltic pump grab sample
	pH, alkalinity, COD, total phosphorus, fecal coliform and *E.coli*	50% of the samples	
	anions and cations	10% of the samples	

see Tables 3.5 and 3.6 for analysis methods, detection limits, preservation, and holding times.

[a] *The number, location, and frequency of sample collection will be based on the observational method (in-field screening approaches, frequent data review and assessment).*

[b] *Sample locations and frequency based on the findings at the GCREC site.*

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Table 3.3
Summary of Field Measurements

Type of Measurement	Measurement	Frequency[a]	Field Method
Controlled Test Site (GCREC)			
Operational Conditions	HLR	weekly	flow meter
	ponding		visual observation
Weather Conditions	temperature, precipitation, barometric pressure, wind speed, relative humidity, ET	at least weekly	field weather station
Effluent	temperature, specific conductance, pH, DO, and chloride	weekly during the first month of operation, then bimonthly	flow through test cell, ISE
Groundwater	specific conductance and chloride	monthly until plume is established	flow through test cell, ISE
	specific conductance, DO, and chloride	every 2 months after the plume is established	flow through test cell, ISE
Soil moisture	purge and sample volumes	1, 3, 5, 7, 9, and 11 months after effluent delivery	graduated cylinder or flask
	temperature, specific conductance, pH, DO, and chloride		flow through test cell
	soil moisture content	hourly	in situ probes with automated data logger
	soil tension	to be determined	in situ tensiometers
Home Sites[b]			
Operational	HLR, ponding	every visit (4 times)	flow meter and visual observation
Effluent	temperature, specific conductance, pH, DO, and chloride	every visit (4 times)	flow through test cell, ISE
Groundwater	temperature, specific conductance, pH, DO, and chloride	every visit (4 times)	flow through test cell, ISE

see Tables 3.5 and 3.6 for measurement methods, detection limits, preservation, and holding times.

[a] *The number, location, and frequency of field measurements will be based on the observational method (in-field screening approaches, frequent data review and assessment).*

[b] *Sample locations and frequency based on the findings at the GCREC site.*

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Effluent samples will be collected in accordance with FS 2400, Wastewater Sampling. Grab samples will be collected at the controlled test site and the individual home sites. Grab samples will enable estimation of the mass loading of nitrogen to the soil. The frequency of effluent sample collection and analyses methods are summarized in Tables 3.2 and 3.3. Effluent samples will be collected using a peristaltic pump with dedicated tubing (FS 2430). The suction inlet tubing will be located in the mid section of the clear liquid phase in the latter most tank at the home sites and of the effluent holding basins at the GCREC immediately prior to discharge to the soil. Effluent samples will be collected into a 500 mL or larger sample container and placed in a cooler on ice.

Soil samples will be collected from the cores during installation of standpipe piezometers (see Section 3.2.2 for field methods and equipment) following FDEP-SOP FS 3000 using direct push techniques (FS 3220-5.0). Soil characteristics, will be obtained from up to 4 boreholes located within the area of interest (controlled test site or home site). The number and layout of the boreholes may be adjusted as necessary based on field results. Borings will be drilled to a maximum depth of 30 ft using direct-push equipment and GeoProbe sampling tools. Continuous core samples will be obtained starting at the surface. The soils retrieved during coring will be used for field and laboratory analytical analysis (Tables 3.2 and 3.3). Soil samples will be collected at 2-ft intervals from the water table for soil texture, soil features, total organic carbon (TOC), and grain size distribution. Depending upon the results of these field measurements and analyses, specific analytes, locations, or frequency may be altered.

All groundwater samples will be collected using a peristaltic pump and dedicated tubing in accordance with FDEP-SOP (FS 2201-2.1.1, FS 2220-3.4, and FS 2221-1.1). Prior to groundwater sample collection, the piezometer will be micropurged using low-flow purging and sampling methods (USGS 1998, Kearl et al, 1992 and 1994). The flow rate of the peristaltic pump is adjusted to match the piezometer groundwater yield rate by monitoring the water level until it is stabilized. Micropurging is continued until water quality indicators (temperature, pH, specific conductance, DO, turbidity) are stabilized (three consecutive measurements within the limits as stated in FS 2212-3.1). Groundwater samples will be collected into a 500 mL or larger sample container and placed in a cooler on ice. The frequency of groundwater sample collection and analyses methods are summarized in Tables 3.2 and 3.3. The number and location of groundwater samples will be adjusted as necessary based on field screening results and the previous sample results. Field measurements of pH, specific conductivity, temperature, and DO will be conducted in accordance with FDEP-SOPs (FT 1000, FT 1100, FT 1200, FT 1400, and FT 1500).

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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).

In addition, operating and weather conditions will be monitored in the field (Table 3.3). A flow meter installed on the pump discharge will measure daily flow. The flow meter will be recorded at least weekly to determine HLRs to the test area or home site. In addition, a data logger with time stamp may be used to record pump cycles and assess water use patterns and peak flows. Should ponding occur, visual observations will measure the depth of ponding from a standard reference point at each test area or home site. A reference mark will be made on the observation port casing and the distance from this reference to the infiltrative surface measured. Ponding will be measured by lowering a measuring tape, with a hook on the tip, down the observation port so that when the tip of the hook breaks the surface of the effluent the distance on the measuring tape can be recorded. This technique provides a ponding height measurement accurate to ~ ±1/32 in. (±1 mm). There is a weather station currently located at the GCREC. Weather conditions are recorded every minute with data available via a private website. Direct measurements for evapotranspiration (ET) will be conducted if estimates calculated from the available weather data are not sufficient for modeling in Task D.

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 purchased precleaned where applicable; 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. Sample identification nomenclature will provide a unique number for each sample location/type and is summarized in Table 3.4. For example, CE-HS1-DP3-240 is the groundwater sample collected from drive point piezometer 3 (240 cm below ground surface) at home site 1 in Central Florida. For simplification in the field, a 4-digit cross reference code may be noted on the sample label with the full sample identification recorded in the field logbook. 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.

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Due diligence will be exercised to minimize the time between sample removal from 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 on ice or frozen Blue Ice® to the GCREC laboratory or commercial analytical laboratory for analyses. Each sample container will be secured in packing material as appropriate to prevent damage and spills. Sample delivery will be conducted on a daily to weekly basis, dependent upon the sampling frequency.

Table 3.4
Nomenclature for Sample Identification

Site ID				Sample ID		
Region (AA)[a]		**Location (AAN)[b]**		**Sample Type (AAA/N)[b]**		**Depth (NNN)[c]**
GC	Gulf Coast Research Education Center	TA1	test area	STE	effluent sample, septic tank effluent	NA
NO	Northern Florida (Wakulla County)	HS1	home site	NTE	effluent sample, nitrified effluent	NA
CE	Central Florida (Wekiva Study Area)			SB1	soil sample, soil boring	60, 120, etc.
SO	Southern Florida (Charlotte County)			SM1	unsaturated zone, soil moisture probe	15, 30, etc.
				ST1	unsaturated zone, soil tension probe	15, 30, etc.
				LY	unsaturated zone, lysimeter soil pore water	15, 30, etc.
				SD1	groundwater, standpipe piezometer	90, 240, etc.
				DP1	groundwater, drive point piezometer	90, 240, etc.

[a] *character type: A = Alpha, N = Numeric*
[b] *numeric identifier for multiple locations of a similar type (e.g., HS1 = home site 1, SB1 = soil boring 1, etc.)*
[c] *depth in cm below infiltrative surface or below ground surface*

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

- actual possession of a member of the sampling crew,
- view of the sampling crew (constituting actual possession by the crew), or

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- 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 used to document the transfer of samples from field personnel to the GCREC or 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 their 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 3.5 and 3.6 list the analytical methods, target analytes, sample containers, preservatives, and holding times for effluent, soil, soil pore moisture, and groundwater sampling that is anticipated to be conducted during Task C. Constituents of interest will be analyzed on effluent, groundwater, and soil pore moisture samples following standard methods as described in Table 3.5 (FDEP 2008, APHA 2005, Hach 1998). Laboratory analysis of the samples shall be performed on the unfiltered sample within 24 hours of collection or within the appropriate holding times as specified in individual analysis methods (Table 3.6).

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Sample aliquots of approximately 15 mL each will be collected, placed into sterilized containers (e.g., 15 mL conical tubes), and immediately placed on ice for microbial analyses. 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). Both fecal coliforms and *E. coli* will be enumerated using a modified version of the enzyme substrate test or membrane filtration (APHA 2005, 9222D). For the enzyme substrate test, samples are diluted and added to a chromogenic and flourogenic substrate. After adding sample to the substrates, the mixture is incubated at 45°C for 24 hours, the system then provides the concentrations of both fecal coliforms and *E. coli* through a most probable number result based on the substrate color change or UV fluorescence. Note that the incubation temperature has been modified from the manufacturer's recommendation of 35°C in order to enumerate only fecal coliforms rather than total coliforms. However, several groups (Yakub *et al.*, 2002; Chihara *et al.*, 2005) have shown similar fecal coliform counts when comparing the above method to the membrane filtration method.

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Table 3.5
Sample Analyses Methods

Parameter	Detection Limits[a]	Method
Flow	Manufacturer specifications	Water meter
pH	0.1	Electrode - (APHA method 4500-H^+B)
Temperature	0.1 ^oC	Field method - (APHA method 2550B)
Alkalinity	2.0 mg-$CaCO_3$/L 0.2[b] mg-$CaCO_3$/L	Titration - (APHA method 2320B)
$cBOD_5$	1.0 mg/L 0.3[b] mg/L	Carbonaceous 5-day test - (APHA method 5210B)
COD	3.0 mg/L 0.2[b] mg/L	Closed reflux, colorimetric method (APHA method 5220D and HACH 1998 U.S. EPA-approved)
TOC / DOC	1.0 mg-C/L	Combustion-infrared method - (APHA method 5310B)
TS and TSS	5.0 mg/L	Gravimetrically, dried at 103–105^oC - (APHA methods 2540B and 2540D)
TKN	0.03 mg-N/L	Block digestion, flow injection analysis - (APHA method 4500N_{org} D)
Ammonia nitrogen	0.6 mg-N/L 0.03 [b] mg-N/L	Salicylate method - (HACH 1998, U.S. EPA-approved) Distillation and titration - (APHA method 4500-NH_3 C)
Nitrate-nitrogen	0.2 mg-N/L	Spectrophotometric, chromotropic acid method (HACH 1998, U.S. EPA-approved) Ion chromatographic method - (APHA method 4110)
Total phosphorus	0.06 mg-P/L	Nitric acid-sulfuric acid method - (APHA method 4500-P) Persulfate oxidation method - (U.S. EPA 365.2)
Chloride	4.0 mg-Cl/L	Solid state ion selective electrode - (U. S. EPA 9212) Ion chromatographic method - (APHA method 4110)
Fecal coliform	1cfu/100mL	Enzyme substrate test - (APHA method 9223B, modified by incubation at 45°C)
E. coli	1cfu/100mL	Enzyme substrate test - (APHA method 9223B)

[a] *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.*

[b] *Lower estimated detection limit for groundwater samples.*

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Table 3.6
Sample Analyses Requirements[1]

Parameter	Minimum Volume (mL)	Container Requirements	Preservative and Holding Time
Flow	NA	NA	NA
pH	5	Pre-cleaned plastic or glass	None, analyze immediately
Temperature	5	Pre-cleaned plastic or glass	None, analyze immediately
Alkalinity, total	50	Pre-cleaned plastic or glass	<6°C, 24 hours
$cBOD_5$	60	Pre-cleaned plastic or glass	<6°C, 6 hours
COD	2	Pre-cleaned glass	<6°C, 24 hours with H_2SO_4 to <pH2, 28 days
TOC / DOC	5	Pre-cleaned acid washed amber glass	<6°C, 28 days
TS and TSS	20	Pre-cleaned plastic or glass	<6°C, 7 days
TKN	5	Pre-cleaned plastic or glass	<6°C, 24 to 48 hours with H_2SO_4 to <pH 2, 28 days
Nitrate-nitrogen	5	Pre-cleaned plastic or glass	<6°C, 24 to 48 hours with H_2SO_4 to <pH 2
Ammonia-nitrogen	5	Pre-cleaned plastic or glass	<6°C, 24 hours with H_2SO_4 to <pH 2, 28 days
Total phosphorus	5	1:1 HCl acid washed glass	<6°C, 24 hours H_2SO_4 to <pH 2, 28 days
Chloride	<100	Pre-cleaned plastic or glass	<6°C
Fecal coliform	5	Sterile plastic or glass	<6°C, 24 hours
E. coli	5	Sterile plastic or glass	<6°C, 24 hours

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

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 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.

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Table 3.7
Summary of QC Samples Collected and Analyses Conducted

QC Sample	Frequency
Field duplicate	10% of samples collected
Laboratory duplicate	per laboratory SOPs
Equipment rinsate	one per sampling event per region
Field blank	one per sampling event per region
Split sample	10% of samples collected
Laboratory blank	per laboratory SOPs
Laboratory spike	per laboratory SOPs
Non-routine method check	as necessary

Field QC samples will include duplicates, equipment rinsates, and field blanks. Duplicate samples will be collected with the regular samples. Field duplicate samples will be collected from the same 24-hr composite sample container. Duplicate grab samples will be collected at the same location in immediate succession with a regular sample. The number of duplicates collected will be 10% of the total samples collected. The identification numbers and locations of the duplicate and regular samples will be clearly indicated in the log book. Duplicate samples will undergo the same laboratory analyses as regular samples.

Field blanks are samples of the source water used for decontamination. These field QC samples are collected to ensure that constituents of interest (i.e., nitrogen) are not introduced into the sample during decontamination. The rinse water used for decontamination is typically organic-free deionized water. The water used for washing is potable tap water. At a minimum, one sample from each source of water for a given sampling event will be collected for analysis. The field blanks will be analyzed for the same parameters as the associated sample medium. The water used for decontamination will be resampled whenever the source or supplier is changed.

Equipment rinsate samples will be collected to determine the effectiveness of decontamination procedures. These samples will be collected by pouring deionized water into or through the sampling device after it is thoroughly decontaminated. The equipment rinsate samples will be analyzed for the same parameters as the associated samples. At least one equipment rinsate sample will be collected during each sampling event if the sampling involves the use of decontaminated equipment (e.g., samples may be collected with dedicated and/or disposable equipment; therefore, no decontamination is performed).

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3.2.2 Field Testing

Field testing will include operational monitoring, piezometer installation for subsequent groundwater monitoring, field measurements, and weather monitoring. The field equipment for Task C includes a field spectrophotometer, flow meters for effluent delivery, meters for measuring pH, specific conductivity, temperature, DO, water levels, etc., and a weather station. Equipment used in the field will be maintained and calibrated in accordance with the manufacturers specifications (FDEP-SOP FT 1900). 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 (e.g., field spectrophotometer, multiparameter sonde for pH, specific conductivity, temperature, DO) 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, as appropriate, 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.

Piezometers will be installed to enable groundwater monitoring as described in Section 2. During standpipe piezometer installation, soil samples will be collected to characterize the soil and aquifer. Borings for standpipe piezometer installation will be drilled using direct-push equipment and sampling tools. Continuous core samples will be obtained starting at the surface. Soil samples will be collected at 2-ft intervals from the soil cores. The GeoProbe/Terraprobe sampling method utilizes a 4-ft. long x 2-in. inner diameter (ID) dual-tube assembly with polyethylenterephthalate (PETG) liners to collect continuous undisturbed samples. The dual-tube assembly is comprised of an outer stainless steel core barrel (3.25-in ID), an inner stainless steel core barrel (2.25-in ID) and PETG liners (2-in ID) inserted into the inner core barrel. The dual-tube assembly is hammered, without rotation, ~3.5 ft into the ground surface. The inner core barrel with PETG sleeve and soil core is then retrieved to the surface. Upon retrieval to the surface, the PETG liner with the intact soil core is removed from the sampler, capped and stored at 4°C prior to transporting to the laboratory for analyses. A clean PETG sleeve is then replaced into the inner core barrel and reinserted into the outer core barrel retained in the subsur-

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face. The dual-tube assembly is then again advanced ~3.5 ft and the process repeated until a continuous core to the desired depth was obtained. These soil core collection methods enabled relatively intact core samples to be aseptically collected vertically downward.

Standpipe piezometers will be installed in the soil borings to a maximum depth of approximately 30 ft using standard well construction practices (Driscoll 1986). The screen length of each standpipe piezometer will be selected based on the soil profile at that location. All couplings will have flush threaded connections. No glues or lubricants will be used. The annular space will be filled with native filter pack or with a grade of silica sand pack selected based on the soil grain size and the slot size of the screen. The sand pack will extend one to two feet above the top of the screen with a one to two foot bentonite seal placed on top of the sand pack to prevent preferential flow between the multiple completions. Each standpipe piezometer will be grouted at the ground surface and have a locking cap to prevent tampering. Upon completion, all standpipe piezometers will be developed by surging and pumping (Driscoll 1986). Piezometers will be allowed to set for a minimum of 24 hours before development to allow the grout to set. Development will begin at the top of the screen and proceed vertically downward with pumping rates and water levels monitored and recorded during the development process. Development will continue until at least five times the volume of standing water has been removed or the water is as clear as practical. All development water will be recharged to the ground.

All direct push and soil sampling equipment (e.g., drive points, core barrels, sampling utensils, etc.) that contacts potential soil samples will be cleaned according to FDEP-SOP FC 1000 between each piezometer location. Any residual soil will be spread on the ground surface or containerized and disposed of to not alter home site landscaping.

Drive point piezometers will be used to locate and define groundwater plumes and enable collection of groundwater samples. Stainless steel drive points are attach to polyethylene tubing inserted into standard 3/4" (20 mm) NPT steel drive pipe which is widely available through local plumbing and hardware stores. The steel drive pipe allows for the drive point piezometers to be driven into the ground with either direct push drilling or hand methods such as slide hammers (FDEP-SOP FS 3000). The drive casing is then removed leaving the drive point at the desired depth and the attached tubing extending to the surface.

Following standpipe piezometer installation hydraulic tests will be performed. Single well step drawdown tests will be conducted to determine the relative distribution of hydraulic conductivity within the test area or home site. Understanding the permeability distribution will be critical for interpreting the results of the field monitoring. Alternatively, single-well

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recovery tests may be conducted (bail test or slug test). Analysis will be conducted using the Hvorslev (1951) or Bower and Rice (1976).

3.2.3 Non-standard or Alternative Field Methods

Monitoring of the unsaturated zone will require the use of non-standard field methods including suction lysimeters, in situ soil tensiometers, and in situ soil moisture probes. However, these methods have been widely used in field research and are proven techniques (Anderson, 1994; Wolt, 1994; Hart and Lowery, 1997; Tackett, 2004; Dimick, 2005). A brief description is provided here.

Stainless steel suction lysimeters (SW-074, Soil Measurement Systems, Tucson, AZ) will be installed at the controlled field test site (Figure 3-1). Suction lysimeters are preferred due to the minimal subsurface disruption and the ability to easily collect discrete samples compared to pan lysimeters. The 0.86-in. diameter lysimeters are 4.5-in. long including a 3.5-in. length that is porous with a nominal pore size of 0.2 microns and tubing that extends to the ground surface. The small pore size limits sampling for bacteria, but is necessary to inhibit air from entering the lysimeters in lieu of soil water solution. Lysimeters will be installed within a single 2-in. diameter borehole with a sieved native soil and water slurry (3:1 volume:volume) to ensure continuous contact between the porous lysimeter and surrounding undisturbed soil. A bentonite seal will be placed between the lysimeters to prevent preferential flow paths within the borehole that could yield artifacts during soil pore water sampling and analyses (see Figure 3-1).

Individual lysimeter tubing is inserted into a rubber stopper with another set of tubing leading to the vacuum line. A vacuum is applied to the tubing to facilitate sample collection from the unsaturated zone. The vacuum applied must be strong enough to overcome the soil moisture tension and to draw soil water present in the vadose zone into the lysimeter. The SW-074 lysimeters have a bubbling pressure of 700 millibars. This pressure is the air entry value, which is the air pressure required to force air through the thoroughly wetted porous material. The bubbling pressure is a function of pore size; the smaller the pores, the higher the bubbling pressure value. When this critical value is exceeded, the bonds attaching water to the porous material can be broken. Soil solution then travels up from the lysimeter by vacuum and drops into a pre-cleaned stoppered flask for sample collection (Figure 3-1). The initial soil solution volume collected is purged (dumped) in order to ensure a representative sample from the soil profile. To provide the vacuum needed for soil solution sampling, a manifold of PVC pipe will be connected with flexible tubing to vacuum pumps. All glassware will be washed in phosphorus-free soap, followed by acid/base baths separated by DI water rinses, allowed to air dry, and then covered with foil until use.

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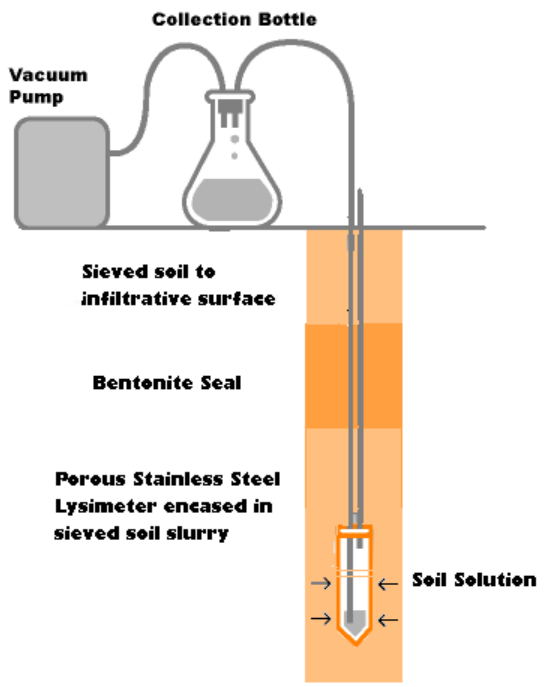

Figure 3-1: Configuration of Soil Suction Lysimeters Used for Pore Water Sample Collection (from www.soilmeasurement.com)

In situ soil tension and soil moisture measurements will be collected for model development in Task D. Parameter estimation for porous media flow by inverse modeling has been shown to be sufficient with four observation depths and at least two of three conditions: soil water content, matric pressure head, and or water flux (Ritter, 2004). The matric potential is the pressure potential due to the interaction of water and soil grains with both positive and negative pressures are measured with a tensiometer (Marshall et al., 1996). Soil moisture tension will be monitored with tensiometers installed at up to 4 depths as described in Section 2. Tensiometers have a ceramic cup and tube assembly equipped with a pressure transducer. The pressure transducer allows for precise measurement of the water potential. Tensiometers can be automated to enable recording of soil moisture tension at up to 15 minute intervals to evaluate short-term changes in soil moisture status associated with wastewater dosing events. Alternatively, tensiometers will be manually read at weekly intervals. Soil moisture will be measured through time domain reflectometry (TDR) probes. TDR measures the travel time of an electric pulse

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down a wave guide inserted in the soil. The travel time of the pulse depends on the apparent permittivity or dielectric constant, ε, of the soil media. Since the ε_{water} is approximately 70 times greater than ε_{soil} (dry soil), the $\varepsilon_{soil\ media}$ depends strongly on the water content (θ_w) of the soil system (Jury et al. 1991). Prior to installation, the global and individual settings for each wave guide will be adjusted according to the manufacturer's recommendations. Wave guides will be connected to a data logger to automatically acquire water content measurements for each TDR wave guide every 2 hours. The frequency of data logging may be modified based on the observational approach. Both tensiometers and soil moisture probes will be installed with direct push hand methods. During installation, the depth intervals may be adjusted to capture the transition between soil layers (e.g., spodic horizon noted in Soil Survey) and the capillary zone of the low water table.

3.3 Laboratory Activities

All laboratory activities will meet the minimum QC as specified in the FDEP-SOPs which meet 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 C 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 effluent, soil, soil pore moisture, and groundwater samples are discussed in Section 3.2.1.3 (Tables 3.5 and 3.6). 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°C (as applicable) until analyses are performed.

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 labora-

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tory 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. Split samples will be sent to an outside commercial analytical laboratory for 10% of the nitrogen samples. 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 of <10%. 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. A summary of the QC samples is presented in Table 3.7 (Section 3.2.1.4).

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

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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 C 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 OSTDS operational conditions,
- 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.

In addition, the latitude and longitude of each fixed monitoring point (piezometers, suction lysimeters, etc.) will be documented. Sufficient information will be included such that all team members can easily locate the monitoring point. At the time of collection, each sample will be labeled with notations made in waterproof, indelible ink. Minimum information on the sample label will include:

- unique sample identification number (Section 3.2.1.2),

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- 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 C 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 can be difficult to evaluate separately. Primary data

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will also be graphically examined to identify obvious effects and trends and then subjected to classic statistical analyses such as multifactor analysis of variance, 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. The accuracy of surveying measurements for the locations of wells and piezometers will be ± 0.5 ft. for horizontal measurements and ± 0.1 ft. for vertical measurements.

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

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

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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 site conditions. The representativeness of all field data will be qualitatively assessed by determining if the data are consistent with known or anticipated environmental conditions 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 using a flow-through cell, if possible. 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.,

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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 C (Deliverable C.19, 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:

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- 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.

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Section 4.0
Health and Safety

4.1 Hazard Assessment

Field activities will consist of drilling, piezometer installation, and environmental sampling. An activity hazard analysis table will be available in the field at all times (see Appendix C). All field activities will be conducted in areas without chemical hazards. However, bentonite pellets will be used during piezometer installation. Bentonite contains crystalline silica which may induce long term respiratory problems at high exposures. Bentonite pellets or granular bentonite will be used to minimize dust. Biological hazards are associated with exposure to high concentrations of microorganisms in wastewater. The most common bacterial pathogens found in untreated wastewater are *Salmonella* and *Shigella* (Bitton 1999). Other bacterial microorganisms include *Vibrio*, *Campylobacter*, and *Leptospira* (Bitton 1999). The following are general personnel hazards anticipated during Task C field work:

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

Proper personal hygiene and use of personal protective equipment (PPE) can significantly reduce or eliminate the biological safety hazard. Constant attention will be given to physical hazards encountered during work activities, particularly those associated with drilling equipment. Qualifications (i.e., demonstrated experience and ability) with respect to the tasks to be performed will be required. Only qualified, competent personnel with prior experience will operate drilling equipment. Prior to any site activities, all equipment will be inspected. Custom modifications to equipment is prohibited unless authorized in writing by the original equipment manufacturer or certified as safe by a registered professional engineer.

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 con-

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cern commonly found in STE include pathogenic bacteria at sustained high concentrations 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	
	Fecal Coliform	10^5-10^8	10^6
	Clostridium perfringens	10^3-10^5	1-10^{10}
	Enterococci	10^4-10^5	
	Fecal streptococci	10^3-10^6	
	Pseudomonas aeruginosa	10^3-10^4	
	Shigella	10^0-10^2	
	Salmonella	10^2-10^4	
Protozoa	*Cryptosporidium* oocysts	10^1-10^3	1-10
	Entamoeba cysts	10^{-1}-10^1	10-20
	Giardia cysts	10^3-10^4	<20
Helminths	Ova	10^1-10^3	
	Ascaris lumbridcoides		1-10
Viruses	Enteric Virus	10^3-10^4	1-10
	Coliphage	10^1-10^4	

(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.

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

Organism		Disease Caused	Symptoms
Bacteria	Salmonella typhi	Typhoid fever	High fever, diarrhea
	Shigella	Bacillary dysentery	Dysentery
	Vibrio cholerae	Cholera	Diarrhea, dehydration
	Yersinia enterocolitica	Gastroenteritis	Diarrhea
	E. coli (pathogenic)	Gastroenteritis	Diarrhea
	Legionella pneumophila	Legionnaires' disease	Malaise, acute respiratory illness
	Leptospira spp.	Weil's Disease	Jaundice, fever
	Campylobacter jejuni	Gastroenteritis	Diarrhea
Virus	Adenovirus	Respiratory disease	
	Enteroviruses	Gastroenteritis, menin-gitis, heart anomalies	
	Poliovirus		
	Echovirus		
	Coxsackie virus	Infectious hepatitis	
	Hepatitis A	Gastroenteritis	Jaundice, fever
	Norwalk	Gastroenteritis	Vomiting
	Parvovirus	Gastroenteritis	Diarrhea
	Rotavirus	AIDS	Diarrhea
	HIV		
Protozoa	Cryptosporidium parvum	Cryptosporidiosis	Diarrhea, low-grade fever
	Giardia lamblia	Giardiasis	Diarrhea, nausea, indigestion
	Balantidium coli	Balantidiasis	Diarrhea, dysentery, intestinal ulcers
	Entamoeba histolytica	Amoebic dysentery	Diarrhea, dysentery
	Cyclospora	Cyclosporasis	Severe diarrhea, nausea, vomiting, severe stomach cramps

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

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Cold and Heat Stress Personnel will be monitored for heat stress during summer monitoring 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.

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). Hearing protection will be worn at all

times in proximity of the direct push drilling rig during soil sampling and piezometer installation.

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. Utility locator surveys will be conducted for each area where piezometer installation will be conducted. In addition, routine hoisting and rigging will be necessary for lifts associated with the drilling activities. Improper lifts 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 gears, belts, and drive shafts where applicable, 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.

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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 C, 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 nitri-

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fied effluent. To mitigate these exposure routes for workers, eating, drinking or smoking will 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 the drilling rig or other overhead hazards.

The primary potential public and environmental exposure risk 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.

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Section 5.0
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Appendix A

GCREC Memo

HAZEN AND SAWYER
Environmental Engineers & Scientists

Hazen and Sawyer, P.C.
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
(813) 630-4498
Fax: (813) 630-1967

M E M O R A N D U M DATE: May 18, 2009

FOR: Elke Ursin, Florida Department of Health

FROM: Damann L. Anderson, P.E.

SUBJECT: Evaluation of Test Facility Site

Hazen and Sawyer is conducting the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study under contract CORCL with the Florida Department of Health. Under Task A of this project, we are in the process of identifying test facility sites where multiple assessments of onsite nitrogen reduction technologies and groundwater quality can be conducted in subsequent phases of the study. Two potential sites identified in the response to the ITN were the University of South Florida Lysimeter Facility property and the University of Florida's Gulf Coast Research and Education Center (GCREC) near Wimauma, FL. Salient issues include space availability, site access, wastewater source of sufficient quantity and quality, subsurface hydrology, power supply and security.

After a preliminary assessment of the USF Lysimeter Facility, we feel that the cost of rehabilitating this facility will be beyond the budget allocated for that effort. Also, since space is limited at the USF facility and it is not conducive for groundwater quality assessments, we have concluded that it would be more cost effective to have only one test facility, where the controlled testing portion of the project could be conducted. It is our recommendation that the GCREC be selected as the test facility site. This memorandum summarizes the characteristics of the GCREC facility, as related to establishment of this test facility.

The GCREC facility is located at 14625 County Road 672, Wimauma, Florida. The facility is situated on 475 acres of land that were donated by Hillsborough County government. The facility contains research trials for vegetables, small fruit and ornamental plants. In addition, 16 laboratories are housed onsite, one being a water quality laboratory which is available and can provide many of the analyses of interest for the FOSNRS project. One of the active programmatic areas is soil and water science. A preliminary agreement to participate has been obtained, and the key personnel at the facility are interested in the FOSNRS study. A suitable area for the proposed work has been identified at the facility as depicted in Figure 1.

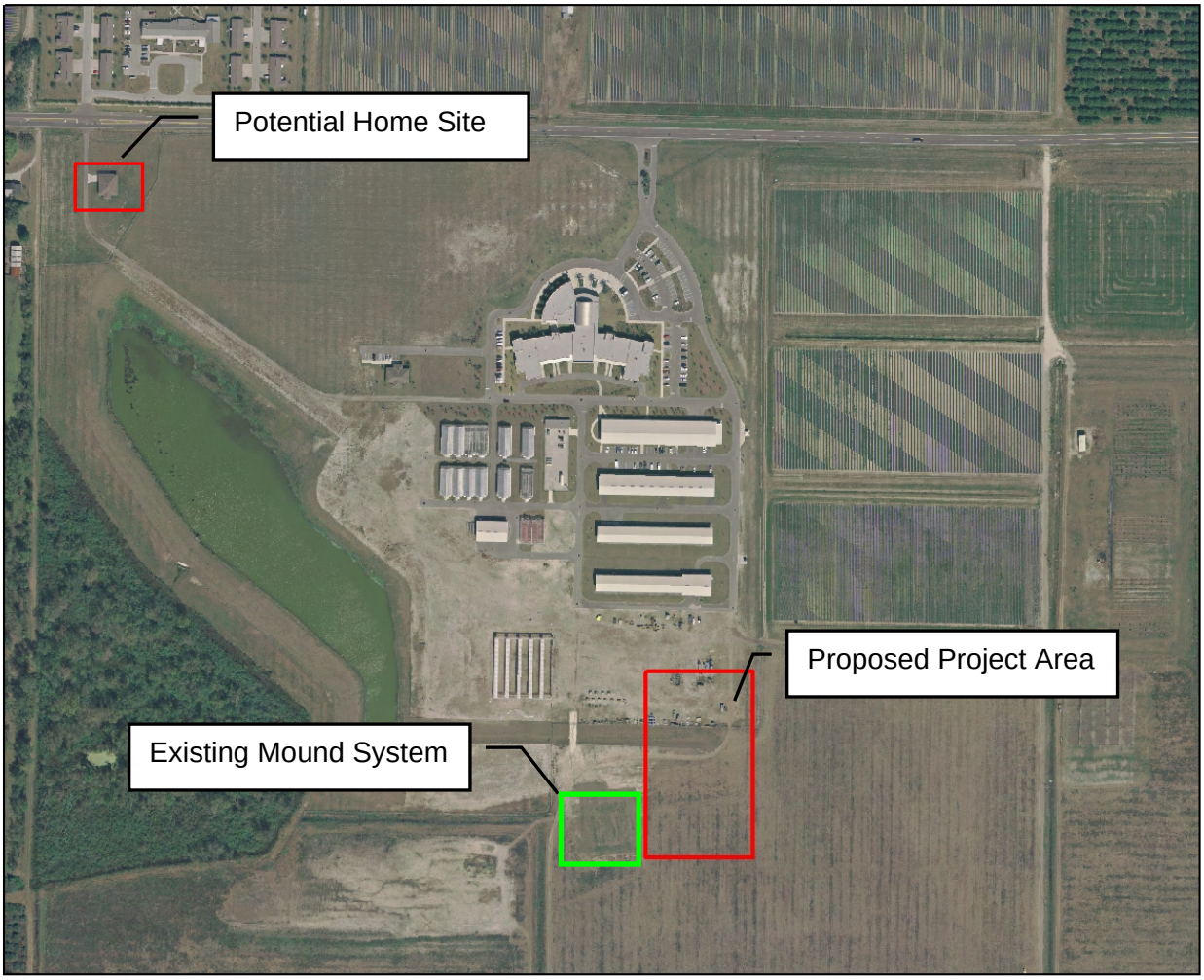


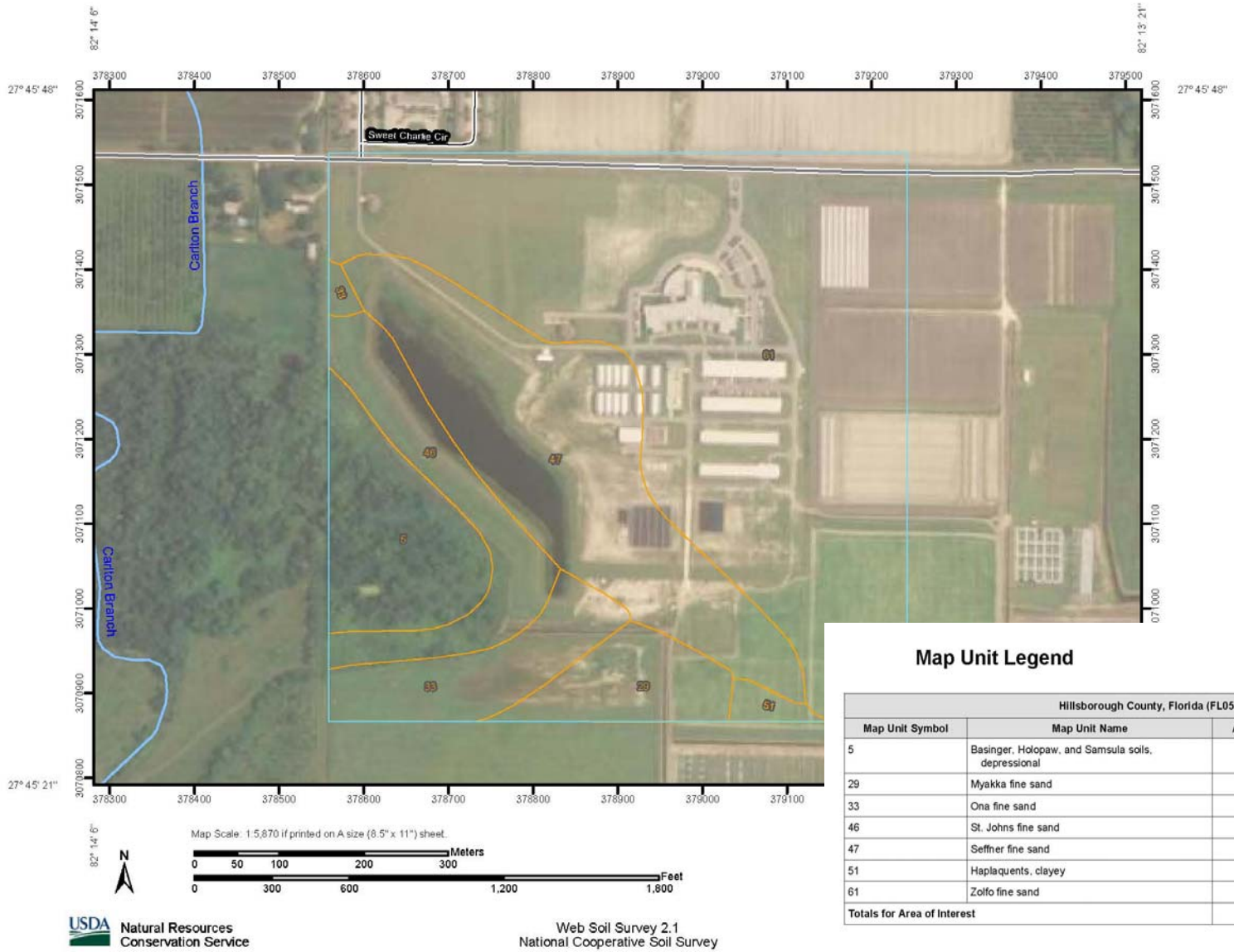
Figure 1. GCREC Facility and Proposed Project Area

Figure 2 is the web soil survey for the project area produced by the National Cooperative Soil Survey operated by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). As shown, the primary classification of soils on the site are Zolfo and Seffner fine sands.

HAZEN AND SAWYER
Environmental Engineers & Scientists

Hazen and Sawyer, P.C.
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
(813) 630-4498
Fax: (813) 630-1967

Soil Map—Hillsborough County, Florida



USDA Natural Resources Conservation Service

Web Soil Survey 2.1
National Cooperative Soil Survey

Map Unit Legend

Hillsborough County, Florida (FL057)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
5	Basinger, Holopaw, and Samsula soils, depressional	9.4	8.2%
29	Myakka fine sand	5.1	4.5%
33	Ona fine sand	7.1	6.3%
46	St. Johns fine sand	8.5	7.5%
47	Seffner fine sand	22.6	19.9%
51	Haplaquents, clayey	0.9	0.8%
61	Zolfo fine sand	59.9	52.8%
Totals for Area of Interest		**113.4**	**100.0%**

Figure 2

HAZEN AND SAWYER
Environmental Engineers & Scientists

Hazen and Sawyer, P.C.
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
(813) 630-4498
Fax: (813) 630-1967

Richard Ford, a Resource Soil Scientist with the NRCS, conducted a preliminary soils assessment of the GCREC project area on March 26, 2009. The objective of the soils assessment was to confirm the soil characteristics on the site, obtain soil profile descriptions and morphology, and obtain an estimate of the depth to seasonal high water table at the site. The mapped soils in this area are primarily Seffner fine sand (47) and Zolfo fine sand (61), with a limited area of Myakka fine sand (29). These are soils of the Florida flatwoods land resource area. Seffner and Zolfo fine sands are classified as somewhat poorly drained and Myakka fine sand is classified as poorly drained. A letter from Mr. Ford describing his assessment is included with this memo as an attachment.

Figure 3 indicates the approximate locations where five soil borings were augered on site to a depth of eighty inches.

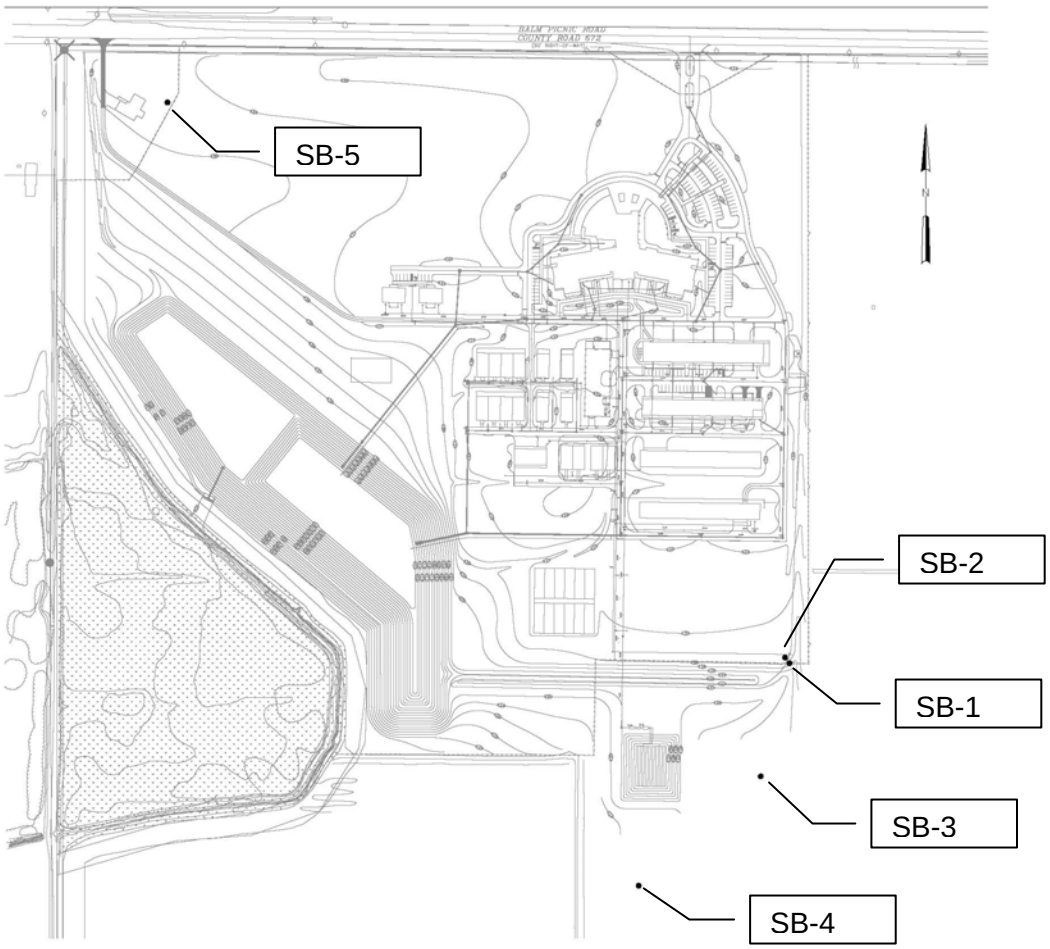


Figure 3. Approximate Soil Boring Locations

Soil boring 1 was identified as Zolfo fine sand. This profile had a well developed spodic horizon at about 58 inches. There was also evidence of some sand fill noted at the surface. It was estimated at approximately 10 inches thick. The soil profile at SB-2 was also identified as Zolfo fine sand. The well developed spodic horizon was at approximately 54 inches. There was about 10 inches of fill on the surface. The seasonal high water table was determined to be 30 inches plus or minus 6 inches. Soil boring 3 was mapped and identified in the field as Zolfo fine sand. The seasonal high water table indicators were found between 24 and 39 inches. The location of SB-4 is in or near an area mapped as Myakka fine sand based on the Soil Survey of Hillsborough County, Florida. However, the soil identified on site more closely resembled Seffner fine sand. This soil differs from Myakka fine sand by being somewhat poorly drained rather than poorly drained. The seasonal high water table was determined to be 30 inches plus or minus 6 inches. Soil boring 5 was identified as Zolfo fine sand. The seasonal high water table was also determined to be 30 inches plus or minus 6 inches. Seffner and Zolfo fine sands are both deep, somewhat poorly drained soils formed in sandy marine sediment. They are found on low-lying ridges on the flatwoods.

Based on the soils found on site, the soil mapping is representative. Water table depths determined on site were within the range of the mapped soils with only one exception. This occurred at soil boring 4 where Seffner fine sand was identified rather than Myakka fine sand. In addition, the area identified as Haplaquents in the Soil Survey of Hillsborough County was not encountered in the area investigated. If present, this area must exist south of the drainage ditch that forms the southern boundary of the study area, which was not investigated.

Another salient issue regarding the project site is a wastewater source of sufficient quantity and representative quality. The existing onsite wastewater treatment system consists of a pressure dosed mound system designed for 2,850 gallons per day. The septic tank receives flow from the research facility offices and approximately 11 graduate students that live in onsite dormitories. The laboratory liquid waste flow is not sent to the onsite wastewater system. Table 1 provides a summary of the system based on design drawings located at the GCREC.

Table 1. GCREC Onsite Wastewater Treatment System Summary

Primary Treatment – two precast septic tanks in series	-One 2,500 gallon precast septic tank-Category 4 without baffle -One 1,250 gallon precast septic tank-Category 4 with outlet screen
Dosing Tank	3,000 gallon precast pump/dosing tank-Category 4
Mound System Drainfield	4,351 ft2 infiltrative area (0.65 gpd/ft2)

A grab sample was collected at the outlet of the second septic tank on March 26, 2009. Results of laboratory analyses of this sample are summarized in Table 2.

Table 2. Septic Tank Effluent Field & Laboratory Analyses

pH (measured in field)	6.51
Temperature (^{o}C, in field)	25.4
Dissolved Oxygen (mg/L, in field)	0.13
Alkalinity (mg/L)	220
TKN (mg/L)	52
Ammonia (mg/L)	39
Nitrate (mg/L)	0.24
Nitrite (mg/L)	0.022
$CBOD_5$ (mg/L)	300
COD (mg/L)	680
Fecal Coliform (Col/100 mL)	10E6
Phosphorus (Total) (mg/L)	8.5
Total Dissolved Solids (mg/L)	590
Total Suspended Solids (mg/L)	80

Six piezometers were installed at the facility on March 17, 2009 to determine subsurface hydrology. Figure 3 depicts the approximate piezometer locations and the water table elevations measured on March 26, 2009.

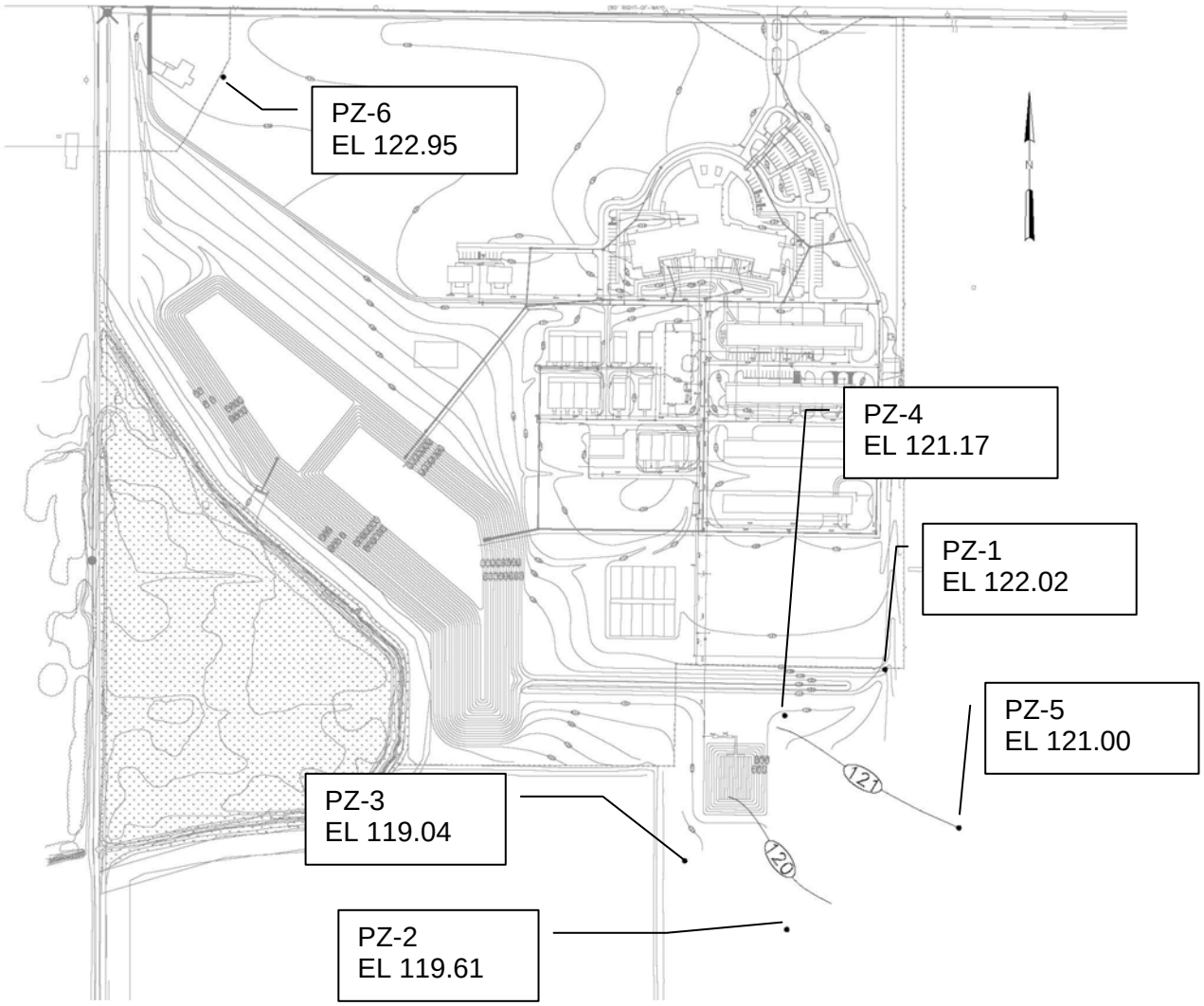


Figure 3. Piezometer Locations and Water Table Elevations on March 26, 2009

Summary

Based on the cost and time associated with rehabilitating the USF facility, it has become apparent that proceeding with construction of two test facility sites will be costly and time consuming. The current budget in the FOSNRS contract for construction of a test facility at USF does not appear to be sufficient for both the rehabilitation work and the testing facility construction. In addition, the USF Lysimeter station can only be used for pilot tests of treatment technologies and unsaturated zone work, since the water table is extremely deep at the site (>25 ft.) and sufficient area for plume delineation and monitoring is not available. Management of two facilities once operational will also be more difficult and expensive in future phases of the project.

The preliminary soils assessment, wastewater (STE) quality, and preliminary GW assessment appear to be conducive to performing the proposed work. While the flatwoods type soils at the site have a shallow groundwater that may be more likely to support *in-situ* denitrification, the soils of the Florida flatwoods land resource area make up approximately 55% of the area of the state, over 60% if the Everglades land resource area is excluded. In contrast, soils of the central Florida ridge land resource area make up approximately 17% of the area of the state (Ayres Associates, 1987). Also, a site conducive to *in-situ* denitrification is desirable from a groundwater modeling perspective. To include denitrification in the models developed in Task D, a study site where denitrification can be measured will be more likely to provide the needed inputs and calibration data for model development. If the mechanisms of *in-situ* denitrification can be identified at the site, then the models developed should be able to predict whether such denitrification is likely to occur at any given site. Additionally, the individual home field sites for Task C will be chosen to include soils of different types, including well drained fine sands typical of the central Florida ridge recharge areas, and the models developed will be tested at these sites.

Treatment technology pilot testing and both the saturated & unsaturated zone investigations could be performed at the GCREC. Therefore, the Project Team recommendation is to conduct all test facility work at the GCREC. This recommendation would include shifting the funds for test facility design and construction in Task A to the design and construction of the test facility for Task C, or vice versa. We would like to proceed with the GCREC site as the only FOSNRS Study testing facility, and request FDOH direction in this regard.

enc: NRCS letter

c: E. Roeder
P. Booher

File 44237-001

NRCS Natural Resources Conservation Service

1700 U.S. Hwy. 17 So., Suite 2 Bartow, FL 33830 Telephone (863) 533-2051 Ext. 3 Fax: (863) 533-1884

April 14, 2009

Hazen and Sawyer, P.C.
10002 Princess Palm Ave.
Suite 200
Tampa, Florida 33619

ATTN: Mr. Anderson
RE: Onsite Wastewater Treatment research

Dear Sir:

An on site soil investigation was conducted March 26, 2009 at the UF Gulf Coast Research and Education Center to determine the seasonal high water table and ascertain whether or not the soils were mapped correctly in the most recent NRCS soil survey documentation for Hillsborough County. The area of concern is located in section 29, T31S, R21E; Hillsborough County, Florida.

Soil borings were made at preselected sites or points to a depth of eighty inches. The mapping units were identified and the seasonal high water table determined. The Soil Survey of Hillsborough County, Florida and the Web based Soil Survey of Hillsborough County were used in this effort.

Five soil borings were made on site to a depth of eighty inches in the area of concern. The mapped soils in this area are Seffner fine sand (47), Zolfo fine sand (61), and Myakka fine sand. These soils are classified as poorly to somewhat poorly drained.

SB#1 was located five feet NW of PZ#1 and was identified as Zolfo fine sand. This profile had a well developed spodic at about 58 inches. There was also evidence of some sand fill noted at the surface. It was estimated at about 10 inches thick.

SB#2 was located 23 feet NW of PZ#1. This profile was identified as Zolfo fine sand. The well developed spodic was at 54 inches. There was about 10 inches of fill on the surface. The seasonal high water table was determined to be 30 inches plus or minus 6 inches.

SB#3 was located 200 feet east of the mound system's eastern edge. The soil mapped on site and identified in the field was Zolfo fine sand. The seasonal high water table indicators were found between 24 and 39 inches.

SB#4 was located 95 feet east of the field road edge and 95 feet north of the line of trees. This area is mapped Myakka fine sand based on the Soil Survey of Hillsborough County, Florida. The soil identified on site was Seffner fine sand. This soil differs from Myakka fine sand by being somewhat poorly drained rather than poorly drained. The seasonal high was determined to be 30 inches plus or minus 6 inches.

SB#5 was located on the east side of the Farm Manager residence inside the chain link fence. Zolfo fine sand was identified on site. The seasonal high was determined to be 30 inches plus or minus 6 inches.

Based on the soils found on site the soil mapping is representative. Water table depths determined on site were within the range of the mapped soils with only one exception. This occurred at SB#4 where Seffner fine sand was identified not Myakka fine sand.

In addition, the area identified as Haplaquents in the Soil Survey of Hillsborough County was not encountered in the area investigated. If present, this area must exist south of the drainage ditch that forms the southern boundary of the study area, which was not investigated.

Please call if you have any questions. Thank you very much.

Yours truly,

Richard D. Ford
Resource Soil Scientist
cc: Juan Vega, District Conservationist

The Natural Resources Conservation Service works in partnership with the American people to conserve and sustain natural resources on private lands.

AN EQUAL OPPORTUNITY EMPLOYER

Appendix B

50% Test Design

Appendix C

Activity Hazard Analysis

Appendix C
Activity Hazard Analysis

Job: FOSNRS Task C	**Occupation**: Drilling Crew and Field Personnel	**Date**: August 2009
Specific Work Location: Controlled Test Site / Home Sites	**Analyzed by:** K. S. Lowe	**Reviewed by**: D. L. Anderson
Tools Required:	**PPE Required**: Gloves, close-toed shoes, and eyewear.	

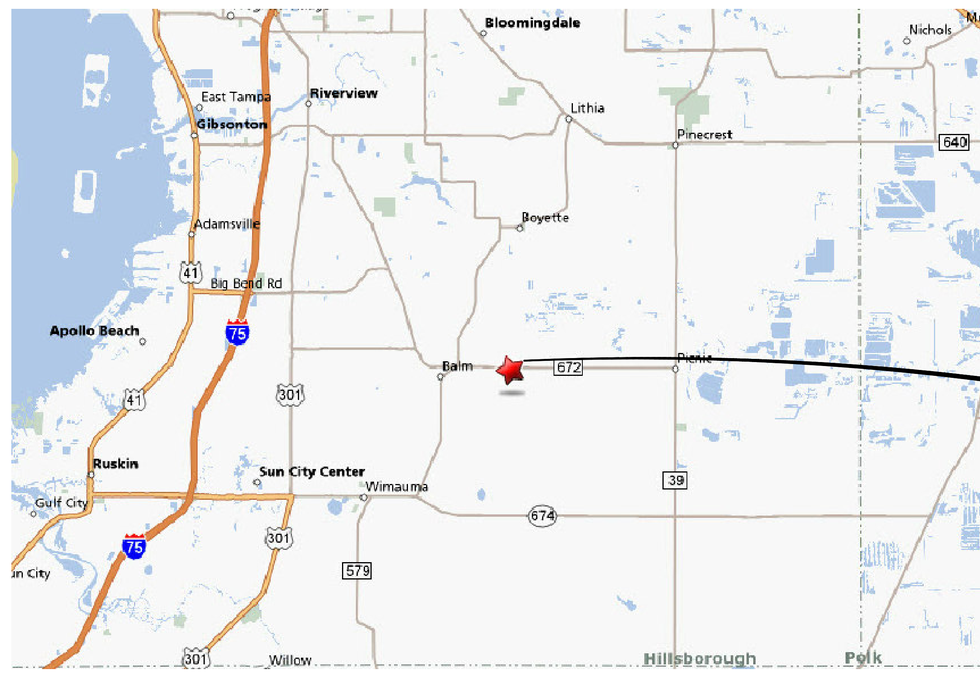
Job Activity	Potential Risks/Hazards	Control Measures
Contact: Damann Anderson, FOSNRS Project Manager: 813-630-4498 office, 813-340-7976 cell phone. Kathryn Lowe, Task C co-leader: 303-273-3685 office and 303-921-3174 cell phone.		
General	Slip, trip, and fall hazards	1. Work will be performed during daylight hours. 2. Personnel will visually survey the site and avoid hazardous areas to the degree feasible. 3. No smoking, eating or drinking at the drilling rig during operation. 4. Use ground fault circuit interrupts (GFCIs). 5. Use proper lifting techniques (use legs not back, do not exceed individual physical capability, use lifting devices where appropriate). 6. First aid kit will be available (access to shower will remain open). 7. Report all injuries to Damann Anderson (813-630-4498). 8. In case of emergency call 911.
Environmental Sample Collection	Spills/splashes/leaks Contact with wastewater Electrical	1. Check and address spills/leaks of wastewater. 2. Check and address potential contact of water/wastewater with electrical cords. 3. Decontaminate work areas and cleaned spills using 70% ethanol. 4. Recognize potential bacterial, virus or blood borne pathogens and eliminate exposure through adequate PPE and work practices. PPE: gloves, close-toed shoes, eyewear. Waste Management (WM): Clean spills/leaks. Segregate trash. Place contact waste bins. Excess effluent will be returned to the septic tank/holding basin. Excess groundwater will be discharged to the ground surface.
Sample Analyses	Spills/splashes Contact with wastewater and/or reactive chemicals (e.g., acids) Broken glass Hot surfaces	1. Clean all spills immediately. Ensure proper spill kits are available. Broken glass should be immediately swept. 2. Properly store incompatible materials and flammables (e.g., separate storage for acids and bases). 3. Close chemical containers when not in immediate use. PPE: lab coat, gloves, close-toed shoes, eyewear. WM: Clean spills/leaks. Segregate trash.

Job Activity	Potential Risks/Hazards	Control Measures
Piezometer Installation and Soil Coring with Direct Push Drilling Rig	General	PPE for all drilling related activities: Hard hat, hard-toed shoes, safety glasses, and work gloves. WM: Soils will be spread on the ground surface.
	Malfunction	1. Equipment will be inspected prior to use.
	Noise	1. Sound levels are expected to reach 95 dBA during hammering. Additional PPE: hearing protection with a minimum NRR of 17 will be used by the drilling operator(s) during operation and personnel within 30 ft of the rig.
	Rotating auger may snag clothing	1. Loose clothing is not to be worn by the drill rig operator or the operator's assistant. 2. No access within four feet of the rotating auger except to the operator and operator's assistant. 3. Kill switches shall be demonstrated to be operable prior to the first use.
	Overhead wires	1. Maximum voltage of overhead lines is 13.8 kV. 2. Minimum 10 ft distance to be maintained between the mast and wires. Ten ft plus 0.4-in. per kV over 50kV. 3. Spotter will be used if approaching the minimum distance.
	Underground utilities	1. A utilities locator survey will be preformed and kept on-site during drilling.
Soil Sample Collection/Handling	Handling heavy equipment and falling equipment	1. Do not exceed personnel physical lifting abilities. WM: Soils will be spread on the ground surface.
Emergencies	Heat stress	1. Breaks will be taken to minimize potential for heat stress. 2. Drinks and a cool location (i.e., truck) will be available near the work area. 3. The buddy system will be used. PPE: Gloves and other PPE to prevent direct contact with metal equipment and prevent exposure to weather conditions.
	Injuries	1. The fire department will be summoned for all injuries that need more than first aid by calling 911.
	Blood borne pathogens	1. One field member will be trained in first aid and blood borne pathogens, but will not provide first aid unless necessary to stabilize a serious injury. 2. If blood is present, the area will be controlled to prevent exposure to blood and potential blood borne pathogens. 3. All injuries and treatment will be documented as described above under General Field Activities.
	Fire	1. Call the fire department. 2. If personnel are trained in the use of fire extinguishers, and it is safe to do so, incipient stage fires may be extinguished using portable fire extinguishers.

FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATEGIES STUDY 50% DESIGN DOCUMENTS

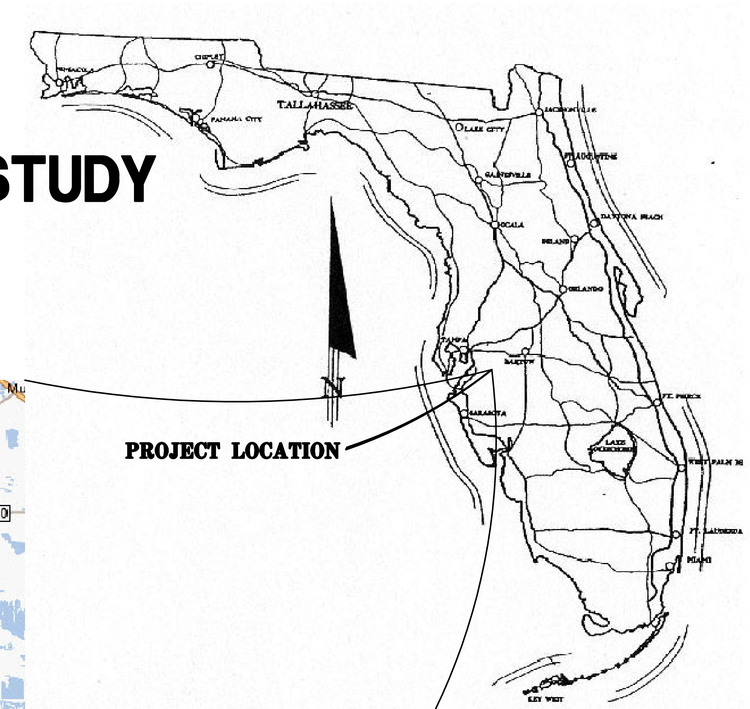
LIST OF DRAWINGS

SHEET COUNT	SHEET NUMBER	SHEET TITLE
		GENERAL
1	G-1	COVER SHEET AND INDEX OF DRAWINGS
		CIVIL
2	C-1	EXISTING ONSITE SEPTIC TANK SYSTEM
3	C-2	PROPOSED OVERALL SITE PLAN
4	C-3	HYDRAULIC PROFILE PNRS II
5	C-4	PNRS II DETAILS
6	C-5	PNRS II DETAILS
7	C-6	TASK C NITROGEN FATE OF TRANSPORT STUDY DETAILS
8	C-7	WASTEWATER SOURCE COMPONENTS DETAILS
9	C-8	MONITORING PLAN
		MECHANICAL
10	M-1	YARD PIPING PLAN
		ELECTRICAL
11	E-1	ELECTRICAL SITE PLAN



LOCATION MAP

N.T.S.



PROJECT LOCATION
UNIVERSITY OF FLORIDA
GULF COAST RESEARCH AND
EDUCATION CENTER
WIMAUMA, FL.

HAZEN AND SAWYER
Environmental Engineers & Scientists

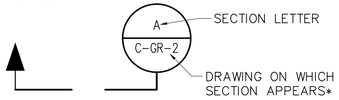
10002 Princess Palm Ave., Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH

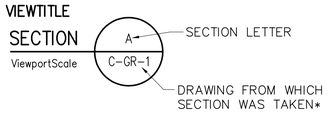
FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FLORIDA 32399-1713
(850)-245-4070

SECTION IDENTIFICATION

(1) SECTION CUT ON DRAWING G-1:

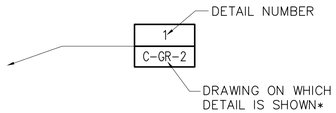


(2) ON DRAWING G-2 THIS SECTION IS IDENTIFIED AS:

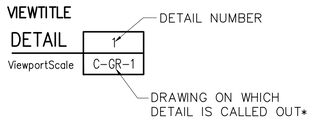


DETAIL IDENTIFICATION

(1) DETAIL CALL-OUT ON DRAWING G-1 AS:



(2) ON DRAWING G-2 THIS DETAIL IDENTIFIED AS:



SITE GENERAL NOTES

1. THE TOPOGRAPHIC INFORMATION SHOWN HEREON IS BASED ON A SURVEY AS PREPARED BY PHOTOGRAMMETRIC TECHNOLOGIES, INC. DATED FEBRUARY 2, 2003. THE BOUNDARY SURVEY IS AS PROVIDED BY U.F. I.F.A.S.

2. CONTRACTOR TO REVIEW GEOTECHNICAL REPORT AND BORINGS PRIOR TO BIDDING THE PROJECT AND FOLLOW OUTLINED CONSTRUCTION TECHNIQUES.

3. THE CONTRACTOR IS RESPONSIBLE FOR COORDINATING APPLICABLE TESTING WITH THE SERVICES OF AN APPROVED TESTING LABORATORY AND SOILS ENGINEER, AS REQUIRED BY APPLICABLE REGULATORY AGENCIES AND AS MAY BE FOUND IN THE ENGINEERING CONSTRUCTION DRAWINGS. CONTRACTOR TO VERIFY ALL TESTING WITH THE OWNER PRIOR TO COMMENCING CONSTRUCTION. UPON COMPLETION OF THE WORK, THE SOILS ENGINEER MUST SUBMIT TO THE OWNER'S ENGINEER CERTIFICATIONS STATING THAT ALL REQUIREMENTS HAVE BEEN MET.

4. THE CONTRACTOR IS RESPONSIBLE FOR REPAIRING ANY DAMAGE TO EXISTING FACILITIES, ABOVE OR BELOW GROUND THAT MAY OCCUR AS A RESULT OF THE WORK PERFORMED BY THE CONTRACTOR.

5. IT IS THE CONTRACTOR'S RESPONSIBILITY TO BECOME FAMILIAR WITH THE PERMIT AND INSPECTION REQUIREMENTS OF THE VARIOUS GOVERNMENTAL AGENCIES. THE CONTRACTOR SHALL OBTAIN ALL NECESSARY PERMITS PRIOR TO CONSTRUCTION, AND SCHEDULE INSPECTIONS ACCORDING TO AGENCY INSTRUCTIONS.

6. ALL WORK PERFORMED SHALL COMPLY WITH THE REGULATIONS AND ORDINANCES OF THE VARIOUS GOVERNMENTAL AGENCIES HAVING JURISDICTION OVER THE WORK INCLUDING LANDSCAPING.

7. REPAIR AND REPLACEMENT OF ALL PRIVATE AND PUBLIC PROPERTY AFFECTED BY THIS WORK SHALL BE RESTORED TO A CONDITION EQUAL TO OR BETTER THEN EXISTING CONDITIONS BEFORE COMMENCING CONSTRUCTION WORK UNLESS SPECIFICALLY EXEMPTED BY THE PLANS. ADDITIONAL COSTS ARE INCIDENTAL TO OTHER CONSTRUCTION AND NO EXTRA COMPENSATION WILL BE ALLOWED.

8. RECORD DRAWINGS:
THE CONTRACTOR SHALL BE RESPONSIBLE FOR RECORDING INFORMATION ON A SET OF THE APPROVED PLANS CONCURRENTLY WITH CONSTRUCTION PROGRESS. WITHIN TWO WEEKS FOLLOWING FINAL INSPECTIONS THE CONTRACTOR SHALL SUBMIT ONE SET OF DRAWINGS TO THE ENGINEER OF RECORD. THE FINAL RECORD DRAWINGS SHALL COMPLY WITH THE FOLLOWING REQUIREMENTS:

A. DRAWING TO BE LEGIBLY MARKED TO RECORD ACTUAL CONSTRUCTION.

B. DRAWINGS SHALL SHOW ACTUAL LOCATION OF ALL UTILITIES AND RELATED ITEMS, BOTH ABOVE AND BELOW GROUND. ALL CHANGES TO PIPING LOCATION INCLUDING HORIZONTAL AND VERTICAL LOCATIONS OF UTILITIES SHALL BE CLEARLY SHOWN AND REFERENCED TO PERMANENT SURFACE IMPROVEMENTS. DRAWINGS SHALL ALSO SHOW ACTUAL INSTALLED PIPE MATERIAL.

C. DRAWINGS SHALL CLEARLY SHOW ALL FIELD CHANGES OF DIMENSION AND DETAIL.

D. DRAWINGS SHALL CLEARLY SHOW ALL DETAILS NOT ON ORIGINAL CONTRACT DRAWINGS BUT CONSTRUCTED IN THE FIELD. ALL EQUIPMENT AND PIPING RELOCATIONS SHALL BE CLEARLY SHOWN.

E. LOCATIONS OF ALL MANHOLES, HYDRANTS, VALVES AND VALVE BOXES SHALL BE SHOWN.

F. THE CONTRACTOR SHALL PROVIDE CERTIFIED RECORD DRAWING, SIGNED AND SEALED BY A PROFESSIONAL LAND SURVEYOR. THE RECORD DRAWINGS SHALL SHOW FINAL GRADES AND LOCATIONS ON ALL UTILITIES INCLUDING THE SANITARY SEWER, WATER, PRODUCT PIPING, AND STORM WATER COLLECTION SYSTEM (I.E. PIPES, INLETS, AND PONDS). THE CONTRACTOR SHALL PROVIDE TEN COPIES OF THE CERTIFIED RECORD DRAWINGS TO THE OWNER.

9. IT SHALL BE THE SOLE RESPONSIBILITY OF THE CONTRACTOR TO COMPLY WITH AND ENFORCE ALL APPLICABLE SAFETY REGULATIONS.

10. ALL DELETERIOUS MATERIAL (I.E. MUCK, PEAT, BURIED DEBRIS) IS TO BE EXCAVATED IN ACCORDANCE WITH THESE PLANS OR AS DIRECTED BY THE OWNER'S ENGINEER OR OWNER'S SOIL TESTING COMPANY. DELETERIOUS MATERIAL IS TO BE STOCKPILED AND REMOVED FROM THE CAMPUS AREA AND PLACED ON-SITE AS DIRECTED BY THE OWNERS REPRESENTATIVE. EXCAVATED AREAS ARE TO BE BACKFILLED WITH APPROVED MATERIALS AND COMPACTED AS SHOWN ON THESE AREAS.

11. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROTECTING EXCAVATIONS AGAINST COLLAPSE AND SHALL PROVIDE BRACING, SHEETING OR SHORING AS NECESSARY. TRENCHES SHALL BE KEPT DRY WHILE PIPES ARE BEING PLACED. DEWATERING SHALL BE USED AS REQUIRED, AND PERMITTED THROUGH LOCAL GOVERNMENTAL AGENCIES AND WATER MANAGEMENT DISTRICT PER CURRENT REGULATIONS AT THE SOLE COST OF THE CONTRACTOR.

CONSTRUCTION NOTES

1. ALL MATERIALS AND WORK SHALL COMPLY WITH REQUIREMENTS OF CHAPTER 64E-6, FLORIDA ADMINISTRATIVE CODE (FAC), AND REQUIREMENTS, OF PERMITS ISSUED FOR THIS CONSTRUCTION. SHOP DRAWINGS FOR ALL COMPONENTS SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO ORDERING SYSTEM COMPONENTS.

2. CONTRACTOR SHALL BE RESPONSIBLE FOR APPLYING FOR AND OBTAINING APPROPRIATE PERMITS AND FOR SCHEDULE/COORDINATING INSPECTIONS, REVIEWS, AND APPROVALS

3. LOCATIONS SHOWN ON THESE DRAWINGS ARE APPROXIMATE AND MAY BE FIELD ADJUSTED WITH APPROVAL OF OWNER AND HEALTH DEPARTMENT.

4. ENGINEER OF RECORD IS REQUIRED TO DO AN INITIAL INSPECTION. CONTRACTOR TO CALL (48) HOURS PRIOR TO INSPECTION TO REQUEST AN INSPECTOR.

WATER AND WASTEWATER GENERAL NOTES

1. ALL WATER AND WASTEWATER INSTALLATION CONSTRUCTION AND MATERIALS SHALL BE IN ACCORDANCE WITH THE SPECIFICATIONS ON DRAWINGS AND INCLUDED DETAILS.

2. IF THE VERTICAL CLEARANCE AT CROSSING POINTS OF WATER AND SANITARY SEWER LINES IS LESS THAN 18" (IN), THE SANITARY SEWER LINE SHALL THEN BE ENCASED IN A WATER TIGHT CARRIER PIPE FOR 10' (FT) EACH SIDE OF THE CROSSING POINT.

3. CONTRACTOR SHALL SUBMIT FOR REVIEW TO THE OWNER AND OWNER'S ENGINEER SHOP DRAWINGS ON ALL PRECAST AND MANUFACTURED ITEMS TO BE USED ON THIS SITE. FAILURE TO OBTAIN APPROVAL BEFORE INSTALLATION MAY RESULT IN REMOVAL AND REPLACEMENT AT CONTRACTOR'S EXPENSE. ENGINEER'S APPROVAL OF A SHOP DRAWING DOES NOT RELIEVE THE CONTRACTOR'S RESPONSIBILITY FOR THE PERFORMANCE OF THE ITEM.

4. THE CONTRACTOR IS RESPONSIBLE FOR ANY NECESSARY UTILITY FIELD LOCATIONS, RELOCATIONS AS REQUIRED, SHALL BE COORDINATED BY THE CONTRACTOR.

5. THE HORIZONTAL SEPARATION BETWEEN WATER MAINS AND PERMANENT STRUCTURES, TREES AND SANITARY SEWER MAINS SHALL BE 10' (FT) MINIMUM.

6. THE HORIZONTAL SEPARATION BETWEEN SEWER MAINS AND PERMANENT STRUCTURES AND TREES SHALL BE 15' (FT) MINIMUM.

7. WATER MAIN MATERIALS SHALL BE:
   4" – 12" MAINS SHALL BE PER AWWA, C900, DR18, CLASS 150.
   2" AND SMALLER LINES SHALL BE PVC SCHEDULE 80 WITH PRESSURE RATING OF 200.

8. SANITARY SEWER PIPE MATERIALS SHALL BE:
   4" – 8" SEWER SHALL BE PVC, SDR26 MEETING ASTM D3034.
   4" AND SMALLER LINES SHALL BE PVC SCHEDULE 80 WITH PRESSURE RATING OF 200.
   MINIMUM SLOPE FOR LATERALS SHALL BE 1.00%.

9. PROJECT IS LOCATED IN THE HILLSBOROUGH FIRE DISTRICT, STATION NO. 3.

SUMMARY OF TANKAGE

TANK	TANK DESCRIPTION	SIZE
TANK 1	EXISTING STAGE 1	2500 GAL
TANK 2	NEW STE DOSING TANK	900 GAL
TANK 3	NEW STAGE 2 DOSING TANK	30 GAL
TANK 4	NEW STE DRIP DOSE TANK	150 GAL
TANK 5	NEW NO3 DRIP DOSE TANK	150 GAL
TANK 6	NEW WASTE EFFLUENT SUMP	900 GAL

SUMMARY OF PUMPS

PUMP	PUMP LOCATION	TYPE	MANUFACTURER/MAKE	MODEL
P1	TANK 1	SUBMERSIBLE	GOULDS BLASTER	33EB05
P2	TANK 2	SUBMERSIBLE	GOULDS BLASTER	20EB05
P3	TANK 2	SUBMERSIBLE	GOULDS BLASTER	20EB05
P4	TANK 2	SUBMERSIBLE	GOULDS BLASTER	20EB05
P5	DOSES INSITU STAGE 1 BIOFILTERS	PERISTALTIC	ISMATEC	R-78002-10
P6	RECIRCULATION DOSE TANK 1	SUBMERSIBLE	GOULDS BLASTER	20EB05
P7	RECIRCULATION DOSE TANK 2	SUBMERSIBLE	GOULDS BLASTER	20EB05
P8	RECIRCULATION DOSE TANK 3	SUBMERSIBLE	GOULDS BLASTER	20EB05
P9	RECIRCULATION DOSE TANK 4	SUBMERSIBLE	GOULDS BLASTER	20EB05
P10	DOSES STAGE 2 BIOFILTERS	PERISTALTIC	ISMATEC	R-78002-10
P11/12	TANK 4	SUBMERSIBLE	GOULDS BLASTER	20EB05
P13/14	TANK 5	SUBMERSIBLE	GOULDS BLASTER	20EB05

LEGEND

EXISTING	EXISTING ELEVATION CONTOUR	SITE PLAN	NEW BUILDING
EXISTING	EXISTING SPOT ELEVATION	SITE PLAN	NEW SHELL GRAVEL
EXISTING	EXISTING FENCE	SITE PLAN	NEW GRAVITY LINE
EXISTING	EXISTING SANITARY SEWER LINE & MANHOLE	SITE PLAN	NEW PRESSURE LINE
EXISTING	EXISTING WATER LINE & VALVE	SITE PLAN	NEW FLOW METER
EXISTING	EXISTING STORM LINE & STRUCTURE	SITE PLAN	NEW CHECK VALVE
EXISTING	EXISTING ELECTRIC LINE	SITE PLAN	NEW BALL VALVE NORMALLY CLOSED
EXISTING	EXISTING OVERHEAD POWER LINE	SITE PLAN	NEW BALL VALVE NORMALLY OPEN
EXISTING	EXISTING GAS LINE	SITE PLAN	NEW PINCH VALVE (PNEUMATIC) NORMALLY CLOSED
EXISTING	EXISTING LIGHT	SITE PLAN	NEW PINCH VALVE (PNEUMATIC) NORMALLY OPEN
EXISTING	EXISTING UTILITY POLE	SITE PLAN	NEW RECIRCULATION VALVE
EXISTING	EXISTING WOOD POWER POLE	SITE PLAN	NEW WATER MAIN WITH GATE VALVE & BOX
EXISTING	EXISTING TELEPHONE PEDESTAL	SITE PLAN	NEW SILT FENCE LINE
EXISTING	EXISTING GUY ANCHOR	SITE PLAN	NEW ELEVATION CONTOUR
EXISTING	EXISTING WELL	SITE PLAN	NEW STORM STRUCTURE IDENTIFICATION
EXISTING	EXISTING WATER METER	SITE PLAN	NEW SPOT ELEVATION
EXISTING	EXISTING FIRE HYDRANT	SITE PLAN	DIRECTION OF SURFACE DRAINAGE FLOW
EXISTING	EXISTING UNDERGROUND TELEPHONE LINE		
EXISTING	EXISTING TREE (SIZE & TYPE)		
EXISTING	EXISTING STRUCTURE		
EXISTING	PROJECT BENCHMARK		

ELECTRICAL LEGEND

- (E) EQUIPMENT CONNECTION OUTLET – VERIFY LOCATION
- (J) JUNCTION BOX
- (T) TRANSFORMER
- DISTRIBUTION SWITCHBOARD OR PANELBOARD
- BRANCH CIRCUIT PANELBOARD
- CONDUIT
- 1L1-1,3 — HOMERUN TO PANELBOARD. "L1" INDICATES THE PANELBOARD NUMBER. "1,3" INDICATES THE BRANCH CIRCUIT NUMBERS. HATCH MARKS DENOTE NUMBER OF CONDUCTORS EXCLUDING GROUND CONDUCTOR. NO HATCH MARKS DENOTES TWO #12 CONDUCTORS AND ONE #12 GROUNDING CONDUCTOR
- U — UNDERGROUND CONDUIT
- CONDUIT STUB-UP
- 1L1 — PANELBOARD NUMBER

ELECTRICAL ABBREVIATIONS

A	AMPS	HOA	HAND-OFF-AUTOMATIC
AFF	ABOVE FINISHED FLOOR	HP	HORSEPOWER
AICS	AMPS INTERRUPTING CAPACITY SYMMETRICAL	IMC	INTERMEDIATE METAL CONDUIT
BKR	BREAKER	K	KILO
C	CONDUIT	LTG	LIGHTING
CLG	CEILING	MTD	MOUNTED
CKT	CIRCUIT	NEC	NATIONAL ELECTRICAL CODE
CU	COPPER	OHP	OVERHEAD PRIMARY
EF	EXHAUST FAN	P	POLE
EMT	ELECTRICAL METALLIC TUBING	PWR	POWER
FU	FUSE	UGE	UNDERGROUND ELECTRIC
FLR	FLOOR	UL	UNDERWRITERS LABORATORIES
GFI	GROUND FAULT INTERRUPTER	UNO	UNLESS NOTED OTHERWISE
GRD	GROUND	V	VOLTS
		VA	VOLT-AMPERES
		W	WATTS
		WP	WEATHERPROOF
		ø	PHASE

NO.	ISSUED FOR	DATE	BY

DESIGNED –
DRAWN –
CHECKED –
PROJ. ENGR. –
– .
APPROVED

Name: Date:
Florida Professional Engineer's Registration Number: –

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

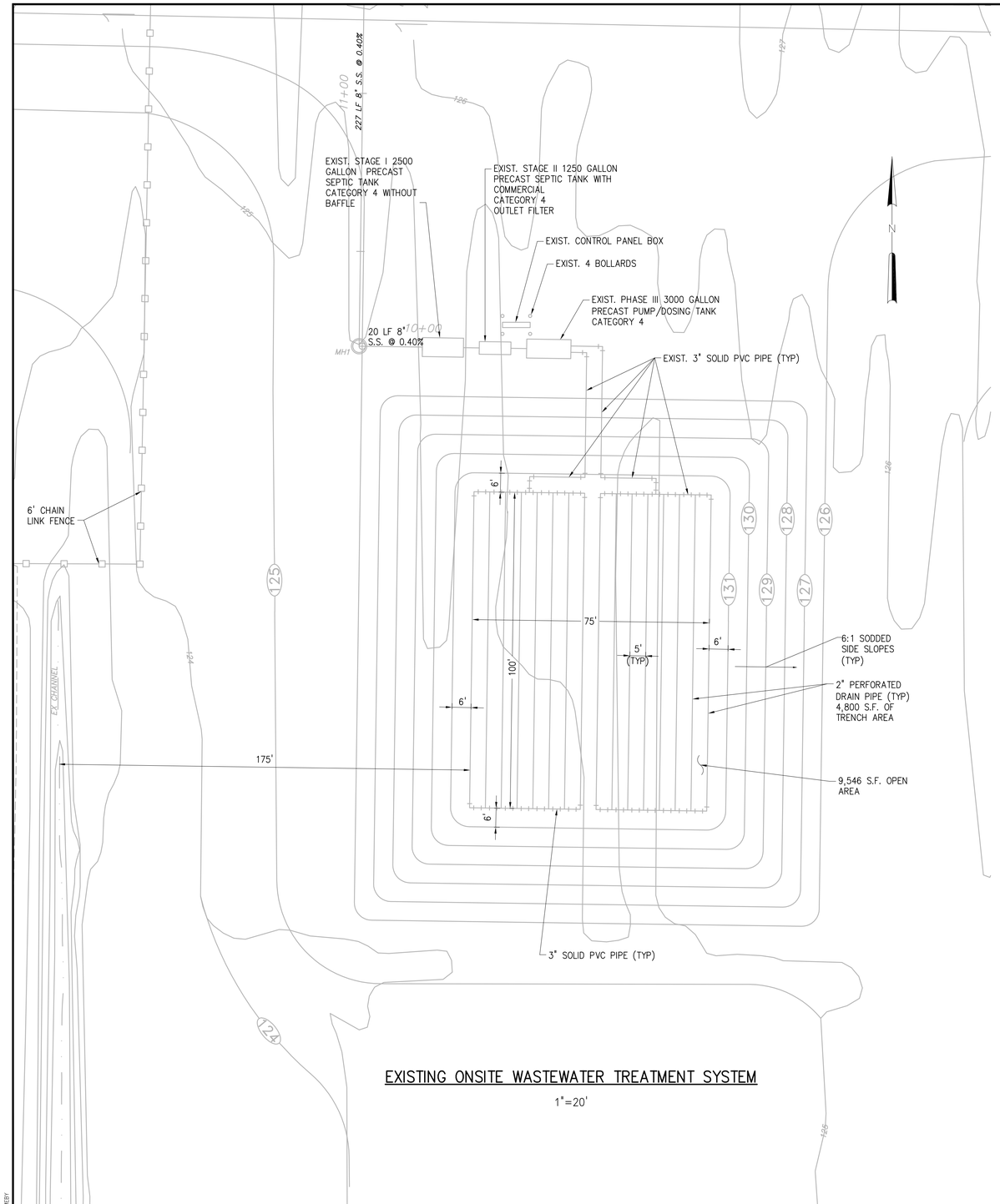
FLORIDA DEPARTMENT OF HEALTH
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

LEGENDS AND NOTES

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER G-2

PLOT DATE: 10/30/2009 12:31 PM BY: JGNEBY
File = Q:\44237-001-PFA\44237-001\Drawings\008 Design - C:2D\general\G-2 LEGENDS AND NOTES Saved by jgnebyne Save date = 10/29/2009 5:15 PM



EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

1"=20'

EXISTING DRAIN FIELD CALCULATION

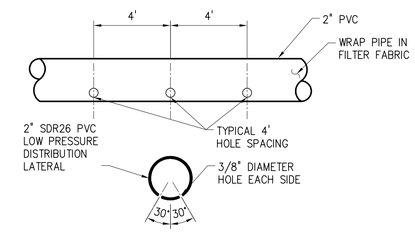
BASED ON UNSUITABLE SUBSURFACE CONDITIONS

LOAD RATE = 0.65
TRENCH AREA = 2828 GPD/0.65 = 4351 SF
OPEN AREA = 2 x 4351 SF = 8702 SF

EXISTING SYSTEM FLOW CALCULATION

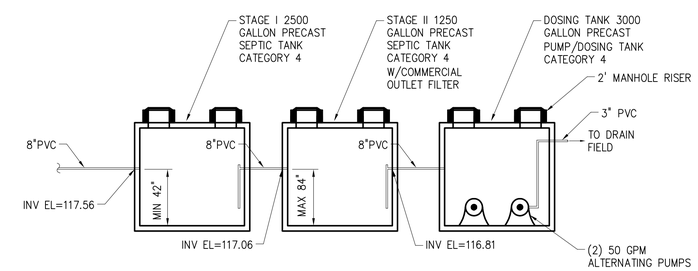
DESIGN FLOW (PER 64E-6.008(1b) TABLE 1)

ADMIN/STAFF (100x15)	= 1500 GPD
SCHOOL [STUDENT BOARDING TYPE] (16 x 75 GPD)	= 1200 GPD
ADD FOR SHOWERS (16 x 4)	= 64 GPD
ADD FOR CAFETERIA (16 x 4)	= 64 GPD
TOTAL	= 2828 GPD



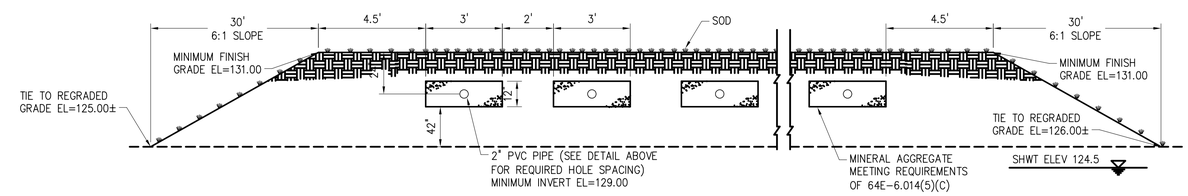
EXISTING HOLE SPACING DETAIL

N.T.S.



EXISTING SEPTIC TANK CROSS-SECTION

N.T.S.



TYPICAL SECTION THRU EXISTING DRAIN FIELD

N.T.S.

1"=20'-0" 20 10 0 20'

NO.	ISSUED FOR	DATE	BY

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PROJ. ENGR. –
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APPROVED

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Registry One Building, Suite 200
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Certificate of Authorization Number: 2771

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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

EXISTING ONSITE WASTEWATER TREATMENT SYSTEM

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-1

PLOT DATE: 10/30/2009 12:31 PM BY: GMEBY
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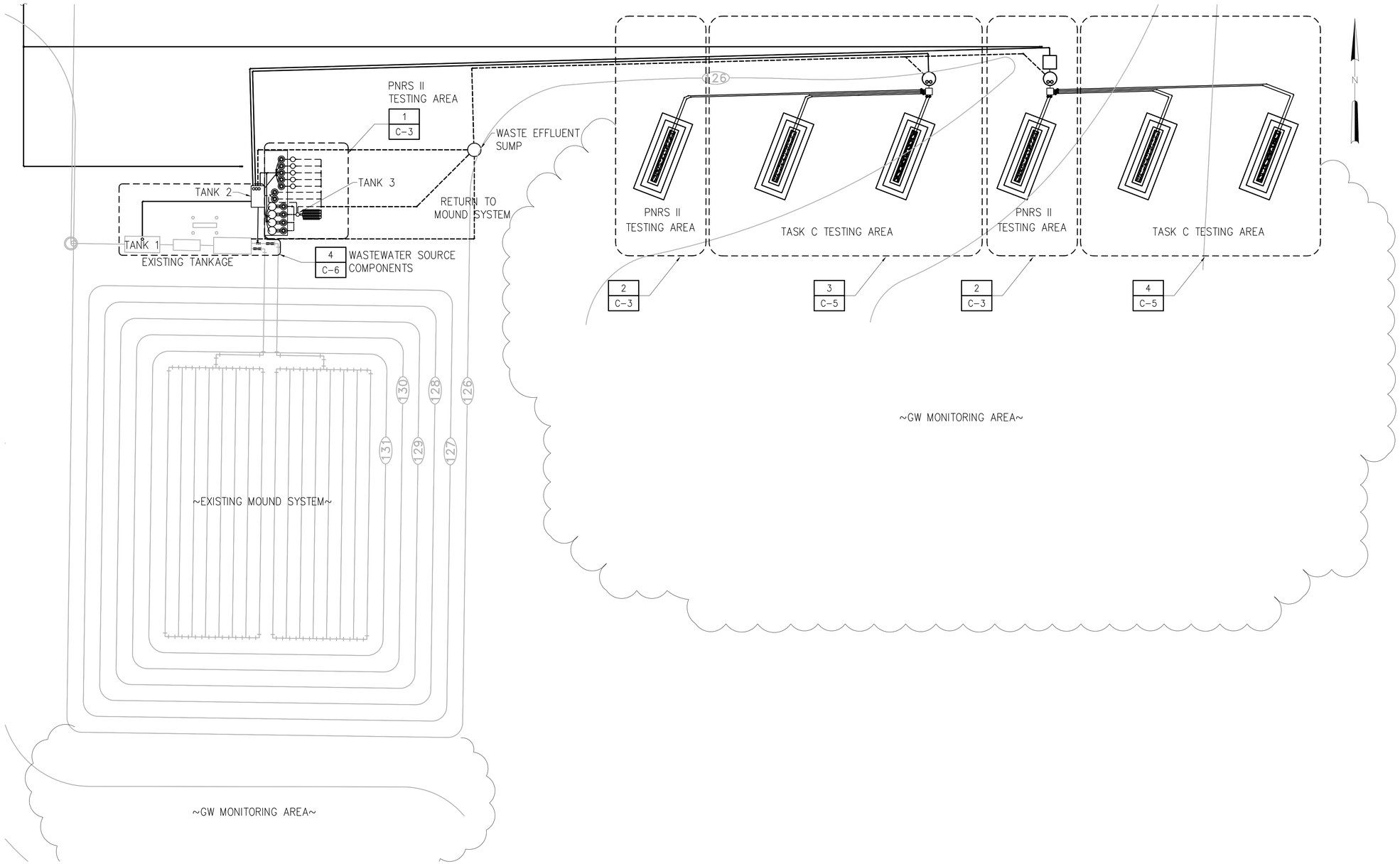

PROPOSED SITE PLAN

1"=20'

1"=20'-0" 20 10 0 20'

NO.	ISSUED FOR	DATE	BY

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DRAWN –
CHECKED –
PROJ. ENGR. –
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
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OVERALL PROPOSED SITE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-2

PLOT DATE: 10/30/2009 12:31 PM BY: JONEBY

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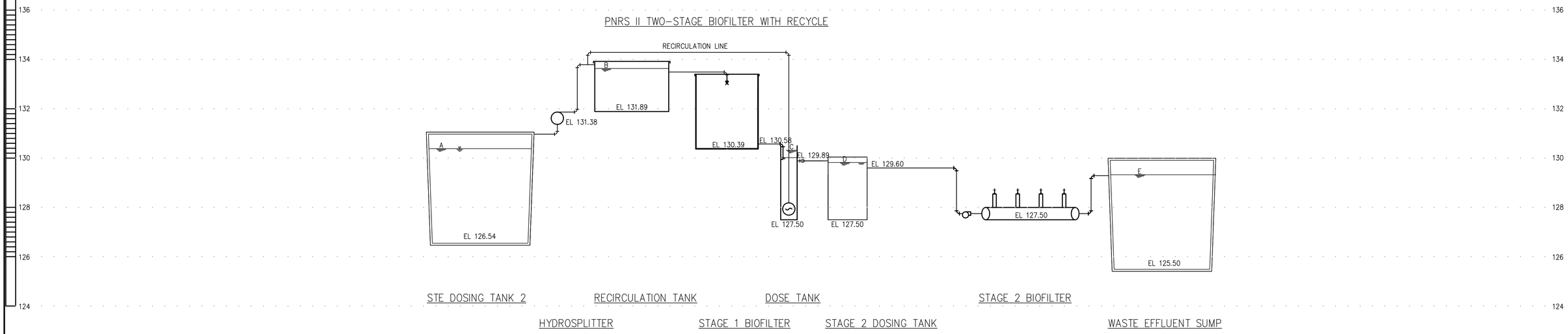
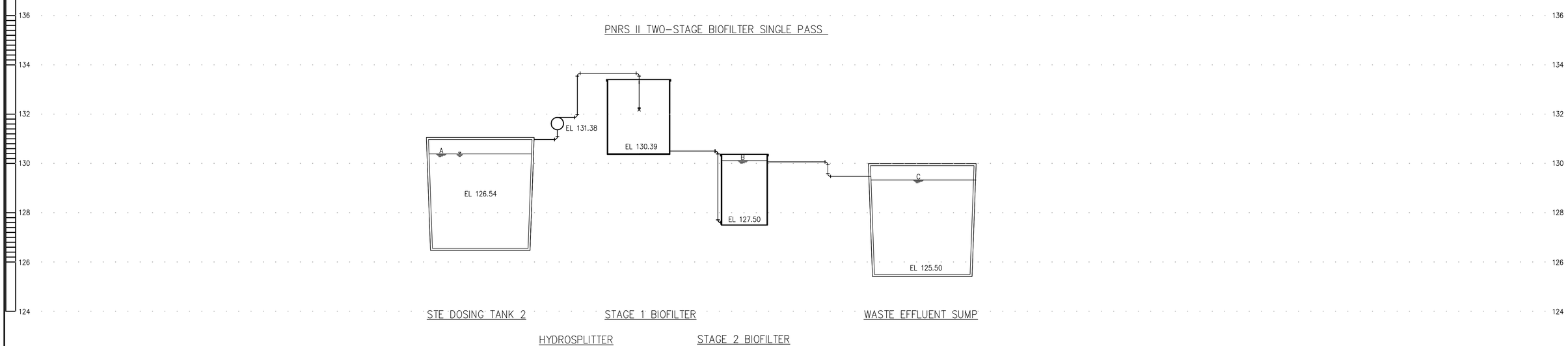
CONDITION	FLOW	A TANK 2	B RECIRCULATION TANK	C DOSE TANK	D STAGE 2 DOSE TANK	E WASTE EFFLUENT SUMP
AVERAGE FLOW	58.8 GPD	130.37	133.64	129.96	129.83	129.33



CONDITION	FLOW	A TANK 2	B STAGE 2 TANK	C WASTE EFFLUENT SUMP
AVERAGE FLOW	73.5 GPD	130.37	130.12	129.33



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TALLAHASSEE, FL 32399-1713
(850)-245-4070

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HYDRAULIC PROFILE PNRS II

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-3

PLOT DATE: 10/30/2009 12:32 PM BY: JSMBY
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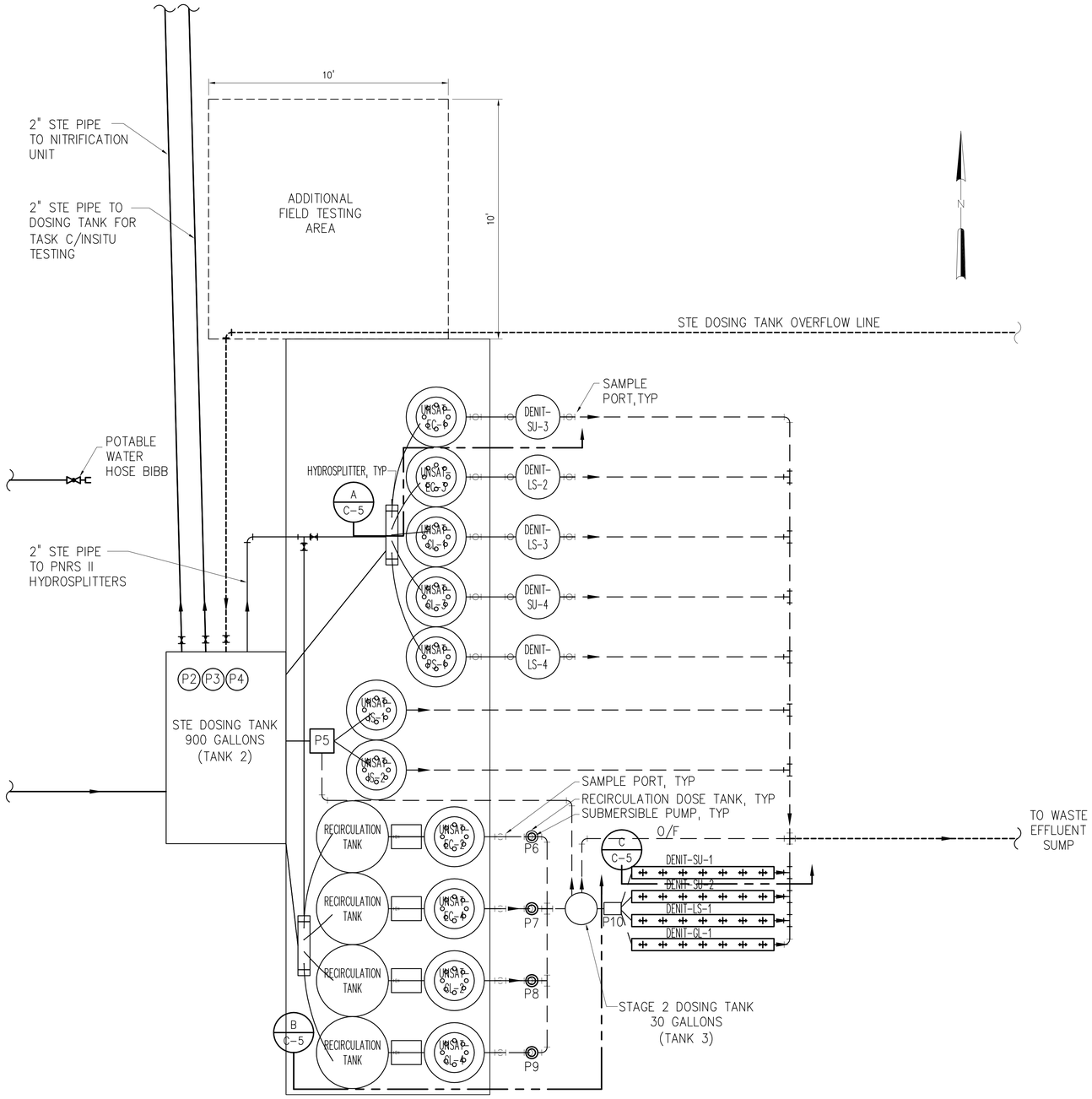
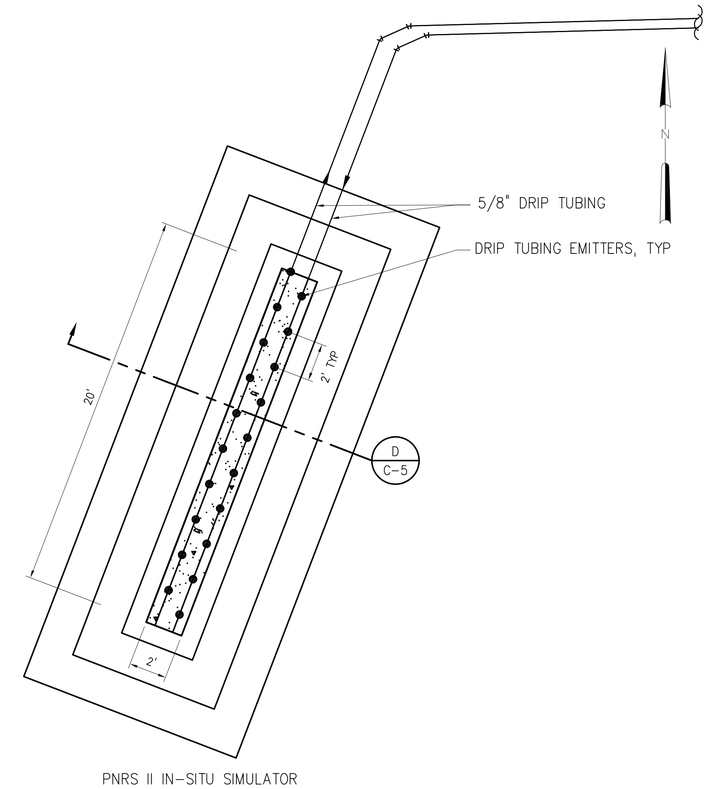


DETAIL 1 / C-2
3/8"=1'-0"



PNRS II IN-SITU SIMULATOR

DETAIL 2 / C-2
3/8"=1'-0"

SUMMARY OF PNRS II BIOFILTERS

		BIOFILTER	TANK SIZE	MEDIA DEPTH	INITIAL SURFACE LOADING RATE	STAGE 2 BIOFILTER DIRECTLY CONNECTED
STAGE 1 BIOFILTER	(SINGLE PASS)	UNSAT-EC-1	30"ID X 36" H	15" EXPANDED CLAY	3 gal/day-ft2; 14.73 gpd	DENIT-SU-3
		UNSAT-EC-3	30"ID X 36" H	30" EXPANDED CLAY	3 gal/day-ft2; 14.73 gpd	DENIT-LS-2
		UNSAT-CL-1	30"ID X 36" H	15" CLINOPTILOLITE	3 gal/day-ft2; 14.73 gpd	DENIT-LS-3
		UNSAT-CL-3	30"ID X 36" H	30" CLINOPTILOLITE	3 gal/day-ft2; 14.73 gpd	DENIT-SU-4
		UNSAT-PS-1	30"ID X 36" H	30" POLYSTYRENE	3 gal/day-ft2; 14.73 gpd	DENIT-LS-4
	(WITH RECYCLE)	UNSAT-EC-2	30"ID X 36" H	15" EXPANDED CLAY	3 gal/day-ft2; 14.73 gpd	
		UNSAT-EC-4	30"ID X 36" H	30" EXPANDED CLAY	3 gal/day-ft2; 14.73 gpd	
		UNSAT-CL-2	30"ID X 36" H	15" CLINOPTILOLITE	3 gal/day-ft2; 14.73 gpd	
		UNSAT-CL-4	30"ID X 36" H	30" CLINOPTILOLITE	3 gal/day-ft2; 14.73 gpd	
		UNSAT-IS-1	30"ID X 36" H	24" MIX	0.8 gal/day-ft2; 3.92 gpd	
		UNSAT-IS-2	30"ID X 36" H	24" MIX	0.8 gal/day-ft2; 3.92 gpd	
STAGE 2 BIOFILTER	(CONNECTED)	DENIT-SU-3	22"ID X 34" H	80% SU; 20% OS	4.7 gal/day-ft2; 12.41 gpd	
		DENIT-SU-4	22"ID X 34" H	80% SU; 20% NS	4.7 gal/day-ft2; 12.41 gpd	
		DENIT-LS-2	22"ID X 34" H	70% LS; 30% EC	4.7 gal/day-ft2; 12.41 gpd	
		DENIT-LS-3	22"ID X 34" H	50% LS; 50% EC	4.7 gal/day-ft2; 12.41 gpd	
		DENIT-LS-4	22"ID X 34" H	30% LS; 70% EC	4.7 gal/day-ft2; 12.41 gpd	
	(COMMON TANK)	DENIT-SU-1	6"ID X 72" L	80% SU; 20% OS	10 gal/day-ft2; 1.96 gpd	
		DENIT-SU-2	6"ID X 72" L	80% SU; 20% NS	10 gal/day-ft2; 1.96 gpd	
		DENIT-LS-1	6"ID X 72" L	70% LS; 30% EC	10 gal/day-ft2; 1.96 gpd	
		DENIT-GL-1	6"ID X 72" L	100% EC	10 gal/day-ft2; 1.96 gpd	

SU: ELEMENTAL SULFUR, LS: LIGNOCELLULOSIC, GL: GLYCEROL, OS: OYSTER SHELL, NS: SODIUM SESQUICARBONATE, EC: EXPANDED CLAY

3/8"=1'-0"

12" 0 1 2 4'

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(850)-245-4070

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PNRS II DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-4

PLOT DATE: 10/30/2009 12:32 PM BY: JSMEBY
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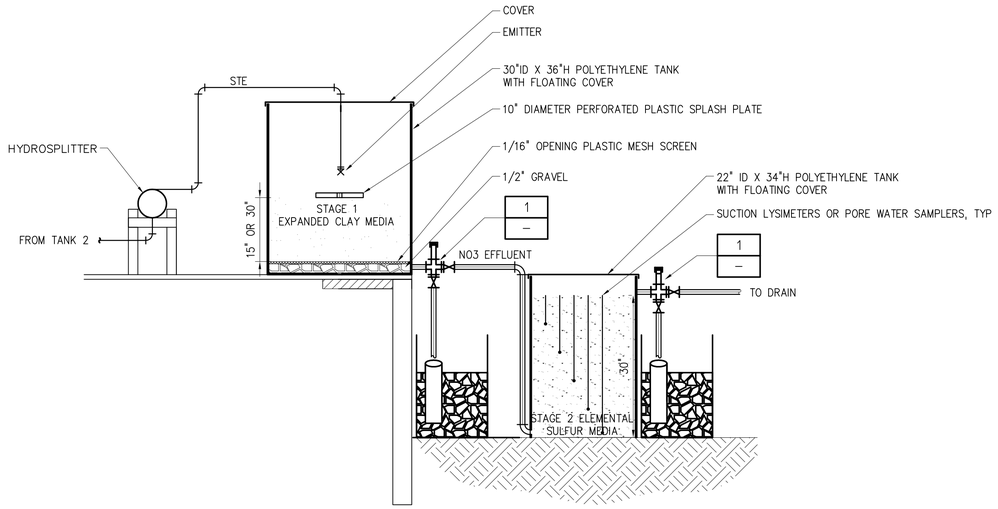
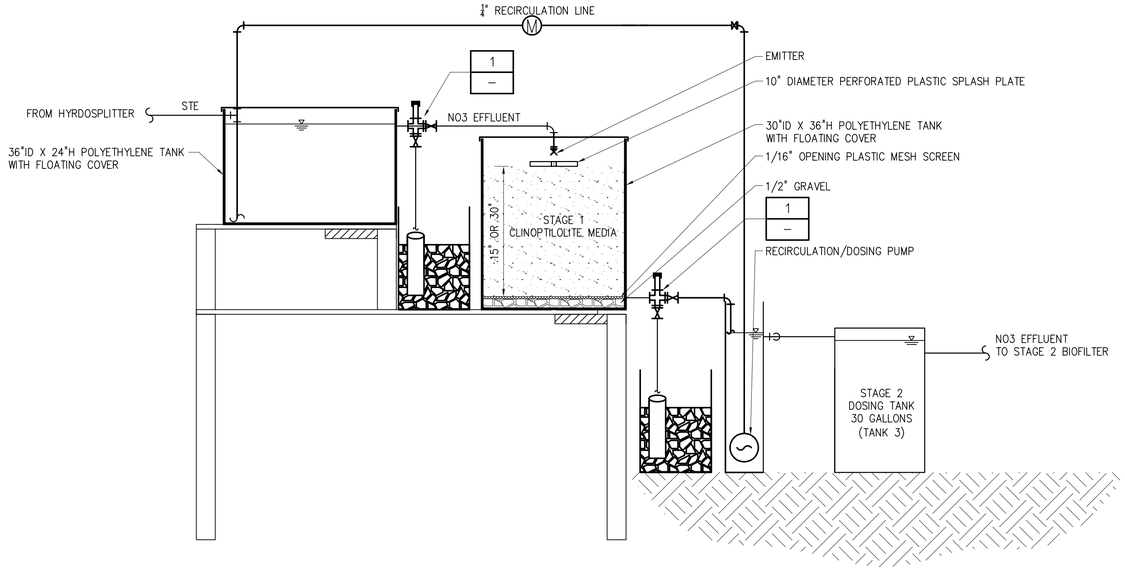


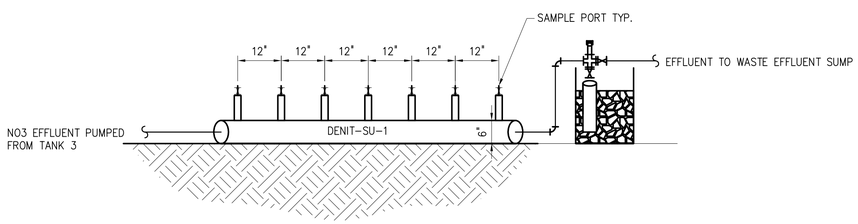
PNRS II TWO-STAGE BIOFILTER SINGLE PASS (TYPICAL)

SECTION A / C-4
NTS



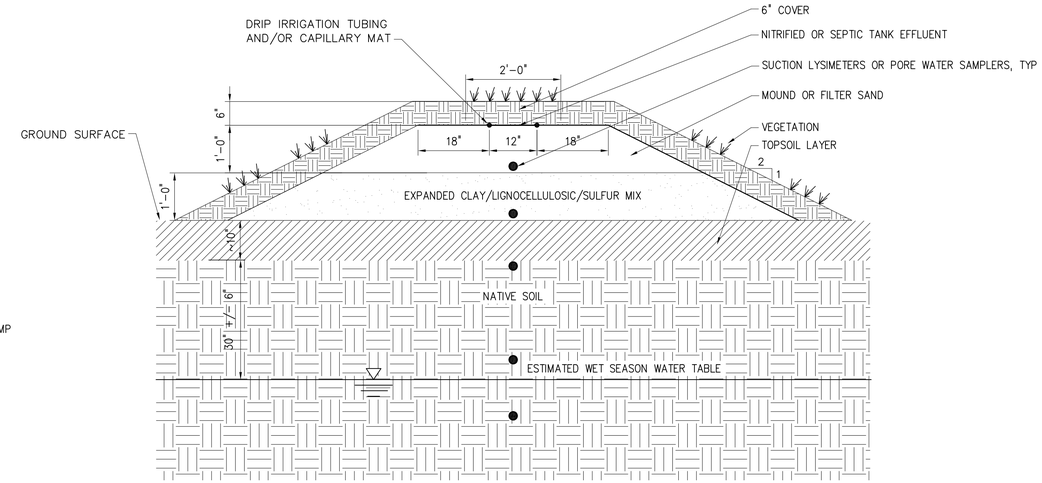
PNRS II TWO-STAGE BIOFILTER WITH RECYCLE (TYPICAL)

SECTION B / C-4
NTS



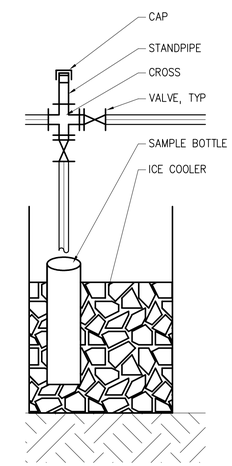
PNRS II STAGE 2 BIOFILTER FED FROM TANK 3

SECTION C / C-4
NTS



PNRS II INSITU SYTEM

SECTION D / C-4
NTS



TYPICAL SAMPLE PORT

DETAIL 1 / —
3/8"=1'-0"

NO.	ISSUED FOR	DATE	BY

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PROJ. ENGR. —
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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

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PNRS II DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-5

PLOT DATE: 10/30/2009 12:32 PM BY: GMEBY

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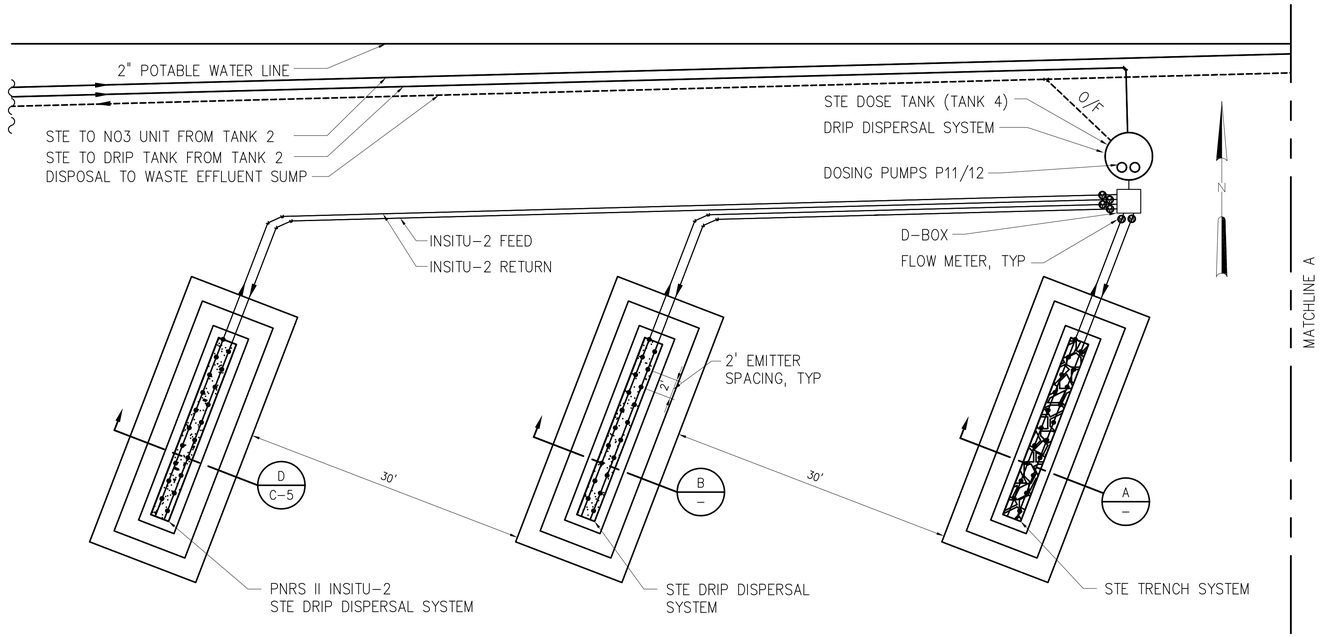
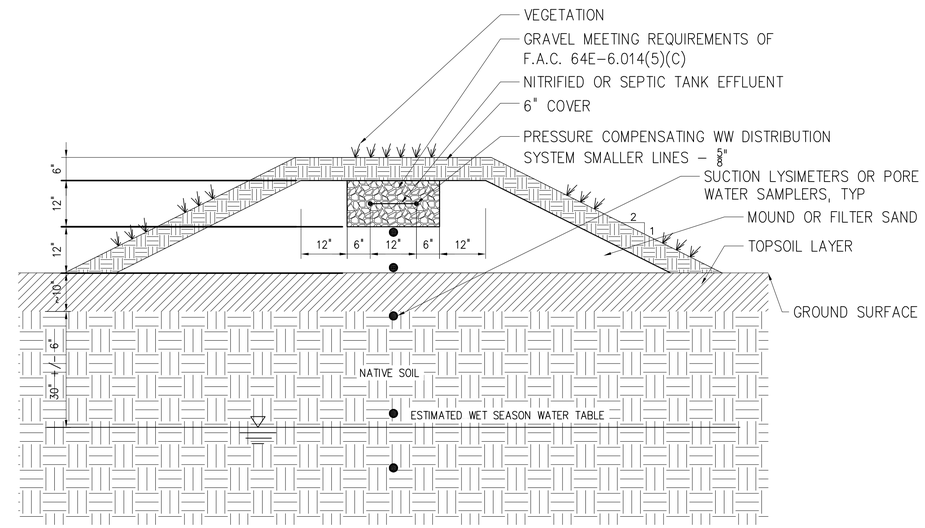
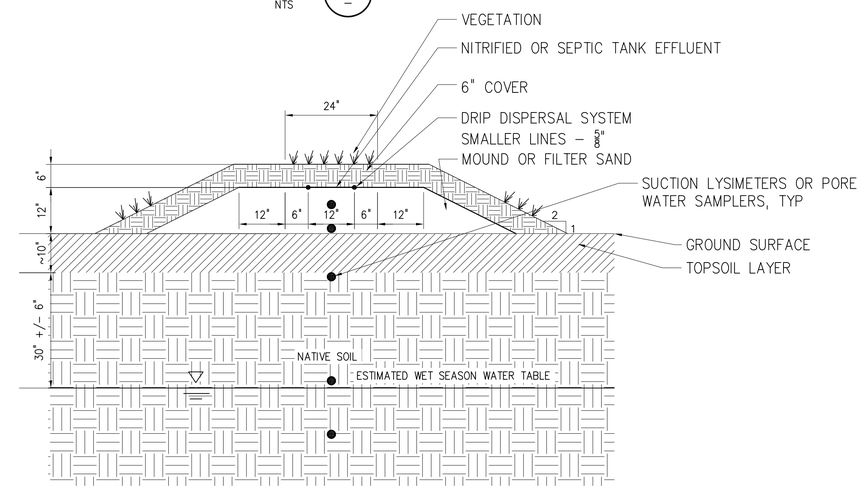


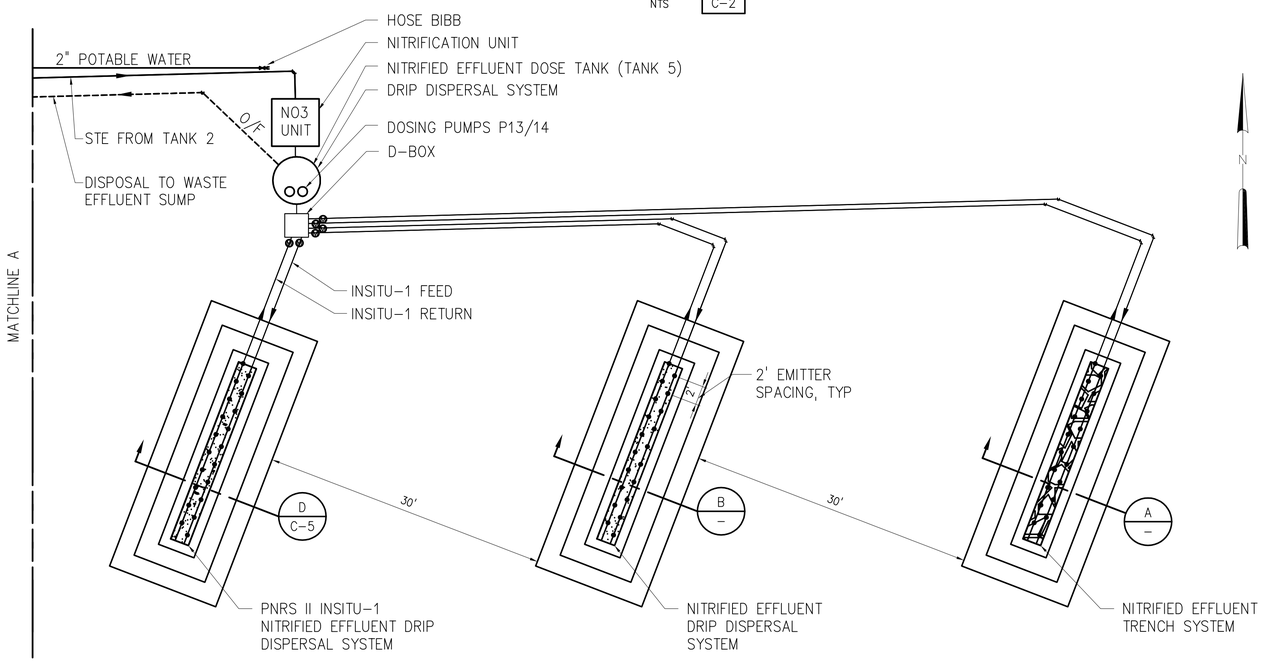
DETAIL 3 / C-2
NTS



SECTION A / –
NTS



SECTION B / –
NTS



DETAIL 4 / C-2
NTS

NOTES

1. PROPOSED NITRIFICATION UNIT AT THIS FACILITY REFERS TO A MANUFACTURED WASTEWATER TREATMENT SYSTEM WHICH MAY UTILIZE SPECIAL EQUIPMENT AND MATERIALS SUPPLIED AS A SINGLE PACKAGE WHERE INDICATED. THIS SYSTEM WILL BE PROVIDED BY OTHERS.
2. TWO PERC-RITE DRIP DISPERSAL SYSTEMS WITH THREE ZONES EACH SHALL BE PROVIDED AS INDICATED. THE SYSTEMS SHALL INCLUDE A PRESSURE REGULATOR AND FLOW METER ON THE RETURN LINE.
3. THE CONTRACTOR IS ADVISED THAT THE NITRIFICATION UNIT AND DRIP DISPERSAL SYSTEMS AND POSSIBLY OTHER DONATED EQUIPMENT WILL BE DELIVERED AND STORED AT THE PROJECT SITE. EXCEPT WHERE INDICATED IN CONTRACT DOCUMENTS ALL SHIPMENTS WILL BE ARRANGED BY FDOH AND THE ENGINEER. MANUFACTURERS REPRESENTATIVES WILL BE AVAILABLE FOR TECHNICAL GUIDANCE AT THE TIME OF INSTALLATION.

NO.	ISSUED FOR	DATE	BY

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CHECKED –
PROJ. ENGR. –
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APPROVED

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Florida Professional Engineer's Registration Number: –

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4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
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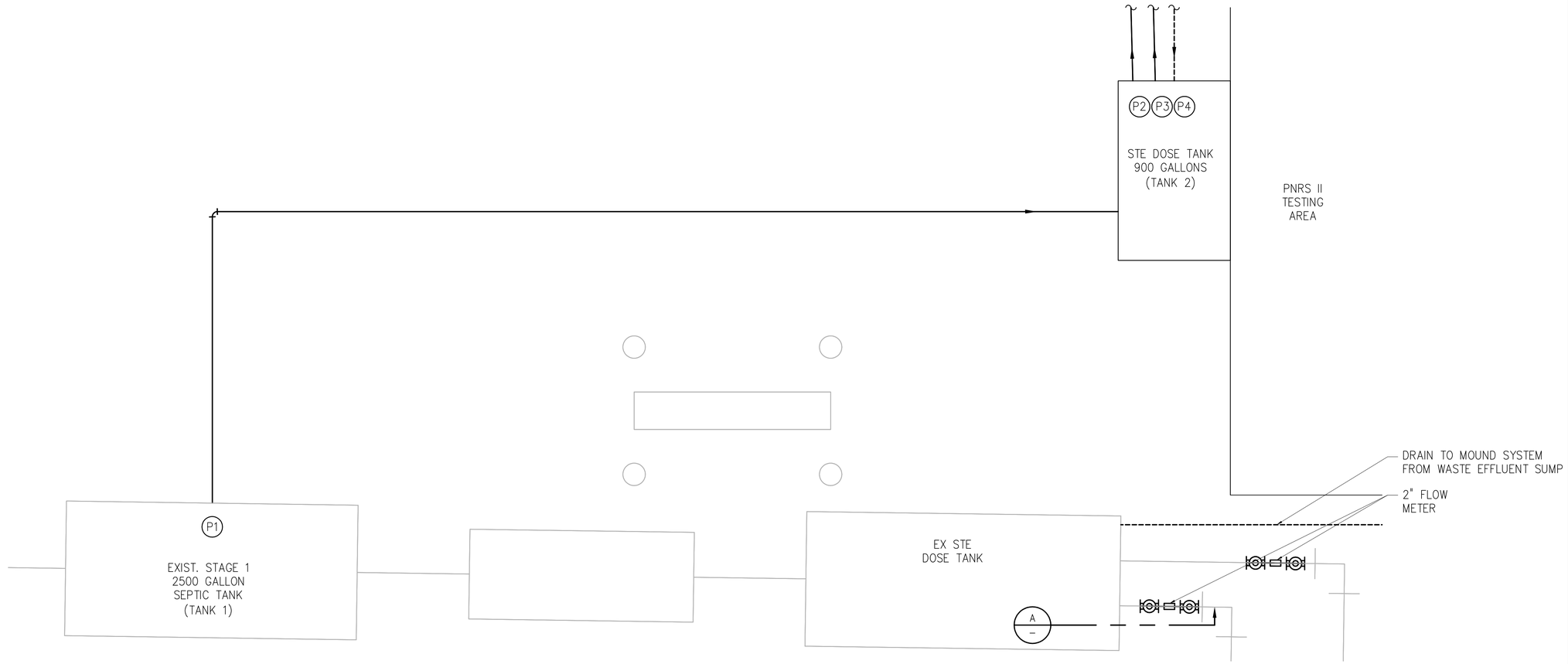
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

TASK C NITROGEN FATE & TRANSPORT STUDY DETAILS

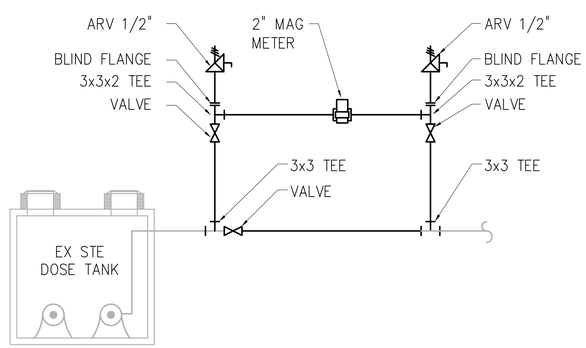
THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-6

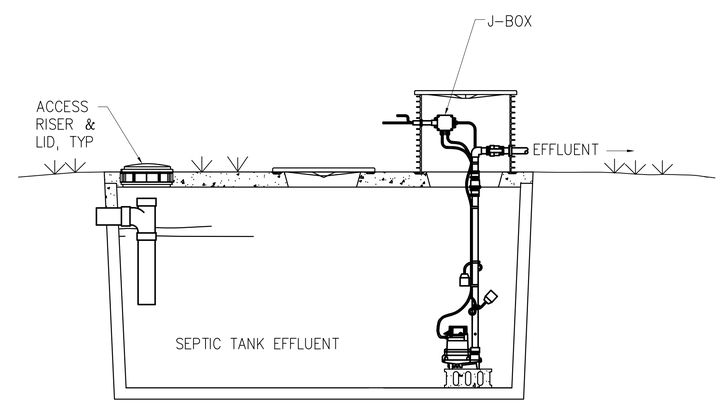
PLOT DATE: 10/30/2009 12:33 PM BY: JGMEBY
File = G:\44237-000-TM\44237-001\Drawings\1\028 Design - C10\Cad\C-4 TASK C NITROGEN FATE & TRANSPORT STUDY CHECKED-SITE PLAN Saved by jgodbeck Sep 09a = 10/30/2009 10:14 AM



DETAIL 4 / C–2
NTS



SECTION A / –
NTS



TYPICAL STE STORAGE & DOSE TANK

DETAIL 5 / M–1
NTS

NO.	ISSUED FOR	DATE	BY

DESIGNED –
DRAWN –
CHECKED –
PROJ. ENGR. –
–.
APPROVED

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Florida Professional Engineer's Registration Number: –

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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

WASTEWATER SOURCE COMPONENTS DETAILS

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237–001
CONTRACT NUMBER
DRAWING NUMBER C–7

PLOT DATE: 10/30/2009 12:33 PM BY: JSMEBY
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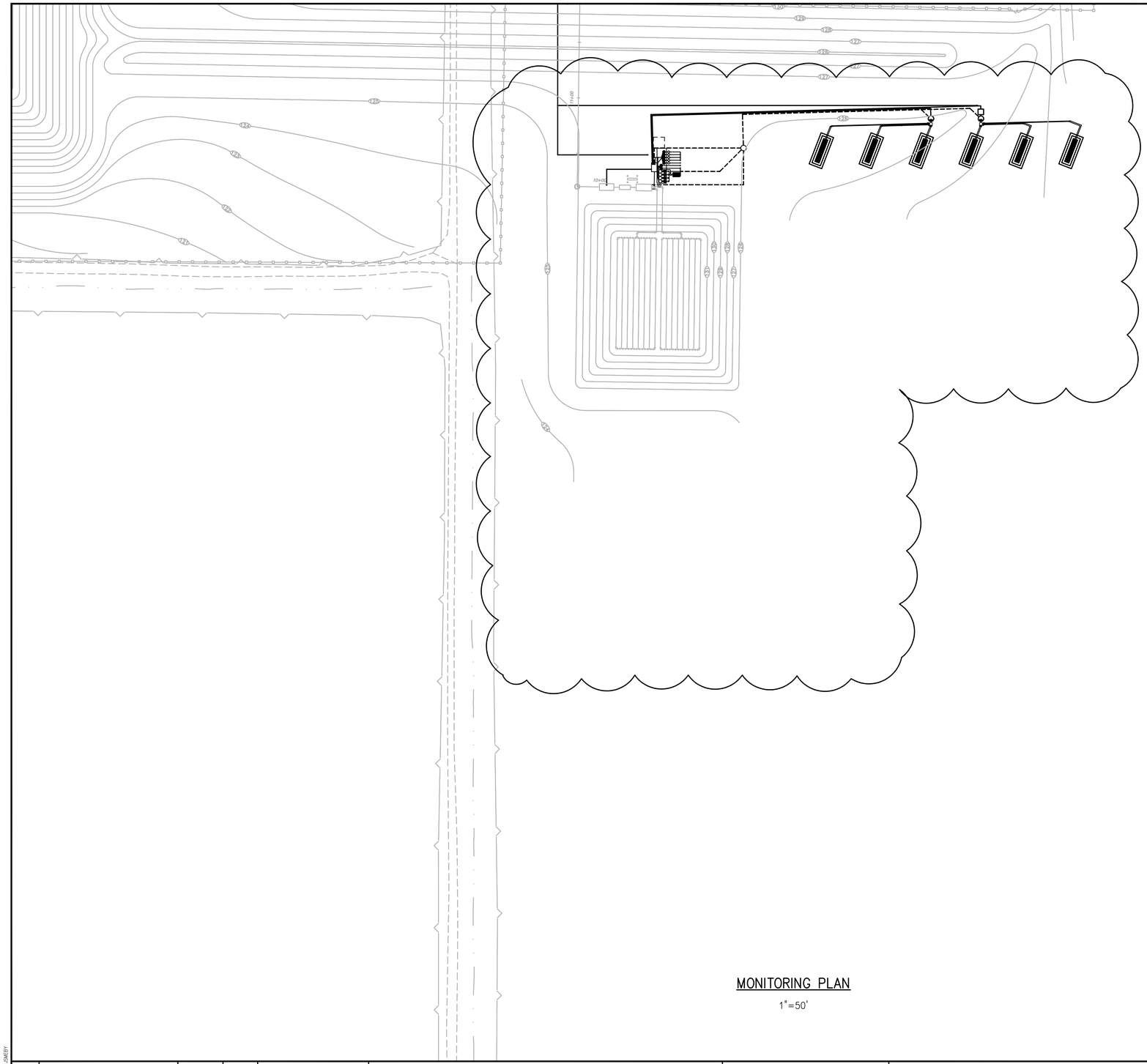

MONITORING PLAN

1"=50'

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PROJ. ENGR. –
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FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

MONITORING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
H & S JOB NUMBER 44237-001
CONTRACT NUMBER
DRAWING NUMBER C-8

PLOT DATE: 10/30/2009 12:34 PM BY: JSMBY
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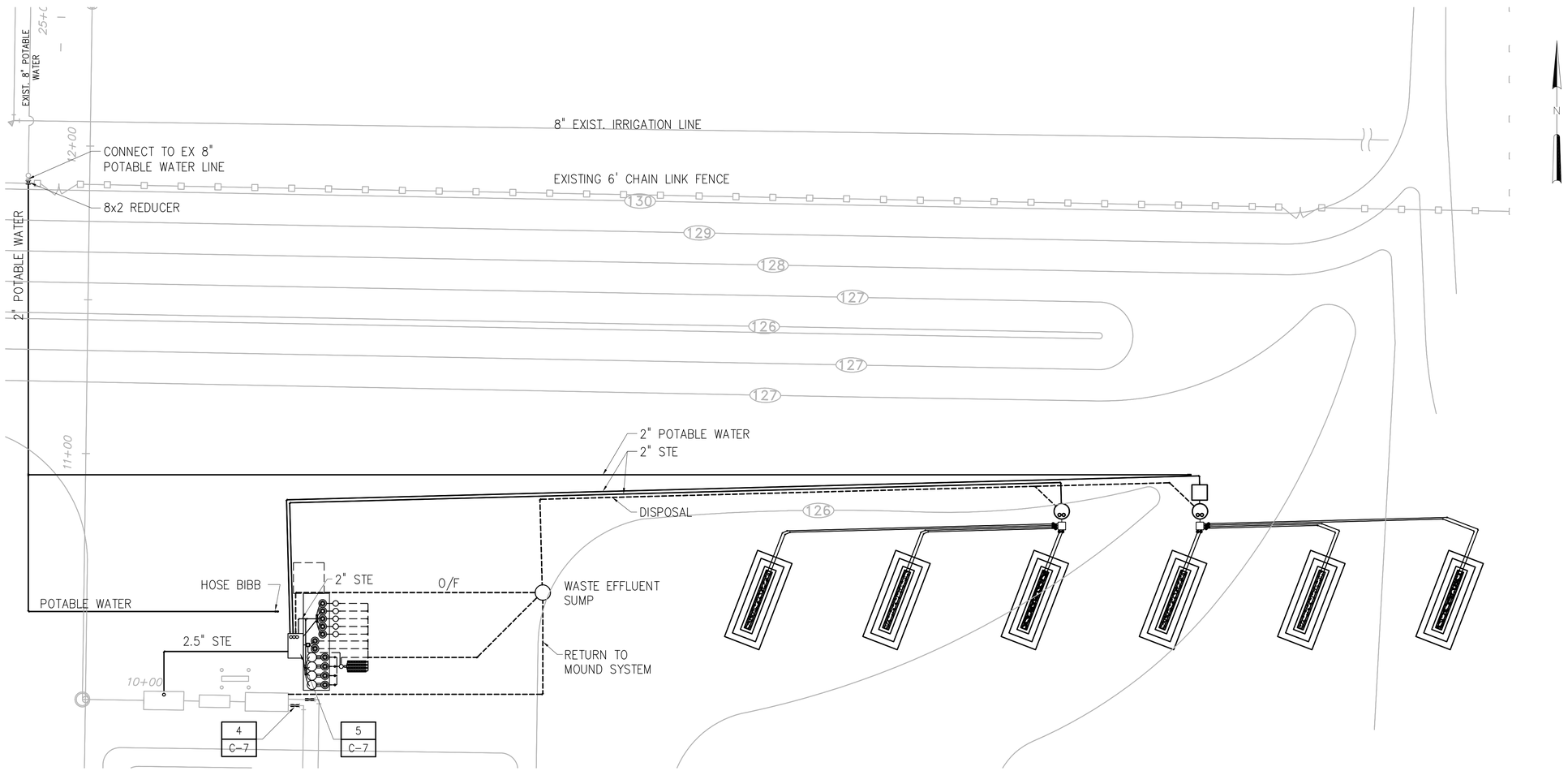

YARD PIPING PLAN

1"=20'

NOTES

1. ALL YARD PIPING, UNLESS OTHERWISE SHOWN SHALL BE SOLVENT WELDED PVC LAID AT EXISTING SITE GRADE AND COVERED WITH FILL MATERIAL.

   PVC PIPING SHALL BE LAID WHERE POSSIBLE IN COMMON TRENCHES AND MARKED WITH PIPE NUMBERS IN PERMANENT MARKINGS AT 2' INTERVALS.

2. MAINTAIN SLOPE AND GRADE OF GRAVITY LINES AS INDICATED ON THE DRAWINGS.

1"=20'-0" 20 10 0 20'

NO.	ISSUED FOR	DATE	BY

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CHECKED –
PROJ. ENGR. –
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APPROVED

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YARD PIPING PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

DATE AUGUST 2009
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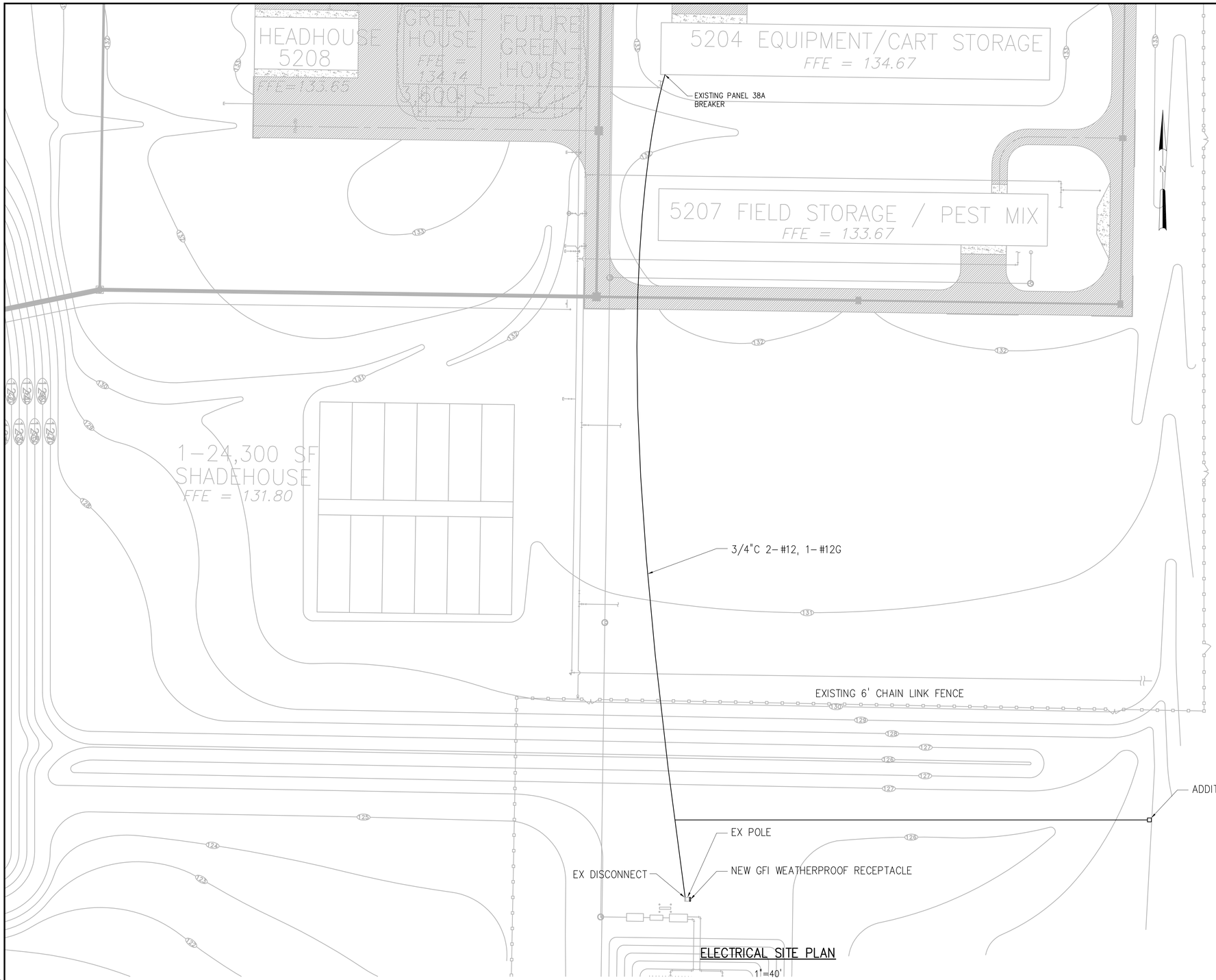

ELECTRICAL SITE PLAN

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ELECTRICAL NOTES

COORDINATE LOCATIONS OF ELECTRICAL EQUIPMENT, DEVICES, OUTLETS, FIXTURES, ETC. WITH ARCHITECTURAL PLANS, ELEVATIONS AND REFLECTED CEILING PLANS, PRIOR TO ROUGH-IN WORK. DO NOT SCALE ELECTRICAL

ALL WIRE SHALL BE COPPER.

PROVIDE INSULATED GROUNDING CONDUCTOR FROM EACH EQUIPMENT CONNECTION AND OUTLET TO GROUNDING BAR IN PANELBOARDS.

PROVIDE AN INSULATED GROUNDING CONDUCTOR IN ALL FEEDER AND BRANCH CIRCUITS.

CONTRACTOR SHALL PROVIDE ADDITIONAL JUNCTION BOXES, CONDUCTORS AND OTHER MATERIALS AND LABOR NECESSARY TO CONNECT PARALLEL FEEDER RUNS WHERE SUCH FEEDERS EXCEED CONNECTION CAPACITY OF CIRCUIT BREAKERS, PANELBOARDS AND OTHER CONNECTION POINTS.

RISER DIAGRAMS SHOW ONLY THE GENERAL CONFIGURATION OF THE SYSTEM. REFER TO THE APPROPRIATE DRAWINGS FOR EXACT DEVICE, QUANTITIES AND LOCATIONS.

ALL ELECTRICAL EQUIPMENT, DEVICES, ETC. LOCATED OUTDOORS SHALL BE WEATHERPROOF.

REFER TO ARCHITECTURAL DRAWINGS FOR PHASING OF CONSTRUCTION, TEMPORARY AND PERMANENT FENCES AND ALL CONCRETE WORK.

EXISTING UTILITIES AND OTHER UNDERGROUND OR CONCEALED ITEMS ARE SHOWN FOR REFERENCE ONLY. ADDITIONAL ITEMS NOT SHOWN MAY BE PRESENT AND LOCATIONS MAY DIFFER FROM THAT SHOWN. CONTRACTOR SHALL EXCAVATE AND CONDUCT DEMOLITION SO AS TO AVOID DAMAGE TO EXISTING ITEMS, SHALL NOTIFY OWNER AND ENGINEER AT ONCE OF ALL DAMAGE AND SHALL REPAIR DAMAGE TO ORIGINAL CONDITION TO THE SATISFACTION OF OWNER AND ENGINEER AT NO CHANGE IN CONTRACT AMOUNT.

DRAWINGS.

ELECTRICAL SPECIFICATIONS

1. THE CONTRACTOR SHALL FURNISH ALL LABOR, MATERIALS AND EQUIPMENT NECESSARY FOR THE INSTALLATION OF A COMPLETE ELECTRICAL SYSTEM AS INDICATED WITHIN THESE DRAWINGS.
2. ALL WORK SHALL BE INSTALLED IN STRICT ACCORDANCE WITH ALL APPLICABLE CODES AND ORDINANCES AND WITH MANUFACTURERS RECOMMENDATIONS. ALL WORK, MATERIALS AND EQUIPMENT SHALL COMPLY WITH THE NATIONAL ELECTRICAL CODE 2002 EDITION.
3. ALL MATERIALS AND EQUIPMENT SHALL BE INSTALLED IN A NEAT, FIRST CLASS, WORKMANLIKE MANNER, TO THE APPROVAL OF THE ENGINEER AND GOVERNING AUTHORITIES.
4. GUARANTEES AND SERVICE: IN ADDITION TO THE MANUFACTURERS STANDARD GUARANTEES, THE CONTRACTOR SHALL GUARANTEE ALL MATERIALS, EQUIPMENT AND WORKMANSHIP AGAINST DEFECTS FOR ONE YEAR FROM THE DATE OF FINAL ACCEPTANCE, AND SHALL CORRECT ANY DEFECTS AT NO ADDITIONAL COST TO THE OWNER. ALL LAMPS SHALL BE GUARANTEED FOR 30 DAYS.
5. CONDUIT AND WIRING: THE CONTRACTOR SHALL PROVIDE COPPER CONDUCTORS IN METALLIC RACEWAY. CONDUITS SHALL CONTAIN AN INSULATED GREEN GROUND CONDUCTOR. FOLLOW RULES AND REGULATIONS OF THE NEC FOR PROPER INSTALLATION REGARDING INSTALLATION AND SUPPORT.

   CONDUIT SHALL BE INSTALLED AS NOTED. IF NOT SPECIFICALLY ADDRESSED THE FOLLOWING SHALL APPLY: (A) PROVIDE GRS (GALVANIZED RIGID STEEL) IN HAZARDOUS LOCATIONS, I.E.: ON EXTERIOR OF BUILDING. (B) PROVIDE EMT (ELECTRICAL METALLIC TUBING) IN WALLS OR ABOVE CEILING. (C) PROVIDE PVC (POLY VINYL CHLORIDE) UNDERGROUND. (D) PROVIDE FLEXIBLE METALLIC CONDUIT FOR EQUIPMENT CONNECTIONS LOCATED INDOORS WHERE POSSIBILITY OF VIBRATION EXISTS. (E) PROVIDE LIQUID-TITE FLEXIBLE METALLIC CONDUIT FOR EQUIPMENT CONNECTIONS LOCATED OUT OF DOORS WHERE POSSIBILITY OF VIBRATION EXISTS. PROVIDE FITTINGS AS MANUFACTURED FOR CONDUIT USED.

   PROVIDE COPPER CONDUCTORS WITH DUAL RATED THWN-THHN TYPE INSULATION.
6. PANELBOARDS: PANELBOARDS SHALL BE FRONT ACCESSIBLE TYPE EQUIPPED WITH BOLT IN CIRCUIT BREAKERS, DEAD FRONT AND FLUSH MOUNTED HINGED DOORS. PROVIDE UNIT WITH TIN-PLATED COPPER BUS, SEPARATE NEUTRAL AND GROUND BUS. MOUNT PANELBOARD WITH OPERATING HANDLES AT NOT OVER 72" ABOVE FLOOR. CIRCUIT BREAKERS SHALL BE MOLDED CASE, WITH QUICK-MAKE/QUICK-BREAK ACTION AND THERMAL TRIP ELEMENTS. TWO POLE BREAKERS SHALL HAVE A COMMON TRIP. ALL CIRCUIT BREAKERS SHALL BE U.L. RATED AND LABELED. PROVIDE INTERRUPTING RATING AS INDICATED ON PANEL SCHEDULES. SERIES RATING WILL NOT BE ACCEPTABLE.
7. TRANSFORMERS: TRANSFORMERS (DRY TYPE) SHALL BE HOUSED IN NEMA 250, TYPE 2, VENTILATED ENCLOSURES SET ON CONCRETE HOUSEKEEPING PADS. COIL MATERIAL SHALL BE COPPER. TRANSFORMERS SHALL BE INSULATED WITH A 185° C INSULATION SYSTEM WITH WINDING TEMPERATURE RISE NOT EXCEEDING 115° C. TRANSFORMER SHALL BE CAPABLE OF CARRYING 115% OF NAME PLATE KVA WITHOUT EXCEEDING INSULATION RATING. TRANSFORMERS WILL BE PROVIDED WITH A UNIVERSAL TAP ARRANGEMENT, 2-1/2% ABOVE AND 2-1/2% BELOW NORMAL PRIMARY VOLTAGE. PROVIDE SOUND/VIBRATION ISOLATION PADS UNDER ALL FLOOR MOUNTED TRANSFORMERS. GROUND

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PROJ. ENGR. –
–
APPROVED

Name: Date:
Florida Professional Engineer's Registration Number: –

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

FLORIDA DEPARTMENT OF HEALTH
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

ELECTRICAL SITE PLAN

THE SCALE BAR SHOWN BELOW MEASURES ONE INCH LONG ON THE ORIGINAL DRAWING.

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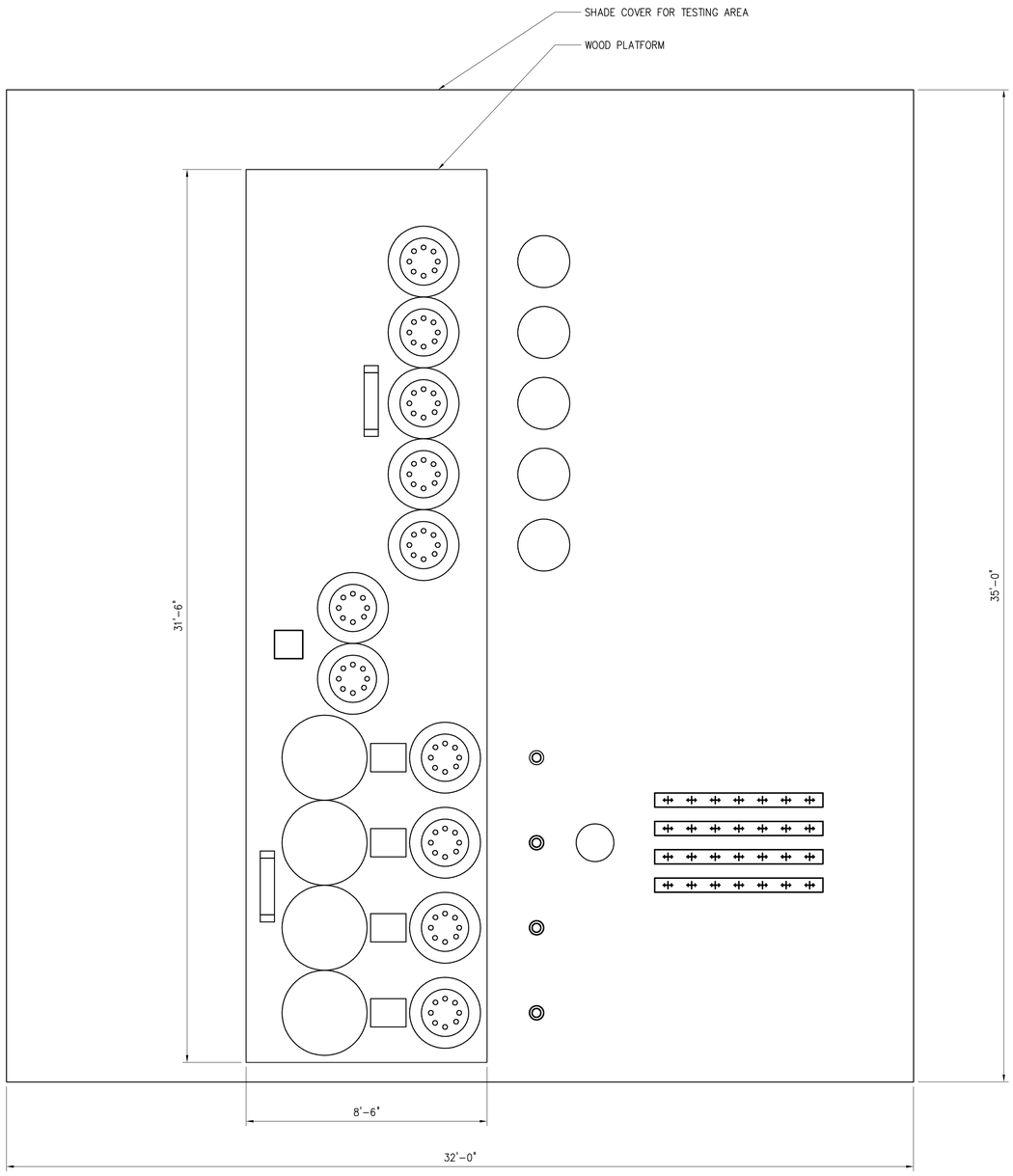

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Name: Date:
Florida Professional Engineer's Registration Number: –

HAZEN AND SAWYER
Environmental Engineers & Scientists
10002 Princess Palm Avenue
Registry One Building, Suite 200
Tampa, Florida 33619
Certificate of Authorization Number: 2771

FLORIDA DEPARTMENT OF HEALTH
4052 BALD CYPRESS WAY, BIN A08
TALLAHASSEE, FL 32399-1713
(850)-245-4070

FLORIDA DEPARTMENT OF HEALTH
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATIGIES STUDY

PNRS II STRUCTURAL SITE PLAN

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FLORIDA DEPARTMENT OF HEALTH

Florida Onsite Sewage Nitrogen Reduction Strategies Study

Task D.2

Literature Review of Nitrogen Fate and Transport Modeling

Final Report

December 2009

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HAZEN AND SAWYER
Environmental Engineers & Scientists

In association with

SCHOOL OF MINES 1874 COLORADO

AET
Applied Environmental Technology

OTIS ENVIRONMENTAL CONSULTANTS, LLC

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK D.2
FINAL REPORT

Literature Review of Nitrogen Fate and Transport Modeling

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

December 2009

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

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Section 1.0
Introduction

1.1 Project Background

As a result of the widespread impacts of nitrogen on groundwater, the management of nitrogen sources, particularly onsite sewage treatment and disposal systems (OSTDS), is of paramount concern for the protection of human health. Mathematical models of groundwater flow and solute transport historically have been utilized for simulating concentration and plume distribution of contaminants and assisting in management practices by providing representations of groundwater behavior. An appropriate model can provide guidance for land-use planning and remedial approaches. As part of the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study, a groundwater flow and transport modeling tool is being developed to provide a management tool for potential impacts of nitrogen from OSTDS. The primary objectives of the model development are to:

- create a user-friendly flow and transport model (i.e., a programmed Microsoft Excel spreadsheet), and
- develop a model that can be used to predict nitrogen concentrations and mass flux/loading at a point or plane down-gradient of an OSTDS or systems assuming the model:
    - adequately represents the identified processes that govern the fate and transport of OSTDS-generated nitrogen in groundwater, and
    - should also be capable of simulating temporally variable source input and account for non-uniform spatial distribution of OSTDS sources.

The following presents a literature review to assess the current state-of-knowledge regarding the mathematical modeling of nitrogen and nitrate movement and distribution in groundwater related to OSTDS. The review will attempt to identify existing models that may satisfy the above-stated objectives, modeling approaches that can be useful, relevant input and calibration parameters and the level of effort required in developing a modeling tool. As part of the literature review, a database of the references was developed in conjunction with this summary report. This database (see separate Excel file

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"CSM_D-1 Nitrogen Modeling Studies") includes a summary table of the relevant features and parameters of each modeling study. As a result of the large number of identified sources, some modeling studies not deemed valuable to this effort are mentioned in this report but are not described in detail and the reader is directed to the database for further information.

1.2 Nitrogen in Ground Water; Conceptual Considerations

Nitrogen is an important concern for water quality and nitrates represent perhaps the most common groundwater pollutant. Animals, crops, ecosystems, and human health can be adversely impacted by the presence of nitrogen in water supplies. Of these concerns, nitrate impacts to human health are a primary consideration. The consumption of nitrates has been linked to various illnesses, including cyanosis in infants and some forms of cancer. As a result, in the United States, a maximum allowable nitrate concentration of 10 mg/L as N has been established as protective of human health (Canter 1996). Other agencies around the world have also established such standards for nitrates in groundwater.

A survey of community service wells and private domestic wells performed by the U.S. Environmental Protection Agency (EPA) indicated that over half of these water supply wells contained detectable levels of nitrate (Canter 1996). The sources of this contamination are various, and include agricultural and domestic fertilizer applications, natural sources, wastewater treatment applications, and the use of OSTDS. The last category is often of concern, as nearly 25% of the population in the U.S. and 30% of all new development utilize OSTDS (Lowe et al., 2007). In Florida, nearly a third of all households are serviced by OSTDS and 92% of water supplies come from groundwater (Briggs et al. 2007, Lowe et al. 2007).

Nitrogen transport in the subsurface is a complex process, especially when considering the nitrogen inputs from OSTDS. The objectives of model development therefore requires the development of a conceptual understanding that includes the relevant fate and transport processes, parameters, and simulation approaches that will appropriately achieve the goals of the model. Figure 1-1 summarizes the conceptual understanding of the inputs of nitrogen and the transformative and advective processes that lead to nitrogen contamination of groundwater. The model development should result in a tool that will consist of the adequate level of complexity to represent these processes to accurately simulate the fate and transport of nitrogen species.

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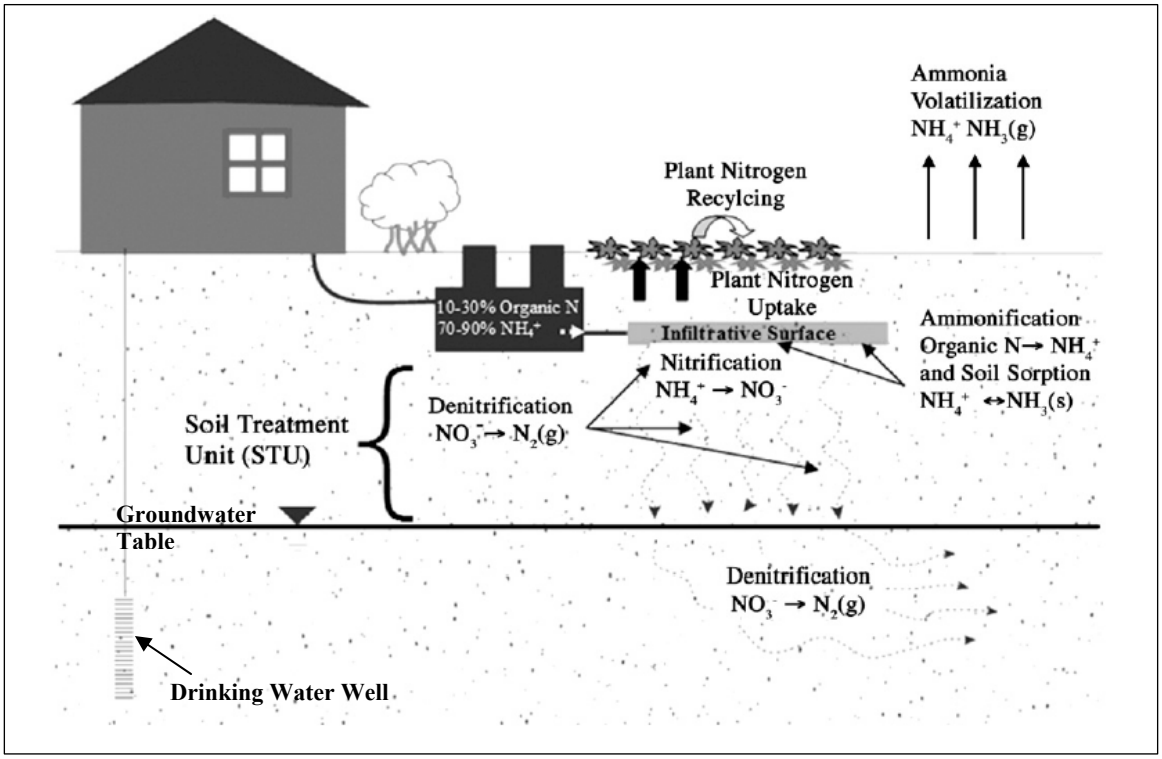

Figure 1-1: Nitrogen Processes Occurring in a Typical OSTDS (adapted from Heatwole and McCray 2007)

Proper OSTDS design, installation, operation, and management are essential to ensure protection of the water quality and the public served by that water source. Assuming soils and site conditions are judged suitable, a wide variety of OSTDS are designed and installed (U.S. EPA, 1997, 2002; Crites and Tchobanoglous, 1998; Siegrist, 2001). Conventional OSTDS rely on septic tanks for the primary digestion of raw wastewater followed by discharge of septic tank effluent (STE) to the subsurface soils for eventual recharge to underlying groundwater (Crites and Tchobanoglous, 1998; Metcalf and Eddy, 1991; U.S. EPA, 2002). However, increasing uses of alternative OSTDS rely on additional treatment of the STE prior to discharge to the environment in sensitive areas (e.g., aerobic filter) or in some designs may eliminate use of a septic tank altogether (e.g., membrane bioreactor).

Conventional septic tanks are anaerobic and have long solids retention times (e.g., years) that can enable digestion resulting in a reduction of sludge volume (40%), biochemical oxygen demand (60%), suspended solids (70%) and conversion of much of the organic nitrogen to ammonium (Reneau et al. 2001). Septic tanks are also important as they attenuate instantaneous peak flows from the dwelling unit or establishment. The effluent discharged from the septic tank (i.e., septic tank effluent or STE) then flows to

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subsequent treatment (e.g., aerobic treatment unit) or directly to the soil treatment unit where the processes of soil adsorption, filtration, and transformation (biological and chemical) occur.

Nitrogen waste products are a considerable component of septic tank effluent. Total nitrogen, composed primarily of organic nitrogen products and ammonium-nitrogen, is typically assumed to range between 20-190 mg-N/L in untreated waste water, and 26-125 mg-N/L in STE (Canter 1996, Crites and Tchobanoglous, 1998, Lowe et al., 2009). Furthermore, in a recent study that evaluated the composition of raw wastewater and STE, the median total nitrogen concentration in STE specific to Florida was determined to be 65 mg-N/L (average = 61 mg-N/L) (Lowe et al., 2009). In terms of mass loading to the subsurface, the median loading rate was determined to be 10 g-N/capita/d (average = 13.3 g-N/capita/d) (Lowe et al., 2009). McCray et al. (2005) suggested that an average subdivision can generate up to 2880 kg/km^2 annually. While this value is significantly higher than estimates of naturally generated deposition (600-1,200 kg/km^2 annually), it is much lower than the loading that results from fertilizer application (10,000-20,000 kg/km^2 annually). Nonetheless, OSTDS should be considered a potential contributor to groundwater nitrogen concentrations.

The first stages of nitrogen transformation related to OSTDS occur in the septic tank. Organic nitrogen is mineralized to the inorganic form (ammonia) via the process of ammonification, followed by volatilization to ammonium ions.

$$NH_3(aq) + H_2O \rightarrow NH_4^+ + OH^- \qquad \text{(equation 1)}$$

Once the liquid portion of the wastewater enters the drainfield through the subsurface infiltration system, nitrogen species (specifically ammonium and nitrate) are further transformed in the soil by nitrification and denitrification. Nitrification is a two step process by which ammonium is converted first to nitrite than to nitrate via biological oxidation.

$$NH_4^+ + O_2 \rightarrow NO_2^- + O_2 \rightarrow NO_3^- \qquad \text{(equation 2)}$$

Although a two step process, it can be assumed to be a one step process since the conversion of ammonium to nitrite is relatively rapid. Nitrification is either described as a zero-order or first-order reaction or via Monod kinetics. This particular reaction is of importance, as it represents the transformation from the relatively immobile nitrogen form (ammonium) to the highly mobile form (nitrate). Most studies of OSTDS with suitable unsaturated soil have indicated that little ammonium reaches the underlying groundwater and that most impacts to groundwater from nitrogen are in the nitrate form. Nitrate behaves essentially as a conservative solute, with virtually no sorption or retardation

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processes affecting its movement in the aquifer. It is, however, subject to transformative processes.

Denitrification is the transformation of nitrate to N_2 gas.

$$5(CH_2O) + 4NO_3 + 4H^+ \rightarrow 5CO_2 + 2N_2 + 7H_2O \qquad \text{(equation 3)}$$

Denitrification occurs in oxygen-free conditions, and is therefore seen in anoxic zones in the soil and groundwater. This reaction is typically described as first-order. However, nitrogen transformations are probably best modeled using Monod kinetics, which result in zero-order rate constants for concentrations typical of nitrate-impacted groundwater. The process, while studied extensively, is not well understood or well quantified. Previous studies identifying significant processes that lead to the reduction of nitrate concentrations identify denitrification rates as relatively small, and that most reductions occur as a result of mixing with ambient groundwater (to be discussed in more detail later in this review).

The development of a conceptual understanding of nitrogen fate and transport from source to receptor indicates that there are potentially a large number of processes that can be simulated depending on the objectives of the model. In the literature review that follows, researchers have in some cases used simplifying assumptions to account for certain processes if data is not available or the model does not need to simulate the process to achieve desired outputs. In other cases, researchers use relatively complex mathematical models in attempt to model multiple transformation or transport processes as accurately as possible. For example, the development of a model that considers all of the sequential steps of denitrification. The approach chosen is highly dependent on the goals of the modeling and the data available, as well as the scale that is to be represented.

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Section 2.0
Literature Review

The following presents a summary of available research related to the modeling of fate and transport of nitrogen in groundwater. Modeling research directly related to nitrogen is presented, as well as modeling for general solute transport. The purpose of the summary is to:

- assess the state-of-knowledge of modeling nitrogen fate and transport in the vadose zone and in groundwater,
- identify the relevant processes, parameters and data used in the simulation of nitrogen transport,
- identify the modeling methods that enable quality simulation with an appropriate level of complexity in the context of the important processes that govern nitrogen fate and transport in the subsurface, and
- identify the merits and drawbacks of the various modeling studies and develop a guidance in designing the mathematical approach to address the project objectives.

2.1 Modeling Research Summary

The literature review discovered over 70 reports or articles related to the modeling of nitrogen fate and transport. Additionally, the review discovered more than 20 modeling codes or solutions not specific to a particular contaminant that could potentially be applied to the simulation of nitrogen in the subsurface, based on the conceptual understanding of the processes governing nitrogen movement and transformation. Only a very small number of models specific to OSTDS were discovered, and generally were concerned with land-use planning related to septic tank density.

A relatively large number of studies investigated the behavior of nitrogen in the vadose zone. These models were typically physically-based deterministic solutions of the Richards' equation for groundwater flow with a variation of the advective-dispersive equation (ADE) to simulate solute transport. Some researchers used a stochastic solution approach; this approach assumes that vadose zone parameters are too heterogeneous

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to be captured by a physical model, and that transport through the unsaturated zone is better modeled by using probabilistic functions for model input parameters.

The review identified fewer models considering nitrogen in the saturated zone. This may be in large part due to the fact that nitrate acts as a conservative solute in groundwater and therefore the development of complex models to describe this movement are not necessarily valuable or appropriate. A number of mass-balance models were created for nitrates in the saturated zone, because such a model could satisfy the objectives of the study. The models in this category consist of land-use planning models, studies identifying nitrate sources, and studies of specific groundwater systems. Modeling efforts that were not specific to nitrogen also tended to fall in this category, as researchers were concerned with developing methods that provided appropriate approximations of the ADE. Because solutions to this equation are approximate, many researchers were developing or comparing solution methods in order to identify the method that provided the most accurate solution.

Fewer still have considered the combined simulation of nitrogen in the vadose and saturated zone, and among these only a handful simulated flow and transport processes at the field scale. The latter category of models is often developed at the watershed scale and included impacts to surface water bodies. The inputs and the models themselves are often fairly large and complex, and include data and simulations for climate, streamflow characteristics and fluxes, and land-use and vegetative patterns. Simulations and calibration procedures are usually time-consuming and complex, and require a considerable amount of input data.

Additionally, a large body of research has exclusively modeled the denitrification processes. In fact, numerous simple models have been developed that generate empirical expressions for denitrification at particular sites of interest. As a result, broad applicability and transferability of the models described to other sites is questionable.

2.2 Vadose Zone Models

Many modeling studies were identified that addressed solute transport in the vadose zone, of which a majority of the models selected for this review specifically simulated nitrogen transport. The simplest approach for estimating nitrogen transport through the vadose zone is mass-balance budget estimates that provide a loading value from the soil to the groundwater. Additionally, a variety of numerical or analytical modeling approaches were identified in the literature review that could generally be classified as either deterministic physical models or stochastic, probabilistic models. Among the studies that examine the problem of nitrogen fate and transport, physically-based deterministic models for the vadose zone are generally solutions of the Richards' equation combined

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with a one-dimensional solution of the ADE for representing vertical flow and transport (in the "z" direction) and assuming horizontal flow vectors are not significant, although in some cases dispersion was also considered.

Mass-balance derived loading estimates can be a simple yet useful tool when considering the transport of nitrogen through the soil zone. Otis (2007) applied data related to Florida soil types and soil characteristics such as drainage potential, permeability, organic carbon content and hydraulic conductivity to develop estimates for the percentage nitrogen reduction through the vadose zone prior to impacting the groundwater. The values generated can be used to provide a source term for a groundwater model as a loading rate. Katz et al. (2009) also generated a mass-balance based estimate of nitrogen loading from a variety of sources including OSTDS in karstic basins in Florida. This approach also considered precipitation rates in the calculation as both a factor for water input and a nitrogen source. While this research considers nitrogen inputs from fertilizers and animal wastes, a useful estimate of loading from OSTDS again can be used as a source term in a groundwater model.

Addiscott and Wagenet (1985) provided a summary of numerical and analytical soil leaching models and provided brief descriptions of modeling approaches and specified studies that applied the various methods. The key distinction the authors make when comparing the modeling approaches is comparing deterministic models with stochastic modeling approaches. The authors note that in most cases the selection of methods is based on the preferences of the researchers and tend to ignore the fact that models are intended for different purposes.

Among the physically-based models, most studies examine the problem of nitrogen transport in the unsaturated zone related to the impacts of fertilizer applications. These include studies by Bakhsh et al. (2004), Hansen et al. (1991), Jabro et al. (2001), Johnson et al. (1999), Moreels et al. (2003), and Johnsson et al. (1987). Generally, these modeling studies used numerical computer simulation programs designed for one-dimensional solutions of the Richards' equation coupled with the ADE or a variation of the ADE that contains provisions for partially-saturated flow and transport. In some cases, these programs are relatively complex, requiring large amounts of computing power and time, as well as complex data inputs. For example, (Bakhsh et al. 2004) used an updated version of the Root Zone Water Quality Model (RZWQM) to simulate nitrogen transport in a watershed in Iowa that is potentially impacted from corn and soybean field fertilizer applications. The RZWQM simulates solute transport using a one-dimensional solution to the Richards' equation and ADE. Input data for meteorological parameters includes daily minimum and maximum temperature, hourly wind speed, and solar radiation. Additionally, a full suite of soil and crop management inputs are required as well.

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Jabro et al. (2001) used the SOIL-SOILN model to simulate nitrogen transport. This model simulates fluid flow and heat transport using a coupled program that solves the ADE for fluids and the Fourier equation for heat transport. Again as with the RZWQM, inputs are complex including meteorological, soil, and crop management data. Simulations were performed for a three-year period and showed generally good model performance. Zhao et al. (2000) used the DRAINMOD-N code to analyze the nitrate nitrogen losses and expected crop yield for a field in Minnesota. DRAINMOD-N is a code with subroutines using water balance, a one-dimensional solution to the ADE, and a crop yield estimator for its simulations. The ADE subroutine considers rainfall, fertilizer dissolution, organic nitrogen mineralization and denitrification as factors in the solution. The study concluded that variations in drain spacing did not influence nitrate losses as much as the fertilizer application rate.

Other unsaturated zone models simulated nitrogen movement associated with the practice of wastewater treatment via land applications. Modeling studies by Reynolds and Iskandar (1995) and Beggs et al. (2005) looked at effectiveness of this practice at minimizing the impacts of effluents. Beggs et al. (2005) used HYDRUS 2D to look at the effectiveness of using subsurface drip irrigation as a means of treating STE. HYDRUS 2D, like the RZWQM, uses the Richard's equation for flow and the ADE with reaction parameters (including rate constants for nitrification and denitrification) for transformation and transport. The study showed an appropriately designed system could reduce annual nitrogen percolation through the soil column. Reynolds and Iskandar (1995) used the previously developed computer code WASTEN to simulate various scenarios of wastewater land application at a treatment facility at Fort Dix, New Jersey. The code utilizes a subroutine for the ADE and can also simulate transformation processes such as nitrification and denitrification. Addtionally, WASTEN is capable of simulating the effects of plant uptake, evapotranspiration, leaching, and rainfall.

Selim and Mansell (1976) and Mironenko and Pachepsky (1984) developed one-dimensional analytical solutions of the ADE for the simulation of solute transport through soils. Selim and Mansell develop a solution that can simulate constant source or pulse source inputs, and can also simulate reversible linear adsorption and irreversible sorption. No parameters for reactions are provided. In comparison to other solutions, the model performed more favorably at lower pore velocities, and performed similarly at higher pore velocities. Mironenko and Pachepsky developed a solution that could simulate adsorption as well as biological or chemical transformations. The heterogeneity of the soil pore scale was addressed by introducing mobile and immobile transport domains. The model was then used to simulate nitrogen transport and denitrification in a soil column. The results are presented as relative concentrations (C/C_0) vs. pore vo-

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lumes, as shown in Figure 2-1. The researchers were able to reasonably match observed data using a model calibration procedure to determine input parameter values.

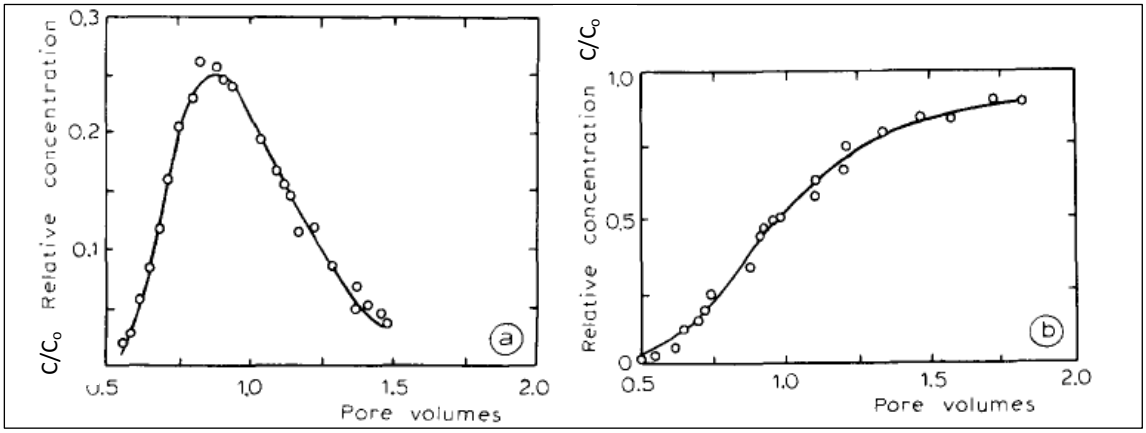

Figure 2-1: Modeling Results from Mironenko and Pachepsky (1984)

A number of modeling studies were found that simulated wastewater vadose zone transport associated with OSTDS. Huntzinger and McCray (2003) used HYDRUS2D to examine the problem of soil pore clogging and its impact on the effectiveness of wastewater soil absorption systems. Results indicated the importance of understanding the influence of clogging on system design to optimize residence times and treatment of wastewater. Heatwole and McCray (2007) applied HDYRUS1D to estimations of nitrogen contamination flux from a proposed housing development in Weld County, Colorado. The modeling used some site-specific data, and statistically-based N-transformation rate parameters to simulate nitrate impacts to the groundwater below. The model was highly sensitive to nitrogen mass-flux input and the denitrification rate coefficient. The latter sensitivity is important, because published denitrification rates are highly variable and therefore the estimates can potentially have a high degree of uncertainty. In contrast, nitrogen mass flux inputs to the subsurface are less uncertain. The WARMF watershed flow and transport model, which is described in detail in a following section, contains an algorithm that simulates the treatment processes in the biologically active soil zone (biozone) associated with OSTDS. As described by Weintraub et al. (2004), this algorithm captures the effects of the accumulating biomass on the porosity of the soil and the possible hydraulic failure of the OSTDS. In this case, the effluent is allowed to infilitrate in areas that are not active biozones or as surface runoff. MacQuarrie and Sudicky (2001) developed a numerical approach to simulating OSTDS-generated nitrogen transport using coupled equations representing flow, solute transport and chemical and biological reactions. The researchers describe the model development and provide an

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example simulation to test model performance. However, no comparison with field data is provided.

In contrast to the physically-based models, a stochastic modeling approach was developed by Jury (1982) for one- or two-dimensional transport of solutes through the vadose zone. The transfer function model (TFM) considers that the spatial distribution of the physical, chemical and biological transport mechanisms are not well known especially when considering a heterogeneous media such as the soil column. Therefore, the model simulation is independent of site-measured characteristics and the behavior of a solute entering the soil matrix is based on probabilistic functions rather than physical functions; in other words, the model produces outputs based on the probability that a solute will reach a defined depth in the soil column. This is done using the probability density function (PDF), a mathematical operator that can estimate solute concentrations at a given depth based on the average and variance values of either travel time or input water flux at the surface. As a result, the model can consider uniform spatial distribution of input water flux or spatially variable inputs. Models in this category, while using agricultural problems as examples, could potentially have simulation capabilities for a variety of sources.

Studies by White (1987) and White et al. (1998) used applications of the TFM at the field scale to address the problem of nitrogen leaching in pasture lands in New Zealand. The first study developed a probability distribution for solute transport times from observed data related to numerous rainfall events and soil moisture conditions. The transfer function was then calibrated against measured quantities of nitrate leached. The TFM was capable of representing the measured data with reasonable accuracy. The researchers suggest that predictive simulations using a TFM are possible using a time and space-averaged value for solute travel times. However, this would require numerous additional studies to characterize a variety of soil types. The second study is similar, using a TFM to simulate nitrate leaching in a soil near Palmerston North, New Zealand. Results are generally good; however, there is a consistent tendency of the TFM to over-estimate the nitrate leaching in this case.

A number of studies compared modeled solute transport through the vadose zone using the TFM and an analytical solution of the ADE. Jury and Sposito (1985) used data collected from soil core and soil solution samplers to calibrate and validate results using both modeling methods. Based on the data collected, model parameters were optimized. In the case of the ADE analytical solution, the parameters were pore-water velocity (V) and a field-scale dispersion coefficient (D). For the TFM, the parameters were mean and variance of travel time through the media. Parameters were estimated using three methods: a sum of squares method, a method of moments, and maximum likelihood esti-

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mation. The parameter estimations for the solution sampler data had relatively high uncertainties, owing to the deviations between the shape of the average data curve and the model estimates of the curve, and the small number of replicate measurements. Therefore, a comparison of performance could not be done. For the soil core samples, the TFM was determined to have provided a better representation of the data.

Dyson and White (1987) conducted a similar study comparing the two modeling approaches for the transport of chloride through a structured clay soil. Also considering soil cores, the researchers found that the TFM model, using an assumption of a log-normal distribution of travel times (characterized by the mean and the variance), could model the flux-averaged breakthrough curves well. Also, the ADE could model the breakthrough curves equally well when the velocity and dispersion parameters were optimized via the least squares method.

2.3 Saturated Zone Flow and Transport Models

Due to the scope of the problem related to the protection of groundwater, the modeling of fate and transport of contaminants in aquifers has been a significant objective for research. A relatively large body of numerical, analytical and mass-balance models has been developed to study the movement of solutes in the saturated zone. Additional effort aims to provide accurate simulation of solute reactions and adsorption. Among many studies that develop general solutions of flow and transport, numerous models have been focused on the behavior of nitrogen (specifically nitrate) in the saturated zone. These can be either site-specific or more broadly-focused nitrate transport models that can potentially be applied to any site or problem.

Among the aquifer models, the simplest form of simulating solute fate and transport is the mass-balance model. This type of model ignores aquifer parameters that influence groundwater direction and velocities and transformative processes. The objective is to simply balance source and groundwater inputs and outputs (usually expressed as fluxes or rates) based on observed data. Typically, these models have numerous simplifying assumptions.

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A simple mass-balance equation was developed and then compared the model-predicted results to field data for three communities in California (Hantzche and Finnemore 1992):

$$n_r = \frac{In_w(1-d) + Rn_b}{(I+R)} \qquad \text{(equation 4)}$$

where: n_r = net nitrate concentration in recharge groundwater, I = volume rate of waste water entering the soil averaged over the gross developed area (inches yr^{-1}), n_w is the total nitrogen concentration of wastewater (mg L^{-1}), d = the fraction of nitrate-nitrogen loss due to denitrification in the soil, R = average recharge rate of rainfall (inches yr^{-1}), and n_b = background nitrate-nitrogen concentration of the rainfall (mg L^{-1}).

Results were plotted as mean nitrogen-nitrate concentration versus wastewater recharge relative to rainfall recharge (I/R) and include comparison to field data values from the different sites in the study (Figure 2-2). In general, model-predicted results compared favorably with the concentrations measured in the field. The authors note that the model has the following limitations:

- The equation considers only vertical components of groundwater recharge, and does not consider fluxes from upgradient areas.
- The predicted concentrations are long-term values, as loading rates may take many years to develop and may be affected by the nature and thickness of the vadose zone.
- Results cannot be applied to a single point, as in considering a specific water supply well.
- This method does not account for other sources of nitrogen, such as fertilizer or animal wastes.

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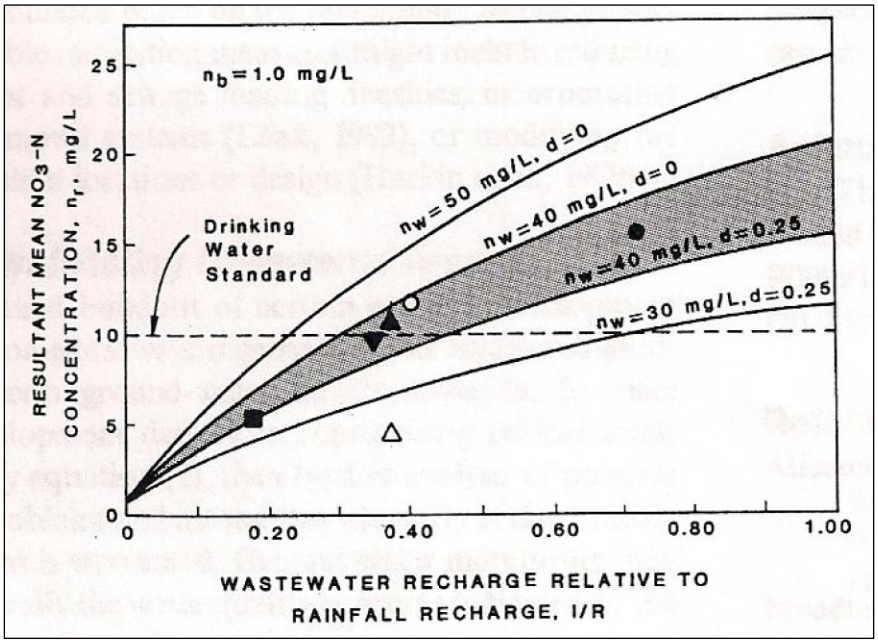

Figure 2-2: Results of Modeling with Comparison to Field Data (Hantzche and Finnemore 1992)

DeSimone and Howes (1998) used a mass-balance solution to estimate fate and transport rate values based on observed field data. The source of nitrogen in this study was a waste treatment facility in Cape Cod, Massachusetts. The objective of the research was to use a mass-balance method to identify the key hydrogeochemical processes, estimate rate values for these processes, and ultimately estimate potential mass flux into nearby surface water bodies.

Calculated wastewater input fluxes from the treatment facility, waste loads to the aquifer, and the observed concentrations at downgradient sampling points were considered and input into the mass-balance equation. Based on the observed data, values for advective and transformative processes were estimated. The researchers determined that within the unsaturated zone, nitrification and ammonification processes were the most important to nitrogen transport, whereas in the saturated zone denitrification and sorption of ammonium had the most influence. They concluded, based on the estimated fate and transport processes, that approximately 75% of the input waste load could potentially reach the nearby surface water body.

Mass-balance models are often utilized as land-planning tools. The objective in most cases is to estimate the optimal lot size or housing density to minimize the impacts from OSTDS. A few examples are summarized below.

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The National Homebuilders Association developed a computer program described by Meyer (1999) and it's applicability to land-use planning in Florida communities. This program is a nitrate mass-balance model that can be utilized to address two problems: 1) estimates of nitrogen concentration in recharge waters given certain assumptions regarding housing density, and 2) estimates of optimal housing density based on nitrogen concentration in recharge waters. The second option can be used to calculate the housing density so that the drinking water standard for nitrate (10 mg/L) is not violated. As with other mass-balance models, this model uses a number of simplifying assumptions. Data inputs are various, including average precipitation, number of persons per household, and nitrogen source distributions. Several proposed developments in various locations in Florida are tested in the model to determine if the development as planned would exceed the standard, and what the optimal housing density should be for these developments. The model predicts that virtually all the developments would violate the standard as they are proposed, and that the ideal housing density is lower than the proposed density. The researcher indicates that a number of questions concerning the model applicability to Florida's unique hydrogeology exist. The author also suggests that the values generated may be overly conservative, given the high precipitation rates and aquifer permeability that can aid dilution

Rogers, Golden and Halpern (1988) developed a groundwater-dilution model based on mass-balance inputs for the State of New Jersey. The ultimate goal of the model was to assess optimal numbers of households and lot sizes in new developments using septic systems to minimize the impact of nitrate groundwater contamination on surface waters. In this case, the model considers dilution of nitrate contamination by recharge fluxes alone as a way to reduce the waste mass flux into the aquifer, and does not consider upgradient groundwater inputs or transformative processes in the soil or the aquifer.

A very simple modeling approach ultimately defines carrying capacity as acres required per household to optimize nitrate dilution from precipitation recharge so as not to exceed the groundwater protection standards. The equation, from an earlier study by Trela and Douglas (1978) is as follows:

$$H = \frac{V_e C_e}{(V_i + C_i) C_q} \qquad \text{(equation 5)}$$

Where: H= carrying capacity; V_e= Volume of septic effluent entering system; C_e= Nitrate concentration in septic effluent; V_i= Volume of infiltrating precipitation; C_i= Nitrate concentration in precipitation; and C_q= Water quality standard for nitrate.

Two example runs considering varying target nitrate concentrations are provided, but not verified with field data.

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A similar dilution-based mass-balance model for land use planning was developed for Pennsylvania (Taylor 2003). Through a mass-balance equation, the model is intended to estimate appropriate lot sizes to allow for adequate dilution of the input nitrogen to minimize the impacts of a septic system:

$$V_s C_s + V_r C_f + V_g C_g = (V_s + V_r + V_g) C_o + (V_s + V_r + V_g) C_d \qquad \text{(equation 6)}$$

Where V_s = volume of septic tank effluent (gpd), C_s = Concentration of nitrate in septic tank effluent (mg/L), V_r = Volume of groundwater recharge/infiltration (gpd), C_f = nitrate concentration in fertilizer that reaches the groundwater (mg/L), V_g = Volume of upgradient recharge water (gpd), C_g = nitrate concentration in upgradient groundwater (mg/L), C_o = nitrate concentration of groundwater leaving the site (mg/L), and C_d = concentration of nitrate lost due to denitrification.

In order to arrive at these terms, this mass-balance approach utilizes a number of site parameters including hydraulic conductivity, gradient, average recharge rate due to precipitation, and mass of fertilizer applied as examples. These parameters are then used in empirical relationships to define the needed inputs for the mass-balance equation. Unlike the model developed for the state of New Jersey, this model does consider upgradient groundwater flux. The model conceptualization is shown in Figure 2-3.

This model, as with the other mass-balance models, has several simplifying assumptions, such as: complete mixing of wastewater and recharge water within a specified aquifer thickness; complete conversion of nitrogen to nitrate; and neglecting most chemical transport and reactive processes including diffusion, dispersion, adsorption, and denitrification. The author provides an example use of the model to calculate the optimal lot size for a hypothetical development in Pennsylvania and makes land-use recommendations based on the results. However, as with the previously described model, the model-predicted results are not verified with field data.

While examination of available research indicated mass-balance models are often used for land planning tools, some researchers have utilized them for nitrate source identification or as a predictive tool. Tinker (1991) compared the results from three mass-balance models, along with other investigative tools, to help identify possible sources of nitrate impacts on wells in Wisconsin. Tinker used a mass-balance model developed by Wehrmann (1984), the BURBS model and a combination of the two models to determine if the nitrate in the groundwater was primarily from fertilizer applications or wastewater treatment.

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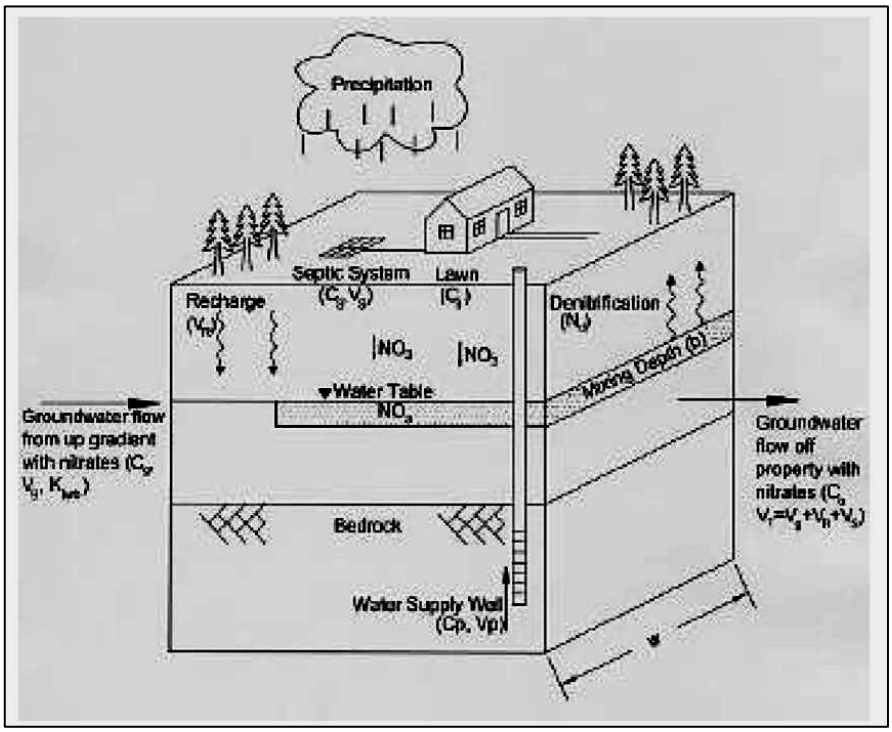

Figure 2-3: Conceptual Model for Mass-Balance Approach (Taylor, 2003)

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nitrate in the groundwater was primarily from fertilizer applications or wastewater treatment.

The Wehrmann mass-balance model uses estimates of water volumes and nitrate concentrations to evaluate the diluted nitrate leaving the area of the subdivision in question. In this case, the model considers upgradient groundwater and also pumped water volumes. The primary source for this model is septic effluent:

$$V_b C_b + V_i C_i + V_s C_s - V_p C_p = (V_b + V_i + V_s - V_p) C_o \qquad \text{(equation 7)}$$

Where V_b = Volume of upgradient groundwater, C_b = Nitrate concentration in upgradient groundwater, V_i = Volume of precipitation infiltration, C_i = Nitrate concentration in the infiltration, V_s = Volume of septic effluent introduced beneath subdivision, C_s = Nitrate concentration in the septic effluent, C_p = Nitrate concentration in the pumped groundwater and C_o = Diluted nitrate concentration leaving the subdivision. The BURBS model is similar, but also considers contributions from turf, impervious land, and natural land. A bulk nitrogen-nitrate concentration (C_{BURBS}) is used in the water contribution from these three sources. The combined mass-balance expression is as follows:

$$V_b C_b + (V_t + V_i + V_n + V_s - V_p) C_{BURBS} = (V_b + V_t + V_i + V_n + V_s - V_p) C_o \qquad \text{(equation 8)}$$

With terms defined as above and also V_t = Volume of recharge water from turf, V_i = Volume of water recharged from impervious land and V_n = Volume of water recharged from natural lands.

The author predicted that a majority of the nitrate in the groundwater could be accounted for by OSTDS and fertilizer applications, and the mass-balance modeling agreed with that prediction, based on sampling results from residential wells.

Frimpter et al. (1990) developed a simple mass balance equation to predict the potential nitrate impacts to municipal supply wells based on loading rates from natural and anthropogenic sources. The model can consider individual sources and therefore is a potential tool for determining septic tank density in new developments. Assumptions of the model are steady-state conditions, complete mixing, and modeling nitrate as a conservative solute. The author provides example calculations in which nitrate concentrations are predicted based on source density and flow rates of withdrawing municipal supply wells.

Beyond mass-balance models, a variety of approximations of the ADE or similar governing equations that apply to nitrates were found in the literature. Methods of simulation were variable, from simple analytical solutions to complex numerical codes.

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Lerner and Papatolios (1993) developed a unique, simple analytical expression for predicting nitrate concentrations in pumped groundwater:

$$C_t = C_o + (C - C_o)\left[1 - \exp\left(-\frac{Rt}{bn}\right)\right] \qquad \text{(equation 9)}$$

Where C_t = Time variant pumped concentration, C_o = Initial groundwater nitrate concentration, C = Concentration of nitrate in groundwater in area of influence of the pumping well, R = Recharge rate, b = Aquifer thickness, t = Time, and n = Porosity.

This expression considers nitrate in the saturated zone with source inputs mostly originating from recharge waters. C_o is arrived at by estimating leaching rates of nitrate through the vadose zone. The model considers only nitrate in groundwater as an initial concentration and does not consider source input rates or flux. The model was applied to a pumping station in England, and predictive calculations were performed. In the two years following the model simulations, field data was collected and then compared to the simulations to verify if the model predictions agreed with the actual observed nitrate concentrations. The model predicted future nitrate concentrations with reasonable accuracy. Also, a sensitivity analysis was done to determine sensitive parameters in terms of conservative solute transport for this system (in this case, porosity, aquifer thickness and estimated leaching rates from the vadose zone that determine C_o).

Young et al. (1976) also develop an analytical approach to predicting future nitrate concentrations in groundwater in a fractured sandstone aquifer in England. The investigators used an unsaturated zone flow model to forward model nitrate impacts to groundwater based on current land use practices. However, the exact analytical approach is not described, except to describe important parameters and processes.

MODFLOW and MODPATH are two commonly used numerical modeling codes that have been widely utilized by both academic and industry hydrogeologists. MODFLOW is a three dimensional, finite difference modeling codes that has a wide variety of capabilities for modeling multiple layers of an aquifer system and heterogeneous parametric distributions. The model code is often employed with a graphical pre- and post-processor to assist with the construction of the input files. MODPATH is an extension of MODFLOW that utilizes model-calculated groundwater velocities and flow vectors to give particle tracking of groundwater movement. The tracking of the groundwater movement can be time-stepped to give estimates of travel time.

Puckett and Lowdery (2002) constructed a MODFLOW groundwater flow and transport model and used it in conjunction with sample analyses and water-aging to determine the relationship between agricultural practices and nitrate concentrations in groundwater in a

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glacial outwash aquifer in Minnesota. The model was constructed as a three layer model with assigned boundary conditions based on the conceptual understanding of the hydrogeologic system. The model was calibrated against observed water levels at monitoring wells in the study area, and MODPATH was used to compute groundwater travel times and flow paths. The modeling was used to indicate expected groundwater travel times and correlated with the groundwater aging aspect of the study, and showed generally good agreement between the two methodologies. Although no transport modeling was done, an extension of MODFLOW, MT3DS is a full transport modeling code and can consider adsorption and chemical processes in numerous ways. This could be a potential extension of the study to further validate the conceptual understanding of the groundwater system.

A study by Molenat and Gascuel-Odeux (2002) provides an example of nitrate modeling using a combination of MODFLOW and MT3DS. In this study, these model codes were coupled to simulate different spatial distribution scenarios of nitrate inputs from agricultural practices in the Kervidy watershed in Brittany, France. The initial simulation of groundwater flow and nitrate distribution was done as a steady-state simulation, and simulation results matched field observations well. Two scenarios reduced the uniform spatial distribution of nitrate recharge from the initial 100 mg/L to 80 mg/L and 60 mg/L, respectively. The other four scenarios redistributed the nitrate recharge to the watershed hillsides, but retained the initial rate of 100 mg/L. The results of the scenarios indicate that the impacts to groundwater could be reduced by reducing the nitrate inputs on the hillsides more than reducing nitrate inputs over the entire watershed.

A simple distributed transport model was developed to simulate and predict ground water nitrate concentrations. Based on a numerical code developed by Bear (1979), a study was completed for the Great Ouse Chalk aquifer in England by Carey and Lloyd (1985). The chalk is a fine-grained fractured limestone aquifer that has seen increasing impacts from nitrate pollution. For the modeling, a groundwater flow and transport model was constructed using numerous computation cells representing small volumes of the aquifer with the nitrate concentrations into and out of the model cells calculated using a mass-balance approach. The model assumed that the concentration of nitrate in groundwater recharge was constant, but that the rate of recharge varied. Nitrate sources in this case were natural land, plowed land, and nitrogen inputs that resulted from fertilizer applications. The downward migration of nitrate is solved via a simple equation that calculates a velocity based on porosity and recharge. The model was calibrated using observed groundwater and nitrate concentration data, and a sensitivity analysis was performed to assess the effects of various parameters. The model was able to simulate past trends of groundwater behavior and nitrate concentration reasonably well. Further, the model pre-

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dicted an increasing trend in nitrate concentrations, but the severity of the increase was dependent on changes in land practices.

Hendry et al. (1983) apply this methodology to the problem of nitrate transport in an aquifer in England with impacts resulting from agricultural practices. The researchers apply a numerical model among other investigative techniques to test two hypotheses of nitrate fate and transport; 1) that the resulting concentrations observed are a result of mixing with upgradient groundwater, and 2) that the vertical concentration distributions are due to denitrification processes. Based on the modeling and other investigations, they conclude that the denitrification processes are dominant.

2.4 Combined Vadose Zone and Saturated Zone Models

The research that examines the combined fate and transport of nitrogen species in both the vadose and saturated zones is limited. However, some models have been developed either on the watershed or field scale that does in fact couple the two zones for simulations of contaminant transport. Among these are several models that could effectively simulate nitrogen transport.

Mehran et al. (1983-1984) developed a two-dimensional numerical solution for the fate and transport of soluble nitrogen species in both the vadose and saturated zones. This model resulted in two separate codes that simulate the vadose zone and saturated zone simultaneously. The vadose zone is represented by the finite-difference code UCD-RANN and the saturated zone by the finite-element code FLOWS.

The model considers numerous parameters for both flow zones including all relevant flow parameters indicated in Darcy's Law (i.e., hydraulic conductivity, gradient, porosity), and transport and transformative parameters in both the vadose zone and saturated zone. Among others, these parameters include saturation index, pressure head, and root zone uptake of nitrates as well as first-order rate constants for nitrification and denitrification, and the retardation factor for ammonium transport in the vadose zone. The retardation factor is defined by:

$$R = 1 + \left(\rho_b / n \right) \left(K_d \right) \qquad \text{(equation 10)}$$

Where R = retardation factor, ρ_b = bulk density of the soil, n = effective porosity, and K_d = soil distribution coefficient.

The model, shown conceptually in Figure 2-4, also provides equations for boundary conditions that are necessary to define the model dimensions.

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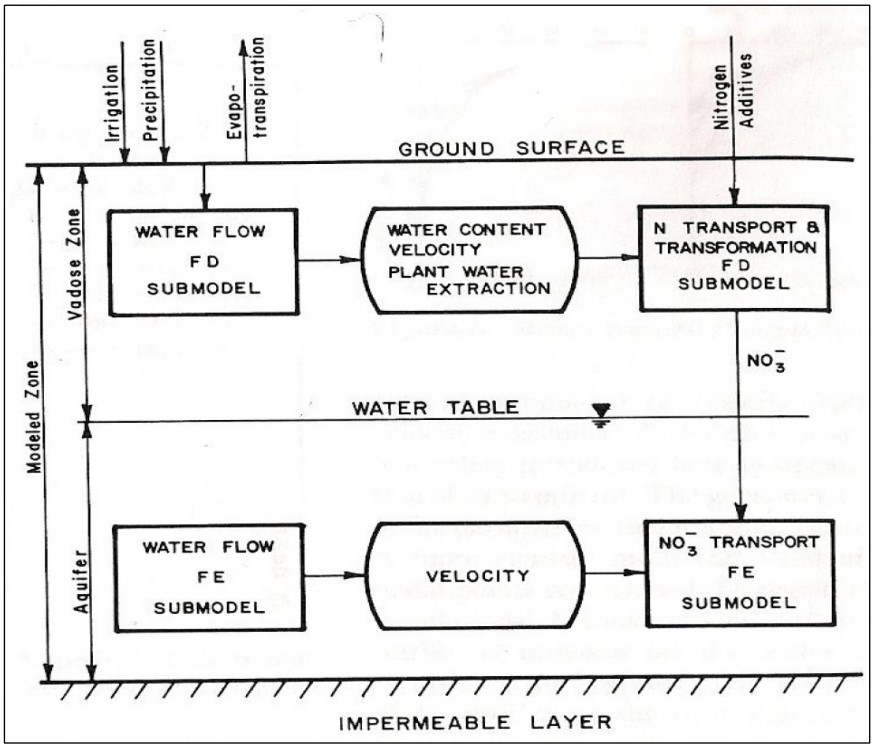

Figure 2-4: Conceptual Schematic of the Model (Mehran et al. 1983-1984)

The outputs of the model include nitrate concentrations at various depths through time for the vadose zone and time-variable depth and distance nitrate concentrations in the aquifer. The researchers provide a model demonstration on a hypothetical aquifer system, shown in Figure 2-5. The model as illustrated consists of a one meter thick vadose zone with a ten meter thick underlying aquifer. The simulation process starts with a model run in the vadose zone with results shown in Figure 2-6. The second step imposes the concentration that results at the bottom of the vadose zone as a constant concentration on the top of the model aquifer. However, it is probable that a varying rate of concentration input can be applied using this code. An example output for the vadose zone simulation is shown in Figure 2-6.

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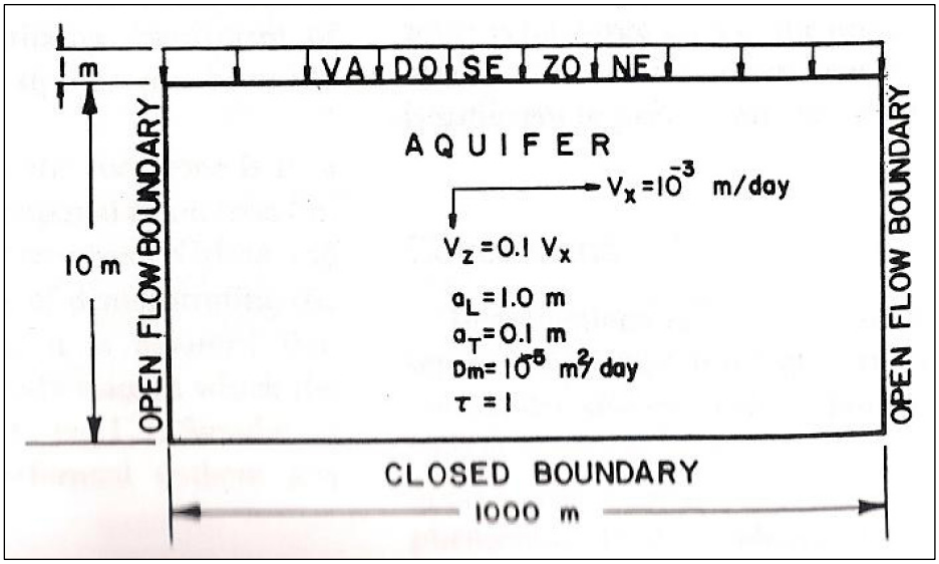

Figure 2-5: Hypothetical Aquifer for Model Example Simulation (Mehran et al. 1983-1984)

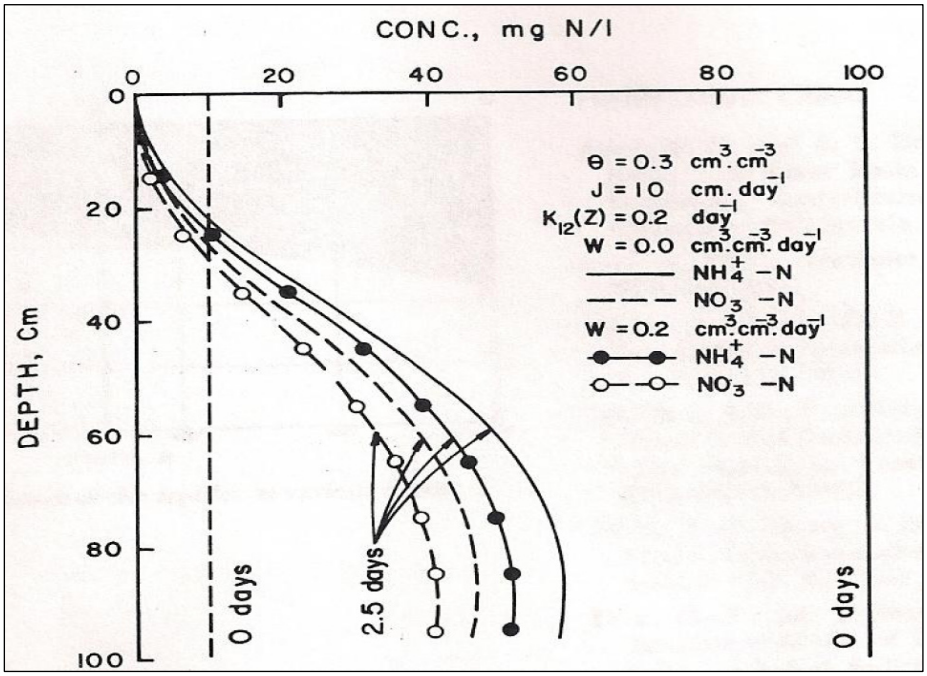

Figure 2-6: Example Depth Profile Output for Vadose Zone (Mehran et al. 1983-1984)

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2.5 Nitrate Modeling at the Watershed Scale

Numerical modeling codes also have been applied to the watershed scale for the simulation of groundwater flow and nitrate leaching in the unsaturated zone and the resulting impacts to surface water bodies. These models represent perhaps the most complex of the models reviewed, requiring large input data sets and complex numerical codes for the simulations. Sonnenburg et al. (2003) and Refsgaard et al. (1999) present modeling of watersheds in Denmark using large scale models. The researchers utilize the code MIKE SHE, which uses numerical solutions for overland 2-D and channel 1-D flow, 1-D unsaturated flow, and 3-D saturated flow. The conceptual model is illustrated in Figure 2-7.

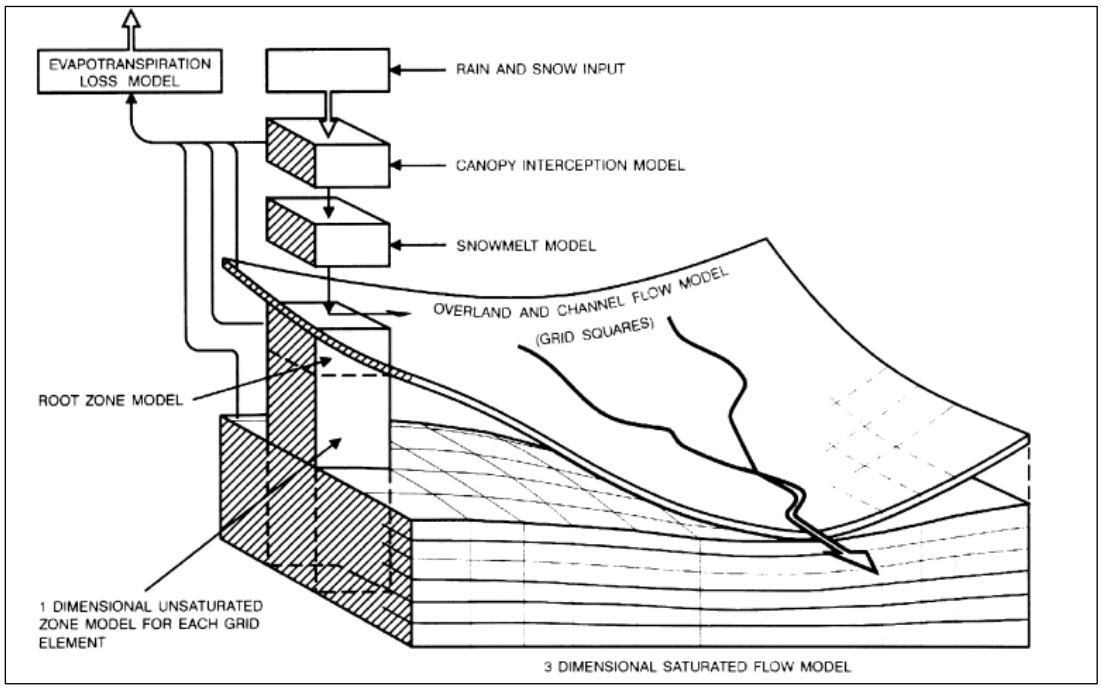

Figure 2-7: Conceptual Schematic of MIKE SHE Model (Refsgaard, 1999)

Refsgaard et. al. conceptualized and constructed groundwater flow and transport models to consider nitrate impacts on two watersheds in Denmark. The intention of the study was to show that such a model could be shown to be a reliable tool for specific watersheds, and that reasonable model performance at such a scale was possible. This model was a coupled model using the MIKE SHE code described above and the Daisy code (see Hanson et al (1991)), which simulates the percolation of water and nitrate at the bottom of the vadose zone. Input, verification, and calibration data for the model were found in GIS-linked databases which provided data for agricultural practices, topogra-

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phy, groundwater data, stream-flow and climatic variables. Representative model grids were constructed using topography and catchment delineation data from the databases. The researchers use an up-scaling method to transfer some field-scale data to the catchment scale. Model parameters were assessed using various transfer functions, and the results of the simulation were validated by comparing model simulated results to observed results for annual water balance, river run-off, and groundwater nitrate concentrations.

Simulations were done for the Karup and Odense watersheds and validation of the model based on watershed-specific water balances over a five-year period and groundwater nitrate concentrations over the same period was also performed. Validation results for the Karup watershed were extremely good, and the simulations of the Odense watershed were acceptable although not at the same level as the simulations for the Karup watershed. The results indicate that similar models can be useful tools for assessing nitrate contamination at such a scale for other watersheds, provided access to adequate databases is available.

Conan et al. (2003) used MODFLOW and MT3DMS coupled with the watershed modeling code SWAT (Soil and Water Assessment Tool) to simulate nitrogen fate in a watershed in Brittany, France that has been impacted by livestock practices. The model considers the full range of transformative processes for nitrogen species, such as ammonification, nitrification, and denitrification. Hydraulically, the combined models simulate groundwater flow, nitrogen transport, and surface water flows and concentrations. Model structure is constructed using digital elevation models and used field data sets for stream flow, groundwater levels and nitrogen concentration over a three-year period. Data collected was used for initial input parameters and calibration of the model. Results were generally good, with some exceptions. The stream flow simulations consistently overestimated flows in June and underestimated flows in December. Simulations done with the SWAT model alone consistently underestimated nitrogen levels in the surface waters, but the coupled model performed much better, perhaps due to being able to account for the stream baseflow. Groundwater concentrations were also well simulated by the coupled model.

Heng and Nikoladis (1998) developed a highly complex, multidimensional watershed scale model for the transport and transformation of nitrogen from non-point sources. The model (NTT-watershed) generates a grid system based on topography and subsurface properties can also be vertically discretized to represent vegetation, overland flow, and the groundwater zones. Flow and solute inputs into the model are temporally and spatially variable and can consider transport and transformation of organic nitrogen, ammonium, and nitrate. For this study, the model was applied to the Muddy Brook watershed

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in Connecticut. Input, calibration, and validation data was collected over a two-year period and included nitrogen species concentrations, field parameters, stream-flow values, precipitation rates, and land use practices and applications (i.e. fertilizer use). Simulations were performed and the model matched groundwater, stream-flow, and concentration data reasonably well. Results indicate that future models for other watersheds can be developed in a similar manner to assist with management planning.

Weintraub et al. (2004) used the GIS-based watershed modeling tool WARMF for investigating watershed-scale impacts from OSTDS in Summit County, Colorado. WARMF is a modeling tool that estimates total maximum daily loads (TMDL) based on a series of modules with various inputs. The model was constructed using a Digital Elevation Model (DEM) of the Blue River Watershed and included input data for regional meteorology, point sources, and land use. Additional data was collected in the field for surface water quality, soil properties, well data and spatial distribution of OSTDS. The model was enhanced by including a biozone module that simulated the transformative processes in the soil column beneath the OSTDS. After constructing the model, simulations were performed representing a period from fall 1998 through fall 2002. Model simulations were compared to observed data, and a calibration was done to adjust the input parameters to improve the fit to observed hydraulic and concentration data. The calibrated model was then used to assess various management scenarios including converting housing subdivision from OSTDS to a centralized sewer system. The results for nitrogen indicate that although nonpoint loading is reduced, the loading to the river increases due to the increased nitrogen loading from the treatment plant. This suggests that conversion to a sewer system would require a higher level of nitrogen treatment at the plant.

Geza and McCray (2007) also applied the WARMF model to assess the influence of various point and non-point sources including OSTDS in the Turkey Creek watershed in Colorado. As with the previous study, a DEM was used to build the model that included land cover and soil type data. Data was also input regarding population, wastewater loading per person, and effluent concentration. Stream flow and water quality data from a previous study was used and a simulation period of five years (1998-2003) was used as a calibration run. Calibration was done using UCODE, an automatic calibration tool and a sensitivity analysis was also done. The analysis showed that groundwater concentrations for nitrate were most sensitive to soil parameters, land cover parameters, and input concentrations of ammonium. However, the model was not sensitive to denitrification rates. Stream concentrations were most sensitive to sediment transport parameters.

Once a calibrated model was completed, four management scenarios related to OSTDS were performed. Stream concentrations of nitrate were shown to be highest when the stream segment was located close to an area with a high density of OSTDS as com-

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pared to locations downstream, an effect likely due to dilution. Soil water concentrations increased with increasing population, but decreased when OSTDS were converted to sewer systems.

2.6 General Fate and Transport Modeling

Numerical or analytical codes for modeling groundwater flow and solute transport have had numerous applications. The use of a particular method, solution, or transport parameter depends largely on the contaminant of interest, the objectives of the modeling, and in some cases site-specific characteristics. For the most part, models in this category are limited to the saturated zone. Within the summary below, several models have been identified that do not model nitrate fate and transport specifically. However, because the codes can consider the important fate and transport processes, they can be useful in developing a model to simulate nitrate in the subsurface. Among the codes identified, 13 analytical solutions to the ADE were found in the literature. These solutions consider different methods, spatial and temporal simulations, and different transport parameters such as retardation, decay, or dispersion. Analytical solutions are appealing in that they can be programmed into a spreadsheet relatively easily, and can therefore be part of a user-friendly modeling tool. Four such spreadsheet programmed solutions are discussed below.

The governing equation in most cases is a variation of the ADE with either chemical (production of solute or degradation) or physical reaction (sorption) or both. An example featuring one-dimensional advection-dispersion with retardation and first-order degradation is shown from Elmore (2007):

$$R\left(\frac{\delta}{\delta t}C\right) = -v_x\left(\frac{\delta}{\delta x}C\right) + D_x\frac{\delta^2}{\delta x^2}C - kRC \qquad \text{(equation 11)}$$

Where R= retardation factor; C = solute concentration; t = time; v_x = average pore water velocity; x = distance from source; D_x = dispersion coefficient; and k = first-order degradation constant.

Virtually all the analytical solutions considered either first-order reaction, equilibrium linear reversible sorption, or a combination of both. Leij et al. (1993) provide expressions for the partitioning of the solute in the mobile and immobile phases. For degradation, the majority of solutions use a first-order degradation rate constant for the solute. Sun et al. (1999) develop a three-dimensional reactive model for the saturated zone via an analytical solution that can simulate degradation as sequential first-order reactions. Example contaminants that can be simulated with this process include tetrachloroethylene (PCE) and its degradation daughter products and the denitrification process from nitrate to nitrite to ammonia to nitrogen gas. A unique three-dimensional code for the simulation of a

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reactive solute in a variably saturated porous media was developed by Srivasta and Yeh (1992). Equations are based on the Richards' equation for flow in variably saturated media and the conventional ADE. This model also considers adsorption via a mobile-immobile partitioning condition and employs the use of a first-order decay function. The solutions are performed using a Galerkian finite element method and a Picard iterative process.

A number of solutions simulate transport considering different source orientations. This may be an important consideration for nitrate contamination from OSTDS, as the impacts to groundwater may be from multiple sources that are not necessarily point sources. Carslaw and Jaeger (1959) derived solutions to the three-dimensional advection-dispersion equation utilizing Green's functions, which were extended to develop an aquifer transport model for a contaminant from a horizontal plane source at the top of the water table (HPS)(Galva 1987). This results in estimates of contaminant transport that are more accurate than simulations using a point source when considering a groundwater contaminant source that may be distributed over a relatively large planar area, such as a source associated with a landfill or a development utilizing OSTDS.

Galva provides the mathematical background to the development of the HPS model, and provides example numerical simulations using a FORTRAN code to illustrate the applicability of the model. Simulation one uses various retardation rates, zero decay, and a continuous source rate. Simulation two varies the retardation rate and the period of source emissions. Finally, simulation three considers constant source input rates with variations in retardation and decay coefficient. Results for the second simulation are shown in Figure 2-8. Results are presented as predicted solute concentrations at a specified point (200 meters down-gradient) through time.

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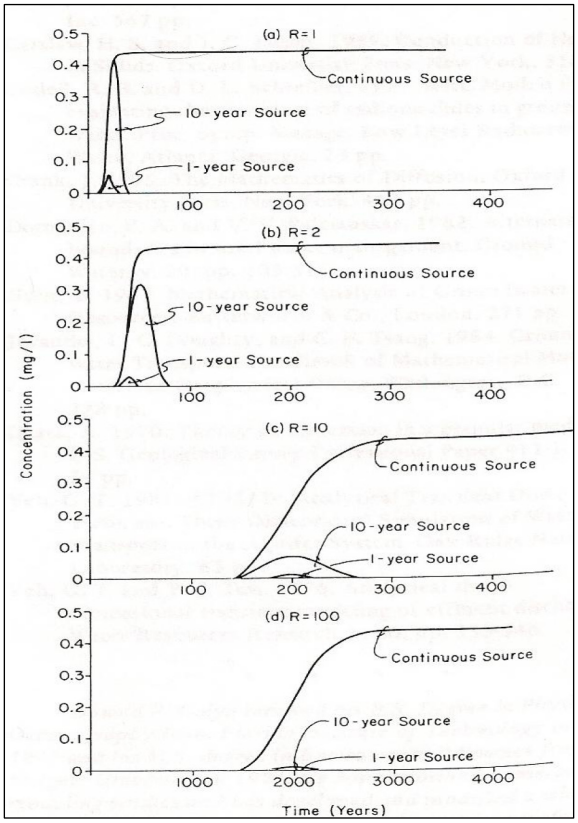

Figure 2-8: Model Output for HPS Model, Simulation Two (Galya 1987)

The model simulations indicate the sensitivity of the varied parameters such as decay factor, retardation factor and the temporal period of source emission. The authors also point out that while this model is useful for quick estimates, the simplifying assumptions required for the analytical solution make it impractical for hydrogeologically complex systems.

Heatwole and McCray (2006) applied the HPS to the problem of wastewaters derived from OSTDS. The research demonstrates that the HPS model has the appropriate parameters and model structure to accurately simulate fate and transport of nutrients from OSTDS, including nitrogen, phosphorus, and fecal coliform. Using an analytical solution of the HPS model in a FORTRAN code, simulations of an example nitrate plume resulting from an OSTDS are run using baseline parameter inputs. Additionally, a sensitivity analysis of input parameters was included. Groundwater velocity is indicated as the most sensitive parameter, and is therefore indicated as an important factor when trying to es-

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timate potential groundwater impacts. The HPS model is identified as a potentially useful tool for simple simulations in support of regulatory compliance and OSTDS planning.

Similarly, Domenico (1987) provided an three-dimensional analytical solution that allows the user to input source dimensions in the x, y, and z directions creating a vertical plane source in contrast to the horizontal plane source described above. A further development of this source orientation was presented in Ollila (1996) for estimating natural attenuation of groundwater contaminants. Superposition of the rectangular source orientations developed by Domenico can provide for simulation of concentration profiles and asymmetric concentration cross sections.

More complex source orientations are proposed by Leij et al. (1991). In the development of this analytical solution, solutions are provided for representing rectangular, circular, cylindrical, and parallelepipedal source regions (Figure 2-9).

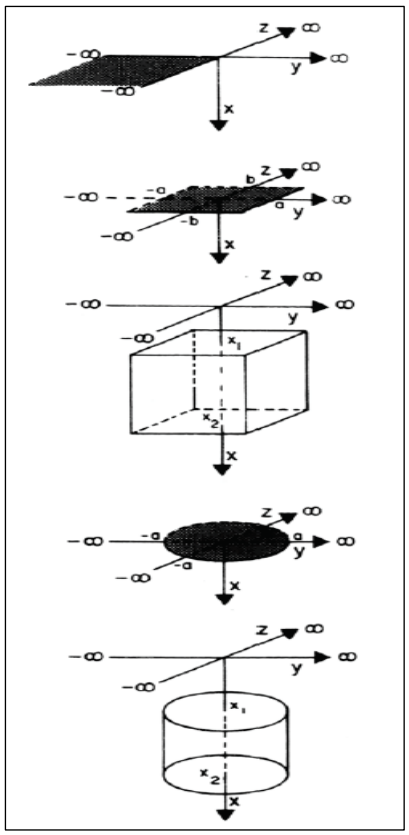

Figure 2-9: Source Orientations (Leij et al. 1991)

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Some researchers utilized novel approaches to the solution of the contaminant transport problem using analytical solutions. Hwang et al. (1985) incorporate a local analytical solution in a numerical model framework. By developing an analytical element at a node in the framework, a relationship with that node and its neighboring nodes is developed via a mathematical relationship. However, such an approach may require large amounts of computing power for more complex problems. Tang and Aral (1992) provide a solution for a layered aquifer that includes the main aquifer body and surrounding aquitards. Different values for degradation and retardation and other parameters are input for the aquifer and aquitards. This approach can therefore simulate different flow regimes in the same system and also can simulate the effects of diffusion into and out of aquitards.

Among the analytical solution models, some researchers created spreadsheet solutions to the ADE that can potentially be useful, simple tools for simulating nitrogen transport in the subsurface. These studies include Ollila (1996), Elmore (2007), Karahan (2006), and Karahan and Ayvaz (2005). While the equations themselves are typical solutions to the partial differential equation of the ADE, the use of a spreadsheet can be a very efficient method of calculating the solutions. Spreadsheets have the advantage of being relatively easy to program and use, wide availability, and iterative solution capabilities.

2.7 Parameter Estimation

Determining appropriate input parameters and the process of parameter estimation for fitting a groundwater model to observed data are an important yet difficult process. Parameter values can never be completely accurate, due to natural variations or incomplete data sets. Uncertainty related to input and calibration parameters leads to uncertainty in outputs. As such, some research has been performed specifically regarding parameter estimation. The objective of this research is to reduce the uncertainty as much as possible when estimating parameters, either as inputs to a model or through the calibration process.

A process of estimating parameters related to the transport of nitrogen and phosphorus from OSTDS was developed by McCray et al. (2005). Cumulative frequency distributions (CFDs) were developed from data collected in the available literature to create statistical distributions for effluent concentrations, and nitrification and denitrification rates. In cases where inadequate data was available to produce a CFD, the mean, median and standard deviation was reported. These diagrams indicate the frequency of a reported value. The 50% value is the most frequently reported, whereas the 80% value means that 80% of the reported values are less than that value. Considering this for effluent concentrations as an example, the selection of the 90 percentile value would be considered as very conservative. This may be an appropriate choice if a simulation is intended to provide a protective concentration for a drinking water well.

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The resulting CFD diagram (for an example see Figure 2-10) can be useful for selecting appropriate water quality input parameters when data is limited either for a site or in the literature. This is particularly true for nitrification and denitrification rates.

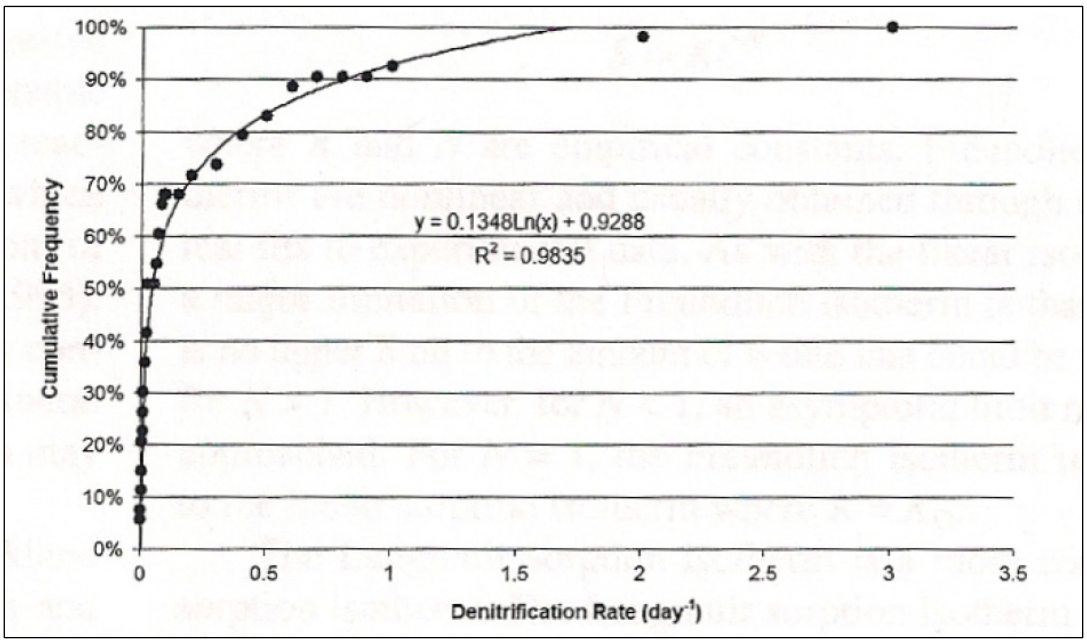

Figure 2-10: Example Cumulative Frequency Distribution (McCray et al. 2005)

Yanyong et al. (1992) describe a statistical process in the estimation of model parameters based on the observed data of the actual system. The method suggests using probability distributions of errors in the observed data to appropriately adjust parameters to reduce model residuals as much as possible. The researchers provide this as a direct method of estimating parameters, as opposed to performing a trial and error method to fit the model to the data. Therefore, the task of parameter fitting is less tedious, creates more optimal parameter sets, and has a statistical justification for the parameter values that were selected.

Regardless of the method chosen to estimate parameters, the analysis of uncertainty should also be included with any modeling effort. It is important to quantify the level of uncertainty as related to the simplifying assumptions of the model used and the quality of the data and how this influences the results.

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2.8 Nitrification and Denitrification Modeling

The simulation of the nitrification process has not received much research beyond the use of Monod kinetics, zero-order or first-order mathematical expressions and is mostly expressed as part of a larger model if the transformation of ammonium to nitrate needs to be represented. However, the simulation of denitrification has resulted in numerous approaches to the problem. This is perhaps due to the complexity of the biogeochemical processes associated with denitrification. The methodology ranges from empirically-based expressions to complex numerical codes. The review of the literature identified 20 studies related to the modeling of denitrification. Heinen (2006) provides a comprehensive summary of over 50 denitrification models, mostly simple empirical expressions. Heinen and other researchers identify numerous influencing factors such as pH, water content, dissolved oxygen, and others that may be beyond the scope of such a modeling tool. The modeling of denitrification is not discussed in great detail in this review. The research is provided for possible reference if desired.

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Section 3.0
Discussion and Analysis

The models addressed in the review represent potential approaches to the model tool being developed for this project. The models were grouped in such a manner since each zone of interest requires different parameters, inputs, and assumptions; the modeling tool being developed will likely consider simulations in the vadose and saturated zones. In addition to identifying models for the different zones, various modeling methods were also identified; mass-balance modeling, analytical modeling, numerical modeling, and transfer function modeling. Each of these has their own advantages and disadvantages.

Mass-balance models are probably the simplest of the models found in the research review. These models are largely based on estimates of mass flux or volumes, and as such do not necessarily require prior knowledge of the subsurface characteristics. These types of models can have value for predicting mass flux in a generalized sense. In fact, many researchers use mass- or flux- balance calculations to assist in estimating input rates and concentrations for transport modeling. However, these models require numerous simplifying assumptions and typically cannot be used to predict solute concentrations at specified points in time and space. Furthermore, they do not account for hydrogeochemical processes; thus, any change in mass flux that may be influenced by such characteristics is represented as a fractional loss that is assumed to be constant over time.

Analytical models are a deterministic approach that simulates systems based on relatively simple, but widely used equations of flow and transport. This approach does require prior knowledge of subsurface characteristics, but the mathematics behind the analytical solution is relatively simple and flexible. Input parameters are relatively few and can be readily adjusted. Therefore, an analytical solution can be applied to multiple sites or hypothetical sites. Furthermore, the solutions can be programmed into a spreadsheet program for ease of use. However, analytical solutions cannot simulate highly heterogeneous systems. Therefore, it is important to consider the level of spatial variability of a system and how accurately this variability must be represented.

Numerical modeling has the most applicability when considering heterogeneous systems that operate under non-steady conditions that are impractical with analytical solutions. This is usually the case when estimating flow and transport in the vadose zone. As with analytical solutions, these models are very flexible. Often, however, numerical models

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are extremely complex, require relatively large amounts of input data (when compared to analytical solutions or mass-balance models), and require the use of computational methods. Furthermore, numerical models are often site-specific and not easily extended to other sites. Nonetheless, when considering a system that is highly heterogeneous or if boundary conditions cannot be simplified to constant, steady conditions, they are extremely useful.

The final category, transfer function models, operates on the assumption that deterministic models cannot appropriately account for the spatial variation in subsurface characteristics. This modeling approach, instead of relying on broadly applied parameter values, generates a probability distribution to account for water and solute movement. The major drawback to this model type is the lack of field studies to validate them and the likely resistance from regulatory agencies to their use since they do not rely on physical site characteristics. However, it is possible to couple stochastic methods with analytical models to better assess the uncertainty associated with the results.

When considering the modeling of nitrification, little research has been devoted to this topic. Generally this process, if it is addressed at all, is usually captured using a rate expression for the transformation of ammonium and therefore this seems to be the most likely approach if it is to be simulated in the model developed for this project. In the case of denitrification, four approaches are possible. The first considers the details of the process, which may require inputs of temperature, pH, microbial population and growth dynamics, soil-moisture, and carbon availability in the modeling to capture the reduction functions that lead to denitrification. Secondly, models such as the analytical solution by Sun et al. (1999) could consider the reaction as a sequential first order process. The third approach simply identifies the process as a single first-order reduction, and therefore uses rate constants as an input parameter. Finally, recent work at Colorado School of Mines involves linking denitrification and nitrification rate constants to soil type and water content in analytical models. This provides an improvement over using only rate constants, without the need to consider all the biogeochemical processes at play. Considering the complexity of the denitrification process and the relative lack of understanding of how it works, the first approach is likely impractical. This may also be true when attempting to model denitrification as a sequential process, as the modeling would require rate constants for each step. Given the goals of the project and the level of influence of the process, the third approach may be sufficient to capture the denitrification process, while requiring the least amount of data collection. Field data and application of various models will be undertaken in this project to determine the appropriate level of complexity.

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Section 4.0
Conclusions

A review of the literature, the conceptual understanding of the transport of nitrogen as related to OSTDS, and the goals of the project are all taken into consideration when beginning to describe the tool that will be developed. From this, several conclusions and some suggestions for the modeling tool can be developed.

The literature review was intended to identify the state-of-knowledge of nitrate fate and transport modeling, identify past models that may have provide good templates for the model developed by the FOSNRS Study, and assist in identifying key parameters and processes that need to be represented in a predictive tool.

As with any model development project, the appropriate approach can depend on numerous factors. When conceptualizing a model, several key questions need to be posed, such as:

- Will this model be constructed to represent a specific site of interest or be a predictive tool with broad applicability to a variety of sites?
- What is the desired output?
- What is the most appropriate method of calculating the output?
- Will this model require calibration to existing data sets?
- What, if any, regulatory requirements constrain the model choice?

The modeling tool that is being developed to simulate nitrate fate and transport will require certain features, some of which include:

- ease-of-use;
- ability to simulate time-variable OSTDS inputs;
- simulation of transport and fate in both the vadose zone and saturated zones;

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- representation of the numerous advective-dispersive and transformative processes that affect nitrate transport;
- simulation of temporal and spatial concentrations and mass loading downgradient of the source;
- include the impacts of seasonal rainfall, groundwater table and flow direction variation on the source function; and
- incorporate critical OSTDS operating characteristics that strongly influence nitrogen reduction.

Based on the above questions and objectives, many conclusions about the models and model types in the research summary can be made. No simple model (analytical or mass-balance) identified in the literature can currently achieve all of the above-described goals. Also, numerical models are generally not considered a useful tool for system design or regulatory compliance where broad applicability is desired. Thus, development of a new modeling tool is likely required and rigorous numerical modeling may be needed as a first step to determine the most important parameters to include.

A strictly mass-balance modeling approach will likely be inappropriate, as it either does not consider the known physical processes that influence nitrate transport or makes simplifying assumptions about these processes. Furthermore, the output will not satisfy the objectives of the model (time-variable estimations of concentrations at specific spatial points). Nonetheless, these approaches have value in the conceptualization of model inputs and should not be ignored. Transfer function models have not been widely applied and will likely encounter regulatory resistance, since they are based strictly on probabilities and do not directly consider measured site characteristics. Both analytical and numerical modeling methods are the most promising approaches when considering the FOSNRS Study model to be developed. These approaches will have wide applicability, regulatory acceptance, and are capable of estimating the important hydrogeochemical properties associated with nitrate fate and transport.

The modeling tool will need to consider transport and transformation (chemical and physical) in the vadose zone, because the Nitrogen transformations that occur in this zone have considerable influence on the mass-flux input into the underlying aquifer. This can be a numerical one-dimensional solution of the Richards' Equation as suggested by (Bakhsh et al. 2004) or (Heatwole and McCray 2007) coupled with the ADE applied to the unsaturated zone as found in (Selim and Mansell 1976). A one-dimensional formulation can likely be implemented in a spreadsheet. Additionally, the modeling will need to

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consider temporally and spatially variable inputs for multiple OSTDS, as would be found in a community development. This could be addressed through a series of one-dimensional vadose zone models that could provide input to a multi-dimensional groundwater flow and transport model such as those suggested by (Ollila 1996) or (Galya 1987). Both of these studies use the horizontal plane source model or some variation and are also capable of transient simulations. However, the models likely will not be capable of interacting with each other in the vadose zone (i.e., strictly vertical flow is assumed). Nonetheless, the value of including these model features is important when simulating the areal distribution of OSTDS in a potential housing development and the temporal variation of source input due to changes in wastewater input rate and precipitation recharge. These combined models can likely be implemented in a spreadsheet or using Fortran or C++ programming while maintaining simple and straight-forward input requirements. Of course, no similar model is available to our knowledge, so considerable model research and development must be achieved by this project. Within the models identified by the research review, the model developed by (Mehran et al. 1983-1984) is an example of a coupled modeling code for the transport and transformation of nitrogen but it lacks certain features for simulating nitrogen fate and transport related to OSTDS.

The literature review has suggested the most likely processes and parameters that will need to be considered when developing the modeling tool. The fate and transport of nitrogen products is a result of advective movement, retardation via adsorption, and the transformative processes of nitrification and denitrification. These processes are to be calculated in the model tool via the solutions of the appropriate equations using the necessary parameters, described below. Key parameters to consider for simulation should consist of:

- physical parameters of the media such as bulk density, water content, and soil characteristics;
- advective-dispersive parameters such as hydraulic conductivity, hydraulic gradient, porosity (or groundwater velocities), and dispersivity values;
- retardation factor values for ammonium sorption; and
- rate coefficients for transformative reactions, typically first-order rate constants

A majority of the parameter values needed for model input can be collected during site characterization. McCray et al. (2005) utilize CFD's for the estimation of initial parameter values if utilizing literature values but the approach results in an uncertain model output where the degree of uncertainty must be quantified.

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Within the models identified by the research review, the model developed by (Mehran et al. 1983-1984) is a representative example of a coupled modeling code for the transport and transformation of nitrogen. Additionally, many analytical models were found in the literature review (nitrate-specific and general analytical solutions) that are appropriate for the modeling tool, since these can be programmed into a spreadsheet and can be user-friendly.

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Section 5.0
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