Florida Onsite Sewage Nitrogen Reduction Strategies Study

Final Report

December 31, 2015

Rick Scott

Governor

John H. Armstrong, MD, FACS

Surgeon General and Secretary of Health

Abstract

Environmental impacts of nitrogen from wastewater are a growing concern throughout the nation. Onsite sewage systems are one of the sources of nitrogen loading to the environment. As directed by the Florida Legislature in 2008, a contractor (Hazen and Sawyer) completed a project to: (1) understand and illustrate how nitrogen moves underneath onsite sewage systems; and (2) develop cost-effective and passive methods to reduce nitrogen from onsite sewage. Evaluations of wastewater plumes from existing OSTDS were used to refine and calibrate a nitrogen fate and transport model to estimate nitrogen contribution from OSTDS in shallow aquifers. The project also developed and tested nitrogen-reducing technologies for full-scale systems. These systems were installed and tested at existing homes under real-world conditions. Results demonstrated effective and consistent removal of nitrogen from the test systems' wastewater. Recommendations are presented to facilitate decision making for nitrogen reduction from onsite sewage systems and to make passive nitrogen reduction technology available for use with existing and new systems.

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Executive Summary

Overview

Nitrogen in the environment is receiving increased national attention. Many water bodies are sensitive to excess nitrogen loading from many different sources, including onsite sewage systems. Recent research performed for the state of Florida is being used to develop strategies to manage and reduce nitrogen loading from onsite sewage systems and to protect groundwater and surface waters.

In 2008, the Florida Legislature directed the Department of Health to contract with experts to develop cost-effective nitrogen reduction strategies for onsite sewage treatment and disposal systems (OSTDS). In January 2009 the Department, in consultation with the Research Review and Advisory Committee (RRAC), contracted with a project team comprising nationally recognized experts led by Hazen and Sawyer. The Department and the RRAC coordinated the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) project, with participation from the Florida Department of Environmental Protection (DEP).

The project had two main areas of focus: development of passive nitrogen reduction technologies, and evaluation and prediction of the fate and transport of nitrogen from OSTDS. Objectives included:

- Development of cost-effective, passive strategies for nitrogen reduction from onsite sewage systems
- Characterization of nitrogen removal in the soil and shallow groundwater
- Development of simple models to determine fate and transport of nitrogen from OSTDS in soil and groundwater

A passive system was defined as one that used no mechanical components other than one effluent pump that uses a reactive media for denitrification. A reactive media, such as wood chips or sulphur, is used to reduce nitrogen concentrations. Passive nitrogen reduction was defined based on previous research done for the Department.

The study led by Hazen and Sawyer was developed around four major tasks (Figure ES-01):

Task A - Select promising technologies and pilot test them at a Florida university research facility to determine preliminary design criteria for new passive nitrogen reduction systems.

Task B - Install top candidates for nitrogen reduction technologies at existing Florida homes, with documentation of performance and cost.

Task C - Determine efficacy of nitrogen reduction in Florida soils and contributions to shallow groundwater.

Task D - Develop simple user-friendly computer models for nitrogen fate and transport from onsite sewage systems in Florida to support environmental assessment, planning, and system selection.

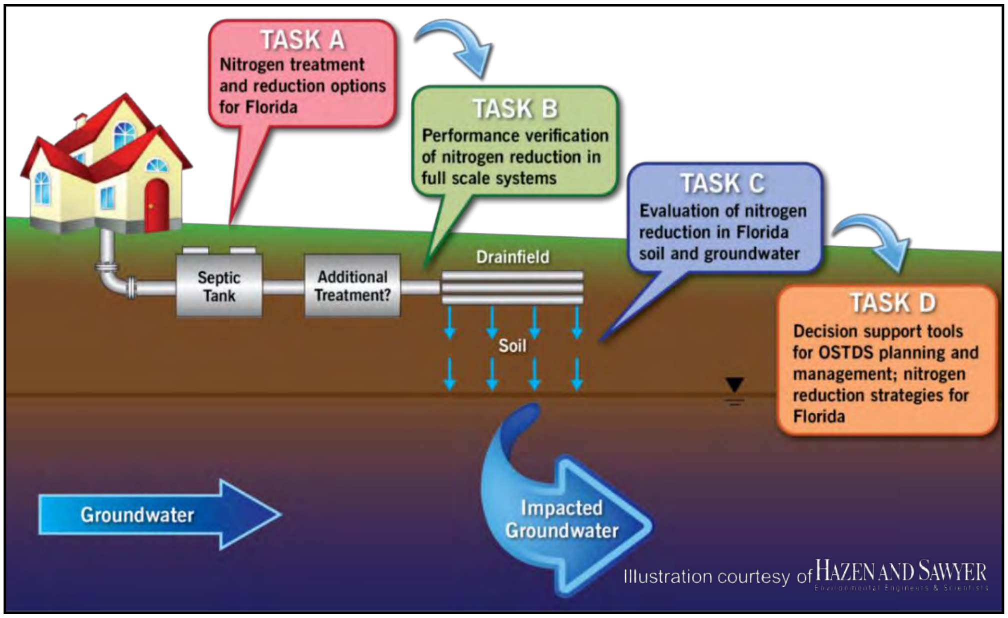

Figure ES-01. Depiction of the Four Main Tasks Associated with the Florida Onsite Sewage Nitrogen Reduction Strategies Study (Hazen and Sawyer 2015b)

Results

Development of passive nitrogen reduction technologies

A rigorous prioritization process completed during public meetings of the RRAC determined which nitrogen reduction options were to be tested in this study. There was a desire not to overlap too much with existing proprietary system testing, and to expand on promising laboratory-scale research results from a previous Department research project.

A test facility was established at the University of Florida Gulf Coast Research and Education Center (GCREC), using an existing sewage source from an onsite dormitory and office/conference center. The sewage nitrogen (N) concentrations ranged from 35 to 75 mg-N/L, which was representative of domestic strength sewage (40 to 70 mg-N/L) (Oakley 2005). Numerous design concepts for passive systems were tested to develop further design criteria for implementation of full scale Passive Nitrogen Reduction Systems (PNRS) for testing at home sites. Nitrogen removal by two-stage biofiltration was selected as the most operationally simple, effective, and applicable nitrogen removal process for development of PNRS for onsite sewage treatment. Two-stage biofiltration consists of a first stage in which nitrogen from the wastewater is converted to nitrate by passively aerating the wastewater as it trickles down through an unsaturated media, and a saturated second stage in which the nitrate is reduced to nitrogen gas that then escapes into the atmosphere (Figure ES-02). The saturated biofilters contained reactive media, such as lignocellulosic material (e.g., saw dust) and sulfur to assist with conversion to nitrogen gas. The tested configurations resulted in several options that consistently reduced total nitrogen influent values by 95% or more.

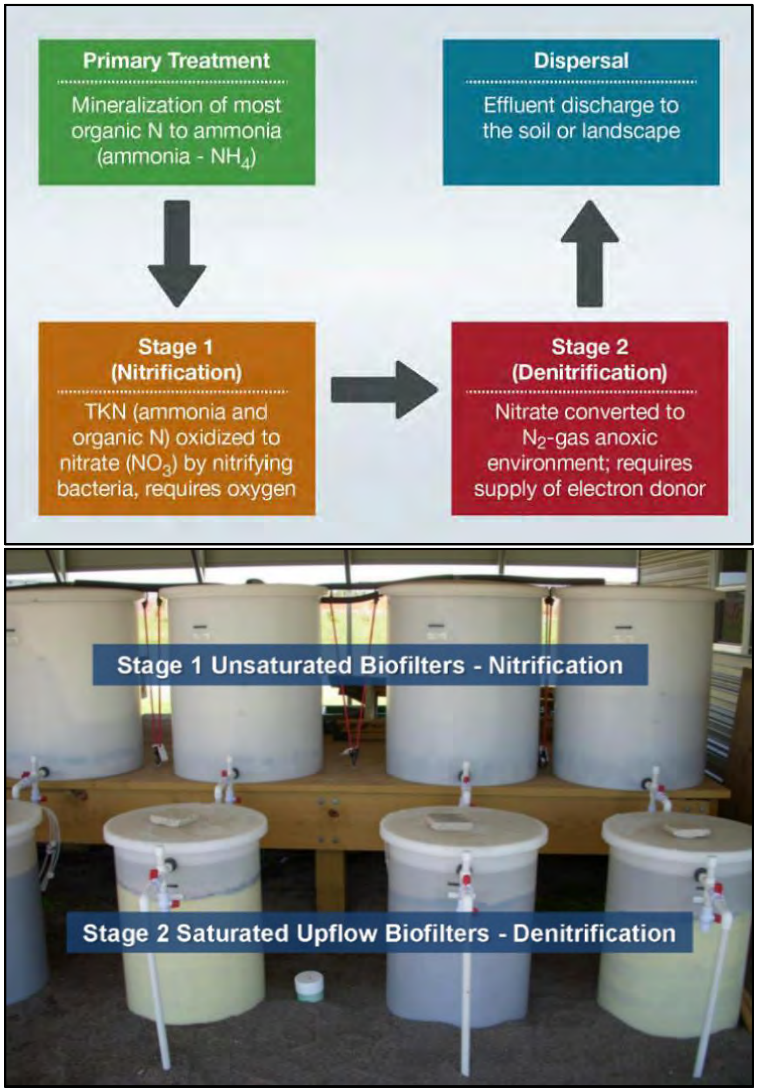

Figure ES-02. Two Stage Denitrification Concept: Diagram and Test Facility Pilot-Scale Configurations (Hazen and Sawyer 2015b)

Based on approximately two years of Hazen and Sawyer's pilot study results, seven full scale innovative prototype two-stage biofilter designs were constructed for evaluation at existing homes in Florida (Figure ES-03). Site locations included three dispersed locations in Florida to provide geographical variety. Construction of each system was evaluated for cost and ease of construction. The performance and operation of the systems were subsequently monitored for approximately two-years with water quality sampling conducted bi-monthly over 18 months. Most of the prototype systems performed very well in actual home site conditions. The results indicated 90-95% nitrogen reduction for most systems prior to effluent arrival at the soil treatment unit (STU, aka drainfield). Nitrogen removal performance of the full scale PNRS confirmed the results of previous PNRS pilot testing and established the two-stage biofiltration process as an effective and viable technology for onsite nitrogen removal. The prototype system demonstrations provided valuable guidance for further PNRS design for individual home sites and for planning level analysis to achieve nitrogen reduction goals in Florida. Systems and results are discussed in more detail in the final technical summary report by Hazen and

Sawyer (2015).

Figure ES-03. Field Site Locations for Full-Scale Passive Nitrogen Reducing Systems

For each of the field-tested prototype site configurations, life-cycle cost assessments were developed, which outline in detail system cost estimates and cost comparisons to existing approved systems. Cost documentation for the systems was categorized by permitting, design, materials and construction, and operation and maintenance. Documentation of the installation, operating, and maintenance costs enabled comparative life-cycle cost estimates between the different field-tested systems. These were prototype or innovative systems that had not been designed and constructed previously in Florida and were therefore unfamiliar to the installing contractors. Costs for PNRS are expected to come down with more standard designs and widespread implementation.

Hazen and Sawyer developed a life-cycle cost assessment tool to estimate the present worth and capital costs for multiple system configurations. The tool is a computer spreadsheet consisting of a series of linked worksheets that can estimate the life-cycle costs of passive onsite sewage nitrogen removal systems, as well as for conventional systems. The tool calculates the life-cycle cost for a conventional system at $5,500, which includes design, permitting, construction, and operation and maintenance costs. This tool was used to standardize the cost estimates for each tested system to a standard 300 gallon per day system, representing a typical three-bedroom, single-family residence. Two scenarios were calculated: a new system installation, and a retrofit of an existing system. For the new system scenario, the tool estimated a construction cost of $4,000 for a conventional septic tank and STU. For the retrofit of an existing system scenario, it was assumed that the existing septic tank and STU could be used, but that the anticipated complexity of installation would be greater. The standardized estimated costs for the PNRS components for new construction ranged from $8,700-

$16,300 with an average of $13,700, and the range for a retrofit of an existing system was $12,000-$20,700 with an average of $16,500.

Hazen and Sawyer applied the life-cycle cost assessment tool to the results from the seven prototype PNRS and estimated an average present worth cost per pound of nitrogen removed of $42/lb. N, with a range from $29 to $52/lb. N. The average energy use was 0.5 kWh/day with an average field-tested percentage of nitrogen reduction of 85%. When the results from the field systems were standardized to 300 gallons per day for a typical three-bedroom, single-family residence and compared to other cost estimates for more active performance-based treatment system nitrogen removal, the systems associated with this study operated at a lower present worth cost per pound of nitrogen removed ($13.50 less/lb. N.), saved over 2 kWh/day in energy use, and achieved significantly greater (21%) effluent nitrogen removal efficiencies.

Several of the passive nitrogen systems designed and tested as part of this study provide a significant improvement in nitrogen reduction over conventional systems, achieving consistent removal of over 90-95% of the nitrogen and having a concentration less than 5 mg N/L. Current advanced systems available on the market typically achieve 40-70% reduction in nitrogen. The passive systems designed and developed as part of this study were simple to operate, and only required minimal maintenance after startup. The media used in these systems to perform the nitrogen reduction is expected to last up to 50 years.

Evaluation and prediction of the fate and transport of nitrogen from OSTDS

Nitrogen loading to groundwater by OSTDS is influenced by a wide variety of factors. The number, density and wastewater characteristics of OSTDS in a given area allow an estimate of potential impacts. Monitoring of septic tank effluent during the course of the study confirmed earlier estimates by the Department of how much nitrogen is discharged. Annually, about 10 pounds of nitrogen per person leave a septic tank (Katz et al., 2010). For any particular system, nitrogen transport from the septic tank through the soil treatment unit (STU, aka drainfield) to groundwater can be influenced by factors such as wastewater characteristics, STU configuration, wastewater loading rate, soil characteristics, oxygen content, and water table elevation and fluctuation.

To determine movement of nitrogen in soil and groundwater, three OSTDS at existing homes in Polk, Seminole, and Hillsborough counties were assessed over a 12-month period. Additionally, the plume from a large OSTDS at GCREC was delineated, and some monitoring around one of the PNRS prototype systems in Marion County and an additional home site in Wakulla County was performed. In nearly all cases, some of the nitrogen from the OSTDS entered the groundwater and formed a plume. Nitrogen concentrations tended to be lower further away from the STU, which, when compared to other field parameters, was largely due to dilution. At one site where a passive nitrogen removal treatment systems was installed as part of the study, the high treatment effectiveness resulted in nitrogen disappearing from the effluent plume. In Figure ES-04, sampling point B08 (red dashed circle) showed a Total Nitrogen concentration over 35 mg-N/L before installation of a passive nitrogen reduction system and at background levels (0-5 mg-N/L) within a few months after installation. The nitrogen plume under the STU disappeared.

Information from these systems was used for the adaptation of a numerical model to develop and

corroborate a model for nitrogen fate and transport through the unsaturated soil to groundwater. Results of this effort were used to develop a series of look-up tables based on illustrative simulations, such as the one shown in Figure ES-05. These simulation results can be used to evaluate different combinations of variables such as STU configuration, water table elevation, input nitrogen concentration, and wastewater distribution consistency. The trench system configuration shown in Figure ES-05 shows that with a 2-foot separation from the water table, ammonium converted to nitrate very quickly.

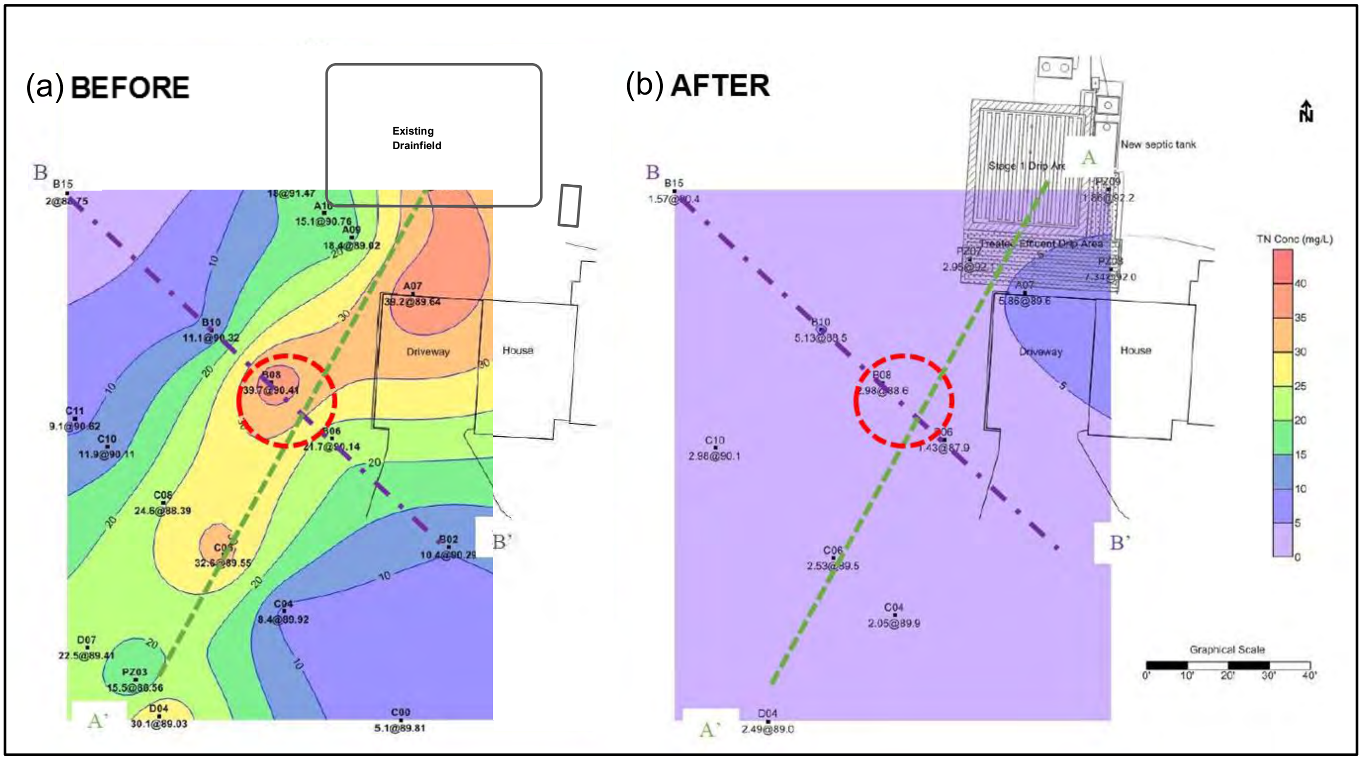

Figure ES-04. Groundwater Total Nitrogen Concentration at One Home Site Before (a) and After (b) Installation of a Passive Nitrogen Reduction System (Adapted From Hazen and Sawyer 2015b)

Hazen and Sawyer (2015d) also developed a spreadsheet model for groundwater transport of nitrogen from OSTDS to predict nitrogen fate and transport from the bottom of the STU, through the soil, and in the groundwater downgradient of the system.

Figure ES-06 shows the user interface of this model. This easy-to-use tool was based on a complex model. This increased the applicability of the model while maintaining an adequate ability to predict contaminant fate and transport. With such a model, barriers to understanding and steep learning curves are lessened. The model calculates the mass flux of nitrogen downstream at a specified distance from one or multiple sites.

The modeling tools can also be used to incorporate more site specific data, and corroborative examples are included.

These tools can be employed by users with various levels of expertise to quantify vadose and groundwater transport of nitrogen from OSTDS. This model can be combined with other tools to allow for a refinement of nitrogen loading estimates for specific remediation areas, such as spring basins.

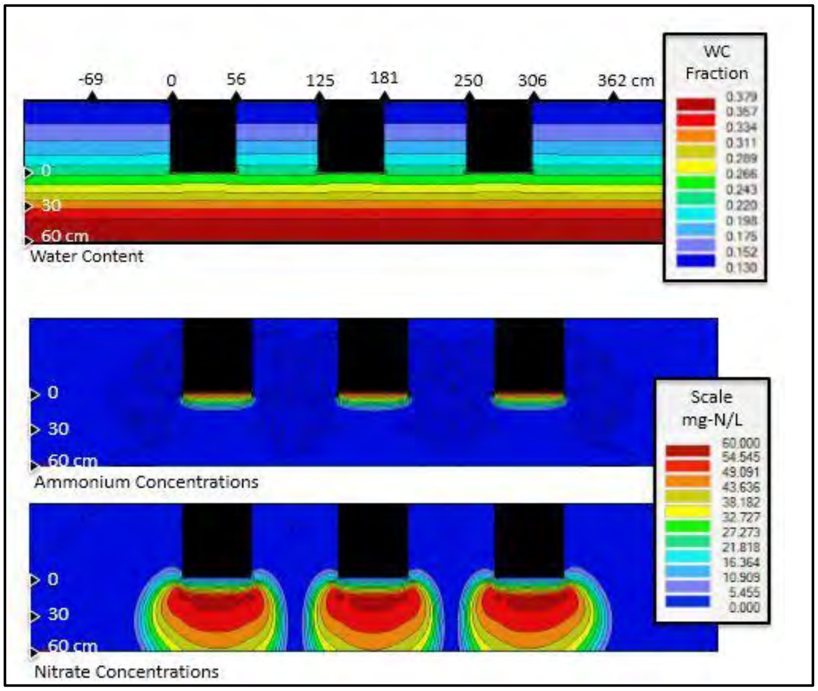

Figure ES-05. Vadose Zone Model Example Showing Ammonium and Nitrate Concentrations under an Equally Loaded Trench Configuration with a Groundwater Elevation of 60 cm (2 ft) under the Bottom of the Soil Treatment Unit (Hazen and Sawyer 2013c)

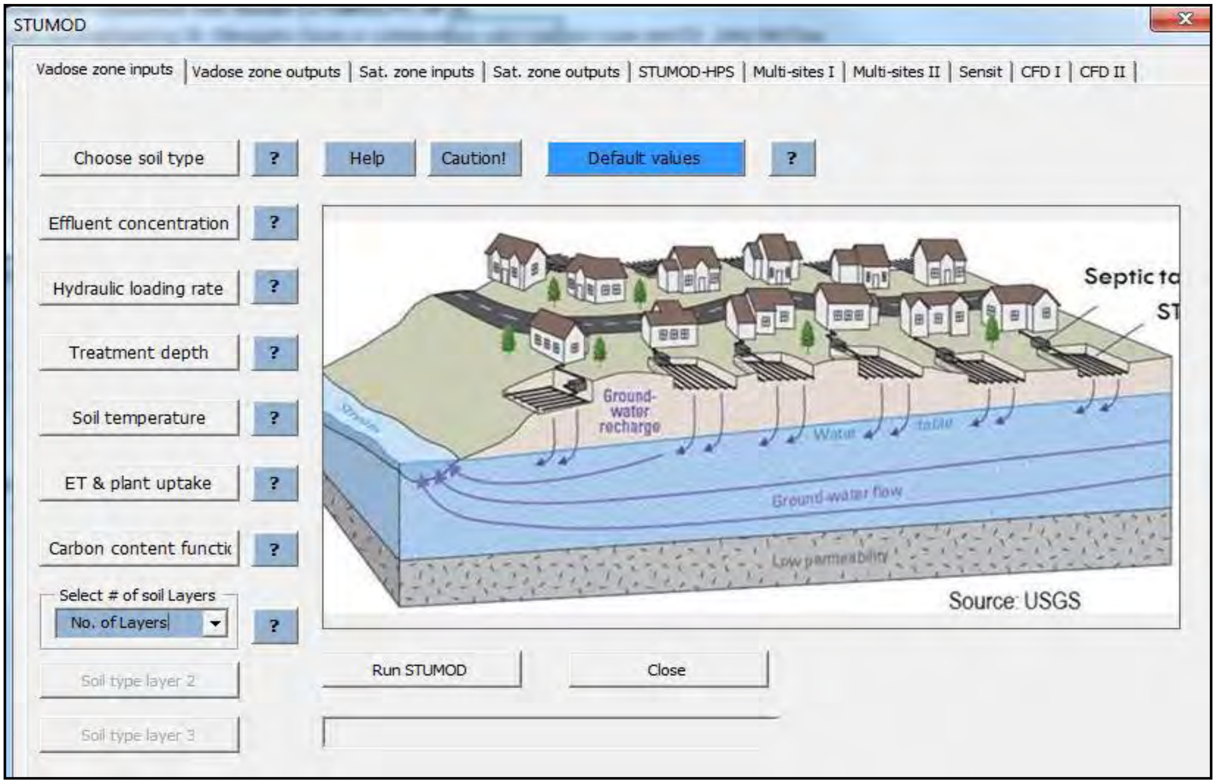

Figure ES-06. User Interface of Nitrogen Fate and Transport Model for Estimating Nitrogen Contribution from OSTDS (Hazen and Sawyer 2015d)

Conclusions

The nitrogen sensitivity of Florida watersheds varies greatly, and includes areas of extremely high sensitivity to nitrogen loading and other areas where nitrogen loading from OSTDS may be less critical. DEP and local governments are expected to identify nitrogen sensitive watersheds and address high nitrogen loading via the Total Maximum Daily Load (TMDL - maximum amount of a pollutant that a body of water can receive while meeting water quality standards), and Basin Management Action Plan (BMAP – "blueprint" for restoring impaired waters by reducing pollutant loading) processes.

As specific TMDLs and BMAPs are developed for Florida watersheds, it will become important to have a range of available options for nitrogen load reductions from OSTDS. The Department will use the results of the FOSNRS study to develop strategies to promote nitrogen reduction in OSTDS. These strategies will provide planning-level tools to state agencies, local governments, stakeholders, and other interested entities to enhance their ability to assess nitrogen loading from OSTDS, select enhanced designs for OSTDS which provide a range of options for nitrogen removal, and facilitate education and training for industry professionals and the public. This will enhance the abilities of resource managers, regulators, land use managers, and engage community partners to make informed decisions on the most effective strategies to limit nitrogen inputs from OSTDS. Further, care must be taken to ensure the cost effectiveness of strategies based on community resources.

In a press release by the St. Johns River Water Management District on October 7, 2015, DEP

Secretary Jon Steverson said, "combining efforts and resources with local governments, stakeholders, and the water management districts enables us to take a more comprehensive and efficient approach to springs protection." A collaborative approach to nitrogen reduction from all sources at the local level is the approach that can make the most impact. The results of this project help characterize and 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 Florida residents.

The results of this study have provided Floridians:

- Field-tested designs for "passive" user-friendly systems effective at removing nitrogen
- System cost estimates and cost comparisons to existing approved systems
- Nitrogen fate and transport model for estimating nitrogen contribution from OSTDS
- Options for nitrogen reduction OSTDS in sensitive watersheds where sewers are not feasible

In consultation with the Department of Environmental Protection and the Research Review Advisory Committee, the Department has used the results of the Florida Onsite Sewage Nitrogen Reduction Strategies study to develop this final report to the Florida Governor and Florida Legislature. The total estimated project cost was $5 million, but $4.8 million was spent over a six-year period.

Introduction

Importance of Florida Springs

Florida is home to more than 900 freshwater springs, one of the greatest concentrations on earth (FDEP 2014b). There are 33 “first magnitude” springs which discharge more than 64 million gallons of groundwater per day. Most springs in Florida are located in the north and central part of the state with thirty-nine counties containing springs: Alachua, Bay, Bradford, Calhoun, Citrus, Clay, Columbia, Dixie, Flagler, Franklin, Gadsden, Gilchrist, Hamilton, Hernando, Hillsborough, Holmes, Jackson, Jefferson, Lafayette, Lake, Leon, Levy, Liberty, Madison, Marion, Orange, Pasco, Pinellas, Polk, Putnam, Seminole, Sumter, Suwannee, Taylor, Union, Volusia, Wakulla, Walton, and Washington (Florida Springs Taskforce 2000).

These natural wonders provide tremendous economic support to local communities and the state. The Florida Department of Economic Opportunity (DEO) noted visitor spending, between 2002 – 2004, of over $10 million at a number of springs, with Marion County receiving over $65 million in revenue for the local economy (FDEO 2015).

The DEO found that state parks associated with some of Florida's springs bring in about one million out-of-state tourists a year, with a $46 million economic impact. In particular, visitor spending at Ichetucknee Springs (Suwannee County) was $23 million, Wakulla Springs (Wakulla County) $22 million, and Blue Spring (Volusia County) $10 million (FDEO 2015).

DEO also highlights, “The buildup of nitrates is contributing to the loss of spring habitats, which in turn can adversely affect local economies that rely on tourist dollars from recreational opportunities Florida's springs provide” (FDEO 2015).

Governor Rick Scott, together with the Florida Legislature, understands the importance of springs to both Florida residents and visitors. In 2013, Governor Scott championed a $10 million investment in spring restoration. Additional funds from the Florida Department of Environmental Protection (DEP) and through local partnerships provided a total of $37 million for spring restoration. In 2014, Governor Scott allocated an additional $55 million for spring protection. The state also invested $15 million to improve spring water quality and flow through improved research, monitoring, education, and landowner assistance. Additionally, to protect Florida’s groundwater, Florida set aside for conservation, almost 27,000 acres that are recharge springs locations.

On October 5, 2015, Governor Scott announced distribution of over $82 million that focuses on spring restoration in 26 locations in the state. Restoration plans include improvement in nitrogen control and agricultural practices in sensitive spring watersheds. Additional activities will also include facilitating centralized sewer connections. “Florida’s 900 freshwater springs bring families, visitors and job creators to our state. Over the last three years, we have invested record funding for Florida’s springs, and the projects we are announcing today will ensure our springs are protected for future generations to enjoy,” Governor Scott said in a press release. The initiative, with the support and design of the Florida Legislature, will provide record funding for springs restoration. The project is a collaborative effort and implemented by DEP, local governments, stakeholders, and Water Management Districts, and enables more comprehensive and efficient approach to springs restoration (State of Florida 2015).

Springs and Onsite Sewage

The Department, including its Onsite Sewage Program within the Bureau of Environmental Health, Division of Disease Control and Health Protection, recognizes the vital importance of protecting public health and the environment. Onsite Sewage Treatment and Disposal Systems (OSTDS) are a cost-effective, public health protective, permanent solution to wastewater treatment in many locations throughout Florida. An estimated 2.7 million OSTDS are in use statewide (FDOH 2015a), serving approximately one third of its population (FDEP 2014a). The great majority of Florida OSTDS include a septic tank for primary treatment followed by dispersal into the environment using a soil treatment unit (aka drainfield) for further treatment. They contribute one of the largest “artificial” ground water recharge sources in the state. Ninety percent of the water used for drinking comes from ground water. The Department, through the implementation of the OSTDS program in all of its 67 county facilities, is an important asset for ensuring the protection of public health and the environment, including this treasured resource.

Primary motivations for this study are the environmental impacts of increased levels of nitrogen in water bodies. Programs within DEP identify water bodies impaired by excessive nitrogen, establish targets for maximum nitrogen loads, and develop management action plans to restore water bodies. Nitrogen sources to the environment include: atmospheric deposition, fertilizer from both agricultural and residential land applications, livestock waste, wastewater from both centralized wastewater treatment systems and OSTDS, and other localized sources such as sinking streams and drainage wells. The combination of these sources adds up to a cumulative nitrogen load to ground and surface waters. The relative contribution of OSTDS to nitrogen impacts varies by watershed with estimates ranging from below five percent to more than 50 percent. As land uses change and the population and OSTDS increase, the relative contribution of OSTDS to nitrogen sources in an area may change. There is widespread interest in the management of OSTDS and their nitrogen impacts.

Various investigators have evaluated the relative contribution of OSTDS to cumulative nitrogen impacts in specific watersheds and discussed opportunities to reduce this contribution. In response to prior legislation, the Department has been involved in such efforts in the Wekiva Study Area of central Florida and provided reports on nitrogen and OSTDS to the Governor in 2004, 2007, and from 2009-2015. An increasing motivator for such evaluations is the need to maintain and restore water bodies to their designated uses, implemented through the Total Maximum Daily Load (TMDL) program by DEP.

Onsite Sewage Treatment and Disposal Systems

Conventionally, OSTDS consist of a septic tank and a soil treatment unit (STU, aka drainfield). Construction and use standards for OSTDS in Florida began in 1921. A major revision to the standards occurred in 1982 when a separation of 24 inches was required between the soil infiltrative surface (bottom) of a newly constructed STU and the estimated seasonal high groundwater table. Over the last few decades, attention has shifted from disposal of sewage to treatment occurring particularly underneath the STU. Terms, such as “onsite sewage treatment and disposal system” (introduced in 1995), and the term “soil treatment unit for the drainfield and underlying soil” reflect that. Figure 01 illustrates a conventional onsite sewage system. Research in Florida and elsewhere has shown that OSTDS installed to these relatively modern standards effectively reduce the concentration of

pathogens found in normal wastewater, and that nitrogen levels are reduced from less than 30 percent in a system installed less than 24 inches from the estimated seasonal high groundwater table, to 30-40 percent removal for systems located 24 inches or more from groundwater (Roeder 2008).

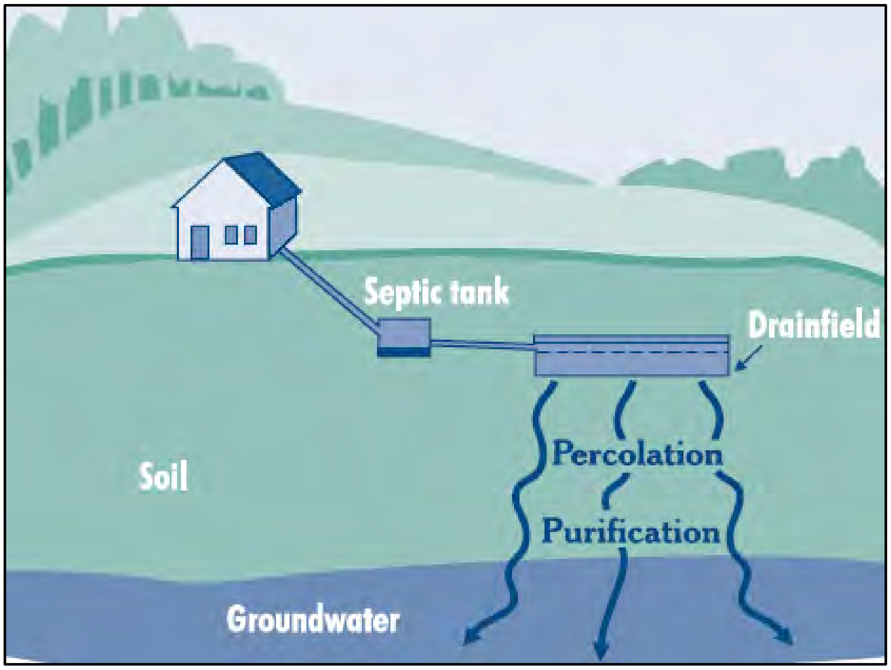

Figure 01. Conventional Onsite Sewage Treatment and Disposal System (From http://www3.epa.gov/npdes/pubs/homeowner_guide_long_customize.pdf)

Where local regulations require more treatment or where relatively small lots make it difficult to install a conventional system, more advanced treatment options exist. These fall generally into two permitting categories:

Aerobic treatment units (ATUs) are complex mechanical and energy intensive units that add air to the sewage so that oxygen demanding compounds in the sewage can be digested before the sewage enters the drainfield. Aerobic treatment units are permitted based on a standardized technology test by a third-party who certifies that the technology functions properly in removing oxygen demanding compounds and solids. ATUs are required to have lifetime operating permits and monitoring and maintenance by an approved maintenance entity.

Performance-based treatment systems (PBTS) are a type of OSTDS that have been designed to meet specific performance criteria for certain wastewater constituents as defined by Florida Administrative Code Rule 64E-6.025(10). Nitrogen is only one of the possible constituents in wastewater that can be addressed by performance-based treatment systems. Other constituents that are addressed include carbonaceous oxygen demand, total suspended solids, total phosphorus, or fecal coliforms as a pathogen indicator. 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, where air is introduced into the sewage.

In 2007-2008, the Department conducted a study of passive technologies for nitrogen removal. The definition of "passive" adopted in the study is:

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

This definition excludes some approaches to achieving aeration (aerator pumps), and it requires a particular approach (reactive media) for nitrogen removal. Because of the flat topography common to Florida, the definition of "passive" included the use of up to one pump as the only mechanical input to the system. These elements are based on an understanding that nitrogen removal from wastewater generally occurs in two steps. In the first step associated with aeration, nitrification occurs when nitrogen is converted to nitrate. In the second step, which occurs without air (anoxic conditions), denitrification occurs when nitrate is converted to nitrogen gas that subsequently leaves the sewage. Figure 02 illustrates the sequence of processes occurring in a passive system. The same processes can be achieved by non-passive technological approaches.

Before a new technology becomes classified as a performance-based treatment system for nitrogen reduction it passes through a period of "innovative" system testing in Florida. A technology has to document third-party testing data similar to those required for aerobic treatment units. During innovative system testing, a limited number of systems are installed and monitored to ensure they will perform as designed in Florida-specific conditions. Data generated during field testing in this project provided support for a number of new technologies.

The addition of reactive media, or the dosing of other reactants in non-passive systems, to achieve treatment processes in onsite sewage treatment systems, should be evaluated for production of ground or surface water contaminants. Florida regulations require a review of such compounds and their proposed dosing rates to prevent such contamination.

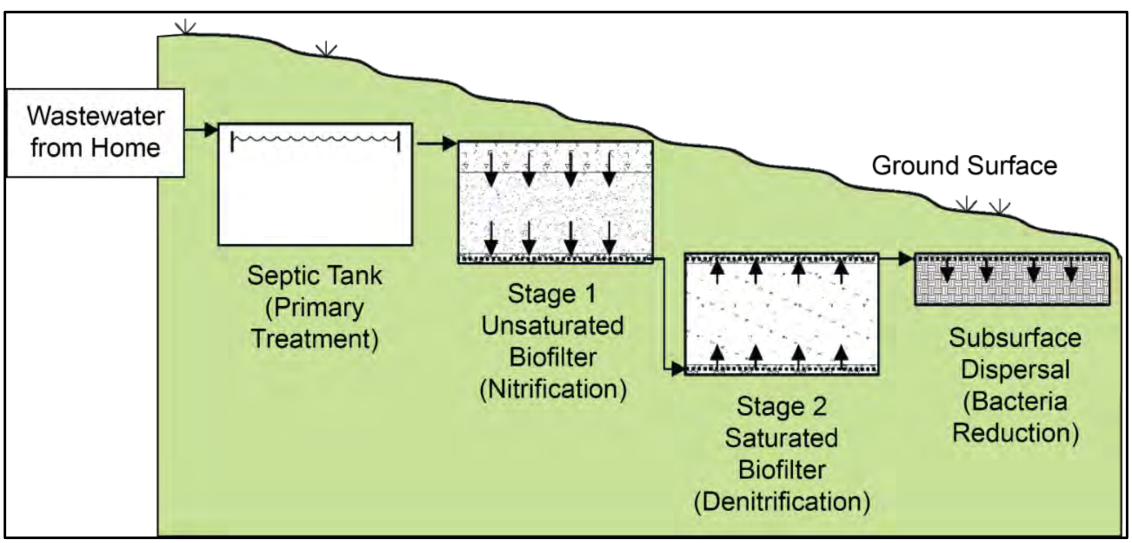

Figure 02. Sequence of Processes in a Passive System (Hazen and Sawyer 2015b)

Project Overview

Legislative History and Budget

This report is submitted in compliance with Specific Appropriation 470 of chapter 2015-232, Laws of Florida:

> "From the funds in Specific Appropriation 470, $10,000 from the General Revenue Fund is provided to the Department of Health to conclude the nitrogen reduction study authorized in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida, by August 31, 2015. The study shall include an analysis of field monitoring of performance and cost of technologies at various sites, an analysis of soil and groundwater sampling at various sites to determine how nitrogen moves, an analysis of various models to show how nitrogen is affected by treatment in Florida-specific soils, and final reporting on all tasks with recommendations for science-based nitrogen reduction options for onsite sewage treatment and disposal systems. The department shall submit a final report by December 31, 2015, to the Executive Office of the Governor, the President of the Senate, and the Speaker of the House of Representatives."

Original legislation authorizing this study was in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida:

> "From the funds in Specific Appropriation 1682, $1 million from the Water Protection and Sustainability Program Trust Fund shall be transferred to 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."

Cross references between the sections of this report with the legislative language from 2008 and 2015 are provided in Table 01. This report summarizes and excerpts deliverables by Hazen and Sawyer, with limited additional material and discussion.

Table 01. Cross Reference between Report and Legislative Directive

Year	Legislative Language	Section(s) in Report
2008	Comprehensive review of existing or ongoing studies on passive technologies	Selection of technologies for testing (page 26); Appendix C. Review, Prioritization, and Recommendations for Field Testing Nitrogen Reduction Technologies (page 139)
2008	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	Pilot-scale study (page 27); Prototype testing at actual home sites (page 32); Appendix D. Passive Nitrogen Reducing Systems at Home Sites (page 157)
2008	Documentation of all capital, energy and life-cycle costs of various technologies for nitrogen reduction	Life cycle cost analysis (page 34); Appendix E. Life Cycle Cost Assessment Results (page 171)
2008	Evaluation of nitrogen reduction provided by soils and the shallow groundwater below and down gradient of various systems	Analysis of Nitrogen in Soil and Groundwater (page 41); Appendix F. Results of Groundwater Monitoring at Field Sites (page 197)
2008	Development of a simple model for predicting nitrogen fate and transport from onsite wastewater systems	Nitrogen Treatment in Florida-Specific Soils: An Analysis of Various Models (page 49); Appendix G. An Analysis of Various Nitrogen Models (page 217)
2015	Analysis of field monitoring of performance and cost of technologies at various sites	Pilot-scale study (page 27); Prototype testing at actual home sites (page 32); Life cycle cost analysis (page 34); Appendix E. Life Cycle Cost Assessment Results (page 171)
2015	Analysis of soil and groundwater sampling at various sites to determine how nitrogen moves	Analysis of Nitrogen in Soil and Groundwater (page 41); Appendix F. Results of Groundwater Monitoring at Field Sites (page 197)
2015	Analysis of various models to show how nitrogen is affected by treatment in Florida-specific soils	Nitrogen Treatment in Florida-Specific Soils: An Analysis of Various Models (page 49); Appendix G. An Analysis of Various Nitrogen Models (page 217)
2015	Final reporting on all tasks	This report. Appendix B. Contractual History, Tasks, and Deliverables (page 97)
2015	Recommendations for science-based nitrogen reduction options for onsite sewage treatment and disposal systems	Recommendations for Science-Based Nitrogen Reduction Options for Onsite Sewage Treatment and Disposal Systems (page 55)

Appendix A contains the appropriations and implementation language for this project from each fiscal year where the study was re-authorized. Legislation was passed and signed into law by the Governor on June 11, 2008 which directed the Department of Health to develop cost-effective nitrogen reduction strategies for onsite sewage treatment and disposal systems (OSTDS). The 2008 legislation required that the Department's Research Review and Advisory Committee (RRAC) have oversight of the study. In 2009, legislation specified that no state agency could implement any rule or policy that requires nitrogen reducing systems or increase their costs until the study was complete. In 2010, legislation required that the DEP work together with the Department and the RRAC to provide technical oversight of the project. The 2010 legislation also specified that the focus for work would be to develop, test, and recommend cost-effective passive technology design criteria for nitrogen reduction and authorized the Department to install experimental systems at home sites with extensive field testing and monitoring. The 2014 legislation specified that the current contract could be extended until the study was complete. The 2015 legislation required conclusion of the study by August 31, 2015, with the final report due by December 31, 2015.

The Florida Legislature appropriated $4.7 million for the contractual work associated with this project (Table 02). The Department spent an additional $100,000 for costs associated with RRAC meetings to discuss the scope of the project, to rank proposals, and to provide updates on the project; as well as other project related expenses.

Table 02. Summary of Cash and Expenses

Fiscal Year	Cash	Expenses	Funding Source(s)
2008-2009	$900,000	$313,727	DEP Trust Fund, –$100,000 for Department administration of contract included in expenses
2009-2010	$0	$485,720	
2010-2011	$2,000,000	$742,016	Department Grants and Donations Trust Fund
2011-2012	$0	$678,773	
2012-2013	$1,103,566	$1,103,566	$1,500,000 in non-recurring funds from Department General Revenue
2013-2014	$114,772	$794,536	Department Grants and Donations Trust Fund
2014-2015	$603,995	$603,995	$650,000 in non-recurring funds from Department General Revenue
2015-2016	$107,532	$107,532	$10,000 in non-recurring funds from Department General Revenue, $81,314 from Department Administrative Trust Fund, and $16,218 from Department Grants and Donations Trust Fund
TOTAL	**$4,829,865**	**$4,829,865**	

Contractual History

Implementation of this study was done through the Onsite Sewage Program in the Bureau of Environmental Health, Division of Disease Control and Health Protection. The research component of the onsite sewage program began in 1983 and focuses on evaluating the impact of OSTDS on public health and the environment as well as studying improvements in technology. The research program is advised by a statutorily established committee, the Research Review and Advisory Committee (RRAC), in section 381.0065(3) (j) Florida Statutes. A variety of stakeholder groups are represented on the committee: the Department, onsite sewage industry, home building industry, environmental interest group, state university system, professional engineering industry, local government, real estate profession, restaurant industry, and consumers. The RRAC advises the Department on research priorities, comments on research reports, and assists in selecting contractors for research projects. Implementation of the nitrogen study required close cooperation with the RRAC, which the Florida Legislature charged to oversee the study and provide recommendations to the Department. To date, 33 public meetings of the RRAC have been held since the original appropriation in July 1, 2008.

Appendix B gives a summary of the contractual history of the study. In January 2009, after a rigorous selection process, the Department awarded a 6-year, $5-million contract to a project team comprising nationally recognized experts led by Hazen and Sawyer. A list of the contract tasks and deliverables are also included in this appendix. This information, as well as links to each deliverable, is also available at http://www.floridahealth.gov/environmental-health/onsite-sewage/research/nitrogenstudydeliverables.html.html.

The accelerated timeline and amended budget resulted in the refinement of a limited number of contract deliverables as indicated in Appendix B.

Figure 03 shows the contractual timeline of the major project milestones.

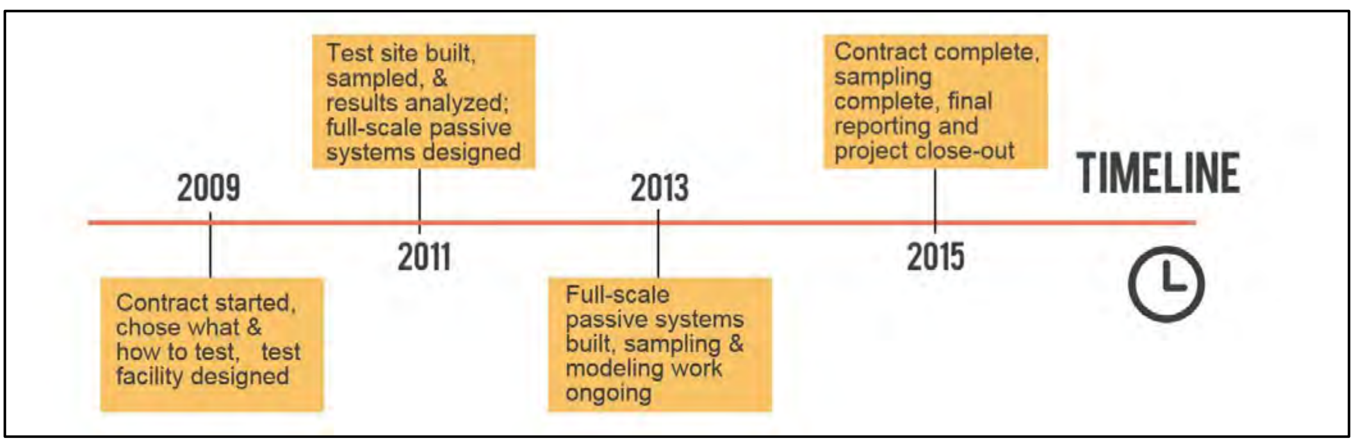

Figure 03. Timeline of Major Project Milestones

Goals/Objectives of the Project

The overall goal of the project was to make tools available that can be used to reduce nitrogen contributions from OSTDS. The objectives of the project were to develop cost-effective, passive strategies for nitrogen reduction from onsite sewage; characterize nitrogen removal in the soil and shallow groundwater; and develop simple models on fate and transport of nitrogen in soil and groundwater (Figure 04).

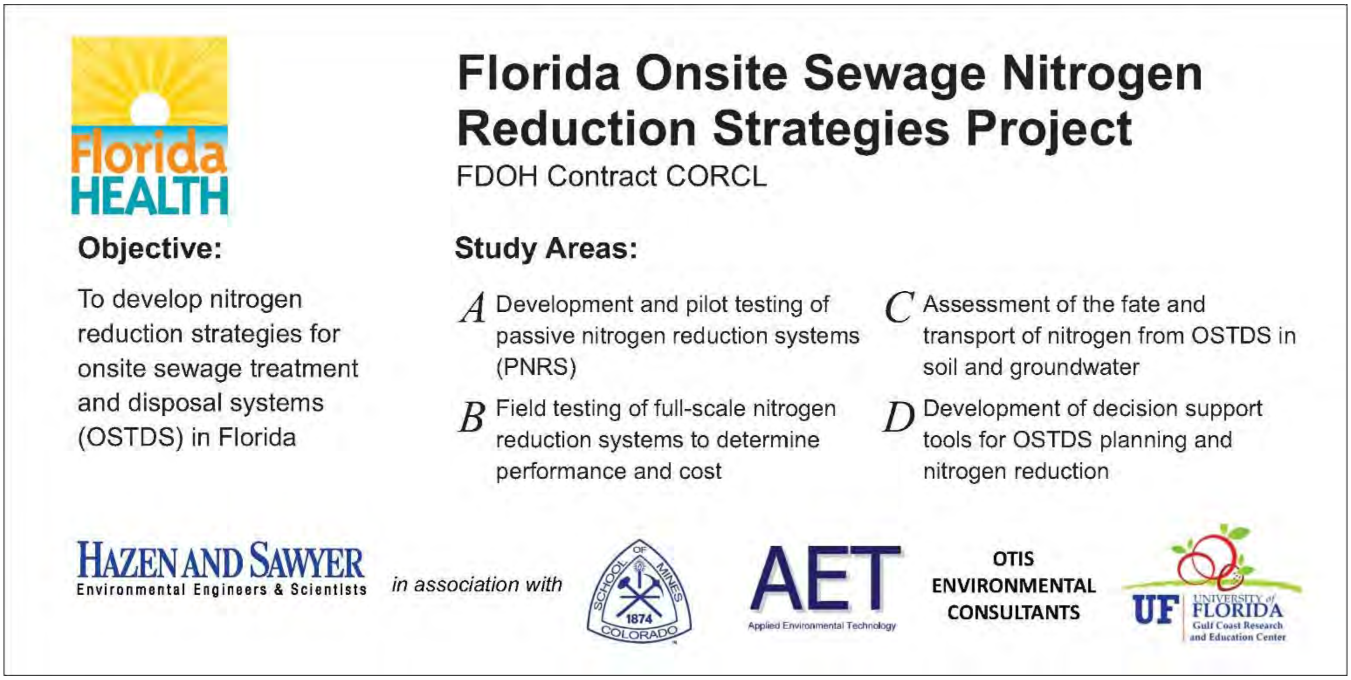

Figure 04. Sign Posted at the University of Florida's Gulf Coast Research & Education Center's Test Facility Showing Project Objective and Study Areas (Sign Designed by Hazen and Sawyer)

The project had two main areas of focus: development of passive nitrogen reduction technologies, and evaluation and prediction of the fate and transport of nitrogen from OSTDS. The project was divided into four main tasks (Figure 05):

Task A - Select promising technologies and pilot test the at a Florida university research facility to determine preliminary design criteria for new passive nitrogen reduction systems.

Task B - Install top candidates for nitrogen reduction technologies at existing Florida homes, with documentation of performance and cost.

Task C - Determine efficacy of nitrogen reduction in Florida soils and contributions to shallow groundwater.

Task D - Develop a simple user-friendly computer model for nitrogen fate and transport from onsite sewage systems in Florida conditions supporting environmental assessment, planning, and system selection.

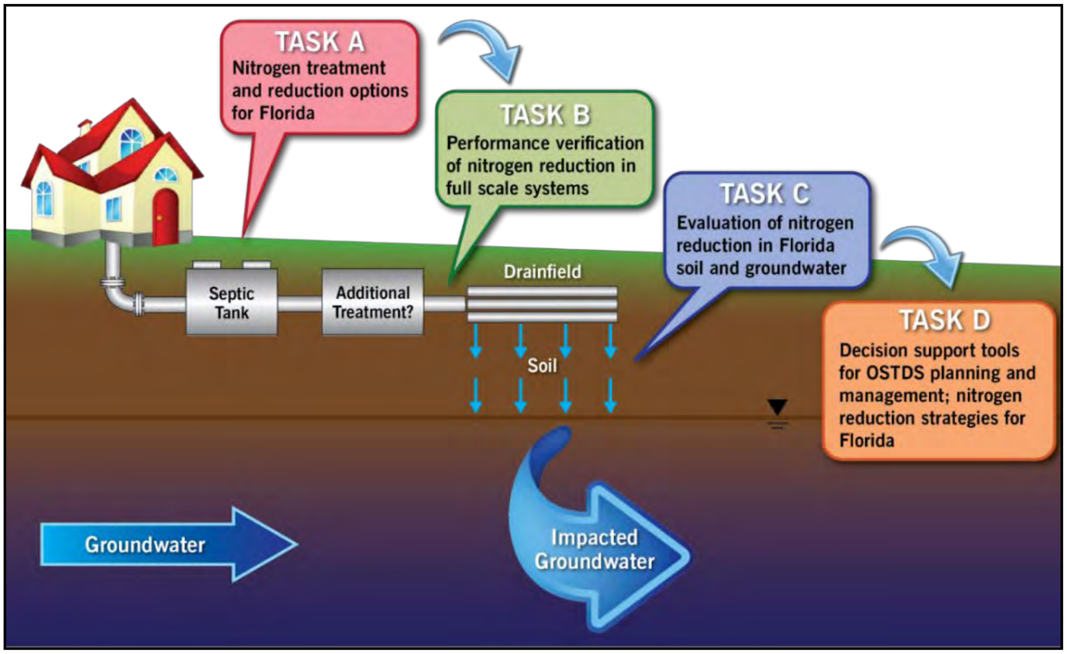

Figure 05. Depiction of the Four Main Tasks Associated with the Florida Onsite Sewage Nitrogen Reduction Strategies Study (Hazen and Sawyer 2015b)

The objectives of Task A, Technology Evaluation for Field Testing: Review, Prioritization, and Development, were:

- Perform literature review to evaluate nitrogen reduction technologies
- Develop technology classification scheme
- Formulate criteria for ranking of nitrogen reducing technologies
- Rank and prioritize nitrogen reduction technologies for field testing
- Conduct technology ranking workshop with RRAC
- Conduct technology development testing and analysis at a constructed test facility

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

- Identify home sites and establish agreements with property owners
- Develop Quality Assurance Project Plan
- Design and construct test facilities
- Install field systems at test facilities and home sites
- Operate and monitor field systems
- Compile results in report format
- Provide description of tested nitrogen removal technologies
- Acceptance of systems by homeowners
- Conduct Life Cycle Cost Analyses
- Final Report for Task B

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

- Literature review of nitrogen reduction in Florida soils and groundwater
- Develop Quality Assurance Project Plan
- Establish a controlled soil and groundwater test facility
- Identify home sites and obtain agreements with property owners
- Install field monitoring instruments at test facility and home sites
- Monitor field sites
- Compile data in report format
- Close-out of home sites and controlled test facility

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

- Literature review on fate and transport models
- Develop Quality Assurance Project Plan
- Develop a model demonstrating unsaturated soil treatment
- Create and calibrate a model demonstrating saturated aquifer transport
- Create a development-scale model, allowing multiple spatial inputs, combining the saturated aquifer transport and unsaturated soil treatment models
- Perform uncertainty analysis
- Validate and refine models using data from Task C

There was also a component of the project that focused on Project Management, Coordination and Meetings, which had the following components:

- Conduct project kickoff meeting
- Prepare progress reports
- Make presentations to RRAC and TRAP

Field Monitoring of Performance and Cost of Nitrogen Reducing Technologies

Selection of technologies for testing

Appendix C gives a detailed summary of the review, prioritization, and ranking of available nitrogen removal technologies. An extensive literature review was performed, which provided a critical assessment of available literature on nitrogen reduction practices, treatment processes, and existing technologies that were suitable for use in individual home and small commercial OSTDS (Hazen and Sawyer 2009a). The review catalogued well over 600 papers, proceedings, reports, and manufacturers' technical materials regarding existing and emerging technologies. The review also discussed nitrogen in the environment and in wastewater, wastewater nitrogen reduction technologies and practices, and Florida-specific strategies for nitrogen reduction in OSTDS.

Results of the findings from the literature review and recommendations for application of nitrogen reduction strategies in Florida led to development of a scheme for classifying nitrogen reduction technologies. This allowed comparisons to be made between the many options that are available for use in onsite sewage treatment systems.

A rigorous prioritization process completed during public meetings of the RRAC determined which nitrogen reduction options were to be tested in this study. In addition to the ranking scores, the criteria used to establish priorities for testing include a representation of several technology classifications, nitrogen effluent performance data, similarity of technologies, and maturity level of technologies. The purpose of prioritization was 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.

More details on individual criteria and how their scores were determined can be found in the Hazen and Sawyer's report on Technology Classification, Ranking and Prioritization of Technologies (Hazen and Sawyer 2009b). It should be noted that the weights assigned to various criteria, the scores, and the resulting ranking were developed by the contractor for the specific purpose within this project of the selecting the technologies for field testing. Other purposes might warrant other weighting or scoring approaches.

Nitrogen removal by two-stage biofiltration was selected as the most operationally simple, effective, and applicable nitrogen removal process for development of Passive Nitrogen Reduction Systems (PNRS) for onsite sewage treatment. Two-stage biofiltration consists of a first stage in which nitrogen from the wastewater is converted to nitrate, and a second stage in which the nitrate is reduced to nitrogen gas that then escapes into the atmosphere.

Pilot-scale study

A test facility was constructed at the University of Florida's Gulf Coast Research and Education Center (GCREC) in Wimauma, Florida to evaluate nitrogen removal by scalable two-stage biofiltration systems, evaluate various unsaturated and saturated media and process configurations, monitor individual performance of unsaturated and saturated biofilters, and monitor performance of configurations that employ both unsaturated and saturated biofilter components in vertical single pass flow. Some of the key features examined were:

- The effects of hydraulic and nitrogen loading rates, on average daily and per dose basis, on first stage effluent nitrogen concentrations.
- The effects of first stage media composition and depth on effluent nitrogen levels.
- The effects of hydraulic and nitrogen loading rates, on average daily basis, on second stage effluent nitrogen concentrations.
- The effects of second stage media composition and depth on effluent nitrogen levels.
- Second stage effluent TN concentrations and speciation into organic, ammonia, and oxidized nitrogen forms.
- Use of first stage recycle to lower nitrogen concentrations prior to Stage 2.

The GCREC is located in southern Hillsborough County, approximately 30 miles from the city of Tampa. It serves as an agricultural research center for the University of Florida and has numerous agricultural demonstration plots located around the facility. The facility has an on-site dormitory and office/conference center/research laboratory space where approximately 71 people work. The constructed test facility used this existing wastewater source (Figure 06 and Figure 07). The sewage nitrogen (N) concentrations ranged from 35 to 75 mg-N/L, which was representative of domestic strength sewage (40 to 70 mg-N/L) (Oakley 2005). This work extended and expanded the previous experimental studies of the two-stage biofiltration process that were conducted by Smith et al. (2008) in a previous study for the Department (PNRS I) into field pilot testing. PNRS II performed field testing of prototype passive nitrogen reduction treatment systems using a variety of candidate biofiltration media. The experiments were set up to closely resemble the functioning of actual OSTDS and were continuously operated such that microbial populations could be established and respond to conditions similar to that found in an operating system (Hazen and Sawyer 2009c).

Figure 06. Test Facility Constructed at the University of Florida's Gulf Coast Research & Education Center (Hazen and Sawyer 2014a)

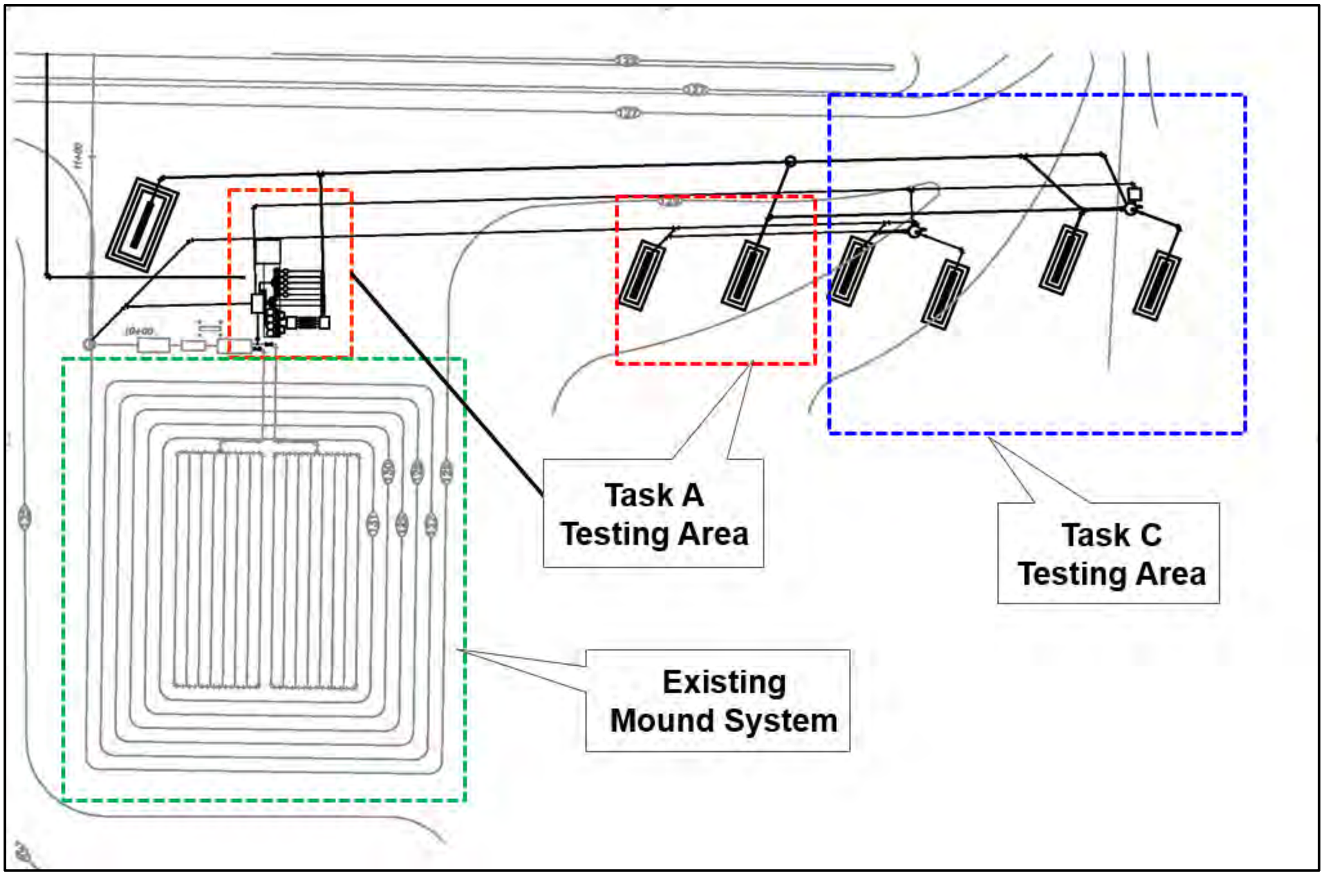

Figure 07. Gulf Coast Research & Education Center Florida Onsite Sewage Nitrogen Reduction Strategies Study Pilot Facility Project Area (Adapted from Final Design Documents for Soil and Groundwater Test Facility)

Prior to beginning the tests candidate materials for reactive media underwent product composition testing in accordance with section 381.0065(4) (m) Florida Statutes, which establishes specific testing and evaluation requirements for materials that are added to OSTDS. The testing requirements include evaluation of volatile organic chemicals by US EPA Method 8260 and acute toxicity bioassay testing by the US EPA Whole Effluent Toxicity 96 hour bioassay protocol.

The concept was that of a two stage biofilter treatment system, where nitrification would occur during the first stage as wastewater trickled down an unsaturated biofilter, and denitrification would occur in the second stage as wastewater flowed up through a saturated biofilter (Figure 08). The unsaturated biofilters included expanded clay, clinoptilolite, expanded polystyrene, and sand media. The saturated biofilters contained reactive media, such as lignocellulosic material (saw dust), oyster shells, and sulfur. The pilot test systems consisted of various configurations of in-tank biofilters and passive in-situ systems (Figure 09 and Figure 10). A total of 22 pilot-scale biofilters were studied for approximately two years with ten monitoring events. Each sampling event consisted of monitoring of field parameters, collection of water samples for laboratory analyses, and measurement of flow volumes and adjustment of flow rates if warranted. There were nine unsaturated biofilters, nine saturated biofilters, and four vertically stacked biofilters. The vertically stacked biofilters were constructed so that both the saturated and unsaturated zones were contained in one unit.

The unsaturated stage in the pilot facility successfully transformed the nitrogen from Total Kjeldahl Nitrogen (TKN) to nitrate. An influent TKN mean of 52.5 mg-N/L was reduced to a mean of 2.4-4.0 mg-N/L. This is an important first step, because TKN does not degrade in the saturated stage. The saturated stage also was successful at transforming the nitrate to nitrogen gas for most of the systems. Nitrogen removal was highly effective with the mean oxidized nitrogen (NO_x) ranging from 0.04 to 0.11 mg-N/L.

The tested configurations resulted in several options that consistently reduced TN influent values by 95% or more (Figure 11). The results of PNRS II, as shown in the final report (Hazen and Sawyer 2014a), were used to develop and implement subsequent evaluations of full-scale systems conducted under the field prototype testing of this project. Design recommendations for the single-family home biofiltration systems generally follow the applied loading rates, media types, media particle sizes, and depth and size configurations of the most successful biofilters used in the pilot study with some recommended modifications based on the pilot-scale results.

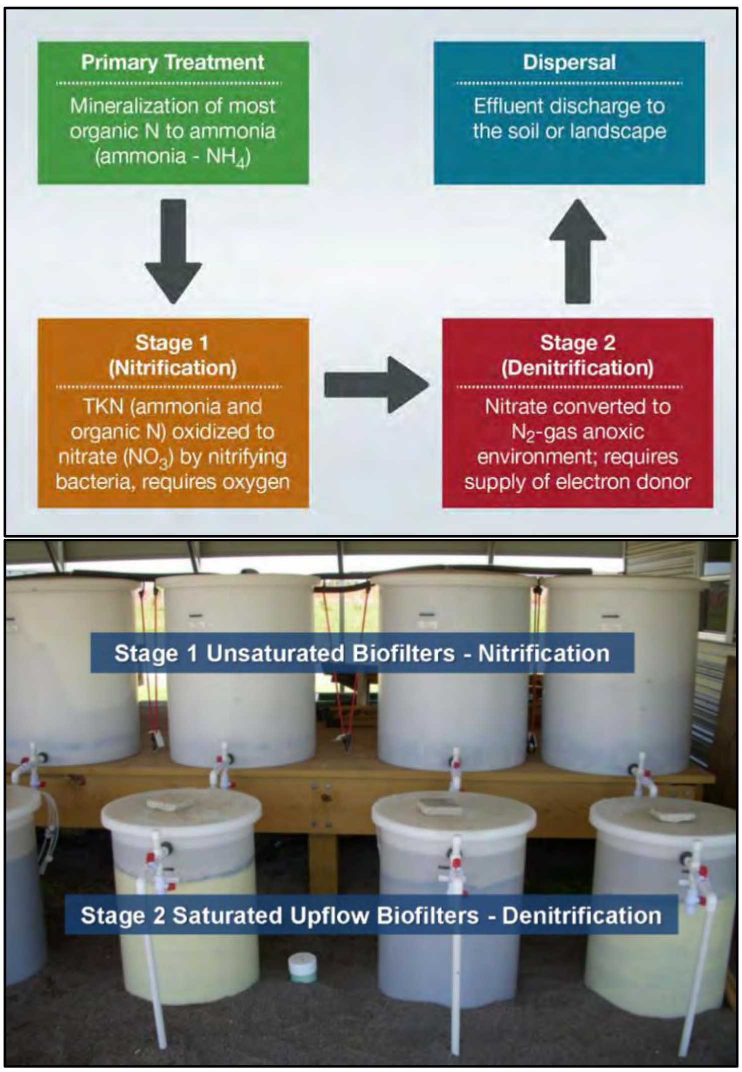

Figure 08. Two Stage Denitrification Concept: Diagram and Test Facility Pilot-Scale Configurations (Hazen and Sawyer 2015b)

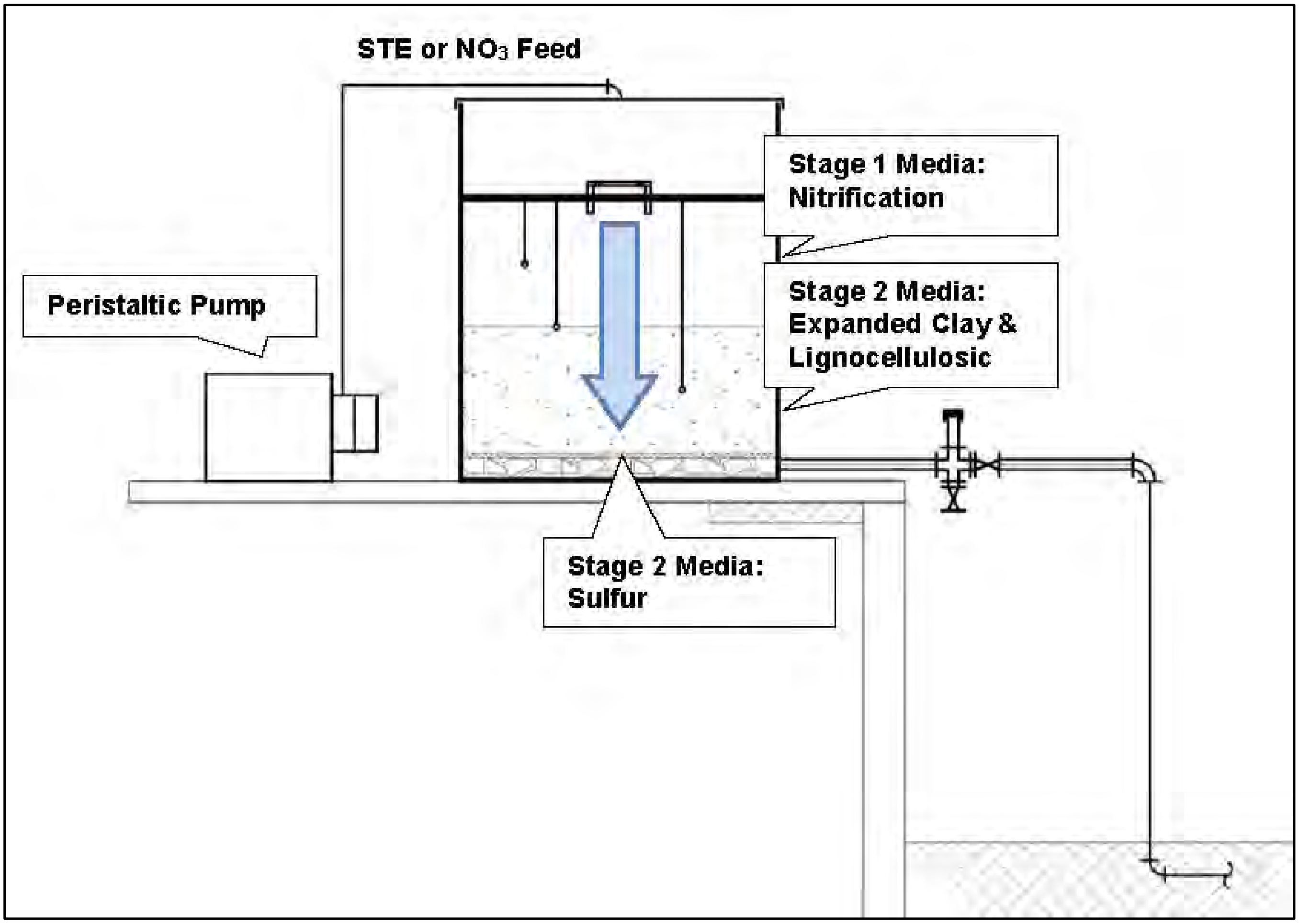

Figure 09. Schematic of Vertically Stacked In Situ Biofilter System (Hazen and Sawyer 2015b)

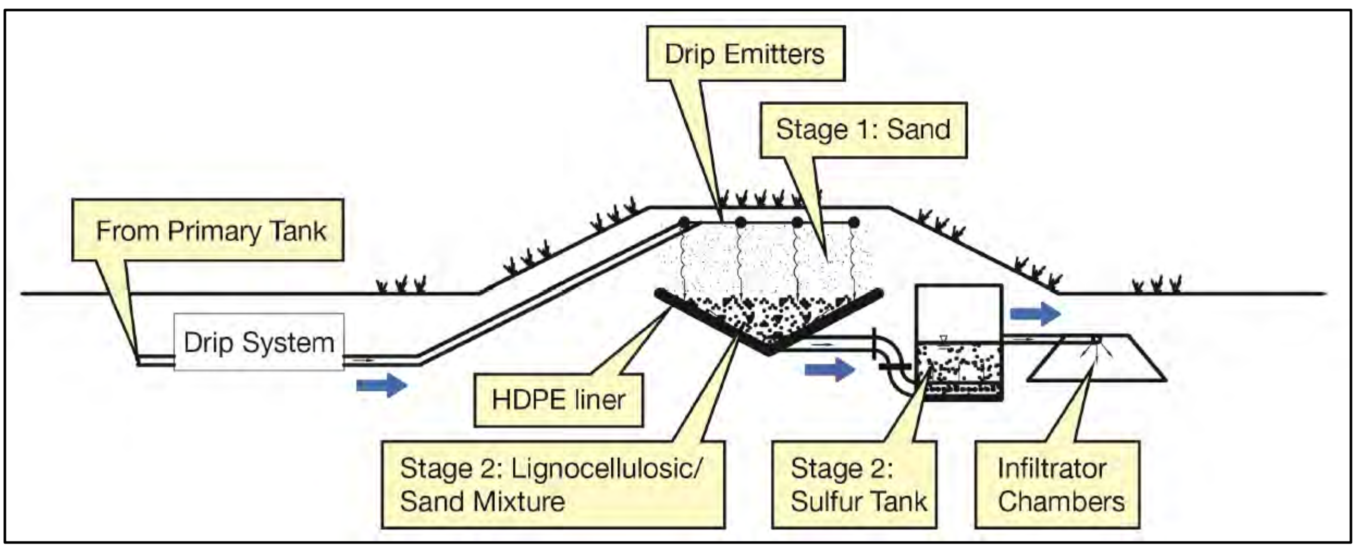

Figure 10. Flow Schematic for the In-Ground Vertically Stacked Biofilter System (Hazen and Sawyer 2015b)

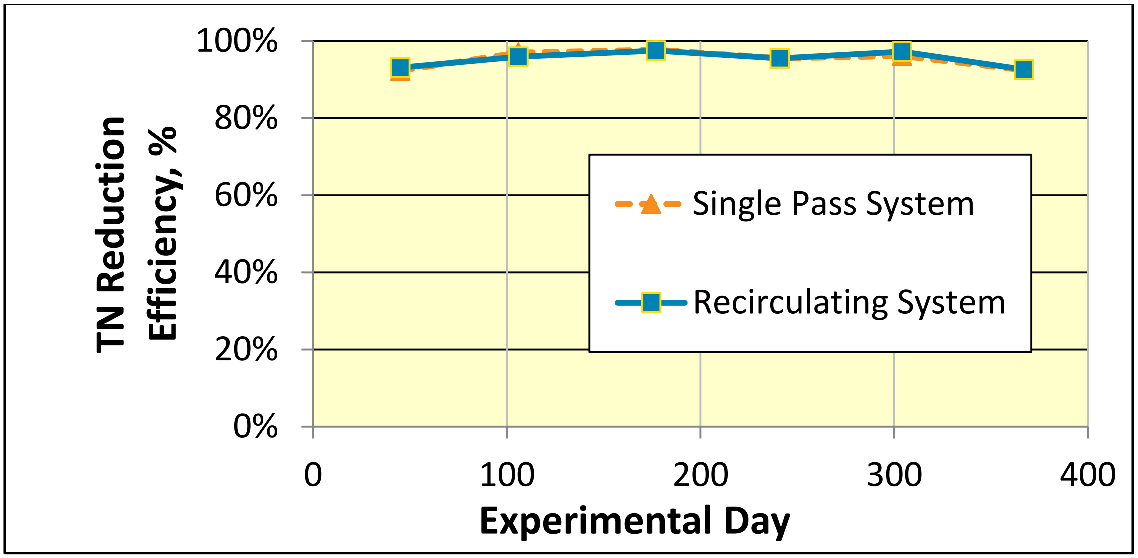

Figure 11. Efficiency of TN Reduction for Pilot-Scale Two-Stage Biofilters with Either a Single Pass or Recirculating Design

Prototype testing at actual home sites

Based on the encouraging pilot system results, seven full-scale systems representing a variety of configurations were installed and tested at existing homes throughout the state (Figure 12). The overall goal for this was to perform field experiments under full scale actual operating conditions to critically assess nitrogen reduction technologies. To accomplish this, several objectives were identified:

- Identify homeowner test sites and establish homeowner agreements
- Install technologies at test sites and document installation issues
- Document installation costs of technologies
- Monitor performance of treatment systems for nitrogen and other water qualtiy parameters and assess performance
- Monitor the energy used and other operational costs associated with system operation
- Monitor routine and non-routine maintenance costs to support life cycle economic analysis
- Close out sites

Site locations were to include three dispersed locations in Florida to provide geographical variety. Example candidate locations were the Wakulla area (north Florida), the Wekiva area (central Florida), and south Florida. Over sixty field site locations were evaluated for suitability for installation of either a full-scale passive nitrogen reduction system or groundwater monitoring instruments (Table 03). After the evaluation, only some of the sites were found to be suitable. Criteria considered in the suitability analysis included: homeowner willingness to host treatment system, site access, number of residents, continuousness of occupancy, power supply, site security, adequate space, access for monitoring and maintenance, participation in previous or concurrent studies, and pre-existing treatment technologies. A homeowner agreement was obtained prior to commencement of work.

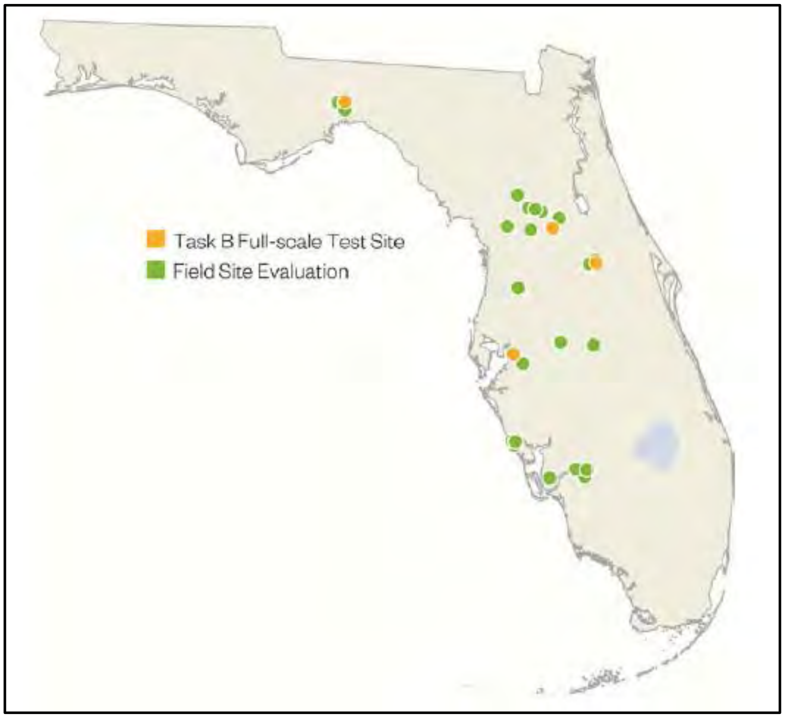

Figure 12. Field Site Evaluation and Test Site Locations for Full-Scale Passive Nitrogen Reducing Systems (Hazen and Sawyer 2015b)

Table 03. Field Work Sites by County for Installation of Passive Nitrogen Systems or Groundwater Monitoring (Hazen and Sawyer 2015b)

County	# Sites Evaluated	# Agreements	System Installation Sites	Groundwater Monitoring Sites
Charlotte	12	0	0	0
Hernando	1	0	0	0
Hillsborough	4	3	1	1 [a]
Lake	1	0	0	0
Lee	4	1	0	0
Marion	8	3	1	0
Orange	2	0	0	0
Polk	3	1	1	1
Sarasota	13	0	0	0
Seminole	8	6	3	1 [a]
Wakulla	4	4	1 [b]	1
TOTAL	**60**	**18**	**7**	**4**

a – Site had both groundwater monitoring and a passive nitrogen system installed
b – Two passive nitrogen systems installed at the same site

The seven prototype single-family residence PNRS evaluated in this study encompassed a variety of designs of passive two-stage biofiltration systems for nitrogen removal. Details on each system are shown in Appendix D.

A Quality Assurance Project Plan was developed (Hazen and Sawyer 2010a) to standardize testing procedures for the field sampling. Each site included monitoring of flowrate or volume of wastewater treated; energy use; media consumption; chemical and microbiological analyses of influent, effluent, and intermediate treatment locations where possible or applicable; and routine and non-routine maintenance. The data sets generated enabled quantification of hydraulic, organic, and nitrogen loading rates; average influent and effluent concentrations; removal efficiencies for nitrogen and other parameters; and effluent nitrogen concentrations achieved.

Field parameters analyzed included temperature, pH, specific conductance, dissolved oxygen, and oxygen reduction potential. Samples were analyzed by the laboratory for the parameters, methods, and detection limits listed in Table D-1 in Appendix D. Specifically the analytical parameters measured were Total Alkalinity as $CaCO_3$, Total Kjeldahl Nitrogen (TKN), Ammonia Nitrogen (NH_3-N), Nitrate/Nitrite Nitrogen (NO_x-N), Carbonaceous BOD ($CBOD_5$), Total Suspended Solids (TSS), Volatile Suspended Solids (VSS), Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), Total Phosphorus (TP), Orthophosphate as P (Ortho P), Fecal Coliform (fecal), E.coli, Sulfate (SO_4), Hydrogen Sulfide Unionized (H_2S), and Sulfide.

Energy consumption was monitored for each system that used electricity. The power usage of the system is primarily due to the single pump, although a small amount of power is used by the control panel itself. The energy use is indicative of the size of the pump motor, the number of pump starts (doses per day), pump runtime (dose volume), and system hydraulic design.

There were two main design ideas for these systems: a tank-based design and an in-ground design. The tank-based designs were based off the pilot biofilter concept in Figure 08. The in-ground designs were based off the vertically stacked biofilters pilot test concepts (Figure 09 and Figure 10).

Life cycle cost analysis

For each of the field site configurations, life-cycle cost assessments were developed, which outline in detail system cost estimates and cost comparisons to existing approved systems (Figure 13). Cost documentation for the systems was categorized by permitting, design, materials and construction, and operation and maintenance. Documentation of the actual field installation, operating, and maintenance costs enabled comparative life cycle cost estimates between the different field-tested systems.

A planning level life-cycle cost tool was developed to estimate the present worth and capital costs for multiple system configurations. Present worth costs are derived by applying discounting to future costs at a specified net interest rate. Total system costs over the entire project life are incorporated in the tool: construction, engineering fees, state and county permitting, system maintenance, media and pump replacement, water quality monitoring and energy, as well as primary treatment solids removal. Capital costs are the sum of construction costs, including tank, STU, media, and contractor fees. The tool is a computer spreadsheet consisting of a series of linked worksheets that can estimate the life cycle costs

of passive onsite sewage nitrogen removal systems, as well as for conventional systems (Appendix E). The user specifies a desired nitrogen removal efficiency range, and the tool provides selections for treatment processes that achieve the removal and estimates the costs for the system. The user guide for the tool (Hazen and Sawyer 2015a) provides detailed instructions on the tool structure and application. Costs are automatically entered based on estimates derived from multiple sources, but these costs allow for user override if more definite costs are known. The tool includes installation costs for new PNRS as well as costs for the addition of PNRS components to existing OSTDS. The recurring annual costs for operation, maintenance, and compliance are also included in the model. Costs are expressed in a variety of ways, such as uniform annual cost and cost effectiveness of nitrogen removal. The tool provides detailed cost breakouts for each life cycle analysis in both tabular and graphical format. Estimates are also provided for the mass of nitrogen removed by each system and the unit cost of nitrogen removed.

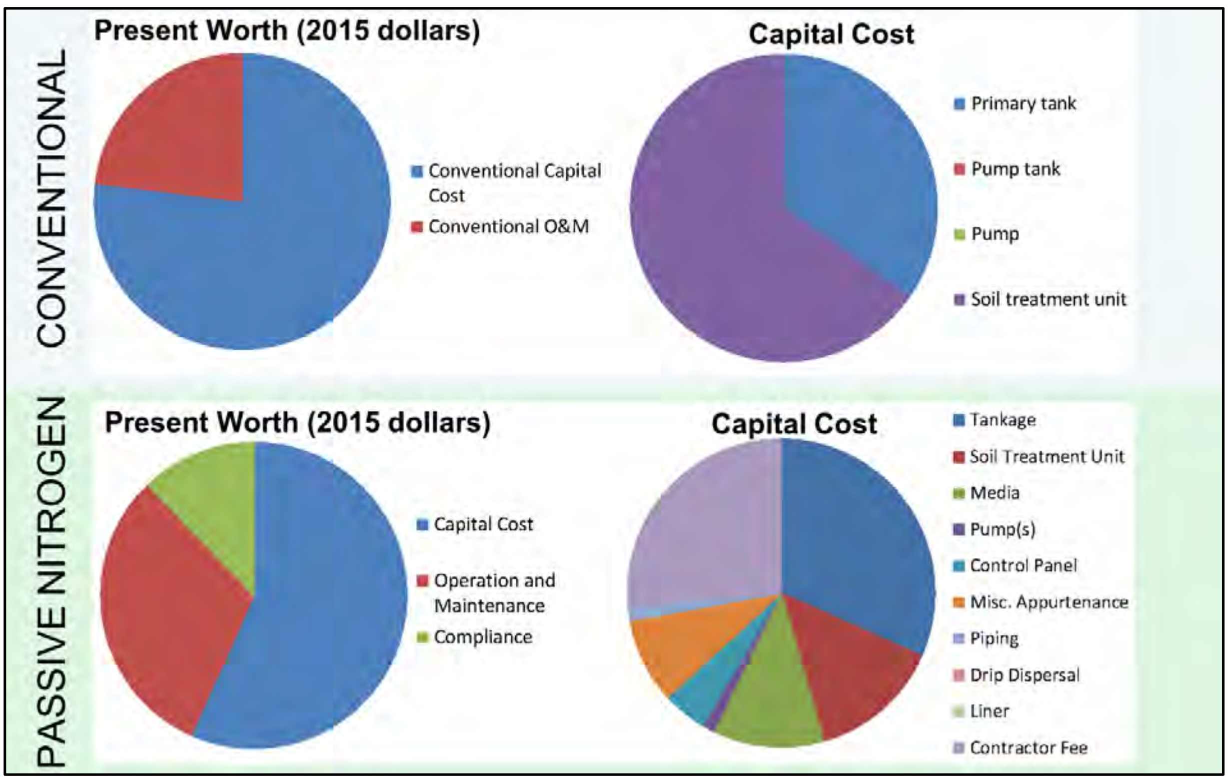

Figure 13. Comparison of Present Worth and Capital Cost for Conventional and One of the Passive Nitrogen Reduction Systems (Adapted from Hazen and Sawyer 2015b)

Appendix E shows the tool results for a conventional system and a passive nitrogen reducing system, as well as the detailed life cycle cost analysis results for each of the actual and standardized field systems. A comparison of the estimated construction costs between the tool and the actual construction costs for the seven prototype systems showed good agreement, with a relative percent error between the two costs of approximately 11%. Of key importance is that non-construction costs accounted for 38 to 57% of the total Present Worth of the prototype PNRS. In general order of higher to lower cost, these items included annual inspection and maintenance fees, water quality monitoring, primary tank solids removal, operating permit fees, energy costs, and media and equipment replacement. The average Present Worth cost per pound of nitrogen removed for the seven prototype

PNRS was $42/lb. N, and ranged from $29 to $52 /lb. N. The average energy use was 0.5 kWh/day with an average field-tested percentage of nitrogen reduction of 85%. When the results from the field systems were standardized to 300 gallons per day for a typical three-bedroom, single-family residence and compared to other cost estimates for more active performance-based treatment system nitrogen removal, the systems associated with this study operated at a lower present worth cost per pound of nitrogen removed ($13.50 less/lb. N.), saved over 2 kWh/day in energy use, and achieved significantly greater (21%) effluent nitrogen removal efficiencies.

Results and Discussion

Systems and results are discussed in more detail in the final technology summary report by Hazen and Sawyer (2015b). Table 04 shows the overall performance of the prototype PNRS.

Table 04. Overall Performance of Prototype Passive Nitrogen Reduction Systems (Hazen and Sawyer 2015b)

System	Stage 1 Operation[3]	Mean TN Removal Efficiency, %	Mean $CBOD_5$ Removal Efficiency, %	Mean TSS Removal Efficiency, %	Mean TP Removal Efficiency, %
Home Site 1 (BHS-5)	SP	97%	87%	94%	85%
	R internal	98%	86%	90%	83%
Home Site 2 (BHS-2)	R tank	93%	36%	76%	40%
	R internal	97%	78%	97%	51%
Home Site 3 (BHS-4)	SP	89%	91%	93%	72%
Home Site 4 (BHS-6[1])	SP	81%	90%	87%	49%
Home Site 5 (BHS-1)	R tank	91%	75%	93%	12%
Home Site 6 (BHS-3)	Drip SP	96%	80%	81%	96%
Home Site 7 (BHS-7[2])	In-ground LP	65%[2]	87%[2]	88%[2]	90%[2]

1 Clogging of internal drainage and distribution pipes within this system caused flooding of the Stage 1 media on several occasions, which hampered performance. Different construction materials for drains and a revised design would eliminate these problems.
2 The reported values are calculated using the mean perimeter monitoring samples. Since it is believed that the hydraulics of the system as designed did not allow most flow to pass through the liner media, this reduction is most likely not attributed to lignocellulosic media, but to reductions in the Stage 1 media. A revised liner design could solve this problem.
3 R tank=recirculation to tank; R internal=recirculation to top of Stage 1 media; SP=single pass; LP=low pressure distribution

Construction of each system was evaluated for cost and ease of construction. The performance and operation of the systems were subsequently monitored for approximately two years with water quality sampling conducted bi-monthly over 18 months. Most of the prototype systems performed very well in actual home site conditions. Several of these two-stage biofiltration systems were capable of consistently achieving more than 90% TN removal from the primary septic tank effluent. Nitrogen

removal performance of the full scale PNRS confirmed the results of previous PNRS pilot testing and established the two-stage biofiltration process as an effective and viable technology for onsite nitrogen removal. The prototype system demonstrations provided valuable guidance for further PNRS design for individual home sites and for planning level analysis to achieve nitrogen reduction goals in Florida.

Detailed soil and groundwater assessments were conducted at one of the home sites prior to and after installation of the full-scale passive nitrogen reduction system. At this home site a marked improvement in groundwater total nitrogen concentrations occurred after the installation of the passive nitrogen reduction system (Figure 14). Sampling point B08 (red dashed circle) showed a TN concentration in the wastewater plume over 35 mg-N/L before installation of a passive nitrogen reduction system and at background levels (0-5 mg-N/L) within a few months after installation. The nitrogen plume under the STU disappeared.

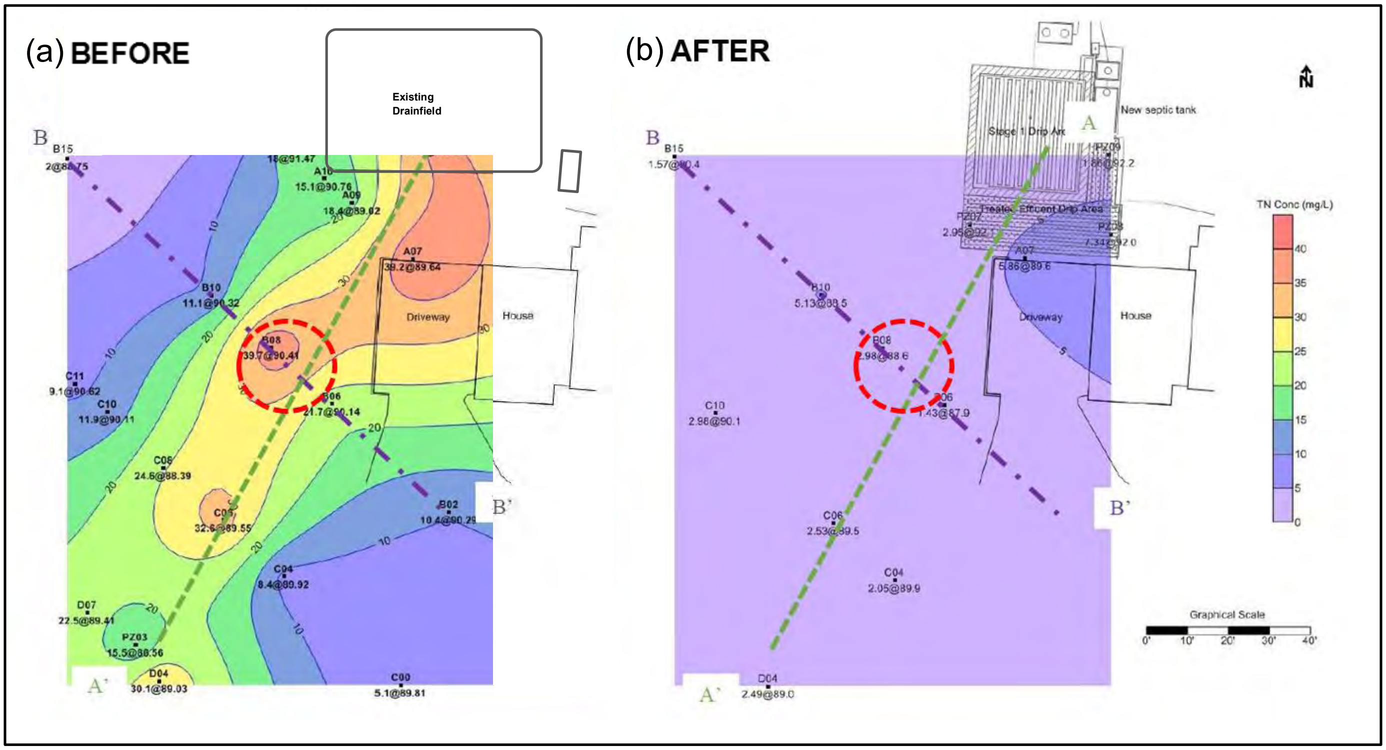

Figure 14. Groundwater Total Nitrogen Concentrations at One Home Site Before (a) and After (b) Installation of a Passive Nitrogen Reduction System (Adapted From Hazen and Sawyer 2015b)

System longevity could not be directly determined in the seven prototype PNRS evaluations due to the very low use of media over the approximately two-year observation period. Theoretical calculations and results of literature review suggests that it would not be difficult to design systems for media life of 25 years or longer. Also, for the in-tank Stage 2 biofilters, it would also be relatively easy to add reactive media, and the sizing of these systems could potentially be reduced if routine media additions were made during the life of the system.

All seven prototype PNRS were installed at existing homes, which required additional construction time and restoration of property, increasing costs as compared to a new home installation. Additionally, these were prototype or innovative systems that had not been designed and constructed previously in Florida and were therefore unfamiliar to the installing contractors. Costs for PNRS are expected to come down with more standard designs and widespread implementation.

The mean estimated as-built construction cost for the seven prototype PNRS was $17,726 and ranged from $10,399 to $32,116. The lowest construction cost was for an in-ground PNRS, which was also the simplest system. While this system's performance (approximately 60% nitrogen reduction) was less than optimal, design revisions to the Stage 2 liner module could potentially make it the most cost-effective of all systems. Highest construction cost was for home site 6, a dual drip dispersal PNRS with effluent reuse for landscape irrigation. Construction costs of in-tank two-stage biofilter PNRS were in the middle of the range with actual construction costs of $18,000 to $20,000.

The LCCA tool calculates the life-cycle cost for a conventional system at $5,500, which includes design, permitting, construction, and operation and maintenance costs. Actual construction costs vary throughout Florida and depend on the local market and specific site conditions.

For a more effective comparison, the LCCA tool was applied to estimate costs for each prototype system for a standardized estimated sewage flow of 300 gallons per day for a typical three-bedroom, single-family residence. This step of "normalizing" the costs narrowed the range of estimated costs considerably. These standardized results were used for two scenarios: a new system installation, and a retrofit of an existing system. For the new system scenario, the tool estimated a construction cost of $4,000 for a conventional tank and STU. For the retrofit of an existing system scenario, it was assumed that the existing septic tank and STU could be used, but that the anticipated complexity of installation would be greater. The standardized estimated costs for the PNRS components for new construction ranged from $8,700-$16,300 with an average of $13,700, and the range for a retrofit of an existing system was $12,000-$20,700 with an average of $16,500.

A conceptual design not tested during this study was one which added a media layer under a gravity fed drainfield. However, this concept is similar in concept to the in-ground PNRS system tested at home site 7, only gravity fed and without the liner. The estimated total system installation costs for that system, based on the LCCA tool results for home site 7, would be $5,200. As this concept was not tested during the study, the theoretical nitrogen reduction effectiveness cannot be calculated using the LCCA tool.

The total life cycle costs calculated for these prototype systems show that a significant component (approximately 50%) are recurring costs. While these recurring costs are based on the current regulatory structure for PBTS systems in Florida, this may change as regulatory schemes adapt to these new technology options. Recurring costs must be included in any economic and planning analysis of PNRS and other alternative technologies as well.

Construction and installation of the prototype systems included the prototyping of several components, such as filter media tanks and liners. Tankage specifically designed for biofiltration is not readily available in Florida. The Stage 1 biofilter tank typically requires an outlet positioned near the bottom of the tank to allow unsaturated operation. In addition, for long term operation and maintenance, easy

access to the surface of the biofilter for maintenance activities is required. A tank with a hinged, lightweight cover which provides secured access to the entire upper surface area of the biofilter is recommended. Similar needs for model specifications and component designs and approvals exist for liners, filter design and treatment media.

Over the course of the study, some problems or precursors to problems were observed in a few systems during the monitoring events. Sampling after a short period of initial operation could serve to establish that an installed system actually performs as designed. The issues included clearly visible problems such as increases in the water level in one of the Wakulla county systems, as well as less visible increases in effluent concentrations after one of the stage 2 filter components. By using two stage 2 components (lignocellulosic and sulfur materials), the final effluent continued to reach low concentrations. Longer-term monitoring is recommended to see if systems continue to reliably work.

The conceptual design for both the in-tank and the in-ground PNRS are shown in Figure 15 and Figure 16, and a summary of each concept is described.

In-Tank System Concept

Wastewater flows through the septic tank (STE) to a tank filled with an unsaturated layer of expanded clay (Stage 1) (Figure 15). Then the wastewater goes to a pump tank (NO_3 Recycle) which recycles a portion back to the top of Stage 1 and pumps a portion to a tank with two sections: a section filled with a saturated layer of wood-chip material (Stage 2A) and a second section filled with a saturated mixture of sulfur and oyster shells (Stage 2B). The wastewater then flows by gravity to the existing STU (Dispersal).

Estimated media longevity:	10-149 years
System performance:	85-95% reduction of nitrogen
Estimated energy cost:	$36 annually / $3 monthly
Standardized cost:	New construction cost estimate for PNRS components: $13,000
	Retrofit of an existing system for PNRS components: $15,500

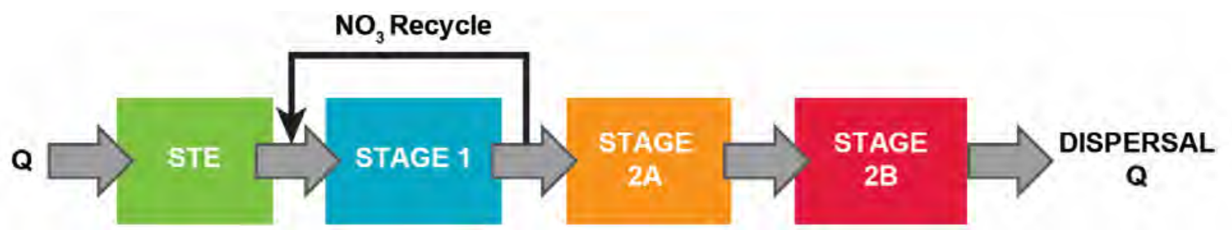

Figure 15. Example Flow Diagram: In-Tank Two Stage Biofilter with Recirculation Stage 1, Dual Media Stage 2 Lignocellulosic (2a) Followed by Elemental Sulfur (2b) (Hazen and Sawyer 2015b)

In-Ground System Concept

Wastewater flows through the septic tank (STE) to a pump tank which pressure doses a lined drainfield to spread the sewage throughout the STU (Figure 17). Under the STU, within the liner, are two layers: an unsaturated layer of regular STU sand (Stage 1 Sand) above a saturated layer of wood-chip material (Stage 2). The treated wastewater flows over the rim of the liner (Perimeter) into the soil (Dispersal).

Estimated media longevity: 10-135 years

System performance: 40-70% reduction of nitrogen

Estimated energy cost: $9 annually / $0.75 monthly

Standardized cost: New construction cost estimate for PNRS components: $8,700

Retrofit of an existing system for PNRS components: $12,000

Figure 16. Example Flow Diagram: In-Ground Stacked Biofilter, Single Pass Stage 1 Over Stage 2 Lignocellulosic (Hazen and Sawyer 2015b)

The results of individual home PNRS testing revealed:

- The PNRS Stage 1 biofilters were all very effective in nitrifying ammonia and organic nitrogen to nitrate+nitrite (NOx) nitrogen. Mean ammonia removal efficiencies for the seven prototype PNRS Stage 1 biofilters ranged from 88 to 100%, which provided a Stage 1 effluent (Stage 2 influent) suitable for denitrification and high TN removal efficiency. The Stage 1 biofilters also achieved 18 – 61% denitrification.
- The PNRS Stage 2 biofilters were very effective in denitrifying NOx nitrogen, thus reducing TN in the system effluent. Mean NOx-N removal efficiency for the Stage 2 lignocellulosic biofilters ranged from 41 to 100%. Mean NOx-N removal efficiency for the Stage 2 elemental sulfur biofilters ranged from 74 to 100%, and concentrations ranged from below detection limits (0.02 mg N/L) to 4.4 mg NOx-N/L.
- The mean TN removal efficiency for seven full scale prototype passive two-stage nitrogen removal systems ranged from 65 to 98% with an overall mean of 90% for all systems.
- The mean effluent TN concentration for the seven prototype PNRS ranged from 1.8 to 19.1 mg/L. The most refined and best performing prototype systems (home sites 1, 2, and 6) produced a mean effluent TN concentration of 2.6 mg/L.
- The mean $CBOD_5$ removal efficiency for the seven full scale prototype passive two-stage nitrogen removal systems ranged from 36 to 91% with an overall mean of 79% for all systems. The mean Stage 2 effluent in most of the systems showed an increase in $CBOD_5$ concentration as compared to the Stage 1 effluent which may be attributed to $CBOD_5$ release from the lignocellulosic media itself.
- The mean TSS removal efficiency for the seven full scale prototype passive two-stage nitrogen

removal systems ranged from 76 to 97% with an overall mean of 89% for all systems. The mean effluent TSS concentration for all seven systems was below 10 mg/L.

- The mean Total Phosphorus (TP) removal efficiency for the seven full scale prototype passive two-stage nitrogen removal systems ranged from 12 to 96% with an overall mean of 64% for all systems.
- The geomean of effluent fecal coliform concentration for the seven prototype PNRS ranged from 1 to 1,838 cfu/100 mL. The most refined and best performing prototype systems (home sites 1, 2, and 6) produced an effluent fecal coliform concentration below 60 cfu/100 mL.
- The mean effluent sulfate concentration for the five full scale prototype passive two-stage nitrogen removal systems that utilized sulfur media ranged from 37 to 248 mg/L. Therefore, the mean effluent sulfate levels were below the secondary drinking water guideline of 250 mg/L for all systems utilizing sulfur media.
- Mean electrical consumption of the prototype PNRS was 4.5 kw-hour per 1000 gallons of wastewater flow from the home and ranged from 0 to 28.7 kw-hr/1000 gallon. The highest energy usages were for home site 5 due to a Stage 1 biofilter with a very high recirculation ratio. The average electrical use, excluding home site 5, was estimated to be less than $2.00 per month for a PNRS.
- Operation and maintenance (O&M) of the prototype PNRS systems reflected system complexity. The simplest system O&M was the home site 7 in-ground PNRS, which has O&M requirements similar to a conventional OSTDS with pressure dosed STU. Slightly more complex were the in-tank PNRS with single pass Stage 1 biofilters but the O&M of these PNRS was also relatively simple. The O&M of the in-tank PNRS with Stage 1 recirculation is only slightly more complex than the single pass systems, in that timed dosing is added to the controls, and the recirculation ratio must be checked and adjusted occasionally.
- The longevity of the PNRS reactive media could not be determined directly in the seven prototype PNRS evaluations due to the very low use of media over the approximately two-year observation period. Theoretical calculations and literature experience with both lignocellulosic and sulfur Stage 2 biofilters suggests that it would not be difficult to design systems for media life of 25 years or longer. It would also be relatively easy to add reactive media to the in-tank Stage 2 biofilters, and sizing of these systems could potentially be reduced if routine media additions were made during the life of the system.

Analysis of Nitrogen in Soil and Groundwater

Review of existing research

A literature review was performed to establish the current state of research on nitrogen impacts to groundwater resulting from the use of OSTDS (Hazen and Sawyer 2009d). Fate and transport processes that are present in the OSTDS, vadose zone, and saturated zone will influence the extent of nitrogen impacts to groundwater. These factors, along with factors related to groundwater/surface water interactions, will also determine if nearby surface water bodies are adversely affected. A searchable database was developed containing available literature examining the influences of OSTDS-derived

nitrogen inputs, the transformative processes that impact nitrogen distribution, and the key factors that result in a significant effect to groundwater quality from OSTDSs. Sampling plans were developed to collect data for the factors described in the literature. Predictive models and strategies for reduction of impacts were also developed based on findings presented from the literature review.

Nitrogen leaving the septic tank

As a starting point for the analysis of nitrogen in soil and groundwater, one needs to know how much nitrogen enters the soil. This input is estimated by the amount of nitrogen leaving a septic tank, unless higher pretreatment is provided. This section is an addition to the literature review by Hazen and Sawyer (2009d). Input and loading generally requires the measurement or estimation of two parameters: flow and concentrations. Both are variable within a household and between households, due to variations in how and how much wastewater is generated. This variability then leads to uncertainty about the best representative value. One approach to standardize inputs and reduce variability is to refer to inputs per person and time.

An estimated 5 kg (or 11 lb) of nitrogen per person and year enters a septic tank. Wastewater engineering handbooks provide a range of values typically between 4.1-5.5 kg (9-12 lb) TN per person and year. These sources tend to cite each other. A literature review for a Water Environment Research Foundation (WERF) project (Lowe et al. 2009) to characterize sewage encountered in OSTDS identified only very few data sets for which both per person flow and concentrations of raw wastewater had been determined. For this WERF-project, 16 single-family residences were monitored over a year. The average for the raw sewage entering the septic tank of each house was 5.3 kg (11.6 lb) of TN per person and year.

Approximately 4.5 kg (10 lb) TN per person and year leaves the septic tank. Many past estimates used values for flow and concentration from different studies to arrive at an estimate of nitrogen inputs from a septic tank to the STU. The data for the WERF-project (Lowe et al. 2009), result in an average for each house of 5.0 kg (11.1 lb) TN per person and year, with a range from 1.8 to 17.5 kg per person and year. The difference between raw sewage and septic tank effluent was not significant in this study relative to the variability of inputs.

For Florida-specific septic tank effluent nitrogen mass loading rates, the results of the WERF-study systems in Wakulla County were combined with other results from studies in Florida. This included the three systems studied for the Department’s Wekiva study and three systems studied during a DEP/USGS/FSU study in Wakulla (Katz et al., 2010) (Figure 17). Figure 17 also shows the results of single-family residences and all individual daily sample events during the WERF-study. The average was 4.5 kg (10 lb) TN per person and year leaving the septic tank.

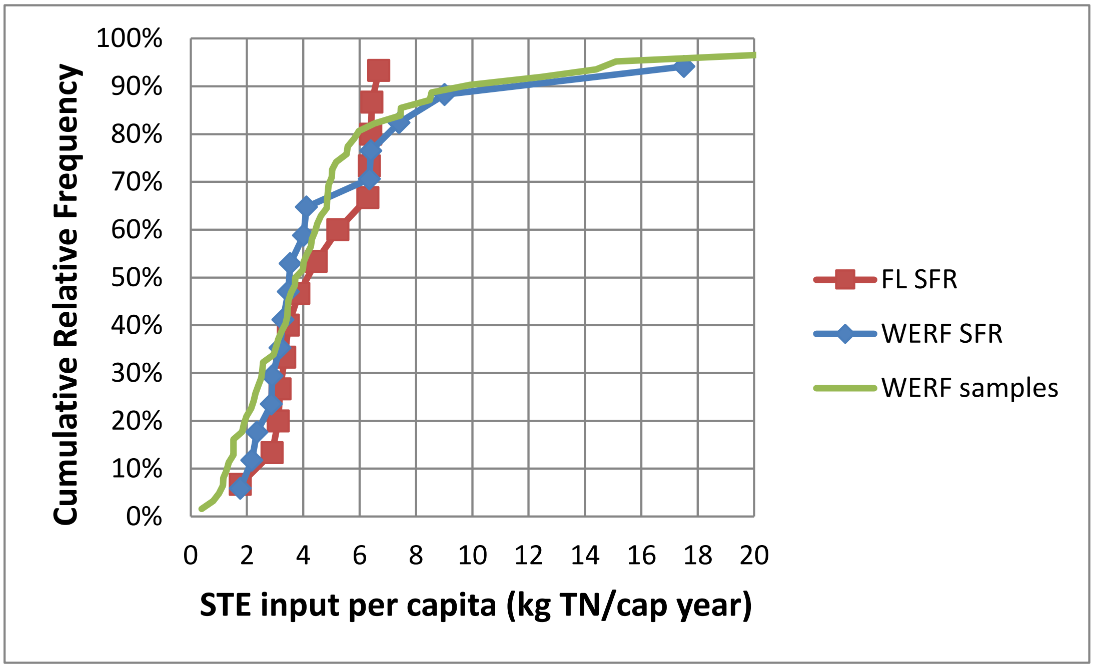

Figure 17. Estimated Nitrogen Input per Person from Septic Tanks serving Single-Family Residences based on WERF-project Data (Lowe et al. 2009), and Florida Studies

The information gathered during the course of the study provides more data on how much nitrogen leaves OSTDS (Table 05). The data for C-HS1 and C-HS2 are treated separately, because only one sampling event occurred (C-HS1) or several sampling events seemed to include water use, such as pool filling, construction activities, and irrigation that would be unrepresentative of regular onsite system use (C-HS2). All data for the location of PNRS home sites 4 and 5 were averaged because no changes in occupancy and use were reported. Based on the provided average concentrations and flows, an average of 28 pounds per year left the septic tanks investigated over the study periods of at least a year. The average input per capita was 9.6 pounds per year, ranging from 6.8 to 13.2 pounds per year (3 to 6 kg per capita and year). This range is similar to the ranges found in the studies summarized in Figure 15. The average flow per capita was approximately 50 gallons per day.

Table 05. Summary of Nitrogen Leaving OSTDS Investigated During the Study ("Input")

Location	TN Concentration (mg-N/L)	Flow (gpd[1])	TN input (lb/yr)	Occupancy (capita)	Per capita TN input (lb/cyr[2])	Per capita TN input (g/cday[3])
PNRS home site 1	72.1	135	29.6	3	9.9	12.3
PNRS home site 2	54.7	101	16.8	2	8.4	10.4
PNRS home site 3	70.1	297	63.4	5	12.7	15.8
PNRS home sites 4 and 5	74.5	120	27.1	4	6.8	8.4
PNRS home site 6	50.5	119	18.3	2	9.1	11.4
PNRS home site 7	54.9	158	26.4	2	13.2	16.4
C-HS3	45.7	98	13.6	2	6.8	8.5
Average	**60.4**	**147**	**27.9**	**2.9**	**9.6**	**11.9**
C-HS1	110.2	146	48.9	4	12.2	15.2
C-HS2 sampling event 7/26/11	80.1	178	43.4	2	21.7	27.0

1) Gallons per day
2) Pounds per capita and year
3) Grams per capita and day
4) C-HS2= PNRS home site 6, sampling event 7/26/11

Nitrogen reduction in unsaturated soils

Hazen and Sawyer (2009d) reviewed the literature on the fate and transport of contaminants from on-site systems. Soil treatment of nitrogen from OSTDS in the vadose zone can have a significant influence on the resulting nitrogen concentrations in the aquifer. The transformations and reactions of sorption, nitrification, and denitrification occur 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.

Reneau et al. (1989) considered multiple factors, including soil type, loading rates, effluent quality, and carbon content. In this review the authors describes the important mechanisms related to OSTDS performance. First, there is 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.

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)
- Recirculating sand filters (and other aerobic treatment units may improve denitrification)

Based on the literature review, a 30-40% removal appears to provide a central estimate for nitrogen reduction in the vadose zone. Anderson and Otis (2000) estimated a 10-50% removal range from many studies. For STUs meeting current code (post 1983), and having a 24-inch separation to the estimated seasonal high groundwater table, R. Otis (2007) estimated fractions of discharged nitrogen that would reach the water table based on soil conditions for the Wekiva study. These estimates were based on pretreatment, drainage class and amount of organic carbon found in the soil. Katz et al. (2010) found, "After adjusting for dilution, about 25 to 40% N loss (from denitrification, ammonium sorption, and ammonia volatilization) occurs as septic tank effluent moves through the unsaturated zone to the water table." A 2010 Mactec estimated that 44% of the nitrogen leaving the septic tank reached the groundwater as nitrate. This was based on an evaluation of the results of the Department’s 2007 field study in the Wekiva Study Area. The removal rate was somewhat higher than estimated by the Department because it was based only on nitrate reaching the groundwater, rather than TN. The Department assumed a 40% reduction of TN input in the Wekiva Study Area.

Nitrogen reduction in saturated soils and groundwater

The literature review (Hazen and Sawyer, 2009d) suggested reductions in groundwater nitrogen impacts associated with OSTDS are achievable with a few steps. Nitrate is highly mobile in groundwater and the only significant method of natural attenuation is denitrification, a process that the review indicated does not always occur in Florida’s aquifers. Therefore, reduction of nitrate contamination may be most efficiently approached in the design and installation processes when considering OSTDS as a treatment alternative.

The review also indicated that reducing nitrogen prior to infiltration by including additional treatment of wastewater could improve effluent quality. 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, could impact the treatment ability of OSTDS by varying oxygen content and redox conditions. The presence of karst topography under the OSTDS could also impact nitrogen flow paths and rates. If unfavorable conditions are observed at a site being considered for OSTDS, other methods of wastewater treatment may be appropriate. This could also be true for areas identified as “vulnerable” or “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.

Land use planning and density of OSTDS in new developments is one mechanism to limit nitrogen inputs to the soil and groundwater. Recognizing the importance of dilution for nitrate concentration reductions, lot size considerations may also be evaluated to allow adequate dilution of nitrogen enriched recharge water in groundwater.

Test facility groundwater monitoring

Monitoring of the effluent plume in groundwater was initially performed at a large mounded STU on the GCREC test facility site. The OSTDS serving the GCREC facility was designed for flows of 2,500 gallons per day and receives primarily domestic wastewater from the offices. This OSTDS provided controlled conditions and the size of the mound made it easier to find the plume and gather insights on the effects of size. Elements of the groundwater monitoring are outlined in Table 06 and in Appendix F.

Table 06. Steps to Monitor an OSTDS Effluent Plume (Hazen and Sawyer 2015b)

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 using a conservative tracer	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 plume delineation, denitrification rates, aquifer properties, etc.

Test areas representative of typical mounded OSTDS were constructed at the GCREC Soil and Groundwater Test Facility to enable controlled testing and evaluation of nitrogen reduction in soil and groundwater. Four test areas were 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. STE was delivered at the maximum hydraulic loading rate, representing the highest allowable mass loading rate

to the soil, and provided the most conservative nitrogen removal resulting in the highest expected concentrations of nitrogen reaching the groundwater. However, it was 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 enabled 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 were 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 was designed to optimize nitrogen removal through plant uptake and reduced the mobile nitrate-nitrogen fraction that recharges the groundwater.

Each test area was monitored for operational conditions, unsaturated and saturated nitrogen concentrations, soil properties, groundwater properties, and weather conditions. Details on the monitoring plan can be found in the Quality Assurance Project Plan (Hazen and Sawyer 2010b).

Tracer tests were conducted at two times during test area operation; prior to effluent delivery and after six months or more of effluent delivery. Bromide (Br-) was 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 occurred. The first tracer test, prior to effluent delivery to the test areas, enabled characterization of the background groundwater velocity and dilution. A second test was conducted after the groundwater plume had been defined and enabled comparison of the subsurface changes attributed to effluent delivery.

Groundwater monitoring at home sites

Three detailed soil and groundwater assessments were completed to evaluate existing OSTDS over a 12-month period to capture seasonal variability. These home sites were located at existing homes in Polk, Seminole, and Hillsborough counties. Additionally, some monitoring at one of the prototype PNRS systems in Marion County and an additional home site in Wakulla County was performed. At each site, initial visits inspected the OSTDS and attempted to identify the nitrogen plume in the groundwater beneath the STU. This included instrumentation of the site with a combination of drive points (one-inch long screens driven to a specific depth), piezometers (PVC-pipes with five or ten-foot long screens installed in the shallow groundwater, and lysimeters (nine-inch long ceramic suction cups). Details of the methods are outlined in the Quality Assurance Project Plan (Hazen and Sawyer 2010b). The Marion county site, also Home Site 7 of the technology evaluation, included soil treatment but not groundwater monitoring. Results and conclusions from the groundwater monitoring are discussed in more detail in Appendix F.

Discussion

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. The project approach, by monitoring selected individual OSTDS, observed the nitrogen fate and transport resulting from the combination of such factors in effect at each site. The modeling tools discussed later were better suited to assess the impact of particular factors. Having an understanding of the processes that occur within these two locations is important, rather than just considering processes in the aquifer.

To determine movement of nitrogen in soil and groundwater, the plume from a large OSTDS at GCREC was delineated. Additionally, three OSTDS at existing homes in Polk, Seminole, and Hillsborough counties were assessed. There was also some monitoring performed at one of the PNRS prototype systems in Marion County and an additional home site in Wakulla County.

Within the contract, Hazen and Sawyer collected the data and processed them in the form of contour plots. This allowed a visualization of where elevated concentrations of, in particular, nitrate could be found relative to the location of the STU. Hazen and Sawyer and the Colorado School of Mines performed limited additional analyses of the data in the context of corroborating the modeling tools. Subsequently, Department staff compared nitrogen and other data, in particular specific conductance, to assess the plume behavior. Based on the assumption that specific conductance behaves as a conservative tracer, reactions and dilutions could be distinguished as factors in explaining nitrogen reductions in the soil and groundwater.

The plume from the existing GCREC-mound was assessed over several sampling events, with numerous sampling points, and varied influent concentrations. The location in the mound showing the highest nitrogen concentration was located close to the upstream end of the STU. There are several scenarios that may explain the increased concentrations over part of the monitoring domain. The project team suspected agricultural fertilizer impacts from upstream. Variations in flow and concentration in the septic tank effluent could have influenced part of the plume more than others. The location close to the tanks could also suggest a less well distributed source of wastewater.

Regardless of scenario that explains elevated concentrations, the monitoring points show predominantly nitrified samples. At most points with high concentrations of nitrogen, when compared to other field parameters, any reductions of concentrations appear to be mainly due to dilution rather than denitrification. This indicates that even though the soil series at the site have a high water table that is expected to assist in denitrification, during the monitoring event denitrification was not effective at the core of the plume.

All four of the constructed test areas exhibited high total nitrogen concentrations at a depth 42-inches below the infiltrative surface and complete ammonia nitrification 12-inches below the infiltrative surface. The ATU effluent test areas show substantially lower nitrogen concentrations than the STE test areas, as would be expected based on the ATU-effluent containing lower nitrogen concentrations than the septic tank effluent fed to the test areas.

Surfer™ is a useful tool for contour mapping; however, it cannot project a 3-dimensional view of concentrations with depth. Therefore, the concentrations of parameters were "lumped" from the different sampling locations into "slices" of similar depth, allowing the different "slices" to be compared.

The results of the data collected at the constructed test areas have allowed for estimations of groundwater flow, gradient, and velocity, and provided additional insights into the general trend of the nitrogen transformations and NOx plume for each of the test areas.

Most of the monitored STUs at the home sites were effective at converting nitrogen from its organic and ammonia forms leaving the septic tank into nitrate in the unsaturated soil. In most cases, this conversion was complete. At most monitored field sites, a nitrogen plume was identified that extended beyond the STU. The data at these sites were consistent with movement to surface water features at three sites. The Polk County site indicated at least partial movement to a lake, at the Seminole County and GCREC mound site groundwater moved toward drainage or stormwater conveyance features. An exception to the complete conversion to nitrate was observed in part of the plume at the Seminole County site, where some sampling points in the plume showed incomplete conversion to nitrate. These sampling points showed no nitrate, indicating nitrogen reduction. This was an STU that had been installed during a repair with lesser separation to the water table. The remainder of the STU appeared to achieve complete conversion of septic tank nitrogen to nitrate, which then traveled to the property boundary. In most cases, the plume moved horizontally and remained in the shallow groundwater. In the case of the Polk County and Wakulla County sites, the deeper observation points still contained nitrogen concentration. Vertical transport was not completely characterized. Vertical transport would provide a pathway into deeper groundwater.

The main conclusions reached using the data from the literature review and the groundwater monitoring done as part of this study are that modern STUs are effective at converting nitrogen from septic tank effluent into nitrate and that the nitrate travels well in groundwater. STUs closer than 24 inches to the seasonal high water table and STUs in karst are more difficult to monitor and characterize completely. These conclusions can be applied to nitrogen impact estimates in future studies and how to appropriately monitor and sample a site that will utilize OSTDS. The insight gained from monitoring the soil and groundwater plumes provided information for the development of the models. 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, leading to better predictive methods for estimating nitrogen impacts.

Nitrogen Treatment in Florida-Specific Soils: An Analysis of Various Models

Review of existing research and modeling approach

A review of the literature, the conceptual understanding of the transport of nitrogen as related to OSTDS, and the goals of the project were all taken into consideration in the development of modeling tools. The literature review was intended to identify the state-of-knowledge of nitrogen fate and

transport modeling, identify past models that may provide good templates for the model developed by the study, and assist in identifying key parameters and processes that needed to be represented in a predictive tool (Hazen and Sawyer 2010c). Appendix G provides details on the results of the literature review as well as details on work performed on model development for this project.

The objectives for the model development were the following:

- Simple soil tool to estimate nitrogen removal in different Florida soils
- Complex soil treatment module for input into the groundwater modeling tool
- Analytical groundwater transport modeling tool to predict temporal and spatial concentrations and fluxes of nitrate in groundwater
- Integration of complex soil treatment module with the groundwater analytical model
- Incorporation of multiple spatial inputs (i.e., development scale model)

A combination of approaches were used in the development of the modeling tools:

The first nitrogen model approach (simple soil tool) consisted of the adaptation of an existing detailed numerical model to simulate nitrogen transport in two dimensions in the vadose zone. Results from a range of soil and effluent loading scenario simulations of this complex model were then incorporated into a look-up table as a very easy-to-use model.

The second modeling approach (complex soil treatment module) consisted of the further development of a one-dimensional vertical transport model that describes the transport from the infiltrative surface of the STU through the unsaturated soil (vadose zone). Adaptations included the consideration of soil layers and the water table at the bottom of the modeled zone, as well as a characterization of Florida soils to obtain model parameters. One product of this approach was a set of graphs that describe nitrogen reduction with depth.

The third modeling approach (groundwater transport model) was based on a set of equations that describe nitrogen transport and removal in groundwater. The groundwater module describes horizontal transport with the groundwater flow and some spreading in lateral and vertical direction. The flow of groundwater is assumed to be horizontal through uniform material that behaves like sand. Therefore, this model is not well suited for transport in karst areas, or high recharge areas. In such areas, vertical flow directions and flow through conduits make the transport more complex.

Subsequently, the soil treatment module was integrated with the groundwater transport module. In its final form, the model had the capability to either model only the vadose zone, only model the groundwater, or model the transport of nitrogen through both the vadose zone and groundwater.

This soil and groundwater model was subsequently adapted to allow for the calculation of concentrations stemming from multiple OSTDS.

The development of guidance documents for model application, parameter choices, and addressing uncertainty was anticipated for the very end of the project. A few of these tasks were eliminated due to budget and time constraints. Hazen and Sawyer (2015d) presented the user's guide for the model. Early in the project, an analysis was done on soil survey information for typical Florida soils. The results of this analysis lead to the determination that a grouping of Florida soils into three soil types for

modeling purposes would cover a range of likely situations: more permeable sands (MPS), less permeable sands (LPS), and sandy clay loam (SCL).

Two-dimensional model of unsaturated soils

Information from the literature review and some of the sample results collected during this project were used for the adaptation of a numerical model (HYDRUS-2D) to develop and corroborate a model for nitrogen fate and transport through the unsaturated soil to groundwater. A range of scenarios were simulated to obtain estimates of nitrogen removal based on the model. Results of this effort were used to develop a series of look-up tables based on illustrative simulations, such as the one shown in Figure 18. These simulation results can be used to evaluate different combinations of variables such as STU configuration, water table elevation, input nitrogen concentration, and wastewater loading consistency.

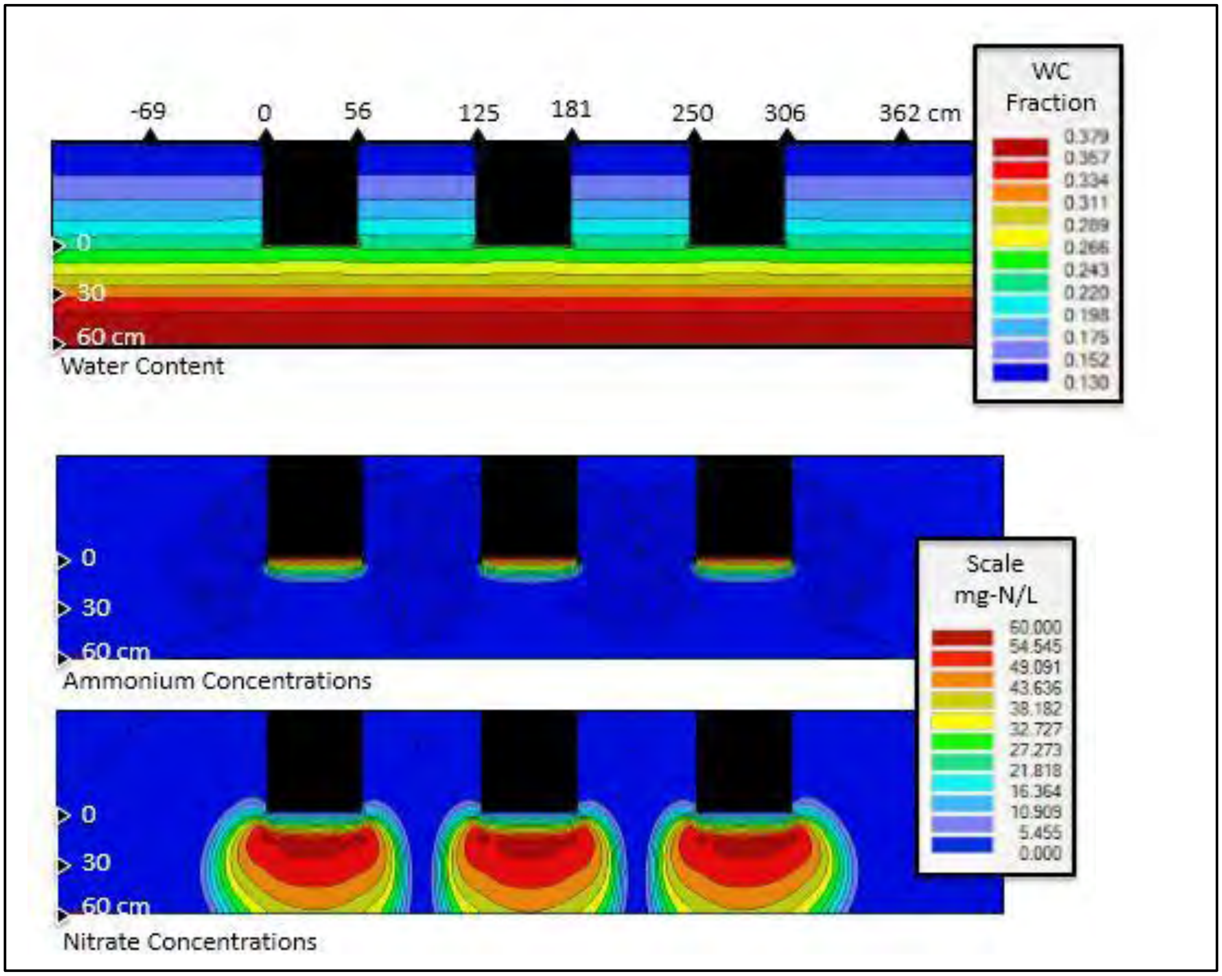

Figure 18. Vadose Zone Model Example Showing Ammonium and Nitrate Concentrations under an Equally Loaded Trench Configuration with a Groundwater Elevation of 60 cm under the Bottom of the Soil Treatment Unit in Less Permeable Sand (Hazen and Sawyer 2013c)

One-dimensional vertical nitrogen transport and transformation unsaturated soil model

The model was originally developed at the Colorado School of Mines through support from the WERF and was called the Soil Treatment Unit Model, or STUMOD (McCray et al. 2010; Geza et al. 2013). This modeling tool considered one-dimensional vertical transport and transformation (chemical and physical) of water and nitrogen in the vadose zone, because the nitrogen transformations that occur in this zone have considerable influence on the mass-flux input into the underlying groundwater. This model was modified through this project to include Florida specific soil and climate conditions, such as the existence of a water table. This new version was called STUMOD-FL. The one-dimensional model was used to estimate nitrogen removal for a range of scenarios. Detailed discussions are found in the reports for Task D10 (Hazen and Sawyer 2014b). In the final implementation, the model allowed for inputs for multiple OSTDS with varying soils.

An example of the results from this model is shown in Figure 19. The results are for a water table located two feet below the infiltrative surface. The line colors represent different soil textures. For each color, different load configurations are included (trenches and beds, equal or unequal distribution). The TN concentration in septic tank effluent is assumed to be 60 mg/L, therefore this is where all lines start at the infiltrative surface. With increasing depth (to the right), concentrations are reduced as a result of the combined effect of nitrification and denitrification. The model results showed that much of the nitrogen reduction occurs in the transition zone between unsaturated and saturated soil just above the water table

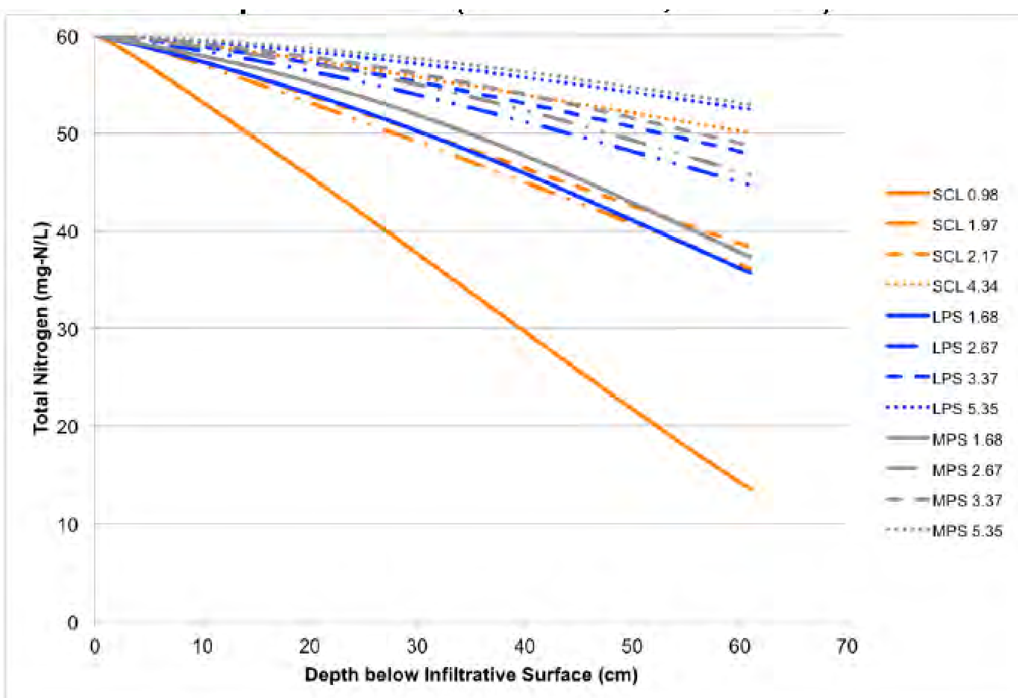

Figure 19. Example of Graphical Summary of One-Dimensional STUMOD-FL Estimates of TN Reduction (Hazen and Sawyer 2014b)

Nitrogen transport in groundwater model

A spreadsheet model for groundwater transport of nitrogen from OSTDS was further developed to simulate nitrogen transport through the soil and in shallow groundwater (Hazen and Sawyer 2015d). Figure 20 shows the user interface of this model.

The modeling tool built on the one-dimensional soil transport model discussed before. It was implemented in a spreadsheet while maintaining simple and straight-forward input requirements. For groundwater transport, a horizontal plane source (HPS) was used as a conceptual model. In this model, the nitrate arriving from the STU (either from the soil model or input directly) is spread out over some rectangular area (e.g., the STU area) and enters the groundwater at the water table. From there, the transport follows groundwater flow horizontally with dispersive spreading vertically and laterally. The model calculates the mass flux and concentrations of nitrogen downstream at a specified distance from one or multiple sites.

The model assumes that the vertical and subsequent horizontal transport of nitrogen from one system does not interact with that from the other system. Nonetheless, the model allows for the assessment of multiple OSTDS, which may have value when simulating the impact of several OSTDS in a potential housing development.

This easy-to-use tool was based on a complex model. This increased the applicability of the model while maintaining an adequate ability to predict contaminant fate and transport. With such a model, barriers to understanding and steep learning curves are lessened. The tools developed can be employed by users with various levels of expertise to quantify vadose and groundwater transport from OSTDS. This model can be combined with other models and tools to allow for a refinement of nitrogen loading estimates for specific remediation areas.

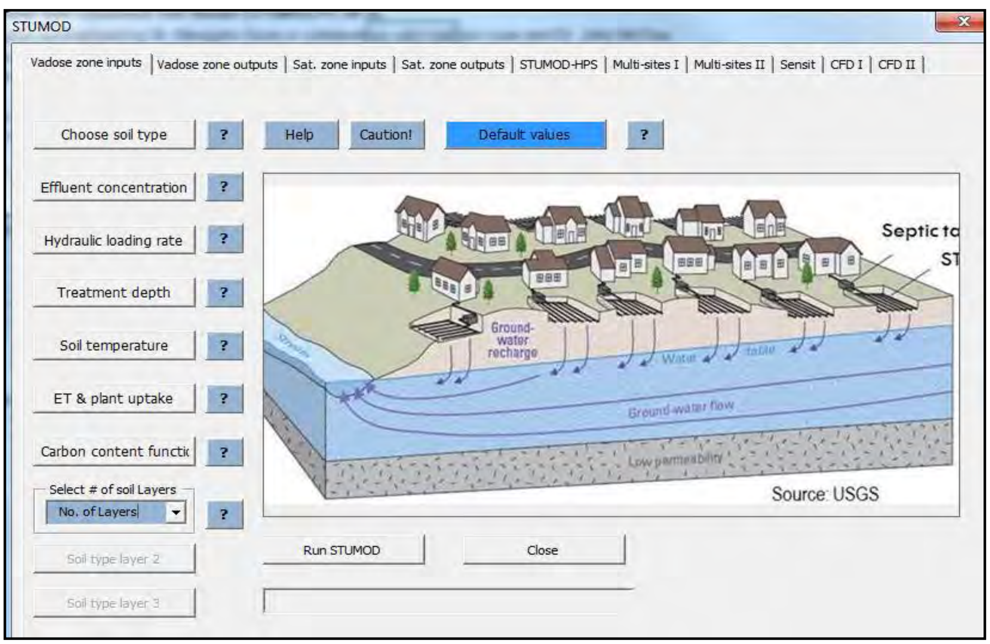

Figure 20. User Interface of Nitrogen Fate and Transport Model for Estimating Nitrogen Contribution from OSTDS (Hazen and Sawyer 2015d)

Discussion

The look-up table based on two-dimensional model runs and graphs based on one-dimensional model calculations provided estimates for the same scenarios. Department staff utilized this for a comparison between the tools. This provides an opportunity to gain insights, such as which predictions should be considered more uncertain than others. In addition, the comparison may provide an indication of how important the consideration of two-dimensional transport is. Generally, there was a high correlation between the two models. Where there were differences, they tended to be largest at water table.

A second opportunity for comparisons were Otis' (2007) estimates for nitrogen reduction or denitrification potentials for soils in the Wekiva Study Area. This estimation approach was based on a literature review and his expert judgement. It included considerations of the form of applied nitrogen, texture, drainage class, and carbon content. The availability of a look-up table based on the two-dimensional model table invited a comparison between the results of the two approaches. For nitrogen reductions up to 60% there appeared to be a reasonably good agreement between the two approaches.

The monitoring results from some of the field sites that had groundwater monitoring also allowed for a comparison with the modeling results for nitrogen transport through the soil. Overall concentration reduction estimates that include dilution and denitrification or other removal processes are generally higher than the adjusted reduction estimates that subtract dilution. Dilution is not a removal process and is not included in the current models. The least amount of dilution was observed in the lysimeters in the Marion County site. This is consistent with the understanding that dilution is more pronounced by effluent missing with groundwater that flows underneath a STU.

The monitoring results from the mounded STU at the GCREC test facility site were used for corroboration and calibration of the groundwater model (Hazen and Sayer, 2015c; Tonsberg, 2014). While the limitations of the aquifer model should be considered, they do not preclude the usefulness of model estimates. During model corroboration it was concluded that denitrification was not as low as estimated by the aquifer model via calibration, though it was likely limited within the area monitored at the GCREC mound. An independent evaluation of the denitrification potential of soils collected at the GCREC site concluded that it was exceedingly low, affirming the conclusion from model corroboration (Farrell 2013; Farrell et al., 2014). Estimates of transverse horizontal dispersivity were likely less than reported from calibration of the aquifer model. This illustrates that the aquifer model is a versatile and powerful tool but that it does have limitations that should be recognized before using the model.

Parallel to the soil and groundwater nitrogen transport model developed as part of this project, the Florida Department of Environmental Protection has funded development of a nitrogen transport modeling tool kit (Rios et al. 2013, Wang et al. 2013). The modeling is incorporated in a geographical information system (GIS) environment, leading to the name ArcGIS-based Nitrogen Load Estimation Toolkit (ArcNLET). The toolkit allows estimation of nitrogen transport through the soil (VZMOD, Wang et al., 2012). This module incorporates the same processes as STUMOD-FL. The groundwater transport module is based on very similar processes as STUMOD-FL-HPS. There are at least two areas in which additional work on either of the models appears recommended before relying solely on them for calculating nitrogen loads from OSTDS and their reductions. One area for additional work includes calibration of models at the plume scale. Plume-specific investigations could serve to assess

how well the model assumptions match the real plumes and provide guidance for more appropriate models if needed. Such investigations could also serve to build up a data set of appropriate plume parameters for future use. Another area for additional work is addressing additional sources of nitrogen. The models assume that the effluent from OSTDS are the only source of nitrogen in the model domain. This may not always be the case.

Detailed discussion of the modeling tools developed in this project can be found in Appendix G.

Recommendations for Science-Based Nitrogen Reduction Options for Onsite Sewage Treatment and Disposal Systems

Overview

The Department will use the results of the FOSNRS study to develop strategies to promote nitrogen reduction in OSTDS. These strategies will provide planning-level tools to state agencies, local governments, stakeholders, and other interested entities to enhance their ability to:

- Assess nitrogen loading from OSTDS
- Select enhanced designs for OSTDS which provide a range of options for nitrogen removal
- Facilitate education and training for industry professionals and the public

DEP and local governments are expected to address nitrogen loading in sensitive watersheds via the:

- Total Maximum Daily Load allocations (TMDL - maximum amount of a pollutant that a body of water can receive while meeting water quality standards), and
- Basin Management Action Plans (BMAP – "blueprint" for restoring impaired waters by reducing pollutant loading) processes.

The various system options identified in the Department's nitrogen reducing systems tool box will enhance the abilities of resource managers, regulators, and land use managers to engage community partners to make informed and scientifically appropriate decisions on the most effective strategies to limit nitrogen inputs from OSTDS.

As specific TMDLs and BMAPs are developed for Florida water bodies, it will become important to have a range of available options for nitrogen load reductions from OSTDS. There are six main strategies proposed in Table 07 and described in more detail in the following sections.

Table 07. Implementation Plan to Reduce Nitrogen Contributions from Onsite Sewage Treatment and Disposal Systems

	Strategy	Requirements
1	**Modify regulations to allow a conventional OSTDS to achieve enhanced nitrogen reduction (lined drainfield)**	Requires rule change
2	**Incorporate nitrogen study systems as approved performance-based systems**	Requires development of system specifications
3	**Develop section in Florida Administrative Code Rule 64 E-6 on new nitrogen reducing systems**	Requires rule and possibly statute changes
4	**Provide education and training to stakeholders on nitrogen reduction strategies**	Requires training development and message standardization
5	**Share planning-level tools to assess nitrogen reducing strategies (inventory, model)**	Requires coordination with local stakeholders
6	**Develop state, local, and private sector funding strategies for nitrogen reduction efforts**	Requires coordination with Department of Environmental Protection and local stakeholders

Range of Treatment Options

The FOSNRS study developed a two-stage treatment approach and assessed nitrogen transport in soil and groundwater. Beyond the technologies discussed in this report, other treatment options exist. One difficulty in comparing different approaches is the consideration of treatment in and below the STU. For some treatment approaches, the drainfield, or soil treatment unit, is an additional treatment step that is usually not considered in the performance assessment. For other treatment systems that are installed as in-ground systems, the soil treatment unit is integrated in the system, and no additional soil treatment occurs. In order to effectively compare the two approaches, an estimation of the overall effectiveness must occur.

For discussion purposes, the following approach is used for estimating overall treatment effectiveness: A pretreatment (stage 1 and stage 2, if included) effectiveness is estimated. If dispersal to a STU occurs, then additional nitrogen reduction in the soil is estimated. For this planning level estimate, the

assumption is that the typical soil treatment removal applies to the remaining nitrogen. This may be an overestimate if some nitrogen is less reactive than typical. Given the variability of treatment performance, this bias should be small relative to overall treatment effectiveness estimates. Table 08 summarizes the estimates and the following discussion elaborates on the approaches.

Legacy systems with insufficient separation to the water table. This category refers to OSTDS that were installed with little to no separation to the water table. This could have been the result of installation before the modern requirement for water table separation came into place (1983), siting or installation errors or illegal installations. Current repair requirements allow installation with six (pre-1983) to twelve (1983 and later) inches of separation to the wet season water table. With less or no separation to the water table, septic tank effluent can enter the groundwater more easily than in modern STU systems. An overall treatment effectiveness of zero is assigned.

Conventional septic tank with STU. These are systems installed with a water table separation of two feet or more. The treatment effectiveness can vary widely depending on site and configuration conditions. Groundwater monitoring performed during this study raises the concern that some nitrogen reduction ascribed to STUs represents dilution rather than removal. For planning purposes and consistency with the project report, a typical reduction of 30% is assumed.

STUs with additional layers. This approach was tested in two home sites. Due to the low number of systems and the uncertainty in system functioning the estimates for overall removal are most uncertain. Installation under a typical STU must address concerns that the effluent has a path to move further out into the environment after treatment and that soil treatment (24 inches of unsaturated soils) is available to ensure pathogen removal.

NSF-40 ATU. Aerobic treatment units certified to this treatment capability standard are not specifically assessed for nitrogen reduction. These systems can be easily permitted without requiring an engineer, unless more complex configurations, such as drip dispersal systems, are included. These systems require an operating permit, maintenance contract and site visits to ensure their proper functioning. Lack of proper maintenance reduces the treatment effectiveness for nitrogen significantly.

Subset of ATUs with established nitrogen reduction/NSF 245. NSF-245 is a treatment capability standard that establishes that a treatment unit can reduce TN from the influent by 50%. The test for this standard occurs concurrently with NSF-40. Some aerobic treatment units and similar treatment systems have also established through field testing in various states that they can reduce nitrogen. Currently, Florida's regulation does not recognize NSF-245 specifically. Such systems would generally be permitted as performance-based treatment systems if the performance is required. Some could be permitted as aerobic treatment units (NSF-40 ATU), when the performance is desired but not required.

Intermittent sand filters (single pass). This is a treatment approach that has become rare in Florida. Depending on the exact configuration, this approach functions similar to a mound STU. By itself, it achieves little nitrogen reduction.

Table 08. Estimated Overall TN Reduction for several Treatment Options

Type of System	Stage 1 (Nitrifi-cation)	Stage 2 (Denitrifi-cation)	Dispersal	Pre-treatment nitrogen reduction	Pretreatment reduction assumed for planning purposes	Post-Dispersal nitrogen reduction	Soil nitrogen reduction assumed	Overall treatment effectiveness estimate	Current permitting
Legacy systems with insufficient separation to water table	n/a	n/a		0	0	Less than baseline	0%	0%	Out of compliance with current rules
Conventional Septic Tank STU	n/a	n/a		0	0	Baseline (0-60%)	30%	30%	Conventional system construction permit
STU with additional layers	integrated	integrated	integrated	0	0	Assume 40% beyond conventional (table 6-3)	70%	70%	Conflicts with effective soil depth requirements in some settings, possible water table separation
NSF-40 ATU	yes	n/a		20-50%	30%	Baseline	21%	51%	ATU
Subset of ATUs with established nitrogen reduction/NSF 245	yes	n/a (recirc)		40-70%	50%	Baseline	15%	65%	PBTS or (ATU)
Intermittent Sand Filter	yes	n/a		0-40%	20%	Baseline	24%	44%	Legacy system
Recirculating Media Filter	yes	n/a (recirc)		40-65%	50%	Baseline	15%	65%	PBTS/ATU/innovative
Florida Two-Stage	yes	Yes		90+%	90%	Baseline	3%	93%	TBD (PBTS)
Denitrification media filter	required	Yes		90+%	90%	Baseline	3%	93%	TBD (innovative or PBTS)

Recirculating media filter. This treatment approach has been used both as a proprietary and as a public domain treatment unit. The recirculation is generally used to achieve some denitrification by bringing nitrified filter effluent into contact with septic tank effluent. The performance varies considerably. Some such filters have been certified to the nitrogen reduction standard NSF-245. Depending on the details, such systems could be permitted as aerobic treatment units (if certified to NSF-40), performance-based treatment systems, or could be considered innovative systems.

Florida Two-Stage systems. These systems were the focus of the field performance evaluations. Such systems were the most effective for nitrogen removal. Permitting of such systems requires the establishment of a good system description and effective system of monitoring. One approach would be the permitting as a performance-based treatment system.

Denitrification media filter. This approach describes only the second stage of the Florida Two-Stage system. Nitrification would occur in a pretreatment system that could be one of the systems discussed before. A key consideration is that the nitrification step has to be complete for this approach to work. Permitting of such systems requires the establishment of a good system description and effective system of monitoring. One approach would be permitting as a performance-based treatment system.

Product approval and rule promulgation

The sensitivity of Florida watersheds to nitrogen varies greatly, and includes areas of extremely high sensitivity to nitrogen loading and other areas where nitrogen loading from OSTDS may be less critical. The Department recommends an overall strategy to provide a range of onsite sewage nitrogen removal treatment levels. To accommodate local variability, three levels of nitrogen reduction are identified that can be used to categorize various technologies and planning-level decisions:

- **Level 1** provides adequate, fundamental treatment of wastewater which includes some nitrogen removal. The system model for this is the properly operating conventional two chamber septic tank and STU in a trench or bed configuration. The system is required to maintain a two-foot separation to the seasonal high groundwater table meeting and must meet all applicable regulations. These are industry-accepted designs that are proven and reliable tools for protecting public health and provide adequate nitrogen treatment in less sensitive areas.
- **Level 2** includes nitrogen removal in addition to providing the basic functional capability consistent with level 1. The system model for this includes modified STUs to include a nitrification and denitrification step, as well as existing aerobic treatment units and performance-based treatment system technologies. These systems have been established and tested, with performance objectives and provide an alternative where nitrogen treatment is desired.
- **Level 3** was the focus of technology development and field testing at home sites during this project. It transforms nitrogen removal options, creating opportunities for significant nitrogen removal in sensitive areas where centralized wastewater treatment options are not available. The system model for this level has not yet been fully developed, and is the focus of current Department work. Generally, it will consist of a two-stage biofiltration system. The immediate plan is to place systems at this level in the same regulatory structure as performance-based treatment system technologies. Subsequently, revisions to the regulatory structure will be

developed. These systems are state-of-the-art for environmental protection but have varying levels of performance testing depending on the technology. They may be an option where nitrogen treatment is a priority and cost is not as much a factor in decision making.

The need for nitrogen reduction is not likely to be the same for all receiving environments, so deciding which level is appropriate will require analysis of multiple variables. Effluent quality from residential OSTDS can be highly variable, and depends on many factors in the home and the treatment system itself. For this reason, a range of expected treatment is provided at each of the three nitrogen removal levels. Because most nitrogen reduction options (levels 2 and 3) are more costly and complex to install and operate than traditional OSTDS (level 1), the requirements for nitrogen reduction should be carefully considered. These may include availability of resources, timeframe, regulation, community needs, and monitoring accuracy and frequency. The resulting decision on appropriate treatment level requirements should result in a reduction in the nitrogen loading from OSTDS and should be credited toward the TMDL and BMAP target levels.

For level 1 systems, the nitrogen reduction is variable, may be highly site specific, and depends on multiple variables such as the input concentration and volume of nitrogen from the source, dispersal mechanism, soils, depth of the infiltrative surface, and estimated seasonal high groundwater table. For planning level purposes nitrogen reduction for a code compliant conventional system will be considered to be 30%. As a cautionary note, several of the STUs monitored in this study suggested that the 30% was due to dilution rather than actual removal and/or required extended transport in groundwater. Many systems in Florida are below the level 1 standard due to grandfathering provisions in the current rule based on the age of the system or plat date. One strategy for nitrogen reduction from OSTDS would be to bring substandard systems to the level 1 standard.

For level 2 systems, which include some existing Aerobic Treatment Units and Performance-Based Treatment Systems. A nitrogen reduction of 40-70% reaching the water table below the OSTDS is estimated. Level 2 would also include less complex in-ground passive nitrogen reducing systems similar to the lined in-ground systems tested in the study (strategy 1 from Table 07) or an in-tank approach with a Stage 1 unsaturated biofilter with recirculation. Simplifying regulation for these systems would also reduce costs, so the Department proposes requiring no operating permit or additional monitoring requirements for the in-ground passive approach. The in-ground system does require development of system specifications for additional layers under the STU and a small number of rule changes. The rule change process requires public meetings of the Technical Review and Advisory Panel (TRAP) and the Variance Review and Advisory Committee. The TRAP met on October 22, 2015, and tabled the proposal. The panel wanted more specificity regarding media, design, installation, and maintenance of systems; some assumption of guaranteed performance; an implementation plan; and to simplify the approval process for additional technologies. A follow-up meeting is anticipated in early 2016. The Department is developing all these standards with the goal of having these enhanced systems available as soon as possible.

For level 3 systems, a high level of nitrogen removal is required, around 85-95% reduction in TN prior to discharge to the STU. Technologies for level 3 include both in-tank and in-ground designs with the general concept including a septic tank, a Stage 1 unsaturated biofilter, a Stage 2 saturated media biofilter, and a STU. The following characteristics could be customized for each system:

- single pass unsaturated biofilters followed by denitrification biofilters with lignocellulosic media
- single pass unsaturated biofilters followed by denitrification biofilters with sulfur media
- single pass unsaturated biofilters followed by denitrification biofilters with lignocellulosic and sulfur media (dual media)
- recirculating unsaturated biofilters followed by denitrification biofilters with sulfur media
- recirculating unsaturated biofilters followed by denitrification biofilters with lignocellulosic and sulfur media (dual media)

Level 3 systems developed as part of this study have a two stage implementation plan. First (strategy 2 from Table 07) the existing technologies developed as part of this study will be incorporated into the current list of approved PBTS technologies. The next step is to develop a new nitrogen reduction rule in Florida Administrative Code Rule 64 E-6 (strategy 3 from Table 07). This new rule is anticipated to include the ability to mix and match tested concepts; and refine the permitting, inspection, and continued operation and maintenance schemes.

Management, operation, and maintenance considerations

Uniform requirements for inspecting and maintaining PNRS should be established and updated as necessary. Having sufficient Department staffing for review and permitting of PNRS is also critical to ensure efficiency.

Management and proper maintenance and operation of OSTDS are essential. For level 1 conventional systems, operation and maintenance requirements are minimal. Removal of the septic tank contents should happen every three to five years. Systems with a pump require periodic inspection and pump replacement if necessary, which could occur at the time of septic tank pumping.

In Florida, a regulatory structure for aerobic treatment units and performance-based treatment systems already exists that provides a current framework for the management of the more advanced nitrogen reducing technologies (level 2 and 3).

Where PNRS systems are installed to meet the requirements of a TMDL, the local BMAP should address performance monitoring. To ensure the target nitrogen reduction strategies are working in these advanced systems, water quality sampling might be necessary, at least until adequate experience with in-ground systems is gained. If there will be monitoring, it is important to standardize where the nitrogen value will apply as there are several options. 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.

Alternatively, rather than water quality sampling, nitrogen reduction assumptions could be based on proper technology selection with processes that are known to meet the desired removal and routine maintenance and/or inspections to ensure the technology is functioning as intended, similar to the current ATU and PBTS mechanism. This latter approach to stating standards would likely be much less costly to monitor. An approach combining both types of assurance would require initial sampling to confirm the system is functioning as attended and routine maintenance and inspection to ensure that the technology is continuing to function.

There are several different approaches for operation and maintenance for level 2 systems. Existing ATUs and PBTSs, as mentioned before, fall under the existing regulatory scheme of twice per year maintenance inspections and annual Department inspections. Each approved system has specific operation and maintenance manuals that should be followed. For the passive options, which include the in-tank Stage 1 recirculating biofilter and the in-ground stacked biofilter, inspection should include pump operation and electrical connections, a general hydraulic inspection including flow distribution, flushing and cleaning of distribution lines, inspection of any media surfaces, and measurement of recycle flowrate and adjustment if needed. As with the level 1 systems, primary tank solids should be removed every three to five years. Systems with a pump require periodic inspection and pump replacement if necessary, which could occur at the time of septic tank pumping. The frequency and intensity of inspections for level 2 systems developed under this study is anticipated to be less than those required for current ATUs and PBTSs.

Level 3 systems would fall under the existing ATUs and PBTSs permitting and inspection requirements until a new rule is developed to further clarify nitrogen reducing systems (strategy 3 in Table 07). This new rule will provide uniform and streamlined guidance for regulation and permitting specific to PNRS. Modifications to the existing permitting structure as applied to the new PNRS technology could relieve some administrative burden. Inspections and sampling early after installation should ensure that treatment performance is as required. Inspection should include checks on the pump operation and electrical connections, general hydraulic inspections including flow distribution to the Stage 1 and Stage 2 biofilters, flushing and cleaning distribution lines, inspection of biofilter media surfaces, and measurement of recycle flowrate and adjustment if needed. As with the level 1 and 2 systems, primary tank solids should be removed every three to five years. Systems with a pump require periodic inspection and pump replacement if necessary, which could occur at the time of septic tank pumping.

Education and outreach

The Department will work with DEP, industry professionals, the public, and other stakeholders to develop educational tools and provide education on the study results, use of the tools developed, OSTDS impacts, analysis and modeling of groundwater impacts, proposed and any resulting rule changes, training on how to install and maintain resulting nitrogen reduction system designs, as well as an overall understanding of OSTDS.

Throughout this project there have been numerous opportunities for education and outreach (Appendix H). A total of 15 conference papers and 28 conference presentations were made. Public education through speaking at meetings, presentations, and seminars was one of the most utilized methods for

education and outreach, with a total of 60 speaking opportunities. Five newsletters and other articles for professional organizations and 11 legislative reports (not including this one) were written.

Currently, the Department is involved in education via attendance and participation at local BMAP meetings. The Department is also currently working with DEP in the development of educational strategies. Existing educational campaigns are being compiled into a mutltiagency and multisource library.

Industry training will be developed and provided in coordination with state professional organizations such as the Florida Onsite Wastewater Association and the Florida Environmental Health Association.

The Life Cycle Cost Assessment and the groundwater modeling tools developed during this project are also part of the education and outreach plan. The most recently executed BMAPs, Wekiva, Wakulla, and Silver Springs, will include a target group of individuals who can receive hands-on training on the applicablity and use of these tools.

Planning-level tools

Tools available to help determine nitrogen loading from OSTDS include the Department's Florida Water Management Inventory, a parcel-based map showing the drinking water source and wastewater treatment method for every built property in the state (FDOH 2015b); and the nitrogen fate and transport model developed as a part of the FOSNRS project. These tools can be used by engineers and planners as well as in the BMAP process to further refine nitrogen loading estimates to impaired waters.

According to DEP (2015), clusters of OSTDS that are built at a density of more than four per acre in sensitive springs areas can be nitrogen contribution sources of concern. However, the sensitivity of any given area to surface water impacts from OSTDS depends on a variety of factors.

Determination of necessary nitrogen reductions to protect or improve water quality by watershed and GIS mapping of nitrogen sensitive zones would allow determination of which level of nitrogen reduction is required for implementation in a given location. Nitrogen load reductions from OSTDS are not always necessary, and in many locations upgrading existing OSTDS to current standards may be enough.

The output of the STUMOD-FL-HPS model, developed as part of this project to quantify vadose and groundwater nitrogen transport from residential OSTDS, provides soil treatment, groundwater fate and transport, and quantitative estimations of nitrogen. These outputs could be used at a planning level to identify areas where level 1, 2, or 3 nitrogen reduction options would be appropriate solutions, or areas where centralized wastewater collection would be more appropriate.

Funding

Local-state partnerships are traditionally used to fund infrastructure improvement projects (DEP 2015). Estimates of funding needs can be developed using the tools created as part of this study in combination with other developed tools and resources.

Refined estimates of OSTDS locations and density from the Florida Water Management Inventory could help with locating areas in sensitive spring areas with high OSTDS densities.

The life-cycle cost assessment tool could then be used to estimate the funding needs for OSTDS improvements. The tool was used to compare level 1, 2, and 3 nitrogen removal system costs and detailed results are shown in Appendix E. As the nitrogen removal level of the recommended systems increases; construction costs, total present worth of life cycle costs, and pounds per year of nitrogen removed also increase. Table 09 compares the present worth costs between the level 1, 2, and 3 nitrogen reduction levels. The cost breakdown for each estimate is shown in Appendix E.

Table 09. Comparison of PNRS LCCA Results for Recommended Nitrogen Removal Systems (Adapted from Hazen and Sawyer 2015b)

Nitrogen Removal Level	System	Present Worth, $					Lbs/year Nitrogen Removed	$ PW/lb. Nitrogen Removed
		Construction	Engineering Design and Permit	Operation and Maintenance	Compliance	Total Lifecycle Cost		
Low (25-35%)	Conventional: primary treatment + soil treatment unit	$4,025.00	$580.00	$937.90	$0.00	$5,542.90	8.1	22.8
Medium (50-70%)	Conventional + In-tank PNRS Stage 1 + R tank	$13,604.07	$1,660.00	$8,766.39	$3,807.40	$27,837.86	18.9	49.07
	Conventional + PNRS In-ground Stage 1 underlain by Stage 2	$15,333.85	$1,660.00	$8,214.22[1]	$3,807.40	$29,015.47	18.9	51.15
High (85-95%)	Conventional + PNRS In-tank Stage 1 + PNRS In-tank Stage 2	$18,968.67	$1,660.00	$9,503.98	$3,807.40	$33,940.05	25.7	44.09
	Conventional + PNRS In-ground Stage 1&2a + PNRS In-tank Stage 2b	19,477.44	$1,660.00	$8,896.75	$3,807.40	$33,841.59	25.7	43.96

1) These recurring costs are based on the current regulatory structure for PBTS systems in Florida. Costs may change as regulatory schemes adapt to these new technology options.

Local utilities could also determine costs for expansion of centralized wastewater or identify areas that might benefit from a decentralized cluster system approach.

Potential state and federal funding sources include the DEP State Revolving Fund loan program which is funded by the EPA Clean Water State Revolving Fund (CWSRF), other federal grant funds, water management district funds, or other state appropriated funds. The CWSRF is able to fund the construction, repair, or replacement of decentralized wastewater treatment systems that treat municipal wastewater or domestic sewage. The state programs are responsible for selecting projects to receive funding based on the water quality restoration benefits, cost effectiveness, and level of local commitment. DEP, which administers this program, may also have specific rules and guidelines about grantee eligibility, cost share, and other considerations.

The development of funding mechanisms to select the most cost-effective nitrogen reduction projects is of critical importance. Two mechanisms were suggested in the Wekiva Study Area.

The first mechanism is a grant program to solicit cost-effective nitrogen reduction projects from any source, funded by payments from dischargers of nitrogen such as onsite system owners. The discharge fee could be initially oriented on costs to remove the first few pounds of nitrogen. This mechanism would allow for continued monitoring of the increasing costs as the loading is reduced toward the target level to meet spring water-quality standards, and would allow for an adjustment of fees. The second mechanism consists of wastewater management entities that are funded by all onsite system owners to reduce the nitrogen load from OSTDS. These entities will be in a position to select the most cost-effective wastewater nitrogen reduction projects to address nitrogen in their service area. Both of these mechanisms could be combined to increase the rate at which nitrogen reduction projects are implemented in order to reach the pollution reduction goal. Costs to the system owners will depend on the extent and speed of nitrogen reduction. Estimates developed for the Wekiva Study Area suggest about $60 per year per system initially for an area-wide grant program, and about $200 per year per system for a program to upgrade failing systems to achieve nitrogen reduction (Roeder 2007).

Wastewater management entities can provide grants or loans to support repairs of failing systems and upgrades to new standards. While outside grants and loans can and should support such programs, pooling of the resources within the service area could move such a program forward even in the absence of outside support. These entities, either existing utilities, newly formed onsite sewage management providers, or county health departments in an expanded role could be funded by an onsite system fee, which would cover costs of this function as well as periodic monitoring, inspection, and inventory of OSTDS

Through the TMDL and BMAP process, the Department will assist DEP and local stakeholders to identify and evaluate funding options to assist homeowners requiring nitrogen reducing systems, test system performance, to refine planning-level tools, and to provide education and training.

Conclusions and Next Steps

This study benefits Floridians by providing:

- Field-tested designs for "passive" user-friendly systems effective at removing nitrogen;
- System cost estimates and cost comparisons to existing approved systems;
- Nitrogen fate and transport model for estimating nitrogen contribution from OSTDS; and
- Options for nitrogen reduction OSTDS in sensitive watersheds where sewers are not feasible.

In consultation with the Department of Environmental Protection and the Research Review Advisory Committee, the Department has used the results of the Florida Onsite Sewage Nitrogen Reduction Strategies study to develop this final report to the Florida Governor and Florida Legislature. The total estimated project cost was $5-million, but $4.7 million was spent over a six-year period. In addition to summarizing the project work, this report provides several strategies to assist with nitrogen reduction in OSTDS. These strategies include planning-level tools to help assess nitrogen loading, enhanced designs which provide a range of options for nitrogen removal, and recommendations for onsite sewage system education and training for industry professionals and the public.

The results of this project help characterize and 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 Florida residents.

In 2008, the Florida Legislature directed the Department of Health to develop cost-effective nitrogen reduction strategies for OSTDS. As detailed in Line Item 1682, Chapter 2008-152, General Appropriations Act for Fiscal Year 2008-2009, this study includes 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."

Figure 21 shows a comparison between each of the five major tasks in the original legislative language and the major results from the project.

Several of the passive nitrogen systems designed and tested as part of this study provide significant improvements in nitrogen reduction over conventional systems, achieving consistent removal of over 90-95% of the nitrogen and having a concentration less than 5 mg N/L. Current advanced systems

available on the market typically achieve 40-70% reduction in TN. The passive systems designed and developed as part of this study were simple to operate, and only required minimal maintenance after startup. The media used in these systems to perform the nitrogen reduction is expected to last many years, with theoretical estimates based on media stoichiometry indicating a media life of more than 50 years.

Prior to implementing any of these systems, several actions need to occur:

- Develop standard procedures for system performance and maintenance tracking, construction and maintenance inspection requirements, and continued system monitoring and enforcement
- Build service provider qualification and certification programs and ensure sufficient service provider capacity
- Develop a public awareness campaign

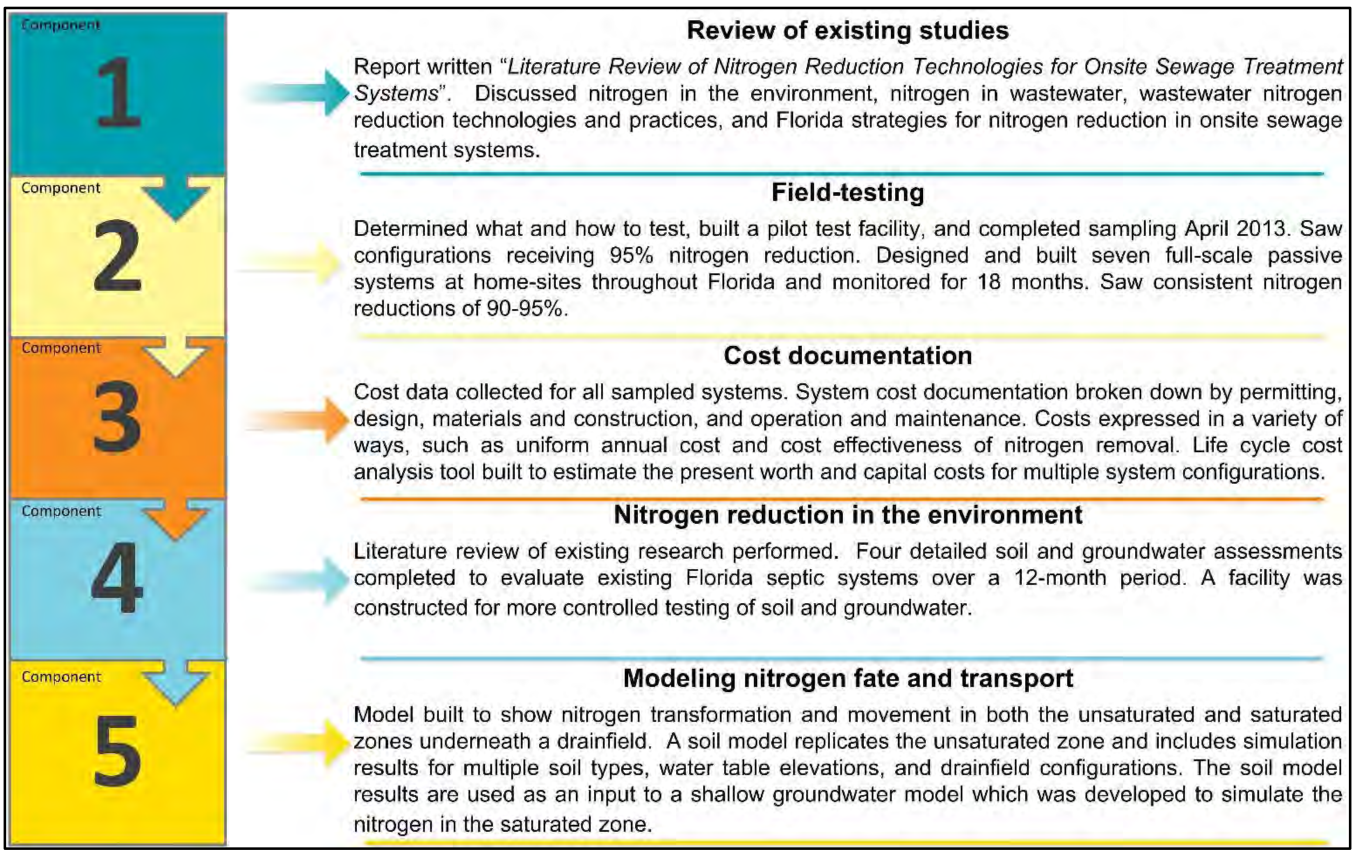

Figure 21. Summary of Project Results in Response to the Tasks Defined in the 2008 Legislative Language

In a press release by the St. Johns River Water Management District on October 7, 2015, DEP Secretary Jon Steverson said, "combining efforts and resources with local governments, stakeholders, and the water management districts enables us to take a more comprehensive and efficient approach to springs protection." A collaborative approach to nitrogen reduction from decentralized wastewater sources at the local level is the approach that can make the most impact.

Some of the more immediate next steps that will occur now that this study is complete are:

- Establish long term monitoring of experimental PNRS systems at home sites from this study to provide knowledge of continued system performance, the longevity of media, further guidance for system designs, and the long term needs for maintenance and monitoring.
- Identify equipment, tanks, and media required for the PNRS and make them available in the areas where PNRS will likely be installed.
- Develop detailed design criteria for several standardized PNRS designs, including specifications for media, liners, tanks, and tank lids.

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Appendix A. Legislative Language

2008 Legislative Language

SECTION 5 - NATURAL RESOURCES/ENVIRONMENT/GROWTH MANAGEMENT/TRANSPORTATION

1675	SPECIAL CATEGORIES TRANSFER TO FISH AND WILDLIFE CONSERVATION COMMISSION FOR MANAGEMENT OF CARL LANDS FROM CONSERVATION AND RECREATION LANDS TRUST FUND			18,787,994
1676	SPECIAL CATEGORIES TRANSFER TO DEPARTMENT OF STATE FOR GRANTS AND DONATIONS TRUST FUND FROM CONSERVATION AND RECREATION LANDS TRUST FUND			7,842,753
1677	SPECIAL CATEGORIES TRANSFER TO DEPARTMENT OF MANAGEMENT SERVICES - HUMAN RESOURCES SERVICES PURCHASED PER STATEWIDE CONTRACT FROM CONSERVATION AND RECREATION LANDS TRUST FUND			6,559
	FROM INTERNAL IMPROVEMENT TRUST FUND . . .			38,517
TOTAL:	LAND MANAGEMENT FROM TRUST FUNDS			60,688,910
	TOTAL POSITIONS		102.00	
	TOTAL ALL FUNDS			60,688,910

PROGRAM: DISTRICT OFFICES

WATER RESOURCE PROTECTION AND RESTORATION

APPROVED SALARY RATE 19,292,811

1678	SALARIES AND BENEFITS	POSITIONS	463.00	
	FROM GENERAL REVENUE FUND		10,022,264	
	FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND			3,852,255
	FROM FEDERAL GRANTS TRUST FUND			828,960
	FROM LAND ACQUISITION TRUST FUND			1,299,159
	FROM PERMIT FEE TRUST FUND			9,662,178

Of the funds in Specific Appropriation 1678, $3,814,050 from the Permit Fee Trust Fund for the Drinking Water and Environmental Permitting Program is contingent upon Senate Bill 1294 or similar legislation, relating to permit fees, becoming a law.

1679	OTHER PERSONAL SERVICES FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND			294,303
1680	EXPENSES FROM GENERAL REVENUE FUND		152,112	
	FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND			1,633,735
	FROM FEDERAL GRANTS TRUST FUND			36,826
	FROM LAND ACQUISITION TRUST FUND			217,399
	FROM PERMIT FEE TRUST FUND			354,937
1681	SPECIAL CATEGORIES WATER QUALITY MANAGEMENT/PLANNING GRANTS FROM FEDERAL GRANTS TRUST FUND			2,904,072
	FROM GRANTS AND DONATIONS TRUST FUND . . .			288,000
1682	SPECIAL CATEGORIES CONTRACTED SERVICES FROM GENERAL REVENUE FUND		8,225	
	FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND			6,750
	FROM FEDERAL GRANTS TRUST FUND			30
	FROM LAND ACQUISITION TRUST FUND			1,100
	FROM PERMIT FEE TRUST FUND			5,370
	FROM WATER PROTECTION AND SUSTAINABILITY PROGRAM TRUST FUND			1,000,000

From the funds in Specific Appropriation 1682 , $1 million from the Water Protection and Sustainability Program Trust Fund shall be transferred to the Department of Health to further develop

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SECTION 5 - NATURAL RESOURCES/ENVIRONMENT/GROWTH MANAGEMENT/TRANSPORTATION

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.

The Department of Health shall also submit a report to the Executive Office of the Governor, the President of the Senate and the Speaker of the House of Representatives by no later than October 1, 2008, which identifies the range of costs to implement a mandatory statewide 5-year septic tank inspection program to be phased in over 10 years pursuant to the Department of Health's procedure for voluntary inspection, including use of fees to offset costs.

From the research fees collected pursuant to section 381.0066, Florida Statutes, $150,000 shall be used by the Department of Health to provide a statewide inventory of onsite treatment and disposal systems.

1683	SPECIAL CATEGORIES RISK MANAGEMENT INSURANCE FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND		44,296
	FROM FEDERAL GRANTS TRUST FUND		3,045
	FROM PERMIT FEE TRUST FUND		8,766
1684	SPECIAL CATEGORIES TRANSFER TO DEPARTMENT OF MANAGEMENT SERVICES - HUMAN RESOURCES SERVICES PURCHASED PER STATEWIDE CONTRACT FROM GENERAL REVENUE FUND	101,080	
	FROM ECOSYSTEM MANAGEMENT AND RESTORATION TRUST FUND		28,045
	FROM FEDERAL GRANTS TRUST FUND		5,201
	FROM LAND ACQUISITION TRUST FUND		9,458
	FROM PERMIT FEE TRUST FUND		43,340
TOTAL:	WATER RESOURCE PROTECTION AND RESTORATION FROM GENERAL REVENUE FUND	10,283,681	
	FROM TRUST FUNDS		22,527,225
	TOTAL POSITIONS	463.00	
	TOTAL ALL FUNDS		32,810,906

AIR ASSESSMENT

APPROVED SALARY RATE 661,094

1685	SALARIES AND BENEFITS POSITIONS	16.00	
	FROM AIR POLLUTION CONTROL TRUST FUND . .		885,185
	FROM GRANTS AND DONATIONS TRUST FUND . . .		100,830
1686	OTHER PERSONAL SERVICES FROM AIR POLLUTION CONTROL TRUST FUND . .		28,445
	FROM GRANTS AND DONATIONS TRUST FUND . . .		60,000
1687	EXPENSES FROM AIR POLLUTION CONTROL TRUST FUND . .		86,341
1688	OPERATING CAPITAL OUTLAY FROM AIR POLLUTION CONTROL TRUST FUND . .		9,572

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2009 Appropriations Language

SECTION 3 - HUMAN SERVICES

468	AID TO LOCAL GOVERNMENTS		
	CONTRIBUTION TO COUNTY HEALTH UNITS		
	FROM GENERAL REVENUE FUND	3,278,293	
	FROM ADMINISTRATIVE TRUST FUND . . .		1,417,426
	FROM GRANTS AND DONATIONS TRUST FUND		1,204,571
469	OPERATING CAPITAL OUTLAY		
	FROM ADMINISTRATIVE TRUST FUND . . .		15,000
	FROM FEDERAL GRANTS TRUST FUND . . .		46,698
	FROM RADIATION PROTECTION TRUST FUND		56,997
470	SPECIAL CATEGORIES		
	ACQUISITION OF MOTOR VEHICLES		
	FROM ADMINISTRATIVE TRUST FUND . . .		80,000
	FROM RADIATION PROTECTION TRUST FUND		130,856
471	SPECIAL CATEGORIES		
	CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	189,084	
	FROM ADMINISTRATIVE TRUST FUND . . .		340,000
	FROM FEDERAL GRANTS TRUST FUND . . .		348,235
	FROM GRANTS AND DONATIONS TRUST FUND		671,203
	FROM RADIATION PROTECTION TRUST FUND		150,000

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 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.

472	SPECIAL CATEGORIES		
	GRANTS AND AIDS - CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	86,399	
	FROM FEDERAL GRANTS TRUST FUND . . .		750,000
473	SPECIAL CATEGORIES		
	RISK MANAGEMENT INSURANCE		
	FROM GENERAL REVENUE FUND	67,993	
	FROM RADIATION PROTECTION TRUST FUND		14,575
474	SPECIAL CATEGORIES		
	TRANSFER TO DEPARTMENT OF MANAGEMENT SERVICES - HUMAN RESOURCES SERVICES PURCHASED PER STATEWIDE CONTRACT		
	FROM GENERAL REVENUE FUND	12,630	
	FROM ADMINISTRATIVE TRUST FUND . . .		25,242
	FROM FEDERAL GRANTS TRUST FUND . . .		9,712
	FROM GRANTS AND DONATIONS TRUST FUND		1,382
	FROM RADIATION PROTECTION TRUST FUND		40,522
475	SPECIAL CATEGORIES		
	STATE UNDERGROUND PETROLEUM ENVIRONMENTAL RESPONSE (SUPER) ACT REIMBURSEMENT		
	FROM ADMINISTRATIVE TRUST FUND . . .		534,775
TOTAL:	ENVIRONMENTAL HEALTH SERVICES		
	FROM GENERAL REVENUE FUND	5,825,883	
	FROM TRUST FUNDS		21,321,969
	TOTAL POSITIONS	218.50	
	TOTAL ALL FUNDS		27,147,852

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Section 33. The amendment to s. 403.1651(1), Florida Statutes, made by this act shall expire July 1, 2010, and the text of that subsection shall revert to that in existence on June 30, 2009, except that any amendments to such text enacted other than by this act shall be preserved and continue to operate to the extent that such amendments are not dependent upon the portions of such text which expire pursuant to this section.

Section 34. In order to implement Specific Appropriations 1294 through 1454 of the 2009-2010 General Appropriations Act, subsection (2) of section 570.20, Florida Statutes, is amended to read:

570.20 General Inspection Trust Fund.—

(2) For the 2009-2010 ~~2008-2009~~ fiscal year only and notwithstanding any other provision of law to the contrary, in addition to the spending authorized in subsection (1), moneys in the General Inspection Trust Fund may be appropriated for programs operated by the department which are related to the programs authorized by this chapter. This subsection expires July 1, 2010 ~~2009~~.

Section 35. In order to implement Specific Appropriation 1760 of the 2009-2010 General Appropriations Act, present subsection (7) of section 403.7095, Florida Statutes, is redesignated as subsection (8), and a new subsection (7) is added to that section, to read:

403.7095 Solid waste management grant program.—

(7) Notwithstanding any provision of this section to the contrary, and for the 2009-2010 fiscal year only, the Department of Environmental Protection shall award the sum of $2,600,000 in grants equally to counties having populations of fewer than 100,000 for waste tire and litter prevention, recycling education, and general solid waste programs. This subsection expires July 1, 2010.

Section 36. In order to implement Specific Appropriation 1407 of the 2009-2010 General Appropriations Act and to provide consistency and continuity in the promotion of agriculture throughout the state, notwithstanding s. 287.057, Florida Statutes, the Department of Agriculture and Consumer Services, at its discretion, may extend, revise, and renew current contracts or agreements created or entered into pursuant to chapter 2006-25, Laws of Florida. This section expires July 1, 2010.

Section 37. (1) In order to implement proviso following Specific Appropriation 471 of the 2009-2010 General Appropriations Act, and for the 2009-2010 fiscal year only, notwithstanding any law to the contrary, a state agency may not adopt or implement a rule or policy that:

(a) Mandates or establishes new nitrogen-reduction limits that apply to existing or new onsite sewage treatment systems;

(b) Has the effect of requiring the use of performance-based treatment systems; or

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(c) Increases the cost of treatment for nitrogen reduction from onsite systems,

before the study and report required in proviso following Specific Appropriation 471 is completed.

(2) This section is repealed July 1, 2010.

Section 38. In order to implement Specific Appropriation 2577 of the 2009-2010 General Appropriations Act, paragraphs (c) and (d) of subsection (4) of section 288.1254, Florida Statutes, are amended to read:

288.1254 Entertainment industry financial incentive program.—

(4) PRIORITY FOR INCENTIVE FUNDING; WITHDRAWAL OF ELIGIBILITY; QUEUES.—

(c) Independent Florida filmmaker queue.—Ten ~~Five~~ percent of incentive funding appropriated in any state fiscal year must be dedicated to the independent Florida filmmaker queue. If there are no qualified applications in the queue, any funding in the queue shall be made available to a qualified project in the digital media projects queue. A production certified under this queue is eligible for a reimbursement equal to 15 percent of its actual qualified expenditures. An independent Florida film that meets the criteria of this queue and demonstrates a minimum of $100,000, but not more than $625,000, in total qualified expenditures is eligible for incentive funding. To qualify for this queue, a qualified production must:

1. Be planned as a feature film or documentary of no less than 70 minutes in length.

2. Provide evidence of 50 percent of the financing for its total budget in an escrow account or other form dedicated to the production.

3. Do all major postproduction in this state.

4. Employ Florida workers in at least six of the following key positions: writer, director, producer, director of photography, star or one of the lead actors, unit production manager, editor, or production designer. As used in this subparagraph, the term "Florida worker" means a person who has been a resident of this state for at least 1 year before a production's application under subsection (3) was submitted or a person who graduated from a film school, college, university, or community college in this state no more than 5 years before such submittal or who is enrolled full-time in such a school, college, or university.

(d) Digital media projects queue.—Five ~~Ten~~ percent of incentive funding appropriated in any state fiscal year shall be dedicated to the digital media projects queue. A production certified under this queue is eligible for a reimbursement equal to 10 percent of its actual qualified expenditures. A qualified production that is a digital media project that demonstrates a minimum of $300,000 in total qualified expenditures is eligible for a maximum of $1 million in incentive funding. As used in this paragraph, the term

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2010 Appropriations Language

SECTION 3 - HUMAN SERVICES

485	SPECIAL CATEGORIES ACQUISITION OF MOTOR VEHICLES		
	FROM ADMINISTRATIVE TRUST FUND . . .		80,000
	FROM RADIATION PROTECTION TRUST FUND		130,856
486	SPECIAL CATEGORIES CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	153,772	
	FROM ADMINISTRATIVE TRUST FUND . . .		337,765
	FROM FEDERAL GRANTS TRUST FUND . . .		348,235
	FROM GRANTS AND DONATIONS TRUST FUND		2,648,438
	FROM RADIATION PROTECTION TRUST FUND		150,000

From the funds in Specific Appropriation 486, $2,000,000 from the Grants and Donations Trust Fund is provided to the department to continue phase II and complete the study authorized in Specific Appropriation 1682 of chapter 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 report of phase II on February 1, 2011, a subsequent status report on May 16, 2011, and a final report upon completion of phase II to the Governor, the President of the Senate, and the Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities.

487	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED SERVICES		
	FROM FEDERAL GRANTS TRUST FUND . . .		750,000
488	SPECIAL CATEGORIES RISK MANAGEMENT INSURANCE		
	FROM GENERAL REVENUE FUND	66,504	
	FROM RADIATION PROTECTION TRUST FUND		14,575
489	SPECIAL CATEGORIES TRANSFER TO DEPARTMENT OF MANAGEMENT SERVICES - HUMAN RESOURCES SERVICES PURCHASED PER STATEWIDE CONTRACT		
	FROM GENERAL REVENUE FUND	12,630	
	FROM ADMINISTRATIVE TRUST FUND . . .		18,342
	FROM FEDERAL GRANTS TRUST FUND . . .		9,712
	FROM GRANTS AND DONATIONS TRUST FUND		8,282
	FROM RADIATION PROTECTION TRUST FUND		40,522
490	SPECIAL CATEGORIES STATE UNDERGROUND PETROLEUM ENVIRONMENTAL RESPONSE (SUPER) ACT REIMBURSEMENT		
	FROM GRANTS AND DONATIONS TRUST FUND		534,775
TOTAL:	ENVIRONMENTAL HEALTH SERVICES		
	FROM GENERAL REVENUE FUND	5,436,035	
	FROM TRUST FUNDS		23,407,013
	TOTAL POSITIONS	217.50	
	TOTAL ALL FUNDS		28,843,048

COUNTY HEALTH DEPARTMENTS LOCAL HEALTH NEEDS

APPROVED SALARY RATE 474,197,601

492	SALARIES AND BENEFITS POSITIONS	12,359.00	
	FROM COUNTY HEALTH DEPARTMENT TRUST FUND		652,737,029
493	OTHER PERSONAL SERVICES		
	FROM COUNTY HEALTH DEPARTMENT TRUST FUND		32,697,185

CODING: Language ~~stricken~~ has been vetoed by the Governor

operating margin for the previous fiscal year to the Agency for Health Care Administration through hospital-audited financial data; and

(e) The department may not execute a contract for health care services at hospitals for rates other than rates based on a percentage of the Medicare allowable rate.

(2) For purposes of this section, the term "hospital" means any hospital licensed under chapter 395, Florida Statutes.

(3) This section expires July 1, 2011.

Section 12. In order to implement Specific Appropriations 3214 through 3216, 3218, 3222, and 3245A of the 2010-2011 General Appropriations Act, subsection (3) is added to section 44.108, Florida Statutes, to read:

44.108 Funding of mediation and arbitration.—

(3) For the 2010-2011 fiscal year only and notwithstanding any other provision of law to the contrary, moneys in the Mediation and Arbitration Trust Fund may be used as specified in the General Appropriations Act. This subsection expires July 1, 2011.

Section 13. In order to implement Specific Appropriations 324 through 355 of the 2010-2011 General Appropriations Act, paragraphs (b) and (c) of subsection (3) of section 394.908, Florida Statutes, are amended to read:

394.908 Substance abuse and mental health funding equity; distribution of appropriations.—In recognition of the historical inequity in the funding of substance abuse and mental health services for the department's districts and regions and to rectify this inequity and provide for equitable funding in the future throughout the state, the following funding process shall be used:

(3)

(b) Notwithstanding paragraph (a) and for the 2010-2011 ~~2009-2010~~ fiscal year only, funds appropriated for forensic mental health treatment services shall be allocated to the areas of the state having the greatest demand for services and treatment capacity. This paragraph expires July 1, 2011 ~~2010~~.

(c) Notwithstanding paragraph (a) and for the 2010-2011 ~~2009-2010~~ fiscal year only, additional funds appropriated for substance abuse and mental health services from funds available through the Community-Based Medicaid Administrative Claiming Program shall be allocated as provided in the 2010-2011 ~~2009-2010~~ General Appropriations Act and in proportion to contributed provider earnings. This paragraph expires July 1, 2011 ~~2010~~.

Section 14. In order to implement Specific Appropriation 486 of the 2010-2011 General Appropriations Act, and for the 2010-2011 fiscal year only, the

following requirements shall govern Phase 2 of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

(1) The underlying contract for which the study was let shall remain in full force and effect with the Department of Health and funding the contract for Phase 2 of the study shall be through the Department of Health.

(2) The Department of Health, the Department of Health's Research Review and Advisory Committee, and the Department of Environmental Protection shall work together to provide the necessary technical oversight of Phase 2 of the project, with the Department of Environmental Protection having maximum technical input.

(3) Management and oversight of Phase 2 shall be consistent with the terms of the existing contract; however, the main focus and priority for work to be completed for Phase 2 shall be in developing, testing, and recommending cost-effective passive technology design criteria for nitrogen reduction.

(4) The systems installed at actual home sites are experimental in nature and shall be installed with significant field testing and monitoring. The Department of Health is specifically authorized to allow installation of these experimental systems. In addition, before Phase 2 of the study is complete and notwithstanding any law to the contrary, a state agency may not adopt or implement a rule or policy that:

(a) Mandates, establishes, or implements any new nitrogen-reduction standards that apply to existing or new onsite sewage treatment systems or modification of such systems;

(b) Increases the cost of treatment for nitrogen reduction from onsite sewage treatment systems; or

(c) Directly requires or has the indirect effect of requiring, for nitrogen reduction, the use of performance-based treatment systems or any similar technology; provided the Department of Environmental Protection administrative orders recognizing onsite system modifications, developed through a basin management action plan adopted pursuant to section 403.067, Florida Statutes, are not subject to the above restrictions where implementation of onsite system modifications are phased in after completion of Phase 2, except that no onsite system modification developed in a basin management action plan shall directly or indirectly require the installation of performance-based treatment systems.

Section 15. Effective June 29, 2010, in order to implement Specific Appropriation 270 through 375 of the 2010-2011 General Appropriations Act, subsection (3) of section 1 of chapter 2007-174, Laws of Florida, is amended to read:

Section 1. Flexibility for the Department of Children and Family Services.-

2011 Appropriations Language

SECTION 3 - HUMAN SERVICES

ENVIRONMENTAL HEALTH SERVICES

	APPROVED SALARY RATE	9,769,560		
459	SALARIES AND BENEFITS	POSITIONS	215.50	
	FROM GENERAL REVENUE FUND		1,684,847	
	FROM ADMINISTRATIVE TRUST FUND . . .			2,359,097
	FROM FEDERAL GRANTS TRUST FUND . . .			1,612,406
	FROM GRANTS AND DONATIONS TRUST FUND			1,896,302
	FROM RADIATION PROTECTION TRUST FUND			6,143,674
460	OTHER PERSONAL SERVICES			
	FROM ADMINISTRATIVE TRUST FUND . . .			71,060
	FROM FEDERAL GRANTS TRUST FUND . . .			131,791
	FROM GRANTS AND DONATIONS TRUST FUND			130,415
	FROM RADIATION PROTECTION TRUST FUND			33,393
461	EXPENSES			
	FROM GENERAL REVENUE FUND		209,662	
	FROM ADMINISTRATIVE TRUST FUND . . .			978,799
	FROM FEDERAL GRANTS TRUST FUND . . .			348,011
	FROM GRANTS AND DONATIONS TRUST FUND			321,055
	FROM RADIATION PROTECTION TRUST FUND			1,734,991
462	AID TO LOCAL GOVERNMENTS CONTRIBUTION TO COUNTY HEALTH UNITS			
	FROM GENERAL REVENUE FUND		2,200,270	
	FROM ADMINISTRATIVE TRUST FUND . . .			427,426
	FROM GRANTS AND DONATIONS TRUST FUND			2,194,571
463	OPERATING CAPITAL OUTLAY			
	FROM ADMINISTRATIVE TRUST FUND . . .			15,000
	FROM FEDERAL GRANTS TRUST FUND . . .			31,698
	FROM RADIATION PROTECTION TRUST FUND			56,997
464	SPECIAL CATEGORIES ACQUISITION OF MOTOR VEHICLES			
	FROM ADMINISTRATIVE TRUST FUND . . .			80,000
	FROM RADIATION PROTECTION TRUST FUND			130,856
465	SPECIAL CATEGORIES CONTRACTED SERVICES			
	FROM GENERAL REVENUE FUND		97,489	
	FROM ADMINISTRATIVE TRUST FUND . . .			335,165
	FROM FEDERAL GRANTS TRUST FUND . . .			643,776
	FROM GRANTS AND DONATIONS TRUST FUND			3,401,038
	FROM RADIATION PROTECTION TRUST FUND			150,000

From the funds in Specific Appropriation 465, $2,725,000 in nonrecurring funds from the Grants and Donations Trust Fund is provided to the department to complete phase II and phase III and complete the study authorized in Specific Appropriation 1682 of chapter 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 report of the completion of phase II and progress on phase III on February 1, 2012, a subsequent status report on May 16, 2012, and a final report upon completion of phase III to the Governor, the President of the Senate, and the Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities.

466	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED SERVICES			
	FROM FEDERAL GRANTS TRUST FUND . . .			750,000

services shall be allocated to the areas of the state having the greatest demand for services and treatment capacity. This paragraph expires July 1, 2012 ~~2011~~.

(c) Notwithstanding paragraph (a) and for the 2011-2012 ~~2010-2011~~ fiscal year only, additional funds appropriated for substance abuse and mental health services from funds available through the Community-Based Medicaid Administrative Claiming Program shall be allocated as provided in the 2010-2011 General Appropriations Act and in proportion to contributed provider earnings. This paragraph expires July 1, 2012 ~~2011~~.

Section 7. In order to implement Specific Appropriation 465 of the 2011-2012 General Appropriations Act, and for the 2011-2012 fiscal year only, the following requirements govern the completion of Phase 2 and Phase 3 of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

(1) The Department of Health's underlying contract for the study remains in full force and effect and funding for completion of Phase 2 and Phase 3 is through the Department of Health.

(2) The Department of Health, the Department of Health's Research Review and Advisory Committee, and the Department of Environmental Protection shall work together to provide the necessary technical oversight of the completion of Phase 2 and Phase 3 of the project.

(3) Management and oversight of the completion of Phase 2 and Phase 3 must be consistent with the terms of the existing contract. However, the main focus and priority to be completed during Phase 3 shall be developing, testing, and recommending cost-effective passive technology design criteria for nitrogen reduction.

(4) The systems installed at homesites are experimental in nature and shall be installed with significant field testing and monitoring. The Department of Health is specifically authorized to allow installation of these experimental systems. Notwithstanding any other law, before Phase 3 of the study is completed, a state agency may not adopt or implement a rule or policy that:

(a) Mandates, establishes, or implements more restrictive nitrogen-reduction standards to existing or new onsite sewage treatment systems or modification of such systems; or

(b) Directly or indirectly requires the use of performance-based treatment systems or similar technology, such as through an administrative order developed by the Department of Environmental Protection as part of a basin management action plan adopted pursuant to s. 403.067, Florida Statutes. However, the implementation of more restrictive nitrogen-reduction standards for onsite systems may be required through a basin management action plan if such plan is phased in after completion of Phase 3.

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2012 Appropriations Language

SECTION 3 - HUMAN SERVICES

	FROM FEDERAL GRANTS TRUST FUND . . .		31,698
	FROM RADIATION PROTECTION TRUST FUND		56,997
511	SPECIAL CATEGORIES ACQUISITION OF MOTOR VEHICLES FROM RADIATION PROTECTION TRUST FUND		210,856
512	SPECIAL CATEGORIES CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	2,047,489	
	FROM ADMINISTRATIVE TRUST FUND . . .		335,165
	FROM FEDERAL GRANTS TRUST FUND . . .		643,776
	FROM GRANTS AND DONATIONS TRUST FUND		676,038
	FROM RADIATION PROTECTION TRUST FUND		150,000

From the funds in Specific Appropriation 512, $1,500,000 in nonrecurring funds from the General Revenue Fund is provided to the department to complete phase II and phase III of the study authorized in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida. The funds will be spent for installing field systems and sampling, installing and sampling the soil and groundwater at various sites throughout Florida to determine how nitrogen moves, and developing various models to show how nitrogen is affected by treatment in Florida-specific soils. The department shall submit a status report before October 1, 2012, a subsequent status report before February 1, 2013, and a final report upon completion of phase III to the Governor, the President of the Senate, and the Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities.

From the funds in Specific Appropriation 512, $450,000 in recurring funds from the General Revenue Fund is provided to the Birth Defects Registry.

513	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED SERVICES FROM FEDERAL GRANTS TRUST FUND . . .		750,000
514	SPECIAL CATEGORIES RISK MANAGEMENT INSURANCE		
	FROM GENERAL REVENUE FUND	79,670	
	FROM RADIATION PROTECTION TRUST FUND		14,575
515	SPECIAL CATEGORIES LEASE OR LEASE-PURCHASE OF EQUIPMENT		
	FROM GENERAL REVENUE FUND	7,348	
	FROM ADMINISTRATIVE TRUST FUND . . .		1,748
	FROM FEDERAL GRANTS TRUST FUND . . .		1,532
	FROM RADIATION PROTECTION TRUST FUND		1,052
516	SPECIAL CATEGORIES TRANSFER TO DEPARTMENT OF MANAGEMENT SERVICES - HUMAN RESOURCES SERVICES PURCHASED PER STATEWIDE CONTRACT		
	FROM GENERAL REVENUE FUND	12,667	
	FROM ADMINISTRATIVE TRUST FUND . . .		13,220
	FROM FEDERAL GRANTS TRUST FUND . . .		9,758
	FROM GRANTS AND DONATIONS TRUST FUND		13,529
	FROM RADIATION PROTECTION TRUST FUND		40,713
517	SPECIAL CATEGORIES STATE UNDERGROUND PETROLEUM ENVIRONMENTAL RESPONSE (SUPER) ACT REIMBURSEMENT FROM GRANTS AND DONATIONS TRUST FUND		534,775

CODING: Language ~~stricken~~ has been vetoed by the Governor

Section 2. In order to implement Specific Appropriations 6, 7, 8, 84, and 85 of the 2012-2013 General Appropriations Act, the calculations of the Florida Education Finance Program for the 2012-2013 fiscal year in the document entitled "Public School Funding-The Florida Education Finance Program," dated March 6, 2012, and filed with the Clerk of the House of Representatives, are incorporated by reference for the purpose of displaying the calculations used by the Legislature, consistent with the requirements of the Florida Statutes, in making appropriations for the Florida Education Finance Program. This section expires July 1, 2013.

Section 3. In order to implement Specific Appropriation 16A of the 2012-2013 General Appropriations Act, paragraph (c) of subsection (3) of section 216.292, Florida Statutes, is amended to read:

216.292 Appropriations nontransferable; exceptions.—

(3) The following transfers are authorized with the approval of the Executive Office of the Governor for the executive branch or the Chief Justice for the judicial branch, subject to the notice and objection provisions of s. 216.177:

(c) The transfer of appropriations for fixed capital outlay from the Survey Recommended Needs-Public Schools appropriation category to the Maintenance, Repair, Renovation and Remodeling appropriation category. The allocation of transferred funds must be in accordance with s. 1013.62. This paragraph expires July 1, 2013 ~~2012~~.

Section 4. In order to implement Specific Appropriation 129 of the 2012-2013 General Appropriations Act and notwithstanding any other law, for the 2012-2013 fiscal year only, a university board of trustees may expend reserve or carryforward balances from previous years' operational and programmatic appropriations for legislatively approved fixed capital outlay projects authorized for the establishment of a new campus.

Section 5. (1) In order to implement Specific Appropriation 512 of the 2012-2013 General Appropriations Act, and for the 2012-2013 fiscal year only, the following requirements govern the completion of Phase 2 and Phase 3 of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

(a) The Department of Health's underlying contract for the study remains in full force and effect and funding for completion of Phase 2 and Phase 3 is through the Department of Health.

(b) The Department of Health, the Department of Health's Research Review and Advisory Committee, and the Department of Environmental Protection shall work together to provide the necessary technical oversight of the completion of Phase 2 and Phase 3 of the project.

(c) Management and oversight of the completion of Phase 2 and Phase 3 must be consistent with the terms of the existing contract. However, the

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main focus and priority to be completed during Phase 3 shall be developing, testing, and recommending cost-effective passive technology design criteria for nitrogen reduction.

(d) The systems installed at homesites are experimental in nature and shall be installed with significant field testing and monitoring. The Department of Health is specifically authorized to allow installation of these experimental systems. Notwithstanding any other law, before Phase 3 of the study is completed, a state agency may not adopt or implement a rule or policy that:

1. Mandates, establishes, or implements more restrictive nitrogen-reduction standards to existing or new onsite sewage treatment systems or modification of such systems; or

2. Directly or indirectly requires the use of performance-based treatment systems or similar technology, such as through an administrative order developed by the Department of Environmental Protection as part of a basin management action plan adopted pursuant to s. 403.067, Florida Statutes. However, the implementation of more restrictive nitrogen-reduction standards for onsite systems may be required through a basin management action plan if such plan is phased in after completion of Phase 3.

(2) This section expires July 1, 2013.

Section 6. In order to implement Specific Appropriations 187, 193 through 195, and 198 of the 2012-2013 General Appropriations Act, the calculations of the Medicaid Low-Income Pool, Disproportionate Share Hospital, and Hospital Exemptions Programs for the 2012-2013 fiscal year in the document entitled "Medicaid Supplemental Hospital Funding Programs" dated March 6, 2012, and filed with the Clerk of the House of Representatives, are incorporated by reference for the purpose of displaying the calculations used by the Legislature, consistent with the requirements of the Florida Statutes, in making appropriations for the Low-Income Pool, Disproportionate Share Hospital, and Hospital Exemptions Programs. This section expires July 1, 2013.

Section 7. In order to implement Specific Appropriations 283 through 390 of the 2012-2013 General Appropriations Act, subsection (4) of section 20.04, Florida Statutes, is amended to read:

20.04 Structure of executive branch.—The executive branch of state government is structured as follows:

(4) Within the Department of Children and Family Services there are organizational units called "circuits" and "regions." Each circuit is aligned geographically with each judicial circuit, and each region comprises multiple circuits that are in geographical proximity to each other ~~"program offices," headed by program directors~~.

2013 Appropriations Language

SECTION 3 - HUMAN SERVICES

qualify as state matching funds for the Ryan White grant.

489	AID TO LOCAL GOVERNMENTS GRANTS AND AIDS - STATEWIDE ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS) NETWORKS		
	FROM GENERAL REVENUE FUND	10,463,853	
490	AID TO LOCAL GOVERNMENTS CONTRIBUTION TO COUNTY HEALTH UNITS		
	FROM GENERAL REVENUE FUND	14,662,823	
	FROM ADMINISTRATIVE TRUST FUND . . .		427,426
	FROM GRANTS AND DONATIONS TRUST FUND		2,194,571
491	OPERATING CAPITAL OUTLAY		
	FROM GENERAL REVENUE FUND	2,500	
	FROM ADMINISTRATIVE TRUST FUND . . .		15,000
	FROM FEDERAL GRANTS TRUST FUND . . .		210,024
493	SPECIAL CATEGORIES CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	1,115,183	
	FROM ADMINISTRATIVE TRUST FUND . . .		335,165
	FROM FEDERAL GRANTS TRUST FUND . . .		5,856,290
	FROM GRANTS AND DONATIONS TRUST FUND		1,538,038
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		609,948
	FROM RADIATION PROTECTION TRUST FUND		1,500

From the funds in Specific Appropriation 493, $700,000 in nonrecurring funds from the Grants and Donations Trust Fund is provided to the department to continue Phase III of the study authorized in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida, which is scheduled to be completed January 16, 2015 based on the February 1, 2013 status report submitted by the department. The funds shall be spent for field monitoring of performance and cost of technologies at various sites, sampling the soil and groundwater at various sites to determine how nitrogen moves, refinement of various models to show how nitrogen is affected by treatment in Florida-specific soils and final reporting on all tasks with recommendations of nitrogen reduction strategies for onsite sewage treatment and disposal systems. The department shall submit a final report upon completion of Phase III to the Governor, the President of the Senate, and the Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities.

From the funds in Specific Appropriation 493, $450,000 from the General Revenue Fund is provided to the Birth Defects Registry.

494	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	1,530,876	
	FROM FEDERAL GRANTS TRUST FUND . . .		11,896,717
495	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED PROFESSIONAL SERVICES		
	FROM GENERAL REVENUE FUND	1,995,141	
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		3,000,000
496	SPECIAL CATEGORIES GRANTS AND AIDS - ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS) INSURANCE CONTINUATION PROGRAM		
	FROM GENERAL REVENUE FUND	6,454,951	
	FROM FEDERAL GRANTS TRUST FUND . . .		8,516,293
497	SPECIAL CATEGORIES PURCHASED CLIENT SERVICES		
	FROM GENERAL REVENUE FUND	498,687	
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		252,395
498	SPECIAL CATEGORIES RISK MANAGEMENT INSURANCE		
	FROM GENERAL REVENUE FUND	162,599	

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notwithstanding any other law, in order to provide consistency and continuity in the provision of mental health and substance abuse treatment services to individuals throughout the state, the Department of Children and Families may not require managing entities contracting with the department under s. 394.9082, Florida Statutes, to conduct provider network procurements during the 2013-2014 fiscal year. The department shall amend its contracts with each managing entity, if necessary, to remove contractual provisions that have the effect of requiring a managing entity to conduct a provider network procurement during the 2013-2014 fiscal year. This section expires July 1, 2014.

Section 8. (1) In order to implement Specific Appropriation 493 of the 2013-2014 General Appropriations Act, the following requirements govern the continuation of Phase 3 of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

(a) The Department of Health's underlying contract for the study remains in full force and effect and funding for continuation of Phase 3 is provided through the department.

(b) The Department of Health's Research Review and Advisory Committee and the Department of Environmental Protection shall work together to provide the necessary technical oversight of the continuation of Phase 3.

(c) Management and oversight of the continuation of Phase 3 must be consistent with the terms of the existing contract. However, the main focus and priority to be completed during Phase 3 is testing and recommending cost-effective passive technology design criteria for nitrogen reduction. Notwithstanding any other law, before Phase 3 is completed, a state agency may not adopt or implement a rule or policy that:

1. Mandates, establishes, or implements more restrictive nitrogen reduction standards to existing or new onsite sewage treatment systems or modification of such systems; or

2. Directly or indirectly, such as through an administrative order developed by the Department of Environmental Protection as part of a basin management action plan adopted pursuant to s. 403.067, Florida Statutes, requires the use of performance-based treatment systems or similar technology. However, more restrictive nitrogen reduction standards for onsite systems may be required through a basin management action plan if such plan is phased in after completion of Phase 3.

(2) This section expires July 1, 2014.

Section 9. (1) In order to implement Specific Appropriation 267 of the 2013-2014 General Appropriations Act, and notwithstanding s. 393.065(5), Florida Statutes, individuals from the Medicaid home and community-based waiver programs wait list shall be offered a slot on the waiver as follows:

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2014 Appropriations Language

Ch. 2014-51 LAWS OF FLORIDA Ch. 2014-51

SECTION 3 - HUMAN SERVICES

	FROM RADIATION PROTECTION TRUST FUND		60,615
485	AID TO LOCAL GOVERNMENTS GRANTS AND AIDS - AIDS PATIENT CARE		
	FROM GENERAL REVENUE FUND	12,709,807	
	FROM FEDERAL GRANTS TRUST FUND . . .		7,560,522

From the funds in Specific Appropriation 485, $100,000 in nonrecurring funds from the General Revenue Fund is provided to Care Resource for the acquisition of a mobile health clinic to provide HIV/AIDS services to individuals in Miami-Dade and Broward counties.

486	AID TO LOCAL GOVERNMENTS GRANTS AND AIDS - RYAN WHITE CONSORTIA		
	FROM FEDERAL GRANTS TRUST FUND . . .		20,754,358

Funds in Specific Appropriation 486 from the Federal Grants Trust Fund are contingent upon sufficient state matching funds being identified to qualify for the federal Ryan White grant award. The Department of Health and the Department of Corrections shall collaborate in determining the amount of general revenue funds expended by the Department of Corrections for AIDS-related activities and services that qualify as state matching funds for the Ryan White grant.

487	AID TO LOCAL GOVERNMENTS GRANTS AND AIDS - STATEWIDE ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS) NETWORKS		
	FROM GENERAL REVENUE FUND	10,463,853	
488	AID TO LOCAL GOVERNMENTS CONTRIBUTION TO COUNTY HEALTH UNITS		
	FROM GENERAL REVENUE FUND	14,662,823	
	FROM ADMINISTRATIVE TRUST FUND . . .		427,426
	FROM GRANTS AND DONATIONS TRUST FUND		2,194,571
489	OPERATING CAPITAL OUTLAY		
	FROM GENERAL REVENUE FUND	2,500	
	FROM ADMINISTRATIVE TRUST FUND . . .		15,000
	FROM FEDERAL GRANTS TRUST FUND . . .		210,024
490	SPECIAL CATEGORIES CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	1,800,183	
	FROM ADMINISTRATIVE TRUST FUND . . .		335,165
	FROM FEDERAL GRANTS TRUST FUND . . .		5,856,290
	FROM GRANTS AND DONATIONS TRUST FUND		838,038
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		609,948
	FROM RADIATION PROTECTION TRUST FUND		1,500

From the funds in Specific Appropriation 490, $650,000 in nonrecurring funds from the General Revenue Fund is provided for the Department of Health to continue the study authorized in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida. The funds shall be spent for field monitoring of performance and cost of technologies at various sites, sampling the soil and groundwater at various sites to determine how nitrogen moves, refinement of various models to show how nitrogen is affected by treatment in Florida-specific soils and final reporting on all tasks with recommendations of nitrogen reduction strategies for onsite sewage treatment and disposal systems. The department shall submit a final report upon completion of the study to the Governor, President of the Senate, and Speaker of the House of Representatives prior to proceeding with any nitrogen reduction activities.

From the funds in Specific Appropriation 490, $35,000 in nonrecurring funds from the General Revenue Fund is provided to update the Behavioral Risk Factor Surveillance System to include response questions that address Alzheimer's Disease.

From the funds in Specific Appropriation 490, $450,000 from the General Revenue Fund is provided to the Birth Defects Registry.

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final taxable value, multiplied by the prior year district required local effort millage. If the district's prior year preliminary taxable value is less than the district's prior year final taxable value, the prior period unrealized required local effort funds are zero.

c. For the 2014-2015 fiscal year only, if a district's prior period unrealized required local effort funds and prior period district required local effort millage cannot be determined because such district's final taxable value has not yet been certified pursuant to s. 193.122(2) or (3), for the 2014 tax levy, the Prior Period Funding Adjustment Millage for such fiscal year shall be levied in 2014 in an amount equal to 75 percent of such district's most recent unrealized required local effort for which a Prior Period Funding Adjustment Millage was determined as provided in this section. Upon certification of the final taxable value for the 2013 tax roll in accordance with s. 193.122(2) or (3), the Prior Period Funding Adjustment Millage levied in 2015 shall be adjusted to include any shortfall or surplus in the prior period unrealized required local effort funds that would have been levied in 2014, had the district's final taxable value been certified pursuant to s. 193.122(2) or (3) for the 2014 tax levy. This provision shall be implemented by a district only if the millage calculated pursuant to this paragraph when added to the millage levied by the district for all purposes for the 2014-2015 fiscal year is less than or equal to the total millage levied for the 2013-2014 fiscal year. This sub-subparagraph expires July 1, 2015.

Section 6. In order to implement Specific Appropriation 28A of the 2014-2015 General Appropriations Act and notwithstanding s. 1013.64(2), Florida Statutes, any district school board that generates less than $1 million in revenue from a 1-mill levy of ad valorem tax shall contribute 0.75 mills for fiscal year 2014-2015 toward the cost of funded special facilities construction projects. This section expires July 1, 2015.

Section 7. In order to implement Specific Appropriations 203, 210, 211, 212, and 215 of the 2014-2015 General Appropriations Act, the calculations for the Medicaid Low-Income Pool, Disproportionate Share Hospital, and Hospital Reimbursement programs, and the parameters and calculations for the diagnosis-related group (DRG) methodology for hospital reimbursement, for the 2014-2015 fiscal year contained in the document titled "Medicaid Hospital Funding Programs," dated April 29, 2014, and filed with the Clerk of the House of Representatives, are incorporated by reference for the purpose of displaying the calculations used by the Legislature, consistent with the requirements of state law, in making appropriations for the Medicaid Low-Income Pool, Disproportionate Share Hospital, and Hospital Reimbursement programs, and the parameters and calculations for the diagnosis-related group methodology for hospital reimbursement. This section expires July 1, 2015.

Section 8. (1) In order to implement Specific Appropriation 490 of the 2014-2015 General Appropriations Act, the following requirements govern the continuation of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

CODING: Words ~~stricken~~ are deletions; words underlined are additions.

(a) Funding for completion of the study is through the Department of Health. Notwithstanding s. 287.057, Florida Statutes, the current contract may be extended until the study is completed.

(b) The Department of Health, the Department of Health's Research Review and Advisory Committee, and the Department of Environmental Protection shall work together to provide the necessary technical oversight to complete the study.

(c) Management and oversight of the completion of the study must be consistent with the terms of the existing contract. However, the main focus and priority shall be developing, testing, and recommending cost-effective passive technology design criteria for nitrogen reduction. Notwithstanding any other provision of law, before the study is completed, a state agency may not adopt or implement a rule or policy that:

1. Mandates, establishes, or implements more restrictive nitrogen reduction standards to existing or new onsite sewage treatment systems or modification of such systems; or

2. Directly or indirectly, such as through an administrative order issued by the Department of Environmental Protection as part of a basin management action plan adopted pursuant to s. 403.067, Florida Statutes, requires the use of performance-based treatment systems or similar technologies. However, more restrictive nitrogen reduction standards for onsite systems may be required through a basin management action plan if such plan is phased in after the study is completed.

(d) Any systems installed at home sites are experimental in nature and shall be installed with significant field testing and monitoring. The Department of Health is specifically authorized to allow installation of these experimental systems.

(2) This section expires July 1, 2015.

Section 9. (1) In order to implement Specific Appropriation 268 of the 2014-2015 General Appropriations Act, and notwithstanding s. 393.065(5), Florida Statutes, individuals on the Medicaid home and community-based waiver programs wait list shall be offered a slot in the waiver as follows:

(a) Individuals in category 1, which includes clients deemed to be in crisis as described in rule, shall be given first priority in moving from the wait list to the waiver.

(b) Individuals in category 2 at the time of finalization of an adoption with placement in a family home, reunification with family members with placement in a family home, or permanent placement with a relative in a family home, shall be moved to the waiver.

(c) In selecting individuals in category 3 or category 4, the Agency for Persons with Disabilities shall use the Agency for Persons with Disabilities

2015 Appropriations Language

SECTION 3 - HUMAN SERVICES

381.986(5) and 385.212, Florida Statutes. The Department of Health is authorized to submit budget amendments for the release of the lump sum appropriation pursuant to the provisions of chapter 216, Florida Statutes. Rate may be established for these positions at an amount not to exceed 187,149.

470	SPECIAL CATEGORIES CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	1,291,055	
	FROM ADMINISTRATIVE TRUST FUND . . .		335,165
	FROM FEDERAL GRANTS TRUST FUND . . .		6,479,690
	FROM GRANTS AND DONATIONS TRUST FUND		838,038
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		609,948
	FROM PLANNING AND EVALUATION TRUST FUND		2,458,489
	FROM RADIATION PROTECTION TRUST FUND		1,500

From the funds in Specific Appropriation 470, $10,000 from the General Revenue Fund is provided to the Department of Health to conclude the nitrogen reduction study authorized in Specific Appropriation 1682 of chapter 2008-152, Laws of Florida, by August 31, 2015. The study shall include an analysis of field monitoring of performance and cost of technologies at various sites, an analysis of soil and groundwater sampling at various sites to determine how nitrogen moves, an analysis of various models to show how nitrogen is affected by treatment in Florida-specific soils, and final reporting on all tasks with recommendations for science-based nitrogen reduction options for onsite sewage treatment and disposal systems. The department shall submit a final report by December 31, 2015, to the Executive Office of the Governor, the President of the Senate, and the Speaker of the House of Representatives.

From the funds in Specific Appropriation 470, $450,000 from the General Revenue Fund is provided to the Birth Defects Registry.

471	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED SERVICES		
	FROM GENERAL REVENUE FUND	2,530,876	
	FROM FEDERAL GRANTS TRUST FUND . . .		11,896,717

From the funds in Specific Appropriation 471, $1,000,000 in nonrecurring funds from the General Revenue Fund is provided for Florida academic and research institutions designated as Centers for AIDS Research (CFAR) by the National Institutes of Health to enhance high quality HIV/AIDS research projects conducted in response to the health needs of Florida's citizens.

472	SPECIAL CATEGORIES GRANTS AND AIDS - CONTRACTED PROFESSIONAL SERVICES		
	FROM GENERAL REVENUE FUND	1,995,141	
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		3,000,000
473	SPECIAL CATEGORIES GRANTS AND AIDS - ACQUIRED IMMUNE DEFICIENCY SYNDROME (AIDS) INSURANCE CONTINUATION PROGRAM		
	FROM GENERAL REVENUE FUND	6,454,951	
	FROM FEDERAL GRANTS TRUST FUND . . .		8,516,293
474	SPECIAL CATEGORIES PURCHASED CLIENT SERVICES		
	FROM GENERAL REVENUE FUND	498,687	
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		252,395
475	SPECIAL CATEGORIES RISK MANAGEMENT INSURANCE		
	FROM GENERAL REVENUE FUND	96,085	
	FROM OPERATIONS AND MAINTENANCE TRUST FUND		200,945
	FROM PLANNING AND EVALUATION TRUST FUND		100,576

CODING: Language ~~stricken~~ has been vetoed by the Governor

Section 17. (1) In order to implement Specific Appropriation 470 of the 2015-2016 General Appropriations Act, the following requirements govern the continuation of the Department of Health's Florida Onsite Sewage Nitrogen Reduction Strategies Study:

(a) Funding for completion of the study is through the Department of Health. Notwithstanding s. 287.057, Florida Statutes, the current contract may be extended until the study is completed.

(b) The Department of Health, the Research Review and Advisory Committee of the Department of Health, and the Department of Environmental Protection shall work together to provide the necessary technical oversight to complete the study.

(c) Management and oversight of the completion of the study must be consistent with the terms of the existing contract. However, the main focus and priority shall be developing, testing, and recommending cost-effective passive technology design criteria for nitrogen reduction. Notwithstanding any other provision of law, before the study is completed, a state agency may not adopt or implement a rule or policy that:

1. Mandates, establishes, or implements more restrictive nitrogen reduction standards for existing or new onsite sewage treatment systems or modification of such systems; or

2. Directly or indirectly, such as through an administrative order issued by the Department of Environmental Protection as part of a basin management action plan adopted pursuant to s. 403.067, Florida Statutes, requires the use of performance-based treatment systems or similar technologies. However, more restrictive nitrogen reduction standards for onsite systems may be required through a basin management action plan if such plan is phased in after the study is completed.

(d) Any systems installed at home sites are experimental in nature and shall be installed with significant field testing and monitoring. The Department of Health is specifically authorized to allow installation of these experimental systems.

(2) This section expires July 1, 2016.

Section 18. In order to implement sections 49 and 52 of the 2015-2016 General Appropriations Act, paragraph (a) of subsection (4) of section 20.435, Florida Statutes, is amended to read:

20.435 Department of Health; trust funds.—The following trust funds shall be administered by the Department of Health:

(4) Medical Quality Assurance Trust Fund.

(a)1. Funds to be credited to the trust fund shall consist of fees and fines related to the licensing of health care professionals. Funds shall be used for

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Appendix B. Contractual History, Tasks, and Deliverables

Contractual History

Implementation of this study was done through the Onsite Sewage Program in the Bureau of Environmental Health, Division of Disease Control and Health Protection. The research component of the onsite sewage program began in 1983 and focuses on evaluating the impact of OSTDS on public health and the environment as well as studying improvements in technology. The research program is advised by a statutorily established committee, the Research Review and Advisory Committee (RRAC), in section 381.0065(3) (j) Florida Statutes. A variety of stakeholder groups are represented on the committee: the Department, onsite sewage industry, home building industry, environmental interest group, state university system, professional engineering industry, local government, real estate profession, restaurant industry, and consumers. The RRAC advises the Department on research priorities, comments on research reports, and assists in selecting contractors for research projects. Implementation of the nitrogen study required close cooperation with the RRAC, which the Florida Legislature charged to oversee the study and provide recommendations to the Department. To date, there have been a total of 33 public meetings of the RRAC held since the original appropriation in July 1, 2008 (Appendix H). In preparation for the first committee meeting to discuss implementation of this project on July 30, 2008, Department staff addressed two issues: a draft scope for which proposals would be requested and the form of the request for proposals.

The draft scope developed by staff elaborated on elements specified in the legislative language regarding objectives, activities, and deliverables. $1,000,000 had been appropriated for the first phase of the project, and the total cost of the contract was not to exceed $5,000,000. Funding for future years was dependent on future legislative appropriations.

After consultation with Department procurement staff, a determination was made that an Invitation to Bid or a Request for Proposal would not result in the best value to the state for this procurement and decided to use an Invitation to Negotiate (ITN), according to section 287.054(3) (a) Florida Statutes.

Justification for selecting an ITN was to focus on vendor qualifications as this project involved detailed scientific knowledge of OSTDS as well as a need for project flexibility. Negotiations allowed for greater flexibility in development of the final scope, such as incorporation of ideas that were not included initially in a proposal by a vendor. Even though one basic approach would be outlined in the draft scope, there could be many different approaches to reaching the objectives for this project. Allowing different vendors the opportunity to offer their expertise in developing an alternative approach and proposing innovative solutions was considered an advantage. Site locations and sampling parameters could be subject to negotiations rather than being fixed at the outset. Small changes in specifications could make a significant difference in the likelihood of success.

The RRAC was to rank proposals for contracts, review high-level draft deliverables and provide comments, 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 with development of a solicitation. The Department’s Technical Review and Advisory Panel (TRAP), which advises the Department on onsite sewage rule making and policy per section 381.0068, Florida Statutes, voted to approve the project as presented to them and requested they be kept informed on the status of this project.

The Department advertised the ITN 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”. All submitted proposals were ranked by the RRAC at a public meeting, and the proposal by the team led by Hazen and Sawyer was ranked highest, both overall and by each individual evaluator. In January 2009, the Department awarded a 6-year, $5-million contract to a project team comprised of nationally recognized experts led by Hazen and Sawyer.

The Department invited the top-ranked team to begin negotiations. The Department’s negotiation team consisted of three negotiators from the Onsite Sewage Program office, as well as a certified contract negotiator from the Department’s procurement office. After several negotiation sessions when the proposals were clarified, a more detailed scope of work was defined.

Hazen and Sawyer represented an experienced and cohesive team to conduct the tasks necessary to evaluate nitrogen reduction technologies for OSTDS. All team members all had extensive academic and field experience and a proven track record of achievement in the assessment of OSTDS and nitrogen fate and transport. References for past performance all gave excellent reviews, confirming that Hazen and Sawyer had a high quality of performance, they were able to adapt quickly to changes in funding, and delivered on time and on budget.

The proposal demonstrated a strategic approach, with many tasks occurring simultaneously. The detailed and logical approach provided an excellent launching point to assure success for achieving the goals of the Florida Onsite Sewage Nitrogen Reduction Strategies Study. Hazen and Sawyer’s methodology addressed three of the Department’s 2008 Onsite Sewage Program research priorities identified by the RRAC. This allowed for cost-efficient project management by having all activities authorized by the terms of the contract to be concurrently performed under one contract.

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

TASK NO.	Task	Task Description	Deliverables from contract
A.1	Draft Literature Review Report	The literature review of nitrogen reducing technologies completed as part of the Passive Nitrogen Removal Study commissioned by FDOH in 2007 will be updated with information which has emerged since the original study. The scope of the review will be expanded from the Passive Nitrogen Removal Study to include source separation, active systems, modifications to conventional onsite treatment systems, including modified soil treatment units, in addition to passive systems. The provider shall produce a searchable literature reference database, compatible with Endnote X or other department approved software format. The literature reference database shall not infringe on any copyrights. The provider shall also produce a technology database, in tabular or other department approved format, that will facilitate establishment of categories for summary and comparison, assessment of individual citations within the context of organizational categories, and analysis of trends and differences among systems. The categories shall include items such as treatment classification, media type, wastewater source, treatment configuration, documented effectiveness, documented and theoretical longevity, cost, nutrient recovery, and effect of water chemistry. The provider shall summarize the updated literature review in a report.	Draft updated literature reference database; draft updated technology database; draft updated literature review report - pdf.
A.2	Final Literature Review Report	The department will gather comments on the draft documents of sub-task A1 from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables for the literature review within one month of receiving comments.	Updated literature reference database; updated technology database; updated literature review report - pdf.
A.3	Draft Classification of Technologies Report	The provider will develop a scheme to classify and group identified nitrogen reduction technologies and practices to summarize the literature and facilitate comparisons between similar technologies. Four classifications are envisioned: waste stream alteration (such as blackwater systems, and urine separation); conventional OSTDS alteration (such as dosed vs. gravity systems, operational strategies, installation depth); passive nitrogen removal (OSTDS systems using no more than one pump and excluding aerators); active nitrogen removal	Draft classification scheme of technologies report - pdf.

TASK NO.	Task	Task Description	Deliverables from contract
		(mechanical systems utilizing more than one pump or aerators). The preliminary classification scheme will be presented to the RRAC at a workshop, which will provide a forum for full vetting and discussion.	
A.4	Draft Technology Ranking Criteria Report	The provider will develop evaluation criteria to rank technologies and practices to determine which best meet the goals of the project and shall have priority for further development or field evaluation. Criteria will build on and may lead to revisions to the categories developed in the literature review and include characterizations of nitrogen removal effectiveness, maturity of technology including status in Florida, costs (energy, maintenance, monitoring, replacement of parts and media), critical knowledge gaps, likelihood of success, need to field test, and the feasibility of obtaining data from existing installations in Florida. The provider will evaluate the technologies classified in sub-task A3 relative to each criterion. The provider will propose draft sets of weights to characterize the relative importance of each criterion for a) work during the initial funding period; b) work during future funding periods. The provider will prepare a working document, such as a calculation table, that shows the ranking of technologies given the evaluations relative to the criteria and the relative weights of each criterion. The provider will summarize criteria and weights in a report.	Draft summary of criteria and proposed weights for short-term and long-term testing, working document for obtaining technology ranks from evaluations to criteria and criteria weights - pdf.
A.5	Draft Priority List for Testing Report	The provider will propose additional criteria to consider in establishing priorities for testing from the top ranked technologies and practices. Such criteria may address representation of several technology classifications (sub-task A3), similarity of technologies or several maturity levels in the study. The purpose of prioritization is to select the more promising technologies that may not have sufficient prior testing or that may be differently configured to improve performance, and to avoid duplicating testing where substantial experience already exists. The provider will also list technologies to be considered for sub task A10 and A11	Draft summary of additional criteria - pdf; Draft priority list for testing - pdf.

TASK NO.	Task	Task Description	Deliverables from contract
		(innovative system application assistance).	
A.6	Technology Classification, Ranking and Prioritization Workshop	The provider will present the preliminary technology classification, rankings and priority lists developed in sub-task A3, A4 and A5 to the RRAC at a public workshop, which will provide a forum for full vetting and discussion of evaluation criteria and their assigned weights. This one day roundtable workshop with the Research Review and Advisory Committee (RRAC) will present the results and recommendations contained in the draft reports of technology classification, ranking and prioritization. The provider will facilitate RRAC's development of guidance on modifications to the draft classification, ranking and prioritization. Unless this guidance results in a need for further information collection by the provider, RRAC will provide comments on the priority lists for the initial and future funding periods. The comments and concerns of the RRAC will be documented and incorporated into the three final reports.	Public RRAC-Workshop, Summary of the workshop - pdf.
A.7	Final Classification of Technologies Report	The provider will incorporate RRAC comments and concerns and comments provided by the department within two weeks of the workshop into the final classification scheme.	Final Report - pdf
A.8	Final Technology Ranking Criteria Report	The provider will incorporate RRAC comments and concerns and comments provided by the department within two weeks of the workshop into the final technology ranking scheme.	Final Report - pdf
A.9	Final Priority List for Testing Report	The provider will incorporate RRAC comments and concerns and comments provided by the department within two weeks of the workshop into the draft priority list.	Final Report - pdf
A.10	**[Task Eliminated]** Draft Innovative Systems Applications Report (per technology)	Based on the technology evaluation in sub-task A5, the provider will identify emerging and innovative technologies that have not matured or are not currently permitted by FDOH but rank high for consideration for testing. For up to five technologies, the provider will complete or assist the	Innovative system application

TASK NO.	Task	Task Description	Deliverables from contract
		manufacturer if appropriate, in completing an innovative system application for acceptance by FDOH, for which field testing of Task B will be part of the proposed innovative system monitoring protocol.	
A.11	**[Task Eliminated]** Final Innovative Systems Applications Report (per technology)	The provider will respond or assist the manufacturer in responding to any requests for additional information by the department in regard to the innovative system applications.	Additional information resulting in an innovative permit by the department (per technology if additional information is requested by the department).
A.12	Identification of Test Facility Sites (per site agreement)	The provider will identify and evaluate potential sites for their suitability for establishing test centers. Among these potential sites will be the Gulf Coast Research and Education Center and the University of South Florida (USF) Lysimeter Station. Test facility site evaluations will include the feasibility of multiple treatment technology testing as well as the ability to monitor non-comingled subsurface plumes and the assessment of subsurface nitrogen fate and transport. Salient issues include space availability, site access, wastewater source of sufficient quantity and availability, subsurface hydrology, power supply, and security. The provider will obtain a letter of authorization from the respective property owners for establishing and operating test centers on their property, and for ownership and continued use after project is completed. If a potential site is deemed unsuitable for use in this project, a brief evaluation memo shall be prepared documenting the evaluation of the site and reasons for not recommending the site as a test facility location.	Site evaluation memo, or letter of authorization: UCF site evaluation memo - pdf, UF GCREC site evaluation memo - pdf, Decision presentation - pdf

TASK NO.	Task	Task Description	Deliverables from contract
A.13	Draft PNRS II QAPP	The provider will develop a draft QAPP that documents the objectives, experimental design, system operation, analytical methods, and sampling frequencies to be used in PNRS II. The objectives are to 1) directly address denitrification, which the provider proposes as the highest priority onsite nitrogen removal knowledge gap; 2) expand the performance envelope for the innovative unsaturated filter media filters demonstrated in the PNRS I; 3) delineate TN removal capability of PNRS I media using pre-denitrification; 4) establish test systems that are close to full scale; 5) enable critical testing of a large number of systems to be completed within the first project year; 5) produce key data which can then be used directly for design of denitrification filters for subsequent full scale testing at home sites; 6) develop data for preliminary life cycle cost analysis and resource needs. The experimental design is expected to consist of a battery of passive nitrogen removal treatment systems fabricated to evaluate salient design features of passive nitrogen removal systems including filter media, media stratification, surface loading rates, filter length, geometry, and aspect ratios, and unsaturated filter recycle for pre-denitrification and alkalinity recovery. The test configuration is anticipated to consist of a common wastewater feedstream, a suite of vertical unsaturated filters supplied by a common septic tank effluent (STE) feedstream, mixing of the unsaturated filter effluents to provide a common influent to the denitrification filters, a suite of horizontal saturated filters using lignocellulosic and sulfur reactive media and liquid carbon dosing as well as other system designs, and a means of final effluent disposal. The draft QAPP will address additives issues per Florida Administrative Code (FAC) Chapter 64E-6. The draft QAPP will propose where the test facility will be located and operated to determine nitrogen removal performance and optimize design variables.	Draft QAPP - pdf

TASK NO.	Task	Task Description	Deliverables from contract
A.14	Recommendation for Process Forward (per meeting)	Based on the details agreed upon in the draft QAPP, the provider will develop a recommendation whether or not to proceed with the remainder of Task A as outlined below, or recommend an amendment to this contract, and present a revised cost estimate. This will include a recommendation on whether the USF Lysimeter Station should be renovated and utilized as a test facility for this project. Both the provider and FDOH shall reach a written agreement prior to moving forward with the remaining parts of Task A.	Meeting summary and recommended scope and budget revisions - pdf.
A.15	Final PNRS II QAPP	The department will gather comments on the draft QAPP from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments. If the provider subsequently recommends modifying or adding procedures to address conditions encountered in the field, the QAPP may be revised or appended upon mutual agreement between provider and the department.	Final QAPP - pdf - to be approved by FDOH
A.16	Materials Testing for FDOH Additives Rule	The engineered media for the biofilters proposed in the PNRSII QAPP will be tested as required to meet 64E-6.0151 F.A.C. for additives. Effluent from the tank based pilot systems will be used as the effluent source for this testing. A brief technical memo describing the results of this testing will be prepared and presented to FDOH prior to constructing biofilter systems at the GCREC test facility or elsewhere in the field. The department may authorize the provider in writing to perform such testing for additional materials.	Technical memo - pdf - describing the results of additives rule testing per 64E-6.0151, per additive tested.
A.17	PNRS Specification Reports	The provider will specify, order and purchase specialty materials for test facility construction and experimental monitoring. The provider will oversee preparation of materials to meet specifications, and prepare procurement and assembly reports that document design and fabrication of the test systems, procurement of treatment system construction materials as well as the media for the filters, site preparation, monitoring instrumentation and equipment, and start-up testing of the PNRS II systems. Actual cost for materials and supplies will be documented as part of this subtask and be	Specification reports, materials list and cost and as-built diagrams - pdf - of the treatment systems to be tested as part of PNRS II, one for the in-tank PNRS II testing and one for the in-situ testing.

TASK NO.	Task	Task Description	Deliverables from contract
		included in the construction budget for PNRSII construction.	
A.18	PNRS II Test Facility Design 50%	The provider will design the test facility. Since the GCREC was chosen as the only test facility, the design will include both PNRSII pilot testing facilities and Task C groundwater fate and transport monitoring facilities. However these components will be separated into two construction phases on the design drawings to the extent possible. The PNRSII test facility 50% design submittal under this subtask will include preliminary layout sketches and design concepts and criteria. Provisions for supporting the installation and operation of in-tank treatment systems and in-situ biofilters monitoring systems, including supply of power, a common wastewater source at controllable flowrates, provision for wastewater source routing to pilot facilities and effluent routing to soil treatment units, sampling collection and monitoring appurtenances, and a preliminary flow diagram will be included. The 50% design documents will be submitted to FDOH for review and comment. The department will provide comments within two weeks of receipt.	50% design documents - pdf (25mb).
A.19	PNRS II Test Facility Design 100%	The provider and the department will agree on the design concepts based on review of the 50% design submittal. The provider will prepare a test facility 100% design submittal based on these concepts. The 100% design submittal will include the design details and technical specifications for the workplan described in the PNRS II QAPP, and include the stage 1 unsaturated biofilters, stage 2 denitrification filters, and in-situ engineered media biofilter systems. These documents will provide the level of detail necessary to estimate construction cost. These documents will be submitted to FDOH for review and comment. The department will provide comments within two weeks of receipt.	100% design documents - pdf.

TASK NO.	Task	Task Description	Deliverables from contract
A.20	PNRS II Test Facility Construction Support and Administration (2 deliverables, 50% at start, 50% at completion)	The provider will work with a construction contractor for facility construction using a design-build methodology within the amount budgeted for construction in this attachment or its amendments. Construction will be completed in two phases, with Phase 1 relating mostly to PNRSII pilot test facilities while Phase 2 will primarily involve construction of facilities related to Task C fate and transport studies. This subtask will cover the Phase 1 construction. There will be some overlap between PNRSII and Task C facilities, for example power supply for the test facility will be constructed in this task but will also serve the Task C facilities. The in-situ biofilter systems for PNRSII will be constructed in Phase II along with the mini-mounds for Task C. Provider will be onsite during construction to review materials and equipment being used to determine if work is conducted in accordance with the construction plans and will assist with installation of monitoring equipment. Construction will be reviewed for completeness by the provider and for conformance with the design intent. As necessary, the provider will propose a contract amendment to increase funds or test facility design changes to decrease costs as feasible.	Compensation for this subtask will be in two phases: 50% upon start of facility construction and the remaining 50% at construction completion - pdf.
A.21	PNRS II Test Facility Construction 50% (2 deliverables, start and 50% complete)	The provider will monitor facility construction as needed to monitor progress and conformance with design documents. For budgeting purposes, the provider and the department have assumed a construction cost value in this scope and budget. At the time the contractor is onsite and construction is started, invoices for materials and mobilization will be submitted to the Department by the Provider for payment. When the provider determines that approximately 50% of the facility construction is complete, a construction progress report will be provided for documentation and this subtask will be deemed complete, and the remaining amount in the Section C. cost schedule for this subtask will be paid to provider.	Construction Progress Report: Report 1 pdf; Report 2 - pdf.

TASK NO.	Task	Task Description	Deliverables from contract
A.22	PNRS II Test Facility Construction 100% (cost reimbursable)	Provider will monitor facility construction as needed to monitor progress and conformance with design documents. This task will include the construction cost of the facility based on the construction estimate and any approved additional costs. For budgeting purpose the provider and the department have assumed a construction cost value in this scope and budget. This subtask will be based on this amount as a cost reimbursable item not to exceed the estimated total construction cost value, and will be documented by contractor invoices, material and equipment bills, and other provider incurred expenses. The amount paid will be the total documented construction cost less the amount paid to provider in subtask A-21 above.	Construction Progress Report - pdf.
A.23	PNRS II Test Facility Construction Substantial Completion	Provider will conduct a site inspection to determine if the project is substantially complete. The inspection will result in the preparation of a punch list to be delivered to the contractor in writing for final completion.	Construction punch list - pdf.
A.24	PNRS II Test Facility Accept Construction	The provider will conduct one final inspection for the project to determine if the work has been completed in accordance with the contract documents and the punch list. Subsequent to this final inspection, the provider will make final payment to the subcontractor. The provider shall give written notice to FDOH that the work is complete. As-built drawings will then be developed by the provider for the facility.	As-built drawings of the test facility - pdf (10 mb)
A.25	Monitoring and Sample Event Reports (per sample event)	After each sampling event, the provider will provide sample event reports verifying operation of the test systems, flowrate monitoring, field parameter results, and chain of custody forms that document sample collection and delivery to the analytical laboratory. The number of events and the parameters to be analyzed shall be as provided in the PNRSII QAPP at a minimum. Sampling events subsequent to the number in the budget for Phase 2 of this task are subject to available funding and the department shall authorize the provider in writing to perform each additional sampling event.	Sampling event report. (per sampling event) - all are pdfs - Sample event 1, Sample event 2, Sample event 3, Sample event 4, Sample event 5, Sample event 6, Sample event 7

TASK NO.	Task	Task Description	Deliverables from contract
A.26	Data Summary Report (per sample event)	The provider will provide data reports that verify completion of analyses by an analytical laboratory and that include compiled data from field and analytical laboratory analyses in electronic and paper form. This task is contingent on the previous task.	Data Summary Reports (per sampling event). Sample event 1, Sample event 2, Sample event 3 (10mb), Sample event 4, Sample event 5, Sample event 6 (6mb) , Sample event 7
A.27	Draft PNRS II Report	The provider will prepare a PNRS II report that includes PNRS II objectives, experimental methods, results, discussion, conclusions and recommendations. For each nitrogen reduction technology tested at the GCREC pilot facility a technical description will be prepared that includes name, supplier, operating principles, salient physical description, flow sequence, pertinent design details, manufacturer or designer claims of treatment goals, and operating recommendations. The draft report will be provided to the department for comments from the department and the RRAC prior to submitting a final report.	Draft Report pdf (8mb)
A.28	Final PNRS II Report	The department will gather comments on the draft report from RRAC and FDOH review and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final Report pdf (27mb)
A.29	**[Task Eliminated]** Draft Task A Final Report	The provider will submit a draft final report summarizing the results of the technology classification, ranking and prioritization efforts in Task A and the conclusions from PNRSII and provide recommendations for onsite nitrogen reduction technologies for Florida. If warranted, this report will also recommend a revised priority list for testing of future systems.	Draft Report
A.30	**[Task Eliminated]** Task A Final Report	The department will gather comments on the draft report from RRAC and FDOH review and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final report.

TASK NO.	Task	Task Description	Deliverables from contract
A.31	Change-order Allowance	From time to time the Department may find it necessary to make minor changes or adjustments to activities under this task based on results that indicate a potential improvement to the project by making a change. Examples of such changes include additional or revised sample locations and parameters, minor modifications to test systems or field activities based on problems encountered, or conditions that develop requiring expedient actions to correct a potentially serious problem. Up to $ 40,000 will be allocated from the contract budget for such minor changes to research activities under this task. Upon determination by the Department that changes should be made, all or a portion of these funds may be authorized by written notification from the Department to the Provider directing specific changes to research activities be made, and the amount budgeted for the changes specified.	Deliverables outlined in authorization letters. Authorization to make design improvements on test facility, Authorization to analyze additives, Authorization to develop design tool for bioreactor filtration treatment, Bioreactor treatment tool literature review and data set specification, Bioreactor tool process forward minutes, Biotool model xls, Biotool user guide
B.1	Identification of Home Sites (per homeowner agreement)	The provider will identify individual homeowner sites for their suitability for establishing technologies for field evaluation. Criteria considered in the suitability will include homeowner willingness, site access, number of residents and continuousness of occupancy, power supply, security, location, adequate space, access for monitoring and maintenance, participation in previous or concurrent studies, and pre-existing treatment technologies. The provider will survey the homeowners and/or system users on use characteristics. Agreements will be established between homeowners and the provider for establishing and monitoring treatment systems. Written homeowner agreements will specify the arrangements in regards to responsibility for application for permits, modifications, operation, maintenance, monitoring, inspections, removal or leaving the system in place at study termination. If a homeowner site will also be used for fate and transport studies (Task C), then access will be needed for monitoring equipment in the downgradient direction and lack of interference with other systems must be ascertained. Up to ten (10) home sites at various locations in Florida (e.g. Wekiva Study Area, Wakulla and south Florida) will be identified for potential testing under this task.	Written agreements between homeowner and provider pdf, completed homeowner survey pdf.

TASK NO.	Task	Task Description	Deliverables from contract
B.2	Vendor Agreement Report (per vendor agreement)	The provider will contact technology vendors to explain the testing project, to identify specifics of the technology offering and special considerations, to delineate to the vendor the arrangements by which testing will be conducted, to identify specific models to be tested, and to obtain a price quotation for purchase or ascertain vendor interest in donating a system. Vendors will agree to specifications that vendors will not be allowed to physically modify or manipulate equipment once installed. Any exceptions to this default policy will be fully documented. Up to 2 vendors will be identified for testing under this task.	Written agreements between vendor and provider pdf.
B.3	Draft QAPP for Field Testing	A QAPP will be developed to document the objectives, specific systems for testing, and technology configurations that will be tested, operation of the systems, sampling and monitoring methodology and frequency, analytical parameters and methods, and data and document management. The monitoring program will develop performance data sets for total treatment systems and also for intermediate points such as aerobic treatment unit effluent or mixed aerobic effluent with STE and pre-denitrification. Monitoring of intermediate locations will provide data sets for separate evaluation of loading and performance for individual treatment components. The anticipated monitoring program will begin six weeks after startup and approximately 8 sample events per system will be conducted. Monitoring points will include septic tank effluent (STE), aerobic effluent (if applicable), and denitrification filter effluent (if applicable). Anticipated parameters for influent STE include TSS, cBOD5, TKN, NH4+, and NOx, as well as temperature, pH, alkalinity, dissolved oxygen and oxidation reduction potential. Stage 1 and Stage 2 effluents will be monitored for the same parameters, with less frequent analyses for TSS and cBOD5. Lower frequency monitoring will be conducted as necessary for a number of parameters: total phosphorus, PO4, and fecal coliform in STE, aerobic and denitrification effluents, SO4 and H2S in sulfur denitrification filter influent and effluent, and cBOD5 in lignocellulosic filter effluents. The provider will develop a data	A draft QAPP pdf will be provided to the Department

TASK NO.	Task	Task Description	Deliverables from contract
		management and storage template for cataloging and assessing performance data from disparate treatment systems and technology combinations and influent wastewater characteristics. The selection of systems for testing will follow the recommendations developed in Task A. The provider will consider the use of and the addition of components to existing systems. The exact sequencing of installations over the multi-year project will be established in the QAPP based on the priority list developed in Task A and refinements through the study.	
B.4	Recommendation for Process Forward (per meeting)	Based on the details agreed upon in the final QAPP, the provider will develop a revised cost estimate and recommendation as to the number of systems included in the initial and future funding phases and whether or not to proceed with the remainder of Task B as outlined below, or recommend an amendment to this contract. Both the provider and FDOH shall reach a written agreement prior to moving forward with Task B.	Meeting summary and recommended scope and budget revisions pdf.
B.5	Final QAPP Field Testing	The department will gather comments on the draft QAPP from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final QAPP pdf accepted by FDOH.

TASK NO.	Task	Task Description	Deliverables from contract
B.6	Field Systems Installation Report (per system)	The provider will submit existing system evaluations performed by individuals authorized by the department to perform such work, modifications, or new system permits as appropriate for the respective home sites and shall ensure proper permitting through the department for such permits. The provider will be, or will hire, an engineer of record for innovative or performance-based treatment system applications and identify the maintenance entity for each system. The provider will be responsible for individual field test systems to be purchased or fabricated and installed at individual homeowner sites. Field system installation will include providing all materials and assembly needed to produce a fully functional and working treatment system, including initial test evaluation and installation report. If necessary an existing system evaluation will be conducted per FAC Chapter 64E-6. The provider will ensure that operating permits and maintenance entity contracts for the system exist, as required by FDOH. The provider will address the event if one or several of the homeowners seek to withdraw from the program by assisting with installing a replacement onsite wastewater system or fund system repair or maintenance.	Copy of final system permit including operating permit if necessary; detailed installation report, construction costs: System 1, System 2, System 3, System 4, System 5, System 6, System 7

TASK NO.	Task	Task Description	Deliverables from contract
B.7	Field Systems Monitoring Report (per system, per event)	Subject to details specified in the QAPP, the provider, in cooperation with the homeowner and the maintenance entity, will operate field technologies for a base period of up to 24 months and monitored for at least the following parameters: temperature, pH, alkalinity, DO, ORP, TKN, NH3, NOx, TSS, C-BOD5. Additional parameters will be monitored less frequently for other parameters of interest (COD, TP, PO4, fecal coliform, total enterococci, and SO4 and H2S for systems with sulfur-based denitrification). Up to 8 sample events will be conducted on each of the systems monitored. The provider will submit deliverables after each monitoring event for the systems installed in Task B6, which will also include results for flowrate or treated volume, electricity and/or media use, field parameter results, chain of custody forms for samples delivered to analytical laboratory, analytical laboratory reports, and compiled results.	Monitoring reports in tabular form: System 1 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 2 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 3 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 4 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 5 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 6 Sample events 1, 2, 3, 4, 5, 6, 7, 8; System 7 Sample events 1, 2, 3, 4, 5, 6, 7, 8.
B.8	Field Systems Operation, Maintenance and Repairs Report (per system)	The provider, in cooperation with the homeowner, maintenance entity, and county health department, will maintain copies of records of repairs, maintenance actions, inspection results and system observations. The provider will develop a report form for each entity and a summary report for each treatment system. Records will include date, description of repair and pertinent factors, and repair cost.	Report form for each system, summary report of observations: System 1, System 2, System 3, System 4, System 5, System 6, System 7.

TASK NO.	Task	Task Description	Deliverables from contract
B.9	**[Task Eliminated]** Technical Description of Nitrogen Reduction Technology Report	The provider will develop a technical description for each nitrogen reduction technology studied, including information such as if the technology is vendor supplied or custom design, trade name, model number, unit specifications, purported operating principals, description of process flows and hydraulics, physical features including tanks, fixed film media, pumps, aerators, and other appurtenances, addition of chemicals or other materials, performance claims, observations, operational experience and measured performance during the study. The report will include a brief description of nitrogen removal processes and factsheets for each nitrogen removal system studied.	Draft and final nitrogen reduction technology report.
B.10	Acceptance of System by Owner Report (per system)	At the conclusion of system monitoring, a homeowner acceptance document will be provided that transfers complete ownership and operational responsibility of the system to the homeowner. In the event the homeowner does not desire to keep the study systems, the funds from Task B6 will be utilized to restore the system to its original condition.	Acceptance of System by Owner Report: System 1, System 2, System 3, System 4, System 5, System 6, System 7
B.11	LCCA Template Report (draft template and user guidelines)	The provider will develop a Life Cycle Cost Analysis (LCCA) template, with the PNRS I LCCA as a starting point and will summarize the features of the template in a user guidelines document. Costs will be expressed in a variety of ways, such as uniform annual cost, cost effectiveness of nitrogen removal, marginal cost effectiveness of additional treatment components etc. The analysis will include equipment, material and installation costs for treatment systems, recurrent costs for energy, maintenance, repair, permitting and monitoring, and replacement of materials such as reactive media or electron donor supply for denitrification. Materials costs include the purchase cost and delivery cost of vendor systems, or costs to purchase and prepare materials and media for custom designed systems. Use of a common LCCA template will enable all nitrogen removal technologies to be evaluated on an equivalent basis, and will be useful for future systems that are not evaluated within this project. In developing the template, the provider will illustrate its use with existing data, such as developed as part of Task A, the Keys Onsite Wastewater Nutrient	Draft LCCA template and user guidelines pdf.

TASK NO.	Task	Task Description	Deliverables from contract
		Reduction Systems study or the information obtained from homeowners surveyed during this task.	
B.12	LCCA Template Report (final template and user guidelines)	The department will gather comments on the draft LCCA from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final LCCA template pdf and user guidelines pdf.
B.13	LCCA Report (per system)	Based on the LCCA Template, the provider will conduct an LCCA analysis for each nitrogen reduction technology evaluated during field testing using actual purchase prices, installation cost estimates, and operational costs records.	LCCA Report pdf (per system tested) including cost analysis.
B.14	Draft Task B Final Report	The provider will develop a final report that will summarize the results of the Task B evaluations of treatment technologies, including an aggregation of technology reports and LCCA completed over the course of the study. The report will provide summary recommendations for deploying the tested technologies to meet the objectives of the Florida Onsite Nitrogen Removal Strategy. The report will include the data on which it is based, in tabular form.	Draft Task B Final Report pdf.
B.15	Task B Final Report	The department will gather comments on the draft final report from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Task B Final Report Appendices

TASK NO.	Task	Task Description	Deliverables from contract
B.16	Change-order Allowance	From time to time the Department may find it necessary to make minor changes or adjustments to activities under this task based on results that indicate a potential improvement to the project by making a change. Examples of such changes include additional or revised sample locations and parameters, minor modifications to test systems or field activities based on problems encountered, or conditions that develop requiring expedient actions to correct a potentially serious problem. Up to $ 50,000 will be allocated from the contract budget for such minor changes to research activities under this task. Upon determination by the Department that changes should be made, all or a portion of these funds may be authorized by written notification from the Department to the Provider directing specific changes to research activities be made, and the amount budgeted for the changes specified.	Deliverables outlined in authorization letters: Authorization to update the Research Review and Advisory Committee on March 24, 2011, Authorization to analyze additives, Authorization to perform a Whole Effluent Toxicity test and ammonia nitrogen analysis, Authorization to enhance design for Site 4 passive nitrogen system, Authorization to provide additional product composition testing, Results of additional product composition testing for Site 2, 3, 4, 5, 6, and 7.
C.1	Draft Literature Review on Nitrogen Reduction in Soil Report	The provider will review available literature to assess the current status of knowledge related to nitrogen fate and transport in saturated and unsaturated soils. Literature from other fields (e.g. agriculture, agronomy, hydrogeology, soil science, environmental science, ecology, biosystems engineering) will be reviewed for its application to OSTDS in Florida. Particular focus will be placed on studies that have measured and documented denitrification rates in soil and groundwater. This review will expand on the literature review on denitrification in soil performed for the department's Wekiva study and a complementary literature review, recently completed by the Colorado School of Mines. Results of the literature reviewed in this task will be added to the searchable literature reference database established in Task A.	Draft literature review and updated reference database.
C.2	Final Literature Review on Nitrogen Reduction in Soil Report	The department will gather comments on the draft final report from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final report and updated reference database.

TASK NO.	Task	Task Description	Deliverables from contract
C.3	Draft QAPP Evaluation of N Reduction by Soils & Shallow GW	The provider will develop a QAPP to document Task C objectives and the monitoring framework for field sites. Information gained during the literature review conducted as part of Task D will be incorporated, as appropriate, into the monitoring framework to ensure data required for model inputs will be collected. The monitoring framework will encompass the "Observational Approach" to allow information obtained in the field and during other tasks (e.g., Task D2, D7, D10, etc.) to be utilized to direct subsequent monitoring. The QAPP will describe the number and type of homeowner systems to be monitored, sample frequency and duration, analytical parameters and methods, data handling and management, and document control. It is anticipated that each site will be monitored to delineate the OSTDS effluent quality, hydraulic and nitrogen loading rates to the soil, and potential groundwater impacts. Flow meters will be installed as needed to determine actual soil loading rates. Shallow piezometers will be installed within the soil treatment unit and downgradient of the system to evaluate nitrogen fate and transport. Tracer tests using a conservative tracer will be conducted to determine connectivity of the OSTDS-vadose zone-groundwater system as well as evaluate subsurface travel times. Water quality analyses will be conducted on all field samples and will include temperature, total nitrogen, ammonium nitrogen, nitrate-nitrogen, and chloride. Less frequent analyses will be conducted on samples as necessary and will include pH, alkalinity, cBOD5, total phosphorus, anions, cations, fecal coliform, and E. coli. Should a total nitrogen plume be identified from an OSTDS, additional piezometers may be installed to enable further hydrogeologic characterization affecting fate and transport (i.e., groundwater velocity, hydraulic gradient) and assessment of nitrogen concentrations over time. This field monitoring framework will enable evaluation of the current nitrogen reduction in soil and groundwater and provide input to parameter selection for Task D. Results will also enable validation and verification of simple models	Draft QAPP for field sites and test center.

TASK NO.	Task	Task Description	Deliverables from contract
		developed and refined as described in Task D. It is anticipated that at least two subsurface monitoring sites will be established at each of three dispersed locations in Florida to provide geographical variety. Example candidate locations are the Wakulla area (north Florida), the Wekiva area (central Florida), and a south Florida site to be determined. It is anticipated that four monitoring events will be conducted at each site. Sites will be selected and monitored to encompass a range of conditions affecting nitrogen mass loading to the environment and the resulting groundwater concentrations. Site selection will be leveraged, to the extent possible, with Task B to enable complete evaluation of the onsite system from STE through nitrogen treatment units and including soils. The key conditions of importance will be the hydraulic loading rate of effluent to the soil, and the effluent quality discharged to the soil. It is anticipated that a soil treatment and groundwater monitoring test center will also be established in this task to provide performance evaluations of multiple wastewater treatment systems; systems that will provide a broad range of nitrogen removal capabilities. The subsequent application of treated effluent to soil treatment and dispersal units will result in separate, non-comingled plumes which can be used for monitoring of nitrogen fate and transport in the subsurface. Subsurface monitoring will be used to develop data sets for nitrogen fate and transport for parallel systems receiving widely varying nitrogen concentrations. Subsurface sites at the test center will be monitored for a variety of parameters at different frequencies, including pH, alkalinity, DO, ORP, TKN, NH3, NOx, C-BOD5, TP, PO4, fecal coliform, and total enterococci. Duration and frequency of monitoring at each of the sites will be specified in the QAPP.	
C.4	Recommendation for Process Forward (per meeting)	Based on the details agreed upon in the draft QAPP, the provider will develop a revised cost estimate and a recommendation whether or not to proceed with the remainder of Task C as outlined below, or recommend an amendment to this contract. Both the	Meeting summary and recommended scope and budget revisions

TASK NO.	Task	Task Description	Deliverables from contract
		provider and FDOH shall reach a written agreement prior to moving forward with Task C.	
C.5	Final QAPP Evaluation of N Reduction by Soils & Shallow GW	The department will gather comments on the draft final report from RRAC and FDOH internal review and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments. If the provider subsequently recommends modifying or adding procedures to address conditions encountered in the field, the QAPP may be revised or appended upon mutual agreement between provider and the department.	Final QAPP acceptable to FDOH.
C.6	S&GW Test Facility Design 50%	The Gulf Coast Research & Education Center of the University of Florida has been evaluated by the provider for establishing a controlled test site for side-by-side evaluation of multiple soil treatment unit regimes and the resulting nitrogen groundwater fate and transport. This task will be leveraged with tasks B and D. Since both the Task A and Task C test facilities will be located at the GCREC, the provider will design the test facility for Task C in concert with the Task A test facility The Task C test facility 50% design submittal will include preliminary layout sketches and design concepts and criteria. Provisions for supporting installation, operation, and monitoring of treatment systems and groundwater plumes, including controllable dosing flowrates, effluent quality, soil hydraulic loading rates, and staging for field efforts. The monitoring framework will support evaluation of time and spatial variations of soil treatment and groundwater plume configurations (e.g. groundwater flow velocity, concentrations, etc.). Provisions will be made for supporting the installation and operation of in-tank treatment systems or unsaturated groundwater monitoring systems, including supply of power, treatment system sub-components, a common wastewater source at controllable flowrates, provision for effluent routing to soil treatment units, sampling collection and monitoring appurtenances, and staging of field analytical work and sampling will be	50% design documents.

TASK NO.	Task	Task Description	Deliverables from contract
		included. The 50% design documents will be submitted to FDOH for review and comment. Comments will be provided by the department within two weeks of receipt.	
C.7	S&GW Test Facility Design 100%	The provider and the department will agree on the test facility design and experimental concepts based on review of the 50% design submittal. The provider will prepare the test facility 100% design submittal based on these concepts. The 100% design submittal will include all design details and technical specifications necessary to estimate construction cost. These documents will be submitted to FDOH for review and comment. Comments will be provided by the department within two weeks of receipt.	100% design documents.
C.8	S&GW Test Facility Design Final	In preparing the test facility final design submittal, the provider will include final revisions based on the review of the 100% design submittal. This will result in a set of signed and sealed construction plans suitable for facility construction.	Signed and sealed construction plans.

TASK NO.	Task	Task Description	Deliverables from contract
C.9	S&GW Construction Support & Administration (2 deliverables, 50% at start, 50% at completion)	The provider will work with a construction contractor for facility construction using a design-build methodology within the amount budgeted for construction in this attachment or its amendments. Construction will be completed in two phases, with Phase 1 relating mostly to PNRSII pilot test facilities while Phase 2 will primarily involve construction of facilities related to Task C soil treatment and groundwater monitoring studies. This subtask will cover the Phase 2 construction. There will be some overlap between PNRSII and Task C facilities, for example, power supply for the test facility will be constructed in Phase 1 (Task A) but will also serve the Task C facilities. The in-situ biofilter systems for PNRSII will be constructed in Phase II along with the mini-mounds for Task C. Provider will be onsite during construction to review materials and equipment being used to determine if work is conducted in accordance with the construction plans and will assist with installation of monitoring equipment. Construction will be reviewed for completeness by the provider and for conformance with the design intent. The provider will propose a contract amendment to increase funds or test facility design changes to decrease costs as necessary and feasible to maintain budget. Provider will respond to Contractor requests for information and prepare any necessary addenda. Construction will be reviewed for completeness by the provider and conformance with contract documents.	Compensation for this subtask will be in two phases: 50% upon start of facility construction and the remaining 50% at construction completion.
C.10	S&GW Test Facility Construction 50% (2 deliverables, start and 50% complete)	The provider will monitor facility construction as needed to monitor progress and conformance with design documents. For budgeting purposes, the provider and the department have assumed a construction cost value in this scope and budget. At the time the contractor is onsite and construction is started, invoices for materials and mobilization will be submitted to the Department by the Provider for payment. When the provider determines that approximately 50% of the facility construction is complete, a construction progress report will be provided for documentation and this subtask will be deemed complete, and the remaining amount in the Section C. cost schedule for	Documentation of contractor and equipment onsite and Construction Progress Report (at 50% complete).

TASK NO.	Task	Task Description	Deliverables from contract
		this subtask will be paid to provider.	
C.11	S&GW Test Facility Construction 100% (cost reimbursable)	Provider will monitor facility construction as needed to monitor progress and conformance with design documents. This task will include the construction cost of the facility based on the construction estimate and any approved additional costs. For budgeting purpose the provider and the department have assumed a construction cost value in this scope and budget. This subtask will be based on this amount as a cost reimbursable item not to exceed the estimated total construction cost value, and will be documented by contractor invoices, material and equipment bills, and other provider incurred expenses. The amount paid will be the total documented Task C construction cost less the amount paid to provider in subtask C-10 above.	Construction progress report.
C.12	S&GW Test Facility Construction Substantial Completion	Provider will conduct a site inspection to determine if the project is substantially complete. The inspection will result in the preparation of a punch list to be delivered to the contractor in writing for final completion.	Construction punch list.
C.13	S&GW Test Facility Accept Construction	The provider will conduct one final inspection for the project to determine if the work has been completed in accordance with the contract documents and the punch list. Subsequent to this final inspection, the provider will make final payment to the subcontractor. Written notice shall be provided to FDOH that the work is complete. As-built drawings will then be developed by the provider for the facility.	As-built drawings of the test facility.

TASK NO.	Task	Task Description	Deliverables from contract
C.14	Soils & Hydrogeologic and Monitoring Plan for S&GW Test Facility	The soil and groundwater characteristics of the test facility site will be determined by the provider as described in the QAPP. Characterization will include soils analyses, aquifer testing, piezometer installation and tracer testing with a conservative tracer to establish groundwater flow parameters. Based on the results of this characterization, a monitoring plan will be established for the six mini-mound systems at the soil and groundwater test facility. The location, number and frequency of sampling will be as generally defined in the QAPP, but refined based on results of this task. Additionally, field assessment for Task D model parameter estimation, model verification and validation will also be included as available from results of this task.	Soil and groundwater characterization memo and revised QAPP element for test facility.
C.15	Tracer Testing at GCREC (per tracer test)	Groundwater tracer tests will be conducted at the research sites based on the protocols outlined in the QAPP. First, an ambient groundwater tracer test will be conducted at or immediately adjacent to the site of the Soil and Groundwater Test Facility to determine existing groundwater flow characteristics using a conservative tracer substance. Second, a groundwater tracer test will be initiated at the GCREC Mound system to delineate groundwater flow characteristics downgradient of the mound. Third, a groundwater tracer test will be conducted at one of the mini-mounds at the Soil and Groundwater Test Facility after start-up to characterize groundwater flow and contaminant transport from these systems. Deliverables for this task will be a tracer test memo describing each test and the results, and payment will be per test memo. The Department may authorize the Provider in writing to perform additional tracer tests as part of this project.	Tracer Test Memo 1 Tracer Test Memo 2 Tracer Test Memo 3
C.16	S&GW Sample Event Reports (per sample event)	The monitoring and data collection framework for the soil and groundwater test facility will be described in the revised QAPP including number of sampling points for each plume, sampling frequency and duration, and analytical parameters. Monitoring reports, based on the QAPP framework, will be provided that describe site conditions and interim sample results (i.e., compiled data from field and analytical laboratory analyses). A brief description of the monitoring progress will be provided.	Sampling event report 1 Sampling event report 2 Sampling event report 3 Sampling event report 4 Sampling event report 5 Sampling event report 6

TASK NO.	Task	Task Description	Deliverables from contract
C.17	S&GW Data Summary Report (per sample event)	The provider will provide data reports that verify completion of analyses by an analytical laboratory and that include compiled data from field and analytical laboratory analyses in electronic and paper form. This task is contingent on the previous task.	Data Summary Report for sampling event 1 Data Summary Report for sampling event 2 Data Summary Report for sampling event 3 Data Summary Report for sampling event 4 Data Summary Report for sampling event 5 Data Summary Report for sampling event 6
C.18	Test Facility Closeout Report	At the conclusion of controlled test site monitoring, the provider will determine if the test facility infrastructure will be transferred to the property owner or the site restored to prior condition. If the property owner wishes to keep the facility, the provider will submit an acceptance document to the department that documents transfer of ownership and complete responsibility of test site infrastructure to the owner. A report will be provided to document close-out of the site.	Test Facility Closeout Report.
C.19	Field Site Selection (per property owner agreement)	Candidate field sites will be identified by the provider for subsurface monitoring activities. FDOH permit information will be gathered by the provider as available on candidate sites, and a system inspection and evaluation conducted on selected sites. Monitoring at the sites will be used to assess the current level of nitrogen reduction obtained by Florida soils, to assess groundwater impacts due to conventional systems, and to provide data for parameter estimation, and verification and validation of models developed in Task D. Sites will be monitored by the provider to encompass a range of conditions affecting nitrogen mass loading to the environment and the resulting groundwater concentrations. Specifically, key conditions of importance will be the hydraulic loading regime, the rate of effluent discharged to the soil, and the effluent quality (e.g. BOD, nitrogen) discharged to the soil. Factors considered during site selection include property owner amenability, site access, occupancy, system age, type of system and daily wastewater flow. While numerous subtleties exist between individual OSTDS, monitoring a range of these key conditions and factors will enable comparison of sites. Based on the previous subtasks and the process forward meeting, the first site to be monitored will be	Property Owner agreement site 1, Property Owner agreement site 2, Property Owner agreement site 3, Property Owner agreement site 4, Property Owner agreement site 5, Property Owner agreement site 6, Property Owner agreement site 7

TASK NO.	Task	Task Description	Deliverables from contract
		the existing mound system at the GCREC, for which the property owner agreement has already been established in subtask A12. This will allow establishment of materials and methods for subsequent field site monitoring, and provides a large, unobstructed area to study a nitrogen plume in more detail than could be accomplished at a private home site. Agreements will be established with property owners by the provider for establishing monitoring systems. It is anticipated that up to seven (7) field sites will be identified for potential inclusion in the study. Availability of funding and site characteristics will be used to establish which of these will be included for monitoring.	
C.20	Instrumentation of GCREC Mound System	The QAPP documents the objectives, monitoring framework, sample frequency and duration and analytical methods to be used at the GCREC existing mound system site. Additional soil and groundwater testing will be conducted, if necessary, based on the results in Task C 14. Instrumentation of the site, in accordance with the QAPP, will include providing all materials and assembly needed to establish the monitoring framework at the site, and will be performed by the provider. A monitoring installation report will be provided by the provider for the GCREC site describing the monitoring system and any additional characterization.	GCREC Mound Characterization and Monitoring Installation progress report 1, progress report 2, progress report 3
C.21	GCREC Mound Sample Event Report (per sampling event)	The monitoring framework established at the GCREC will be described in the QAPP including number of sampling points, sampling frequency and duration, and analytical parameters. Monitoring reports, based on the QAPP framework, will be provided that describe site conditions and interim sample results (i.e., compiled data from field and analytical laboratory	GCREC Mound sampling event report 1, GCREC Mound sampling event report 2, GCREC Mound sampling event report 3, GCREC Mound sampling event report 4.

TASK NO.	Task	Task Description	Deliverables from contract
		analyses).	
C.22	GCREC Mound Data Summary Report (per sampling event)	The provider will provide data reports that verify completion of analyses by an analytical laboratory and that include compiled data from field and analytical laboratory analyses in electronic and paper form. This task is contingent on the previous task.	Data Summary Reports sampling event 1, Data Summary Reports sampling event 2, Data Summary Reports sampling event 3, Data Summary Reports sampling event 4
C.23	Instrumentation of Remaining Field Sites Report (per site)	The QAPP will document the objectives, monitoring framework, sample frequency and duration and analytical methods to be used at the remaining field sites, presumably individual private home sites. Instrumentation of the sites, in accordance with the QAPP, will include providing all materials and assembly needed to establish the monitoring framework at each home site, and will be performed by the provider. A monitoring installation report will be provided by the provider for each of up to four (4) individual home sites describing the monitoring system.	Monitoring Installation report 1, Monitoring Installation report 2, Monitoring Installation report 3, Monitoring Installation report 4
C.24	Field Sites Sample Event Reports (per sample event, per site)	The monitoring framework will be described in the QAPP including number of sampling points at each site, sampling frequency and duration, and analytical parameters. Monitoring reports, based on the QAPP framework, will be provided that describe site conditions and interim sample results (i.e., compiled data from field and analytical laboratory analyses).	Sampling event report (per sampling event, per site). System 1 Sample event 1; System 2 Sample events 1, 2, 3, 4; System 3 Sample events 1, 2, 3, 4; System 4 Sample events 1, 2, 3, 4.

TASK NO.	Task	Task Description	Deliverables from contract
C.25	Field Sites Data Summary Report (per sample event, per site)	The provider will provide data reports that verify completion of analyses by an analytical laboratory and that include compiled data from field and analytical laboratory analyses in electronic and paper form. This task is contingent on the previous task.	Data Summary Reports (per sampling event, per site). System 1 Sample event 1; System 2 Sample events 1, 2, 3, 4; System 3 Sample events 1, 2, 3, 4; System 4 Sample events 1, 2, 3, 4.
C.26	Draft Site Summary and Close-out Memo (per site)	The provider will prepare data tables summarizing the observations for each site, including site conditions, onsite system characteristics and soil and ground water concentrations and conditions found. At the conclusion of home site monitoring, the provider will submit homeowner acceptance documents to the department that either transfer ownership and responsibility of monitoring points to the homeowner (e.g., piezometers) or all monitoring points will be removed by the provider and the site shall be returned to its original configuration. A report will be provided to the department to document close-out of each home site. The draft close-out memos will be submitted to FDOH for review and comment.	Draft Site Close-out memo. Site 1, Site 2, Site 3, Site 4, GCREC Site.
C.27	Final Site Close-Out Memo (per site)	Comments will be provided by the department within two weeks of receipt and the provider will prepare a final close-out memo.	Final site close-out memo acceptable to FDOH. Site 1, Site 2, Site 3, Site 4.
C.28	**[Task Eliminated]** Draft Task C Final Report	The final report will summarize results of Task C activities on nitrogen reduction in Florida soil and shallow groundwater. The report will include task objectives, methods, results, discussion, conclusions and recommendations.	A draft report will be provided for comment prior to submittal of the final report.
C.29	**[Task Eliminated]** Task C Final Report	The department will gather comments on the draft final report from RRAC and FDOH review and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final Report.

TASK NO.	Task	Task Description	Deliverables from contract
C.30	Change-order Allowance	From time to time the Department may find it necessary to make minor changes or adjustments to activities under this task based on results that indicate a potential improvement to the project by making a change. Examples of such changes include additional or revised sample locations and parameters, minor modifications to test systems or field activities based on problems encountered, or conditions that develop requiring expedient actions to correct a potentially serious problem. Up to $ 40,000 will be allocated from the contract budget for such minor changes to research activities under this task. Upon determination by the Department that changes should be made, all or a portion of these funds may be authorized by written notification from the Department to the Provider directing specific changes to research activities be made, and the amount budgeted for the changes specified.	Deliverables outlined in authorization letter. Additional Monitoring Wells for S&GW Test Area 3 Tracer Test Progress Report 1, Additional Monitoring Wells for S&GW Test Area 3 Tracer Test Progress Report 2, Abandonment of Monitoring Wells at S&GW Site 3 and Site 4, Abandonment of S&GW Test Facility.
D.1	Draft Literature Review on Nitrogen Fate & Transport Model Report	A literature review will be conducted to determine the current practice for modeling nitrogen fate and transport in soils and ground-water. Particular attention will be paid to data gathered from the Task C literature reviews that have relevance to model parameterization of nitrogen fate and transport. If feasible, sensitivity analysis will be conducted based on previous work for conditions relevant to Florida soil and hydrology to help direct Task C monitoring and future modeling efforts. Currently available models for nitrogen fate and transport will be reviewed, and the hydraulic and transport/transformation parameters for the models and estimation tools that the provider deems to be applicable, will be summarized so that a plan for fieldwork can begin to be developed at an early stage in the project. Existing available models specific to OSTDS or similar source types will be included in this review to determine the appropriate starting point for model development for this project. Results of the literature reviewed in this task will be added to the searchable literature reference database established in Task A.	Draft literature review and updated reference database.

TASK NO.	Task	Task Description	Deliverables from contract
D.2	Final Literature Review on Nitrogen Fate & Transport Model Report	The department will gather comments on the draft final report from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final literature review and updated reference database.
D.3	Selection of Existing Data Set for Calibration Report	The provider will select data from existing sites in Florida or elsewhere to evaluate the performance of a soil and aquifer model, and will provide recommendations for future data collection efforts for subsequent model calibration. The sites shall have information on a nitrogen plume, and data will be obtained via document review and by working with FDOH.	Brief memo describing calibration data sets.
D.4	Draft QAPP N Fate and Transport Models	A detailed QAPP will be drafted describing the sub-tasks to be completed in Task D. The overall goal will be to develop a model representing soil and shallow groundwater that is capable of predicting nitrogen concentrations at a specified location downgradient of an OSTDS source and determining nitrogen loadings/mass flux at a specified location. A simplified, user friendly modeling approach (e.g., programmed Microsoft Excel spreadsheet) will be employed that includes parameters that model the dominant soil and hydraulic factors that influence nitrogen reduction. The development of the fate and transport model will be accompanied with a parallel assessment of soil characterization at individual sites that provide data for model parameterization and calibration (Task C). The Florida soils classification system is one potential source of soil characterization data that could be used for a simple estimation of unsaturated zone transport. The development of a model can include several steps from the concept over implementation of a mathematical model, assurance of numerical accuracy (code verification), adjustment of model parameters to best match a real world experimental data set (calibration), comparison of predictions from a calibrated model to different experimental data (model validation or verification), analysis of the effect of uncertainty in model parameter values on model results or of uncertainty and variability in data sets on calibrated	Draft Task D QAPP.

TASK NO.	Task	Task Description	Deliverables from contract
		parameter values (sensitivity analysis) and adjustments of the concept, mathematical, or calibrated model to better represent observations (model redesign) can be potentially a never-ending circular process as new data become available for comparison over time. The QAPP will describe how model development will proceed from the literature review, initial model development, calibration to existing data, model verification with other existing data or data gathered during this study, and model redesign to a final model product. It will also describe how the developed models and sensitivity analyses can guide data gathering efforts (in particular for task C), provide insights into nitrogen behavior in the environment, and provide a framework for decision making. The final product of Task D is anticipated to be a simplified site scale model that predicts nitrogen concentration and mass flux at selected distances downgradient from the source loading location. Comparisons of this modeling approach with the results of non-steady state models and complex soil models will characterize the limitations of this model. The model will be a combination of a simple soil model and averaged aquifer model. The simple soil model will predict nitrogen reduction in unsaturated soil and the loading of nitrogen to the aquifer at the groundwater table surface. The simplified soil model may take the form of a simple algorithm or correlation that predicts nitrogen reduction as a function of such unsaturated soil characteristics as grain size distribution, water content and organic matter. The aquifer model will likely be time averaged and predict nitrogen concentration and attenuation with distance from the source. Input information includes the direction of groundwater flow at the average groundwater flow velocity and organic matter content. Model parameter values will be derived from calibration for Florida locations using data from Task C and suggested model parameters will be provided.	
D.5	Recommendation for Process Forward (per meeting)	Based on the details agreed upon in the final QAPP, the provider will develop a recommendation whether or not to proceed with the remainder of Task D as outlined below, a revised cost estimate, or	Meeting summary and recommended scope and budget revisions.

TASK NO.	Task	Task Description	Deliverables from contract
		recommend an amendment to this contract. Both the provider and FDOH shall reach a written agreement prior to moving forward with Task D.	
D.6	Final QAPP N Fate and Transport Models	The department will gather comments on the draft QAPP from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final QAPP acceptable by FDOH.
D.7	Simple Soil Tools	The simple soil tools will be a series of look-up tables providing estimated nitrogen removal based on common OSTDS operating conditions. The tables will be generated from the complex soil model developed in subsequent tasks (subtask D8 through D13), or from existing numerical models (e.g., HYDRUS-2D). The model will be corroborated and calibrated for a subset of conditions for which data exist. The specific conditions included in the simple soil model tools will be limited (not to exceed 60 conditions) and agreed upon by FDOH.	Report describing simple soil tool development, tool use, and the look-up tables.
D.8	Complex Soil Model	This subtask includes development of the conceptual framework for the complex soil model including the coding and code evaluation required to implement the theory. The complex soil model will be based on unsaturated soil transport mechanisms adapted to Florida-specific soil and climate data, but incorporated into a simplified approach (e.g., STUMOD programmed into a Microsoft Excel spreadsheet) that includes parameters representing dominant soil properties. The soil treatment module will enable estimation of site-specific soil treatment in the vadose zone with the model output being the loading at the water table (input to aquifer models). This soil-treatment module will be developed to account for evapotransporation, and the effect of high/seasonal variable water tables on nitrogen removal in the soil.	Complex Soil Model Specification Report including theory for coding and code evaluation progress.

TASK NO.	Task	Task Description	Deliverables from contract
D.9	Complex Soil Model Performance Evaluation	The general user will most likely assess performance by comparing model output to field observations (e.g., simplified comparison of values). Similar implementation checks will be performed using robust field data sets (as available). Performance evaluation will also include corroboration/calibration to better understand the quality and quantity of data required by comparing simulated parameter values to the corresponding measured values (calibration targets). Calibration targets will include nitrogen concentrations (weighted equally in space) and mass loading of contaminant from the OSTDS. In addition, a parameter sensitivity analysis will be performed to identify the most relevant model parameters. An uncertainty analysis will also be performed where probability-based ranges for model input parameters will be used to generate probable model outcomes. A more rigorous performance evaluation approach is required for technical users. For this case, the model-performance assessment will be conducted by using model-evaluation statistics to determine whether the model can appropriately simulate the observed data. Multiple methods for evaluating the model performance will be used to ensure model quality assurance evaluation that is not hindered by the specific limitations of a single calibration statistic or identify if further evaluation of the model is warranted.	Report describing performance evaluation methods and results with the draft model in electronic format (e.g., Microsoft Excel spreadsheet).
D.10	Validate/Refine Complex Soil Model	Based on the results from subtask D9, the complex soil model will be revised/improved. As additional data is available from Task C, the model will be revised to incorporate more complex mechanisms. Validation will be used to compare the corroborated/calibrated model to actual field data. Model validation ensures that the model meets the intended requirements and identifies the range of appropriate conditions (e.g., capabilities and limitations). Data from Task C home sites as well as other available data sources will be used to validate the model.	Complex Soil Model report, nomographs for conditions represented in D7, and the final complex soil model in electronic format (e.g., Microsoft Excel spreadsheet).

TASK NO.	Task	Task Description	Deliverables from contract
D.11	Aquifer Model Combined with Complex Soil Model Development	A steady state or non-steady state aquifer model will be developed, possibly by revising an existing model, to simulate nitrogen concentrations and mass flux in space and time from a single OSTDS source, or a surface area that can be estimated as a single OSTDS source. This aquifer model and the complex soil model (D.10) will be integrated together to produce groundwater output predictions for nitrogen concentration or mass flux from a single OSTDS source. The integration will allow for utilization of simple soil model output as input for the aquifer model.	a. Aquifer Model Specification Report describing review and development of the aquifer model (subtask is 50% complete). b. Aquifer-Complex Soil Model Specification Report describing progress status for integrating the two models (subtask is 75% complete). c. Draft integrated model in electronic format (subtask is 100% complete).
D.12	Aquifer-Complex Soil Model Performance Evaluation	Performance evaluation of the aquifer-complex soil model will include implementation checks, corroboration/calibration, parameter sensitivity analysis and an uncertainty analysis. Data sets from Florida identified during subtask D3 and Task C will be used. Metrics will include comparisons of average concentration in the plume or mass flux crossing a boundary between actual field data (as available) and model output, the range in calibrated parameter set values that result in similar agreement between model results and data, model-parameter correlation and bias, and the potential for different parameter combinations to achieve the same agreement between model results and data. Similar to the complex soil model, a more rigorous performance evaluation is also required. Model-evaluation statistics will be used to determine whether the model can appropriately simulate the observed data. Multiple methods for evaluating the model performance will be used to ensure model quality assurance evaluation that is not hindered by the specific limitations of a single calibration statistic or identify if further evaluation of the model is warranted.	a. Aquifer-Complex Soil Model Specification Memo describing progress status for performance evaluation (subtask is 50% complete). b. Report describing performance evaluation methods and preliminary results (subtask is 100% complete).
D.13	Validate/Refine Aquifer-Complex Soil Model with Data Collection from Task C	Based on the results from subtask D12, the integrated aquifer and complex soil model will be revised/improved using site-scale field data collected from Task C. Validation will be used to compare the corroborated/calibrated model to actual field data. The validation/refinement procedure will be an iterative process and may suggest revisions in the data collection plan or in the	Integrated Aquifer-Complex Soil Model report and the final integrated model in electronic format (e.g., Microsoft Excel spreadsheet).

TASK NO.	Task	Task Description	Deliverables from contract
		model itself (parameterization or improvements). Data from Task C home sites as well as other available data sources will be used to validate the model.	
D.14	Development of Aquifer-Complex Soil Model for Multiple Spatial Inputs	A model will be developed, possibly by revising an existing model, to simulate nitrogen concentrations and mass flux in space and time from several OSTDS in a development-scale area. The model will be calibrated using existing data from a development-scale plume, based on metrics such as average concentration in the plume or mass flux crossing a boundary.	Aquifer-Complex Soil Model for Multiple Spatial Inputs report and the model in electronic format (e.g., Microsoft Excel spreadsheet).
D.15	**[Task Eliminated]** Decision-Making Framework Considering Uncertainty	A methodology will be developed to describe how planners can include the uncertainty associated with both calibrated and non-calibrated models in the decision-making process. The report will be in the form of a guidance manual to guide users through the assessment of parameters, tool selection, and how to use those tools.	Modeling decision-making framework report.
D.16	Task D Guidance Manual (Draft)	The Task D draft final report will be developed based on a compilation of Task D reports, progress reports, and technical memos to summarize the results of the Task D modeling. The report will be in the form of a Guidance Manual and User's Guide providing a decision support framework (Task D.15), model development, input parameter selection, and uncertainty assessment. The Guidance Manual will provide an introduction to each tool, assumptions/limitations of the tool, and how to use the tools. The complementary User's Guide will provide detailed technical data including fundamental assumptions that were incorporated into tool development, description of the tool development, and description of parameters that affect nitrogen reduction performance.	Draft Task D Guidance Manual.
D.17	**[Task Eliminated]** Task D Guidance Manual (Final)	The department will gather comments on the draft guidance manual from RRAC and any other interested parties and transmit such comments to the provider within one month of receiving the draft. The provider will address these comments in preparing final deliverables within one month of receiving comments.	Final Task D Guidance Manual with final models in electronic format.

TASK NO.	Task	Task Description	Deliverables from contract
D.18	**[Task Eliminated]** Change-order Allowance	From time to time the Department may find it necessary to make minor changes or adjustments to activities under this task based on results that indicate a potential improvement to the project by making a change. Examples of such changes include additional or revised sample locations or parameters, minor modifications to test systems or field activities based on problems encountered, or conditions that develop requiring expedient actions to correct a potentially serious problem. Up to $10,000 will be allocated from the contract budget for such minor changes to research activities under this task. Upon determination by the Department the changes should be made, all or a portion of these funds may be authorized by written notification from the Department to the Provider directing specific changes to research activities be made, and the amount budgeted for the changes specified.	Deliverables outlined in authorization letter
E.1	Project Kick-Off Meeting (conference call)	The provider will hold a project kick-off meeting to establish contact information, routes of communication, points of contact, and administrative procedures. A list of attendees, contact information sheet and meeting minutes will be produced by the provider.	Conference call minutes
E.2	PM-Project Progress Reports (per bimonthly report)	Bimonthly progress reports will be provided that summarize the general status of each task, progress during the reporting period, activities planned in the next reporting period, and any issues, problems or decisions with significant effect on project implementation. This task includes time for the project manager, for project team and Program Coordination, Subcontract maintenance, project financial analysis, and invoicing.	Progress Reports 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23
E.3	RRAC or TRAP Presentation (per meeting)	The provider shall present project result updates to the RRAC, TRAP or other occasions as requested by the department in writing.	Meeting agenda and minutes: July 1, 2009; June 10, 2010; December 10, 2010; January 4, 2012; June 21, 2012; September 11, 2013; October 22, 2013; September 25, 2014
E.4	RRAC or TRAP Meeting Attendance (per meeting)	The provider shall attend meetings of the RRAC, TRAP or other occasions as requested by the department in writing.	RRAC or TRAP Meeting Presentations and Attendance: August 27, 2009; December 16, 2009; March, 23, 2010; November 5, 2010; April 10, 2012; November 14,

TASK NO.	Task	Task Description	Deliverables from contract
			2012; December 11, 2012; August 29, 2013; March 3, 2015; July 28, 2015.
E.5	**[Task Eliminated]** PAC Meetings (per meeting)	Project Advisory Committee (PAC) review panel will be assembled and a project review meeting coordinated with the project team. Prior to the review meeting, PAC members will be provided information concerning the background and motivation for this project, goals, methods, and initial results. At the review meeting project team members will present the technical approach and findings such that the PAC can critique the project work. A summary report that documents PAC input and team response will be provided.	Meeting agenda and minutes

Appendix C. Review, Prioritization, and Recommendations for Field Testing Nitrogen Reduction Technologies

Review of existing studies

An extensive literature review was performed, which provided a critical assessment of available literature on nitrogen reduction practices, treatment processes, and existing technologies that were suitable for use in individual home and small commercial OSTDS (Hazen and Sawyer 2009a). The review catalogued well over 600 papers, proceedings, reports, and manufacturers' technical materials regarding existing and emerging technologies. The review also discussed nitrogen in the environment and in wastewater, wastewater nitrogen reduction technologies and practices, and Florida-specific strategies for nitrogen reduction in OSTDS. The following is largely excerpted from this literature review.

A variety of nitrogen reducing technologies were considered for possible Florida-based OSTDS applications. Technologies differed in availability of data on their effectiveness, stage of development, treatment approach, economic feasibility, and other characteristics. To simplify evaluation and provide a framework for further analysis, 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 were broken down further based on distinct process variations within a group (Figure C- 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.

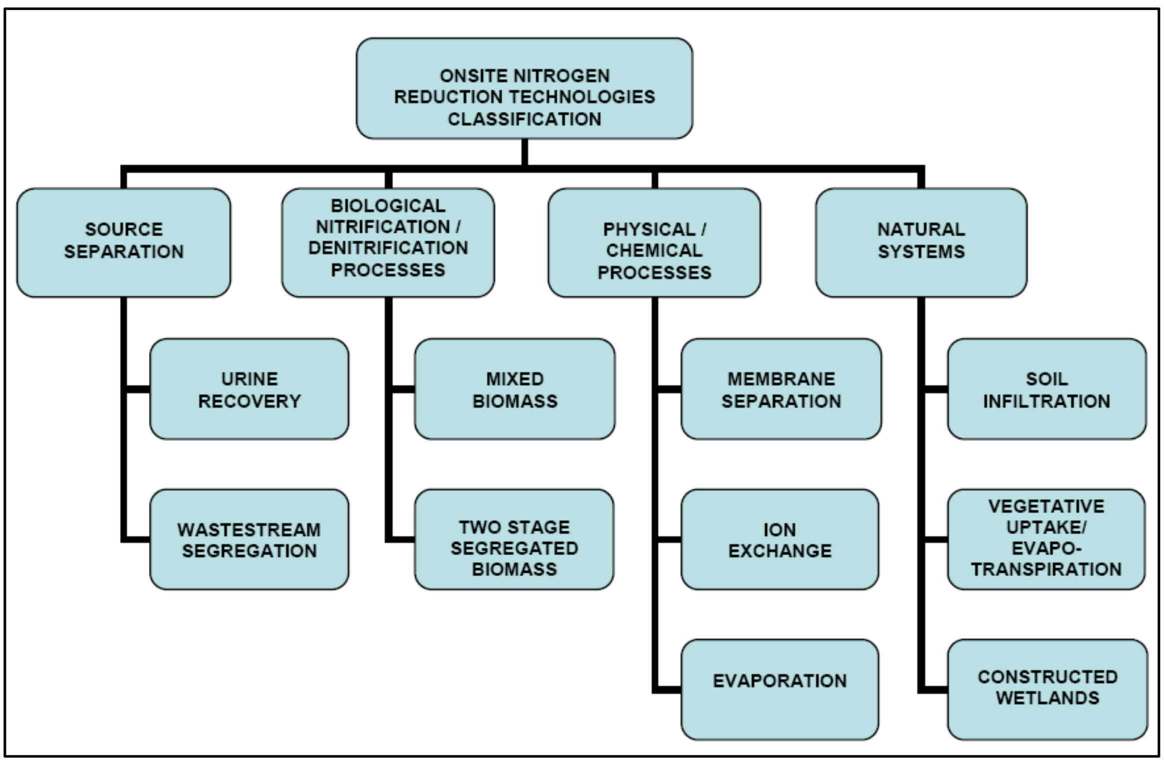


Figure C- 1. Categorization of Treatment Technologies for Nitrogen Reduction (Hazen and Sawyer 2009a)

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.

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, was found to be 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. 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. Urine recovery also has the added benefit of reducing phosphorus discharges. If the infrastructure for urine collection and use as a 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.

Data on the performance of 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 distinguished 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 reduction in Total Nitrogen (TN), but as removal requirements increase, fewer technologies are available.

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

Table C- 1. Relationships between the Terms Conventional System, Performance-Based Treatment System, and Passive System for the Purposes of this Study

<table>
<tr><th>Characteristic</th><th>Conventional System</th><th colspan="2">Performance-Based Treatment System</th></tr>
<tr><td>How important is nitrogen reduction in system?</td><td>Nitrogen reduction is variable and based on soil and groundwater characteristics</td><td colspan="2">Nitrogen reduction is design goal</td></tr>
<tr><td>Where does nitrogen reduction take place?</td><td>Nitrogen reduction limited in STU, site-specific</td><td>Denitrification integrated with aeration process, recirculation</td><td>Additional, separate denitrification stage</td></tr>
<tr><td rowspan="6">What treatment processes beyond a conventional system are included?</td><td rowspan="6">No additional treatment processes included</td><td rowspan="3">Aeration by blowers, recirculation, or similar means</td><td>No separate denitrification stage included</td></tr>
<tr><td>Denitrification by dosing reactants</td></tr>
<tr><td>Denitrification by reactive media</td></tr>
<tr><td rowspan="3">Aeration by sewage flow over porous media, recirculation</td><td>No separate denitrification stage included</td></tr>
<tr><td>Denitrification by dosing reactants</td></tr>
<tr><td>Denitrification by reactive media</td></tr>
</table>

"Passive System" for the purposes of this study

Table C- 2 summarizes the performance capabilities of the different processes. Recent studies by the Florida Department of Environmental Protection and Florida State University, as well as the study that is the topic of this report, have generated data that appear to generally agree with the results of the literature review (Harden et al., 2010).

Table C- 2. Biological Denitrification Processes and Typical Nitrogen Reduction Limits of OSTDS (Hazen and Sawyer 2009a)

Process	**Mixed Biomass (Single Stage - Simultaneous)**	**Mixed Biomass (Single Stage - With Recycle)**	**Segregated Biomass (Two Stage)**
Electron Donor	Organic carbon from bacterial cells	Organic carbon from influent wastewater	External electron donor (Organic carbon; Lignocellulose; Sulfur; Iron; Other)
Typical N Reductions	40 to 65%	45 to 75%	70 to 96%
Typical Technologies	Extended aeration Pulse aeration Recirculating media filters Sequencing batch reactors Reciprocating media beds Membrane bioreactor	Extended aeration with recycle back to septic tank Recirculating media beds with recycle back to septic tank Moving bed bioreactor	Heterotrophic suspended growth Heterotrophic packed bed fixed film Autotrophic packed bed fixed film

The mixed biomass, or 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 40-65 percent TN removal, while OSTDS that regularly recycle nitrified wastewater back to the anoxic septic tank mixes with organic carbon present in the raw wastewater typically achieve 45-75 percent TN reduction.

Segregated biomass, or two stage process, which do not rely on organic carbon in the system but rather add carbon or other food compounds to the denitrification stage from an external source, can achieve nearly complete removal of nitrate by adding carbon into the denitrification reactor. Examples of this approach include two technologies currently in innovative system status in Florida, the passive Nitrex™-reactive media and active dosing with Micro CG™, both of which require nitrifying pretreatment. In a previous Department project completed during 2007-2008 (Smith et al. 2008), a bench-scale study on passive two-stage biofiltration found that after eight months of operation nitrogen in septic tank effluent was reduced by 97% (Figure C- 2). The results of this study showed the feasibility of passive two-stage biofiltration using elemental sulfur as the electron donor for denitrification. Another example is the "bold-and-gold" proprietary treatment media that is currently being developed at the University of Central Florida. A segregated biomass (two stage) biological nitrification/ denitrification process would be necessary where strict TN limits require more than 70 percent removal prior to

discharge to the STU.

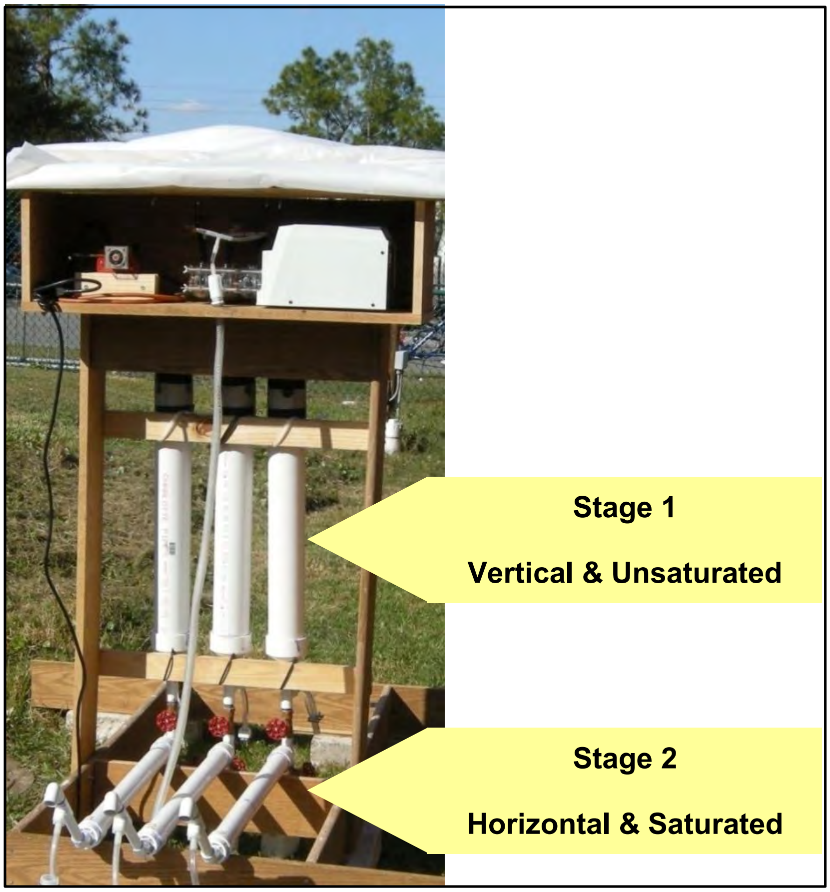


Figure C- 2. Passive Nitrogen Removal Study I (PNRS I) Bench-Scale Design (Smith et al. 2008)

Natural systems, which include the traditional OSTDS, also have inherent performance limitations. Application of septic tank effluent to unsaturated soil results in excellent oxygen demand ($cBOD_5$) and fecal coliform removals. Soils with moderate to high hydraulic permeability with unsaturated (vadose) zones several feet deep below the system infiltrative surface are favored by onsite sewage regulations to achieve such treatment. Such soils are well aerated, which provide efficient and nearly complete nitrification of the influent nitrogen, but as a result of the aerobic soil atmosphere, the vadose zone is unable to retain organic carbon. This is a reason why nitrogen removals in conventional OSTDS are typically less than 40 percent. 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. It is important to ensure that the water will be distributed such that it remains below the ground surface for protection of public health, so this option may require a larger mound infiltration surface.

The effect of timed dosing of septic tank effluent on nitrogen reduction appears to be still subject to discussion. While the project team proposed in their literature review that such drip dispersal could

enhance nitrogen reduction because of wetting and drying cycles with alternating aerobic and anoxic soil conditions, they assigned the lowest possible score to the nitrogen reduction performance of dosed OSTDS, and the second lowest score to the performance of a drip irrigation system (Table C- 4). Comments received on drafts of this literature review cited studies that did not find an enhancement of nitrogen reduction due to dosing. An enhancement has more frequently been found in fine-grained material, such as loam, while case studies that have found no enhancement tended to address coarser material, such as sand, which is more typical of Florida soils.

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. However, like any of the natural systems, carbon management is problematic and because the discharges are below the ground surface, compliance monitoring is difficult and costly.

Technology Classification, Ranking, and Prioritization of Technologies for Field Testing within this Project

Results of the findings from the literature review and recommendations for application of nitrogen reduction strategies in Florida led to development of a scheme for classifying nitrogen reduction technologies. This allowed comparisons to be made between the many options that are available for use in onsite sewage treatment systems. Four categories were identified for classification: source separation, biological treatment via nitrification/denitrification, physical/chemical treatment, and natural systems. In most available onsite nitrogen reduction technologies, it is typical that more than one of these processes are operative in any given treatment system. Classification followed the pattern developed in the literature review (Figure C- 1). Hazen and Sawyer (2009b) provide more detail on the prioritization, which is excerpted and summarized here.

A simple numerical ranking system was developed to prioritize available nitrogen reduction system categories for testing. The relative rankings of technologies were based on thirteen selected criteria such as nitrogen reduction and treatment performance, system reliability and consistency, complexity of operation and maintenance, costs, aesthetics, and stage of development criteria. Each criterion was 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 were 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 complexity 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 C- 3 shows the final criteria with their weights.

Table C- 3. Ranking Criteria and Weighting Factors to Evaluate Technologies for Testing (Hazen and Sawyer 2009b)

Criteria	Maximum Score S	Weighting Factor W	Total Possible Score S x W
Effluent 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 Requirement	5	7	35
Construction Complexity	5	5	25
Operation Complexity	5	5	25
Land Area Required	5	4.5	22.5
BOD/TSS[1] 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
		Total:	**377.5**

1 – BOD: Biological Oxygen Demand, TSS: Total Suspended Solids

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.

Table C- 4 illustrates the scoring system for each criterion.

Table C- 4. Score Assignments for Ranking Criteria (Hazen and Sawyer 2009b)

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	Activated Sludge Nite/Denite	IFAS2	MBR/IMB3	Fixed Film	Physical/ Chemical & Source Separation
4	Construction Cost ($1,000's) 1)	>20	16-20	11-15	5-10	<5
5	Operation and Maintenance Cost ($/year) 2)	>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 manufacturer's representative scheduled visit
9	Land Area Required (ft^2) 3)	>2000	1001-2000	501-1000	250-500	<250
10	BOD/TSS Effluent Concentration (mg-N/L) 4)	>50	30/30		20/20	10/10

11	Restoration of Performance	Activated Sludge Nite/Denite	IFAS [5)]	MBR [6)]	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

1) Construction cost assumes a standard septic tank cost of $2000 and STU cost of $4500 installed
2) Operation and maintenance cost includes inspections, annual operating permit fee ($100), and maintenance entity, but it does not include power costs
3) Land area is for a new entire system, and assumed standard septic tank 50 SF and STU 400 SF
4) BOD: Biological Oxygen Demand, TSS: Total Suspended Solids
5) Integrated Fixed-Film Activated Sludge
6) Membrane Bioreactor

More details on individual criteria and how their scores were determined can be found in the Hazen and Sawyer's report on Technology Classification, Ranking and Prioritization of Technologies (Hazen and Sawyer 2009b). It should be noted that the weights assigned to various criteria, the scores, and the resulting ranking were developed by the contractor for the specific purpose within this project of the selecting the technologies for field testing. Other purposes might warrant other weighting or scoring approaches.

A rigorous prioritization process completed during public meetings of the RRAC determined which nitrogen reduction options were to be tested in this study. There was a desire not to overlap too much with existing proprietary system testing, and to expand on promising laboratory-scale research results from a previous Department research project (PNRS I).

A summary of the individual criterion scores for physical/chemical, biological, natural systems, and source separation technology classifications are presented in Table C- 5 and Table C- 6. While the tables encompass the full range of possible systems contained in the classification, technology classifications that the project team deemed to lack 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 from actual available data.

The rankings did not include a conventional OSTDS in which flow to the STU occurs by gravity. Such a system is likely to achieve a ranking slightly better than that of a dosed STU within the natural system category, based on lower construction and lower electrical costs, and have the same low score on effluent nitrogen concentration. It was not included separately due to the emphasis on prioritizing modifications and alternative technologies for testing during this project.

Table C- 5. Project Ranking Results for Pre-Disposal Treatment Technologies Based on Ranking Criteria (Hazen and Sawyer 2009b)

Technology Classification	Criteria 1: Effluent TN Conc. (mg-N/L)	2: Performance Reliability	3: Performance Consistency	4: Construction Costs ($1000)	5: O&M Cost	6: Energy Req. (kW-h/yr)	7: Construction Complexity	8: Operation Complexity	9: Land Area Req. (ft^2)	10: BOD/TSS Effluent Conc (mg/L)	11: Restoration of Performance	12: System Aesthetics	13: Stage of Technology Development	Total Score
Weighting Factor	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
Autotrophic Denitrification	4	5	4	2	3	2	3	5	3	5	4	5	3	276.5
Source Separation Systems														
Urine Recovery	Not Enough Available Data to Score													
Wastes Segregation	Not Enough Available Data to Score													

Table C- 6. Project Ranking Results for "Natural System" Technologies Based on Ranking Criteria (Hazen and Sawyer 2009b)

Technology Classification	Criteria 1: Effluent of TN Conc. (mg-N/L)	2: Performance Reliability	3: Performance Consistency	4: Construction Costs ($1000)	5: O&M Cost	6: Energy Req. (kW-h/yr)	7: Construction Complexity	8: Operation Complexity	9: Land Area Req. (ft²)	10: BOD/TSS Effluent Conc (mg/L)	11: Restoration of Performance	12: System Aesthetics	13: Stage of Technology Development	Total Score
Weighting Factor	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

The first and second ranked pretreatment or pre-disposal technology classifications for testing were biological systems with two stage segregated biomass employing autotrophic (chemical-fed) and heterotrophic (carbon-fed) denitrification. These systems are passive, expected to require little operator attention, and expected to 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 are expected to 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 Table C- 5 Primary among considerations supporting this division of technologies is the need to consider separately the elements of each system that performs 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 to reduce nitrogen. However, 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, an approach for which the literature review gathered little information. The second ranked natural system is traditional trench STU with timed dosing of septic tank effluent. However, this system received the lowest treatment score. Application of the 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 capabilities, the costs associated with correcting poor performance, and the low nitrogen treatment.

Recommendations for Testing

The technology classification ranking provided the basis from which to formulate recommendations for the field testing conducted in the Florida Onsite Sewage Nitrogen Reduction Strategies Study. In addition to the ranking scores, the criteria used to establish 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 was 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 used for testing is listed in Table C- 7.

Table C- 7. Recommended Technologies for Testing at the Test Facility and in Field Installations (Hazen and Sawyer 2009b)

System	Technology	Project Team Comment	Comments on Previous Florida Experience and Testing Approach
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	-Column experiments performed during PNRS I -Further evaluation, including fate of sulfur, planned in PNRS II test facility
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	-Innovative System Permit for Nitrex™ after biofiltration pretreatment, a passive system per project definition -Innovative System Permit for Pura-Flo™ with Micro CG addition, a biofiltration pretreatment with active carbon dosing -"Bold-and-gold" proprietary treatment media and configurations is in development
3	Natural system: Septic tank/Mound with in-situ reactive media layer	Lower cost natural system that was untested prior to this study but appears capable of achieving 75-78% TN removal before reaching groundwater	-Initial evaluation, including fate of sulfur, planned in PNRS II test facility
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	-Secondary effluent with drip is frequently used in Florida, more performance data needed, secondary pretreatment currently required in Florida for drip -Evaluation at PNRS II test facility in comparison to system 3 planned
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	See system 2

		nitrogen removal	
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	See system 1
7	Mixed biomass integrated fixed film activated sludge system: with recycle	High performance aerobic treatment	-Without recycle, common technology for aerobic treatment units (FAST, JET, Bionest) and nitrogen reducing systems (FAST) in Florida -FAST technology, including internal recycle, evaluated during previous Florida Keys test facility study, preceding establishment of Keys nitrogen treatment standard
8	Mixed biomass integrated fixed film activated sludge system: Moving bed bioreactor	High performance aerobic treatment with simultaneous denitrification	-Very limited information from innovative system testing of one particular technology
9	Mixed biomass suspended growth system: Suspended growth sequencing batch reactor	Aerobic treatment	Common elsewhere, largely absent in Florida
10	Membrane process system: Membrane bioreactor (MBR)		New for single-family residences in Florida
11	Source separation system: Dry toilet (evaporative or composting)	Eliminates liquid disposal of toilet wastes	-Several manufacturers approved based on NSF testing/certification - Section 381.0065 (4) (t), Florida Statutes treats this similar to 50% nitrogen reduction
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	-Requires different plumbing -Need clarification on approval standards

All of the technologies can be employed for new installations. Variations of these technologies (except the source separation systems 11 and 12) should be considered for possible insertion between an existing septic tank and existing STU in existing systems, as long as the existing tank is structurally sound and appropriately sized. This complements and supports the conversion of conventional onsite sewage treatment and disposal systems to nitrogen removal. For systems three and four, a retrofit might involve the addition of pumping and filter mechanisms and the installation of a new STU.

The two highest priorities for testing were biological systems with two stage segregated biomass employing autotrophic (system 1) and heterotrophic (system 2) denitrification. These systems are passive and expected to be highly reliable and require minimal operational monitoring. These systems are the most operationally simple, effective, and applicable nitrogen removal process for development of PNRS for OSTDS.

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. Passive Nitrogen Reduction System Phase II (PNRS II) testing provided additional data for biofiltration with recycle using clinoptilolite, expanded clay, and polystyrene. The best performing media from PNRS II testing was recommended for prototype field testing at actual homesites.

The second stage of these hybrid systems employed autotrophic denitrification and heterotrophic denitrification, respectively. Systems with heterotrophic (carbon addition) denitrification are commercially available. Two such systems, one employing a passive media and one employing more active dosing, already have received an innovative system permit in Florida. Treatment media being developed also fall into this category of heterotrophic denitrification. The project team proposed to use sulfur as medium for autotrophic denitrification. This approach was further evaluated during PNRS II testing, in continuation of the column studies performed during PNRS I.

System 3 is an experimental “natural system” that uses drip dispersal into amended soil of settled or secondary effluent. To enhance denitrification, an in-situ reactive media barrier was constructed below the drip dispersal tubing. Effluent was dispersed within the root zone and percolated downward through the reactive media barrier containing high groundwater retention materials such as expanded clay and lignocellulosic or elemental sulfur electron donors to support heterotrophic or autotrophic denitrification. The literature did provide few data on the merits of this approach. The design of this system was based on the results of PNRS II, in which variants of this basic system were evaluated to determine the design that resulted in the best nitrogen reduction performance. This system would meet the project 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 could be created in the soil near each emitter, which may create the necessary conditions for nitrification/denitrification to occur. This intermittent dosing of septic tank effluent has been shown by several studies to reduce the TN that migrates downward from the point of application. Other studies

have shown a limited effect, and the performance score (Table C- 6) for this approach was relatively low. This approach had the potential of being a relatively low cost modification to conventional system that allows the reuse of wastewater for landscape irrigation. Secondary pretreatment is currently required for drip irrigation in Florida and the combination is frequently used in Florida, but a thorough evaluation of the nitrogen reduction benefits of drip irrigation is missing. This approach was also tested under controlled conditions at the PNRS II test facility in direct comparison to a similarly sized system and a pressure dosed system.

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. 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 Integrated Fixed-Film Activated Sludge (IFAS) 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. Such systems are frequently used as aerobic treatment units in Florida. The performance of one fixed film activated sludge technology (FAST) was previously evaluated under controlled conditions in a study in the Florida Keys that helped to establish nitrogen treatment standards and has been frequently permitted for nitrogen reduction.

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. While common elsewhere, sequencing batch reactors are largely absent from Florida's advanced 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 sewage 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. Composting and incinerating toilets can currently be permitted, and are statutorily considered similar to a 50% nitrogen reduction system.

Appendix D. Passive Nitrogen Reducing Systems at Home Sites

Field Systems

This appendix summarizes performance, operation and maintenance information from the field installations of passive nitrogen removal systems at home sites. It is based on Hazen and Sawyer's (2015a, 2015b) reports, to which estimates of standardized treatment system costs were added based on life-cycle cost analyses (Appendix E). Field parameters analyzed included temperature, pH, specific conductance, dissolved oxygen, and oxygen reduction potential. Samples were analyzed by the laboratory for the parameters, methods, and detection limits listed in Table D- 1.

Table D- 1. Laboratory Analyses Methods (Hazen and Sawyer 2015b)

Analytical Parameter	Method of Analysis	Laboratory Detection Limit
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Total Kjeldahl Nitrogen (TKN)	EPA351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA350.1	0.01 mg/L
Nitrate/Nitrite Nitrogen (NO_x-N)	EPA353.2	0.01 mg/L
Carbonaceous BOD ($CBOD_5$)	SM 5210B	2 mg/L
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Volatile Suspended Solids (VSS)	EPA 160.4	1 mg/L
Total Organic Carbon (TOC)	SM5310B	0.06 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Phosphorus (TP)	SM 4500PE	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Fecal Coliform (fecal)	SM9222D	1 cfu/100mL
E.coli	SM9223B	2 cfu/100mL
Sulfate (SO_4)	EPA300.0	0.2 mg/L
Hydrogen Sulfide Unionized (H_2S)	SM4500S F	0.01 mg/L
Sulfide	SM4500S F	0.1 mg/L

Tank-based systems

HOME SITE 1

Location: Seminole County

System: In-tank two stage biofilter with recirculation stage 1, dual media stage 2 lignocellulosic (2a) followed by elemental sulfur (2b)

Description: Figure D- 1 shows the process flow for this system. This is identified as system BHS-5 from the final report by Hazen and Sawyer (2015b). Wastewater flows through the existing septic tank to a tank filled with an unsaturated layer of expanded clay. Then the wastewater goes to a pump tank which recycles some of the wastewater back to the Stage 1 tank and pumps part of the wastewater to a tank which has two sections: a section filled with a saturated layer of wood-chip material and a second section filled with a saturated mixture of sulfur and oyster shells. The wastewater then flows by gravity to the existing STU.

Estimated media longevity: 10-47 years

System performance: 98% reduction of nitrogen (influent TN 75 mg-N/L, effluent TN 1.8 mg-N/L)

Actual cost as studied: $18,295 for 500 gallon per day house

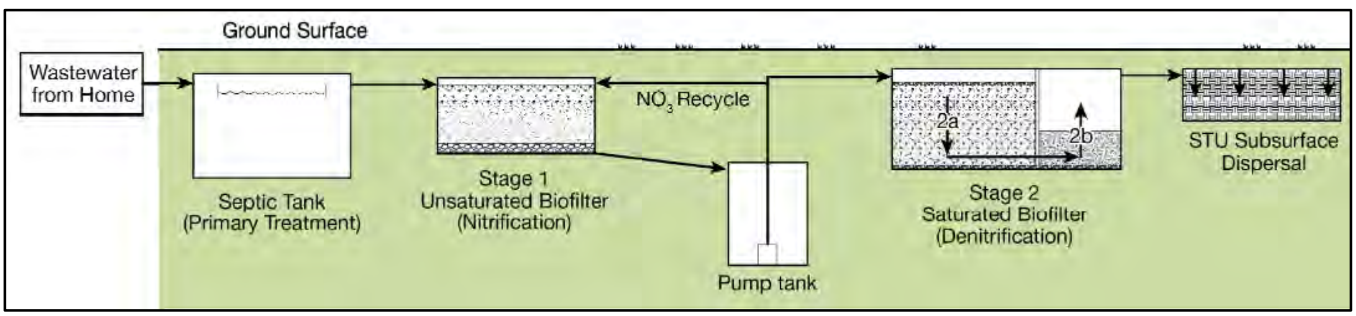


Figure D- 1. Home Site 1 Process Flow Diagram: In-Tank Two Stage Biofilter with Recirculation Stage 1, Dual Media Stage 2 Lignocellulosic (2a) Followed by Elemental Sulfur (2b) (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $12,794
- Retrofit of an existing system is $15,269

Estimated energy cost: $36 annually / $3 monthly

HOME SITE 2

Location: Hillsborough County

System: In-tank two stage biofilter with stage 1 recirculation, dual media stage 2; lignocellulosic (2a) followed by elemental sulfur (2b)

Description: Figure D- 2 shows the process flow for this system. This is identified as system BHS-2 from the final report by Hazen and Sawyer (2015b). Wastewater goes through a septic tank to a small storage tank. The wastewater then goes to a tank filled with an unsaturated layer of expanded clay to a pump tank which splits the wastewater- part goes back to the small storage tank and the remainder to another tank which has two sections: one filled with a saturated layer of wood-chip material which flows to the second filled with a saturated mixture of sulfur and oyster shells. Once the wastewater flows up through the second saturated section it flows by gravity to the existing STU.

Estimated media longevity: 10-149 years

System performance: 93% reduction of nitrogen (influent TN 50.5 mg-N/L, effluent TN 3.5 mg-N/L)

Estimated energy cost: $36 annually / $3 monthly

Actual cost as studied: $18,056 for 400 gallon per day house

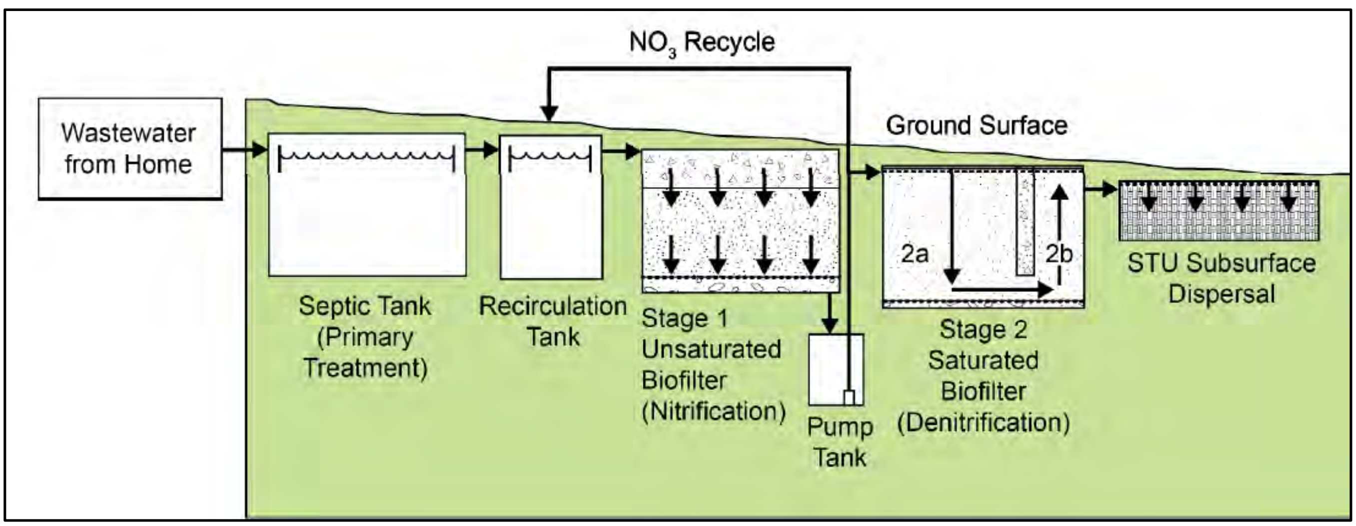


Figure D- 2. Home Site 2 Process Flow Diagram: In-Tank Two Stage Biofilter with Stage 1 Recirculation, Dual Media Stage 2; Lignocellulosic (2a) Followed by Elemental Sulfur (2b) (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $13,394
- Retrofit of an existing system is $15,869

Estimated energy cost: $36 annually / $3 monthly

HOME SITE 3

Location: Seminole County

System: In-tank gravity system two stage biofilter with single pass stage 1, dual media stage 2; lignocellulosic (2a) followed by elemental sulfur (2b)

Description: Figure D- 3 shows the process flow for this system. This is identified as system BHS-4 from the final report by Hazen and Sawyer (2015b). The property originally had two OSTDS. One system was converted to a lift station and now discharges to the existing septic tank and new gravity flow PNRS. The wastewater flows through the existing septic tank to a new tank filled with an unsaturated layer of expanded clay. Next, the wastewater flows to a new tank with two sections: one filled with a saturated layer of wood-chip material and a second filled with a saturated mixture of sulfur and oyster shells. Finally, the treated wastewater flows by gravity to a new STU.

Estimated media longevity: 10-21 years

System performance: 89% reduction of nitrogen (influent TN 70.1 mg-N/L, effluent TN 7.4 mg-N/L)

Actual cost as studied: $16,097 for 400 gallon per day house

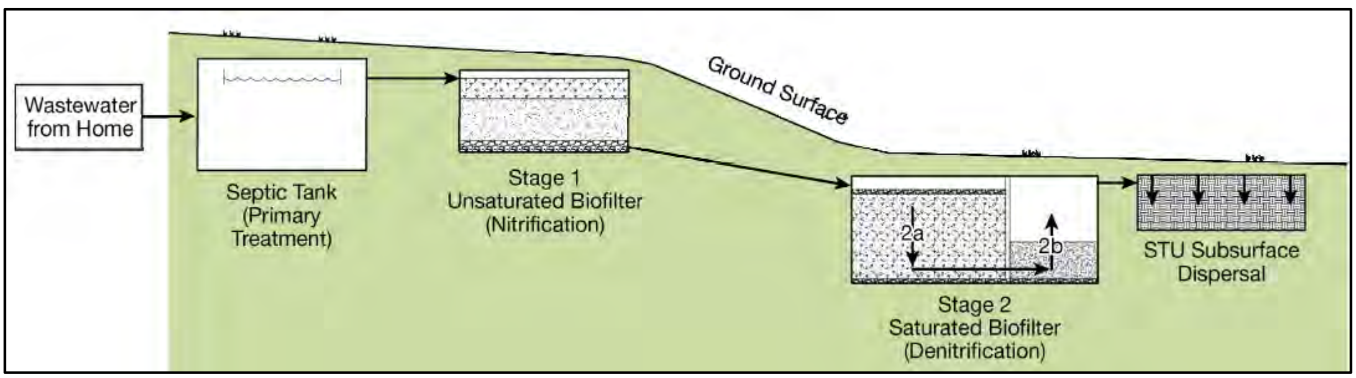


Figure D- 3. Home Site 3 Process Flow Diagram: In-Tank Gravity System Two Stage Biofilter with Single Pass Stage 1, Dual Media Stage 2; Lignocellulosic (2a) Followed by Elemental Sulfur (2b) (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $15,106
- Retrofit of an existing system is $17,581

Estimated energy cost: $0 annually / $0 monthly

HOME SITE 4

Location: Wakulla County

System: In-tank gravity system two stage biofilter with single pass stage 1, dual media stage 2; lignocellulosic (2a) followed by elemental sulfur (2b)

Description: Figure D- 4 shows the process flow for this system. This is identified as system BHS-6 from the final report by Hazen and Sawyer (2015b). Wastewater goes through a septic tank to a pump tank which pumps the wastewater to a tank with two layers: an unsaturated layer of expanded clay above a saturated layer of wood-chip material. The wastewater flows out of this tank into the bottom of a tank with a sulfur and oyster shell media mixture. The treated wastewater flows by gravity to the STU.

Estimated media longevity: 10-30 years

System performance: 81% reduction of nitrogen (influent TN 66.3 mg-N/L, effluent TN 12.4 mg-N/L)

Actual cost as studied: 10,399 for 300 gallon per day house

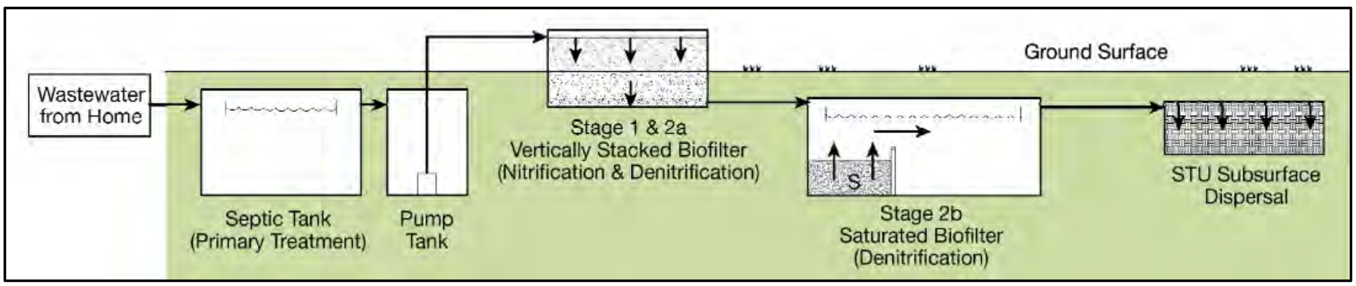


Figure D- 4. Home Site 4 Process Flow Diagram: In-Tank Gravity System Two Stage Biofilter with Single Pass Stage 1, Dual Media Stage 2; Lignocellulosic (2a) Followed by Elemental Sulfur (2b) (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $16,318
- Retrofit of an existing system is $18,793

Estimated energy cost: $9 annually / $0.75 monthly

HOME SITE 5

Location: Wakulla County

System: Proprietary system: stage 1 Aerocell™ stage 2 Nitrex™

Description: Figure D- 5 shows the process flow for this system. This is identified as system BHS-1 from the final report by Hazen and Sawyer (2015b). Wastewater goes through a septic tank with two sections: one section performs like a standard septic tank and the second section has a pump which lifts the wastewater to a second tank filled with small foam Aerocell™ cubes. The wastewater then flows by gravity through the unsaturated media. Part of the wastewater is diverted back to the septic tank and the rest flows by gravity to another tank filled with a proprietary Nitrex™ media which is formulated from wood byproducts. The treated wastewater flows by gravity to a new STU.

Estimated media longevity: 10-65 years

System performance: 91% reduction of nitrogen (influent TN 82.7 mg-N/L, effluent TN 7.1 mg-N/L)

Actual cost as studied: $18,606 for 300 gallon per day house

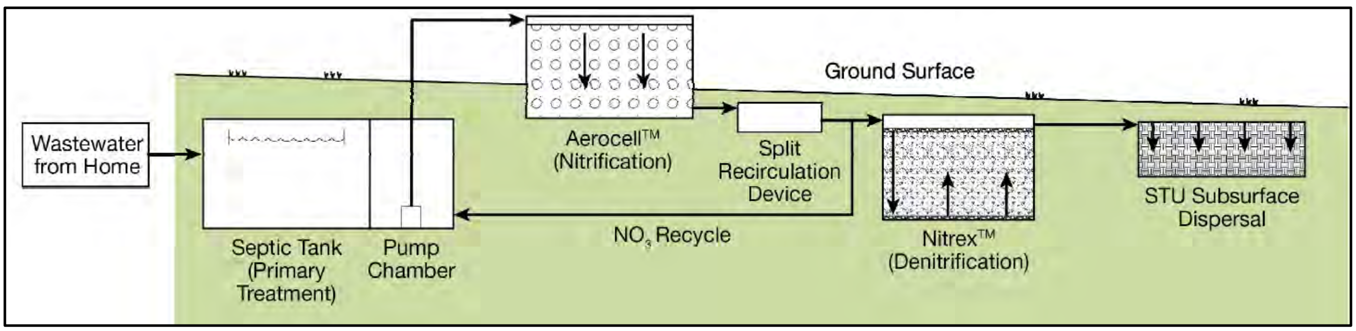


Figure D- 5. Home Site 5 Process Flow Diagram: Existing Proprietary System (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $13,899
- Retrofit of an existing system is $15,124

Estimated energy cost: $374 annually / $31 monthly

In-ground systems

HOME SITE 6

Location: Seminole County

System: In-ground stacked biofilter, single pass stage 1 over stage 2a with supplemental stage 2b tank; stage 2a lignocellulosic/sand mixture; stage 2b elemental sulfur tank

Description: Figure D- 6 shows the process flow for this system. This is identified as system BHS-3 from the final report by Hazen and Sawyer (2015b). Wastewater goes through a septic tank to a dosing tank which pumps to a drip irrigation area contained within a liner with two layers: an unsaturated layer of slightly limited fine sand above a layer of wood-chip material. The wastewater is collected at the bottom of the liner then flows by gravity to a tank filled with a saturated mixture of sulfur and oyster shells. The final treated wastewater is pumped by the same pump to a drip irrigation system installed in the natural soil providing reuse of reclaimed water.

Estimated media longevity: 10-86 years

System performance: 96% reduction of nitrogen (influent TN 50.5 mg-N/L, effluent TN 1.9 mg-N/L)

Actual cost as studied: $32,115 for 580 gallon per day house

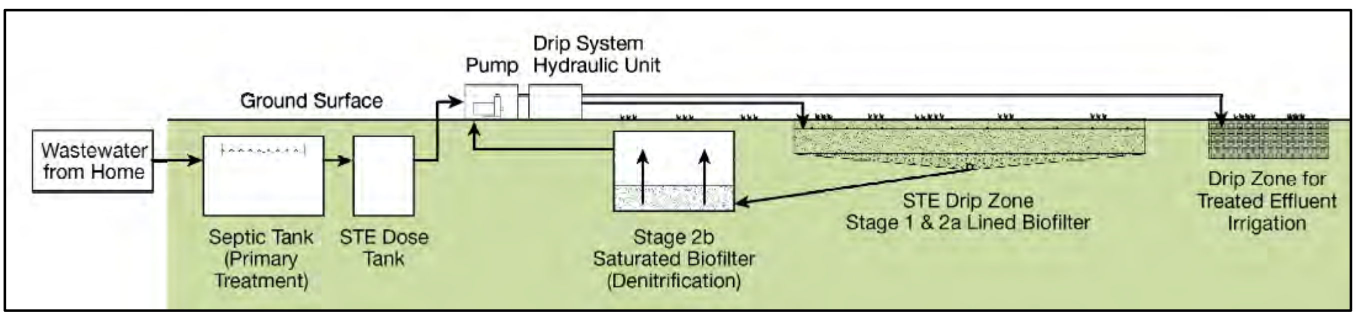


Figure D- 6. Home Site 6 Process Flow Diagram: In-Ground Stacked Biofilter, Single Pass Stage 1 over Stage 2a with Supplemental Stage 2b Tank; Stage 2a Lignocellulosic/Sand Mixture; Stage 2b Elemental Sulfur Tank (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $15,635
- Retrofit of an existing system is $20,735

Estimated energy cost: $39 annually / $3.25 monthly

HOME SITE 7

Location: Marion County

System: In-ground stacked biofilter, single pass stage 1 over stage 2 lignocellulosic

Description: Figure D- 7 shows the process flow for this system. This is identified as system BHS-7 from the final report by Hazen and Sawyer (2015b). Wastewater flows through the existing septic tank to a pump tank which pressure doses a stage 1 soil treatment unit for nitrification. Under the STU, within a liner, is a layer of wood-chip material. The treated wastewater was intended to saturate the wood chips in the liner, and then flow into the soil over the rim of the liner. System monitoring showed little saturation of the wood material, and moisture appeared to be wicked laterally from the fine sand into the surrounding soil. It is thought that a larger liner area and that a different stage 2 mixture is needed in the liner to collect and hold moisture from the sand above.

Estimated media longevity: 10-135 years

System performance: 64% reduction of nitrogen (influent TN 54.9 mg-N/L, effluent TN 19.9 mg-N/L)

Actual cost as studied: $10,515 for 300 gallon per day house

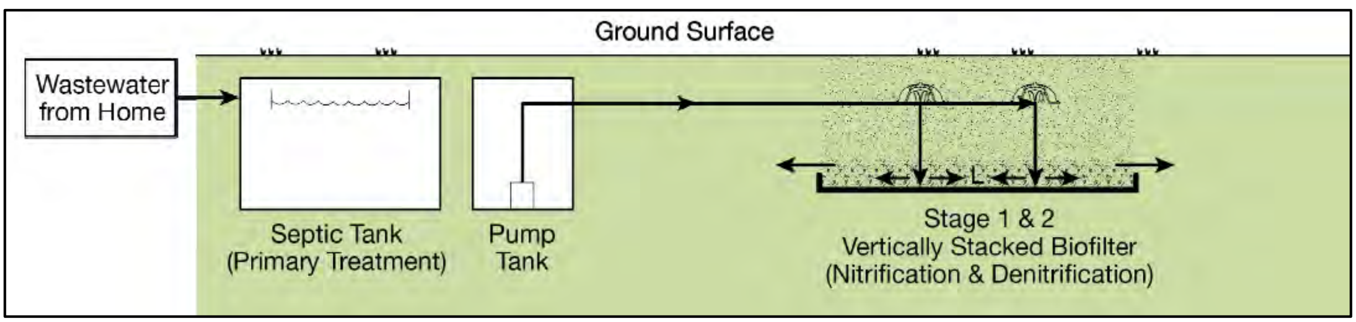


Figure D- 7. Home Site 7 Process Flow Diagram: In-Ground Stacked Biofilter, Single Pass Stage 1 Over Stage 2 Lignocellulosic (Hazen and Sawyer 2015b)

Standardized cost: Utilizing this design for a 300 gallon per day house, the PNRS components:

- New construction cost estimate is $8,709
- Retrofit of an existing system is $12,059

Estimated energy cost: $8.55 annually / $0.71 monthly

Operation and Maintenance

Overall, the prototype PNRS operated continually following start-up with very limited or no downtime. A field technician visited the sites monthly and very limited maintenance was required.

Operation and maintenance (O&M) of the prototype systems reflected the complexity of the systems. The simplest system O&M was the in-ground PNRS for home site 7, which had similar requirements to a conventional system with a pressure dosed STU. Slightly more complex were the in-tank systems with single pass Stage 1 biofilters, which added the Stage 1 effluent distribution to the O&M requirements. Next, and only slightly more complex, were the in-tank systems with recirculation of Stage 1, which added timed dosing to the controls and the recirculation ratio must be checked and adjusted occasionally. The most complex system was for the in-ground system at home site 6 which was due to the use of drip dispersal for both the effluent application in Stage 1 and irrigation of final treated effluent to turf grass, all with one pump. The O&M requirements for this system were similar to more complex PBTS or drip irrigation systems. However, without the irrigation component, and with low pressure distribution instead of drip, this system would be similar in complexity to the single pass Stage 1 in-tank systems. Table D- 2 summarizes the actual operation and maintenance requirements for the PNRS prototype systems.

Table D- 2. System Operation and Maintenance (Hazen and Sawyer 2015b)

System	Major Issues encountered	General O&M requirements	Other O&M
Home Site 1 (BHS-5)	During start-up: • Float placement During study period: • During recirculation mode of operation sprayers required adjustment	• Cleaning of septic tank effluent screen	• Stage 1 mode of operation was revised from single pass to recirculating using sprayers installed above Stage 1 biofilter media.
Home Site 2 (BHS-2)	During start-up: • Float placement	• Cleaning of septic tank effluent screen	• Recirculation mode of operation was revised from recirculation tank to sprayers installed above Stage 1 biofilter media
Home Site 3 (BHS-4)	During start-up: • Oversized STE transfer pump caused significant mixing in primary	• Cleaning of septic tank effluent screen • Raking of Stage 1 biofilter media surface	• High cleaning frequency of septic tank effluent screen attributed to flow transfer pump flow into single chamber septic tank

System	Major Issues encountered	General O&M requirements	Other O&M
	tank (was replaced) During study period: • Additional centerline distribution pipe was installed above Stage 1 media to improve coverage of effluent over entire surface of biofilter		• Solids carryover from the septic tank led to biomat formation and some ponding near Stage 1 distribution box
Home Site 4 (BHS-6)	During start-up: • Loose wiring During study period: • Stage 1 spray nozzle clogging and inadequate distribution • Stage 1&2a effluent collection pipe clogged • Stage 2 inlet pipe clogged	• Cleaning of Stage 1 spray nozzles • Clearing blockages in Stage 1&2a effluent collection pipe and Stage 2 inlet pipe • Cleaning of process flowmeter	Operational issues are associated with design and construction problems. A better dosing system for the Stage 1 biofilter, a better underdrain design for the Stage 1&2a tank and improved inlet to the Stage 2 tank without bends between the tanks would likely eliminate most of the operational problems.
Home Site 5 (BHS-1)	During start-up: • Flow splitter device flow split • Control panel wiring • Float placement within pump vault During study period: • Leaks detected in flow splitter device (was replaced)	• Recirculation ratio adjustment to meet target of 10:1	• Recirculation ratio was increased to target of 10:1 for better performance

System	Major Issues encountered	General O&M requirements	Other O&M
Home Site 6 (BHS-3)	During start-up: • Solenoid valve malfunction due to construction debris	• Cleaning of septic tank and STE dose tank effluent screens • Air release valve replacement	• The drip system controller includes automated cleaning sequences which leads to system complexity (9 solenoid valves) which requires additional oversight for system operation
Home Site 7 (BHS-7)	During start-up: • Float placement During study period: • Pump had erroneously been installed with a connection to a GFI breaker (replaced with regular 30-amp breaker)	• Cleaning of septic tank effluent screen Flushing of low pressure distribution pipe	• It appears that the liner is was not large enough to capture the unsaturated plume from the Stage 1 biofilter, and some of the nitrified effluent missed the liner. Also, a better transitional interface between the sand and the lignocellulosic media is needed to direct the effluent into the liner. • However, this system type would provide the simplest operation and maintenance of all the systems tested.

Based on the field results, there were some general recommendations for operation and maintenance. Table D- 3 summarizes the general O&M recommended by the design engineer for these prototype systems.

Table D- 3. General Operation & Maintenance as Recommended by the Design Engineer (Hazen and Sawyer 2015b)

System Component	General Maintenance Action	General Frequency
Primary (septic) tank	Pump-out to remove solids	3-5 years
	Effluent screen cleaning	1-2 times annually
	Water level within the tank	1-2 times annually
Pump tank	Pump-out to remove solids	Same frequency as septic tank
	Water level within the tank	1-2 times annually

Distribution box	Check for debris, equalized flow, pipe placement	1-2 times annually
	Water level within the box	1-2 times annually
Stage 1 biofilter	Check for clogging or ponding (raking if required)	1-2 times annually
	Water level within the biofilter	1-2 times annually
Pump	Check dose volume	1-2 times annually
	Grease, etc. (follow manufacturer's guidelines)	1-2 times annually
Float switches	Check register within control panel	1-2 times annually
Stage 2 biofilter	Reactive media consumption (replenish as needed)	Check Annually
	Water level within the biofilter	1-2 times annually
Soil Treatment Unit (drainfield)	Check for odors, ponding, etc.	1-2 times annually

Appendix E. Life Cycle Cost Assessment Results

The Life Cycle Cost Assessment Tool (LCCA) includes multiple worksheets which are listed in Table E-1. The resulting cost breakdowns are shown on the following pages for these scenarios:

1. Conventional OSTDS
2. Total system including a conventional OSTDS and passive nitrogen removal
3. Low level nitrogen removal option (30%)
4. Medium level in-tank nitrogen removal option (70%)
5. Medium level in-ground nitrogen removal option (70%)
6. High level in-tank nitrogen removal option (95%)
7. High level in-ground nitrogen removal option (95%)
8. Standardized cost for a new system at home site 1 – tank-based PNRS
9. Standardized cost for a retrofit of existing system at home site 1 – tank-based PNRS
10. Standardized cost for a new system at home site 2 – tank-based PNRS
11. Standardized cost for a retrofit of existing system at home site 2 – tank-based PNRS
12. Standardized cost for a new system at home site 3 – tank-based PNRS
13. Standardized cost for a retrofit of existing system at home site 3 – tank-based PNRS
14. Standardized cost for a new system at home site 4 – tank-based PNRS
15. Standardized cost for a retrofit of existing system at home site 4 – tank-based PNRS
16. Standardized cost for a new system at home site 5 – tank-based PNRS
17. Standardized cost for a retrofit of existing system at home site 5 – tank-based PNRS
18. Standardized cost for a new system at home site 6 – in-ground PNRS
19. Standardized cost for a retrofit of existing system at home site 6 – in-ground PNRS
20. Standardized cost for a new system at home site 7 – in-ground PNRS
21. Standardized cost for a retrofit of existing system at home site 7 – in-ground PNRS

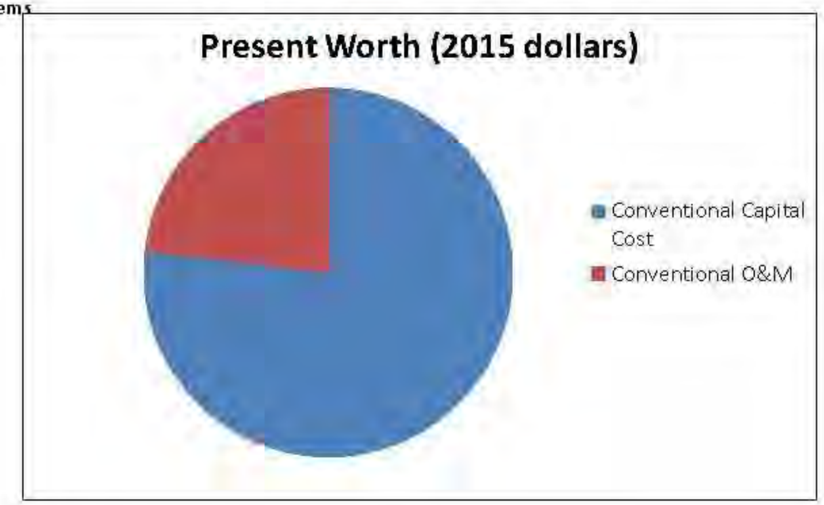
Table E- 1. Worksheets in the Passive Nitrogen Reduction Systems Life Cycle Cost Assessment Tool

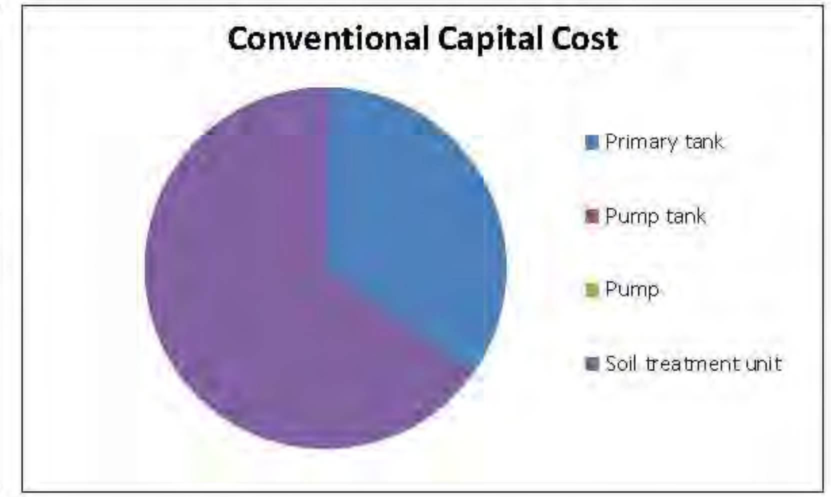
Worksheet	Contents
1. LCCA Structure	Two-Stage PNRS Description * Basic Model Structure * Example PNRS Systems
2. Table of LCCA Worksheets	Summary Table of LCCA Worksheets
3. Wastewater Quantity & System Parameters	Determine Design flowrate * Specify conventional system parameters * Select nitrogen removal level as high, medium, or low @ 95%, 50-70%, or 25-30% * specify PNRS system parameters * specify recurring costs * specify net interest rate
4. PNRS Process Selection	Select specific PNRS system
5. Baseline Design & Cost	Summary of conventional system default design & cost * Summary of PNRS design and default cost
6. Baseline Design Cost Summary	Default cost summary for conventional system, for PNRS system, and for total system
7. User Override Costs	User specified costs for conventional system * User specified costs for PNRS
8. LCCA: Conventional	Characteristics of conventional system * Life Cycle Cost Analysis of conventional system
9. LCCA: Total System	Characteristics of conventional system + PNRS * Life Cycle Cost Analysis of conventional system + PNRS
10. Design Data	Compilation of flow and sizing criteria, unit cost factors for materials, energy, site access, and installation complexity
11. Example LCCAs	Example Life Cycle Costs

Results of Life Cycle Cost Analysis Tool for a Conventional OSTDS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: Stage 1 with recirculation, dual media Stage 2

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Default Design & Cost
6. Default Design Cost Summary
7. User Specified Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





8. LCCA Conventional

Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	2,000
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	existing
Design wastewater flow, gallon/day	300

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	1.500
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	24.016
A/P PL/IR	0.04164
A/F TI	0.19409
P/A PL	20.720
A/F EI	0.09343
P/A EL	17.169
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	30.0
Mass removal/year, lbs.	8.1

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	58.29	26.8
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	109.30	50.2
Subtotal	4,025.00	167.60	76.9
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Primary tank pump out	1,206.44	50.24	23.1
Equipment replacement	0.00	0.00	0.0
Subtotal	1,206.44	50.24	23.1
Total	5,231.44	217.83	100.0

Capital Cost

Installed Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Primary tank	1,400.00	58.29	34.8
Pump tank	0.00	0.00	0.0
Pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	109.30	65.2
Total	4,025.00	167.60	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional Capital Cost	4,025.00	167.60	76.9
Conventional O&M	1,206.44	50.24	23.1
Total	5,231.44	217.83	100.0
$/lb nitrogen removed	21.52	26.88	

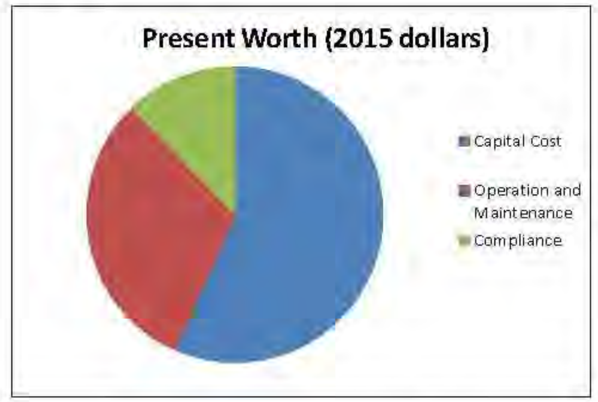
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

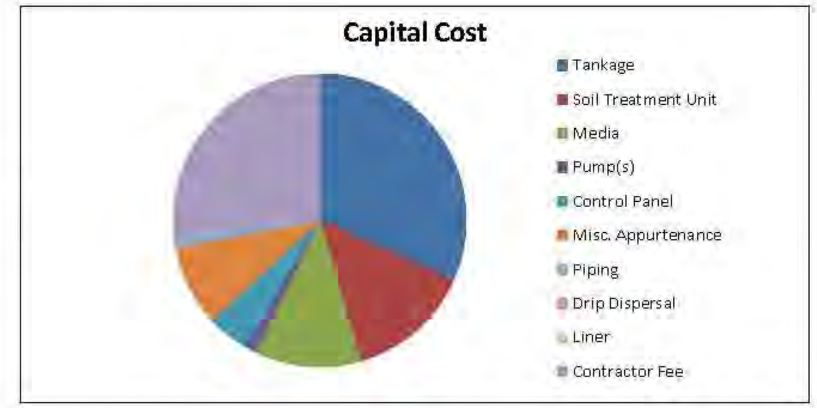
Results of Life Cycle Cost Assessment Tool for a Total System including Conventional OSTDS and Passive Nitrogen Removal

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: Stage 1 with recirculation, dual media Stage 2

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Default Design & Cost
6. Default Design Cost Summary
7. User Specified Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2000
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	existing
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	9
Stage(s)	Stage 1 &2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	1.500
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	24.016
A/P PL/IR	0.04164
A/F TI	0.19409
P/A PL	20.720
A/F MI	0.05994
P/A ML	13.343
A/F EI	0.09343
P/A EL	17.169
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	58.29	4.2
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	109.30	7.8
Subtotal	4,025.00	167.60	12.0
PNRS Installation			
Tankage	4,609.29	191.93	13.8
Media	2,226.78	92.72	6.7
PNRS Pump	250.00	10.41	0.7
Control Panel	875.00	36.43	2.6
Piping	289.60	12.06	0.9
Misc. Appurtenance	1,693.00	70.50	5.1
Stage 1 Drip Dispersal System	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	208.20	14.9
Subtotal	14,943.67	622.24	44.7
Total System Installation	18,968.67	789.84	56.7
Operation and Maintenance			
Annual energy cost	789.46	32.87	2.4
Annual inspection & maintenance	7,204.75	300.00	21.5
Primary tank pump out	1,206.44	50.24	3.6
Stage 2 media replacement	794.01	33.06	2.4
Equipment replacement	401.03	16.70	1.2
Subtotal	10,395.69	432.87	31.1
Compliance			
Permit fee	1,200.79	50.00	3.6
Water quality monitoring	2,881.90	120.00	8.6
Subtotal	4,082.69	170.00	12.2
Total	33,447.06	1,392.71	100.00

Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	6,009.29	250.22	31.7
Soil Treatment Unit	2,625.00	109.30	13.8
Media	2,226.78	92.72	11.7
Pump(s)	250.00	10.41	1.3
Control Panel	875.00	36.43	4.6
Misc. Appurtenance	1,693.00	70.50	8.9
Piping	289.60	12.06	1.5
Drip Dispersal	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	208.20	26.4
Total System	18,968.67	789.84	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Capital Cost	18,968.67	789.84	56.7
Operation and Maintenance	10,395.69	432.87	31.1
Compliance	4,082.69	170.00	12.2
Total	33,447.06	1,392.71	100.0
$/lb nitrogen removed	43.44	54.27	

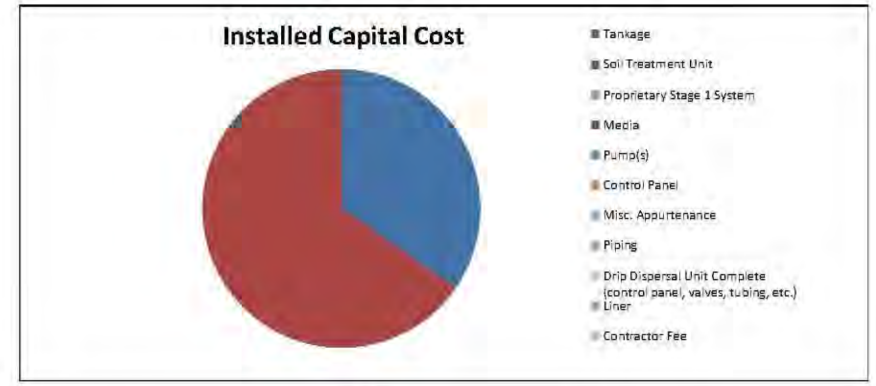
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Assessment for Low Level Nitrogen Removal Option (30%)

PNRS LCCA: Planning Level Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: Low Level

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs



9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	0
Stage 1: PNRS or proprietary	0
PNRS Stage(s)	0
Stage 1 in-tank or in-ground	0
Stage 1 single pass or recirculation	0
Stage 1 media type	0
Ligno disposition	0
Stage 2 media type	0
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	Low

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	0.0
Stage 2 media cost analysis life (ML), years	#DIV/0!
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	#DIV/0!
P/A ML	#DIV/0!
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	30.0
Mass removal/year, lbs.	8.10

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	25.3
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	47.4
Subtotal Conventional	4,025.00	179.72	72.6
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	0.00	0.00	0.0
Media	0.00	0.00	0.0
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	0.00	0.00	0.0
Misc. Appurtenance	0.00	0.00	0.0
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	0.00	0.00	0.0
Subtotal	0.00	0.00	0.0
Total System Installation	4,025.00	179.72	72.6
Engineering Design & Construction Permit			
Construction permit	580.00	25.90	10.5
Engineering design fees	0.00	0.00	0.0
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Annual inspection & maintenance	0.00	0.00	0.0
Primary tank pump out	937.90	41.88	16.9
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	0.00	0.00	0.0
Subtotal	937.90	41.88	16.9
Compliance			
Operating permit fee	0.00	0.00	0.0
Water quality monitoring	0.00	0.00	0.0
Subtotal	0.00	0.00	0.0
Total	5,542.90	247.49	100.00

Installed Capital Cost

Installation / Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	1,400.00	62.51	34.8
Soil Treatment Unit	2,625.00	117.21	65.2
Proprietary Stage 1 System	0.00	0.00	0.0
Media	0.00	0.00	0.0
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	0.00	0.00	0.0
Piping	0.00	0.00	0.0
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	0.00	0.00	0.0
Total System	4,025.00	179.72	100.0

Life Cycle Cost

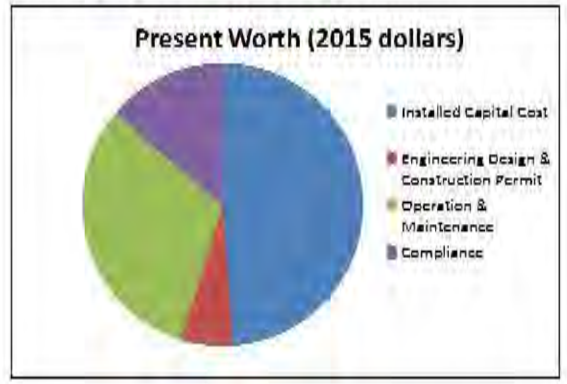
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	4,025.00	179.72	72.6
Engineering Design & Construction Permit	580.00	25.90	10.5
Operation & Maintenance	937.90	41.88	16.9
Compliance	0.00	0.00	0.0
Total	5,542.90	247.49	100.0
$/lb nitrogen removed	22.80	30.54	

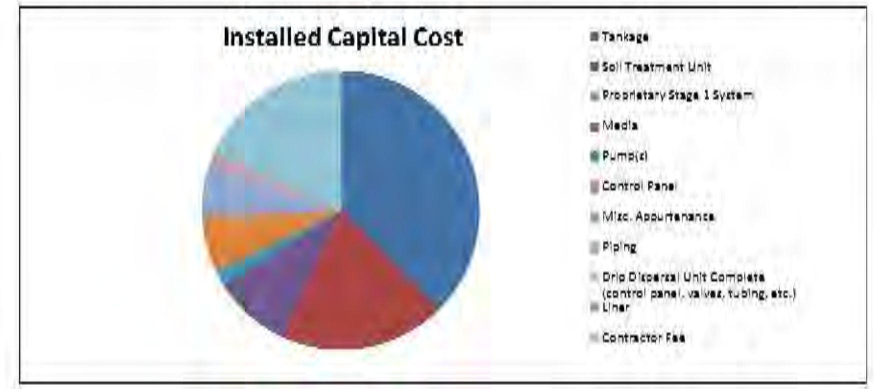
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Assessment for Medium Level In-tank Nitrogen Removal Option (70%)

PNRS LCCA: Planning Level Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: Medium Level In-tank

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	22
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1 only
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	EC
Ligno disposition	None
Stage 2 media type	None
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	Medium

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	70.0
Mass removal/year, lbs.	18.91

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	5.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	9.4
Subtotal Conventional	4,025.00	179.72	14.5
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	3,728.69	166.49	13.4
Media	1,234.09	55.10	4.4
PNRS Pump	250.00	11.16	0.9
Control Panel	875.00	39.07	3.1
Piping	144.80	6.47	0.5
Misc. Appurtenance	846.50	37.80	3.0
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	9.0
Subtotal	9,579.07	427.70	34.4
Total System Installation	13,604.07	607.42	48.9
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.4
Engineering design fees	1,000.00	44.65	3.6
Operation and Maintenance			
Annual energy cost	736.23	32.87	2.6
Annual inspection & maintenance	6,718.94	300.00	24.1
Primary tank pump out	937.90	41.88	3.4
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	373.33	16.67	1.3
Subtotal	8,766.39	391.42	31.5
Compliance			
Operating permit fee	1,119.82	50.00	4.0
Water quality monitoring	2,687.57	120.00	9.7
Subtotal	3,807.40	170.00	13.7
Total	27,837.86	1,242.96	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	5,128.69	229.00	37.7
Soil Treatment Unit	2,625.00	117.21	19.3
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,234.09	55.10	9.1
Pump(s)	250.00	11.16	1.8
Control Panel	875.00	39.07	6.4
Misc. Appurtenance	846.50	37.80	6.2
Piping	144.80	6.47	1.1
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	18.4
Total System	13,604.07	607.42	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	13,604.07	607.42	48.9
Engineering Design & Construction Permit	1,660.00	74.12	6.0
Operation & Maintenance	8,766.39	391.42	31.5
Compliance	3,807.40	170.00	13.7
Total	27,837.86	1,242.96	100.0
$/lb nitrogen removed	49.07	65.73	

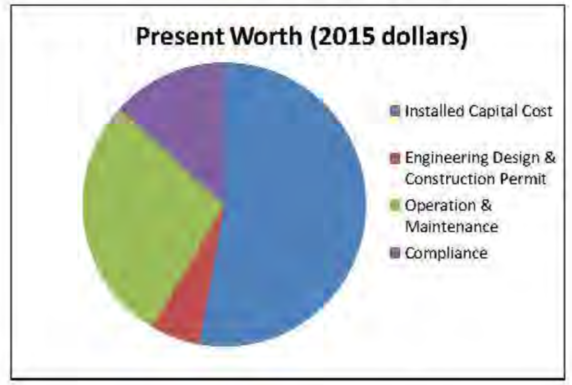
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

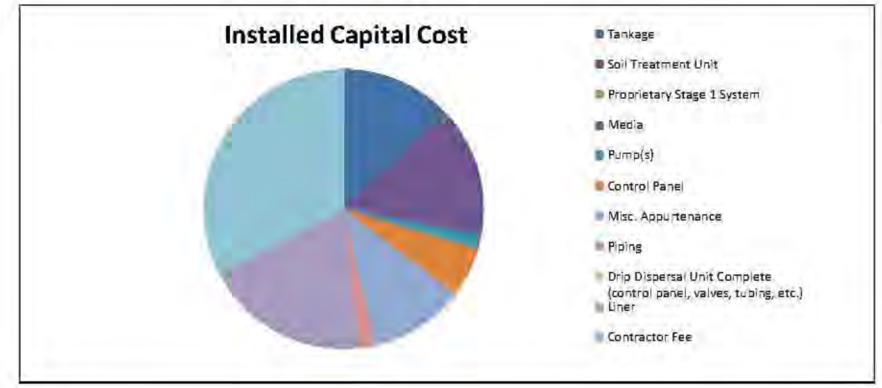
Results of Life Cycle Cost Assessment for Medium Level In-ground Nitrogen Removal Option (70%)

PNRS LCCA: Planning Level Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: Medium Level In-ground

Worksheet

1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	17
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	In-ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in-ground liner
Stage 2 media type	Ligno only
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	Medium

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	30.0
Stage 2 media cost analysis life (ML), years	0.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.02465
P/A ML	0.000
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	70.0
Mass removal/year, lbs.	18.91

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.8
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	1,400.00	62.51	4.8
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	600.00	26.79	2.1
Media	2,301.25	102.75	7.9
PNRS Pump	250.00	11.16	0.9
Control Panel	875.00	39.07	3.0
Piping	289.60	12.93	1.0
Misc. Appurtenance	1,693.00	75.59	5.8
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	10.1
Contractor Fee	5,000.00	223.25	17.2
Subtotal	13,933.85	622.15	48.0
Total System Installation	15,333.85	684.66	52.8
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.3
Engineering design fees	1,000.00	44.65	3.4
Operation and Maintenance			
Annual energy cost	184.06	8.22	0.6
Annual inspection & maintenance	6,718.94	300.00	23.2
Primary tank pump out	937.90	41.88	3.2
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	373.33	16.67	1.3
Subtotal	8,214.22	366.76	28.3
Compliance			
Operating permit fee	1,119.82	50.00	3.9
Water quality monitoring	2,687.57	120.00	9.3
Subtotal	3,807.40	170.00	13.1
Total	29,015.47	1,295.54	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	2,000.00	89.30	13.0
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,301.25	102.75	15.0
Pump(s)	250.00	11.16	1.6
Control Panel	875.00	39.07	5.7
Misc. Appurtenance	1,693.00	75.59	11.0
Piping	289.60	12.93	1.9
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	19.1
Contractor Fee	5,000.00	223.25	32.6
Total System	15,333.85	684.66	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	15,333.85	684.66	52.8
Engineering Design & Construction Permit	1,660.00	74.12	5.7
Operation & Maintenance	8,214.22	366.76	28.3
Compliance	3,807.40	170.00	13.1
Total	29,015.47	1,295.54	100.0
$/lb nitrogen removed	51.15	68.51	

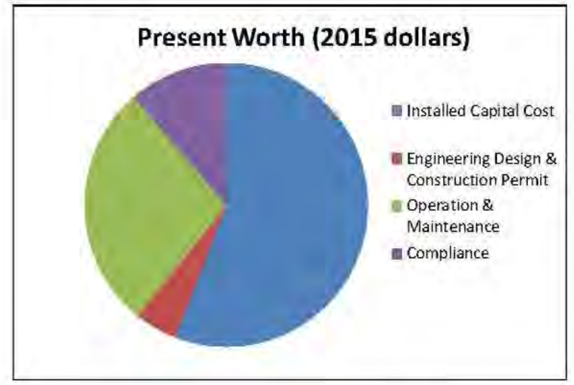
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

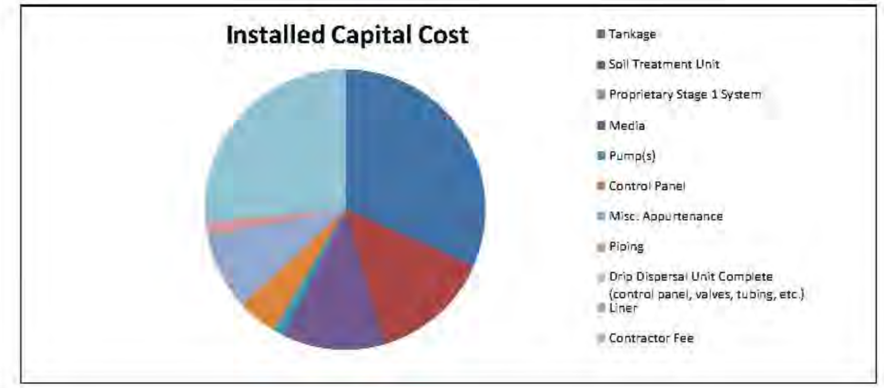
Results of Life Cycle Cost Assessment for High Level In-tank Nitrogen Removal Option (95%)

PNRS LCCA: Planning Level Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: High Level In-tank

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.1
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	7.7
Subtotal Conventional	4,025.00	179.72	11.9
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	4,609.29	205.80	13.6
Media	2,226.78	99.43	6.6
PNRS Pump	250.00	11.16	0.7
Control Panel	875.00	39.07	2.6
Piping	289.60	12.93	0.9
Misc. Appurtenance	1,693.00	75.59	5.0
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	14.7
Subtotal	14,943.67	667.23	44.0
Total System Installation	18,968.67	846.95	55.9
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	1.9
Engineering design fees	1,000.00	44.65	2.9
Operation and Maintenance			
Annual energy cost	736.23	32.87	2.2
Annual inspection & maintenance	6,718.94	300.00	19.8
Primary tank pump out	937.90	41.88	2.8
Stage 2 media replacement	737.58	32.93	2.2
Equipment replacement	373.33	16.67	1.1
Subtotal	9,503.98	424.35	28.0
Compliance			
Operating permit fee	1,119.82	50.00	3.3
Water quality monitoring	2,687.57	120.00	7.9
Subtotal	3,807.40	170.00	11.2
Total	33,940.05	1,515.42	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	6,009.29	268.31	31.7
Soil Treatment Unit	2,625.00	117.21	13.8
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,226.78	99.43	11.7
Pump(s)	250.00	11.16	1.3
Control Panel	875.00	39.07	4.6
Misc. Appurtenance	1,693.00	75.59	8.9
Piping	289.60	12.93	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	26.4
Total System	18,968.67	846.95	100.0

Life Cycle Cost

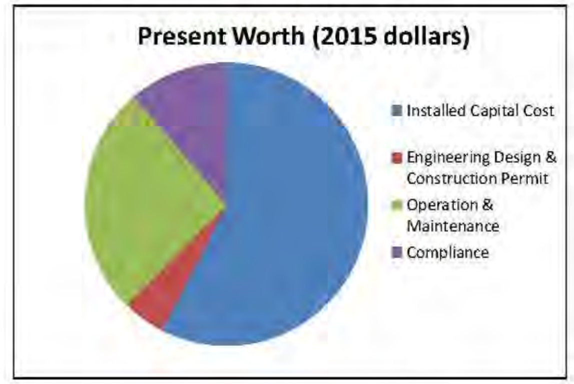
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	18,968.67	846.95	55.9
Engineering Design & Construction Permit	1,660.00	74.12	4.9
Operation & Maintenance	9,503.98	424.35	28.0
Compliance	3,807.40	170.00	11.2
Total	33,940.05	1,515.42	100.0
$/lb nitrogen removed	44.09	59.05	

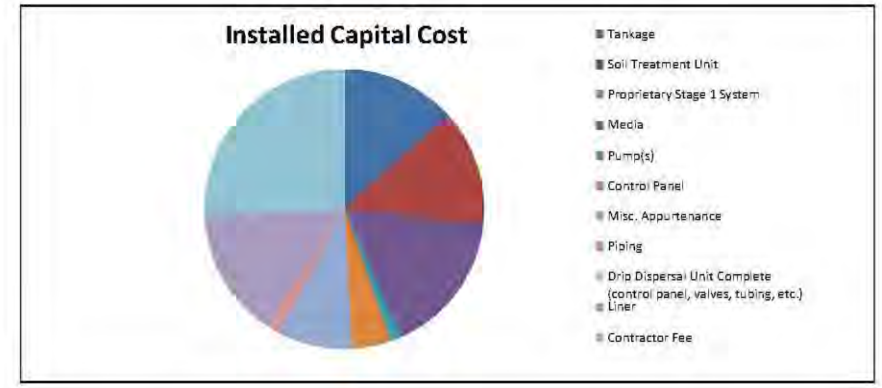
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Assessment for High Level In-ground Nitrogen Removal Option (95%)

PNRS LCCA: Planning Level Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: High Level In-ground

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	2200
Depth to seasonal high water table (inches)	42
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

PNRS System Summary

PNRS System	18
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in-tank or in-ground	In-ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in-ground liner
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.1
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	7.8
Subtotal Conventional	4,025.00	179.72	11.9
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	1,200.00	53.58	3.5
Media	3,219.84	143.77	9.5
PNRS Pump	250.00	11.16	0.7
Control Panel	875.00	39.07	2.6
Piping	289.60	12.93	0.9
Misc. Appurtenance	1,693.00	75.59	5.0
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	8.6
Contractor Fee	5,000.00	223.25	14.8
Subtotal	15,452.44	689.95	45.7
Total System Installation	19,477.44	869.67	57.6
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.0
Engineering design fees	1,000.00	44.65	3.0
Operation and Maintenance			
Annual energy cost	184.06	8.22	0.5
Annual inspection & maintenance	6,718.94	300.00	19.9
Primary tank pump out	937.90	41.88	2.8
Stage 2 media replacement	682.53	30.47	2.0
Equipment replacement	373.33	16.67	1.1
Subtotal	8,896.75	397.24	26.3
Compliance			
Operating permit fee	1,119.82	50.00	3.3
Water quality monitoring	2,687.57	120.00	7.9
Subtotal	3,807.40	170.00	11.3
Total	33,841.59	1,511.02	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	2,600.00	116.09	13.3
Soil Treatment Unit	2,625.00	117.21	13.5
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,219.84	143.77	16.5
Pump(s)	250.00	11.16	1.3
Control Panel	875.00	39.07	4.5
Misc. Appurtenance	1,693.00	75.59	8.7
Piping	289.60	12.93	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	15.0
Contractor Fee	5,000.00	223.25	25.7
Total System	19,477.44	869.67	100.0

Life Cycle Cost

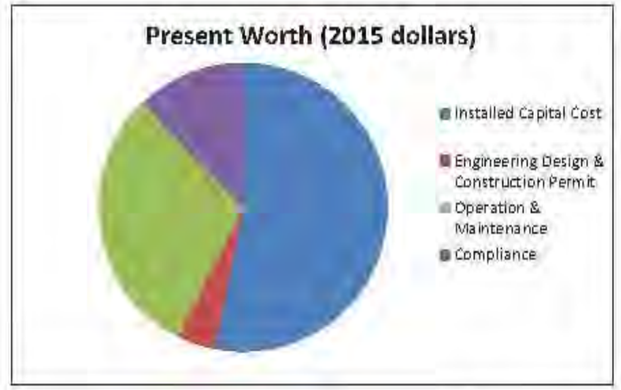
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	19,477.44	869.67	57.6
Engineering Design & Construction Permit	1,660.00	74.12	4.9
Operation & Maintenance	8,896.75	397.24	26.3
Compliance	3,807.40	170.00	11.3
Total	33,841.59	1,511.02	100.0
$/lb nitrogen removed	43.96	58.88	

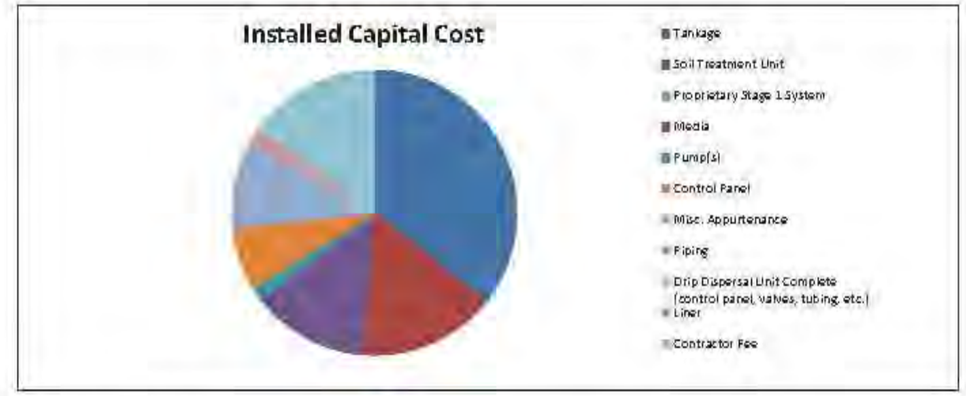
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 1 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-5

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	35.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.4
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	8.3
Subtotal Conventional	4,025.00	179.72	12.8
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	4,609.29	205.80	14.6
Media	2,226.78	99.43	7.1
PNRS Pump	250.00	11.16	0.8
Control Panel	1,200.00	53.58	3.8
Piping	289.60	12.93	0.9
Misc. Appurtenance	1,693.00	75.59	5.4
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	7.9
Subtotal	12,768.67	570.12	40.5
Total System Installation	16,793.67	749.84	53.2
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.2
Engineering design fees	1,000.00	44.65	3.2
Operation and Maintenance			
Annual energy cost	809.85	36.16	2.6
Annual inspection & maintenance	6,718.94	300.00	21.3
Primary tank pump out	937.90	41.88	3.0
Stage 2 media replacement	737.58	32.93	2.3
Equipment replacement	373.33	16.67	1.2
Subtotal	9,577.60	427.64	30.4
Compliance			
Operating permit fee	1,119.82	50.00	3.5
Water quality monitoring	2,687.57	120.00	8.5
Subtotal	3,807.40	170.00	12.1
Total	31,553.67	1,408.87	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	6,009.29	268.31	35.8
Soil Treatment Unit	2,625.00	117.21	15.6
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,226.78	99.43	13.3
Pump(s)	250.00	11.16	1.5
Control Panel	1,200.00	53.58	7.1
Misc. Appurtenance	1,693.00	75.59	10.1
Piping	289.60	12.93	1.7
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	14.9
Total System	16,793.67	749.84	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	16,793.67	749.84	53.2
Engineering Design & Construction Permit	1,375.00	61.39	4.4
Operation & Maintenance	9,577.60	427.64	30.4
Compliance	3,807.40	170.00	12.1
Total	31,553.67	1,408.87	100.0
$/lb nitrogen removed	40.99	54.90	

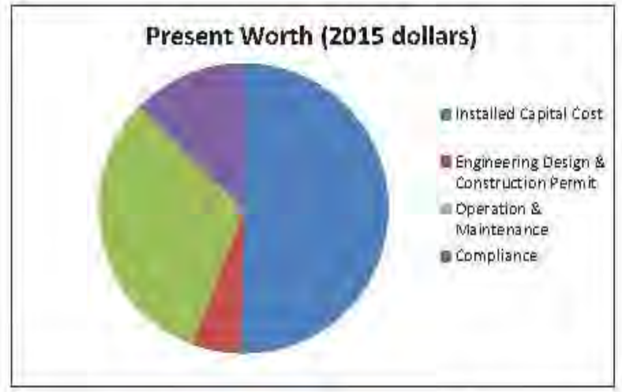
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

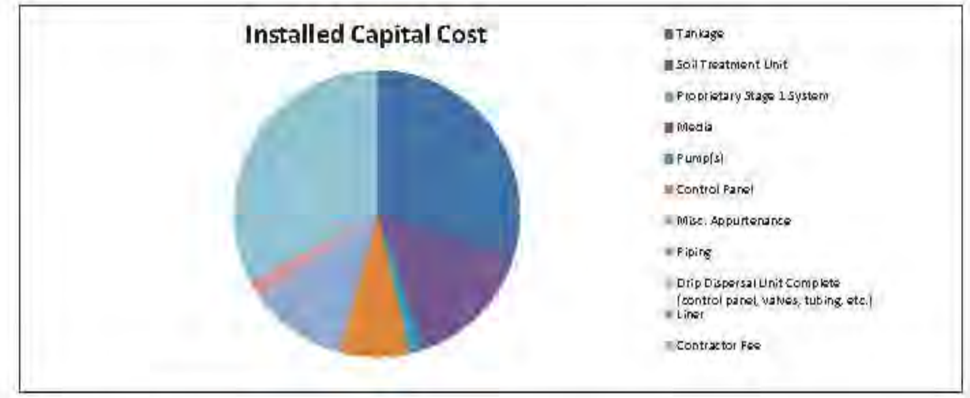
Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 1 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-5

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
F/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
F/A PL	19.523
A/F MI	0.05783
F/A ML	12.849
A/F EI	0.09133
F/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	4,809.29	205.80	15.2
Media	2,226.78	99.43	7.3
PNRS Pump	250.00	11.16	0.8
Control Panel	1,200.00	53.58	4.0
Piping	289.60	12.93	1.0
Misc. Appurtenance	1,693.00	75.59	5.6
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	16.5
Subtotal	15,268.67	681.75	50.4
Total System Installation	15,268.67	681.75	50.4
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.2
Engineering design fees	1,000.00	44.65	3.3
Operation and Maintenance			
Annual energy cost	809.85	36.16	2.7
Annual inspection & maintenance	6,718.94	300.00	22.2
Primary tank pump out	937.90	41.88	3.1
Stage 2 media replacement	737.58	32.93	2.4
Equipment replacement	373.33	16.67	1.2
Subtotal	9,577.60	427.64	31.6
Compliance			
Operating permit fee	1,119.81	50.00	3.7
Water quality monitoring	2,687.57	120.00	8.9
Subtotal	3,807.40	170.00	12.6
Total	30,313.67	1,353.50	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	4,809.29	205.80	30.2
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,226.78	99.43	14.6
Pump(s)	250.00	11.16	1.6
Control Panel	1,200.00	53.58	7.9
Misc. Appurtenance	1,693.00	75.59	11.1
Piping	289.60	12.93	1.9
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	32.7
Total System	15,268.67	681.75	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	15,268.67	681.75	50.4
Engineering Design & Construction Permit	1,660.00	74.12	5.5
Operation & Maintenance	9,577.60	427.64	31.6
Compliance	3,807.40	170.00	12.6
Total	30,313.67	1,353.50	100.0
$/lb nitrogen removed	39.37	52.74	

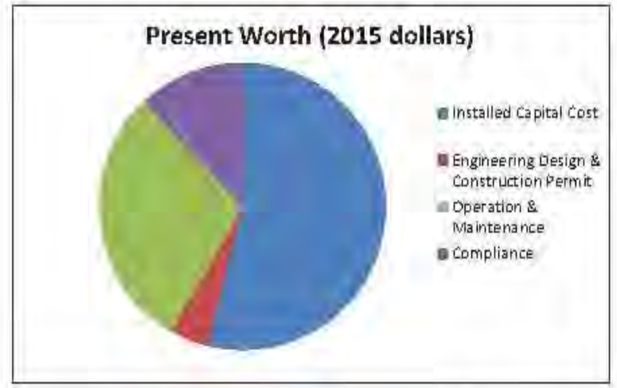
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

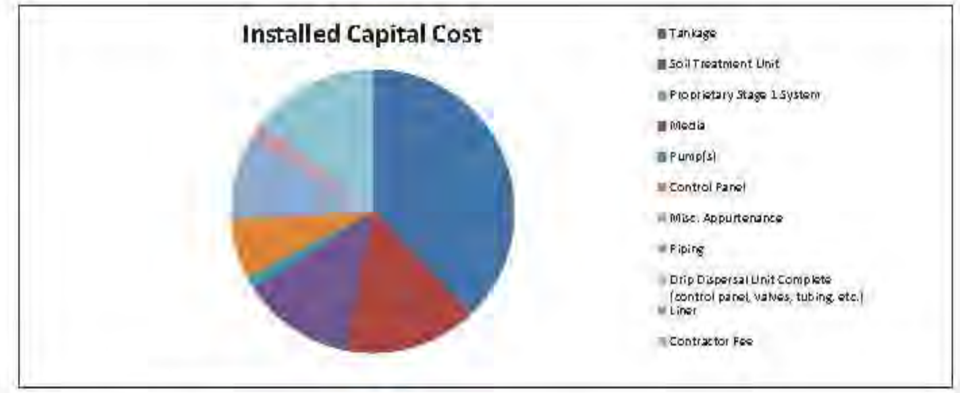
Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 2 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-2

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary

PNRS System	9
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	35.0
Mass removal/year, lbs.	15.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.4
Pump tank	600.00	26.79	1.9
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	8.2
Subtotal Conventional	4,625.00	206.51	14.4
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	4,609.29	205.80	14.3
Media	2,226.78	99.43	6.9
PNRS Pump	250.00	11.16	0.8
Control Panel	1,200.00	53.58	3.7
Piping	289.60	12.93	0.9
Misc. Appurtenance	1,693.00	75.59	5.3
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	7.8
Subtotal	12,768.67	570.12	39.7
Total System Installation	17,393.67	776.63	54.1
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.2
Engineering design fees	1,000.00	44.65	3.1
Operation and Maintenance			
Annual energy cost	809.85	36.16	2.5
Annual inspection & maintenance	6,718.94	300.00	20.9
Primary tank pump out	937.90	41.88	2.9
Stage 2 media replacement	737.58	32.93	2.3
Equipment replacement	373.33	16.67	1.2
Subtotal	9,577.60	427.64	29.8
Compliance			
Operating permit fee	1,119.81	50.00	3.5
Water quality monitoring	2,687.57	120.00	8.4
Subtotal	3,807.40	170.00	11.8
Total	32,153.67	1,435.66	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	6,609.29	295.10	38.0
Soil Treatment Unit	2,625.00	117.21	15.1
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,226.78	99.43	12.8
Pump(s)	250.00	11.16	1.4
Control Panel	1,200.00	53.58	6.9
Misc. Appurtenance	1,693.00	75.59	9.7
Piping	289.60	12.93	1.7
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	14.4
Total System	17,393.67	776.63	100.0

Life Cycle Cost

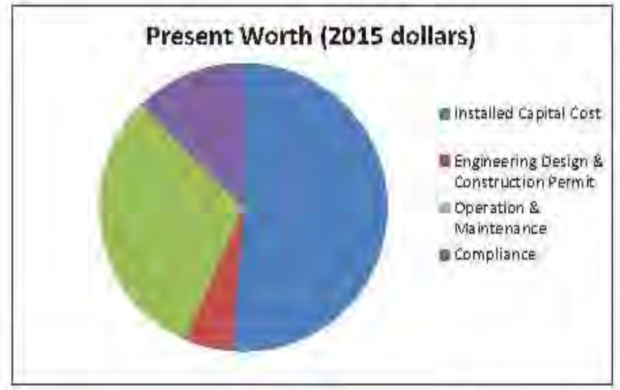
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	17,393.67	776.63	54.1
Engineering Design & Construction Permit	1,375.00	61.39	4.3
Operation & Maintenance	9,577.60	427.64	29.8
Compliance	3,807.40	170.00	11.8
Total	32,153.67	1,435.66	100.0
$/lb nitrogen removed	41.76	55.94	

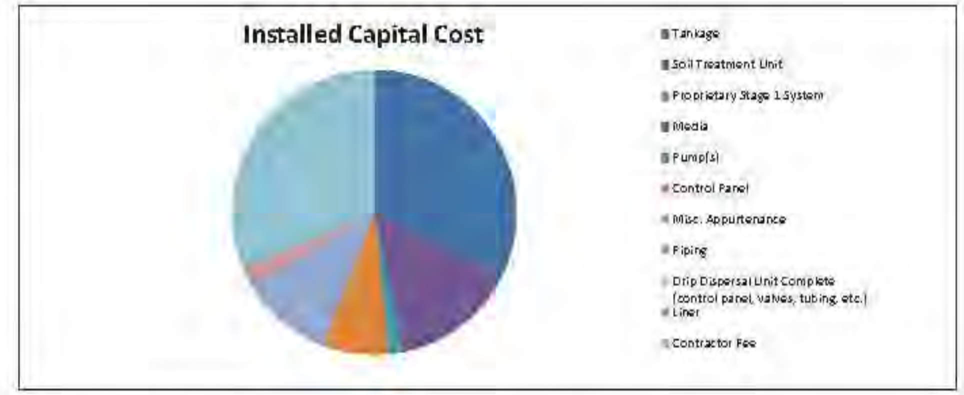
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 2 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-2

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary

PNRS System	8
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Recirculation
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	600.00	26.79	1.9
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	600.00	26.79	1.9
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	4,609.29	205.80	14.9
Media	2,226.78	99.43	7.2
PNRS Pump	250.00	11.16	0.8
Control Panel	1,200.00	53.58	3.9
Piping	289.60	12.93	0.9
Misc. Appurtenance	1,693.00	75.59	5.5
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	16.2
Subtotal	15,268.67	681.75	49.4
Total System Installation	15,868.67	708.54	51.3
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.1
Engineering design fees	1,000.00	44.65	3.2
Operation and Maintenance			
Annual energy cost	809.85	36.16	2.6
Annual inspection & maintenance	6,718.94	300.00	21.7
Primary tank pump out	937.90	41.88	3.0
Stage 2 media replacement	737.58	32.93	2.4
Equipment replacement	373.33	16.67	1.2
Subtotal	9,577.60	427.64	31.0
Compliance			
Operating permit fee	1,119.81	50.00	3.6
Water quality monitoring	2,687.57	120.00	8.7
Subtotal	3,807.40	170.00	12.3
Total	30,913.67	1,380.29	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	5,209.29	232.59	32.8
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	2,226.78	99.43	14.0
Pump(s)	250.00	11.16	1.6
Control Panel	1,200.00	53.58	7.6
Misc. Appurtenance	1,693.00	75.59	10.7
Piping	289.60	12.93	1.8
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	31.5
Total System	15,868.67	708.54	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	15,868.67	708.54	51.3
Engineering Design & Construction Permit	1,660.00	74.12	5.4
Operation & Maintenance	9,577.60	427.64	31.0
Compliance	3,807.40	170.00	12.3
Total	30,913.67	1,380.29	100.0
$/lb nitrogen removed	40.15	53.79	

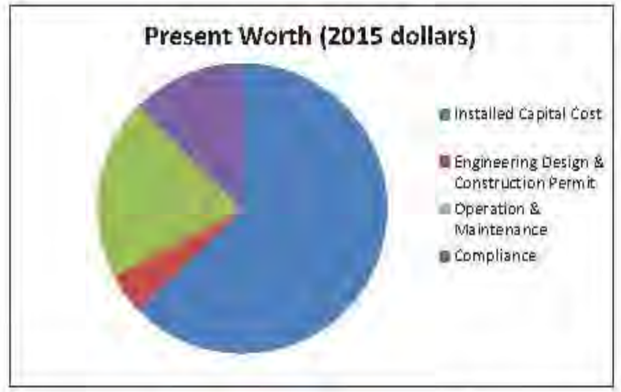
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

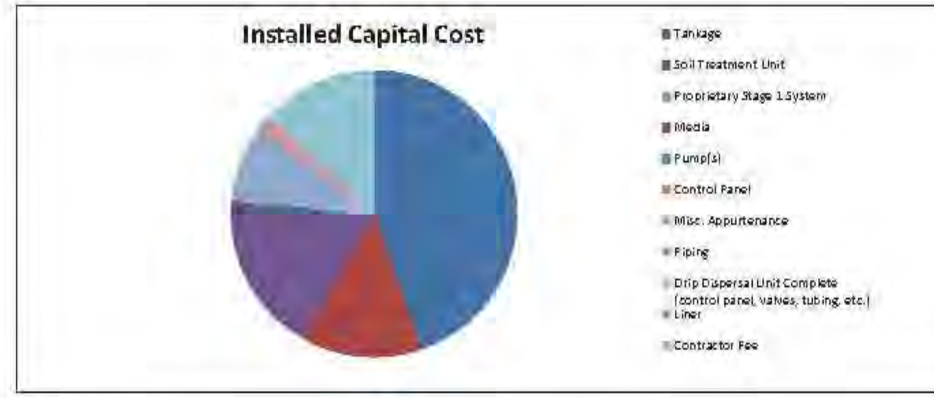
Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 3 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-4

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System





Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	3
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	4.6
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	8.6
Subtotal Conventional	4,025.00	179.72	13.2
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	7,137.97	318.71	23.4
Media	3,460.88	154.53	11.4
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.0
Misc. Appurtenance	1,693.00	75.59	5.6
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	8.2
Subtotal	15,081.45	673.39	49.5
Total System Installation	19,106.45	853.10	62.8
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.2
Engineering design fees	1,000.00	44.65	3.3
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Annual inspection & maintenance	4,479.29	200.00	14.7
Primary tank pump out	937.90	41.88	3.1
Stage 2 media replacement	737.58	32.93	2.4
Equipment replacement	0.00	0.00	0.0
Subtotal	6,154.77	274.81	20.2
Compliance			
Operating permit fee	1,119.81	50.00	3.7
Water quality monitoring	2,687.57	120.00	8.8
Subtotal	3,807.40	170.00	12.5
Total	30,443.62	1,359.31	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	8,537.97	381.22	44.7
Soil Treatment Unit	2,625.00	117.21	13.7
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,460.88	154.53	18.1
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	8.9
Piping	289.60	12.93	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	13.1
Total System	19,106.45	853.10	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	19,106.45	853.10	62.8
Engineering Design & Construction Permit	1,375.00	61.39	4.5
Operation & Maintenance	6,154.77	274.81	20.2
Compliance	3,807.40	170.00	12.5
Total	30,443.62	1,359.31	100.0
$/lb nitrogen removed	39.54	52.97	

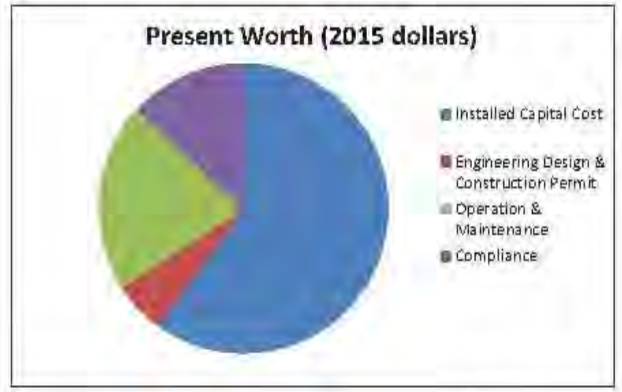
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

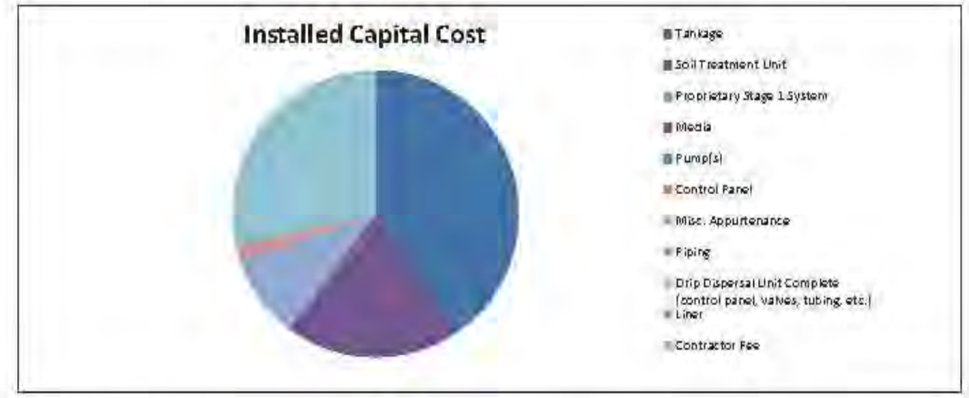
Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 3 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-4

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. **LCCA Total System**





Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary	
PNRS System	3
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	7,137.97	318.71	24.4
Media	3,460.88	154.53	11.9
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.0
Misc. Appurtenance	1,693.00	75.59	5.8
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	17.1
Subtotal	17,581.45	785.01	60.2
Total System Installation	17,581.45	785.01	60.2
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.3
Engineering design fees	1,000.00	44.65	3.4
Operation and Maintenance			
Annual energy cost	0.00	0.00	0.0
Annual inspection & maintenance	4,479.29	200.00	15.3
Primary tank pump out	937.90	41.88	3.2
Stage 2 media replacement	737.58	32.93	2.5
Equipment replacement	0.00	0.00	0.0
Subtotal	6,154.77	274.81	21.1
Compliance			
Operating permit fee	1,119.81	50.00	3.8
Water quality monitoring	2,687.57	120.00	9.2
Subtotal	3,807.40	170.00	13.0
Total	29,203.62	1,303.94	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	7,137.97	318.71	40.6
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,460.88	154.53	19.7
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	9.6
Piping	289.60	12.93	1.6
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	28.4
Total System	17,581.45	785.01	100.0

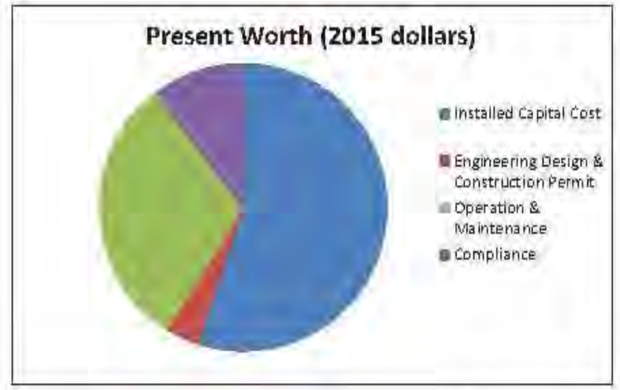
Life Cycle Cost

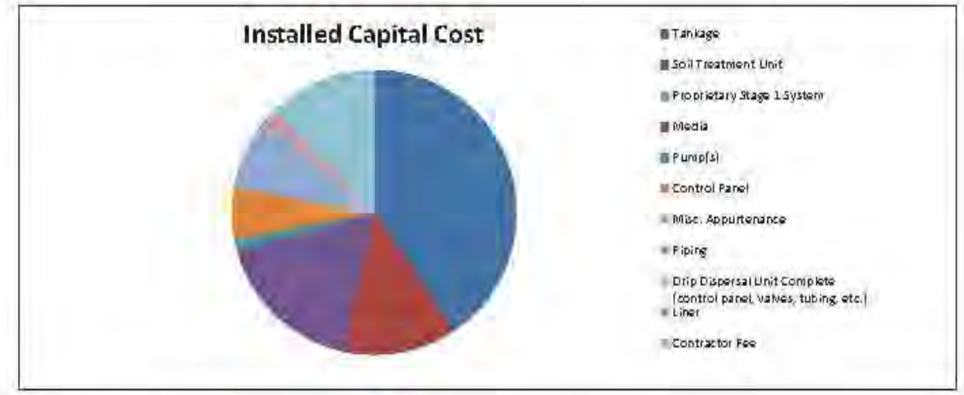
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	17,581.45	785.01	60.2
Engineering Design & Construction Permit	1,660.00	74.12	5.7
Operation & Maintenance	6,154.77	274.81	21.1
Compliance	3,807.40	170.00	13.0
Total	29,203.61	1,303.94	100.0
$/lb nitrogen removed	37.98	50.81	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 4 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-6





Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs

9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	13
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Underlying Stage 1 in Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	3.8
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	7.1
Subtotal Conventional	4,025.00	179.72	10.9
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	6,857.36	306.18	18.6
Media	3,503.02	156.41	9.5
PNRS Pump	250.00	11.16	0.7
Control Panel	1,200.00	53.58	3.3
Piping	289.60	12.93	0.8
Misc. Appurtenance	1,693.00	75.59	4.6
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	6.8
Subtotal	16,292.98	727.48	44.3
Total System Installation	20,317.98	907.20	55.2
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.0
Engineering design fees	1,000.00	44.65	2.7
Operation and Maintenance			
Annual energy cost	202.46	9.04	0.5
Annual inspection & maintenance	6,718.94	300.00	18.2
Primary tank pump out	937.90	41.88	2.5
Stage 2 media replacement	3,084.91	137.74	8.4
Equipment replacement	373.33	16.67	1.0
Subtotal	11,317.54	505.33	30.7
Compliance			
Operating permit fee	1,119.83	50.00	3.0
Water quality monitoring	2,687.57	120.00	7.3
Subtotal	3,807.40	170.00	10.3
Total	36,817.92	1,643.92	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	8,257.36	368.69	40.6
Soil Treatment Unit	2,625.00	117.21	12.9
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,503.02	156.41	17.2
Pump(s)	250.00	11.16	1.2
Control Panel	1,200.00	53.58	5.9
Misc. Appurtenance	1,693.00	75.59	8.3
Piping	289.60	12.93	1.4
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	12.3
Total System	20,317.98	907.20	100.0

Life Cycle Cost

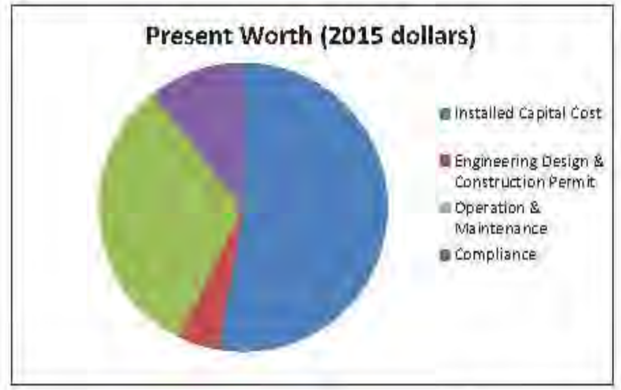
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	20,317.98	907.20	55.2
Engineering Design & Construction Permit	1,375.00	61.39	3.7
Operation & Maintenance	11,317.54	505.33	30.7
Compliance	3,807.40	170.00	10.3
Total	36,817.92	1,643.92	100.0
$/lb nitrogen removed	47.82	64.06	

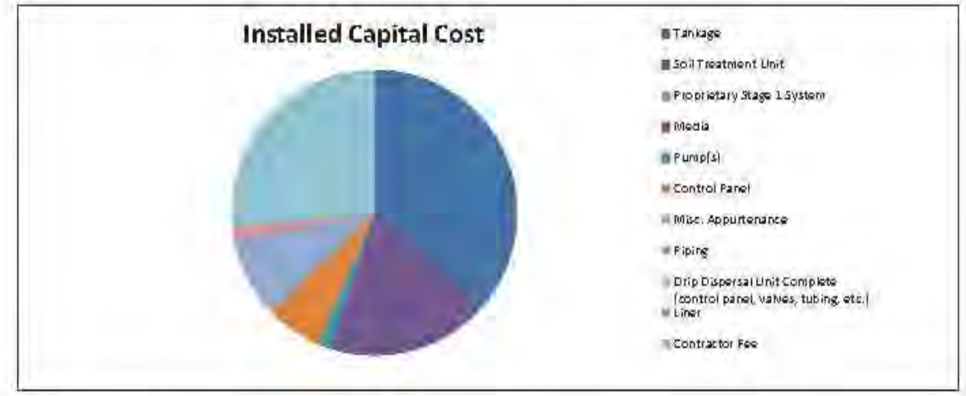
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 4 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-6

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary	
PNRS System	13
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	Tank
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Expanded Clay
Ligno disposition	Underlying Stage 1 in Tank
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	6,857.36	306.18	19.3
Media	3,503.02	156.41	9.8
PNRS Pump	250.00	11.16	0.7
Control Panel	1,200.00	53.58	3.4
Piping	289.60	12.93	0.8
Misc. Appurtenance	1,693.00	75.59	4.8
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	14.1
Subtotal	18,792.98	839.11	52.8
Total System Installation	18,792.98	839.11	52.8
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	1.9
Engineering design fees	1,000.00	44.65	2.8
Operation and Maintenance			
Annual energy cost	202.46	9.04	0.6
Annual inspection & maintenance	6,718.94	300.00	18.9
Primary tank pump out	937.90	41.88	2.6
Stage 2 media replacement	3,084.91	137.74	8.7
Equipment replacement	373.33	16.67	1.0
Subtotal	11,317.54	505.33	31.8
Compliance			
Operating permit fee	1,119.82	50.00	3.1
Water quality monitoring	2,687.57	120.00	7.6
Subtotal	3,807.40	170.00	10.7
Total	35,577.92	1,588.55	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	6,857.36	306.18	36.5
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	3,503.02	156.41	18.6
Pump(s)	250.00	11.16	1.3
Control Panel	1,200.00	53.58	6.4
Misc. Appurtenance	1,693.00	75.59	9.0
Piping	289.60	12.93	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	5,000.00	223.25	26.6
Total System	18,792.98	839.11	100.0

Life Cycle Cost

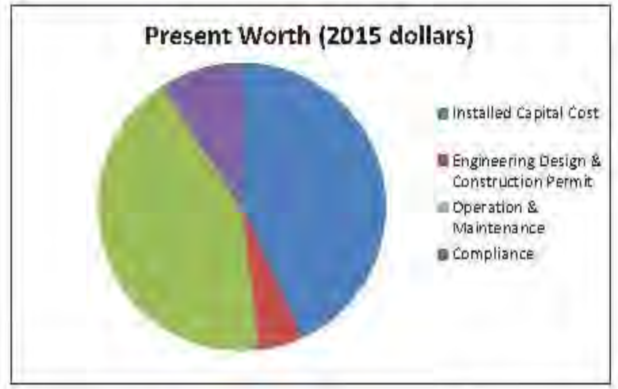
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	18,792.98	839.11	52.8
Engineering Design & Construction Permit	1,660.00	74.12	4.7
Operation & Maintenance	11,317.54	505.33	31.8
Compliance	3,807.40	170.00	10.7
Total	35,577.92	1,588.55	100.0
$/lb nitrogen removed	46.21	61.90	

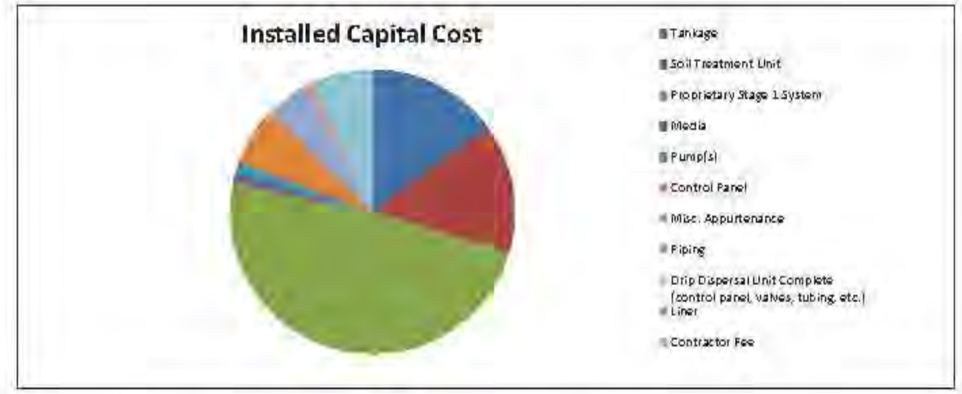
Developed by: Hazen and Sawyer Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 5 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-1

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary

PNRS System	2E
Stage 1: PNRS or proprietary	proprietary
PNRS Stage(s)	Stage 2 only
Stage 1 in tank or in ground	0
Stage 1 single pass or recirculation	0
Stage 1 media type	0
Ligno disposition	Tank
Stage 2 media type	Ligno only
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pump out analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	3.4
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	6.3
Subtotal Conventional	4,025.00	179.72	9.7
Proprietary Stage 1 system	8,700.00	388.45	21.0
PNRS Installation			
Tankage	1,300.00	58.04	3.1
Media	182.54	8.15	0.4
PNRS Pump	250.00	11.16	0.6
Control Panel	1,200.00	53.58	2.9
Piping	144.80	6.47	0.3
Misc. Appurtenance	846.50	37.80	2.0
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	1,250.00	55.81	3.0
Subtotal	5,173.84	231.01	12.5
Total System Installation	17,898.84	799.18	43.2
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	0.9
Engineering design fees	1,700.00	75.90	4.1
Operation and Maintenance			
Annual energy cost	8,367.39	373.60	20.2
Annual inspection & maintenance	7,838.76	350.00	18.9
Primary tank pump out	937.90	41.88	2.3
Stage 2 media replacement	135.63	6.06	0.3
Equipment replacement	373.33	16.67	0.9
Subtotal	17,653.01	788.21	42.6
Compliance			
Operating permit fee	1,119.81	50.00	2.7
Water quality monitoring	2,687.57	120.00	6.5
Subtotal	3,807.40	170.00	9.2
Total	41,434.24	1,850.04	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	2,700.00	120.55	15.1
Soil Treatment Unit	2,625.00	117.21	14.7
Proprietary Stage 1 System	8,700.00	388.45	48.6
Media	182.54	8.15	1.0
Pump(s)	250.00	11.16	1.4
Control Panel	1,200.00	53.58	6.7
Misc. Appurtenance	846.50	37.80	4.7
Piping	144.80	6.47	0.8
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	1,250.00	55.81	7.0
Total System	17,898.84	799.18	100.0

Life Cycle Cost

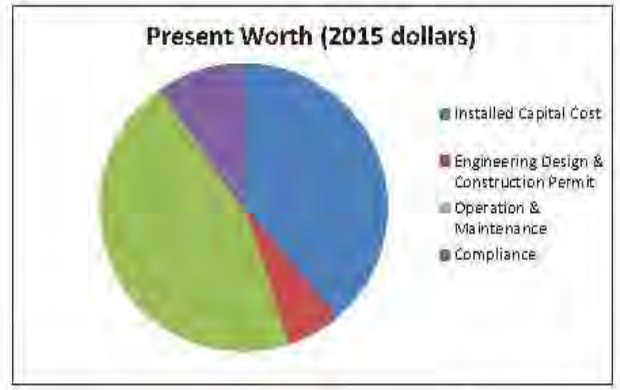
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	17,898.84	799.18	43.2
Engineering Design & Construction Permit	2,075.00	92.65	5.0
Operation & Maintenance	17,653.01	788.21	42.6
Compliance	3,807.40	170.00	9.2
Total	41,434.24	1,850.04	100.0
$/lb nitrogen removed	53.82	72.09	

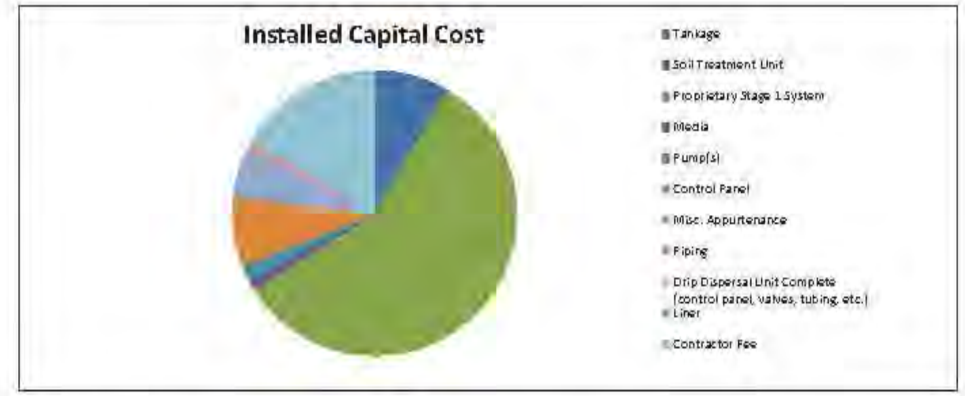
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 5 - Tank-based PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-1

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

No user override Conventional costs have been specified

PNRS System Summary	
PNRS System	2E
Stage 1: PNRS or proprietary	proprietary
PNRS Stage(s)	Stage 2 only
Stage 1 in tank or in ground	0
Stage 1 single pass or recirculation	0
Stage 1 media type	0
Ligno disposition	Tank
Stage 2 media type	Ligno only
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	35.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	0.00	0.00	0.0
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	0.00	0.00	0.0
Proprietary Stage 1 system	8,700.00	388.45	22.3
PNRS Installation			
Tankage	1,300.00	58.04	3.3
Media	182.54	8.15	0.5
PNRS Pump	250.00	11.16	0.6
Control Panel	1,200.00	53.58	3.1
Piping	144.80	6.47	0.4
Misc. Appurtenance	846.50	37.80	2.2
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	6.4
Subtotal	6,423.84	286.81	16.5
Total System Installation	15,123.84	675.28	38.8
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	1.7
Engineering design fees	1,700.00	75.90	4.4
Operation and Maintenance			
Annual energy cost	8,367.39	373.60	21.5
Annual inspection & maintenance	7,838.76	350.00	20.1
Primary tank pump out	937.90	41.88	2.4
Stage 2 media replacement	135.63	6.06	0.3
Equipment replacement	373.33	16.67	1.0
Subtotal	17,653.01	788.21	45.3
Compliance			
Operating permit fee	1,119.82	50.00	2.9
Water quality monitoring	2,687.57	120.00	6.9
Subtotal	3,807.40	170.00	9.8
Total	38,944.24	1,738.86	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	1,300.00	58.04	8.6
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	8,700.00	388.45	57.5
Media	182.54	8.15	1.2
Pump(s)	250.00	11.16	1.7
Control Panel	1,200.00	53.58	7.9
Misc. Appurtenance	846.50	37.80	5.6
Piping	144.80	6.47	1.0
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	0.00	0.00	0.0
Contractor Fee	2,500.00	111.62	16.5
Total System	15,123.84	675.28	100.0

Life Cycle Cost

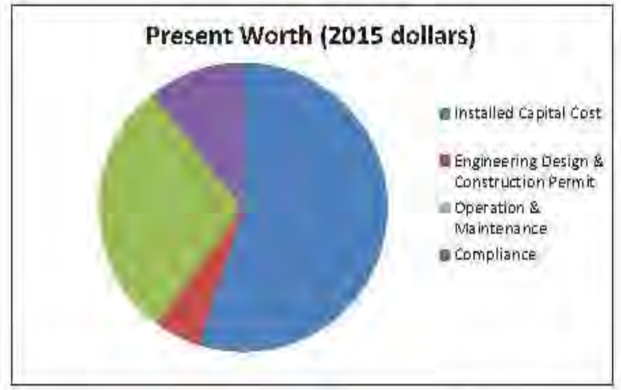
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	15,123.84	675.28	38.8
Engineering Design & Construction Permit	2,360.00	105.37	6.1
Operation & Maintenance	17,653.01	788.21	45.3
Compliance	3,807.40	170.00	9.8
Total	38,944.24	1,738.86	100.0
$/lb nitrogen removed	50.59	67.76	

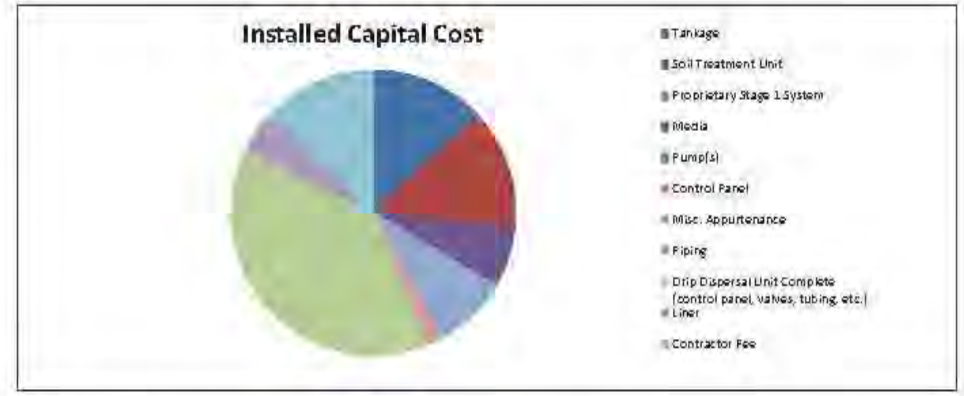
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 6 - In-ground PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-3

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary

No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary

PNRS System	18
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	In ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in ground liner
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations

Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	3.9
Pump tank	600.00	26.79	1.7
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	7.4
Subtotal Conventional	4,625.00	206.51	13.0
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	600.00	26.79	1.7
Media	1,352.23	60.38	3.8
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	0.8
Misc. Appurtenance	1,693.00	75.59	4.7
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	21.3
Liner	974.76	43.52	2.7
Contractor Fee	2,500.00	111.62	7.0
Subtotal	15,009.59	670.18	42.1
Total System Installation	19,634.59	876.68	55.1
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.1
Engineering design fees	1,500.00	66.97	4.2
Operation and Maintenance			
Annual energy cost	881.30	39.35	2.5
Annual inspection & maintenance	7,838.76	350.00	22.0
Primary tank pump out	937.90	41.88	2.6
Stage 2 media replacement	682.53	30.47	1.9
Equipment replacement	0.00	0.00	0.0
Subtotal	10,340.49	461.70	29.0
Compliance			
Operating permit fee	1,119.81	50.00	3.1
Water quality monitoring	2,687.57	120.00	7.5
Subtotal	3,807.40	170.00	10.7
Total	35,657.48	1,592.10	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	2,600.00	116.09	13.2
Soil Treatment Unit	2,625.00	117.21	13.4
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,352.23	60.38	6.9
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	8.6
Piping	289.60	12.93	1.5
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	38.7
Liner	974.76	43.52	5.0
Contractor Fee	2,500.00	111.62	12.7
Total System	19,634.59	876.68	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	19,634.59	876.68	55.1
Engineering Design & Construction Permit	1,875.00	83.72	5.3
Operation & Maintenance	10,340.49	461.70	29.0
Compliance	3,807.40	170.00	10.7
Total	35,657.48	1,592.10	100.0
$/lb nitrogen removed	46.32	62.04	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 6 - In-ground PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-3

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
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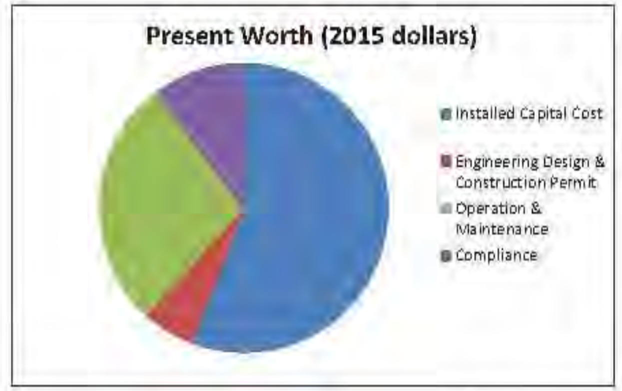
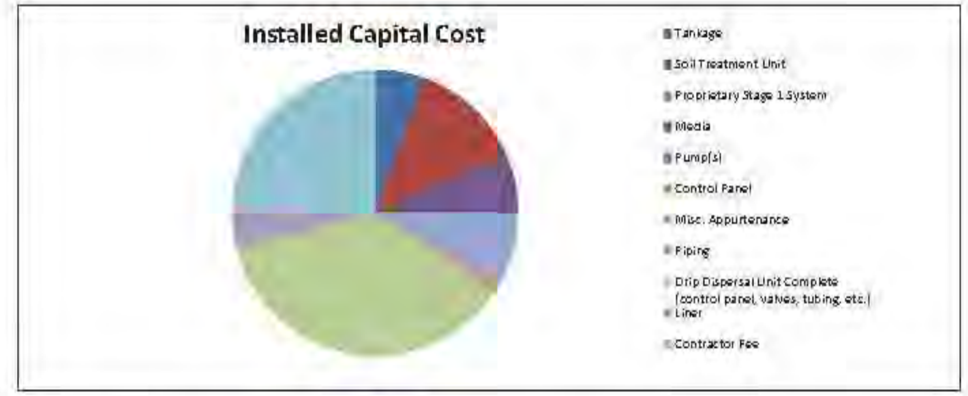
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary	
PNRS System	18
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	In ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in ground liner
Stage 2 media type	Dual: Ligno & sulfur
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	High

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	95.0
Mass removal/year, lbs.	25.66

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	600.00	26.79	1.6
Conventional system pump	0.00	0.00	0.0
Soil treatment unit	2,625.00	117.21	7.1
Subtotal Conventional	3,225.00	144.00	8.7
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	600.00	26.79	1.6
Media	1,352.23	60.38	3.6
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	0.8
Misc. Appurtenance	1,693.00	75.59	4.6
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	20.5
Liner	974.76	43.52	2.6
Contractor Fee	5,000.00	223.25	13.5
Subtotal	17,509.59	781.80	47.2
Total System Installation	20,734.59	925.80	56.0
Engineering Design & Construction Permit			
Construction permit	675.00	30.14	1.8
Engineering design fees	1,500.00	66.97	4.0
Operation and Maintenance			
Annual energy cost	881.30	39.35	2.4
Annual inspection & maintenance	7,838.76	350.00	21.2
Primary tank pump out	937.90	41.88	2.5
Stage 2 media replacement	682.53	30.47	1.8
Equipment replacement	0.00	0.00	0.0
Subtotal	10,340.49	461.70	27.9
Compliance			
Operating permit fee	1,119.81	50.00	3.0
Water quality monitoring	2,687.57	120.00	7.3
Subtotal	3,807.40	170.00	10.3
Total	37,057.48	1,654.61	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	1,200.00	53.58	5.8
Soil Treatment Unit	2,625.00	117.21	12.7
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,352.23	60.38	6.5
Pump(s)	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	8.2
Piping	289.60	12.93	1.4
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	7,600.00	339.34	36.7
Liner	974.76	43.52	4.7
Contractor Fee	5,000.00	223.25	24.1
Total System	20,734.59	925.80	100.0

Life Cycle Cost

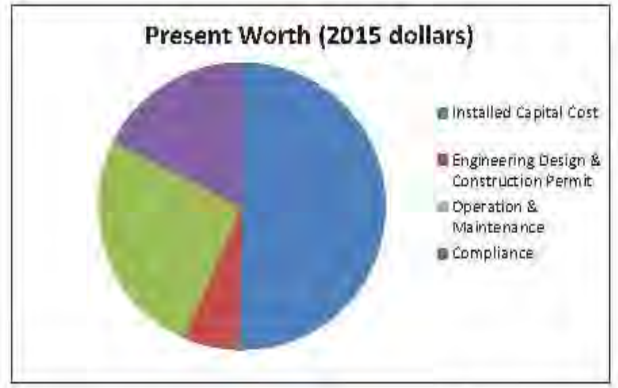
Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	20,734.59	925.80	56.0
Engineering Design & Construction Permit	2,175.00	97.11	5.9
Operation & Maintenance	10,340.49	461.70	27.9
Compliance	3,807.40	170.00	10.3
Total	37,057.48	1,654.61	100.0
$/lb nitrogen removed	48.13	64.48	

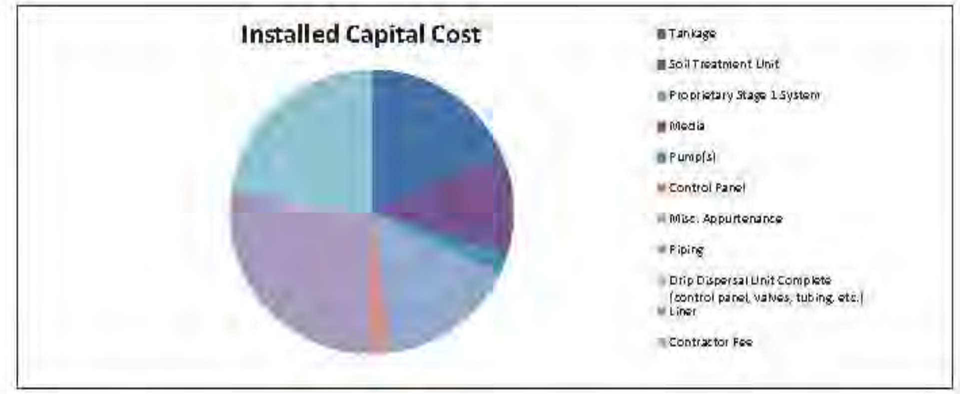
Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a New System at Home Site 7 - In-ground PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-7

Worksheet
1. LCCA Structure
2. Table of LCCA Worksheets
3. WW Quantity & System Parameters
4. PNRS Process Selection
5. Baseline Design & Cost
6. Baseline Design Cost Summary
7. User Override Costs
8. LCCA Conventional
9. LCCA Total System
10. Design Data
11. Example LCCAs





9. LCCA Total System

Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	new
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary	
PNRS System	17
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	In ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in ground liner
Stage 2 media type	Ligno only
Construction Complexity	Simple
Level of nitrogen removal efficiency provided by system	Medium

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/F PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	60.0
Mass removal/year, lbs.	16.21

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	1,400.00	62.51	6.4
Pump tank	600.00	26.79	2.8
Conventional system pump	250.00	11.16	1.1
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	2,250.00	100.46	10.3
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	0.00	0.00	0.0
Media	1,301.25	58.10	6.0
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.3
Misc. Appurtenance	1,693.00	75.59	7.8
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	13.4
Contractor Fee	2,500.00	111.62	11.5
Subtotal	8,708.85	388.85	40.0
Total System Installation	10,958.85	489.31	50.4
Engineering Design & Construction Permit			
Construction permit	375.00	16.74	1.7
Engineering design fees	1,000.00	44.65	4.6
Operation and Maintenance			
Annual energy cost	191.49	8.55	0.9
Annual inspection & maintenance	4,479.29	200.00	20.6
Primary tank pump out	937.90	41.88	4.3
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	0.00	0.00	0.0
Subtotal	5,608.68	250.43	25.8
Compliance			
Operating permit fee	1,119.82	50.00	5.1
Water quality monitoring	2,687.57	120.00	12.4
Subtotal	3,807.40	170.00	17.5
Total	21,749.93	971.13	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	2,000.00	89.30	18.3
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,301.25	58.10	11.9
Pump(s)	250.00	11.16	2.3
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	15.4
Piping	289.60	12.93	2.6
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	26.7
Contractor Fee	2,500.00	111.62	22.8
Total System	10,958.85	489.31	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	10,958.85	489.31	50.4
Engineering Design & Construction Permit	1,375.00	61.39	6.3
Operation & Maintenance	5,608.68	250.43	25.8
Compliance	3,807.40	170.00	17.5
Total	21,749.93	971.13	100.0
$/lb nitrogen removed	44.73	59.92	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Results of Life Cycle Cost Analysis Tool Standardized for a Retrofit of Existing System at Home Site 7 - In-ground PNRS

PNRS LCCA: Life Cycle Cost Analysis Tool for Passive Nitrogen Reduction Systems
LCCA Identification: BHS-7

Worksheet
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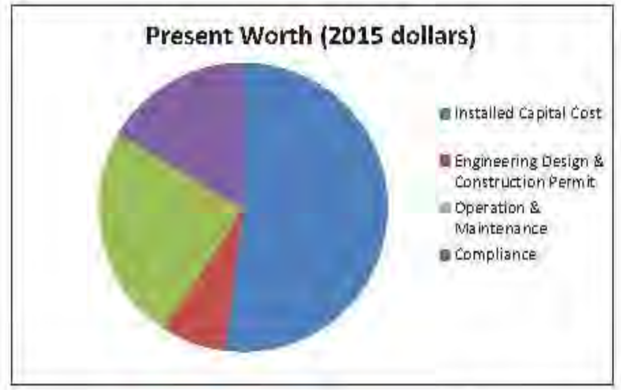
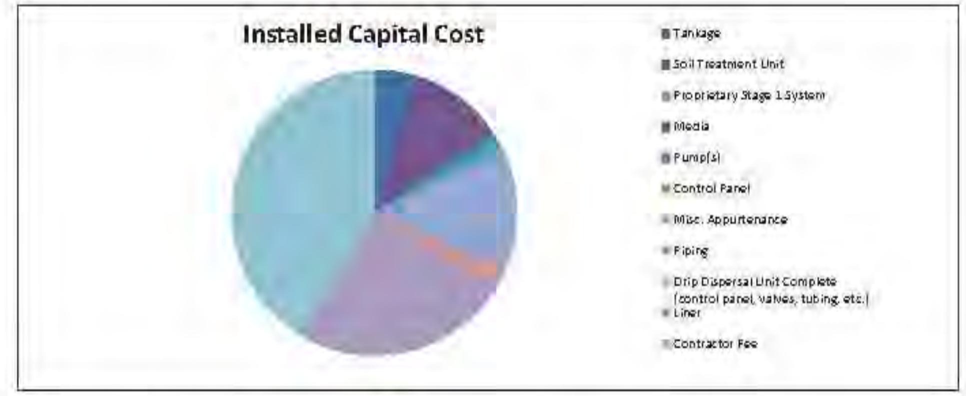
9. LCCA Total System





Conventional System Summary	
No. of Bedrooms	3
Building area, square feet	1800
Depth to seasonal high water table (inches)	72
New OSTDS installation or retrofit of existing system	retrofit
Design wastewater flow, gallon/day	300

User override Conventional costs have been specified

PNRS System Summary	
PNRS System	17
Stage 1: PNRS or proprietary	PNRS
PNRS Stage(s)	Stage 1&2
Stage 1 in tank or in ground	In ground
Stage 1 single pass or recirculation	Single pass
Stage 1 media type	Native Sand
Ligno disposition	Underlying Stage 1 in ground liner
Stage 2 media type	Ligno only
Construction Complexity	Moderate
Level of nitrogen removal efficiency provided by system	Medium

No user override PNRS costs have been specified

Life Cycle Cost Calculations	
Project Life (PL), years	30
Interest Rate (IR), %	2.000
Primary tank pump out interval (TI), years	5.0
Pumpout analysis life (PL), years	25.0
Stage 2 media replacement interval (MI), years	15.0
Stage 2 media cost analysis life (ML), years	15.0
Equipment replacement interval (EI), years	10.0
Equipment replacement analysis life (EL), years	20.0
Compound Interest Factors	
P/A PL/IR	22.396
A/P PL/IR	0.04465
A/F TI	0.19216
P/A PL	19.523
A/F MI	0.05783
P/A ML	12.849
A/F EI	0.09133
P/A EL	16.351
Nitrogen Removal	
Mass loading/year, lbs.	27.0
Removal efficiency, %	60.0
Mass removal/year, lbs.	16.21

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Conventional System Installation			
Primary treatment tank	0.00	0.00	0.0
Pump tank	600.00	26.79	2.6
Conventional system pump	250.00	11.16	1.1
Soil treatment unit	0.00	0.00	0.0
Subtotal Conventional	850.00	37.95	3.7
Proprietary Stage 1 system	0.00	0.00	0.0
PNRS Installation			
Tankage	0.00	0.00	0.0
Media	1,301.25	58.10	5.6
PNRS Pump	0.00	0.00	0.0
Control Panel	0.00	0.00	0.0
Piping	289.60	12.93	1.3
Misc. Appurtenance	1,693.00	75.59	7.3
Stage 1 Drip Dispersal System Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	12.6
Contractor Fee	5,000.00	223.25	21.6
Subtotal	11,208.85	500.47	48.4
Total System Installation	12,058.85	538.43	52.1
Engineering Design & Construction Permit			
Construction permit	660.00	29.47	2.9
Engineering design fees	1,000.00	44.65	4.3
Operation and Maintenance			
Annual energy cost	191.49	8.55	0.8
Annual inspection & maintenance	4,479.29	200.00	19.4
Primary tank pump out	937.90	41.88	4.1
Stage 2 media replacement	0.00	0.00	0.0
Equipment replacement	0.00	0.00	0.0
Subtotal	5,608.68	250.43	24.2
Compliance			
Operating permit fee	1,119.82	50.00	4.8
Water quality monitoring	2,687.57	120.00	11.6
Subtotal	3,807.40	170.00	16.5
Total	23,134.93	1,032.97	100.00

Installed Capital Cost

Installation Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Installation Cost
Tankage	600.00	26.79	5.0
Soil Treatment Unit	0.00	0.00	0.0
Proprietary Stage 1 System	0.00	0.00	0.0
Media	1,301.25	58.10	10.8
Pump(s)	250.00	11.16	2.1
Control Panel	0.00	0.00	0.0
Misc. Appurtenance	1,693.00	75.59	14.0
Piping	289.60	12.93	2.4
Drip Dispersal Unit Complete (control panel, valves, tubing, etc.)	0.00	0.00	0.0
Liner	2,925.00	130.60	24.3
Contractor Fee	5,000.00	223.25	41.5
Total System	12,058.85	538.43	100.0

Life Cycle Cost

Cost Item	Present Worth, $	Uniform Annual Cost, $	% of Total Life Cycle Cost
Installed Capital Cost	12,058.85	538.43	52.1
Engineering Design & Construction Permit	1,660.00	74.12	7.2
Operation & Maintenance	5,608.68	250.43	24.2
Compliance	3,807.40	170.00	16.5
Total	23,134.93	1,032.97	100.0
$/lb nitrogen removed	47.58	63.73	

Developed by: HAZEN AND SAWYER Environmental Engineers & Scientists and AET

Appendix F. Results of Groundwater Monitoring at Field Sites

GCREC Mound Site

A large mound OSTDS designed for flows of 2,500 gallons per day serves the GCREC facility and receives primarily domestic wastewater from the offices. The site plan of the test facility where monitoring took place is shown in Figure F- 1. The plume from the existing GCREC-mound was assessed over several sampling events. The number of sampling points was different during each sampling event. Influent concentrations also varied over the course of the monitoring period. For these reasons, only the data from the most intensive, the second sampling event are included in the analysis by Department staff. The scatter plot in Figure F- 2 shows an interesting complication. While some data points are on the mixing line between septic tank effluent concentration and background groundwater, many data points are consistent with a mixing line between groundwater and a monitoring point with higher TN concentrations. This monitoring point is at the northwest corner of the mound.

Figure F- 3 shows a contour plot of the highest nitrate concentrations measured over the course of the monitoring period. The point with the highest nitrogen concentration is indicated by a red circle. Points with elevated nitrogen concentration consistent with stemming from a source at that location are encompassed by the dashed line. This dashed line includes some monitoring points that are more consistent with the septic tank effluent concentrations at the time. The plume extends initially in a southern direction, at the end of the STU it changes directions towards the west. Broadly, it follows the southwesterly direction of groundwater flow inferred from groundwater elevations.

There are several scenarios that may explain the increased concentrations over part of the monitoring domain. The project team suspected agricultural fertilizer impacts from upstream. Variations in flow and concentration in the septic tank effluent could have influenced part of the plume more than others. The location close to the top of the STU could also suggest a less well distributed source of wastewater.

Regardless of scenario that explains elevated concentrations, the monitoring points show predominantly nitrified samples. Most points with high concentrations appear to show dilution rather than denitrification causing a reduction in concentrations. This indicates that even though the soil series have a high water table that was expected to assist in denitrification, during the monitoring event denitrification was not effective at the core of the plume.

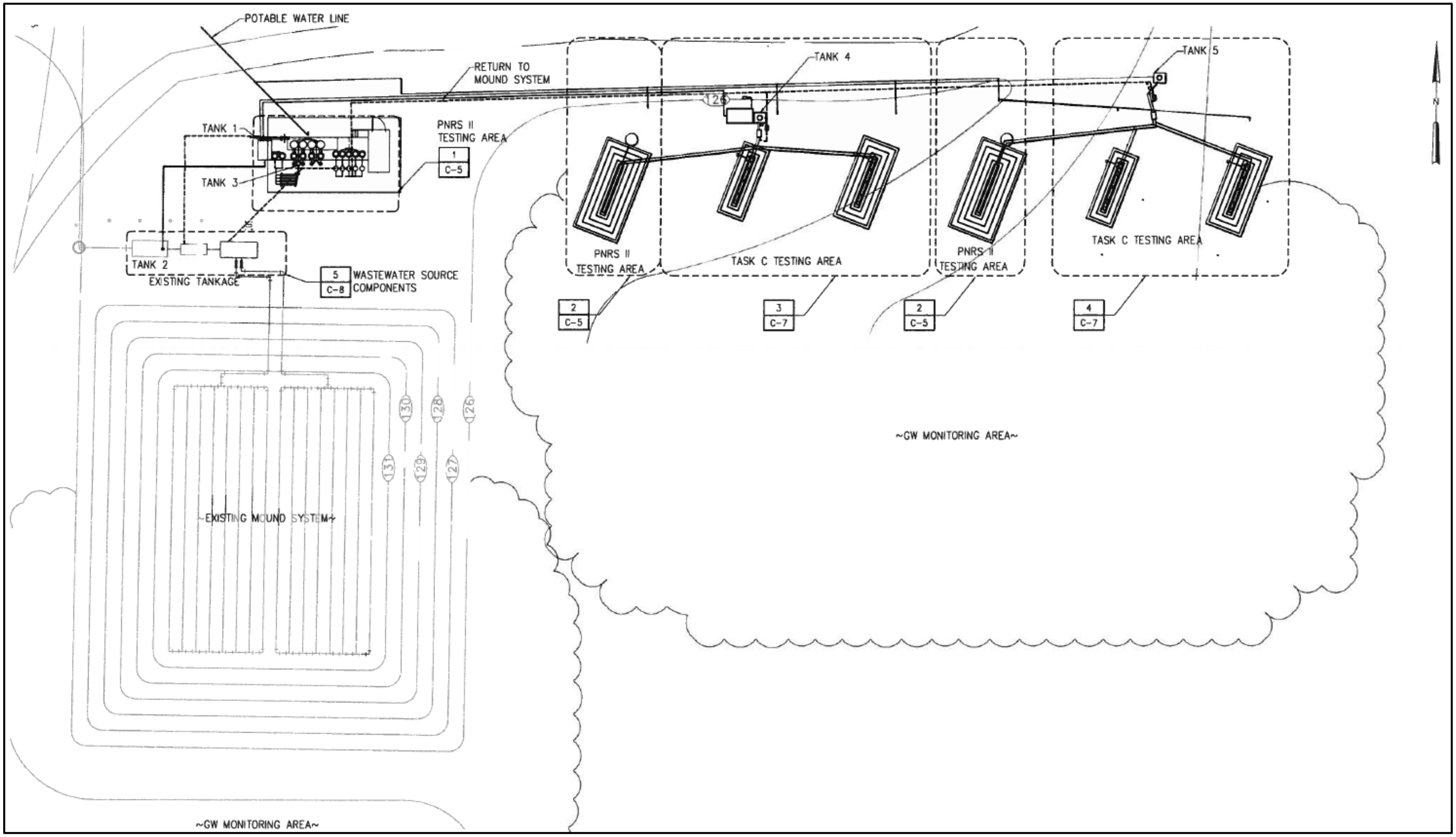


Figure F- 1. Site Plan of the Groundwater Monitoring Area at the Test Facility (Hazen and Sawyer 2010b)

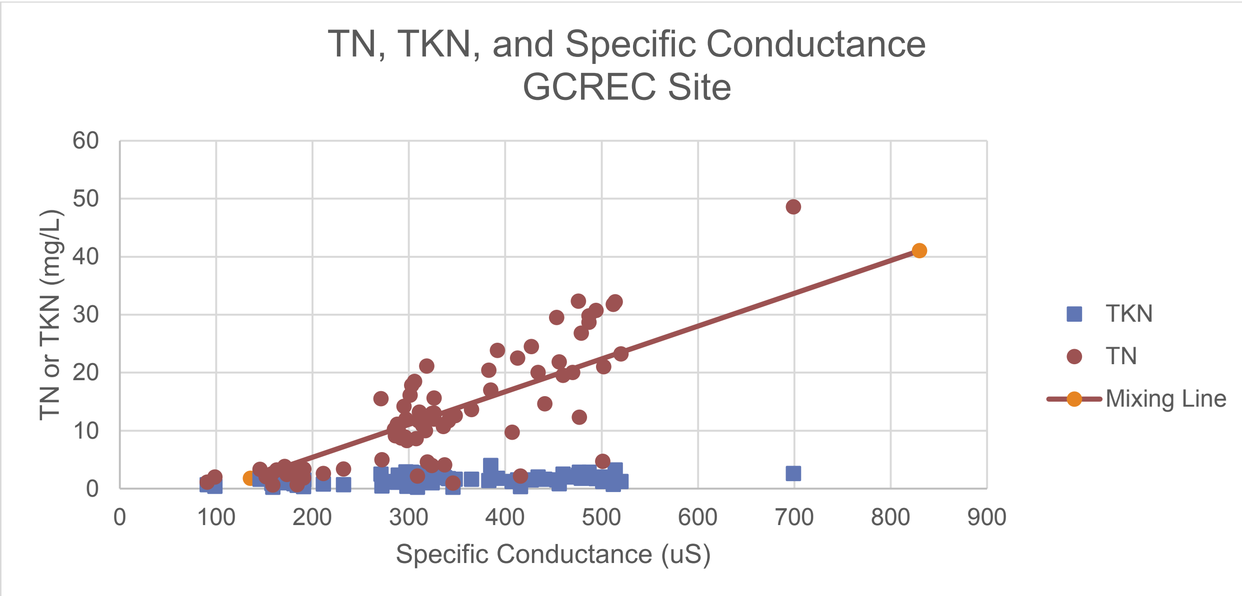


Figure F- 2. TN, TKN and Specific Conductance during a Sampling Event during March/April of 2011 at the GCREC Mound

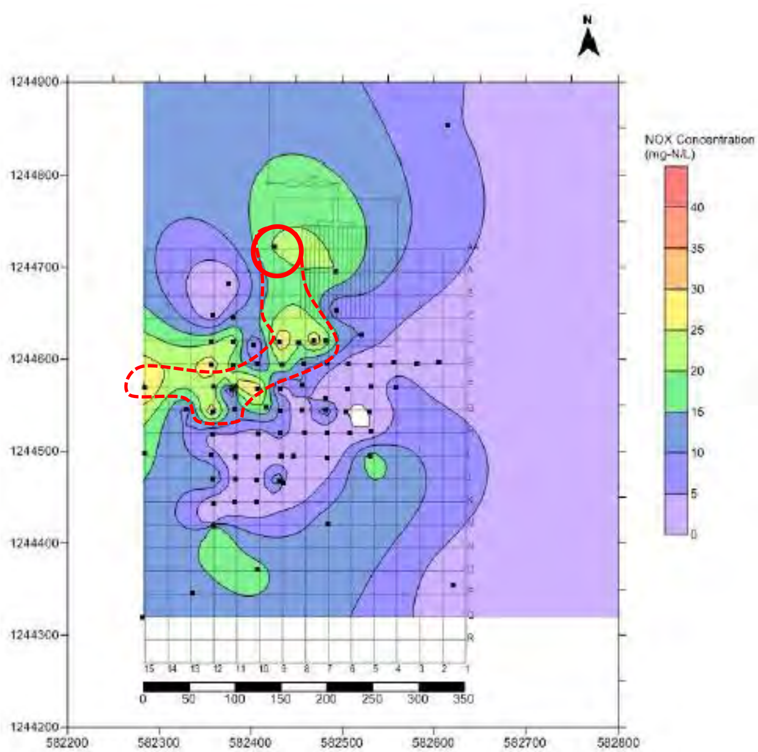


Figure F- 3. Highest NO_x Concentration in Monitoring Points Observed Over the Monitoring Period at the GCREC Mound March/April 2011 Sampling Event Monitoring Point with Highest Nitrogen Concentration in Red Circle, and Plume Consistent with that Monitoring Point Outlined with Dashed Line (adapted from Hazen and Sawyer 2015e)

Groundwater monitoring at home sites

Three detailed soil and groundwater assessments were completed to evaluate existing OSTDS over a 12-month period to capture seasonal variability. These home sites were located at existing homes in Polk, Seminole, and Hillsborough counties. Additionally, the plume from a large OSTDS at GCREC was delineated, and some monitoring around one of the PNRS prototype systems in Marion County and an additional home site in Wakulla County was performed. Also, a test facility was constructed for more controlled testing of soil and groundwater. At each site, initial visits inspected the OSTDS and attempted to identify the nitrogen plume in the groundwater beneath the STU. This included instrumentation of the site with a combination of drive points (one-inch long screens driven to a specific depth), piezometers (PVC-pipes with five or ten-foot long screens installed in the shallow groundwater, and lysimeters (nine-inch long ceramic suction cups). Details of the methods are outlined in the Quality Assurance Project Plan (Hazen and Sawyer 2010b).

Two approaches were used to analyze the data. First, the absolute values of measurements were assessed and the overall concentration reduction described by how much the concentration was reduced between the septic tank effluent and the sample observation point. Such an analysis does not take into account that the septic tank effluent plume is diluted during travel in groundwater. Second, by drawing a comparison with concentration data of a compound that does not react allows for an estimate of the dilution. The dilution calculation utilizes the septic tank effluent and background concentrations of a tracer that is assumed to be conservative (chloride, or specific conductance). The background concentration could stem from a particular background well or group of them. The adjusted concentration reduction describes which fraction of the reduction in TN concentration from septic tank effluent is not due to dilution.

Monitoring of effluent plumes in groundwater at individual home sites utilized the same methodology as the monitoring of the mound at the test facility. Selected home sites were located throughout Florida, to capture diversity in site conditions. Table 03 in the main report shows the number of home sites evaluated and selected for groundwater monitoring. Each site had a signed homeowner agreement prior to the start of the monitoring process. In the following figures possible mixtures between septic tank effluent and background water, in which no reaction has occurred, are indicated by a “mixing line”.

Polk Site

This field site is located in Polk County, Florida, adjacent to Big Gum Lake in a rural area surrounded by commercial orange groves. The OSTDS for the single-family residence consists of an old existing 750 gallon single compartment septic tank. It is unknown if the tank is fitted with an outlet tee and it is likely not to have an outlet filter. The septic tank is located adjacent to the soil treatment unit, which is a gravity fed standard STU, in a 10 ft by 20 ft bed configuration. The residence is occupied by two persons.

The land surface slopes down to the North towards Big Gum Lake with a relief of about 10 feet sloping to the lake. The soil survey of the area shows the southern half of the property mapped as Astatula and the northern half as Tavares soil series. The current aerial image provided by the Natural Resources Conservation Service (NRCS) soil survey shows an area with more intense green coloration directly

over the STU, indicating the higher availability of water throughout the STU. The site's soil investigations determined the material to be of sand texture.

A sampling grid for groundwater screening was developed downgradient of the soil treatment unit as depicted in Figure F- 4. A 6-foot by 5-foot grid spacing was staked. Transect lines A through U run east-west, roughly perpendicular to the groundwater flow direction and increase (higher letter identification) moving northward from the STU. Transect lines 0 through 7 run north-south, roughly parallel to the groundwater flow direction and increase moving from east to west. Based on initial screening data, 22 monitoring locations were chosen within the grid for standpipe piezometer installation. Groundwater monitoring points were installed in June 2012. Standpipe piezometers were installed using either hand or drilling methods. Standpipe piezometers consist of either ¾-inch or 1-inch diameter PVC with a 1-foot or 5-foot screen (0.010-inch slots) and a riser extending to the ground surface (Hazen and Sawyer 2010b, Hazen and Sawyer 2012).

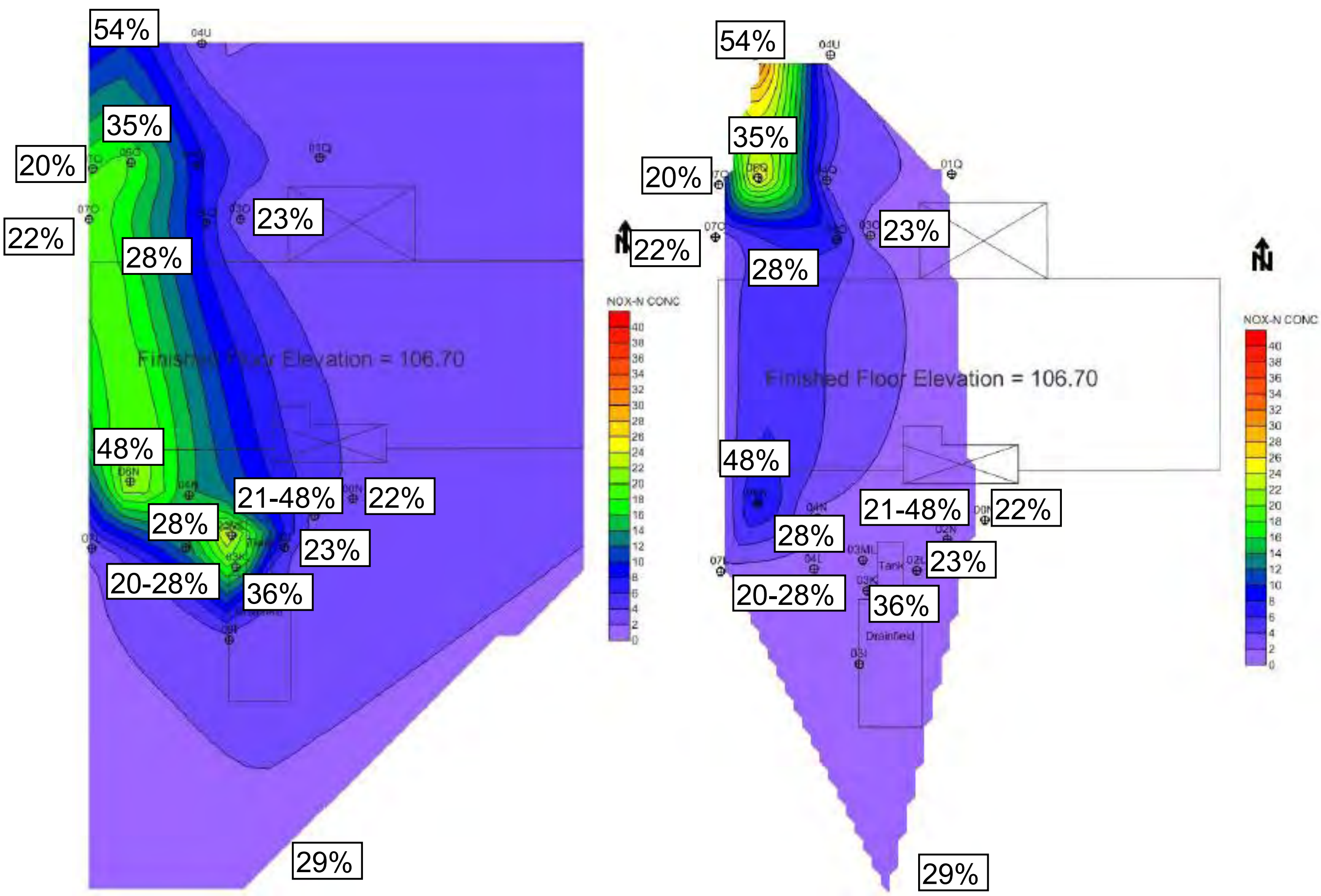


Figure F- 4. Maximum Nitrate Concentration in Shallow (90-95.6 Ft above MSL) and Intermediate (87-90 Ft above MSL) Groundwater and Highest Estimated Fraction of Septic Tank Effluent Up To a Depth of 21 Ft below Ground Surface (Only Values At Least 20% Shown) (adapted from Hazen and Sawyer 2014d)

Each monitoring location was assigned a unique grid identification location, and the depth in feet below the ground surface to the bottom of the well screen. For example A03-15 is a standpipe piezometer

sampler located on the grid at A03 at 15 feet below ground surface. Four sampling events were performed (August 28, 2012, November 26, 2012, February 25, 2013, and May 20, 2013), with some additional groundwater table monitoring between those dates. Over the course of the year of monitoring, groundwater elevations varied by about three feet throughout the site. The highest groundwater elevation occurred between the first and second sampling events. The groundwater gradient at this site was very low, less than a 1 ft drop in groundwater elevation across the entire site. On several occasions the gradient was nearly flat. The site topography slopes significantly towards the lake, so this result is somewhat unexpected in that the groundwater gradient did not reflect topography.

Figure F- 5 summarizes the results of the field monitoring at this site. Median values for TN and total Kjeldahl nitrogen are plotted against the specific conductance as an indicator of the fraction of septic tank effluent in the sample. The background values are based on the piezometers PZ 01 BKG and PZ02 BKG, which screened in the topmost groundwater. The figure shows that nitrogen is nearly completely nitrified throughout the monitoring area. Many observations with high specific conductance are on or close to the mixing line, indicating that dilution is the dominant concentration-reducing process. At lower values of specific conductance, some observations indicate more denitrification. While most of the observations were taken from the top of the shallow groundwater, the two deepest observations (PZ-06U-34 and PZ-03A-34) also indicate elevated fractions of septic tank effluent and no appreciable reduction (dashed circle). This deeper section of the groundwater was only observed in a few points.

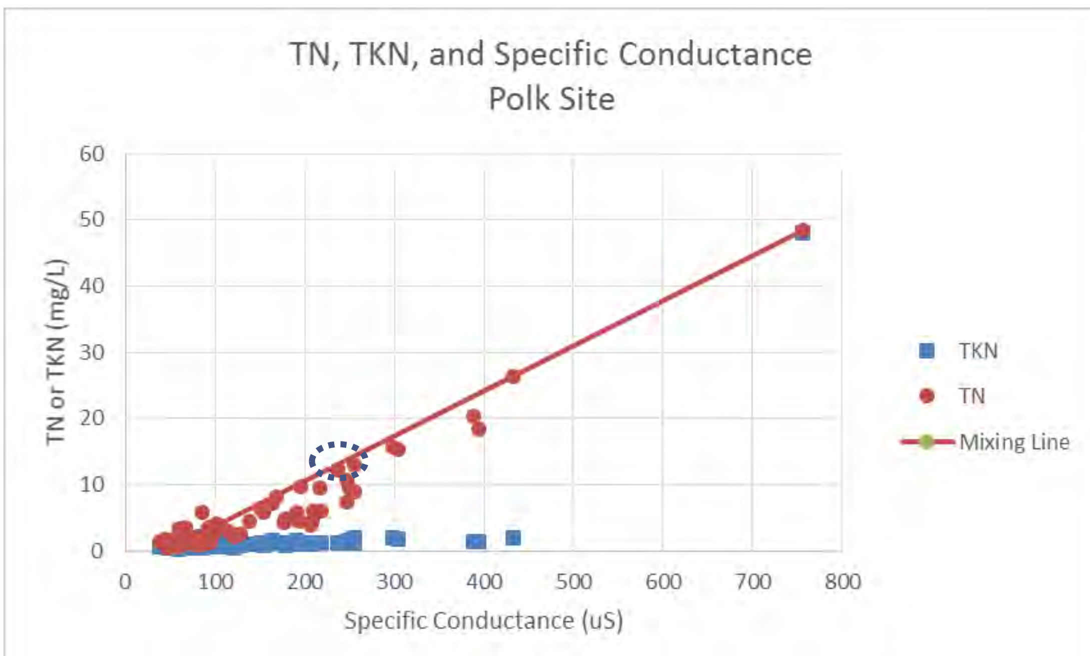


Figure F- 5. Median TN, TKN Concentrations Relative to Specific Conductance at the Polk County Site

Table F- 1 summarizes nitrogen concentrations, specific conductance, and the results of dilution and nitrogen reduction assessments for those observations that indicated the highest fractions of septic tank effluent. The fraction of TKN is between 5% and 20%, mostly indicating largely complete nitrification. Interestingly, two of the observations with high specific conductance stem from a location PZ-03A, 30 foot south of the STU, opposite the northerly plume direction that was the focus of the investigation. The highest median specific conductance and TN concentrations were found in PZ-06U-14, about 75 feet north of the septic tank and STU. The overall TN reduction for this observation was 46%, which appeared to be exclusively due to dilution.

Table F- 1. Results of Monitoring in the Plume of the Polk County Site Sorted by Estimated Fraction of Septic Tank Effluent in the Sample; Median TN and Specific Conductance (SC) Concentrations, TKN Fraction, and Estimated Fraction of Effluent in Sample; Reductions of Nitrogen Concentrations Adjusted For Dilution and Overall; Observations with at Least 25% Septic Tank Effluent Shown; Bold=Deepest Observations; Italic=Observation 30 Ft South of STU

Location	TN (mg-N/L)	SC (uS)	Fraction TKN	Fraction STE	Reduction adjusted	Reduction overall
STE	48.3	755.5	99%			
PZ-06U-14	26.3	432.5	7%	54%	0%	46%
PZ-03ML-15	18.5	394.0	8%	48%	11%	62%
PZ-06N-15	20.4	389.0	7%	48%	6%	58%
PZ-03K-15	15.4	304.0	11%	36%	4%	68%
PZ-06Q-15	15.7	298.8	12%	35%	3%	67%
PZ-03A-21	*8.9*	*255.5*	*13%*	*29%*	*11%*	*82%*
PZ-06U-34	**13.0**	**255.0**	**16%**	**29%**	**3%**	**73%**
PZ-04L-15	9.6	249.5	17%	28%	9%	80%
PZ-04N-15	10.8	247.0	13%	28%	6%	78%
PZ-04O-21	7.4	247.0	15%	28%	13%	85%
PZ-03A-34	***12.2***	***237.3***	***10%***	***26%***	***2%***	***75%***
PZ-01BKG	0.6	60.1	47%	1%		
PZ-02BKG	0.5	47.6	90%	-1%		

Figure F- 4 reproduces two of the contour plots from the close-out report of the field monitoring site (TaskC26_CHS3). The contour plots group observations together by elevation above mean sea level. By placing the plots side-by-side, the descent in northerly direction becomes more clearly visible. The contour plots have been augmented with the highest estimated fractions of septic tank effluent that were found. As Figure F- 5 indicated, there is a strong correspondence between increased specific conductance as indicator of septic tank effluent and TN concentrations.

Site conclusions:

- A nitrate plume extends to at least 75 foot north of the STU from the septic tank and STU.
- Concentrations and specific conductance observations indicate that dilution is the main concentration-reducing mechanism in the core of the plume.
- The groundwater gradient was small and inconsistent over the monitoring period. A limited number of observations suggest that parts of a nitrate plume extended at least 10 foot deeper and in the opposite direction of the main plume.

Seminole Site

This field site is located in Seminole County, Florida, in a neighborhood near the Wekiva River. It is also located near to one of the field sites evaluated in the Department's 2007 Wekiva Study. The STU was installed in a mound. Permit information from a system repair performed in 2003 indicates that the STU was installed in a mound trench configuration with 14 inches of separation from the estimated seasonal high groundwater table. However, project staff identified the STU as a mounded STU in a bed configuration. The soil in the STU area is mapped as Myakka/Eaugallie, soil series with a spodic horizon. Consistent with the mapping, the repair permit required 36 inches of excavation to remove the spodic horizon. The permitted estimated sewage flow during monitoring was 600 gallons per day based on the size of the structure.

Site activities: A sampling grid for groundwater screening was developed downgradient of the OSTDS. A 10-foot by 40-foot grid was staked then locations surveyed (x, y, and z). Transect lines A through D were located perpendicular to the groundwater flow direction (southwest) and increased (higher letter identification) moving southward from the mound. Transect lines 0 through 15 were located parallel to the groundwater flow direction and increased moving from southeast to northwest. Groundwater monitoring points were installed in June and July 2011. Stand pipe monitoring piezometers were installed using either hand or drilling methods. Four sample events were conducted at this site as part of Task C monitoring: July 2011, November 2011, March 2012, and July 2012 and the sample events were documented in the Task C.24 C-HS2 Sample Event Reports. Several ¾ inch stand pipes or Piezometer (PZ) with five foot screen length were installed with the top of the screen close to the water surface. The remaining sample points were usually ¾ inch diameter stand pipes with one or two foot long screens. Clusters of monitoring points were established to assess changes of concentration with depth.

Median results of TN, TKN and specific conductance are shown in Figure F- 6. For a given specific conductance the difference between TN and TKN concentrations is an indication of how much nitrate is in the groundwater. Points in red dotted oval represent nitrate-dominated groundwater where TN concentration reduction was only due to dilution. Points in blue dashed oval represent TKN-dominated groundwater where incomplete nitrification appears to be the limiting factor to nitrogen reduction with about 10 mg-N/L TN left. Many observations points with above background concentrations appear to be in conditions with some nitrate and little TKN remaining.

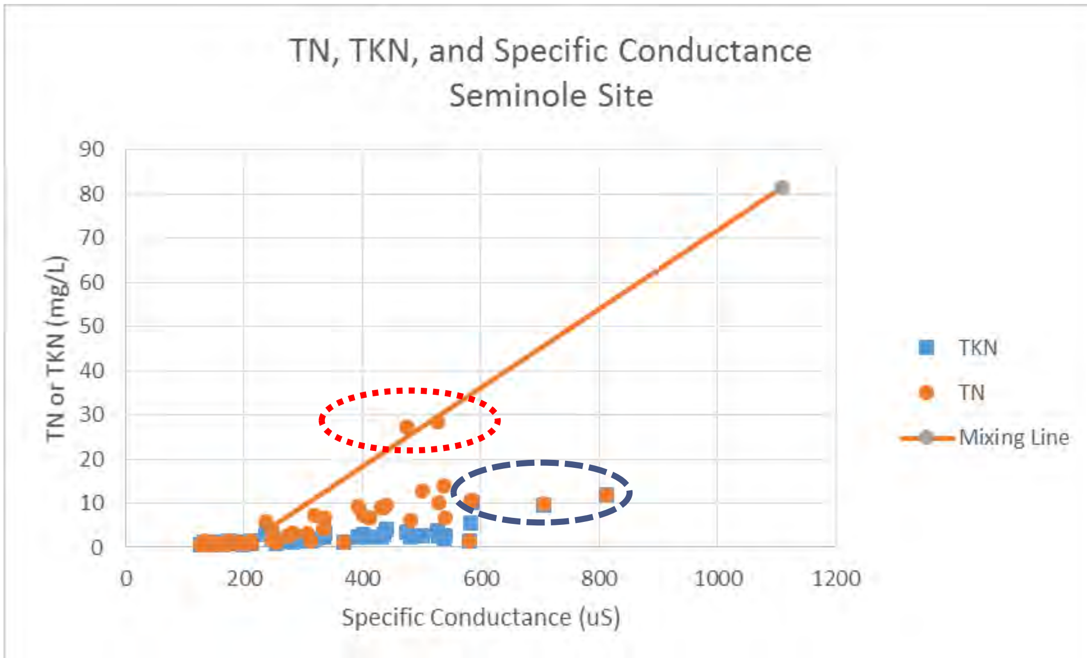


Figure F- 6. TN, TKN Relative to Specific Conductance; the Mixing Line Represents Mixtures Between Septic Tank Effluent and Background Groundwater; Points in Red Dotted Oval Represent Nitrate-Dominated Groundwater Where TN Concentration Reduction Was Only Due to Dilution; Points in Blue Dashed Oval Represent TKN-Dominated Groundwater Where Incomplete Nitrification Appears to be the Limiting Factor to Nitrogen Reduction

Figure F- 7 reproduces a contour plot of maximum nitrate concentrations from the C26-HS2 report. The contour plot shows a nitrate plume extending southeast from the STU. Further insights are gained by looking at the estimated fraction of septic tank effluent in the sampled groundwater. The septic tank effluent with high specific conductance tends to stay on the top few feet of the groundwater. The plume extends with 25% of septic tank effluent to the southeastern corner of the property. Specific conductance measurements indicate a broader plume than the nitrate plume, with an extension to the south. A comparison of the nitrogen speciation pattern discussed for Figure F- 6 to the observation point locations indicates that two parallel plumes exist. A TKN plume with about 10 mg-N/L starts at the western end of the STU (A10, A11). A nitrate plume with about 25-30 mg-N/L nitrate begins at the center of the STU and extends for at least 40 feet (A07, B08). Between the two plumes are some observation points (A09, B10) with a TN concentration of about 10 mg-N/L and a nitrate fraction of about 50%. The observation point directly below the STU, PZ06-12 shows intermediate concentrations of nitrate and of septic tank effluent in groundwater (35%). One explanation for this relatively lower concentration is that the top of the screen was below the water table for some sampling events and did not sample the highest concentrations at the water table. The bottom of the five foot long screen extended into groundwater with background concentrations.

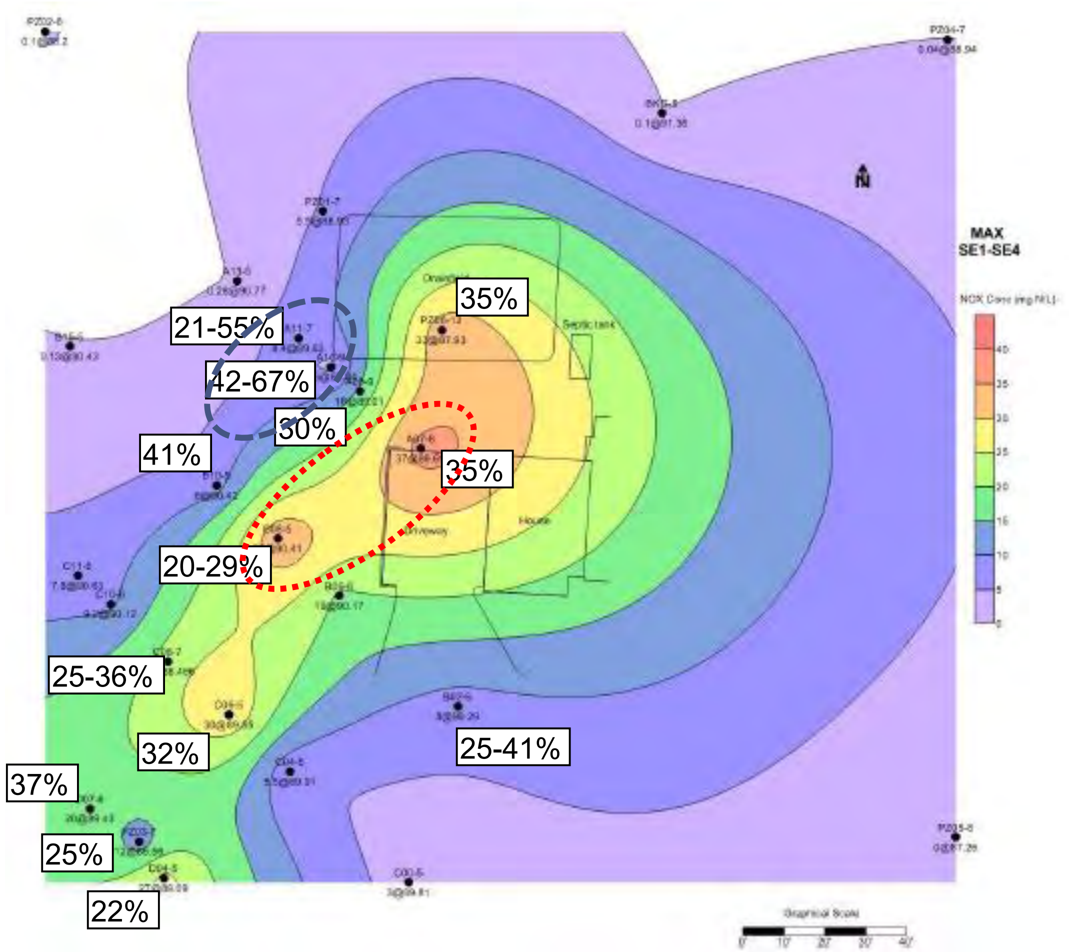


Figure F- 7. Contour Plot of Maximum Nitrate Concentrations during Four Sampling Events in Shallow Groundwater at a Mound for One STU in Seminole County; Numbers Are Estimated Fraction of Septic Tank Effluent in Sample Based on Specific Conductance (Limited to Values at Least 20%); Oval Outlines Correspond to Points Shown in Figure F- 6 (adapted from Hazen and Sawyer 2015f)

The samples included several from a stormwater drain and catchment basin about 44 foot southwest of the property. In the absence of a rain event, water of these structures is likely derived from groundwater. These samples indicated slightly elevated specific conductance (11-16% septic tank effluent) and increased TN concentration (about 97% overall reduction, 10-15% adjusted reduction).

The existence of two different parts of the plume point to the complexity of nitrogen fate and transport on this site. The TKN-plume indicates that for part of the STU, water table separation was not sufficient to achieve complete nitrification. To the extent that nitrification occurred before reaching this part of the plume, the nitrate disappeared before reaching the first monitoring points. The nitrate center of the plume was diluted but showed little indications of denitrification. This center also showed the highest absolute concentrations of TN (Table F- 2).

Table F- 2. Results of Monitoring in The Plume of Seminole County Site Sorted by Estimated Fraction of Septic Tank Effluent in the Sample; Median TN and Specific Conductance (SC) Concentrations, TKN Fraction, and Estimated Fraction of Effluent in Sample; Reduction of Nitrogen Concentrations Adjusted and Overall and Bottom of Monitoring Point Relative to Median Groundwater Elevations; Bold: Center Of Nitrate Plume; Italic: TKN Plume

Location	TN (mg-N/L)	SC (uS)	Fraction TKN	Fraction STE	Reduction adjusted	Reduction overall	Elevation relative to GW (ft)
STE	81.6	1108	100%				
A10-7	*12.0*	*812*	*100%*	*67%*	*53%*	*85%*	*-2.02*
A11-5	*9.9*	*706*	*97%*	*55%*	*44%*	*88%*	*-1.28*
A10-9	*10.7*	*585*	*95%*	*42%*	*29%*	*87%*	*-3.93*
B10-5	10.5	584	52%	41%	30%	87%	-1.97
B02-8	1.5	582	96%	41%	41%	98%	-4.27
D07-6	6.7	541	37%	37%	30%	92%	-2.01
C08-7	13.8	538	16%	36%	21%	83%	-3.58
PZ06-12	10.1	529	27%	35%	24%	88%	-5.02
A07-8	**28.4**	**528**	**13%**	**35%**	**2%**	**65%**	**-3.02**
C06-5	12.8	500	22%	32%	18%	84%	-2.46
A09-7	6.0	482	40%	30%	24%	93%	-0.99
B08-5	**27.2**	**476**	**13%**	**29%**	**-3%**	**67%**	**-1.98**
C08-5	9.7	440	41%	25%	15%	88%	-1.85
PZ03-7	9.0	436	33%	25%	15%	89%	-4.74
PZ04-7	1.4	212	99%				-4.73

Relative to septic tank effluent the lowest reduction observed was 65%, which appeared to be due to dilution rather than mass loss. In the TKN-plume the concentration reduction was between 80 and 90% about half of which was due to dilution and half of which can be attributed to reactions underneath the STU and in the groundwater.

Site conclusions:

- Identifiable parts of the septic tank effluent plume reach the southwestern corner of the property, about 150 feet away from the edge of the STU. The plume appeared to travel largely horizontal and remain close to the surface.
- There was large variability in the behavior of the STU groundwater system observed at this site. Part of the plume, predominantly nitrate, showed no nitrogen reduction beyond dilution at a distance of about 50 feet away from the STU.

- Another part of the plume showed elevated TKN-concentrations consistent with incomplete nitrification underneath the STU followed by rapid denitrification.

Wakulla Site

This field site is located in Wakulla County, Florida in a neighborhood near the Wakulla River. The STU mound at the site contains two STUs. One STU serves the residence onsite and the second STU is part of the onsite sewage system for the house across the street which is located adjacent to the Wakulla River. The OSTDS for the residence on-site consists of a standard baffled (multi-compartment) septic tank located within the mound and has a gravity-fed STU in a bed configuration that utilizes plastic tubing industries (PTI) multi-pipe alternative STU product. The OSTDS for the house across the dirt road has a standard baffled tank and a pump tank used to deliver the effluent under the road to a separate PTI bed STU. The 2005 site evaluation for the construction of the first STU described the soil as Pilgrims or Moriah-like, fine sands, with clay or limestone existing at a depth of about 20 inches or 45 inches, respectively. The estimated seasonal high groundwater table was identified at 20 inches below grade. Based on permit information, the infiltrative surface of the STU was installed to provide 42 inches of separation from the limestone and clay, or 22 inches above grade. The permitted estimated sewage flow is 200 gallons per day.

Site activities: Project staff visited the site for investigation and instrumentation in September 2010, November 2010, April 2011, and May 2011 with a sampling event on May 19 and 20, 2011. The site was sampled for one sampling event. Permit information and the instrumentation report found clay and limestone frequently within two feet of grade. This precluded installation of some instruments. All instrumentation was installed below the level of clay and rock. The combination of these observations suggests that instrumentation was predominantly installed in solution holes of the limestone.

Results: One septic tank was sampled once. While this septic tank effluent sample serves as point of comparison for the nitrogen concentrations and specific conductance of other samples, the second septic tank may have had different effluent characteristics and effluent concentrations may have varied. Nitrogen, when found in the monitoring devices, was mostly in nitrate form, indicating that the mound was effective in allowing nitrification. Lysimeters showed levels of nitrogen below 10 mg-N/L. The highest nitrogen concentrations (36.6 mg-N/L) were found in a piezometer directly below the STU. The plume was not clearly defined beyond the foot print of the mound. An area of elevated specific conductance extended in several directions.

Table F- 3 summarizes the results for the septic tank effluent, lysimeters, the highest specific conductance groundwater samples and the background (most upstream) well location. The observation with the highest concentration (PZ07) indicated an overall concentration reduction of 67% and adjusted concentration reduction of 25%. One of the lysimeters was indicative of undiluted septic tank effluent with a 96% overall reduction of TN. The other lysimeter showed diluted septic tank effluent with an overall concentration reduction of 93% and an adjusted reduction of 28%. PZ 11, PZ 12, and DP 06 showed slightly elevated TN concentrations with an overall reduction over 90% and adjusted reductions in the 40-50% range. PZ 01 had distinctly low specific conductance observations. Figure F- 8 summarizes specific conductance measurements as an indication of dilution extent and the overall and adjusted TN reductions.

Table F- 3. TN, Specific Conductance and Estimated Dilution, and Nitrogen Reduction at Wakulla Site

Location	TN (mg-N/L)	SC (uS)	Fraction STE	Reduction adjusted	Reduction overall	Elevation relative to GW (ft)
STE	110.16	1367				
LY 01	7.67	788	34%	28%	93%	2.4' above
LY 02	4.31	1433	107%	104%	96%	2.4' above
PZ 07	36.6	999	58%	25%	67%	.8' above to 4.2' below
PZ 12	6.9	933	51%	45%	94%	2.7' above to 3.3' below
DP 06	2.21	926	50%	48%	98%	4 ft below
PZ 11	3.9	913	49%	45%	96%	1' to 6' below
Background (PZ 04)	0.86	484				

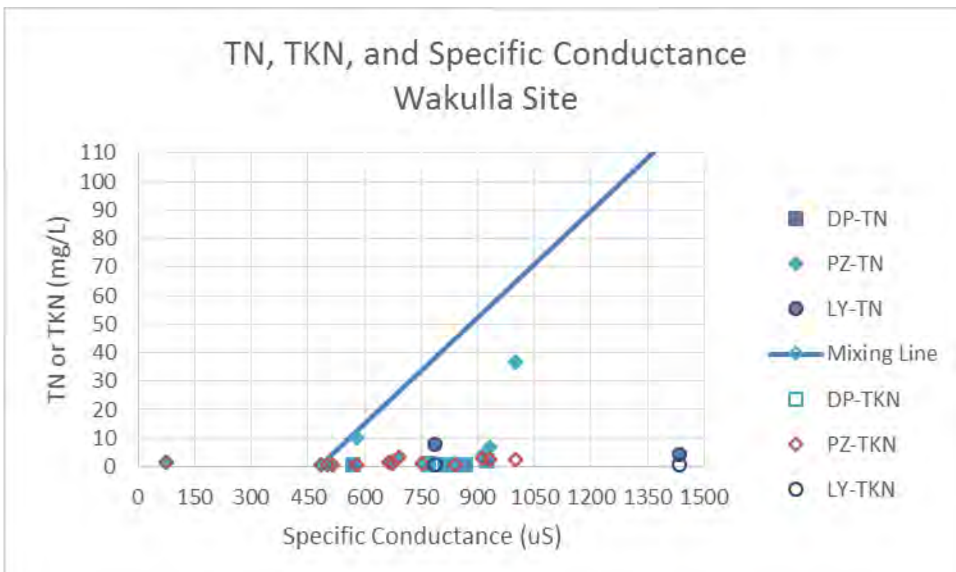


Figure F- 8. Observed TN, TKN, and Specific Conductance at Observation Points at Wakulla Site

Figure F- 9 reproduces the contours of nitrate concentrations at the sampling event along with an estimate of the fraction of septic tank effluent in the sample. Similar to indications by groundwater table elevations, there appears some spreading of the plume to the south-southeast and north, away from and in opposite flow direction to the adjacent river, respectively.

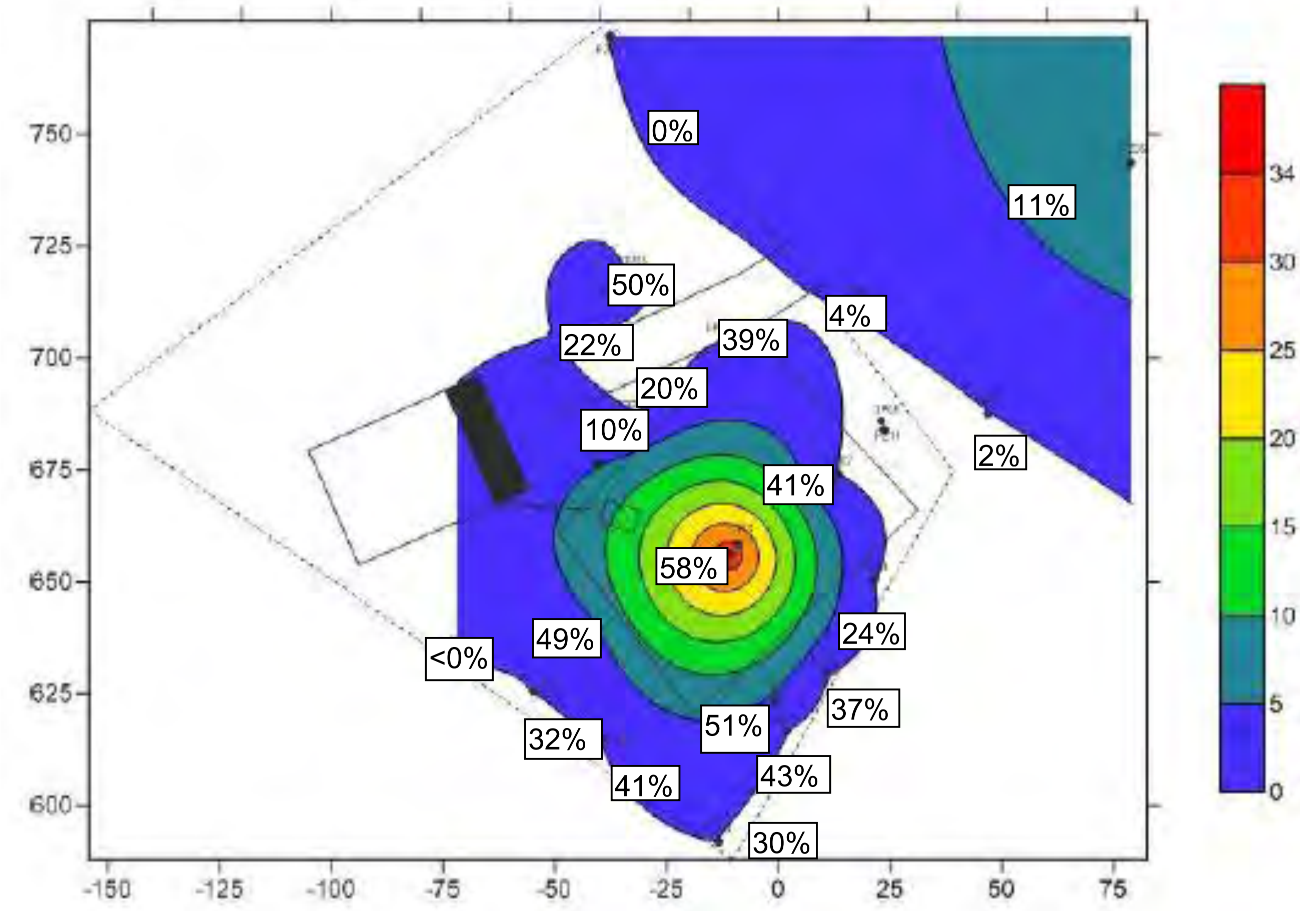


Figure F- 9. Contour Plot of Nitrate Concentrations in Shallow Groundwater at a Mound for Two STUs in Wakulla County; Numbers are Estimated Fraction of Septic Tank Effluent in Sample Based on Specific Conductance (adapted from Hazen and Sawyer 2011)

The decision to abandon the CHS-1 site was made as further sampling would not assist with the overriding goal to develop a simple groundwater model (Task D). The results of the May 2011 sampling event served to identify the general trend of the NOX plume and indicated that:

Although the groundwater fluctuates, the direction of flow does not appear to change.

There are small variations in field parameters over the site with no clear correlations between field parameters and NO_X concentrations identified.

The nitrogen plume appears to be flowing in a vertically downward direction and possibly extend towards the southeast similar to the groundwater contours with elevated concentrations in the mound. The nitrogen plume appears to be flowing in a vertically downward direction and possibly extend towards the southeast similar to the groundwater contours with elevated concentrations in the mound.

Results of lysimeters in the vadose zone gave different results and indicated more nitrogen removal than the shallow monitoring well beneath them. Changing conditions on a small scale may make lysimeter results more variable.

These results indicated that further monitoring at this site would not assist in developing the simple groundwater model as the plume flow path appears to be in a vertical downward direction. Installation of additional monitoring points was impractical as the variability of the underlying limestone and clay layers made installation of monitoring points very difficult as discussed in the Task C.23 Instrumentation Report.

Karst is a term applied to areas where extensive dissolution of rock (in this area lime-stone) which has led to the development of subterranean channels through which groundwater flows in conduits (enclosed or semi-enclosed channels). These conduits can vary in size from slightly enlarged cracks to tunnels many feet in diameter and many feet in length. Two notable features due to fracture controlled flow of karst hydrology are: the often unknown flow paths and the wide variability of flow rates. The NOX map (Figure F- 9) indicates that the nitrogen plume flow path may be dropping vertically in a down-ward direction at this site. Although the May 2011 sampling event did provide some in-sight into the nitrogen plume at that time, the fracture/karst flow made the plume identification very difficult. (Hazen and Sawyer 2013b).

Hillsborough Site

This field site in Hillsborough County is also the home site 2 passive nitrogen reduction system site located adjacent to Eagle Lake and Bullfrog Creek in a rural area. The Task B.6 installation report for the PNRS homes site 2 system documents the experimental system design which was installed in September 2012. The soil treatment unit (STU, aka drainfield), is mounded and utilizes alternative P.T.I.™ drainfield products.

Groundwater was monitored to assess the movement of the plume as the old effluent was displaced by new effluent treated to higher levels. A sampling grid for groundwater screening was developed downgradient of the soil treatment unit A, and 10-foot by 5-foot grid spacing was staked. Transect lines A through S run east-west, roughly parallel to the groundwater flow direction and increase (higher letter identification) moving southward from the STU. Based on initial screening data, 29 monitoring locations were chosen within the grid for standpipe piezometer installation. Groundwater monitoring points were installed in September and December 2012. Two types of monitoring points were installed using either hand or drilling methods: stainless steel drive points and standpipe piezometers. Stainless steel drive points consist of small stainless steel points with 7/8-inch screens connected to polypropylene tubing which extended to the ground surface. Standpipe piezometers consisted of either ¾-inch or 1-inch diameter PVC with a 1-foot or 5-foot screen (0.010-inch slots) and a riser extending to the ground surface (Hazen and Sawyer 2010b, Hazen and Sawyer 2013a).

The site was sampled four times, in January 2013, April 2014, July 2014, and October 2014. The tank-based PNRS had been installed in September 2012. Figure F- 10 shows median nitrogen concentrations compared to specific conductance as indicator of onsite system influence. Concentrations in the groundwater are low. The highest median concentration was observed at location PZ J7-15, about 70 foot downstream of the STU. These concentrations were predominantly TKN, with 17% septic tank effluent fraction estimated. Such results would be consistent with old septic tank effluent that was only half-way nitrified and the nitrate then denitrified. The second highest

concentration was 4 mg-N/L, of which two thirds were nitrate. The location of these observations was PZ-C1, about 10 foot from the STU. This suggests that little, if any, of this nitrogen was left behind from the pre-PNRS treatment. It may reflect additional nitrification of the effluent.

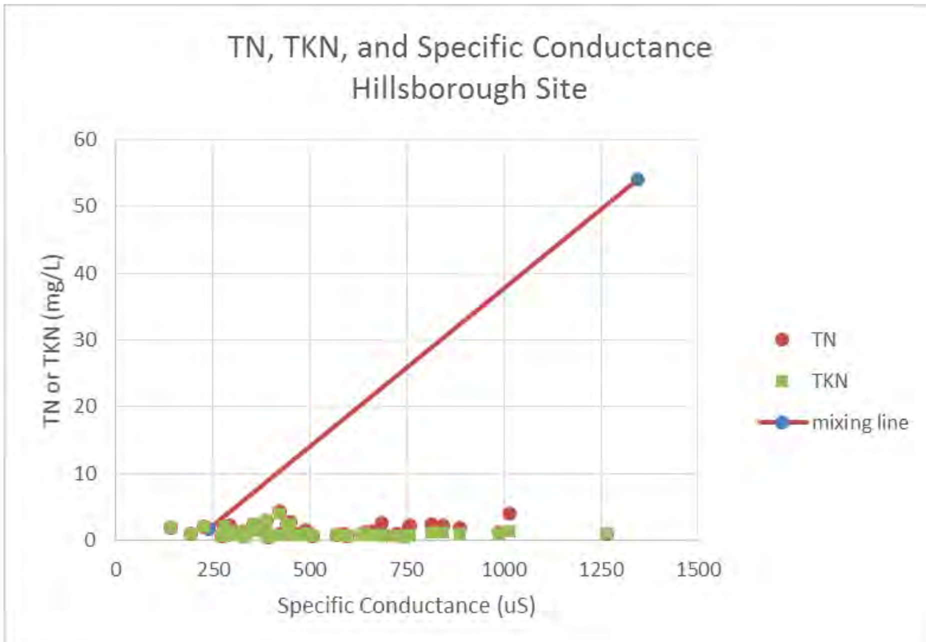


Figure F- 10. Median TN, TKN, and Specific Conductance for the Hillsborough County Site after Installation of a PNRS

Marion Site

One of the in-ground systems consisted of a STU utilizing a low-pressure distribution system. This distribution system dispersed effluent over native soil material that had been excavated and then placed back into the site and compacted. This system (PNRS) was installed in Marion County, Florida in November 2013. It consists of adding a 300 gallon concrete pump tank, low-pressure distribution network, and a lined Stage 1 and 2 STU. The existing 900 gallon dual chamber septic tank continued to provide primary treatment for the new PNRS system.

Household wastewater enters the first chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen. Screened effluent is directed to the pump tank which contains the pump and float switches. Pump tank contents are discharged through a low-pressure distribution network installed inside the Infiltrator EQ36-LPTM chambers alternative STU product. The low-pressure distribution network consists of a central manifold design with (4) 33-foot long, 1.25-inch diameter perforated laterals. The perforations are 0.25-inch in diameter and spaced 3-feet off-center. Below the infiltrators, 24-inches of native soil was installed. Below the native soil, 12-inches of lignocellulosic media was installed above a 30 mil PVC liner with a 6-inch lip around the outer perimeter. Therefore, approximately 6-inches of the lignocellulosic media is saturated, promoting denitrification of the nitrified effluent. The treated effluent is discharged into the soil around the perimeter of the liner. A cross section of the system is shown in Figure F- 11.

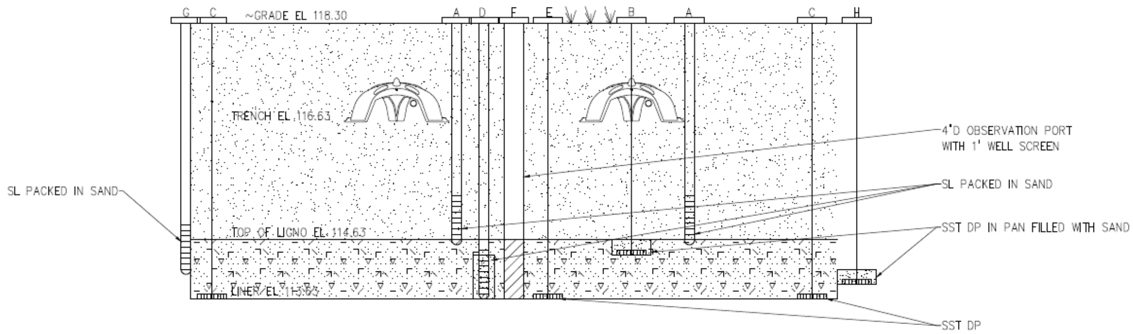


Figure F- 11. Cross Section of Marion County Site STU (Hazen and Sawyer 2014c)

The monitoring included samples from the unsaturated zone below the STU. These samples allow an assessment of the functioning of approximately 24 inches of unsaturated soil. Median results for each monitoring device for TN, TKN, and specific conductance are shown in Figure F- 12. The “stage 1” results stem from the monitoring points labeled “A” in Figure F- 11, nearly directly under the dispersal chambers. The “perimeter” results stem from the monitoring points labeled “G” and “H” in Figure F- 11. TN concentrations are variable between the individual monitoring devices. There appears less dilution (reduction in specific conductance) in these observations than for the groundwater monitoring sites. The results show a largely nitrified effluent, with remaining TKN concentrations between 1.5 and 3 mg-N/L. TN concentration overall reductions vary between 16 and 77% for stage 1 with an average of 45% (adjusted 14-56%). Overall reductions for the perimeter samples vary between 38-84% with an average of 67% (adjusted -3-107%). There are several potentially plausible explanations for the increase in reductions between the stage 1 and the perimeter samples, but this is a question for further analysis.

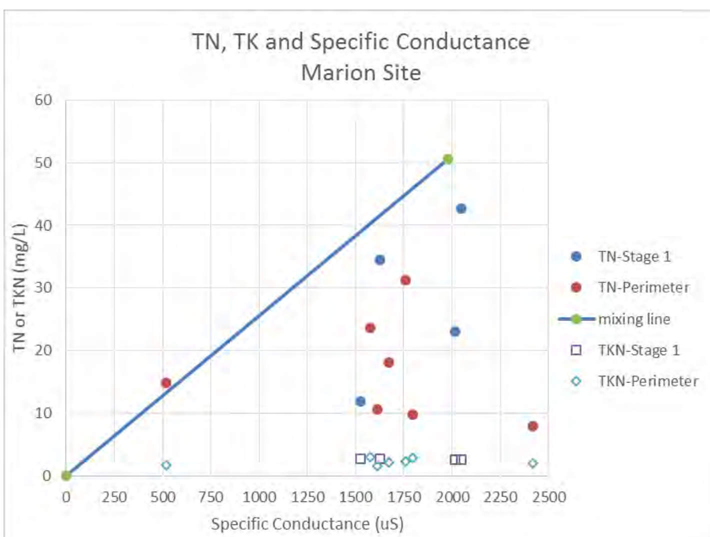


Figure F- 12. Median TN, TKN, and Specific Conductance for the Marion Site, for the Mixing Line a Background Concentration of Zero was assumed

Appendix G. An Analysis of Various Nitrogen Models

Introduction

A review of the literature, the conceptual understanding of the transport of nitrogen as related to OSTDS, and the goals of the project were all taken into consideration in the development of modeling tools. The literature review was intended to identify the state-of-knowledge of nitrogen fate and transport modeling, identify past models that may provide good templates for the model developed by the study, and assist in identifying key parameters and processes that needed to be represented in a predictive tool. The project benefited from being able to build on recent efforts by the modelers to model soil treatment unit performance (McCray et al. 2009). Several initial documents assessed recent literature, and planned the detailed scope of this area of the project (Hazen and Sawyer 2010c). The objectives for the model development were the following:

- Simple soil tool to estimate nitrogen removal in different Florida soils
- Complex soil treatment module for input into the groundwater modeling tool
- Analytical modeling tool to predict temporal and spatial concentrations and fluxes of nitrate in groundwater
- Integration of complex soil treatment module with the groundwater analytical model
- Incorporation of multiple spatial inputs (i.e., development scale model)

Once the models were developed, guidance was developed to determine model input parameters.

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 serve as an educational tool to illustrate the processes involved, to improve the understanding of processes involved by matching data at specific sites of interest, or to be a predictive tool either at a screening level of detail or a site specific level?
- 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 following characteristics were desired for the modeling tools that were developed to simulate nitrogen fate and transport desired, including:

- Ease-of-use;
- Simulation of transport and fate in both the vadose zone (soil) and saturated zones (groundwater);
- Representation of the key advective-dispersive and transformative processes that affect nitrogen transport;
- Simulation of the spatial distribution of nitrogen concentrations and mass loading downgradient of the source;
- Include the impacts of seasonal water table variation on the source function; and
- Incorporate critical OSTDS operating characteristics that strongly influence nitrogen reduction.

Based on the above questions and objectives, a review of available models and model types in the research was conducted and the following conclusions were reached. No simple model identified in the literature could achieve all of the above-described goals. More complex models, for example detailed numerical models, are generally not considered a useful tool where ease of use and broad applicability are desired. But, some models were found in the literature review (nitrate-specific and general analytical solutions) that were appropriate for the modeling tool. These can be programmed into a spreadsheet and can be user-friendly. Members of the project team had previous experience with the implementation of such a spreadsheet approach to develop a nitrogen transport model for the soil underneath a STU.

The literature review suggested the most important processes and parameters to consider during the modeling tool development. This conceptual model simplified the complexity of the processes in order to keep the complexity of the model manageable.

One simplification was to have the model run as a steady-state. For a given model run, processes have come to a balance, so that no changes over time are occurring during the model run (steady-state). This represents some averaging of conditions over time, such as a season. The effect of slowly changing conditions, such as seasonal water table changes, can be represented by a series of model runs.

Another simplification to help with the modeling effort was to include only the two most common nitrogen compounds, ammonia and nitrate. The fate and transport of nitrogen compounds is a result of advective movement (movement with the water), dispersion (movement driven by concentration differences), retardation via adsorption, and the transformative processes of nitrification (from ammonia to nitrate) and denitrification (removal of nitrate).

The availability of oxygen influences the nitrification and denitrification reactions. The inclusion of this component would have made the model too complex. Instead, the availability of oxygen, which is predominantly transported through the soil air, was described by the influence of water saturation in the soil on the reaction rates. Higher water saturation corresponds to lower air content, which reduces oxygen-dependent nitrification and increases oxygen-inhibited denitrification.

These processes were described in the model tools by a set of equations. These equations employ parameters to characterize the soil and groundwater. Key parameters for simulation included:

- 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.

The parameters are uniform within a region of the model. The regions were the unsaturated soil, with some consideration of layers, and the groundwater or saturated zone. A majority of the site-specific parameter values needed for model input could be collected during site characterization. The model parameters represent some average or representative values to describe the variable reality in the simplified model.

Even if site-specific values are obtained, uncertainty from measurement and subsurface variability remains. In a previous study by members of this project team (McCray et al, 2010), cumulative frequency distributions (CFD's) were utilized for the estimation of initial parameter values from literature values. This approach recognizes that there is uncertainty in the model output and allows quantification of the degree of uncertainty.

Initially, the properties of common Florida soils were analyzed, in particular texture and water retention capacity. This allowed a broader and less site-specific characterization of soils and simplified modeling analyses.

In the end, a combination of approaches were used in the development of the modeling tools:

The first nitrogen model approach consisted of the adaptation of an existing detailed numerical model to simulate nitrogen transport in two dimensions in the vadose zones. Results from a set of scenario simulations of this complex model were then incorporated into a look-up table as a very easy-to-use model.

The second modeling approach consisted of the further development of a one-dimensional vertical transport model that describes the transport from the infiltrative surface of the STU through the unsaturated soil (vadose zone). Adaptations included the consideration of layers and a shallow groundwater, as well as a characterization of Florida soils to obtain model parameters. One product of this approach was a set of graphs that describe nitrogen reduction with depth.

The third modeling approach (groundwater transport model) was based on a set of equations that describe nitrogen transport and removal in groundwater. The groundwater module describes horizontal transport with the groundwater flow and some spreading in lateral and vertical direction. The flow of groundwater is assumed to be horizontal through uniform material that behaves like sand. Therefore, this model is not well suited for transport in karst areas, or high recharge areas. In such areas, vertical flow directions and flow through conduits make the transport more complex.

Subsequently, the soil treatment module was integrated with the groundwater transport module. In its final form, the model had the capability to either model only the vadose zone, only model the groundwater, or model the transport of nitrogen through both the vadose zone and groundwater.

Modeling approach for soils

Grouping Florida soils

Site-specific soil characterization is costly. One goal of the modeling efforts was to provide results for typical Florida soils. In order to obtain representative soil water transport parameters, project researchers analyzed soil survey information. The results of this analysis lead to the determination that a grouping of Florida soils into three soil types for modeling purposes would cover a range of likely situations: more permeable sands (MPS), less permeable sands (LPS), and sandy clay loam (SCL). Parameter choices were based largely on previous research, with some corroboration to data sets

obtained during this study (Hazen and Sawyer 2013c; McCray et al. 2010).The result of this grouping for Florida soils in which OSTDS are frequently installed is shown in Table G- 1. Obviously, the grouping focuses on the similarity between soils and does not consider the differences. The same analytical effort also resulted in a list of soil parameters for each of the reviewed soils.

Table G- 1. Soil Series Grouping Into More and Less Permeable Sands (Hazen and Sawyer 2013c)

Soil Series	Grouping	Soil Series	Grouping
Adamsville	more permeable sand	Myakka	more permeable sand
Albany	less permeable sand	Oldsmar	more permeable sand
Alpin	less permeable sand	Ortega	more permeable sand
Apopka	more permeable sand	Otela	less permeable sand
Arredondo	less permeable sand	Paola	more permeable sand
Astatula	more permeable sand	Pineda	more permeable sand
Basinger	more permeable sand	Placid	less permeable sand
Blanton	less permeable sand	Plummer	less permeable sand
Bonifay	less permeable sand	Pomello	more permeable sand
Candler	more permeable sand	Pomona	less permeable sand
Eau Gallie	more permeable sand	Riviera	less permeable sand
Felda	less permeable sand	Rutledge	less permeable sand
Floridana	less permeable sand	Sapelo	less permeable sand
Holopaw	less permeable sand	Smyrna	more permeable sand
Immokalee	more permeable sand	Sparr	less permeable sand
Lake	more permeable sand	St Lucie	more permeable sand
Lakeland	more permeable sand	Tavares	more permeable sand
Leon	more permeable sand	Troup	less permeable sand
Malabar	more permeable sand	Wabasso	less permeable sand
Millhopper	more permeable sand	Zolfo	more permeable sand

Look-up table based on two-dimensional model

Information from the literature review and some of the sample results collected during this project, were used for the adaptation of a numerical model (HYDRUS-2D developed by Šimůnek et al. 1999) to develop and corroborate a model for nitrogen fate and transport through the unsaturated soil to groundwater. A range of scenarios were simulated to obtain estimates of nitrogen removal based on the model. Results of this effort were used to develop a series of look-up tables based on illustrative simulations, such as the one shown in Figure G- 1. These simulation results can be used to evaluate different combinations of variables such as STU configuration, water table elevation, input nitrogen concentration, and wastewater loading consistency.

Figure G- 1 shows a trench system configuration in less permeable sand. The water table is 60 cm (2 feet) below the infiltrative surface of the trench. The upper part of the figure shows moisture content.

The moisture content is not influenced much by the trenches. Even though the water table is 2 feet below the trenches, high moisture content in the capillary fringe, extends nearly a foot higher. The middle and bottom figures show ammonium and nitrate concentrations, respectively. With a 2-foot separation from the water table ammonium is converted to nitrate very quickly. This process requires low moisture conditions. Farrell et al. (2014) found that the potential for high denitrification rates in native soils from the pilot test facility site at GCREC was greatest with non-nitrified septic tank effluent at a depth of 0-1 cm below the infiltrative surface. The model shows little nitrate reduction at this depth because ammonia, not nitrate, is most available. Nitrate concentrations show a decrease in the high moisture region close to the water table. As moisture increases, the modeled denitrification rate increases.

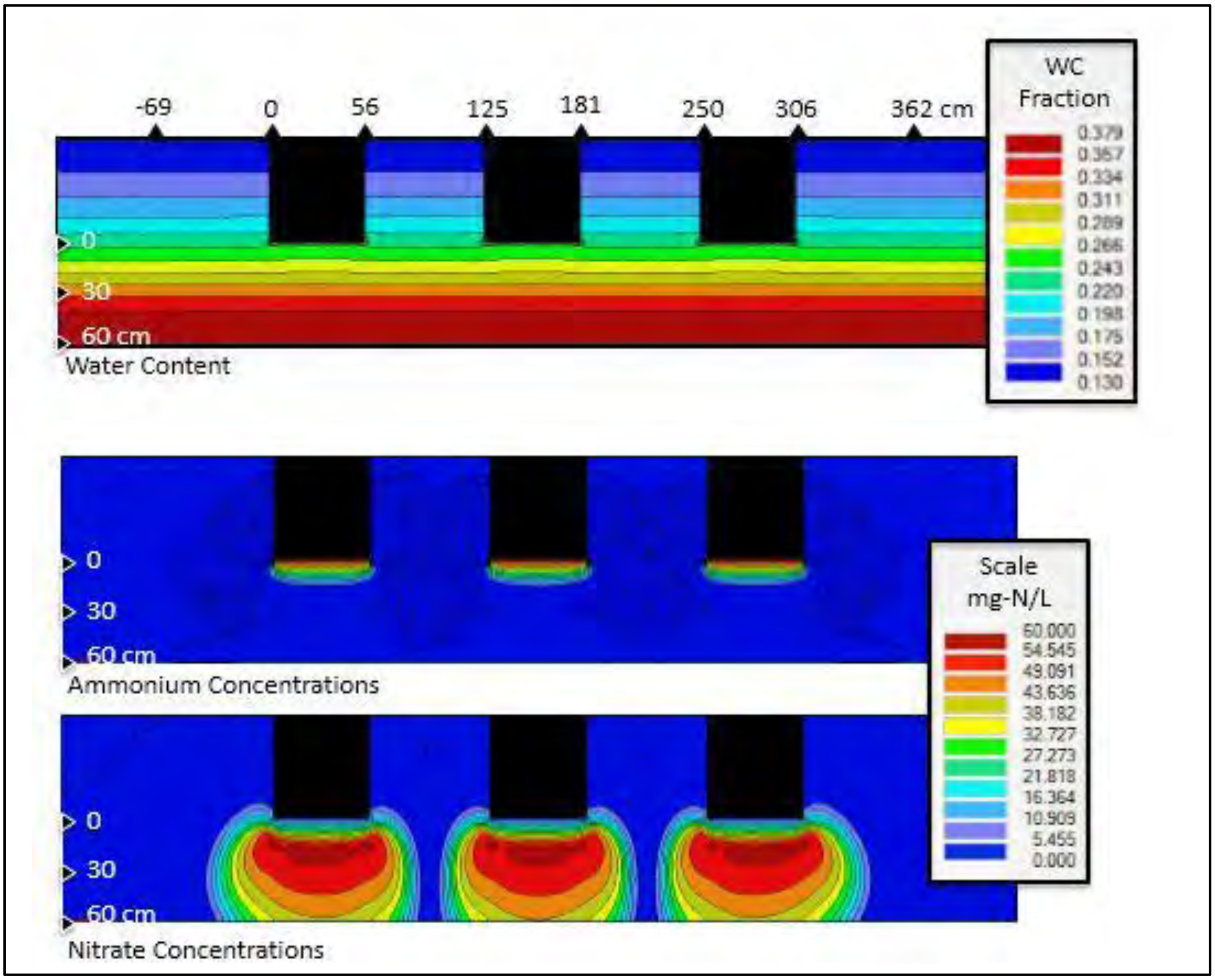


Figure G- 1. Vadose Zone Model Example Showing Ammonium and Nitrate Concentrations under an Equally Loaded Trench Configuration with a Groundwater Elevation of 60 cm under the Bottom of the STU in Less Permeable Sand (Hazen and Sawyer 2013c)

Results of one-dimensional soil model (STUMOD-FL)

The model was originally developed at the Colorado School of Mines through support from the Water Environment Research Foundation (WERF) and was called the Soil Treatment Unit Model, or STUMOD (McCray et al. 2010; Geza et al. 2013). This modeling tool is considered one-dimensional vertical transport and transformation (chemical and physical) of water and nitrogen 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. In the final implementation, the model allowed for inputs for multiple OSTDS with varying soils. This model was modified through this project to include Florida specific soil and climate conditions. This new version was called STUMOD-FL and is based on the principles of water movement and contaminant transport. The one-dimensional model was used to estimate nitrogen removal for a range of scenarios. Detailed discussions are found in the reports for Task D10 (Hazen and Sawyer 2014b).

An example of the results from this model is shown in Figure G- 2. The results are for a water table located two feet below the infiltrative surface. The line colors represent different soil textures. For each color, different load configurations are included (trenches and beds, equal or unequal distribution). The TN concentration in septic tank effluent is assumed to be 60 mg/L, therefore this is where all lines start at the infiltrative surface. With increasing depth (to the right), concentrations are reduced as a result of the combined effect of nitrification and denitrification.

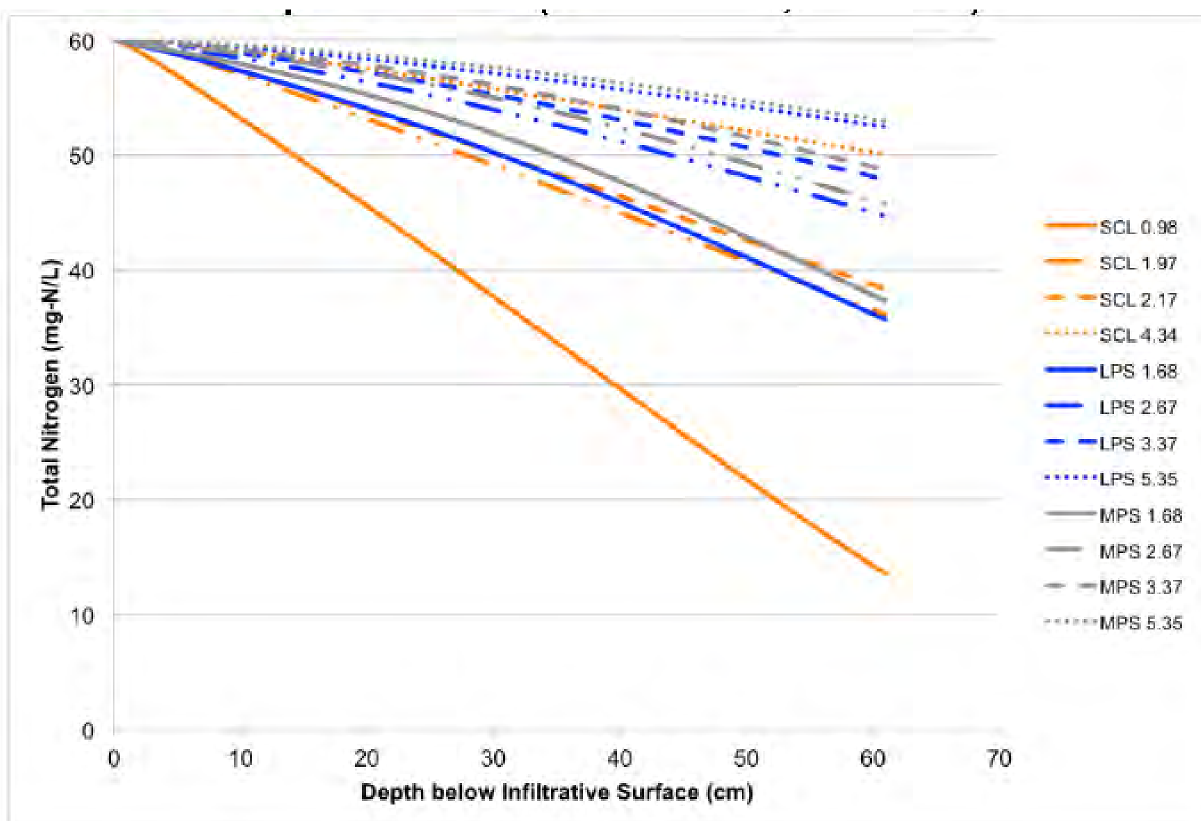


Figure G- 2. Example of Graphical Summary of One-Dimensional STUMOD-FL Estimates of TN Reduction (Hazen and Sawyer 2014b)

Comparison of one-dimensional and two-dimensional model

The two tools discussed previously (look-up table based on two-dimensional model, and graphs based on one-dimensional model) provide estimates for the same scenarios. This allows for a comparison between the tools. This provides an opportunity to gain insights, such as which predictions should be considered more uncertain than others. In addition, the comparison may provide an indication of how important the consideration of two-dimensional transport is.

The tools provided nitrogen reduction estimates for nitrogen from septic tank effluent for three uniform soils (more permeable sands, less permeable sands, and sandy clay loam) at three elevations (one, two, and six foot below infiltrative surface) for four water table scenarios (one, two, six foot below infiltrative surface, and deep water table or free drainage), and four load distribution configurations (equal and unequal trench and bed distributions, respectively). Figure G- 3 compares the results of the two-dimensional approach (HYDRUS-2D) with the results of the one-dimensional approach (STUMOD-FL).

A few observations are:

- Most removal estimates are between 0% and 50%. Higher estimates are generally for sandy clay loam.
- Most comparisons show a high correlation (R^2>0.8). The exception to this is the comparison for the six foot water table depth (R^2>0.57). In some comparisons, the STUMOD-FL reduction estimate tends to be higher, in others it tends to be lower. Overall, the correlation is (R^2=0.85).
- The differences tend to be largest when the water table is at the depth of measurement. One explanation for this could be that the high moisture content in the capillary fringe causes the denitrification reactions to increase. This in turn leads to rapid changes in concentration with depth. Small differences in simulated travel times may have a large impact on estimated reductions.
- Comparisons for a given depth with the water table either at that depth or below illustrate how important the moisture-rich capillary fringe just above the water table is for estimates of nitrogen reduction. The average contribution of the capillary fringe is consistent between one- and two-dimensional models. For assessments at two feet below the STU, a capillary fringe provides about 16% nitrogen removal. In contrast, for assessments at six feet below the STU, a capillary fringe provides about 20-25% nitrogen removal. These estimates vary considerably, depending on the scenario.

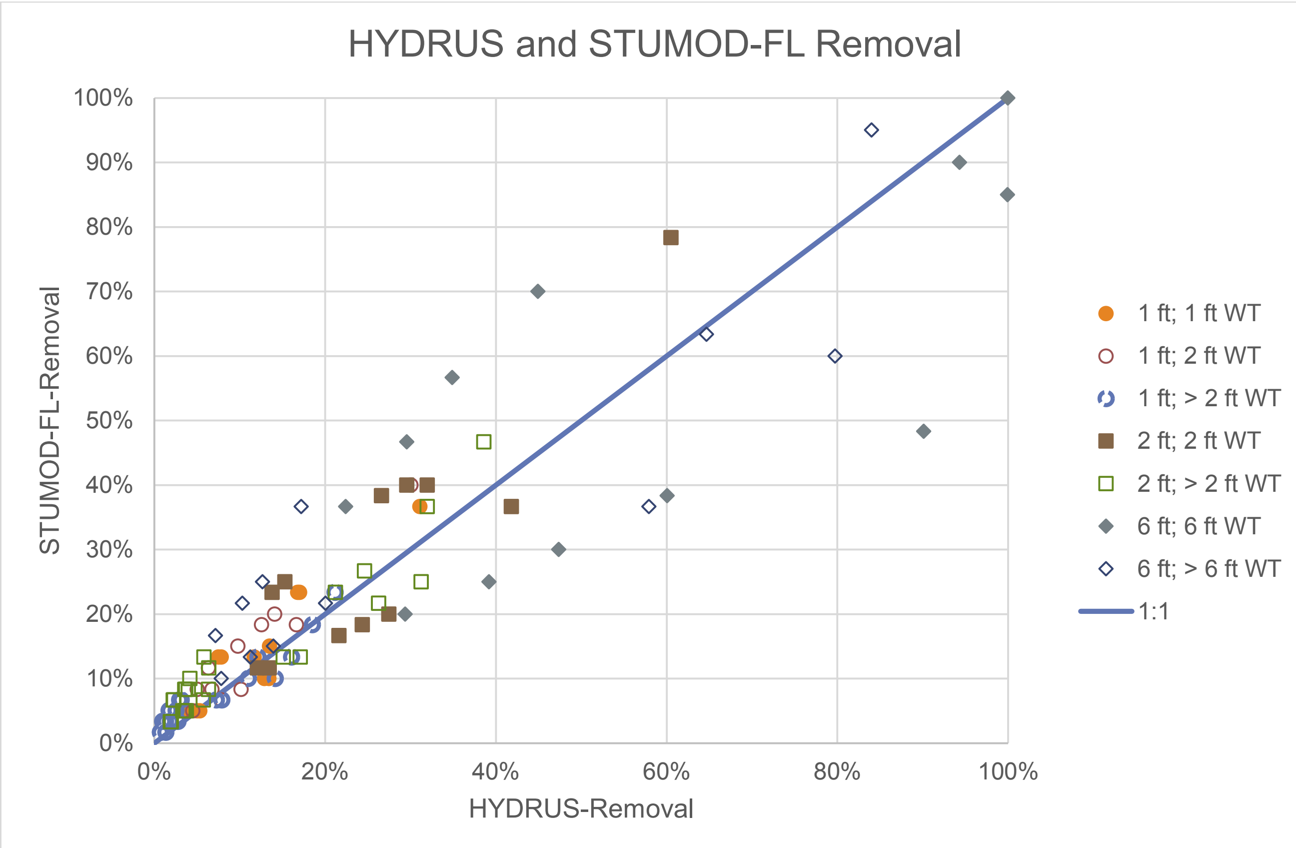


Figure G- 3. Comparisons of Nitrogen Reduction Estimates Using Two Modeling Tools: The Two-Dimensional Modeling Represented by Hydrus-Removal and One-Dimensional Modeling Results Represented by STUMOD-FL (Comparisons are Grouped by Depth Below STU (First Number) and Water Table Depth Below STU (Second Number))

Comparison to denitrification potential estimates by Otis (2007)

In 2007, Otis (2007) estimated nitrogen reduction or denitrification potentials for soils in the Wekiva Study Area. This estimation approach was based on a literature review and his expert judgement. It included consideration of form of applied nitrogen, texture, drainage class, and carbon content. The availability of a look-up table based on HYDRUS simulations invites a comparison between the results of the two approaches.

For this comparison several steps were required: 21 soil series were in common between the two assessments of soils. Otis (2007) provided a range for his estimates. For the look-up table, the range of loading considerations for a given texture-depth/water table depth combinations was used. Otis (2007) distinguished between TKN and nitrate discharging to the soil, which was important in particular for the wetter conditions. For purposes of comparison, the presence of a mound system that converts the effluent-nitrogen into nitrate was assumed. To compare to the modeling tools developed in the course of this study, drainage class was approximated by the depth to water table. For well to excessively well

drained soils, the reduction at six foot depth for free drainage condition was the point of comparison. For moderately drained soils, the reduction at six foot depth with a water table at six foot was used. For wetter soils the reduction at two foot depth for a two foot water table was the reference condition.

Figure G- 4 shows the comparison. The figure shows fewer than 21 points because several soils have identical estimates. For reductions up to 60% there appears to be a reasonably good agreement between the two approaches. Otis' higher estimates for poorly and very poorly drained soils are consistently higher than the look-up table estimates. Both approaches result in complete nitrification (assumed by Otis (2007), modeled by HYDRUS (see Figure G- 1). This indicates that the difference is in the extent of denitrification. Otis (2007) assumed more rapid denitrification in some soils, in part by considering the availability of organic carbon in the soil profile. The denitrification rates in the look-up table were constant between various runs, and did not distinguish between a water table located two feet below the infiltrative surface of a mound (poorly or very poorly drained soil) or of a subsurface system. Another reason for the difference could be that Otis (2007) included the experience with the sampling of shallow groundwater in the reduction estimate. In this case, his estimate would include denitrification in deeper areas (groundwater) that are not included in the modeling for the look-up table. The observation of larger differences between different approaches when a water table is involved is similar to what the comparison between one-dimensional and two-dimensional simulations showed.

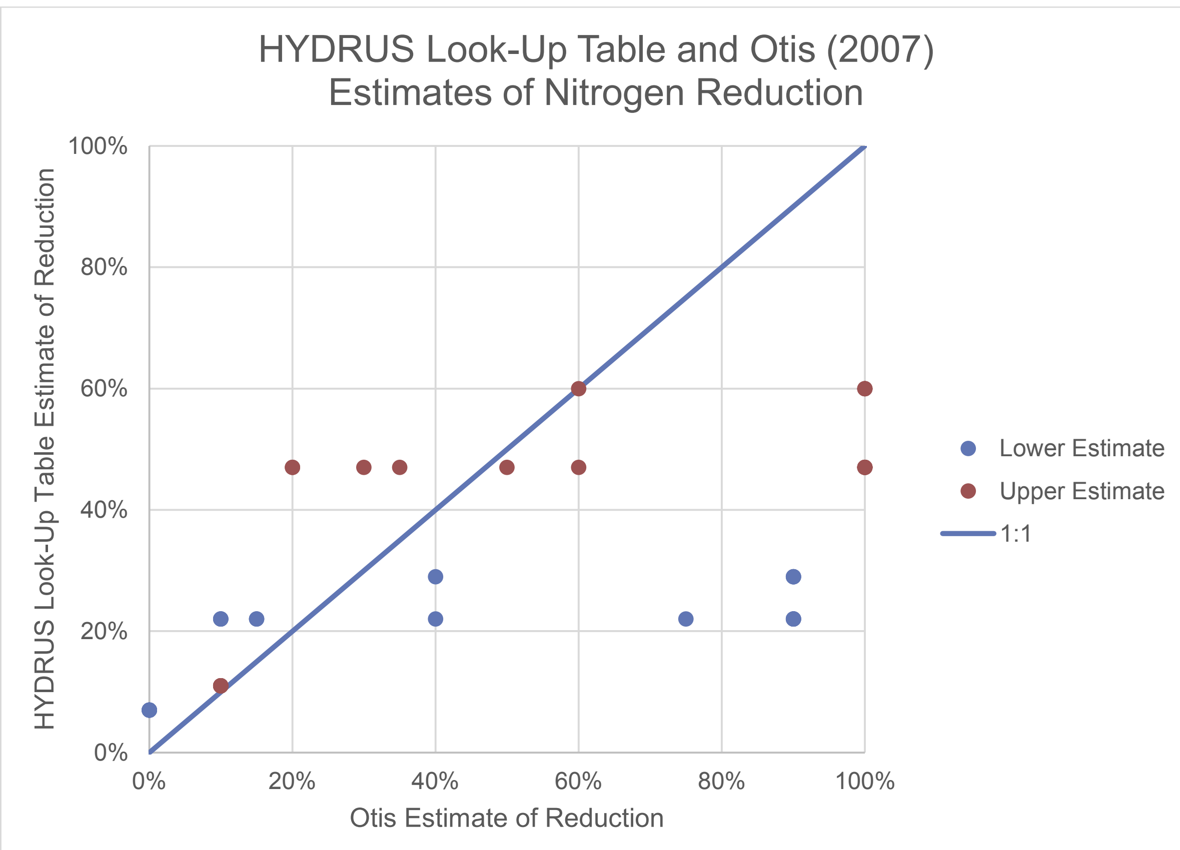


Figure G- 4. Comparison of Soil Nitrogen Reductions Estimated by Otis (2007) and from the HYDRUS Look-Up Table Developed as Part of this Study

Comparison to sampling data

The monitoring results from the field sites allow a comparison with the modeling results for transport through the soil data. The monitoring occurred predominantly in the shallow groundwater. Additional reduction and dilution may have occurred in the shallow groundwater. In this way, the measured groundwater concentrations represent a lower bound to the concentration arriving from the STU through the soil and an upper bound to the nitrogen reduction occurring in the soil. Table G- 2 compares the nitrogen reduction estimates from field sites to estimates from the look-up table based on two-dimensional modeling.

Overall concentration reduction estimates that include dilution and denitrification or other removal processes are generally higher than the adjusted reduction estimates that subtract dilution. Dilution is not a removal process and is not included in the current model runs. The least amount of dilution was observed in the lysimeters in the Marion County site. This is consistent with the understanding that dilution occurs by groundwater that flows underneath a STU.

In three of five plumes are the adjusted groundwater reductions estimated based on concentrations in the core of the plume indicating less removal than the look-up tables. In the Seminole TKN-plume the look-up table estimate is lower than the dilution-adjusted measurement. In this case it is plausible that additional denitrification is occurring in the shallow groundwater upstream of measuring points while the model assumes it to occur only in the capillary fringe. This mechanism was discussed above as addressing the discrepancy between some of Otis' (2007) nitrogen reduction estimates and model results. More detailed measurements would help to address this further. In the Wakulla system, measurements consisted of a single groundwater sample. The heterogeneous layering of soil textures at this site were likely not adequately represented by the model run.

Lysimeter adjusted reductions are most variable. This is consistent with higher variability in the vicinity of the relatively small lysimeters with a small sampling volume. In the Wakulla case the lysimeters, but not groundwater measurements, showed a very high concentration reduction, with variable dilution. In the Marion case, the measurements were variable, with less dilution. Estimates of nitrogen reduction based on the measurements are far higher than look-up table estimates for a deep water table. The look-up table comes closer to measurements when one treats the capillary barrier between fine sand and the treatment media as a shallow water table.

These comparisons are only based on the look-up tables. Closer agreement could likely be achieved with some site specific calibrations of the one-dimensional tool. A detailed corroboration of HYDRUS with field data is included in the D7 report.

Table G- 2. Comparison between Nitrogen Reduction Estimates at Field Sites and Estimates from Hydrus Look-up Table, the Lysimeters Take Samples in the Unsaturated Soil above the Groundwater and Groundwater Reductions are based on Samples with the Highest Concentrations in the Shallow Groundwater Plume

Site		**Polk**	**Seminole**		**GCREC Mound**	**Wakulla**	**Marion**
Soil Series		Tavares	Myakka/Eaugallie/St Johns		Seffner	Moriah/Pilgrims	Candler Sand
Texture		fine sand	fine sand		fine sand	fine sand over clay/rock	fine sand
			(TKN plume)	(NO3 plume)			
Lysimeter reduction	Overall					93-96%	16-77%
	Adjusted					28-104%	14-56%
Groundwater reduction	Overall	46%	85-88%	65-67%	40-50%	67%	
	Adjusted	0%	29-53%	-3-2%	0%	25%	
HYDRUS reduction	Case	6 ft; > 6ft WT	6 ft; 6 ft WT	6 ft; 6 ft WT	6 ft; 6 ft WT	layered-6 ft	2ft > 6ft WT /2 ft; 2 ft WT
	Lower	7%	22%	22%	22%	44%	3%
	Upper	11%	47%	47%	47%	89%	24%

Nitrogen transport in groundwater (STUMOD-FL-HPS)

A spreadsheet model for groundwater transport of nitrogen from OSTDS was further developed to simulate nitrogen transport through the soil and in shallow groundwater (Hazen and Sawyer 2015d). Figure G- 5 shows the user interface of this model.

The modeling tool built on the one-dimensional soil transport model discussed before. It was implemented in a spreadsheet while maintaining simple and straight-forward input requirements. For groundwater transport, a horizontal plane source (HPS) was used as conceptual model. In this model, the nitrate arriving from the STU (either from the soil model or input directly) is spread out over some rectangular area (e.g., the STU area) and enters the groundwater at the water table. From there, the transport follows groundwater flow horizontally with dispersive spreading vertically and laterally. The model calculates the mass flux and concentrations of nitrogen downstream at a specified distance from one or multiple sites.

The model assumes that the vertical and subsequent horizontal transport of nitrogen from one system does not interact with that from the other system. Nonetheless, the model allows for the assessment of multiple OSTDS, which may have value when simulating the impact of several OSTDS in a potential housing development.

This easy-to-use tool was based on a complex model. This increased the applicability of the model while maintaining an adequate ability to predict contaminant fate and transport. With such a model, barriers to understanding and steep learning curves are lessened. The tools developed can be employed by users with various levels of expertise to quantify vadose and groundwater transport from OSTDS. This model can be combined with other models and tools to allow for a refinement of nitrogen loading estimates for specific remediation areas.

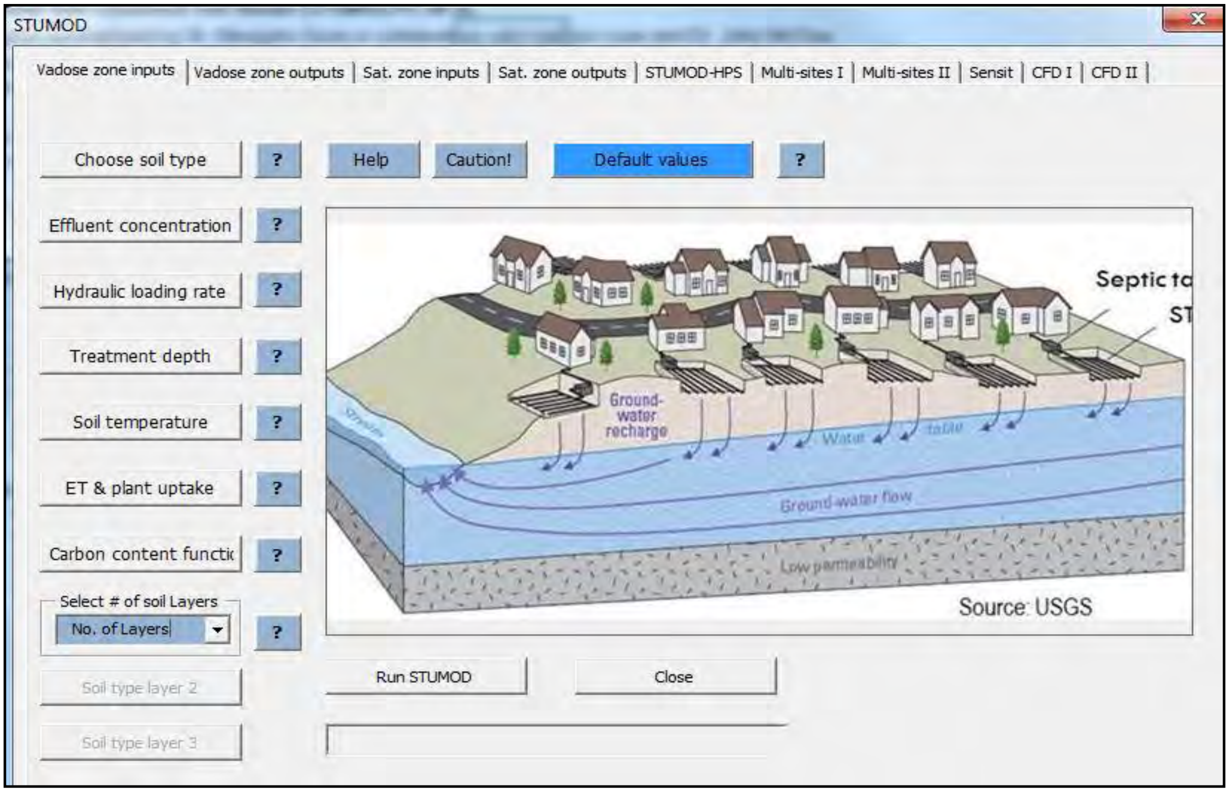


Figure G- 5. User Interface of Nitrogen Fate and Transport Model for Estimating Nitrogen Contribution from OSTDS (Hazen and Sawyer 2015d)

Model application

The combined soil and groundwater model was applied to the plume from the mound at the GCREC site (Tonsberg 2014). The following is an excerpt from the Task D 12 report (Hazen and Sawyer 2015c), which discusses the application. The GCREC, located in southern Hillsborough County Florida, approximately 30 miles from the city of Tampa. It serves as an agricultural research center for the University of Florida and has numerous agricultural demonstration plots located around the facility. The facility has office and research laboratory space where approximately 71 people work. A large mound OSTDS designed for flows of 2,500 gallons per day serves the facility and receives primarily domestic wastewater from the offices. The OSTDS was constructed approximately 6 years prior to the sampling campaign, which is sufficient time to approach steady state conditions in the soil treatment unit.

The GCREC mound OSTDS design hydraulic loading rate was 0.65 gal/ft2/d (2.65 cm/d), however based on a slightly larger infiltrative surface of 4,800 ft^2, the effective design HLR was 0.59 gal/ft^2/d. Review of flows to the mound (to each half and the combined total flow), suggest that the actual median HLR was 0.46 - 0.49 gal/ft^2/d (average HLR was 0.54 - 0.57 gal/ft^2/d). The infiltration area where effluent is dispersed is approximately 82 by 115 feet in dimension. Effluent is applied via low pressure dosing in an alternating pattern to half of the infiltrative area at each dose. The infiltrative area is elevated approximately 4-5 feet above the surrounding land surface. This ensures that an unsaturated region exists beneath the infiltrative area even during high groundwater table conditions.

Twenty-two piezometers were installed in the surficial aquifer in the area surrounding the OSTDS for the purposes of this study. The piezometers have been used to collect hydraulic head measurements beginning about March 2009 through July of 2013, or approximately 4 years. In addition, groundwater sampling points consisting of a stainless steel drive point and screened body connected to ¼-in. tubing were driven into the surficial aquifer at multiple depths on a grid pattern downgradient of the mound. These drive point samplers function in a manner similar to multilevel piezometers and allow groundwater samples to be drawn from multiple depths; sampling locations however cannot be used to measure hydraulic head. There are 118 groundwater sampling locations installed in the surficial aquifer.

Groundwater samples were collected on four occasions: December 2010, April 2011, June 2011 and September 2011. Groundwater quality was not monitored throughout the entire study period due to budget limitations. Groundwater samples were analyzed for various constituents including nitrate, nitrite and ammonium. Concentrations of nitrate and nitrite were reported as a sum of the NOx species. For the purposes of model calibration, the reported NOx as nitrogen concentrations were assumed to be representative of nitrate because nitrite is relatively unstable in the natural environment and is readily converted to other forms of nitrogen (Tan, 1998). This assumption was verified by a group of samples where both nitrate and nitrite concentrations were reported all of which contained very small amounts of nitrite, less than 0.3 mg-N/L. Nitrification as well as ammonium transport were not considered during the corroboration of the aquifer model. The reported ammonium concentrations in groundwater samples did not exceed 3 mg-N/L and the mean concentration was 0.12 mg-N/L (see Section 4.1.3) indicating that the majority of nitrogen exists as nitrate within the surficial aquifer.

Figure G- 6 shows the situation of the GCREC site, with the location of the STU, the monitoring points and the estimated extent of the nitrate plume.

The area in Figure G- 7 was determined to be part of the OSTDS effluent plume based on elevated specific conductance. A limitation of the method is that it does not account for dilution that would reduce the specific conductance of the groundwater and may cause omission of some OSTDS plume data in the evaluation. Vertical hydraulic gradients and water table fluctuations that cause mixing of the OSTDS and agricultural plumes also make it difficult to locate the vertical extent of the OSTDS effluent plume. It is highly likely that this location is variable throughout the aquifer due to water table fluctuations.

Therefore, the data within the area marked in Figure G- 7 were used for model calibration and evaluation of the aquifer model. Other data from piezometers and drive points outside of the delineated plume were not used. Approximately a third of the groundwater samples that were collected were identified as pertaining to the OSTDS effluent plume using this method. The mean nitrate concentration for these samples is slightly higher than for the complete data set while the standard deviation also

increases. This indicates that there is a large variation in the observed nitrate concentration even within the area that is speculated to be directly affected by OSTDS effluent.

The aquifer model constructed for calibration requires nitrate loading data at the water table below the infiltrative area. Nitrogen transformation and attenuation occurs within the STU and heavily controls the mass flux of nitrogen to groundwater. Nitrate mass flux to groundwater was estimated using STUMOD-FL nitrate concentration predictions. Ammonium input concentrations to STUMOD-FL were assumed to be equivalent to what was observed in the septic tank effluent samples from the field site. Parameter values and other site specific conditions were input into STUMOD-FL for each simulation. Because the NRCS soil survey for the area indicates a transition between Zolfo and Seffner sands within the field site, STUMOD-FL simulations were conducted using two groups of parameters representative of the more permeable sand and less permeable sand for a total of 12 STUMOD-FL simulations. These results were initially used as direct inputs for nitrate loading for the aquifer model during calibration. The input concentration was later modified to 25 mg-N/L.

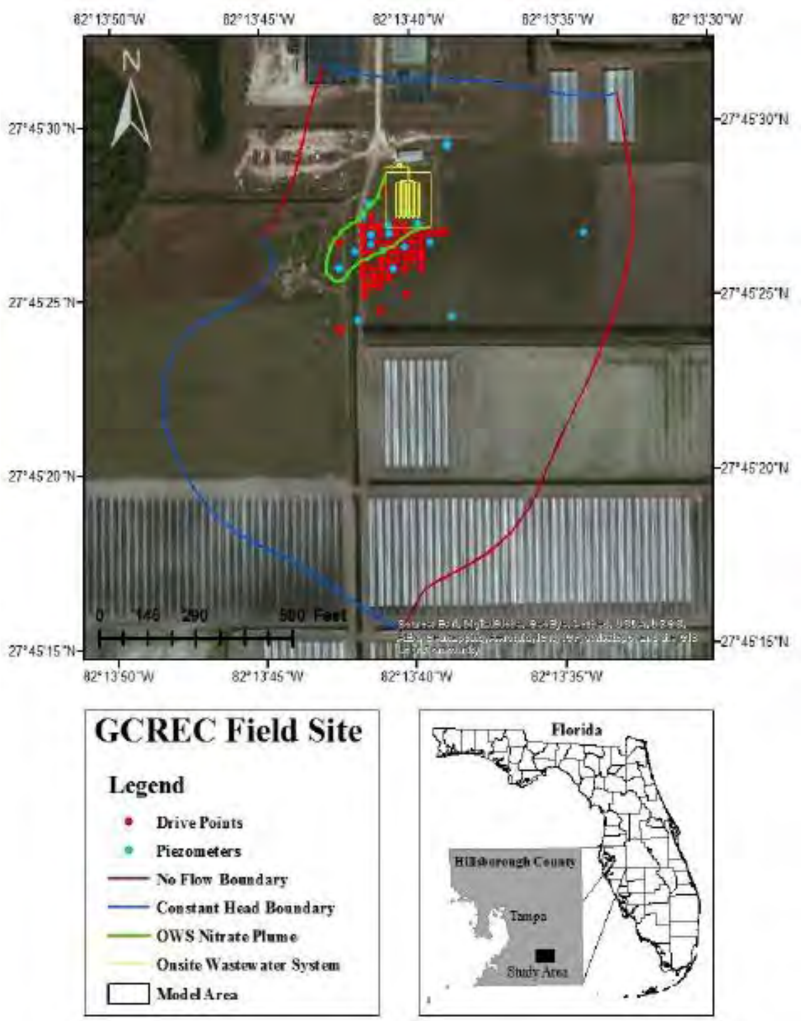


Figure G- 6. GCREC Field Site Layout (Hazen and Sawyer 2015c)

Figure G- 7. Method Used to Estimate X, Y, and Z Values Required by the Aquifer Model to Calculate Concentration (Hazen and Sawyer 2015c)

The aquifer model calculates nitrate concentration as a function of time and position using three dimensional Cartesian coordinates. The time component is assigned a large value to approximate steady state conditions. The estimated groundwater seepage velocity at the GCREC site is 49 m/yr and given that the mound at the GCREC had been in operation for 6 years prior to the commencement of this study, a steady state assumption is appropriate.

The three dimensional position where each groundwater sample was obtained was estimated as the distance between the center of the infiltrative area and the position of the drive point or piezometer. The distance in the 'X' direction was estimated as the distance along a centerline drawn from the center of the infiltrative surface to a point adjacent to the sample location. The distance 'Y' was estimated as the distance from the sample location to a point on the centerline creating perpendicular lines. The 'Z' distance, or depth below the water table, was calculated as the distance between the observed hydraulic head and the piezometer screen. This distance was estimated for groundwater sampling wells as the difference between an interpolated water table created using the average observed hydraulic head and the drive point location. This method was used to calculate the position of the 33 nitrate observations that were used for calibration of the aquifer model. Estimation methods for parameters of the model are further discussed in the report.

Adequate calibration results could only be obtained by increasing the input nitrate concentration at the water table. Reasonable results were achieved with an input nitrate concentration of 25 mg-N/L, slightly higher than the maximum value of 21.7 mg-N/L predicted by STUMOD and the observed results (19 and 20 mg-N/L) in PZ-25. The results from this calibration are presented in Figure G- 8, which contains 23 of the 33 observations.

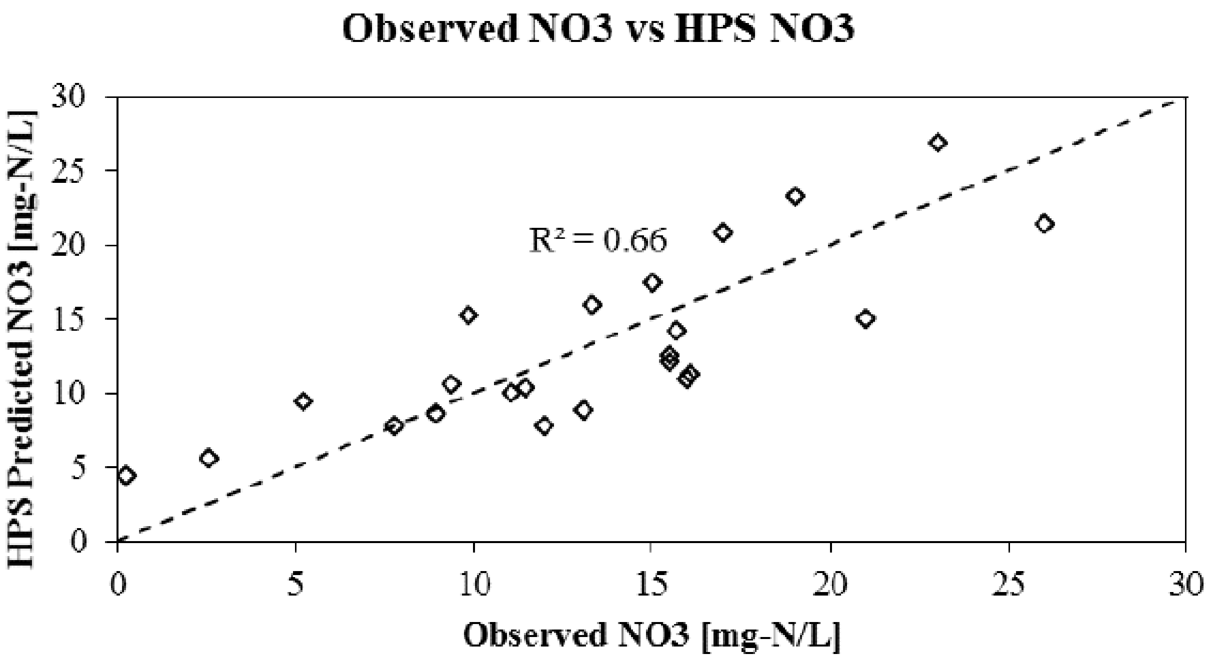


Figure G- 8. Aquifer model calibration results for the 23 observations (subset of complete observations determined to pertain to the mound nitrate plume) (Hazen and Sawyer 2015c)

Calibration of the aquifer model to the observed field data for nitrogen concentration was successful, achieving an R^2 of 0.66. However, 10 of the 33 observations produced relatively large residuals and were removed from the final calibration results because these points appeared to be heavily influenced by the agricultural nitrate plume. These observations were located relatively further off the plume centerline than other observations. Residuals for these 10 points, calculated as the difference between model predictions and observations were all less than zero except for one point. These observations, however, could be adequately fit by the aquifer model by increasing the input nitrate concentration above 60 mg-N/L (note, TN concentration in PZ-25, located within the mound, was observed to be <25 mg-N/L in SE2 and SE4). Because more mass was needed to fit these observations than existed in the observations, it was concluded that these observations were more closely related to the observations of the agricultural nitrate plume.

Three additional calibration approaches were investigated. Notably, the first order denitrification coefficient for all calibration attempts (either 23 or 33 observations) was small while the horizontal and transverse dispersivity value for the calibrations with the 33 observations were generally higher. However, an independent evaluation of the denitrification potential of soils collected at the GCREC field site concluded that it was exceedingly low (~0.002 mg-N/d per L of pore volume) affirming the conclusion from model corroboration (Farrell, 2013; Farrell et al., 2014).

While the limitations of the aquifer model should be considered, they do not preclude the usefulness of model estimates. During model corroboration it was concluded that denitrification was not as low as

estimated by the aquifer model via calibration, though it was likely limited within the area monitored at the GCREC mound. An independent evaluation of the denitrification potential of soils collected at the GCREC site concluded that it was exceedingly low, affirming the conclusion from model corroboration (Farrell 2013; Farrell et al., 2014). Estimates of transverse horizontal dispersivity were likely less than reported from calibration of the aquifer model. This illustrates that the aquifer model is a versatile and powerful tool but that it does have limitations that should be recognized before using the model.

Arc-NLET and STUMOD-FL-HPS

Parallel to the groundwater nitrogen transport model developed as part of this project, the Florida Department of Environmental Protection has funded development of a nitrogen transport modeling tool kit (Rios et al. 2013, Wang et al. 2013). The modeling is incorporated in a geographical information system (GIS) environment, leading to the name ArcGIS-based Nitrogen Load Estimation Toolkit (ArcNLET). The toolkit allows estimation of nitrogen transport through the soil (VZMOD, Wang et al., 2012). This module incorporates the same processes as STUMOD. The transport of nitrogen in the groundwater is approximated with a vertical plane source. In this model, the effluent plume from the STU is mixed across a certain depth and width of the groundwater at an initial concentration. While it is convenient to assume that the concentration reaching the water table from VZMOD is the same as the initial concentration spread over the vertical plane source, this can result in over- or under estimates of the intended mass loading from the system. The transport then occurs in the direction of groundwater flow horizontally and the thickness of the plume remains constant, while spreading some in lateral direction.

Several features of ArcNLET are useful for watershed assessments. The GIS-environment allows import of various layers of information, such as terrain elevation, soil survey data, location of water bodies and location of parcels that are served by OSTDS. Through several graphical preprocessing steps the model establishes flow paths and flow velocities from each assumed OSTDS to a water body. This set of flow paths is not strictly a groundwater water flow model because it does not consider water balances, but it functions as one in the sense that it provides flow directions and velocities at each point of the watershed for use by the groundwater transport module. The concentrations of each plume are mapped onto a raster layer, which allows convenient representations of multiple plumes on a map.

There are at least two areas in which additional work on either of the models appears recommended before relying solely on them for calculating nitrogen loads from OSTDS and their reductions.

One area for additional work includes calibration of models at the plume scale. Both models are based on equations for tracking one nitrogen plume. The example of the application for STUMOD-FL-HPS to the GCREC mounds illustrates the challenges of fitting the model to a field site. ArcNLET's calibration approach has been based on matching concentrations of an ensemble of monitoring wells that were not located to correspond to any particular plume (Wang et al, 2013). Plume-specific investigations could serve to assess how well the model assumptions match the real plumes and provide guidance for more appropriate models. For example, the first-order denitrification models currently used hypothesized that denitrification is largest in the center of the plume. Such investigations could also serve to build up a

data set of appropriate plume parameters for future use.

Another area for additional work is addressing additional sources. The models assume that the effluent of OSTDS are the only source of nitrogen in the model domain. This may not always be the case. The application to the GCREC field data discusses that one approach to matching concentrations in this case is to increase source concentrations and consequently increase the mass loading from the onsite system. Similarly, Wang et al (2012) increased onsite system source concentrations to reflect fertilizer use. There are at least two concerns with this approach. Substituting a model source emanating from a relatively small STU for a widely dispersed source has the risk that calibrated transport parameters will be biased in unpredictable ways. Further, this mixing of sources makes it more likely that subsequent users will utilize the inflated load estimates in their assessments.

Appendix H. List of Papers and Presentations

Awards

	Date	Awarding Organization	Title	To
1	November, 2015	Florida Institute of Consulting Engineers	2016 Engineering Excellence Grand Award	Hazen and Sawyer

Conference Papers

	Date	Organization	Title	By
1	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	The State of Florida's Innovative Approach to Nitrogen Reduction	DOH
2	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	Performance Evaluation of In-tank Passive Nitrogen Reduction Systems	Hazen and Sawyer
3	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	Performance Evaluation of In-ground Passive Nitrogen Reduction Systems	Hazen and Sawyer
4	November 11, 2014	National Onsite Wastewater Recycling Association-Colorado Professionals in Onsite Wastewater Joint Annual Conference	Full-scale Performance of a Two-Stage Biofiltration System for Reduction of Nitrogen	Hazen and Sawyer
5	November 11, 2014	National Onsite Wastewater Recycling Association-Colorado Professionals in Onsite Wastewater Joint Annual Conference	Pilot Study of Two-Stage Biofiltration for Reduction of Nitrogen from OWS	Hazen and Sawyer

	Date	Organization	Title	By
6	September 30, 2014	Water Environment Federation Annual Technical Conference	Backyard BNR: Passive Nitrogen Reduction System Research for Onsite Wastewater Treatment	Hazen and Sawyer
7	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 1: The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study, Project Overview	DOH
8	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 2: Passive, 2-Stage Biofilter Treatment Systems for Reduction of Nitrogen from OWS - Pilot Study Results	Hazen and Sawyer
9	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 3: The Performance of a Full-scale 2 Stage Passive Biofilter System	Hazen and Sawyer
10	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 4: Water and Nitrogen Balance for Mounded Drip Irrigation Systems Receiving Septic Tank Effluent	Hazen and Sawyer
11	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 5: Quantifying Rates of Denitrification in the Biozone and Shallow Subsurface within Soil Treatment Units Used for Wastewater Reclamation	Hazen and Sawyer
12	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 6: STUMOD-FL - A Tool for Predicting Fate and Transport of Nitrogen in Soil Treatment Units in Florida	Hazen and Sawyer
13	April 7, 2014	Florida Water Resources Conference (FWRC)	Two-Stage Passive Biofilters for On-site Wastewater Nutrient Reduction	Hazen and Sawyer
14	April 29, 2013	Florida Water Resources Conference (FWRC)	The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study: Project Overview and Preliminary Results	Hazen and Sawyer
15	April 2-5, 2012	National Onsite Wastewater Recycling Association Annual Conference	Nitrogen Removal Using Unsaturated and Saturated Media Biofilters: Pilot Testing and Simulation Results	Hazen and Sawyer

Conference Presentations

	Date	Organization	Title	By
1	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	The State of Florida's Innovative Approach to Nitrogen Reduction	DOH
2	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	Performance Evaluation of In-tank Passive Nitrogen Reduction Systems	Hazen and Sawyer
3	November 5, 2015	2015 Onsite Wastewater Mega-Conference: National Onsite Wastewater Recycling Association and State Onsite Sewage Regulators Alliance	Performance Evaluation of In-ground Passive Nitrogen Reduction Systems	Hazen and Sawyer
4	September 30, 2015	Maryland Groundwater Symposium	Backyard BRN: An Onsite Wastewater Treatment Approach for Nitrogen Sensitive Watersheds	Hazen and Sawyer
5	September 10, 2015	American Planning Association's Florida Conference	Addressing Concentrations of Septic Systems	DOH, Department of Economic Opportunity, and Florida Atlantic University
6	July 14, 2015	79th National Environmental Health Association Annual Education Conference	Florida Onsite Sewage Nitrogen Reduction Strategies Project Overview	DOH
7	July 14, 2015	79th National Environmental Health Association Annual Education Conference	Quantifying Rates of Denitrification in the Biozone and Shallow Subsurface	Hazen and Sawyer

	Date	Organization	Title	By
8	July 14, 2015	79th National Environmental Health Association Annual Education Conference	Reduction of Nitrogen from OWS: Performance of Tank-based Systems	Hazen and Sawyer
9	July 14, 2015	79th National Environmental Health Association Annual Education Conference	Reduction of Nitrogen from OWS: Performance of In-ground Systems	Hazen and Sawyer
10	July 14, 2015	79th National Environmental Health Association Annual Education Conference	STUMOD-FL: A Practical Tool for Predicting Nitrogen Fate and Transport in Soil Treatment Units	Hazen and Sawyer
11	November 11, 2014	National Onsite Wastewater Recycling Association-Colorado Professionals in Onsite Wastewater Joint Annual Conference	Full-scale Performance of a Two-Stage Biofiltration System for Reduction of Nitrogen	Hazen and Sawyer
12	November 11, 2014	National Onsite Wastewater Recycling Association-Colorado Professionals in Onsite Wastewater Joint Annual Conference	Pilot Study of Two-Stage Biofiltration for Reduction of Nitrogen from OWS	Hazen and Sawyer
13	September 30, 2014	Water Environment Federation Annual Technical Conference	Backyard BNR: Passive Nitrogen Reduction System Research for Onsite Wastewater Treatment	Hazen and Sawyer
14	September 7, 2014	Water Reuse Symposium	Onsite Reuse: A Shortcut to Reclaimed Water Irrigation	Hazen and Sawyer
15	July 25, 2014	Florida Home Builders Association Summer Builders Conference	Wastewater Nitrogen Management in Florida: Septic vs. Sewer	Hazen and Sawyer
16	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 1: The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study, Project Overview	Hazen and Sawyer

	Date	Organization	Title	By
17	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 2: Passive, 2-Stage Biofilter Treatment Systems for Reduction of Nitrogen from OWS - Pilot Study Results	Hazen and Sawyer
18	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 3: The Performance of a Full-scale 2 Stage Passive Biofilter System	Hazen and Sawyer
19	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 4: Water and Nitrogen Balance for Mounded Drip Irrigation Systems Receiving Septic Tank Effluent	Hazen and Sawyer
20	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 5: Quantifying Rates of Denitrification in the Biozone and Shallow Subsurface within Soil Treatment Units Used for Wastewater Reclamation	Hazen and Sawyer
21	April 7, 2014	Soil Science Society of America Onsite Wastewater Conference	FOSNRS 6: STUMOD-FL - A Tool for Predicting Fate and Transport of Nitrogen in Soil Treatment Units in Florida	Hazen and Sawyer
22	April 7, 2014	Florida Water Resources Conference (FWRC)	Two-Stage Passive Biofilters for On-site Wastewater Nutrient Reduction	Hazen and Sawyer
23	April 29, 2013	Florida Water Resources Conference (FWRC)	The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study: Project Overview and Preliminary Results	Hazen and Sawyer
24	April 2-5, 2012	National Onsite Wastewater Recycling Association Annual Conference	Nitrogen Removal Using Unsaturated and Saturated Media Biofilters: Pilot Testing and Simulation Results	Hazen and Sawyer
25	February 15-16, 2012	University of Florida Water Symposium	Effective, User-Friendly Nitrogen Reducing Onsite Wastewater Systems	Hazen and Sawyer
26	October 13, 2011	Florida Industrial and Phosphate Research Institute (FIPR) 26th Annual Phosphate Conference	Onsite Wastewater Treatment: Nutrient Impacts and Solutions	Hazen and Sawyer

	Date	Organization	Title	By
27	June 18, 2011	National Environmental Health Association Annual Education Conference – OWS Summit	Effective, User-Friendly Nitrogen Reducing Onsite Wastewater Systems	Hazen and Sawyer
28	June 18, 2011	National Environmental Health Association Annual Education Conference – Onsite Wastewater Systems Summit	Evaluation of Nitrogen Reduction from Onsite Wastewater Treatment Systems as Provided by Soils and Shallow Groundwater	Hazen and Sawyer

<u>Public education meetings/presentations/seminars</u>

	Date	Organization	Title	By
1	December 12, 2015	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
2	October 22, 2015	Santa Fe River Springs Working Group	Nitrogen Reduction Strategies Study	DOH
3	October 22, 2015	Technical Review and Advisory Panel	Discussion on Rule-making for Nitrogen Reduction	DOH
4	October 19, 2015	Wekiva Commission Meeting	Update On Passive Nitrogen Reduction Project	DOH
5	October 6, 2015	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
6	August 31, 2015	Wakulla Springs Basin Management Plan Technical Meeting	Florida Onsite Sewage Nitrogen Reduction Strategies Study	DOH
7	July 31, 2015	Florida Onsite Wastewater Association Annual Education Conference	Update On Passive Nitrogen Reduction Project	Hazen and Sawyer
8	July 28, 2015	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
9	July 15, 2015	Department of Health Statewide Environmental Health Program Employees	Nutrient Management and How a Map can Impact Florida's Future	DOH
10	March 19, 2015	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH

	Date	Organization	Title	By
11	March 3, 2015	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
12	February 20, 2015	Wekiva Commission Meeting	Update On Passive Nitrogen Reduction Project	DOH
13	January 22, 2015	Silver Springs Basin Management Action Plan Technical Discussion Group	Florida Water Management Inventory and Determination of Nitrogen Loading	DOH
14	January 12, 2015	Fallow Fields Working Group	Overview of the Florida Onsite Sewage Nitrogen Reduction Strategies Study	Hazen and Sawyer
15	November 4, 2014	Florida Water Environment Association Big Bend Chapter	Innovations & Regulations for Septic Systems for Environmentally Sensitive Areas	Hazen and Sawyer
16	November 4, 2014	Florida Water Environment Association Big Bend Chapter Winter Seminar	Innovations & Regulations for Septic Systems for Environmentally Sensitive Areas	DOH
17	September 25, 2014	Technical Review and Advisory Panel	Update On Passive Nitrogen Reduction Project	Hazen and Sawyer
18	August 28, 2014	Florida Environmental Health Association Halifax District Training	Passive Ways to Reduce Nitrogen in Onsite Wastewater Treatment Systems, Part II	Hazen and Sawyer
19	August 21, 2014	Florida Water Environment Association West Coast Chapter Luncheon	Backyard BNR: The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study	Hazen and Sawyer
20	July 29, 2014	Florida Environmental Health Association Annual Education Meeting	Getting Things Done: How government, academia, and private industry collaborate to advance the onsite sewage field in Florida	DOH
21	March 28, 2014	University of South Florida Seminar	Nutrient Removal in Onsite Wastewater Treatment Systems: Two-Stage Passive Biofilters for Nitrogen Reduction	Hazen and Sawyer

	Date	Organization	Title	By
22	February 26, 2014	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
23	December 17-18, 2013	Chesapeake Bay Scientific and Technical Advisory Committee and National Association of Home Builders Workshop	Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study: Project Overview and Preliminary Results	Hazen and Sawyer
24	October 22, 2013	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
25	September 11, 2013	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
26	August 29, 2013	Florida Environmental Health Association Halifax District Training	Passive Ways to Reduce Nitrogen in Onsite Wastewater Treatment Systems	Hazen and Sawyer
27	August 29, 2013	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
28	May 30, 2013	Santa Fe River Springs Working Group	Florida Onsite Sewage Nitrogen Reduction Strategies Study	DOH
29	May 15, 2013	Treasure Coast Training	Passive Ways to Reduce Nitrogen in Onsite Wastewater Treatment Systems	Hazen and Sawyer
30	March 28, 2013	Wakulla Springs Basin Management Plan Technical Meeting	Florida Onsite Sewage Nitrogen Reduction Strategies Study	DOH
31	December 11, 2012	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
32	November 16, 2012	Technical Review and Advisory Panel	Update On Passive Nitrogen Reduction Project	DOH
33	November 14, 2012	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH

	Date	Organization	Title	By
34	September 12, 2012	Department of Health Statewide Environmental Health Program Employees	Current Research Topics in Florida's Onsite Sewage Treatment and Disposal System Program	DOH
35	September 7, 2012	Florida Environmental Health Association Annual Education Meeting	Passive Ways to Reduce Nitrogen in Onsite Wastewater Treatment Systems	Hazen and Sawyer
36	August 30, 2012	Florida Environmental Health Association Gulf Coast District Training	DOH Ongoing Research Including Passive Nitrogen Reduction	DOH
37	August 3, 2012	Florida Onsite Wastewater Association Annual Education Conference	Research Topics in Florida's OSTDS Program	DOH
38	June 21, 2012	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
39	April 10, 2012	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
40	March 22, 2012	Lemon Bay League Seminar	Nitrogen and Onsite Wastewater Treatment: Problems and Solutions	Hazen and Sawyer
41	January 4, 2012	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
42	November 15, 2011	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
43	September 8, 2011	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
44	April 20, 2011	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
45	April 4, 2011	University of South Florida Seminar	Onsite Wastewater Treatment: Nutrient Impacts and Solutions	Hazen and Sawyer
46	March 24, 2011	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH

	Date	Organization	Title	By
47	December 10, 2010	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
48	November 5, 2010	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
49	June 10, 2010	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
50	March 23, 2010	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
51	December 16, 2009	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
52	September 10, 2009	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
53	July 1, 2009	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH, Hazen and Sawyer
54	May 27-28, 2009	Research Review and Advisory Committee Meeting	Nitrogen Reduction Strategies Study Prioritization Meeting	DOH, Hazen and Sawyer
55	February 3, 2009	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
56	January 5, 2009	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
57	December 2, 2008	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
58	November 6, 2008	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
59	October 9, 2008	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH
60	July 30, 2008	Research Review and Advisory Committee Meeting	Update On Nitrogen Reduction Strategies Study	DOH

Newsletters and Other Articles

	Date	Organization	Title	By
1	2014, Volume 2	Florida Onsite Wastewater Association, The Voice of Onsite Wastewater & Portable Restroom Industry	The Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study: Project Overview and Preliminary Results	Hazen and Sawyer
2	2011, Volume 3	Florida Onsite Wastewater Association, The Voice of Onsite Wastewater & Portable Restroom Industry	2011 Priorities for Research for the Bureau of Onsite Sewage Programs.	DOH
3	2010, June	Florida Onsite Wastewater Association, The Voice of Onsite Wastewater & Portable Restroom Industry	Research: Cornerstone of Progress.	DOH
4	2009, December	Florida Onsite Wastewater Association, The Voice of Onsite Wastewater & Portable Restroom Industry	Summary of September 10, 2009 Research Review and Advisory Committee (RRAC) Meeting.	DOH
5	2009, March	Florida Onsite Wastewater Association, The Voice of Onsite Wastewater & Portable Restroom Industry	Onsite Program Update on the 2008 Legislative Mandate.	DOH

Legislative Reports

	Date	Title
1	April 2015	Update on the Florida Onsite Sewage Nitrogen Reduction Strategies Study
2	February 2014	Status Report: Update on the Florida Onsite Sewage Nitrogen Reduction Strategies Study
3	February 2015	Status Report on Phase II and Phase III of the Florida Onsite Sewage Nitrogen Reduction Strategies Study
4	October 2012	Status Report on Phase II and Phase III of the Florida Onsite Sewage Nitrogen Reduction Strategies Study
5	May 2012	Status Report on Phase II and Phase III of the Florida Onsite Sewage Nitrogen Reduction Strategies Study
6	February 2012	Progress Report on Phase II and Phase III of the Florida Onsite Sewage Nitrogen Reduction Strategies Study
7	May 2011	Status Report on Phase II of the Florida Onsite Sewage Nitrogen Reduction Strategies Study

	Date	Title
8	February 2011	Interim Study and Report on Phase II of the Florida Onsite Sewage Nitrogen Reduction Strategies Study
9	May 2010	Final Study and Report on Phase I of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (2008-2010)
10	February 2010	Interim Study and Report on the Florida Onsite Sewage Nitrogen Reduction Strategies Study
11	February 2009	Progress Report on Nitrogen Reduction Strategies for Onsite Sewage Treatment and Disposal Systems