DATE AND TIME:  July 28, 2015 at 9:30 a.m. ET

PLACE:  Florida Department of Health Southwood Complex
4025 Esplanade Way, Room #130 L
Tallahassee, FL 32399

Or via conference call / web conference:
Toll free call in number:  1-888-670-3525
Conference pass code: 8605907413
Website: http://connectpro22543231.na5.acrobat.com/rrac_new/

This meeting is open to the public

AGENDA:

9:30 – 9:40  Introductions and Housekeeping

9:40 – 9:45  Review of minutes:
- March 19, 2015 meeting

9:45 – 2:30  Discussion on Nitrogen Reduction Strategies Study:
- Current status and timeline
- Presentation by Hazen and Sawyer on the project
- Discussion on Task B Draft Final Report

2:30 – 2:45  Updates on Other Projects

2:45 – 2:50  Other Business

2:50 – 2:55  Public Comment

2:55 – 3:00  Closing Comments, Next Meeting, and Adjournment

NOTE: Time slots are approximate and may be subject to change.
Research Review and Advisory Committee
Onsite Sewage Treatment and Disposal Systems

Advisory to the Department of Health

Authority: Section 381.0065(4)(o), Florida Statutes

Approved Minutes of the Meeting held at the Southwood Office Complex, Tallahassee, FL
July 28, 2015

In attendance:

Research Review and Advisory Committee (RRAC) Members and Alternates:

In person:
- Eberhard Roeder (member, Department of Health)

Via teleconference:
- Quentin (Bob) Beitel (member, Real Estate Profession)
- Christopher Pettit (member, Local Government)
- John Schert (member, State University System)
- Clay Tappan (chairman, member, Professional Engineer)

Absent members and alternates:
- Ed Dion (alternate, Home Building Industry)
- Geoff Luebkemann (member, Restaurant Industry)
- Carl Ludecke (vice-chairman, member, Home Building Industry)
- Tony Macaluso (alternate, Real Estate Profession)
- Daniel Meeroff (alternate, State University System)
- Bill Melton (member, Consumer)
- Matt Surrency (alternate, Local Government)
- Robert Washam (alternate, Consumer)

Other attendees:

In person:
- Damann Anderson (Hazen and Sawyer)
- Douglas Buck (Florida Home Builders Association)
- Bill Helmich (FOWA)
- Richard Hick (DEP)
- Josefin Hirst (Hazen and Sawyer)
- Mark Repasky (FRLA)

Via teleconference:
- Maurice Barker (DEP)
- Charles (Ed) Brown (DOH, Marion)
- Glenn William Bryant (DOH, Citrus)
- Nanci Cornwell (Senator Hays Office)
- Jessica Crawford
- Kim Dinkins (Marion County)
- Kim Duffek (DOH, Orange)
- Victor Faconti (DOH, St. Lucie)
- Christianne Ferraro (DEP)
- Roxanne Groover (FOWA)
- Bob Himschoot (Septic Industry)
- Kathryn Lowe
- Christopher Rowe (PTI)
- Pam Tucker (Real Estate Industry)
- Tyler (Unknown)
Department of Health (DOH), Onsite Sewage Program Section:

In person:
- Ed Barranco, Environmental Administrator, Onsite Sewage Programs
- Kendra Goff, State Toxicologist, Bureau of Environmental Health
- Andrew Reich, Acting Bureau Chief, Bureau of Environmental Health
- Elke Ursin, Research Program Coordinator, Onsite Sewage Programs

Via teleconference:
- Bart Harriss, Environmental Manager, Onsite Sewage Programs
- Marcelo Blanco, Environmental Program Consultant, Onsite Sewage Programs

1. Introductions – Five out of eight groups with non-expired members were present, representing a quorum. Chairman Tappan called the meeting to order at 9:45 a.m. The agenda was presented, introductions were made, and some housekeeping issues were discussed. Doug Buck asked for staff to check and see if expired members can stay on the committee until replaced. Elke Ursin would check on that.

2. Review of previous meeting minutes – The RRAC reviewed the minutes of the March 19, 2015 meeting. Quentin Beitel pointed out that he was incorrectly listed as an alternate when he should be a member.

   Motion by Quentin Beitel and seconded by Eberhard Roeder, for the RRAC to approve the minutes of the March 19, 2015 meeting as amended during the meeting. All were in favor, none opposed, and the motion passed unanimously.

3. Nitrogen Study Update – Elke Ursin presented a 10,000 foot overview of the project to get everyone on the same page. In 2008 the Florida Legislature directed the Florida Department of Health to look at strategies to reduce nitrogen in onsite sewage treatment and disposal systems (OSTDS). The Department did a competitive solicitation and Hazen and Sawyer was selected as the contract provider. There has been a great deal of work done, and this would be discussed later during the meeting when Hazen and Sawyer present on the project. Elke Ursin went over what has happened since the March 2015 meeting and what the timeline is moving forward. The current status is that the Legislature appropriated $10,000 to conclude the study. By December 31, 2015, the Department shall submit a final report to the Legislature containing:
   - Analysis of field monitoring of performance and cost of technologies at various sites
   - Analysis of soil and groundwater sampling at various sites to determine how nitrogen moves
   - Analysis of various models to show how nitrogen is affected by treatment in Florida-specific soils
   - Final reporting on all tasks with recommendations for science-based nitrogen reduction options for OSTDS

The Department will use the $10,000 plus some Bureau of Environmental Health cash and budget authority to wrap up the contractor work by August 30, 2015. Elke Ursin is working on a website to have all the tasks and associated deliverables up and available for anyone to view. The holdup in getting this done is making sure any homeowner specific information is redacted from these online...
documents to protect their privacy. She said that if anyone wants a deliverable that they can contact her. The project cost was anticipated to be $5 million, and the final spending amount is likely to come to around $4.7 million which includes all the appropriated funds plus some cash from the Bureau of Environmental Health. Bob Himschoot said that the RRAC had recommended full funding and time to complete the project with the contract ending January 2016, but based on the information presented it appeared that both funding and time were cut. Doug Buck said that the RRAC and the experts have said that $10,000 is a grossly inadequate amount of money to finish the project. Clay Tappan said that there is a great deal of history with this project and it does not look like more time or money will be made available. He suggested that the group make the best out of the situation and to move forward with the agenda. Elke Ursin went over the timeline for the project.

Damann Anderson presented the results for the Florida Onsite Sewage Nitrogen Reduction Strategies Study. He presented an overview of all the parts of the study in detail, then Kathryn Lowe with the Colorado School of Mines demonstrated the groundwater monitoring tool and Josefin Hirst demonstrated the life cycle cost assessment tool. He acknowledged the project team and the volunteer homeowners. Due to the project funding and timeline issues Tasks A, C, and D were not totally completed, but Task B was completed. Damann Anderson presented recommendations for the implementation of passive nitrogen reduction systems. Quentin Beitel asked what the status was on each of the systems now that the sampling is over. Damann Anderson said that systems 1 and 6 (same site) had the system removed due to costs, the homeowner for system 2 loves the system, the homeowner for system 3 is on the fence due to costs, the homeowner for system 4 loves the system, the homeowner for system 5 has mixed feelings due to costs, and the homeowner for system 7 is keeping the system.

The public was allowed to comment throughout. Some of the discussions were about the sulfide created during the denitrification step for the systems with sulfur as the treatment media, possible tank corrosion issues with extra sulfides, and how to apply the results of this work to the DEP Basin Management Action Plans. Andy Reich said that the Bureau is looking for help looking through this work and want the end product to be the best possible. Bob Himschoot recommended continued sampling for these systems. Roxanne Groover said that she was happy to hear about the reports recommendations for continued monitoring and sufficient DOH staffing. She said that implementation needs to address approved media sources, the approval process for the systems, the permitting process and how to handle use of existing tank and drainfield, the contractor processes, and how the systems will be inspected for compliance. Doug Buck asked what did not get done and Damann Anderson said the main thing is that there is no final project report tying all the pieces of the project together. Doug Buck then asked what Damann Anderson’s opinion is on the path forward and if money could be found to create the final report, whether it is too late to do anything. Damann Anderson said that he would need to weigh the options but would require that the Department is on board with the project. Andy Reich hopes that if there is additional money that the project could be picked up and do additional work. He also encouraged everyone to stay engaged with this issue at both a state and local level.

Comments are due to Elke Ursin on the Draft Task B report by 7/30/15. Elke Ursin will send compiled comments to Hazen and Sawyer on the Draft Task B report on 8/1/15. Damann Anderson
said that particular areas of focus for comments would be the recommended framework and conclusions and recommendations.

Damann Anderson mentioned that an article was published in the Water Environment and Technology Journal, which reaches a national audience, as well as an article in the June issue of the Florida Water Resources Journal. Florida is in the news with the work being done. Elke Ursin said she will present at the American Planning Association’s Florida conference in September jointly with the Department of Economic Opportunity and Florida Atlantic University. Also, both Hazen and Sawyer and the Department will present at the National Onsite Wastewater Recycling Association / State Onsite Regulators Association conference in November. Hazen and Sawyer will also present at the Florida Onsite Wastewater Association conference in one week.

4. Updates on Other Projects – Elke Ursin gave an update on the Florida Water Management Inventory. The project is to create a statewide map showing the drinking water source and wastewater treatment method for all built properties. This tool ties in with the nitrogen issue, and will provide refined estimates for loading of nitrogen from OSTDS in sensitive watersheds. She said that funding had run out for the moment, and is actively looking for additional funding.

5. Other Business – None.

6. Public Comment – The public commented throughout the meeting.

7. Closing Comments, Next Meeting, and Adjournment – It was recommended that future meetings be held in larger rooms and possibly also at a centralized location.

Motion by Eberhard Roeder and seconded by Quentin Beitel, for the RRAC to adjourn at 2:56 p.m. All were in favor, none opposed, and the motion passed unanimously.

Summary of action items from meeting:

- Doug Buck asked for staff to check and see if expired members can stay on the committee until replaced. Elke Ursin would check on that.

- Elke Ursin will update the Department Nitrogen Study website to include links to all deliverables for the project.

- 7/30/15 Comments are due to Elke Ursin on the Draft Task B report.

- 8/1/15 Elke Ursin will send compiled comments to Hazen and Sawyer on the Draft Task B report.

- Elke Ursin will post the presentations for this meeting on the website.
Research Review & Advisory Committee Meeting
July 28, 2015

Elke Ursin
Bureau of Environmental Health
Onsite Sewage Programs
Elke.Ursin@flhealth.gov
850-245-4070 x 2708

Division of Disease Control and Health Protection
Florida Department of Health
To protect, promote and improve the health of all people in Florida through integrated state, county, and community efforts.
<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda Item</th>
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<tbody>
<tr>
<td>9:30 – 9:40</td>
<td>Introductions and Housekeeping</td>
</tr>
<tr>
<td>9:40 – 9:45</td>
<td>Review of minutes:</td>
</tr>
<tr>
<td></td>
<td>• March 19, 2015 meeting</td>
</tr>
<tr>
<td>9:45 – 2:30</td>
<td>Discussion on Nitrogen Reduction Strategies Study:</td>
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<tr>
<td></td>
<td>• Current status and timeline</td>
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<tr>
<td>2:55 – 3:00</td>
<td>Closing Comments, Next Meeting, and Adjournment</td>
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</tbody>
</table>
Introductions & Housekeeping

• Committee roll call
• Identification of audience
• How to view web conference
• Mute / unmute phone line = *6
• Do not put phone on hold
• Download meeting material:
Review of Meeting Minutes

• March 19, 2015
Florida Onsite Sewage Nitrogen Reduction Strategies Study

**TASK A**
Nitrogen treatment and reduction options for Florida

**TASK B**
Performance verification of nitrogen reduction in full scale systems

**TASK C**
Evaluation of nitrogen reduction in Florida soil and groundwater

**TASK D**
Decision support tools for OSTDS planning and management; nitrogen reduction strategies for Florida

- Septic Tank
- Additional Treatment?
- Drainfield
- Soil
- Groundwater
- Impacted Groundwater
Florida Onsite Sewage Nitrogen Reduction Strategies Study

Discussion on Nitrogen Reduction Strategies Study:

• Current status and timeline
• Presentation by Hazen and Sawyer on the project
• Discussion on Task B Draft Final Report
• Public Comment
Nitrogen Study – Current Status

• Legislature appropriated $10,000 to conclude the study

• Final report from the Department due 12/31/2015 containing:

  1. Analysis of field monitoring of performance and cost of technologies at various sites

  2. Analysis of soil and groundwater sampling at various sites to determine how nitrogen moves

  3. Analysis of various models to show how nitrogen is affected by treatment in Florida-specific soils

  4. Final reporting on all tasks with recommendations for science-based nitrogen reduction options for OSTDS
Nitrogen Study – Financial Status

• Reviewing invoices
• Anticipated total project spending:
  $4,703,646.60 (estimated through 6/30/2015)
  + $26,218.05 (estimated through 8/30/2015)
  $4,729,864.65 (estimated contracted total)
Nitrogen Study – Timeline

7/2015 - 12/2015
Complete Study

1/2016 - 3/2016
Legislative Session

3/2016 - 6/2016
Implementation

7/15
Presentation at national conference

7/28
RRAC Meeting

8/1
Comments to contractor

8/18
Final technology report due

8/31
Contractor concludes study per 2015 appropriations language

9/30
Final invoice paid

7/1/2015 - 12/30/2015
Complete Study

7/1 - 7/31
Plan and launch final report process

8/1 - 8/31
Stakeholder meetings: technology focus

9/1 - 9/30
Stakeholder meetings: modeling focus

10/1 - 10/31
Write
Nitrogen Study – Timeline

- 9/30: Final invoice paid
- 10/1 - 10/30: Write final report
- 11/1: Draft final report for public comment
- 11/10: RRAC meeting
- 11/1 - 11/30: Edit final report
- 12/1: Final report starts internal routing
- 12/1 - 12/31: Finalize and distribute final report
- 12/31: Final report due to Governor/Legislature
Florida Onsite Sewage Nitrogen Reduction Strategies Study

Discussion on Nitrogen Reduction Strategies Study:

- Presentation by Hazen and Sawyer on the project
Florida Onsite Sewage Nitrogen Reduction Strategies Study

Discussion on Nitrogen Reduction Strategies Study:

• Discussion on Task B Draft Final Report – Final comments due to Elke Ursin (elke.ursin@flhealth.gov) by July 30, 2015

• Public Comment
Updates on Other Projects
Florida Water Management Inventory
HIDDEN GEMS

DATA SILOS
Other Business
Public Comment
Next Meeting Discussion

When and how often should we meet to stay on track with the December 31, 2015 final report deadline?
Closing Comments and Adjournment

Elke Ursin, PMP, CPM
Email: Elke.Ursin@flhealth.gov
Phone: 850-245-4444 x 2708
4052 Bald Cypress Way, Bin A08,
Tallahassee FL, 32399-1710
FLORIDA ONSITE SEWAGE NITROGEN REDUCTION STRATEGIES (FOSNRS) STUDY

Presentation to the FDOH Research Review and Advisory Committee (RRAC)
July 28, 2015

by
Damann L. Anderson, P.E.
Josefin E. Hirst, P.E.
And many support firms and staff!
Special acknowledgements to the volunteer homeowners!
Presentation Outline

■ Excess Nitrogen impacts water quality!
■ Florida onsite sewage nitrogen reduction strategies (FOSNRS) project background
■ Task A: Technology Review and Pilot Testing
■ Task B: Full Scale Prototype PNRS Testing
  ● Proprietary system (System 1)
  ● In-tank PNRS (System 2)
  ● In-ground PNRS (System 3)
■ Task C: Soil and Groundwater Monitoring
■ Task D: Nitrogen Fate & Transport Modeling and Tool Development
■ Summary & Questions
Why are we here?

Excess Nitrogen impacts water quality!
Adverse effects of nitrogen

- **Public Health**: SDWA Limit of 10 mg/L NO$_3$ – N, Harmful Algal Blooms (HABs)

- **Ecosystem Health/ Water Quality**: N is limiting nutrient in many water bodies
  - Algal blooms, loss of habitat, hypoxia

- **Impacts of excess nitrogen on water quality have been documented in many areas**:
  - Tampa Bay, Sarasota Bay, Indian River Lagoon
  - Florida Keys
  - Florida’s Freshwater Springs and elsewhere
In Florida, nitrogen loading has resulted in water quality problems for our freshwater springs...

Photos courtesy of John Moran - SpringsEternalProject.org
Nitrogen reducing onsite wastewater systems (OWS)

- Concerns over nitrogen impacts have led to requirements to reduce nitrogen, typically to a 10 mg/L total nitrogen goal prior to discharge to the soil
  - Florida Keys
  - Wakulla County, FL
- Performance based treatment systems (PBTS) utilizing an activated sludge biological (BNR) process, similar to a municipal treatment plant, have been typically used.
- Inconsistent performance of PBTS has been documented, with systems generally unable to meet 10 mg/L TN goal.
Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS)
project background
FOSNRS project initiated by Florida legislature

- Florida Legislature directed FDOH to conduct a study to further develop more “passive” & cost-effective nitrogen reduction strategies for onsite sewage treatment and disposal systems (OSTDS)

- “Passive” nitrogen reducing OSTDS should be more similar to conventional onsite systems in their operation and maintenance

- Initiated the Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Project in 2009

- RFP identified four primary study areas
Four primary study areas

- **TASK A**: Nitrogen treatment and reduction options for Florida
- **TASK B**: Performance verification of nitrogen reduction in full scale systems
- **TASK C**: Evaluation of nitrogen reduction in Florida soil and groundwater
- **TASK D**: Decision support tools for OWS planning and management; nitrogen reduction strategies for Florida
Task A: Technology Review and Pilot Testing
Task A Components

- Literature review to evaluate nitrogen reducing technologies
- Ranking and prioritization of nitrogen reducing technologies for field testing
- Technology ranking workshop with RRAC conducted on May 28, 2009
- Pilot testing of passive nitrogen reduction systems (PNRS)
- Materials testing for FDOH additives rule
## Treatment Technology Rankings

<table>
<thead>
<tr>
<th>System Rank</th>
<th>Technology/Process</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Two stage (segregated biomass) system:</strong></td>
<td>• Top ranked system capable of meeting the lowest TN concentration standard</td>
</tr>
<tr>
<td></td>
<td><em>Stage 1:</em> Biofiltration with recycle (nitrification)</td>
<td>• Suitable for new systems or retrofit</td>
</tr>
<tr>
<td></td>
<td><em>Stage 2:</em> Autotrophic denitrification with reactive media biofilter</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><strong>Two stage (segregated biomass) system:</strong></td>
<td>• Top ranked system capable of meeting the lowest TN concentration standard</td>
</tr>
<tr>
<td></td>
<td><em>Stage 1:</em> Biofiltration with recycle (nitrification)</td>
<td>• Suitable for new systems or retrofit</td>
</tr>
<tr>
<td></td>
<td><em>Stage 2:</em> Heterotrophic denitrification with reactive media biofilter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><strong>Natural system:</strong></td>
<td>• Lower cost natural system that is untested but appears capable of</td>
</tr>
<tr>
<td></td>
<td>Septic tank/STU (Drainfield) with in-situ reactive media layers, Stage 1 media</td>
<td>achieving 75-78% TN removal before reaching groundwater</td>
</tr>
<tr>
<td></td>
<td>over Stage 2 media</td>
<td>• Suitable for new systems or replacing existing systems at end of useful life</td>
</tr>
</tbody>
</table>
Biological Nitrogen Removal (BNR)

Two stage biofiltration is more stable process

Primary Treatment
Mineralization of most organic N to ammonia (ammonia – NH₄)

Dispersal
Effluent discharge to the soil or landscape

STAGE 1
(Nitrification)
TKN (Ammonia and organic N) oxidized to nitrate (NO₃) by nitrifying bacteria, requires oxygen

STAGE 2
(Denitrification)
Nitrate converted to N₂-gas in anoxic environment; requires supply of electron donor

WW From Home
Unique pilot test facility was designed and constructed

- Follow up to PNRS I with larger, pilot scale units and various media combinations
- Established test facility at Gulf Coast Education and Research Center (University of Florida IFAS)
- Operated on septic tank effluent for 12+ months
- Produce scalable design criteria from pilot scale biofilters for subsequent full-scale testing
What are “passive” nitrogen reduction systems?

- Passive nitrogen reduction systems (PNRS) are OSTDS that reduce effluent N using reactive media for denitrification and a single liquid pump, if necessary.

- Two stage process:
  - Stage 1: “nitrify” nitrogen compounds to $\text{NO}_3$ (nitrification)
  - Stage 2: “denitrify” $\text{NO}_3$ to nitrogen gas (denitrification)

- Nitrification media: sand & expanded clay
- Denitrification media: lignocellulosics
- Denitrification media: elemental sulfur
Two stage single pass pilot-scale biofilters

Septic Tank Effluent (STE) Feed → 3 gal/ft²-d →

Stage 1: Unsaturated Biofilter: Nitrification

Stage 2: Saturated Biofilter: Denitrification

Sample Port → To Drain
Photo of two-stage single pass biofilter pilot units

- **Stage 1 Unsaturated Biofilters - Nitrification**
- **Stage 2 Saturated Upflow Biofilters - Denitrification**
PNRS pilot-scale test results

Both Systems:
Stage 1 Nitrification: Clinoptilolite Biofilter
Stage 2 Denitrification: Sulfur Biofilter

~95% TN Reduction
Vertical sampler profile in upflow biofilters
Development of in-ground PNRS concepts

- Tank based PNRS performed extremely well (previous talk), but large tankage requirements make systems expensive.

- Desired an in-ground system that could be constructed like a soil treatment unit (drainfield).

- Conceptual ideas revolved around a vertically stacked PNRS, where Stage 1 media was placed over the Stage 2 media.

- Liner could be used to saturate Stage 2 media and collect treated effluent.
Vertically stacked Stage 1/Stage 2 concept was first pilot tested in small tanks

Nitrogen Reduction Results

- STE = 52.5 mg TN/L
- Stage 2 Ligno mix: 50-81% reduction
- Stage 2 Sulfur: 60-95% reduction
Successful pilot concept developed into prototype in-ground PNRS for further testing
Prototype In-ground PNRS Construction

Shaping soil for liner
Prototype In-ground PNRS Construction

Underdrain
Prototype In-ground PNRS Construction

Placing sand/ligno mix in liner
Prototype In-ground PNRS Construction
Prototype in-ground PNRS performance

Mean results over 8 sample events, 523 days of operation

<table>
<thead>
<tr>
<th>STE Drip</th>
<th>Stage 1 18” Sand</th>
<th>Stage 2a ligno/sand</th>
<th>Stage 2b sulfur tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>TKN (mg N/L)</td>
<td>NH₃ (mg N/L)</td>
<td>NOₓ (mg N/L)</td>
</tr>
<tr>
<td>8</td>
<td>65.1</td>
<td>55.60</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>3.2</td>
<td>0.03</td>
<td>33.13</td>
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<tr>
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<td>3.0</td>
<td>0.36</td>
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<tr>
<td>8</td>
<td>3.4</td>
<td>0.95</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Lessons learned from pilot test

- Encouraging results from pilot PNRS; several system configurations capable of ≥ 95% N reduction
- Sulfate production vs nitrate reduction
- Highly reactive elemental sulfur media
- Lignocellulosic retention time issues
- Recommended evaluation of combination lignocellulosic and elemental sulfur denitrification systems for full-scale treatment units
Task B: Full Scale Prototype PNRS Testing
Task B Components

- Full scale operation and monitoring of 7 nitrogen reducing technologies at single family residences

- Developed PNRS Life Cycle Cost Analysis tool
Task B: Full scale concepts complement existing OSTDS
Full scale PNRS installed

Systems
- System 2
- Systems 1 & 6
- System 7
- Systems 3, 4 & 5
<table>
<thead>
<tr>
<th>Design</th>
<th>Location (County)</th>
<th>Stage 1 Hydraulics</th>
<th>Stage 2 Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1</td>
<td>Proprietary</td>
<td>Wakulla, Pumped with recirculation</td>
<td>Gravity</td>
</tr>
<tr>
<td>System 2</td>
<td>In-tank PNRS</td>
<td>Hillsborough, Pumped with recirculation</td>
<td>Pumped</td>
</tr>
<tr>
<td>System 3</td>
<td>In-ground PNRS</td>
<td>Seminole, Pumped with subsurface drip irrigation</td>
<td>Gravity</td>
</tr>
<tr>
<td>System 4</td>
<td>In-tank PNRS</td>
<td>Seminole, Gravity</td>
<td>Gravity</td>
</tr>
<tr>
<td>System 5</td>
<td>In-tank PNRS</td>
<td>Seminole, Pumped single pass and tested with recirculation</td>
<td>Pumped</td>
</tr>
<tr>
<td>System 6</td>
<td>In-tank PNRS</td>
<td>Wakulla, Pumped single pass vertically stacked</td>
<td>Gravity</td>
</tr>
<tr>
<td>System 7</td>
<td>In-ground PNRS</td>
<td>Marion, Pumped low pressure distribution</td>
<td>Gravity</td>
</tr>
</tbody>
</table>
Proprietary system
(System 1)
Proprietary System 1

- Single family home
- 3 bedroom
- 4 residents
- Flow of 112 gpd
System 1 construction
System 1 construction
System 1 construction
System 1 construction
System 1
Time series of nitrogen data

Mean Effluent TN = 7.1 mg/L
TN Reduction = 91%
System 1: Operation and maintenance

- Average energy consumption of 3.21 kWh/day or 28.7 kWh/1000 gal treated (~$120 per year)
- Aerocell™ (Stage 1 biofilter) – no surficial biomat or clogging present
- Nitrex™ (Stage 2 biofilter) – reactive media showed very little reduction in volume
In-tank PNRS (System 2)
In-tank PNRS (System 2)

- Single family home
- 3 bedroom
- 2 residents
- Flow of 108 gpd
Stage 1 biofilter construction

- 4”D outlet
- 2”D inlet (R internal)
- 4”D inlet (gravity)
Stage 1 biofilter construction
Stage 2 biofilter construction
Stage 2 biofilter construction

- Underdrain clean-out
- Perforated distribution pipe
System 2
Time series of nitrogen data

Mean Effluent TN = 2.5 mg/L
TN Reduction = 95%

1Daily samples were collected on experimental days 531 through 535
System 2: Operation and maintenance

- Average energy consumption of 0.28 kWh/day or 2.6 kWh/1000 gal treated (~$10 per year)
- Stage 1 biofilter – no surficial biomat or clogging present
- Stage 2 biofilter – reactive media showed very little reduction in volume
In-ground PNRS (System 3)
In-ground PNRS (System 3) with onsite reuse

- 5 bedroom (2 residents)
- Flow of 145 gpd
- Mounded drainfield
- Soils: Myakka and EauGallie fine sands
Construction: Liner installation
Construction: Liner installation

Pipe boot
Gravel Underdrain
Stage 1 biofilter w drip irrigation of STE
Stage 2 sulfur biofilter construction
Subsurface drip irrigation of treated effluent
Subsurface drip irrigation of treated effluent
Subsurface drip irrigation of treated effluent
Drip irrigation controls & headworks
Completed full-scale vertically stacked in-ground PNRS with onsite reuse
System 3
Time series of nitrogen data

Mean Effluent TN = 1.9 mg/L
TN Reduction = 96%

\[\text{Daily samples were collected on experimental days 531 through 535}\]
System 3: Operation and maintenance

- Average energy consumption of ~1 kWh/day or 7.8 kWh/1000 gal treated
- Stage 1 biofilter – no surficial biomat or clogging present
- Stage 2 biofilter – reactive media shows immeasurable reduction in volume
# Summary of full scale prototype PNRS nitrogen results

<table>
<thead>
<tr>
<th>System</th>
<th>Design</th>
<th>System Description</th>
<th>Mean Influent TN, mg/L</th>
<th>Mean Effluent TN, mg/L</th>
<th>Mean TN Removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Proprietary</td>
<td>Stage 1 Aerocell™, Stage 2 Nitrex™</td>
<td>82.7</td>
<td>7.1</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>PNRS In-tank</td>
<td>Stage 1 with R, dual-media Stage 2</td>
<td>54.7</td>
<td>2.5</td>
<td>95</td>
</tr>
<tr>
<td>3</td>
<td>PNRS In-ground</td>
<td>Stacked Stage 1 over Stage 2a ligno with supplemental Stage 2b sulfur</td>
<td>50.5</td>
<td>1.9</td>
<td>96</td>
</tr>
<tr>
<td>4</td>
<td>PNRS In-tank</td>
<td>Gravity Stage 1, dual-media Stage 2</td>
<td>70.1</td>
<td>7.4</td>
<td>89</td>
</tr>
<tr>
<td>5</td>
<td>PNRS In-tank</td>
<td>Stage 1 SP and with R, dual-media Stage 2</td>
<td>72.1</td>
<td>2.1</td>
<td>97</td>
</tr>
<tr>
<td>6</td>
<td>PNRS In-tank</td>
<td>Stacked Stage 1 over Stage 2a ligno with supplemental Stage 2b sulfur</td>
<td>66.3</td>
<td>12.4</td>
<td>81^a</td>
</tr>
<tr>
<td>7</td>
<td>PNRS In-ground</td>
<td>In-ground stacked SP Stage 1 over Stage 2 ligno</td>
<td>54.9</td>
<td>19.1</td>
<td>65^a</td>
</tr>
</tbody>
</table>

^a Performance of systems 6 and 7 may have been significantly improved with design and construction revisions based on lessons learned in this study.
### Lignocellulosic Media Life Estimates

<table>
<thead>
<tr>
<th>System</th>
<th>% Reactive Media</th>
<th>Media Volume, ft³</th>
<th>Calculated Longevity¹, years</th>
<th>Longevity with factor of safety², years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>194.8</td>
<td>83.8</td>
<td>64.5</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>126.0</td>
<td>107.5</td>
<td>82.7</td>
</tr>
<tr>
<td>3</td>
<td>50%</td>
<td>136.5</td>
<td>80.8</td>
<td>62.2</td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>126.0</td>
<td>21.6</td>
<td>16.6</td>
</tr>
<tr>
<td>5</td>
<td>100%</td>
<td>126.0</td>
<td>43.6</td>
<td>33.5</td>
</tr>
<tr>
<td>6</td>
<td>100%</td>
<td>67.0</td>
<td>39.1</td>
<td>30.1</td>
</tr>
<tr>
<td>7</td>
<td>100%</td>
<td>362.0</td>
<td>176.2</td>
<td>135.5</td>
</tr>
</tbody>
</table>

¹ Assumptions regarding lignocellulosic media included: dry bulk density of 20 lb./ft³; 50% carbon content by weight with available carbon being approximately 50% of carbon content

² Factor of safety used was 1.3
# Sulfur Media Life Estimates

<table>
<thead>
<tr>
<th>System</th>
<th>Reactive Media</th>
<th>Media Volume, ft³</th>
<th>Study Conditions</th>
<th>If lignocellulosic depleted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Media</td>
<td></td>
<td>Mean influent NOx-N</td>
<td>Calculated Longevity¹, years</td>
</tr>
<tr>
<td>2</td>
<td>90%</td>
<td>32.4</td>
<td>0.02</td>
<td>N/A</td>
</tr>
<tr>
<td>3</td>
<td>90%</td>
<td>34.7</td>
<td>5.8</td>
<td>461.2</td>
</tr>
<tr>
<td>4</td>
<td>90%</td>
<td>24.3</td>
<td>3.2</td>
<td>348.5</td>
</tr>
<tr>
<td>5</td>
<td>90%</td>
<td>24.3</td>
<td>4.1</td>
<td>520.5</td>
</tr>
<tr>
<td>6</td>
<td>90%</td>
<td>18.0</td>
<td>24.9</td>
<td>57.2</td>
</tr>
</tbody>
</table>

¹Assumptions regarding sulfur media included: dry bulk density of 76 lb./ft³ and influent NOx concentrations from the preceding process. In systems where lignocellulosic denitrification preceded the sulfur, low influent NOx concentrations resulted in very long estimates of longevity.

²Factor of safety used was 1.3
PNRS Cost Analysis Tool

- User specifies nitrogen removal efficiency range, selects desired treatment process, and the tool calculates all system costs over the entire specified project life
  - Low Level (25-35% nitrogen removal efficiency)
  - Medium Level (50-70% nitrogen removal efficiency)
  - High Level (95% nitrogen removal efficiency)
- Derives the Present Worth cost
- Reported as $/lb nitrogen removed
## PNRS Cost Analysis Tool Inputs

### 2. Table of LCCA Worksheets

<table>
<thead>
<tr>
<th>Worksheet</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LCCA Structure</td>
<td>Two-Stage PNRS Description • Basic Model Structure • Example PNRS Systems</td>
</tr>
<tr>
<td>2. Table of LCCA Worksheets</td>
<td>Summary Table of LCCA Worksheets</td>
</tr>
<tr>
<td>3. Wastewater Quantity &amp; System Parameters</td>
<td>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</td>
</tr>
<tr>
<td>4. PNRS Process Selection</td>
<td>Select specific PNRS system</td>
</tr>
<tr>
<td>5. Baseline Design &amp; Cost</td>
<td>Summary of conventional system default design &amp; cost • Summary of PNRS design and default cost</td>
</tr>
<tr>
<td>6. Baseline Design Cost Summary</td>
<td>Default cost summary for conventional system, for PNRS system and for total system</td>
</tr>
<tr>
<td>7. User Override Costs</td>
<td>User specified costs for conventional system • User specified costs for PNRS</td>
</tr>
<tr>
<td>8. LCCA: Conventional</td>
<td>Characteristics of conventional system • Life Cycle Cost Analysis of conventional system</td>
</tr>
<tr>
<td>9. LCCA: Total System</td>
<td>Characteristics of conventional system + PNRS • Life Cycle Cost Analysis of conventional system + PNRS</td>
</tr>
<tr>
<td>10. Design Data</td>
<td>Compilation of flow and sizing criteria, unit cost factors for materials, energy, site access and installation complexity</td>
</tr>
<tr>
<td>11. Example LCCAs</td>
<td>Example Life Cycle Costs</td>
</tr>
</tbody>
</table>

Developed by: Hazen and Sawyer and AET
## PNRS Cost Analysis Tool Inputs

### Nomenclature for LCCA Identification

### Wastewater Quantity

- **No. of Bedrooms**: 3
- **Building area, square feet**: 2,200

### Level of Treatment

What level of nitrogen removal efficiency is needed for the site?
- **Low** conventional (25 - 35%)
- **Medium** (50 - 70%)
- **High** (95+%) - Selected as High

### Conventional System Parameters

**Existing system**
- Size of existing primary treatment tank, gallons: 0
- Size of existing pump treatment tank, gallons: 0
- Size of existing soil treatment unit, square feet: 0

**Soil treatment unit**
- Trench or bed configuration: **trench**
- Infiltrative surface loading rate, gal/ft²-day: 0.80
- Depth to seasonal high water table (inches) at soil treatment unit: 60
### PNRS Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>New OSTDS system installation or retrofit of existing system?</td>
<td>new</td>
</tr>
<tr>
<td>Will a PNRS Stage 1 biofilter be used or a proprietary system (e.g. Hoot, FAST, Norweco)?</td>
<td>PNRS</td>
</tr>
<tr>
<td>What is the construction complexity? enter 1, 2 or 3</td>
<td>1</td>
</tr>
<tr>
<td>1 Simple (new undeveloped property)</td>
<td></td>
</tr>
<tr>
<td>2 Moderate (retrofit of existing system, easy accessibility to site)</td>
<td></td>
</tr>
<tr>
<td>3 Complex (retrofit of existing system, difficult accessibility to site)</td>
<td></td>
</tr>
<tr>
<td>Is there at least an 8 foot elevation drop from the house out 60 feet in the direction of the proposed system?</td>
<td>no</td>
</tr>
<tr>
<td>Standard or complex control panel?</td>
<td>standard</td>
</tr>
</tbody>
</table>

### Construction permit fees

<table>
<thead>
<tr>
<th>Enter new system conventional construction permit County fee add-on, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter new PBTS system construction permit County fee add-on, $</td>
</tr>
</tbody>
</table>
### PNRS Cost Analysis Tool Inputs

#### Annual operating costs

**Energy Consumption**
- Electrical rate, $/kw-hour: 0.100

**Inspections, permit and monitoring**
- Number of inspection visits per year: 2
- Inspection & maintenance cost per visit, $: 150
- Enter PBTS operating permit County fee add-on, $: 1
- Number of water quality monitoring events per year: 1
- Water quality monitoring cost per sample event, $: 120

#### Maintenance costs

**Primary treatment tank pump out**
- Interval, years: 5.0
- Cost, $: 300

**Media Replacement**
- Stage 2 media replacement interval, years: 15

**Equipment Replacement**
- Pump replacement interval, years: 10

#### Cost Analysis Parameters

**Life Cycle Cost Analysis**
- Project life, years: 30
- Net Interest rate, %: 2.000
PNRS LCCA Process Selection

Processes: Stage 1&2, Stage 1 only, or Stage 2 only

All blue shaded cells below must be filled in to fully specify the PNRS process

Stage 1&2 Biofilters System Selections

<table>
<thead>
<tr>
<th>Stage 1 biofilter: in-tank or in-ground</th>
<th>Tank</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the Stage 2 lignocellulosic media underlying the Stage 1 media?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1 biofilter mode of operation, single pass or recirculation?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1 biofilter type of media, expanded clay or sand?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2 biofilter type of media: lignocellulosic, sulfur or dual media?</td>
<td>Tank</td>
<td></td>
</tr>
</tbody>
</table>

Stage 1 Only Selections

Stage 2 Only Selections

PNRS System Number (refers to LCCA logic)

PNRS System Summary

<table>
<thead>
<tr>
<th>PNRS System Summary</th>
<th>Stage 1&amp;2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Removal Efficiency</td>
<td>High</td>
</tr>
<tr>
<td>Stage 1: PNRS or proprietary</td>
<td>PNRS</td>
</tr>
<tr>
<td>PNRS Stage(s)</td>
<td>Stage1&amp;2</td>
</tr>
<tr>
<td>Stage 1: In-tank or in-ground</td>
<td>Tank</td>
</tr>
<tr>
<td>Stage 1: Single pass or recirculation</td>
<td>Recirculation</td>
</tr>
<tr>
<td>Stage 1 media type</td>
<td>Expanded Clay</td>
</tr>
<tr>
<td>Lignocellulosic disposition</td>
<td>Tank</td>
</tr>
<tr>
<td>Stage 2 media type</td>
<td>Dual_Ligno &amp; sulfur</td>
</tr>
</tbody>
</table>
# Summary of PNRS Construction Cost

<table>
<thead>
<tr>
<th>System</th>
<th>System Description</th>
<th>Total PW, $</th>
<th>Total Construction Cost, $</th>
<th>Conv. Component Construction Cost, $</th>
<th>PNRS Component Construction Cost, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHS-1</td>
<td>Proprietary</td>
<td>44,533</td>
<td>20,349</td>
<td>5,225</td>
<td>15,124</td>
</tr>
<tr>
<td>BHS-2</td>
<td>In-tank</td>
<td>34,545</td>
<td>18,697</td>
<td>2,576</td>
<td>16,121</td>
</tr>
<tr>
<td>BHS-3</td>
<td>In-ground</td>
<td>52,763</td>
<td>33,155</td>
<td>10,734</td>
<td>22,421</td>
</tr>
<tr>
<td>BHS-4</td>
<td>In-tank</td>
<td>33,373</td>
<td>19,350</td>
<td>3,171</td>
<td>16,180</td>
</tr>
<tr>
<td>BHS-5</td>
<td>In-tank</td>
<td>39,003</td>
<td>20,920</td>
<td>0</td>
<td>20,920</td>
</tr>
<tr>
<td>BHS-6</td>
<td>In-tank</td>
<td>29,926</td>
<td>12,926</td>
<td>0</td>
<td>12,926</td>
</tr>
<tr>
<td>BHS-7</td>
<td>In-ground</td>
<td>20,940</td>
<td>9,800</td>
<td>0</td>
<td>9,800</td>
</tr>
</tbody>
</table>
PNRS LCCA Construction Costs

[Bar chart showing present worth and construction costs for different system IDs (BHS-1 to BHS-7).]
PNRS LCCA Construction Costs

![Bar chart showing construction costs as percent of present worth for different system IDs (BHS-1 to BHS-7).]
PNRS LCCA Construction Costs

![Chart showing construction costs for different system IDs with Task B As-built and LCCA Model compared.](chart)

**Construction Cost, 1000$**

- **BHS-1**
- **BHS-2**
- **BHS-3**
- **BHS-4**
- **BHS-5**
- **BHS-6**
- **BHS-7**

- **Task B As-built**
- **LCCA Model**
Comparison of PNRS LCCA to Other Studies (Maryland BRF)
Task B Recommendations: Treatment Process – 3 Levels of Treatment

- **Low level onsite wastewater nitrogen removal**
  - TN reductions (from STE) of 25-35% prior to GW
  - Compliant conventional system with STU meets this level of treatment

- **Medium level onsite wastewater nitrogen removal**
  - TN reductions (from STE) of 50 – 70% prior to GW
  - Stage 1 PNRS w recirculation or in-ground Stage1/Stage 2 PNRS followed by STU

- **High level onsite wastewater nitrogen removal**
  - TN reductions of 95% prior to GW
  - Numerous 2-stage PNRS configurations from study followed by STU
Task B Recommendations: Technical Recommendations

- Long term monitoring of PNRS is needed to evaluate reliability and life
- PNRS specific tanks, equipment, media, appurtenances are needed prior to widespread implementation
- Detailed design criteria and designs should be developed for several standardized PNRS
- PNRS specifications should be established for all materials and methods
  - Tanks, lids & covers, liners, media, pipe, controls, process controls, operations
Recommendations: PNRS Implementation

- Establish uniform guidance for PNRS regulation and permitting, streamline permitting requirements.
- Establish uniform requirements for PNRS inspection, operation and maintenance
- Establish uniform requirements for PNRS performance monitoring
- Implement technology transfer and training on PNRS implementation
- Establish sufficient FDOH staffing for PNRS implementation, including wastewater engineering staff
Task C: Soil and Groundwater Monitoring
Task C Components

- Literature review to evaluate nitrogen fate and transport in saturated and unsaturated soils
- Developed the soil and groundwater (S&GW) research test facility
- Conducted soil and groundwater monitoring at test facility
- Conducted 3 tracer tests at the S&GW test facility
- Groundwater monitoring at 4 single family residences
Soil and Groundwater Test Facility: N transport studies

NOx plumes at ~ 400 days
Home site (conventional system) groundwater monitoring network
Groundwater monitoring results
Groundwater monitoring: After PNRS installation (System 3)
Most impacted groundwater well
Total nitrogen time series
Task D: Nitrogen Fate and Transport Modeling and Tool Development
Task D Components

- Literature review to evaluate nitrogen fate and transport models
- Simple soil tool for vadose zone N transport
- Development of Florida specific vadose zone fate and transport model (STUMOD-FL)
- Development of saturated zone fate and transport model (HPS)
- Development of combined vadose and saturated zone fate and transport model (STUMOD-FL-HPS)
- Incorporation of multiple OWTS inputs
- Sensitivity analysis
- Uncertainty analysis
Task D - Overview

- Provide a simple to use tool for assessment of OWTS performance and impact to groundwater
  - Literature Review
  - Simple tool
  - Simple to use spreadsheet model, STUMOD-FL-HPS

![Diagram showing nitrogen input and removal percentages]
Task D – Deliverables

- Simple tools
  - tables of selected Florida conditions

- Outcomes
  - white paper discussing relative differences in nitrogen behavior based on various conditions
  - 64 numerical model simulations (HYDRUS-2D)
  - corroboration to field data
  - look-up tables
Task D - Deliverables

- Complex soil-aquifer model
  - rigorous scientific principals, but simple to use
  - stand alone tool

- Outcomes
  - STUMOD-FL-HPS
  - combined unsaturated and saturated zone model
  - corroborated to field data / validated with numerical model
  - demonstration…
Summary & Questions
FOSNRS Summary

- Multi-prong project for evaluating nitrogen reduction from onsite sewage treatment and disposal systems:
  - Treatment technology evaluation including new passive systems
  - Full scale field testing of PNRS treatment technologies
  - Monitoring of nitrogen fate and transport in subsurface
  - Modeling and planning tools to support regulatory decision making
FOSNRS Summary (cont)

- Results indicate that OSTDS are capable of achieving high levels of nitrogen reduction and can play a role in nitrogen reduction from OSTDS in sensitive watersheds.
- Useful tools were developed to assist with planning and implementation of nitrogen reduction strategies for OSTDS in Florida:
  - PNRS-LCCA
  - Simple Soil Tools
  - STUMOD FL
  - STUMOD FL HPS
**What’s left to do?**

- Link the results of all FOSNRS tasks together into a final database and report.
- Link treatment, soil and groundwater tools to develop onsite wastewater nitrogen reduction best management practices (BMPs)
- Develop onsite wastewater nitrogen reduction management strategies for Florida, based on nutrient sensitivity. Watershed/water body sensitivity varies, N reduction is not needed everywhere.
- Develop detailed design criteria, performance definitions, performance boundaries, and strategy implementation guidance
- Move forward with implementation
QUESTIONS?

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Hazen and Sawyer
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e-mail: danderson@hazenandsawyer.com
       jhirst@hazenandsawyer.com
Hydrus 2D modeling of multiple vadose zone nitrogen fate and transport scenarios

Configuration: trench, equal distribution
Soil Type: less permeable sand
Loading Rate: 2.67 cm/d (0.65 gpd/ft²)
Effluent Nitrogen: 60 mg-N/L as NH₄
Depth to Water Table: 60 cm (2 ft)

[Graphs showing water content, ammonium concentrations, and nitrate concentrations]
### Vadose Zone Operating Conditions Modeled

<table>
<thead>
<tr>
<th>Condition</th>
<th>Variations Simulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Configuration</td>
<td>Trenches, equal effluent distribution to each trench; Trenches, unequal effluent distribution to each trench; Bed, equal effluent distribution to each bed; or Bed, unequal effluent distribution to each bed.</td>
</tr>
<tr>
<td>Soil Texture</td>
<td>sandy clay loam; less permeable sand; or more permeable sand.</td>
</tr>
<tr>
<td>Soil Profile</td>
<td>homogenous; or layered</td>
</tr>
<tr>
<td>Effluent Nitrogen Composition</td>
<td>typical STE; or nitrified effluent.</td>
</tr>
<tr>
<td>Depth to Water Table</td>
<td>1 ft below the infiltrative surface; 2 ft below the infiltrative surface; 6 ft below the infiltrative surface; or free drainage (deep water table).</td>
</tr>
</tbody>
</table>
Simple Soil Tool for estimating vadose zone N transport

Configuration: bed, equal distribution
Soil Type: less permeable sand
Loading Rate: 1.68 cm/d (0.41 gpd/ft²)
Effluent Nitrogen: 60 mg-N/L as NH₄
Depth to Water Table: 183 cm (6 ft)
STUMOD FL: Graphical user interface
Vadose zone output (STUMOD-FL)
Vadose zone output (STUMOD-FL)
Vadose zone output (STUMOD-FL)
Saturated zone (HPS) inputs
Saturated zone (HPS) outputs
Saturated zone (HPS) outputs