Florida Onsite Sewage Nitrogen Reduction Strategies Study

Evaluation of Full Scale Prototype Passive Nitrogen Reduction Systems (PNRS) and Recommendations for Future Implementation - Volume II of II

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Volume I – Report
Volume II - Appendices

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AET

Otis Environmental Consultants, LLC

APPENDIX A SYSTEM INSTALLATION REPORTS

Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

Contract CORCL

TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS1

June 30, 2011

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Wakulla County, Florida (B-HS1).

System Overview

The system installed in Wakulla County, Florida (B-HS1) in June 2011 consists of a 1,500 gallon two chamber concrete tank with 1,000 gallon primary treatment tank (1st chamber) and 500 gallon pump chamber (2nd chamber); an Aerocell unsaturated media filter chamber, and a 1,500 gallon single chamber upflow tank containing Nitrex media. Figure 1 is a site schematic showing the system components and layout of the installation. A complete as-built system diagram is included in the Operation and Maintenance manual which is attached as Appendix A. A few of the details in Figure 1 were revised during the installation and are detailed in the next section of this report.

Household wastewater enters the 1st (i.e. septic) chamber of the primary tank and exits as septic tank effluent through a "filter" into the 2nd chamber. A Quanics pump vault within the 2nd chamber serves as another "filter" and contains the pump, float switches, and a post pump filter. The 2nd chamber contents are pumped to the top of the unsaturated Aerocell chamber, after which all wastewater flow is by gravity. Wastewater proceeds downward through the Aerocell media where nitrification occurs. Aerocell effluent then flows into an adjustable split recirculation device which allows for a portion of the Aerocell chamber effluent to be sent back to the 2nd chamber of the primary tank (recirculation) with the rest proceeding to the Nitrex tank. Recirculation back to the 2nd chamber increases the hydraulic loading on the Aerocell unit. Following the Aerocell unit, the nitrified effluent flows into the Nitrex tank where denitrification occurs. The denitrified treated effluent is discharged into the soil via Infiltrator chambers.

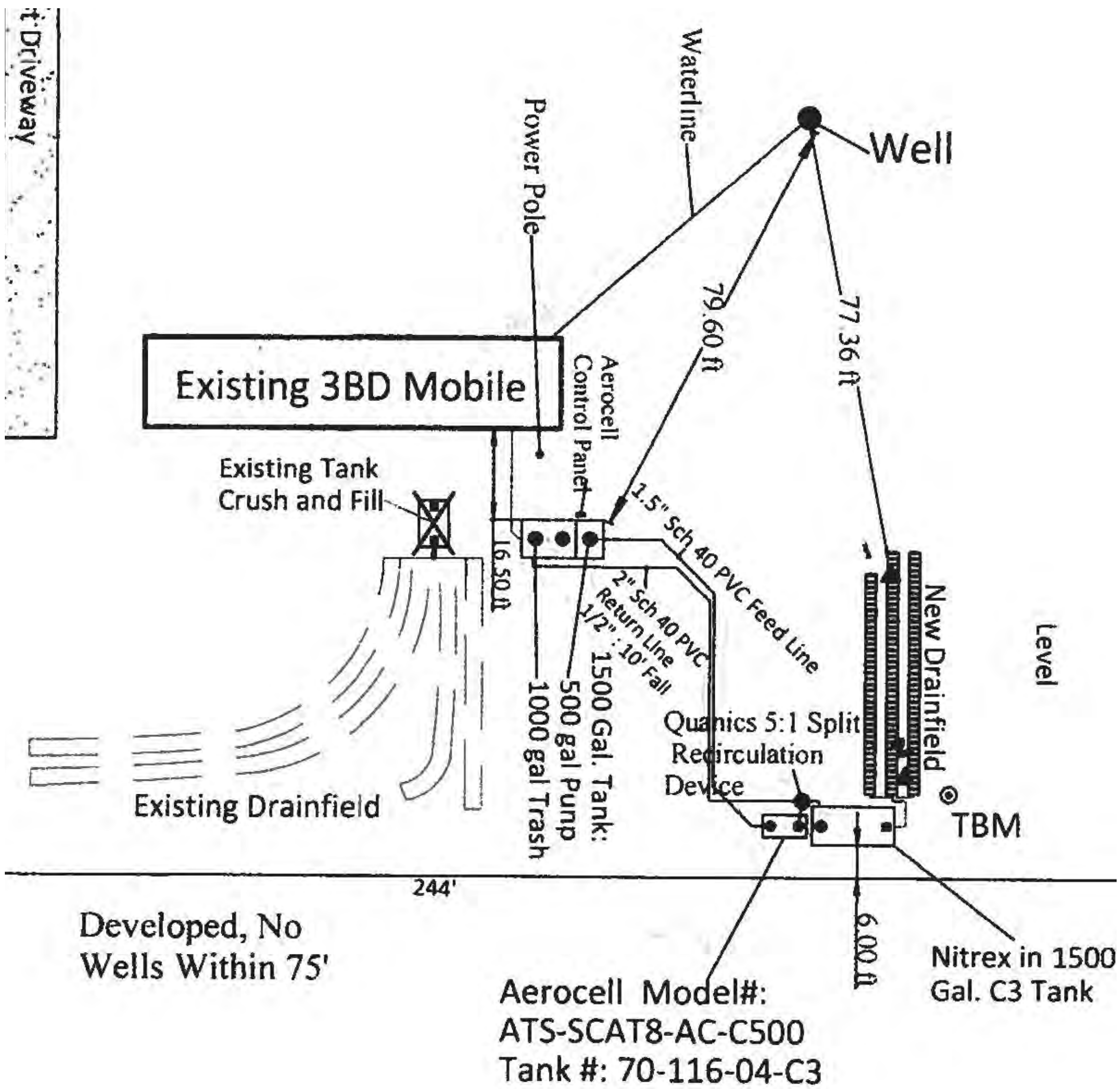

Figure 1
Schematic of PNRS Installed in Wakulla County

Installation

Installation of the system commenced June 7, 2011 and was completed on June 10, 2011. The installation began with a pump out and abandonment of the existing conventional septic system. After the pump out was completed, the old septic tank was crushed and filled with a backhoe (Figure 2).

Figure 2
Old Septic Tank Crushed and Filled

A 1,500 gallon, two compartment tank was installed next to the abandoned tank. The first larger chamber (1,000 gallon) serves as a primary receiving tank, receiving the raw sewage from the household. The second smaller (500 gallon) chamber serves as the pump chamber (Figure 3). Care was taken to assure the tank was installed level. The sewer pipe from the house was plumbed into the side hole at the bottom of Figure 3.

Figure 3
1,500 Gallon Two Chamber Primary Tank

A single chamber (1,500 gallon) concrete tank was then installed towards the back of the property near the planned area of the future drainfield. The purpose of this tank was to hold the Nitrex media. The tank manufacturer delivered a two chamber tank by mistake; therefore the baffle wall was removed using a concrete saw to create a one chamber tank (Figure 4).

Figure 4
1,500 Gallon Single Chamber Nitrex Tank

The Aerocell chamber and the split recirculation device were installed adjacent to the Nitrex tank and leveled. Copper sulfate was applied to the soil underneath these two components to prevent root growth from causing the Aerocell and split recirculation device to become unleveled. Once the Nitrex tank, Aerocell chamber, and the split recirculation device were installed and leveled, plumbing connections were installed (Figure 5). An inline flow meter was installed prior to the Aerocell chamber to record the cumulative flow in gallons pumped from the 2nd chamber of the primary tank (Figure 6). At this location, the flowmeter measurement includes the forward wastewater flow and the recirculation flow. Figure 5 shows the line leading into the Aerocell chamber with water meter, the line coming out of the Aerocell chamber into the split recirculation device, the line from the split recirculation device to the Nitrex tank, and the line from the split recirculation device back to the 2nd chamber of the two chambered primary tank. Flow from the split recirculation device is by gravity to both the Nitrex tank and the 2nd chamber of the primary tank.

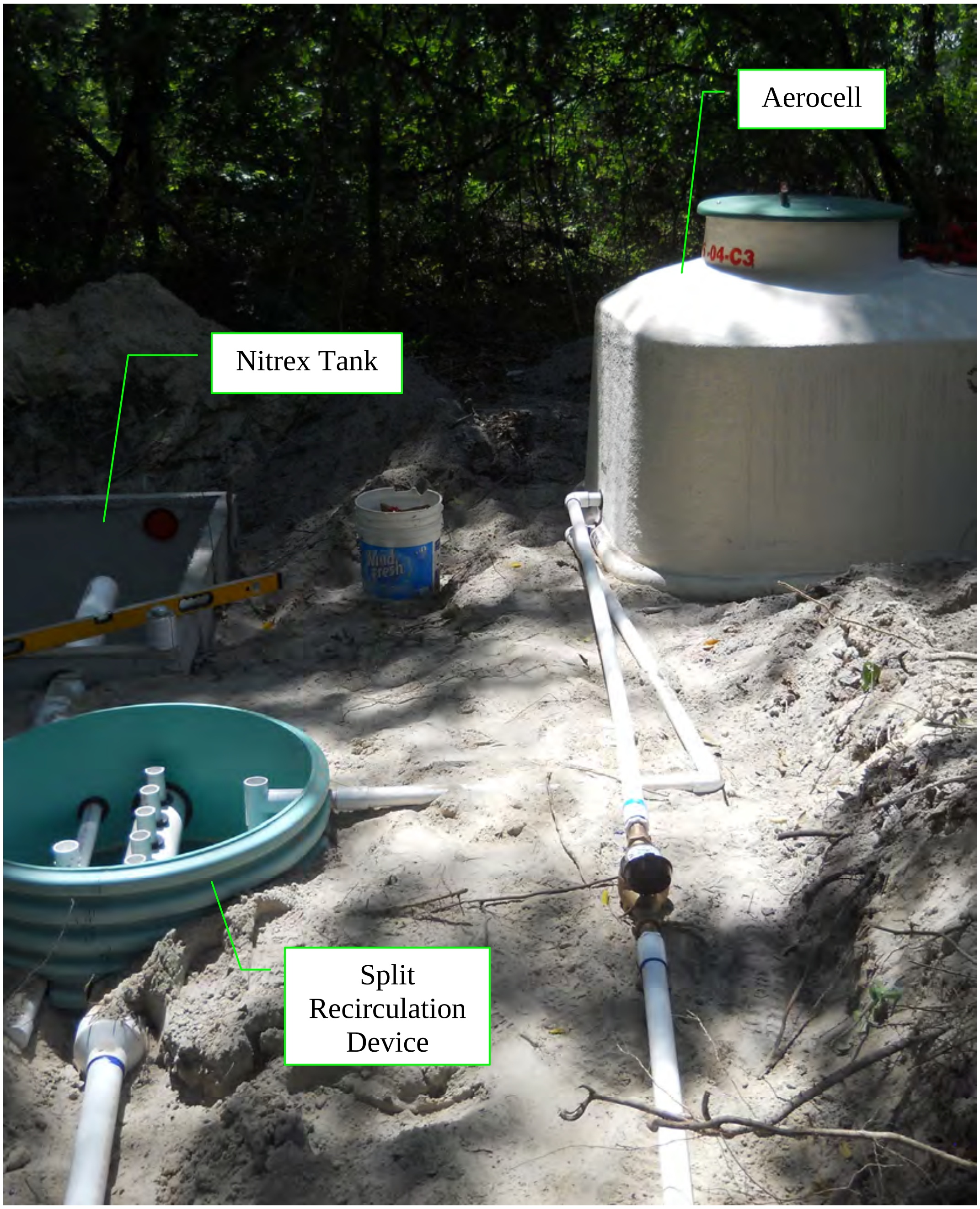

Figure 5
Layout and Plumbing of the Nitrex Tank, Aerocell Chamber and Split Recirculation Device

Figure 6
Aerocell Flow Meter

The Aerocell chamber is a single chamber filled with high density foam cubes. Effluent is applied to the top of the Aerocell high density foam cubes (Figure 7) by four spray nozzles located above the cubes. Not shown are the pressure gauge and the ball valve which allows the pressure of the pumped effluent to be adjusted. The target pressure is between 5 and 10 PSI, with 7 PSI being optimal. The spray nozzles are removable for cleaning in the event clogging occurs despite the filter in the STE tank, the pump tank filter, and the filter installed following the pump (Figure 8).

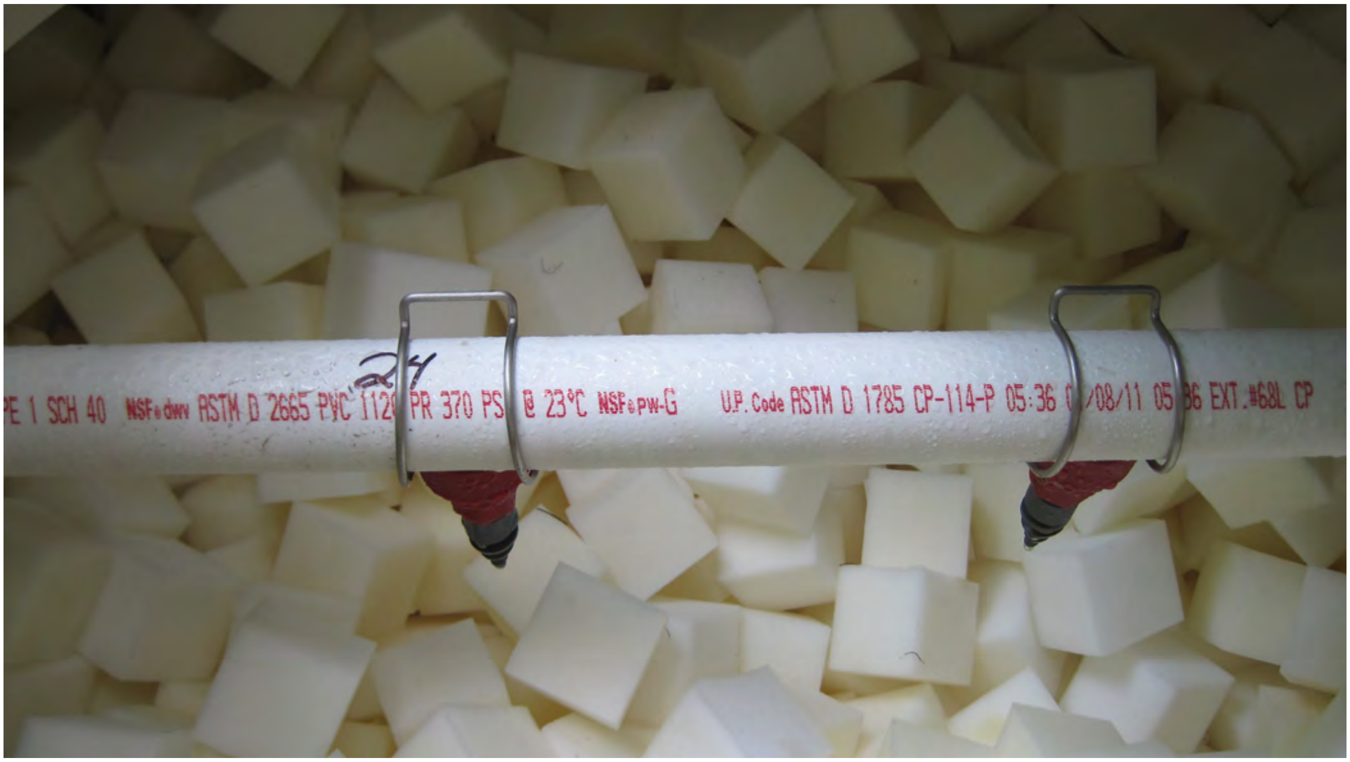

Figure 7
Spray Nozzles and High Density Foam Cubes Inside One Side of Aerocell Chamber

Figure 8
Removable Nozzle from Aerocell Chamber

Although Figure 1 indicates a 5 to 1 split recirculation device, the device installed is capable of a 7 to 1 split. The amount of recirculation is adjustable from 7 parts recirculation back to the 2nd chamber of the primary tank and 1 part going to the Nitrex tank, down to no recirculation to the 2nd chamber. The split recirculation device consists of 7 adjustable PVC pipes that deliver effluent back to the two chamber tank and one fixed PVC pipe that delivers effluent to the Nitrex tank. To reduce the amount of effluent recirculated back to the two chamber tank, one or more of the 7 PVC pipes are simply raised above the water line. The inlet pipe from the Aerocell chamber is shown with a PVC tee. This piece was left unglued so that it can be removed to gather an effluent sample from the Aerocell chamber (Figure 9).

Figure 9
Split Recirculation Device

Figure 1 shows the recirculating effluent flowing back to the 1st chamber of the primary tank via a 2 inch pipe, however the design was modified. As installed, the 2 inch PVC pipe was increased to 4 inch PVC pipe which was fitted with a "Y" and a "bull run" valve (Figure 10 and 11). This gives the option of having the recirculation effluent flow to either the 2nd chamber or the 1st chamber of the primary tank. A riser pipe was installed to grade over the valve, so that the valve can be turned after installation is complete. The valve is turned with a wrench on a rod which is long enough to reach with the riser installed (Figure 11). The valve was initially set so the recirculation goes to the 2nd chamber. Not shown in Figure 10 is the screw cap covering the riser pipe. Shown in the lower left corner of Figure 10, is the sewer pipe from the home.

Figure 10
Split of Recirculation Pipe back towards the Two Chamber Tank

Figure 11
Valve being turned with Tool

The 1st chamber filter was installed in the hole in the baffle separating the first and second chambers (Figure 12). Concrete was used to seal the pipe in the baffle wall. Effluent enters the filter from a 4 inch PVC tee located at the midpoint of the tank depth. The pipe shown extending from the tee downwards is to provide support for the filter. A 4 inch PVC tee was also installed on the recirculation line in the 1st chamber. The down leg of pipe was cut to the midpoint of the tank.

Figure 12
Filter between 1st Chamber and 2nd Chamber of Primary Tank

The tank lid has three risers as shown in Figure 13. The riser to the right allows access to the 1st chamber, which provides the ability to pump out as needed. The middle riser allows the 1st chamber filter to be serviced. STE samples will also be taken from this riser. The riser to the left gives access to the 2nd chamber. The blue cylinder shown in Figure 13 is the pump vault. Figure 14 shows the installed pump vault, the valve for sample access, and the final filter on the pipe leading to the Aerocell chamber. Samples taken from the pump vault represent the water quality characteristics of Aerocell influent. The hose shown in Figure 14 was used to fill the 2nd chamber with potable water prior to testing the system.

Figure 13
Primary Tank Lid and Pump Vault

Figure 14
Plumbing and Filter installed in Pump Vault inside of 2nd Chamber

Four float switches were installed to maintain the effluent level in the 2nd chamber of the primary tank and are attached to a “float tree” installed in the pump vault and connected to the control panel. The height of the floats is adjustable and once the proper heights were established, screws were used to secure the floats to the float tree. Figure 15 shows the float tree being placed into the pump vault after adjustment.

Figure 15
Placing Float Tree into the Pump Vault

A power meter was installed between the main power box of the house and the control panel to record cumulative power usage of the pump in kilowatts. The equipment connected to the power meter are the recirculation pump and the control panel. Figure 16 shows the power meter located above the control panel.

Figure 16
Control Panel and Power Meter

The system control panel (Figure 17) allows for a timed pump cycle which can be overridden if the effluent levels are too low or too high in the 2nd chamber of the primary tank. If the floats indicate a low effluent level in the tank, the timed cycle is turned off to protect the pump. If the floats indicate a high effluent tank level, then the pump cycles faster (off cycle reduced) until the water level reaches the optimal range. An alarm will indicate if the water level goes above a critical level.

Figure 17
Control Panel

The inlet pipe into the Nitrex tank was routed down to the bottom of the tank and a 90 degree bend was used to attach a 4 inch pipe with a row of drilled holes. This allows for the tank to be filled from the bottom in a uniform manner (Figure 18). The pipe shown across the top of the tank is the outlet pipe to be connected at the top.

Figure 18
Inlet Pipe installed in the Nitrex Tank

After the inlet pipe was in place, the tank was filled with the Nitrex media (Figure 19). This media consisted of pine wood chips and pine sawdust. The pipe extending upwards from the inlet tee was used temporarily during media filling to prevent media from entering the inlet pipe.

Figure 19
Filling the Nitrex Tank with Media

After the media was installed to the desired height, the outlet pipe for the tank was installed (Figure 20). The outlet pipe which has two rows of drilled holes on the top and is wrapped with a plastic mesh to prevent wood chips from entering the pipe collects the wastewater for discharge to the drainfield. The PVC pipe underneath the outlet pipe shown in Figure 20 was used to level the pipe above the media.

Figure 20
Outlet Pipe in the Nitrex Tank

Following the outlet pipe install, additional media was used to fill the tank to the level of the influent pipe (Figure 21), and the lid was installed (Figure 22).

Figure 21
Nitrex Tank filled with Media

Figure 22
Nitrex Tank with Lid Installed

Two Risers were cemented over the tank openings and the drainfield was installed (Figure 23). The drainfield consists of Infiltrator chambers in 4 trenches spaced two feet apart. Three rows are 40 feet in length, and the fourth is 36 feet long. The original design shown in Figure 1 only showed three rows, two 44 feet long and the third shorter row being 40 feet long. However, in some areas of the drainfield, the clay layer was shallower than anticipated from the original soil borings, and the drainfield area was therefore enlarged. The chambers were covered in protective fabric to prevent sand from washing into and filling the chambers.

Figure 23
Four Rows of Infiltrator Drainfield Chamber

On the pipe between the Nitrex tank and the drainfield, a catch basin was installed so that the final effluent discharged to the drainfield can be sampled (Figure 24). The black piece extends into the ground approximately three inches. The riser pipe shown was cut at the final grade and capped with a screw cap.

Figure 24
Sampling Port for the Effluent being discharged to the Drainfield

During final testing of the system, leaks were discovered from the split recirculation device around the grommets. The grommets were sealed with PVC glue (Figure 25). The drainfield trenches were filled and all disturbed areas on the property were graded. Sod will be laid after consulting the homeowner concerning placement of the sod.

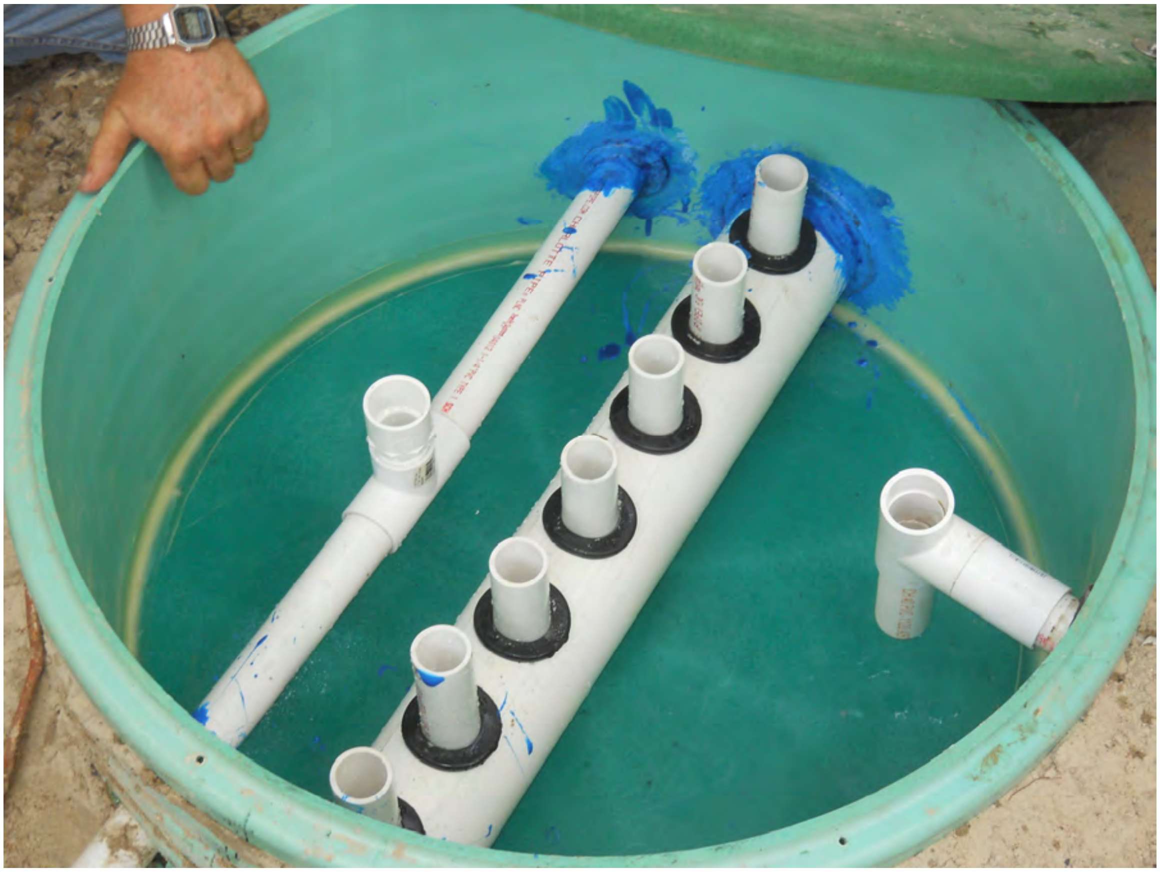

Figure 25
Sealing Leaks around Grommets

A water meter was installed on the water line from the household well. The water line for the one hose bib on the home was re-plumbed so that the junction came before the water meter. This allows for the measurement of the household water use independent of water use outside the home (Figure 26). So we will assume this represents flow to the treatment system.

Figure 26
Water Meter on line leading into the home, installed after junction for hose bib

Operation and Verification

On June 9, 2011, the 2nd chamber of the primary tank was filled with potable water for system operational testing. The pump was tested and found to deliver approximately 26 gallons of water to the Aerocell unit per minute. It was also found that there is a six second delay between pushing the manual pump button (labeled “Hand”) on the control panel and water arriving to the Aerocell chamber. At the end of the day, the split recirculation device was set to a 7 to 1 recycle split, with 7 parts going back to the 2nd chamber of the primary tank and 1 part going to the tank with the Nitrex media. The on and off cycles were set, and the data from the control panel and two water meters were read and recorded (Table 1). The next morning, it was decided that the recirculation was too great as it took approximately 50 cycles to decrease the level of the 2nd chamber of the primary tank to the level when the time dose is turned off. (At this time the 1st chamber had less than 160 gallons, so no other water was added to the 2nd chamber). The split recirculation device was then set so that 5 parts went back to the 2nd chamber and 1 part went to the Nitrex tank by the vendor. At the control panel, the on and off cycles were set for longer times with the decreased recirculation (Table 1). Before leaving the site, the settings and readings on the control panel, the electric meter, and two water meters were read and recorded.

Table 1
Initial Settings and Readings Recorded

	6/9/11 18:15	6/10/11 12:35	Notes
Recirculation Ratio	7:1	5:1	
Control Panel Settings			
Pump Run Time (hr:min)	0:05	1:48	
Pump Activations	9	61	Some from testing floats
Alarm Counter	0	3	From testing alarm
Float Error	0	0	
Timer Override	0	0	
On time cycle (min:sec)	1:36	2:06	
Off time cycle (min:sec)	13:48	18:24	
Electric Meter	1 KW	2KW	Installed with 1 KW on dial
House Water Meter	87.3 (17:10)	148.2 (12:25)	Installed 6/8/11 14:10
Septic Pump Water Meter	NR	629.2 (12:30)	Installed with reading 2.1 gal

Notes: The On Time Cycle and Off Time Cycle are settings. The rest of the parameters are cumulative readings. For both water meters, the actual time read on each date is given in parenthesis.

The Nitrex™ system inspection checklist from July 26th is provided in Appendix B. The system operating permit was issued June 24, 2011, and the construction inspection and final approval was issued August 31, 2011. Both these documents are included in Appendix C. The final construction costs for the installed system was $23,600 as detailed in Appendix D.

Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

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TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS2

September 2012

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Hillsborough County, Florida (B-HS2).

System Overview

The B-HS2 system was installed in Hillsborough County, Florida in September 2012. It consists of a replacement 1,050 gallon two chamber concrete primary tank; 300 gallon concrete recirculation tank; 900 gallon concrete Stage 1 unsaturated media filter; 300 gallon concrete pump tank; and 1,500 gallon two chamber concrete Stage 2 saturated media biofilter. Figure 1 is a site schematic showing the system components and layout of the installation. The complete as-built system drawings are included in the attached Appendix A.

Household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen into the recirculation tank. The recirculation tank contents are discharged by gravity to a distribution box, located inside the Stage 1 biofilter, which splits the flow between two perforated distribution pipes along the top of the unsaturated Stage 1 biofilter media. The Stage 1 biofilter contains 10 inches of coarse expanded clay media (Riverlite™ 1/4; 1.1 to 4.8 mm) above 20 inches of finer expanded clay media (Riverlite™ 3/16; 0.6 to 2.4 mm). Wastewater proceeds downward through the expanded clay media where nitrification occurs. Stage 1 biofilter effluent then flows into the pump tank (which contains the pump and float switches). The pump tank discharge is split via two throttling globe valves which allow for a portion of the Stage 1 biofilter effluent to be sent back for recirculation with the rest proceeding to the Stage 2 biofilter. The system was designed with two recirculation modes of operation. The first option (which will initially be tested) is to have the recirculated effluent return to the recirculation tank for mixing with incoming septic tank effluent. The second option is to have the recirculated effluent return to the top of the Stage 1 biofilter, dispersed by three spray nozzles. Recirculation back to either the recirculation tank or Stage 1 biofilter increases the hydraulic loading on the Stage 1 biofilter. Effluent form the unsaturated (Stage 1) media tank enters the denitrification (Stage 2) biofilter into a standing water column lying above the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell). The Stage 2 biofilter contains 42-inches of lignocellulosic media in the first chamber. A collection pipe along the bottom transfers the effluent to the second chamber which contains 24-inches of elemental sulfur mixed with oyster shell media. The Stage 2 biofilter effluent discharges near the top of the tank; therefore denitrification occurs in the saturated environment. The denitrified treated effluent is discharged into the soil via the existing mounded drainfield (P.T.I.™ bundles). A flow schematic of the system is shown on Figure 2.

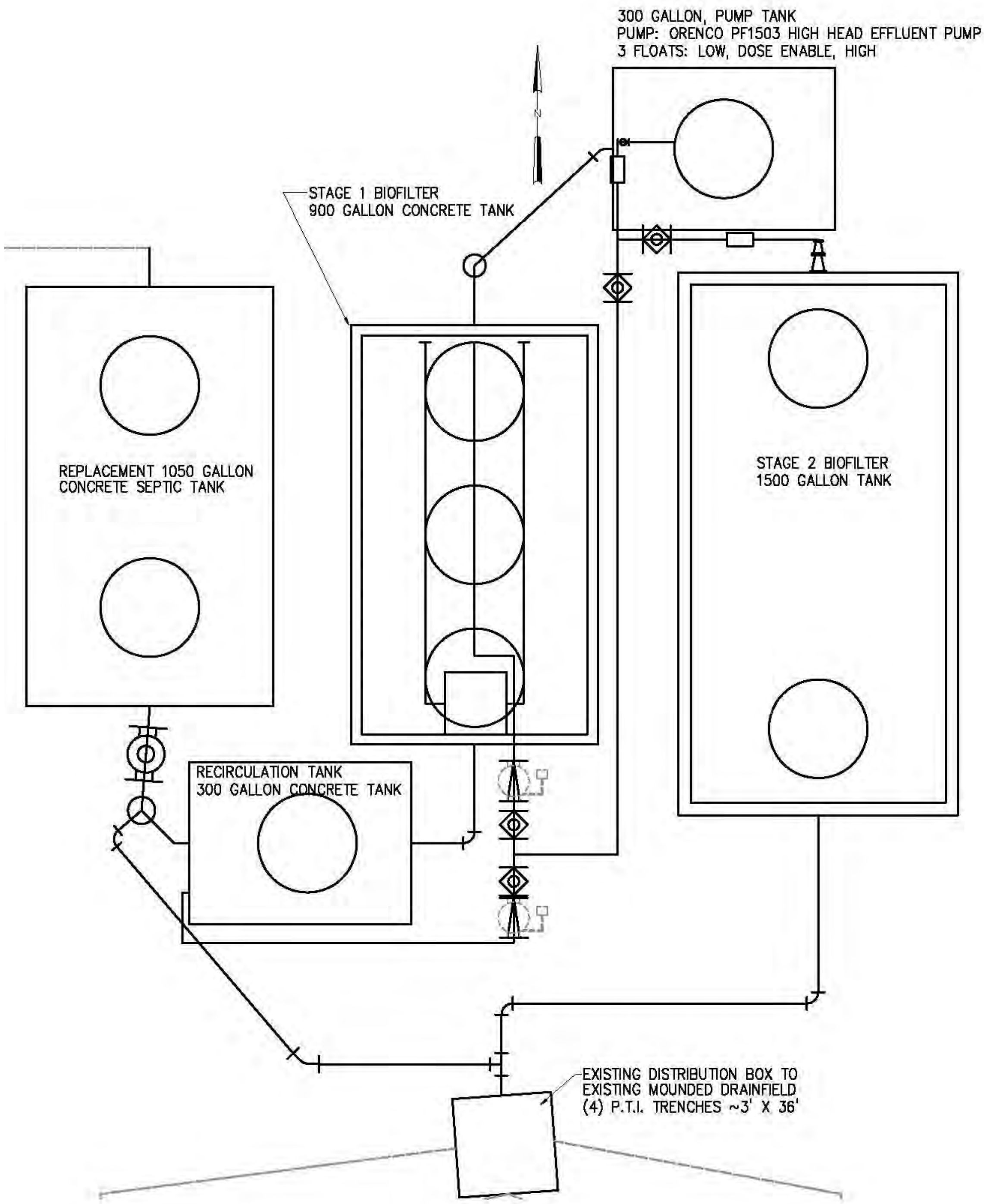

Figure 1
Schematic of B-HS2 PNRS installed in Hillsborough county

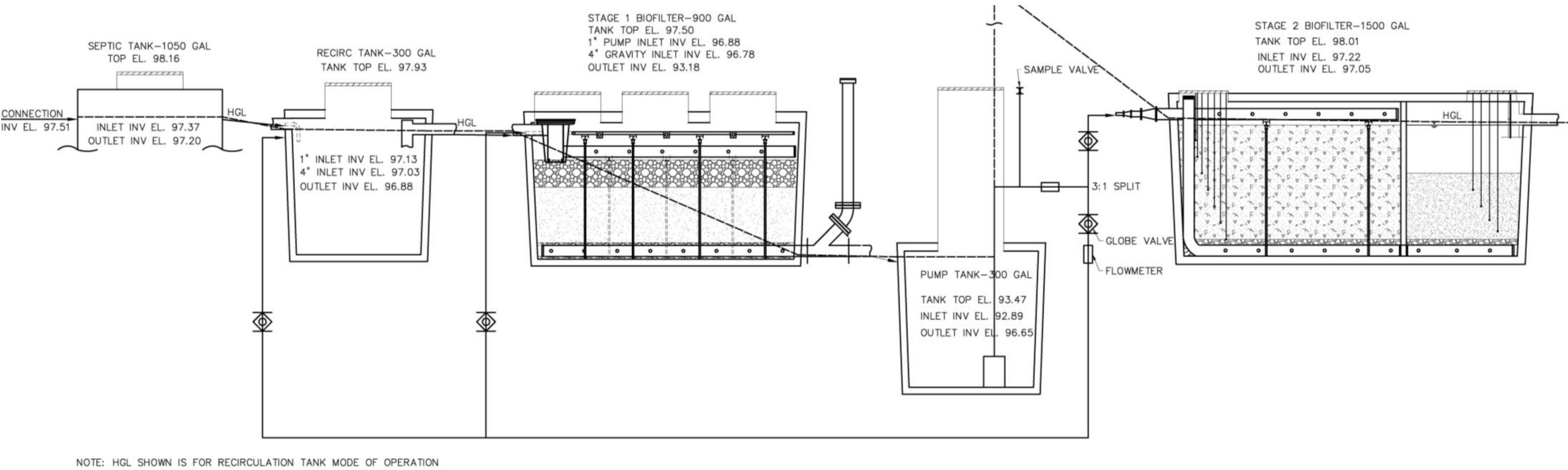

Figure 2
Flow Schematic of B-HS2 PNRS installed in Hillsborough county

Installation

Installation of the system commenced September 10, 2012 and was completed on September 12, 2012. The installation began with a pump out and removal of the existing 1,050 gallon septic tank, which was found to be cracked during the system evaluation. After the pump out was completed, the old septic tank was removed (Figure 3).

Figure 3
Old septic tank removed

A 1,050 gallon, two compartment replacement concrete primary tank was installed. The first larger chamber serves as a primary receiving tank, receiving the raw sewage from the household. The sewer pipe from the house was plumbed into the 4"D (diameter) inlet hole shown in Figure 4. An effluent screen (Polylok^{TM}, PL-68) was installed in the outlet tee of the second chamber (Figure 5).

Figure 4
1,050 gallon, two chamber, primary Tank

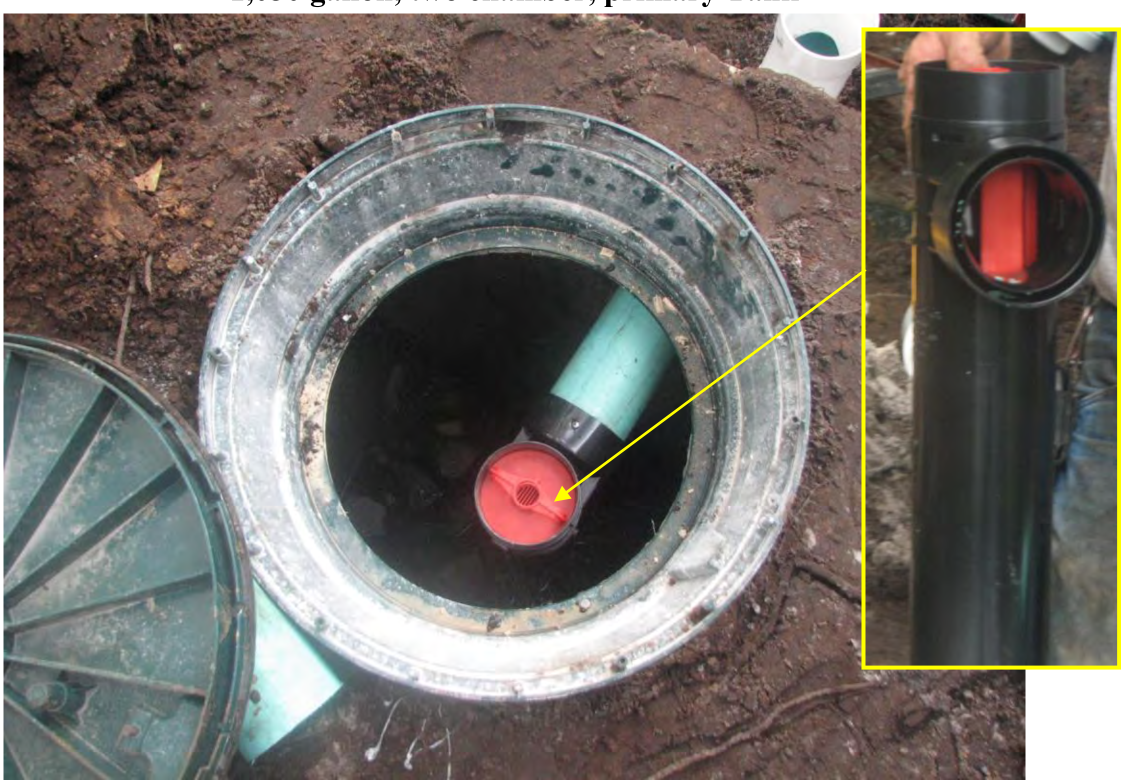

Figure 5
Primary tank effluent screen

Following the primary tank installation, the remaining passive nitrogen reduction system components were installed (Table 1). A single chamber (900 gallon) concrete tank was installed beside the primary tank (Figure 6). The purpose of this tank is to hold the Stage 1 expanded clay media. The 4"D inlet of the tank is connected (gravity flow) to the recirculation tank discharge. The 2"D inlet is connected (pressurized flow) to the recirculation pipe from the pump tank. The 4"D outlet (Figure 7) of the pipe is located near the bottom of the tank to allow for unsaturated operation. The 4"D underdrain pipe (perforated) with gravel surrounding was installed along the centerline of the bottom of the tank for effluent collection (Figure 8). Following gravel installation and leveling, 20-inches of fine (3/16 Riverlite™) expanded clay media was installed (Figure 9). Above the fine media, 10-inches of coarse (1/4 Riverlite™) expanded clay media was installed (Figure 10). Following media installation and leveling, the influent distribution network was installed. The 4"D influent pipe, connected to the recirculation tank discharge, discharges into a distribution box which flows to two 4"D perforated pipes across the top of the media (Figure 11). The distribution box includes two Polylok equalizer™ weirs to allow for the adjustment of the flow split (Figure 12). The 2"D influent pipe is reduced to a 1"D pipe along the centerline with three spray nozzles attached to distribute the recirculated effluent. The spray nozzles are removable for cleaning in the event clogging occurs (Figure 13).

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	1,050	37	none
Recirculation Tank	300	12	none
Stage 1 Biofilter	900	37	• 10" Riverlite 1/4 • 20" Riverlite 3/16
Pump Tank	300	12	none
Stage 2a Biofilter, downflow	1,000 (1,500 total)	36 (54 total)	42" lignocellulosic (Southern yellow pine)
Stage 2b Biofilter, upflow	500 (1,500 total)	18 (54 total)	24" Elemental sulfur (90%) & oyster shell mixture (10%)

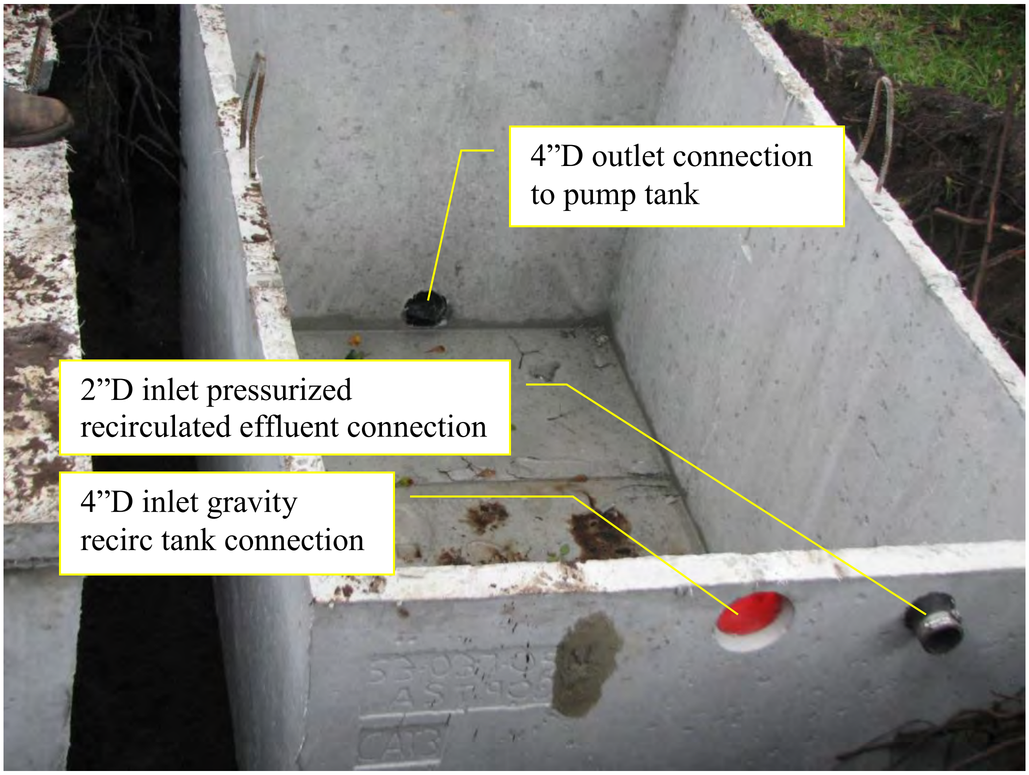

Figure 6
900 gallon, single chamber, stage 1 biofilter tank

Figure 7
Stage 1 biofilter 4”D outlet pipe, with cleanout

Figure 8
Stage 1 biofilter gravel underdrain

Figure 9
Stage 1 biofilter 20-inches of fine media (3/16 Riverlite^{TM})

Figure 10
Stage 1 biofilter 10-inches of coarse media (1/4 Riverlite^{TM})

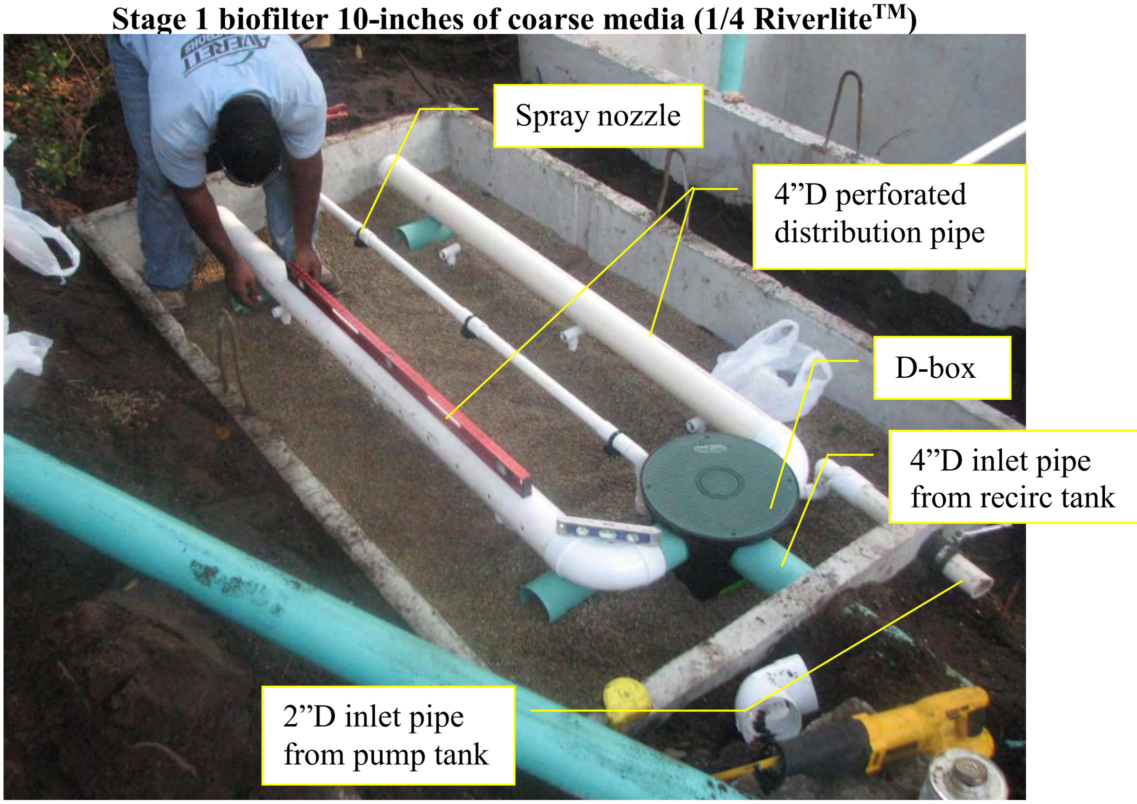

Figure 11
Stage 1 biofilter influent distribution system

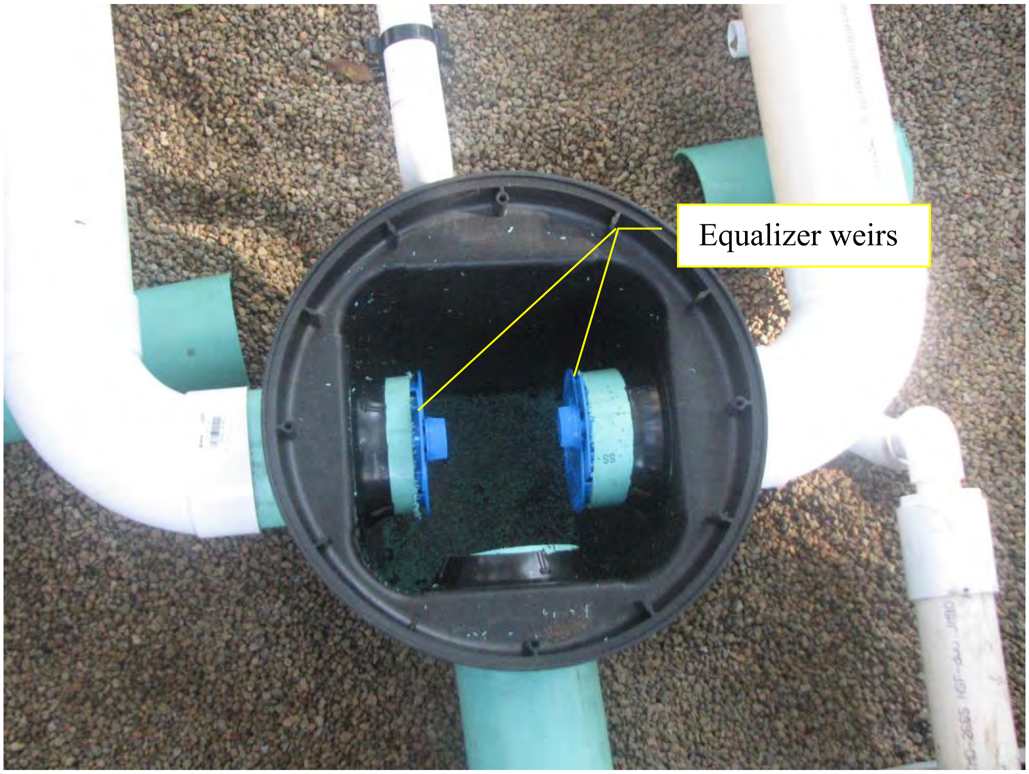

Figure 12
Stage 1 biofilter d-box

Figure 13
Removable spray nozzle

The 300 gallon concrete recirculation tank was then installed (Figure 14). The 4"D inlet is connected to the septic tank effluent discharge, and the 2" D inlet is connected to the recirculation pipe from the pump tank. A bull run valve™ (Figure 15) was installed following the septic tank outlet to allow the flow to either be completely directed to the new passive system (to the recirculation tank) or to the existing distribution box (to the existing drainfield). A riser pipe was installed to grade over the valve, so that the valve can be turned after installation is complete. The valve is turned with a wrench on a rod which is long enough to reach with the riser installed (Figure 15).

Figure 14
300 gallon recirculation tank

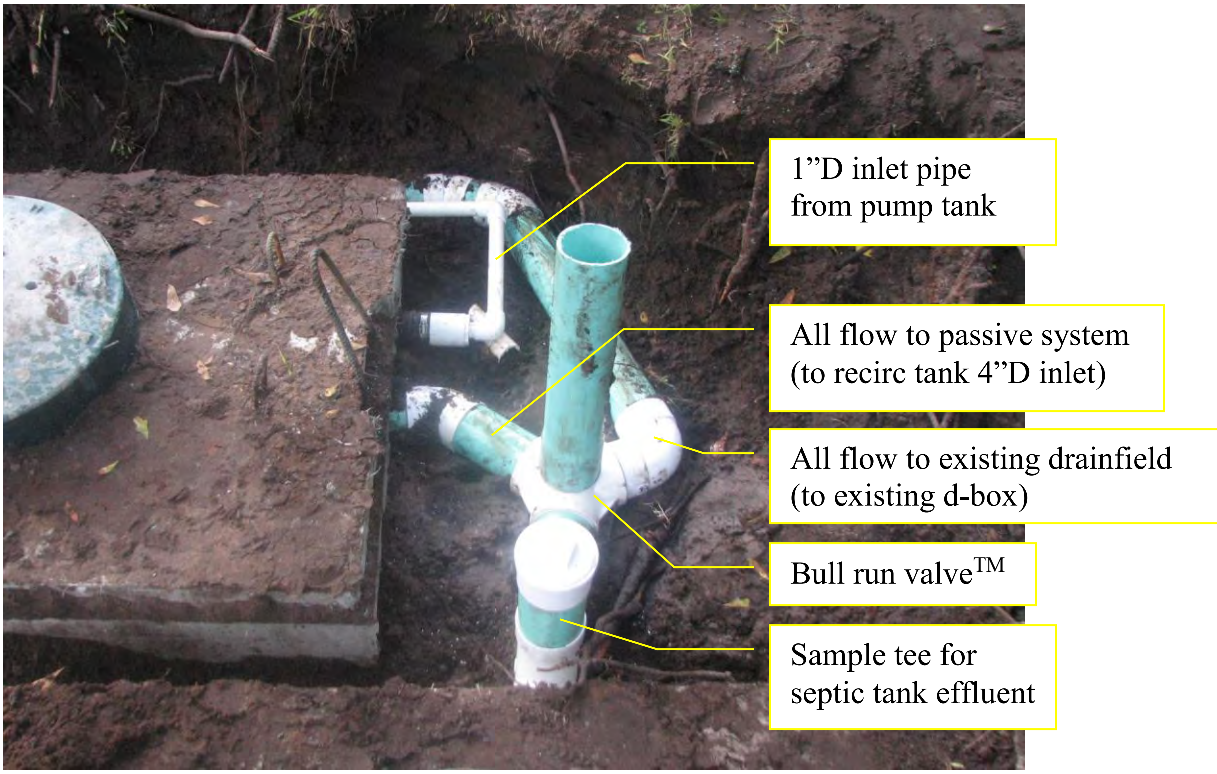

Figure 15
Bull run valve™

Next, the 300 gallon concrete pump tank was installed downgradient of the Stage 1 biofilter (Figure 16). The outlet pipe connection was plugged since the pump discharge pipe is installed through the riser. The pump was installed within a holding bracket which also supports the float tree (Figure 17). Three float switches were installed to maintain the effluent level in the pump tank and are attached to a float tree installed in the pump tank and connected to the control panel. The height of the floats is adjustable and once the proper heights were established, screws were used to secure the floats to the float tree.

Two inline flow meters were installed following the pump discharge. The first inline flow meter was installed prior to the recirculation flow split, to record the cumulative flow in gallons pumped from the pump tank (Figure 18). At this location, the flowmeter measurement includes the forward wastewater flow (F) and the recirculation flow (R). Two throttling globe valves were installed to allow for the adjustment of F and R flow to achieve the target recirculation ratio (initially set at approximately 3:1). The second flowmeter installed downstream of the F globe valve measures the forward wastewater flow to the Stage 2 biofilter (Figure 18). As previously discussed, the design includes two modes of operation for the recirculation of Stage 1 effluent: 1) to the recirculation tank or 2) to the Stage 1 biofilter spray nozzles. Two ball valves were installed (Figure 19) which either shut on or off the recirculation mode desired (initially set so that all the recirculation flow returns to the recirculation tank).

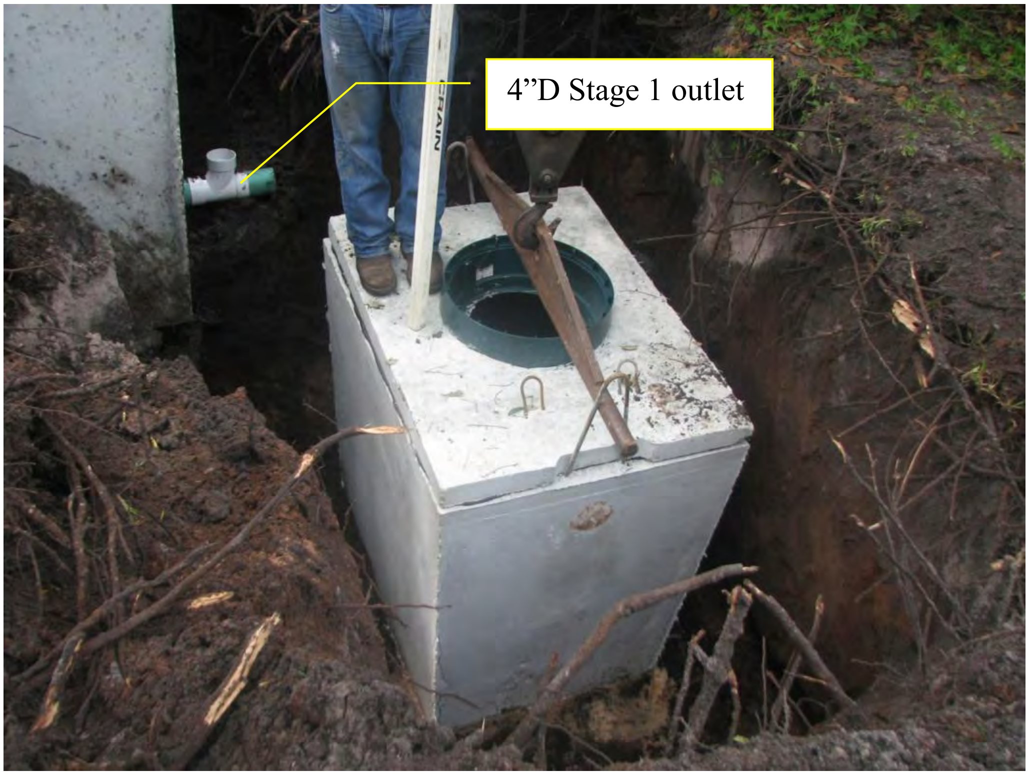

Figure 16
300 gallon pump tank

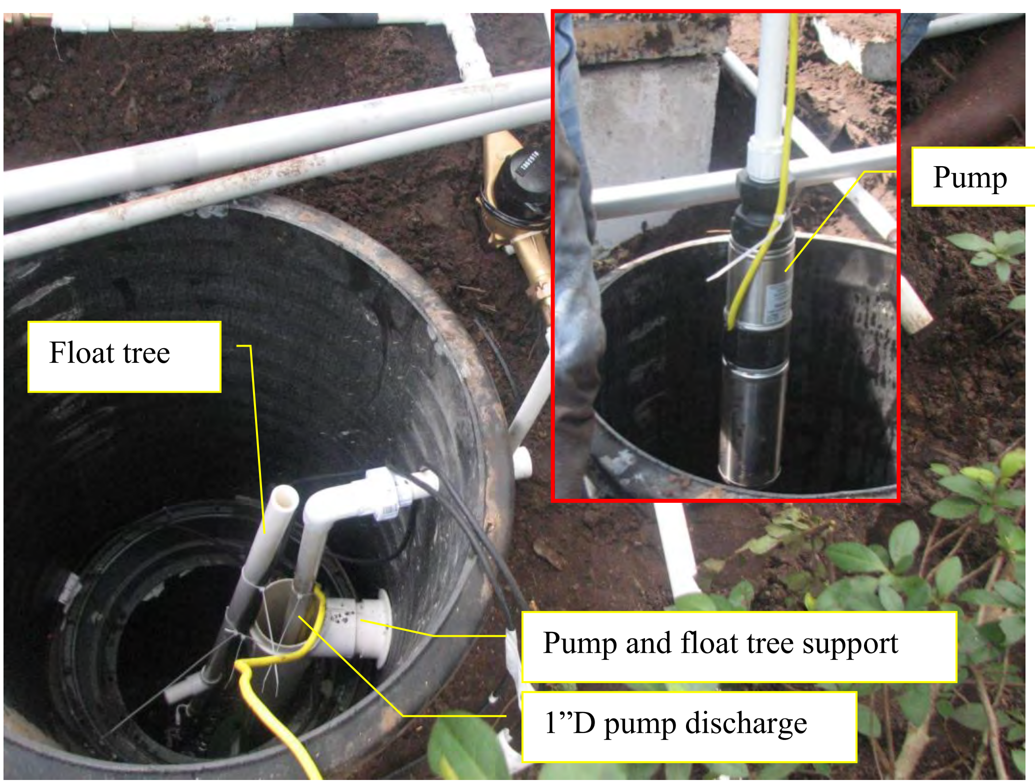

Figure 17
300 gallon pump tank (pump and float tree)

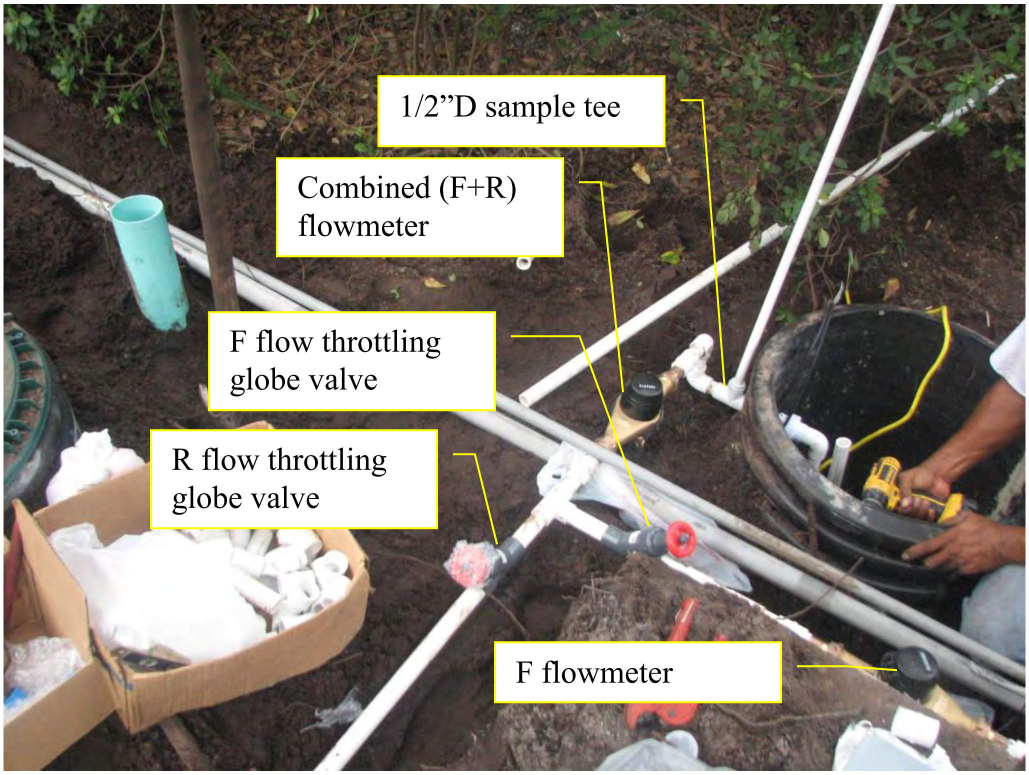

Figure 18
Recirculation flow split and monitoring

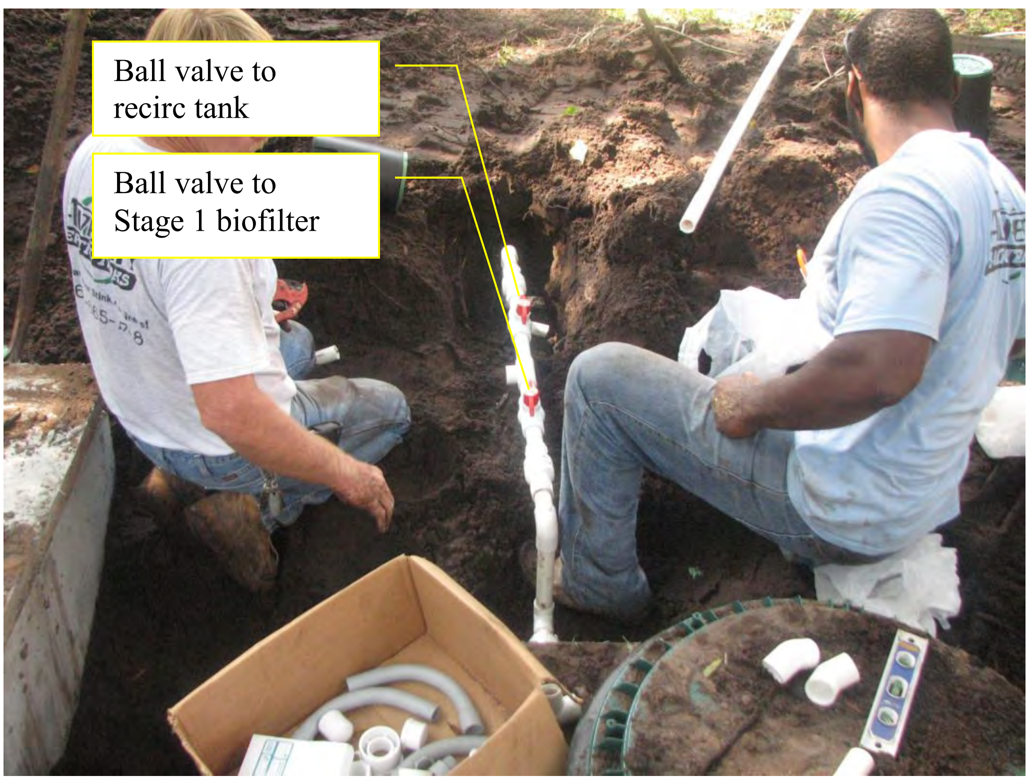

Figure 19
Recirculation mode of operation flow split

The last tank installed was a two chamber (1,500 gallon) concrete tank (Figure 20). The purpose of this tank is to hold the Stage 2 lignocellulosic and sulfur media. The 1”D pipe downstream of the F flowmeter is expanded to 4”D and connects to a perforated pipe which distributes nitrified effluent over the lignocellulosic media within the first chamber of the Stage 2 biofilter. The nitrified effluent flows downward through the lignocellulosic media (within first chamber) and upward through the sulfur media mixture (within second chamber).

A 4”D underdrain pipe (perforated) with gravel surrounding was installed along the centerline of the bottom of the tank for transfer from the first chamber to the second chamber (Figure 21). The tank arrived with a coupling cast into the baffle wall near the bottom to connect both chambers of the tank. Following the underdrain gravel installation (Figure 22) and leveling, 24-inches of elemental sulfur and oyster shell media was installed and mixed (Figure 23) within the second chamber. A stainless steel drivepoint sampler tree (Figure 24) was installed for sampling at 3, 7, 12, and 18-inches above the bottom of the sulfur media mixture (Figure 23).

Above the gravel underdrain within the first chamber of the tank, 42-inches of lignocellulosic media was installed (Figure 25). A stainless steel drivepoint sampler tree was installed for sampling at 0, 6, 12, 18, 24, 30, and 36-inches above the bottom of the lignocellulosic media. A 4”D perforated pipe was connected to the inlet of the tank for effluent dispersal above the lignocellulosic media. A 4”D tee was installed at the outlet of the tank which allows for saturated operating conditions across the biofilter (Figure 26). The 4”D outlet is connected to the distribution box to the existing drainfield.

Figure 20
1,500 gallon stage 2 biofilter tank

Figure 21
Stage 2 biofilter tank perforated pipe along bottom (lignocellulosic chamber)

Figure 22
Stage 2 biofilter tank gravel underdrain (sulfur chamber)

Figure 23
Stage 2 biofilter tank (sulfur mixed with oyster shell)

Figure 24
Stage 2 biofilter tank SST drivepoint sampler tree (sulfur chamber)

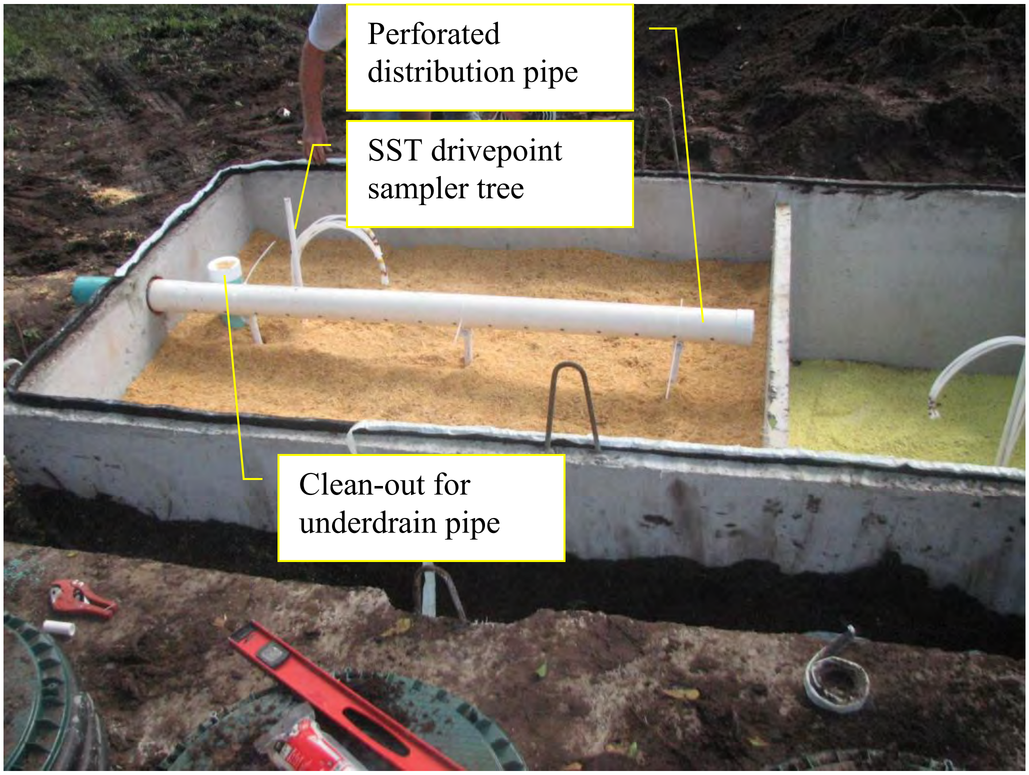

Figure 25
Stage 2 biofilter tank (lignocellulosic media)

Figure 26
Stage 2 biofilter tank outlet tee

A power meter was installed between the main power box of the house and the control panel to record cumulative power usage of the system in kilowatts. The equipment connected to the power meter are the recirculation pump and the control panel. Figure 27 shows the power meter installed inside the control panel.

The system control panel (Figure 27) allows for a timed pump cycle which can be overridden if the effluent levels are too low or too high in the pump tank. If the floats indicate a low effluent level in the tank, the timed cycle is turned off to protect the pump. If the floats indicate a high effluent tank level, then the pump cycles faster (off cycle reduced) until the water level reaches the optimal range. An alarm will indicate if the water level goes above a critical level. The control panel is connected to a phone line which transmits data to Vericomm for monitoring.

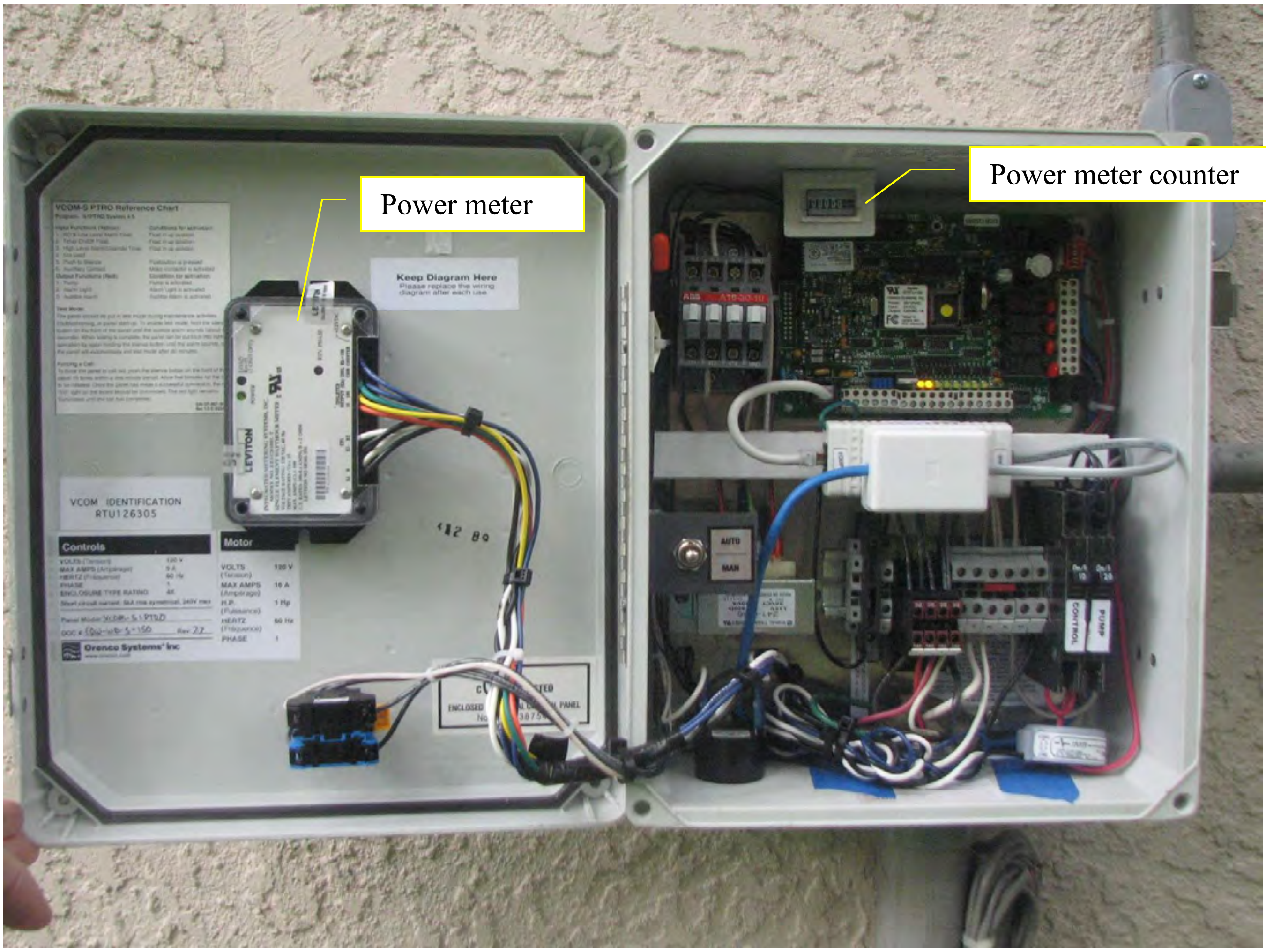

Figure 27
Control Panel

During final testing of the system, the system operated with no visible signs of leaks, etc. The system area was filled and all disturbed areas on the property were graded (Figure 28) and covered with sod (Figure 29).

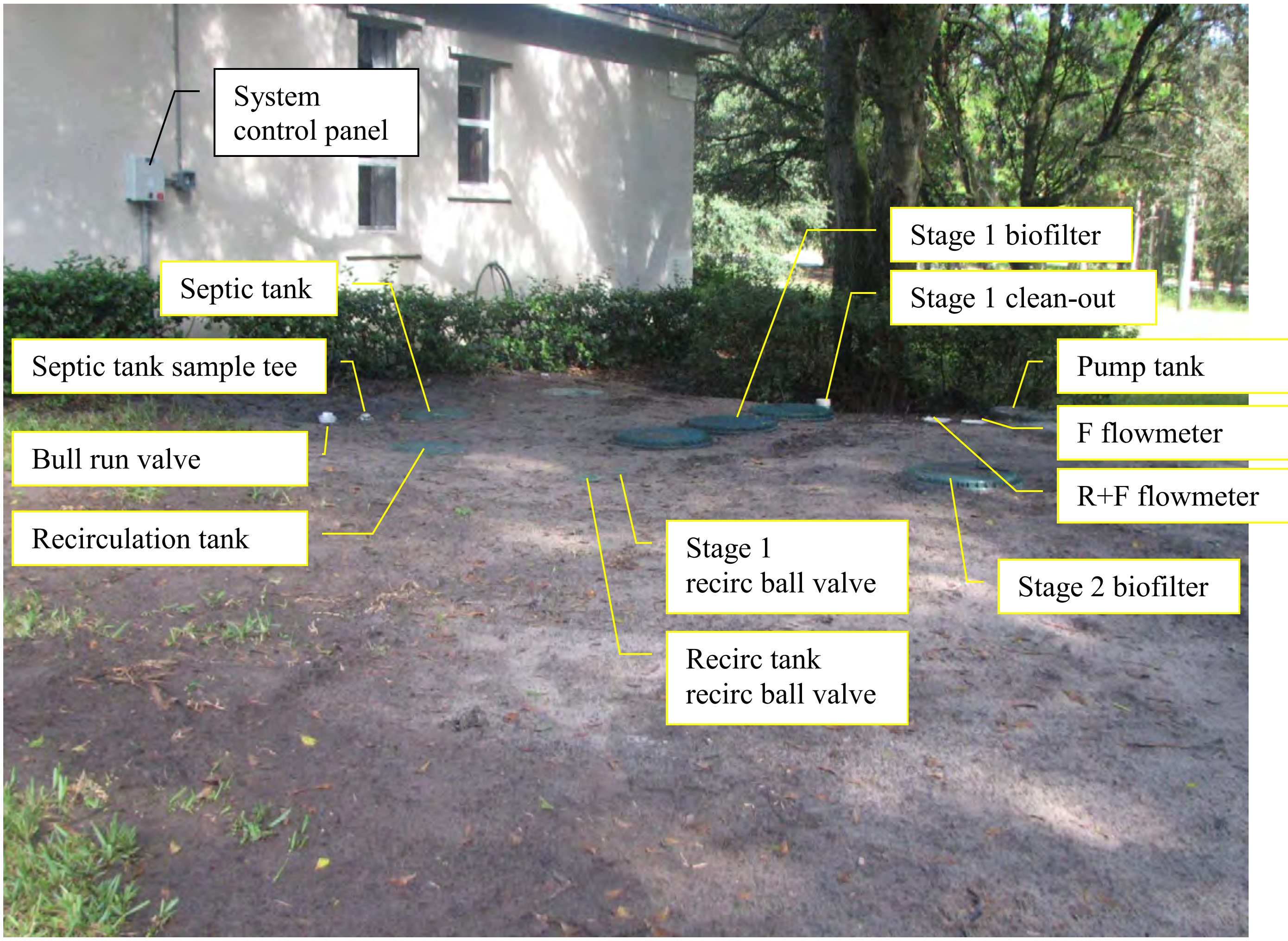

Figure 28
Overall PNRS system installed

Figure 29
Sod cover over PNRS system

Operation and Verification

On September 25, 2012, the pump tank was filled with potable water for system operational testing. The pump was tested, and the globe valves were set to an approximate 3 to 1 recirculation split, with 3 parts going back to the recirculation tank and 1 part going to the Stage 2 biofilter tank. Through the Vericomm system, the on and off pump cycles were set. A call to Vericomm was initiated from the control panel to transmit the data following the testing. In addition, the two flowmeters and electric meter were read and recorded (Table 1).

Table 1
Initial Settings and Readings Recorded

	September 25, 2012 11:45am
Recirculation Ratio	3:1
Control Panel Settings	
Pump Run Time (hr:min)	0:07
Pump Cycles Today	5
Override Cycles Today	1
On time cycle (min:sec)	01:12
Off time cycle (min:sec)	60:00
Electric Meter Reading	
Electric Meter (kWh)	2
Flowmeter Readings	
Household use flowmeter (gal)	32660
Combined flowmeter (R+F) (gal)	00000351.9
Stage 2 flowmeter (F) (gal)	00000102.2

Estimated Cost

The final construction cost for the installed system was $19,142.18 as detailed in Appendix B.

System Start-up

The system was started up September 25, 2012, when all flow was diverted to the new passive system. Routine checks of the system were made for the first two weeks to ensure the system was functioning as intended. Tanks were noted to be full on October 5, 2012. Preliminary sampling will begin in October to monitor nitrification.

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Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

Contract CORCL

TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS3

June 2013

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Seminole County, Florida (B-HS3).

System Overview

The B-HS3 system was installed in Seminole County, Florida in June 2013. It consists of a replacement septic tank which was upgraded to a 1,500 gallon two chamber concrete primary tank; 600 gallon concrete STE dose tank; a two zone drip system, a Stage 1 lined drip zone and a reclaimed water dispersal drip zone, and a 1,050 gallon concrete tank Stage 2 saturated media biofilter. Figure 1 is a site schematic showing the system components and layout of the installation. The complete as-built system drawings are included in the attached Appendix A.

Household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen into the STE dose tank. The STE dose tank contents are pumped through the drip system hydraulic unit and discharged to the Stage 1 drip system (Zone 1). Effluent is dispersed above an 18-inch layer of mound sand (slightly limited sand) and proceeds downward through the sand media where nitrification occurs. Underlying the sand is a 9-inch layer of lignocellulosic and sand media mixture above a 30-mil PVC liner where there is the potential for denitrification prior to the Stage 2 biofilter. The liner effluent is conveyed to the bottom of the Stage 2 biofilter (denitrification) tank containing elemental sulfur reactive media and flows upward through the media for additional treatment. The Stage 2 biofilter contains 12-inches of elemental sulfur mixed with oyster shell media. The outlet is above the media; therefore, denitrification occurs in the saturated environment. The denitrified effluent is pumped through the drip system hydraulic unit and discharged to the reclaimed water drip irrigation system (Zone 2). The denitrified effluent is discharged to the natural soil. A flow schematic of the system is shown on Figure 2.

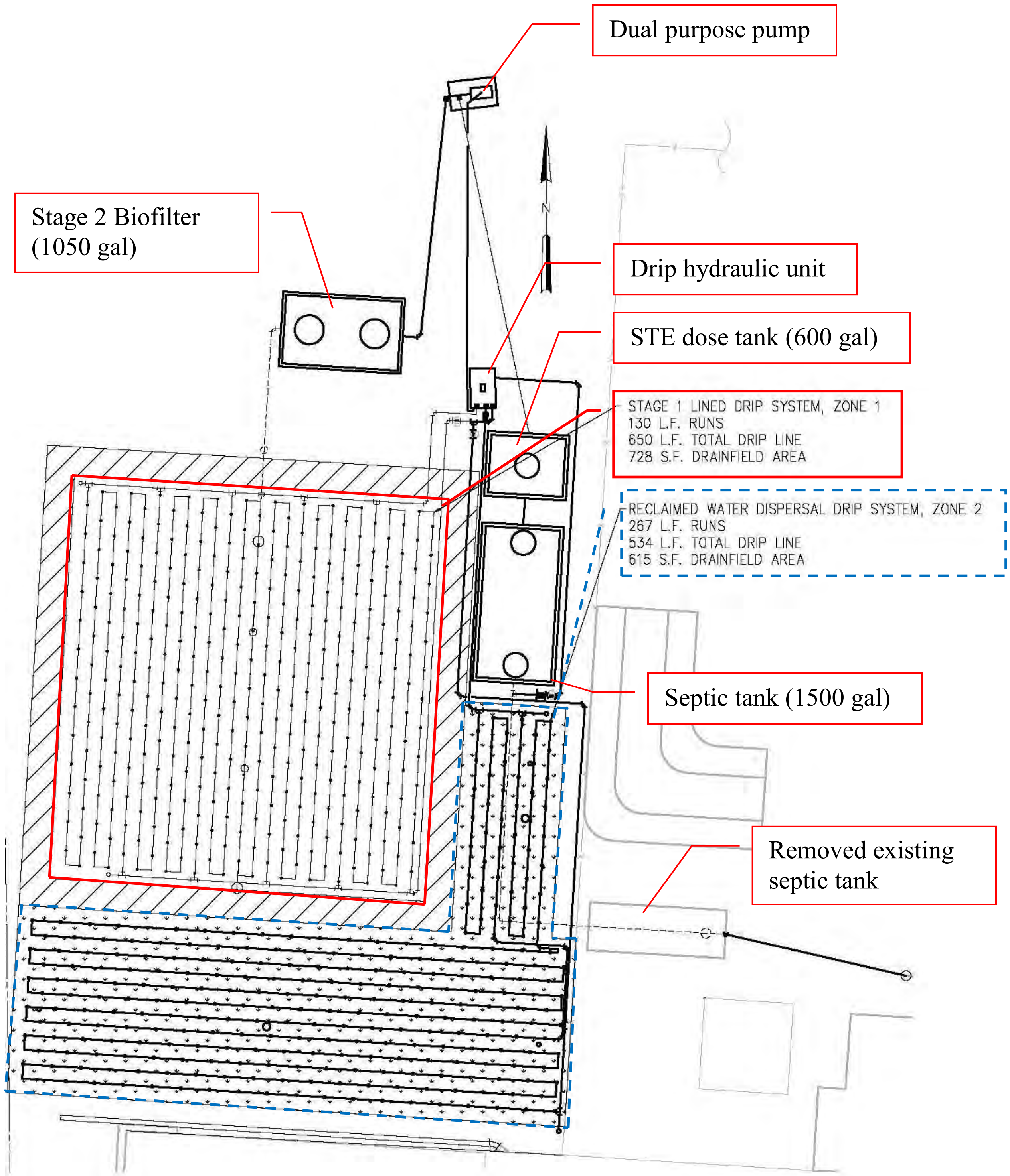

Figure 1
Schematic of B-HS3 PNRS installed in Seminole county

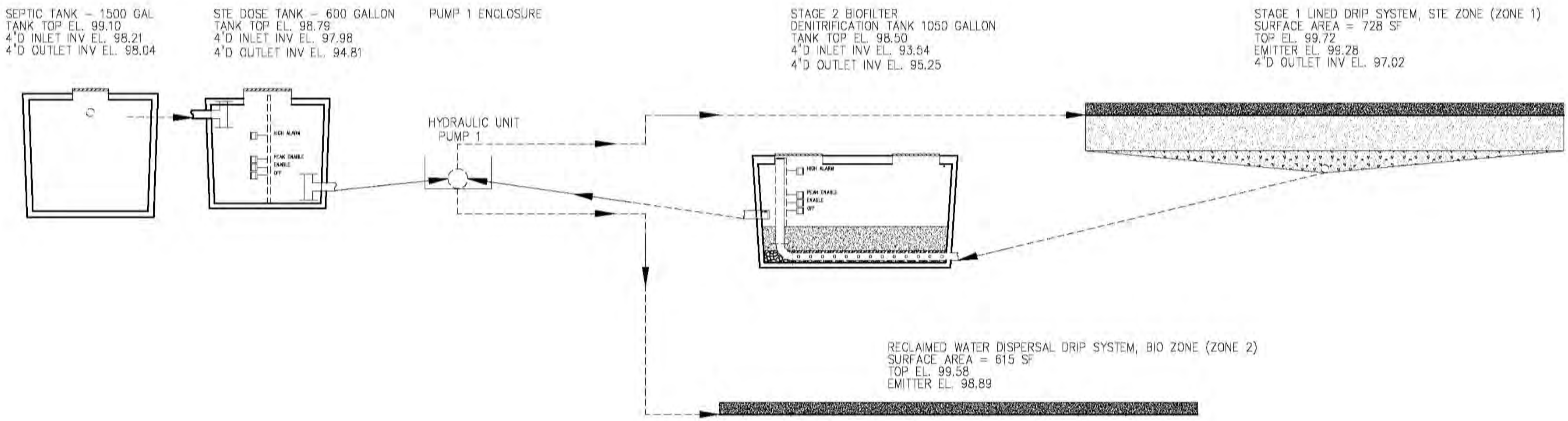

Figure 2
Flow Schematic of B-HS3 PNRS installed in Seminole county

Installation

Installation of the system commenced June 17, 2013 and was completed on June 28, 2013. The installation began with a pump out and removal of the existing 1,050 gallon fiberglass septic tank. After the pump out was completed, the old septic tank was removed (Figure 3).

Figure 3
Old septic tank pumped out and removed

A 1,500 gallon, two compartment replacement concrete primary tank was installed. The first larger chamber serves as a primary receiving tank, receiving the raw sewage from the household. The sewer pipe from the house was plumbed into the 4"D (diameter) inlet hole shown in Figure 4. An effluent screen (Polylok™, PL-68) was installed in the outlet tee of the second chamber (Figure 5).

Figure 4
1,500 gallon, two chamber, primary Tank

Figure 5
Primary tank effluent screen

Following the primary tank installation, the remaining passive nitrogen reduction system components were installed (Table 1). A STE dose tank (600 gallon) concrete tank was installed beside the primary tank (Figure 6). The purpose of this tank is to hold the septic tank effluent to be pumped to the Stage 1 lined drip area. The 4”D inlet of the STE dose tank is connected (gravity flow) to the primary tank discharge. The 2”D outlet is connected to the pump. The 2”D outlet (Figure 7) is located near the bottom of the tank.

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	1,500		none
STE Dose Tank	600		none
Stage 1 Biofilter, lined drip area	N/A	728	• 18” sand • 9” lignocellulosic and sand mixture
Stage 2 Biofilter, upflow	1,050	37	12” Elemental sulfur (90%) & oyster shell mixture (10%)

Figure 6
600 gallon, single chamber, STE Dose Tank

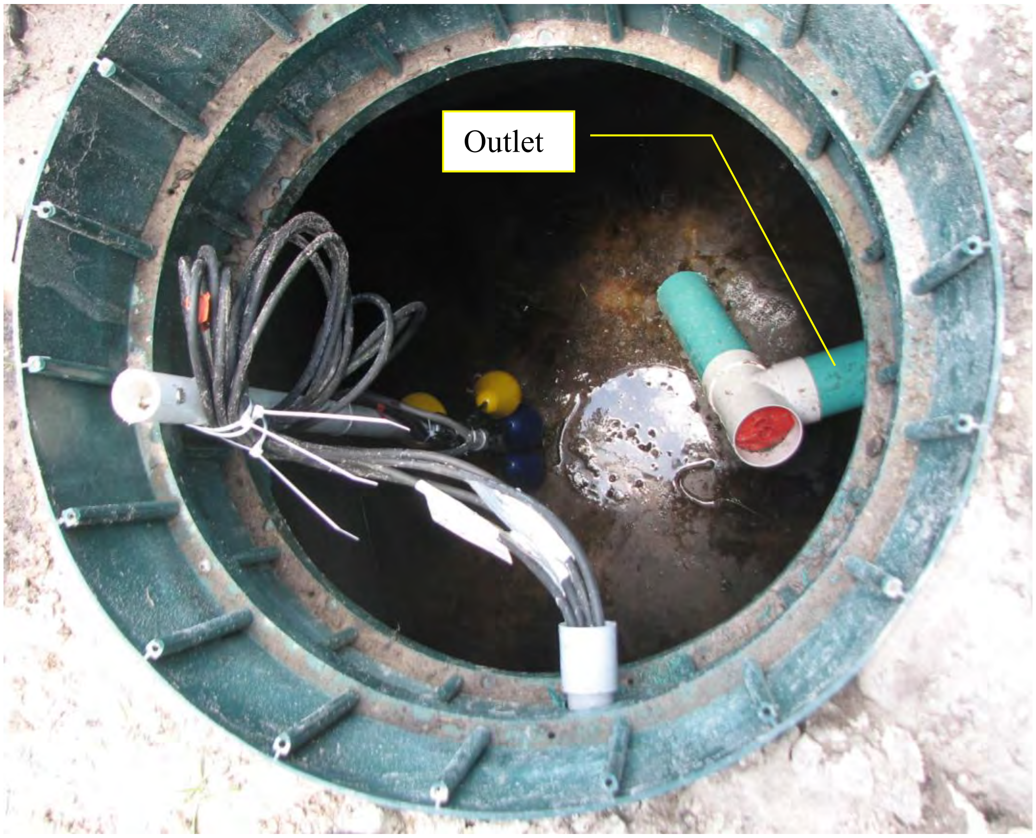

Figure 7
STE Dose Tank outlet pipe

The STE dose tank effluent is pumped (Figure 8) through the drip system hydraulic unit (Figure 9) and discharged to the Stage 1 drip system (Zone 1). The Stage 1 drip system area was prepared by grading a V-shape (Figure 10) so that effluent would collect on the liner (Figure 11) and flow to the center where a perforated pipe within a gravel underdrain conveys the nitrified effluent to the denitrification tank through a pipe boot within the liner (Figure 11). A 9-inch layer of lignocellulosic and sand media mixture was placed above the liner (Figure 12). Overlying the lignocellulosic media mixture is an 18-inch layer of mound sand (slightly limited sand) and the drip emitter lines (Figure 13). An additional 6-inch layer of mound sand was placed above the drip emitter lines (Figure 13).

Figure 8
Dual-purpose pump

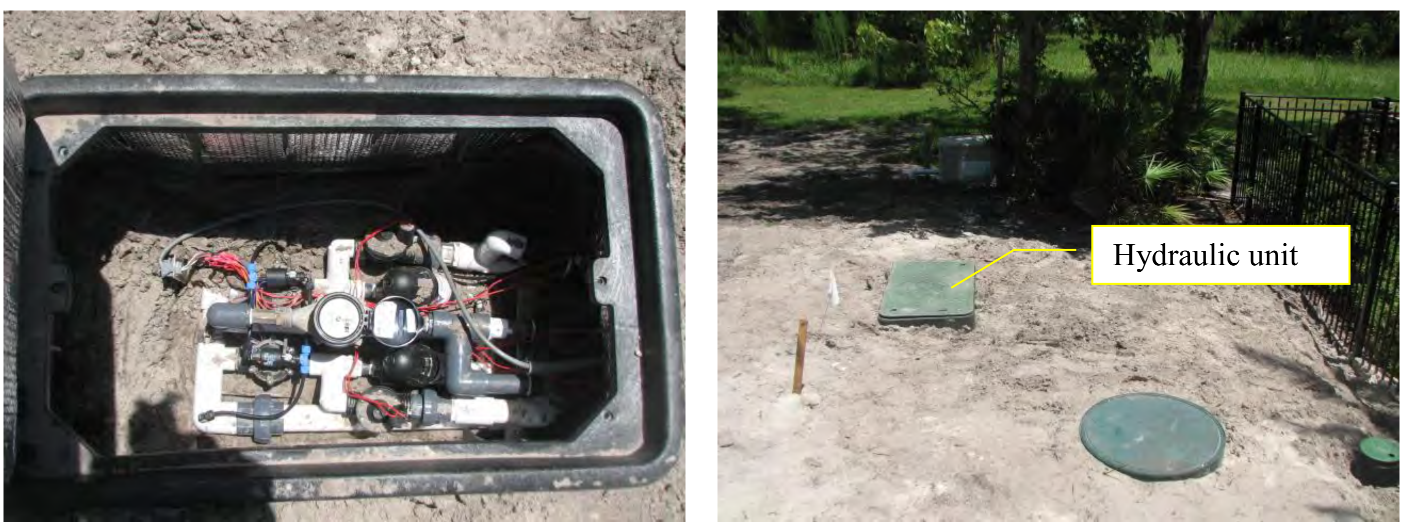

Figure 9
Drip system hydraulic unit

Figure 10
Stage 1 liner area preparation

Figure 11
Stage 1 Liner

Figure 12
Lignocellulosic and sand mixture above liner

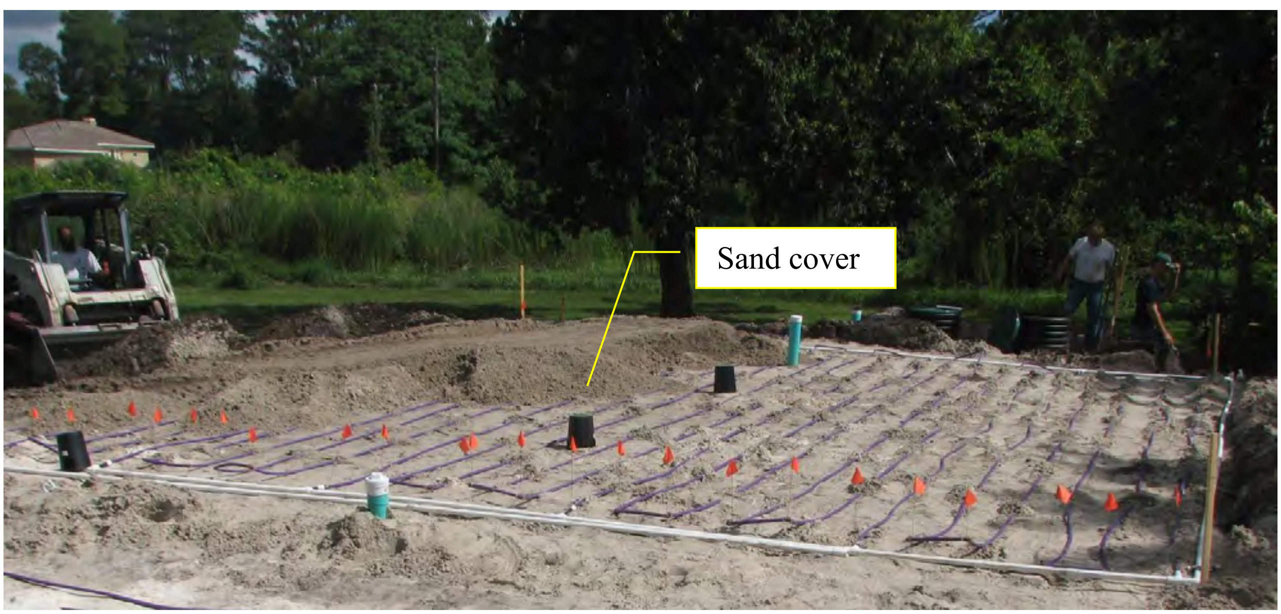

Figure 13
Stage 1 drip emitter lines (Zone 1)

The liner effluent is conveyed to a Stage 2 biofilter (1,050 gallon) containing elemental sulfur reactive media (Figure 14) for additional treatment (denitrification). The denitrified effluent is pumped through the drip system hydraulic unit (Figure 9) and discharged to the reclaimed water drip system (Zone 2) (Figure 15). The denitrified effluent is discharged to the natural soil. A flow schematic of the system is shown on Figure 2.

Figure 14
Stage 2 Biofilter

Figure 15
Reclaimed Water Drip Area (Zone 2)

A power meter was installed between the main power box of the house and the control panel to record cumulative power usage of the system in kilowatts. The equipment connected to the power meter are the drip system dose pump and the control panel. Figure 16 shows the power meter installed inside the control panel.

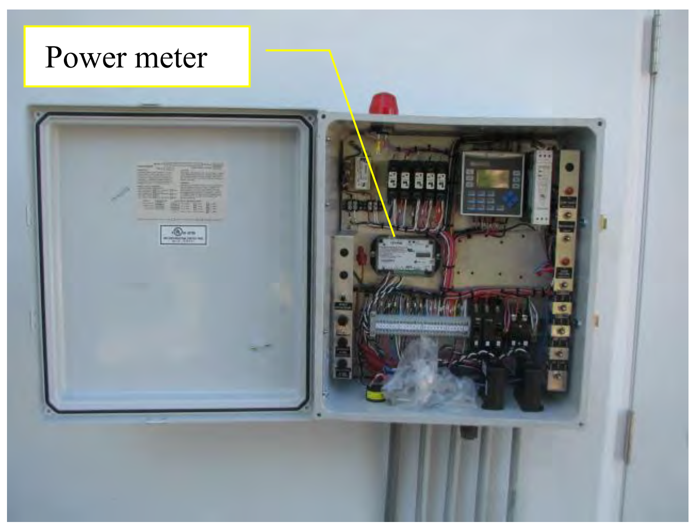

Figure 16
Control Panel

The system control panel (Figure 16) allows for a timed pump cycle which can be overridden if the effluent levels are too low or too high in the dose tanks (STE dose tank and Stage 2 Biofilter). If the floats indicate a low effluent level in the tank, the timed cycle is turned off to protect the pump. If the floats indicate a high effluent tank level, then the pump cycles faster (off cycle reduced) until the water level reaches the optimal range. An alarm will indicate if the water level goes above a critical level. The control panel is connected to a phone line which transmits data for monitoring.

During final testing of the system, the system operated with no visible signs of leaks, etc. The system area was filled and all disturbed areas on the property were graded (Figure 17).

Figure 28
Overall PNRS system installed

Estimated Cost

The final construction cost for the installed system was $40,129.79 as detailed in Appendix B.

System Start-up

The system was started up July 11, 2013, when all flow was diverted to the new passive system. Routine checks of the system will be made, and preliminary sampling will begin in July to monitor nitrification.

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Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

Contract CORCL

TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS4

June 2013

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Seminole County, Florida (B-HS4).

System Overview

The B-HS4 passive nitrogen reduction system (PNRS) was installed in Seminole County, Florida in June 2013. The property had two existing onsite sewage treatment and disposal systems. The existing 1,200 gallon concrete septic tank, located on the west side of the property, will continue to provide primary treatment for the PNRS system. The existing 800 gallon septic tank, located on the northeast side of the property, was converted to a lift station. The passive nitrogen reduction system consists of an addition of two tanks and a new drainfield to the existing permitted systems. A 2,800 gallon concrete Stage 1 unsaturated media biofilter and 1,500 gallon two chamber concrete Stage 2 saturated media biofilter were installed. Figure 1 is a site schematic showing the system components and layout of the installation. The complete as-built system drawings are included in the attached Appendix A.

The septic tank contents are discharged by gravity to a distribution box, located inside the Stage 1 biofilter, which splits the flow between two perforated distribution pipes along the top of the unsaturated Stage 1 biofilter media. The Stage 1 biofilter contains 10 inches of coarse expanded clay media (Riverlite^{TM} 1/4; 1.1 to 4.8 mm) above 20 inches of finer expanded clay media (Riverlite^{TM} 3/16; 0.6 to 2.4 mm). Wastewater proceeds downward through the expanded clay media where nitrification occurs. Stage 1 biofilter effluent then flows by gravity into the Stage 2 biofilter tank. Effluent from the unsaturated (Stage 1) media tank enters the denitrification (Stage 2) biofilter into a standing water column lying above the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell). The Stage 2 biofilter contains 42-inches of lignocellulosic media in the first chamber. A collection pipe along the bottom transfers the effluent to the second chamber which contains 18-inches of elemental sulfur mixed with oyster shell media. The Stage 2 biofilter effluent discharges near the top of the tank; therefore denitrification occurs in the saturated environment. The denitrified treated effluent is discharged into the soil via a new drainfield. The effluent is split between four low-profile Infiltrator chamber trenches by a concrete distribution box. Three of the trenches have 11 chambers and one trench has 12 chambers as depicted in Figure 1. A flow schematic of the system is shown on Figure 2.

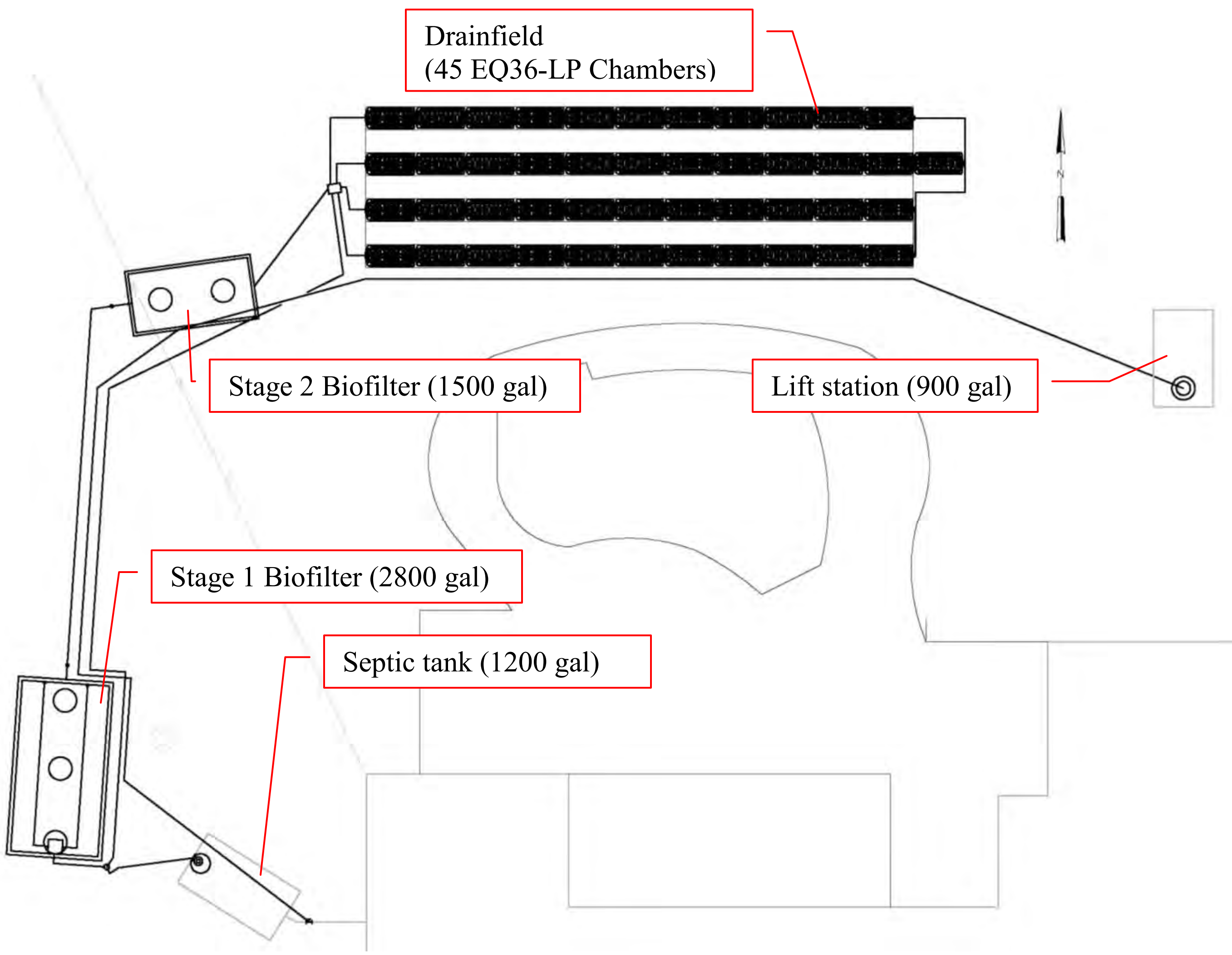

Figure 1
Schematic of B-HS4 PNRS installed in Seminole county

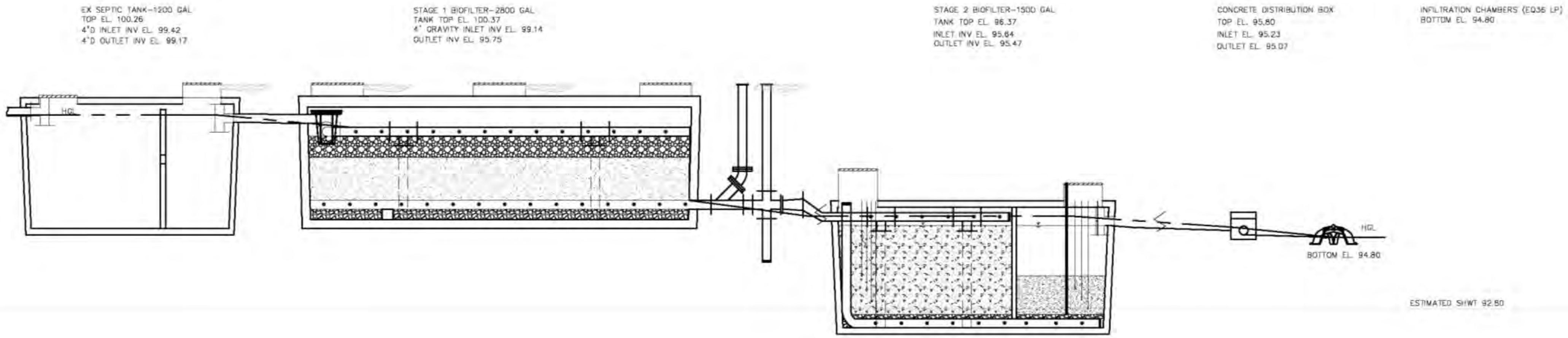

Figure 2
Flow Schematic of B-HS4 PNRS installed in Seminole county

Installation

Installation of the system commenced June 19, 2013 and was completed on June 28, 2013. As previously discussed, the existing 1,200 gallon septic tank will continue to provide primary treatment. Prior to the existing 1,200 gallon septic tank a 2-inch pipe connection was made into the sewer line from the house (Figure 3). The 2-inch diameter pipe conveys the wastewater from the converted 800 gallon lift station via a Liberty grinder pump model number PRG101A-2 (Figure 4) placed within the first chamber. Within the 1,200 gallon septic tank a new effluent filter (Polylok™, PL-68) was installed in the outlet tee (Figure 5). A new lid with manhole (Figure 5) was installed to allow access to the filter for maintenance. Following the 1,200 gallon septic tank, a bull-run-valve (Figure 6) was installed to allow for a means to bypass the PNRS system and discharge septic tank effluent directly into the new drainfield (via the concrete distribution box). A riser pipe was installed to grade over the valve, so that the valve can be turned after installation is complete. The valve is turned with a wrench on a rod which is long enough to reach with the riser installed.

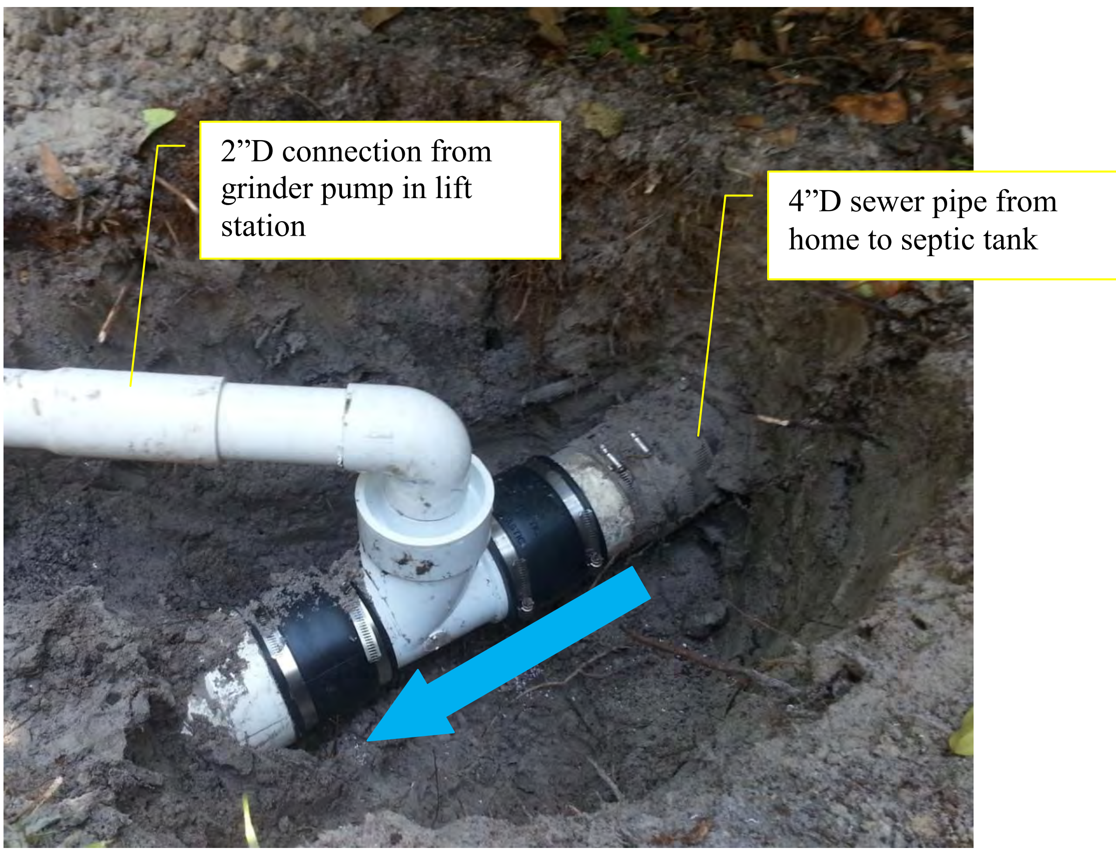

Figure 3
Pipe from Lift Station

Figure 4
Liberty pump within lift station

Figure 5
Septic tank filter and manhole

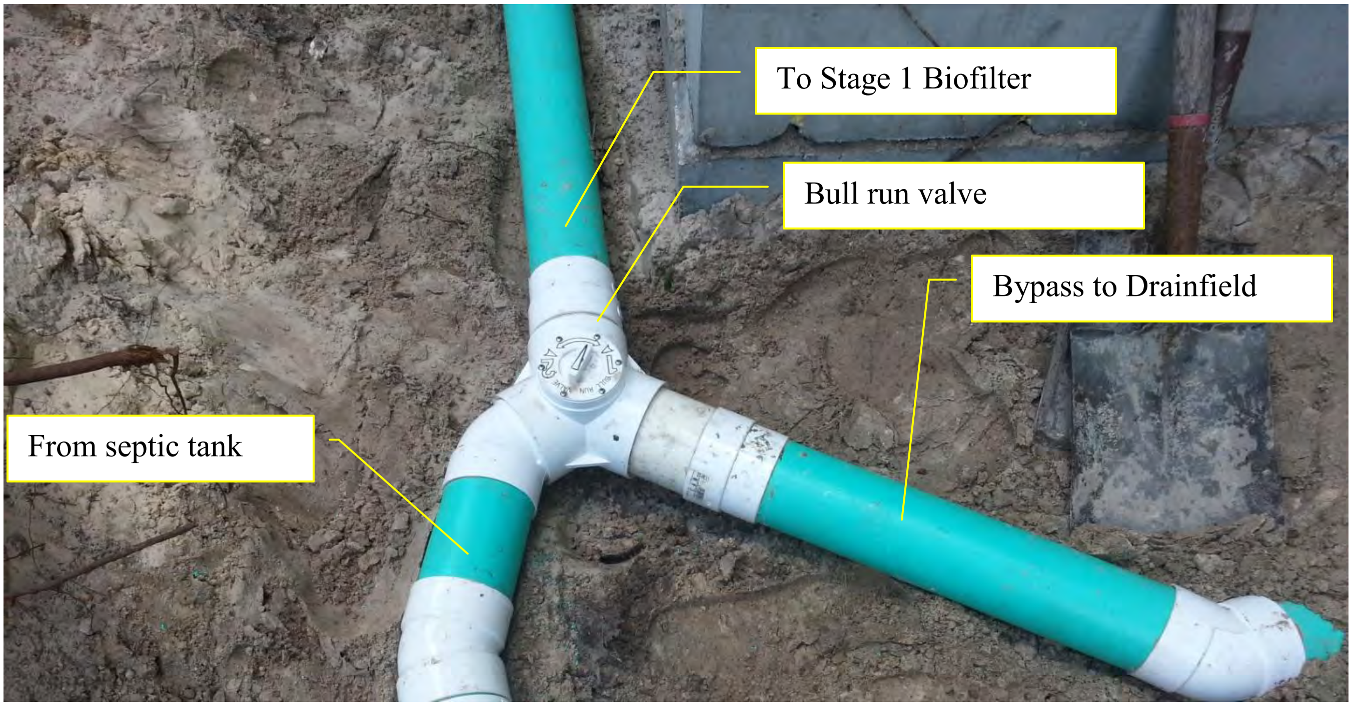

Figure 6
Bull run valve for PNRS bypass

The remaining passive nitrogen reduction system components were installed (Table 1). A single chamber (2,800 gallon) concrete tank was installed beside the primary tank (Figure 7). The purpose of this tank is to hold the Stage 1 expanded clay media. The 4”D inlet of the tank is connected (gravity flow) to the septic tank discharge. The 4”D outlet (Figure 7) of the pipe is located near the bottom of the tank to allow for unsaturated operation. The 4”D underdrain pipe (perforated) with gravel surrounding was installed along the centerline of the bottom of the tank for effluent collection (Figure 8). Following gravel installation and leveling, 20-inches of fine (3/16 Riverlite^{TM}) expanded clay media was installed (Figure 9). Above the fine media, 10-inches of coarse (1/4 Riverlite^{TM}) expanded clay media was installed (Figure 10). Following media installation and leveling, the influent distribution network was installed. The 4”D influent pipe, connected to the septic tank discharge, discharges into a distribution box which flows to two 4”D perforated pipes across the top of the media (Figure 10). The distribution box includes two Polylok equalizer^{TM} weirs to allow for the adjustment of the flow split (Figure 11). The Stage 1 biofilter outlet pipe includes a clean-out (Figure 12).

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	1,200	47.5	none
Stage 1 Biofilter	2,800	113.3	• 10” Riverlite 1/4 • 20” Riverlite 3/16
Stage 2a Biofilter, downflow	1,000 (1,500 total)	36 (54 total)	42” lignocellulosic (Southern yellow pine)
Stage 2b Biofilter, upflow	500 (1,500 total)	18 (54 total)	18” Elemental sulfur (90%) & oyster shell mixture (10%)

Figure 7
2,800 gallon, single chamber, stage 1 biofilter tank

Figure 8
Stage 1 biofilter gravel underdrain

Figure 9
Stage 1 biofilter 20-inches of fine media (3/16 Riverlite^{TM})

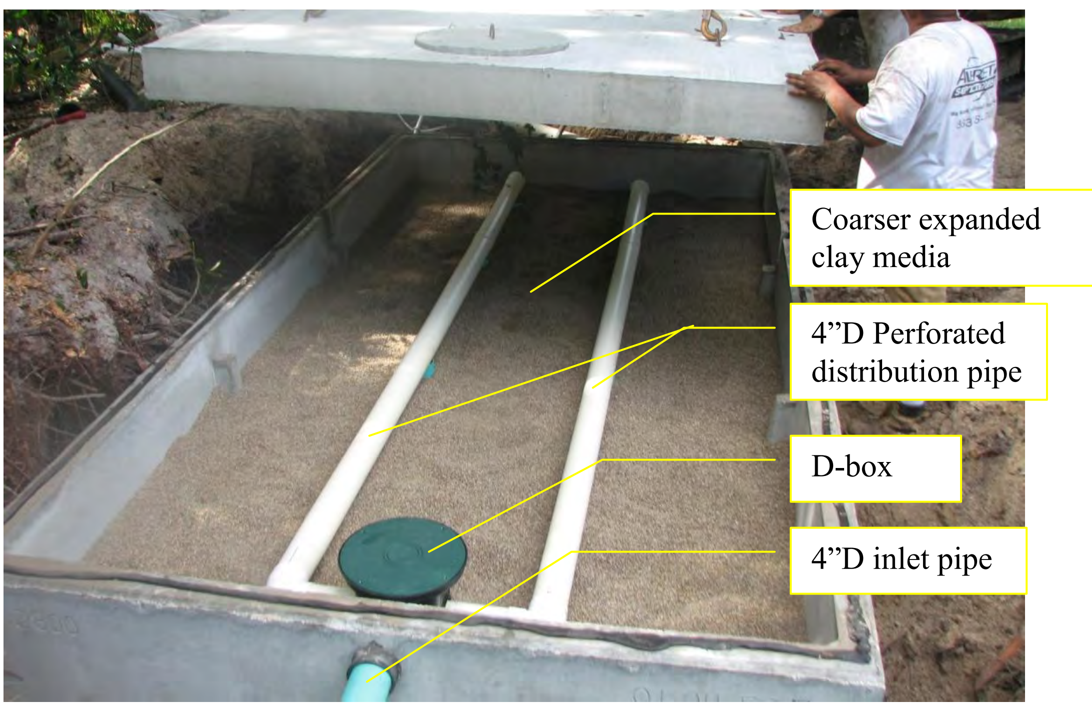

Figure 10
Stage 1 biofilter 10-inches of coarse media (1/4 Riverlite^{TM})

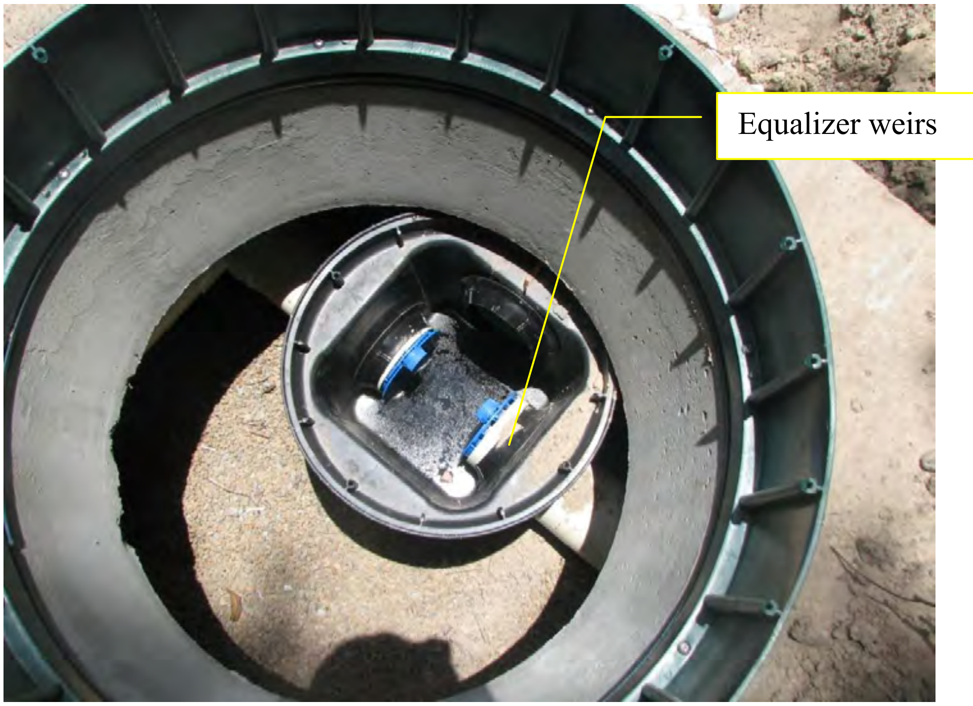

Figure 11
Stage 1 biofilter d-box

Figure 12
Stage 1 biofilter 4"D outlet pipe, with cleanout

The second tank installed was a two chamber (1,500 gallon) concrete tank (Figure 13). The purpose of this tank is to hold the Stage 2 lignocellulosic and sulfur media. The 4"D pipe from the Stage 1 biofilter connects to a perforated pipe which distributes nitrified effluent over the lignocellulosic media within the first chamber of the Stage 2 biofilter. The nitrified effluent flows downward through the lignocellulosic media (within first chamber) and upward through the sulfur media mixture (within second chamber).

A 4"D perforated underdrain pipe (Figure 13) with gravel surrounding (Figure 14) was installed along the centerline of the bottom of the tank for transfer from the first chamber to the second chamber. The tank arrived with a coupling cast into the baffle wall near the bottom to connect both chambers of the tank. Following the underdrain gravel installation (Figure 14) and leveling, 18-inches of elemental sulfur and oyster shell media was installed and mixed (Figure 15) within the second chamber. A stainless steel drivepoint sampler tree (Figure 15) was installed for sampling at 6 and 12-inches above the bottom of the sulfur media mixture.

Above the gravel underdrain within the first chamber of the tank, 42-inches of lignocellulosic media was installed (Figure 16). A stainless steel drivepoint sampler tree was installed for sampling at 0, 12, 24 and 36-inches above the bottom of the lignocellulosic media. A 4"D perforated pipe was connected to the inlet of the tank for effluent dispersal above the lignocellulosic media (Figure 16). A 4"D tee was installed at the outlet of the tank which allows for saturated operating conditions across the biofilter (Figure 17). The 4"D outlet is connected to the distribution box to the existing drainfield.

Figure 13
Stage 2 biofilter perforated pipe through wall

Figure 14
Stage 2 biofilter gravel underdrain

Figure 15
Stage 2 biofilter 18-inches of sulfur and oyster shell media

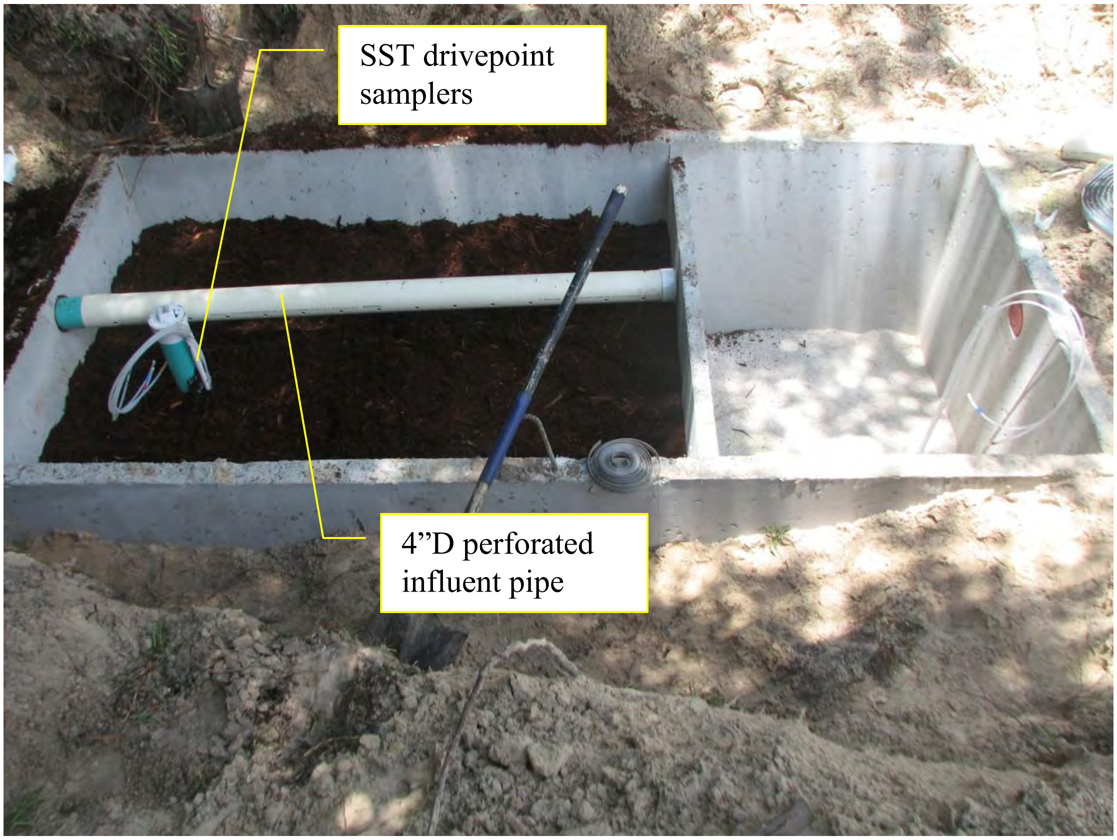

Figure 16
Stage 2 biofilter 42-inches of lignocellulosic media

Figure 17
Stage 2 biofilter outlet tee

The Stage 2 biofilter effluent is discharged into the soil via a new drainfield. The effluent is split between four low-profile Infiltrator chamber trenches by a concrete distribution box (Figure 18). Three of the trenches have 11 chambers and one trench has 12 chambers (Figure 19).

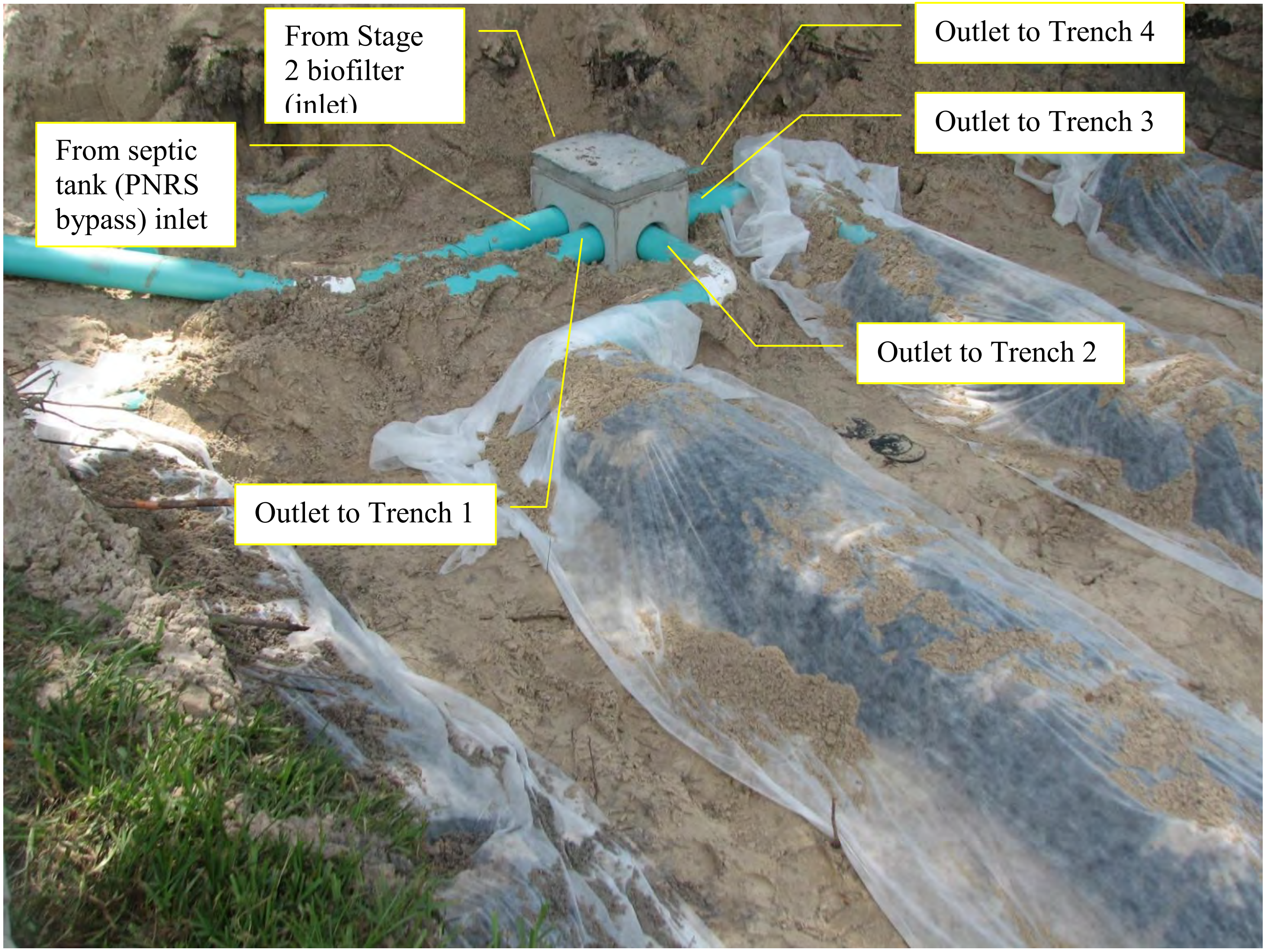

Figure 18
Drainfield distribution box

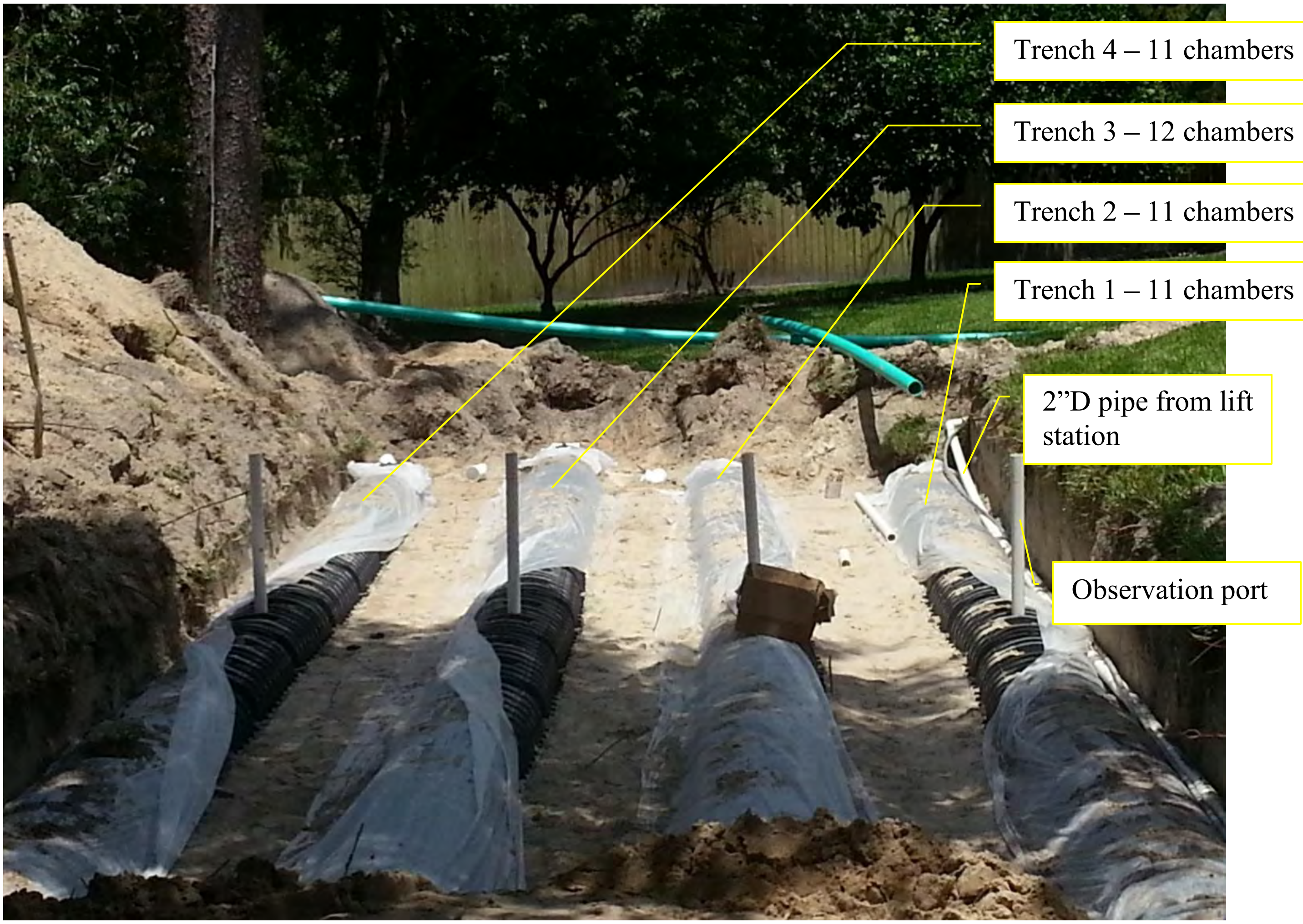

Figure 19
Drainfield trenches

A power meter was installed between the main power box of the house and the grinder pump to record cumulative power usage of the pump in kilowatts. Figure 20 shows the power meter installed inside an outdoor enclosure. Figure 21 shows the electrical outlet that was installed for the pump to plug into.

Figure 20
Power meter inside outdoor enclosure

Figure 21
Power outlet for grinder pump in lift station

During final testing of the system, the system operated with no visible signs of leaks, etc. The system area was filled and all disturbed areas on the property were graded (Figure 22).

Figure 22
Overall PNRS system installed

Estimated Cost

The final construction cost for the installed system was $19,842.84 as detailed in Appendix B.

System Start-up

The system was started up July 8, 2013, when all flow was diverted to the new passive system. Routine checks of the system were made for the first two weeks to ensure the system was functioning as intended. Preliminary sampling will begin in July to monitor nitrification.

Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

Contract CORCL

TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS5

June 2013

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Seminole County, Florida (B-HS5).

System Overview

The B-HS5 system was installed in Seminole County, Florida in June 2013. It consists of three additional tanks to the existing permitted system: 1500 gallon plastic tank Stage 1 unsaturated media filter; 300 gallon concrete pump tank; and 1,500 gallon two chamber concrete Stage 2 saturated media biofilter. Figure 1 is a site schematic showing the system components and layout of the installation. The complete as-built system drawings are included in the attached Appendix A.

Household wastewater enters the existing 1,350 gallon primary tank and exits as septic tank effluent through an effluent screen. The septic tank effluent contents are discharged by gravity to a distribution box, located inside the Stage 1 biofilter, which splits the flow between two perforated distribution pipes along the top of the unsaturated Stage 1 biofilter media. The Stage 1 biofilter contains 12.8 inches of coarse expanded clay media (Riverlite™ 1/4; 1.1 to 4.8 mm) above 21 inches of finer expanded clay media (Riverlite™ 3/16; 0.6 to 2.4 mm). Wastewater percolates downward through the expanded clay media where nitrification occurs. Stage 1 biofilter effluent then flows into the pump tank (which contains the pump and float switches). The pump tank discharge is split via two throttling gate valves which allow for a portion of the Stage 1 biofilter effluent to be sent back for recirculation with the rest proceeding to the Stage 2 biofilter. The system was designed with two modes of operation. The first option (which will initially be tested) is to have 100 percent of the Stage 1 effluent discharge to the Stage 2 biofilter. The second option is to have the recirculated effluent return to the top of the Stage 1 biofilter, dispersed by five spray nozzles. The recirculated effluent would have an opportunity to mix with incoming septic tank effluent discharged by the distribution box. Recirculation back to the Stage 1 biofilter increases the hydraulic loading on the Stage 1 biofilter. Effluent from the unsaturated (Stage 1) media tank enters the denitrification (Stage 2) biofilter into a standing water column lying above the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell). The Stage 2 biofilter contains 42-inches of lignocellulosic media in the first chamber. A collection pipe along the bottom transfers the effluent to the second chamber which contains 18-inches of elemental sulfur mixed with oyster shell media. The Stage 2 biofilter effluent discharges near the top of the tank; therefore denitrification occurs in the saturated environment. The denitrified treated effluent is discharged into the soil via the existing drainfield which is a standard bed. A flow schematic of the system is shown on Figure 2.

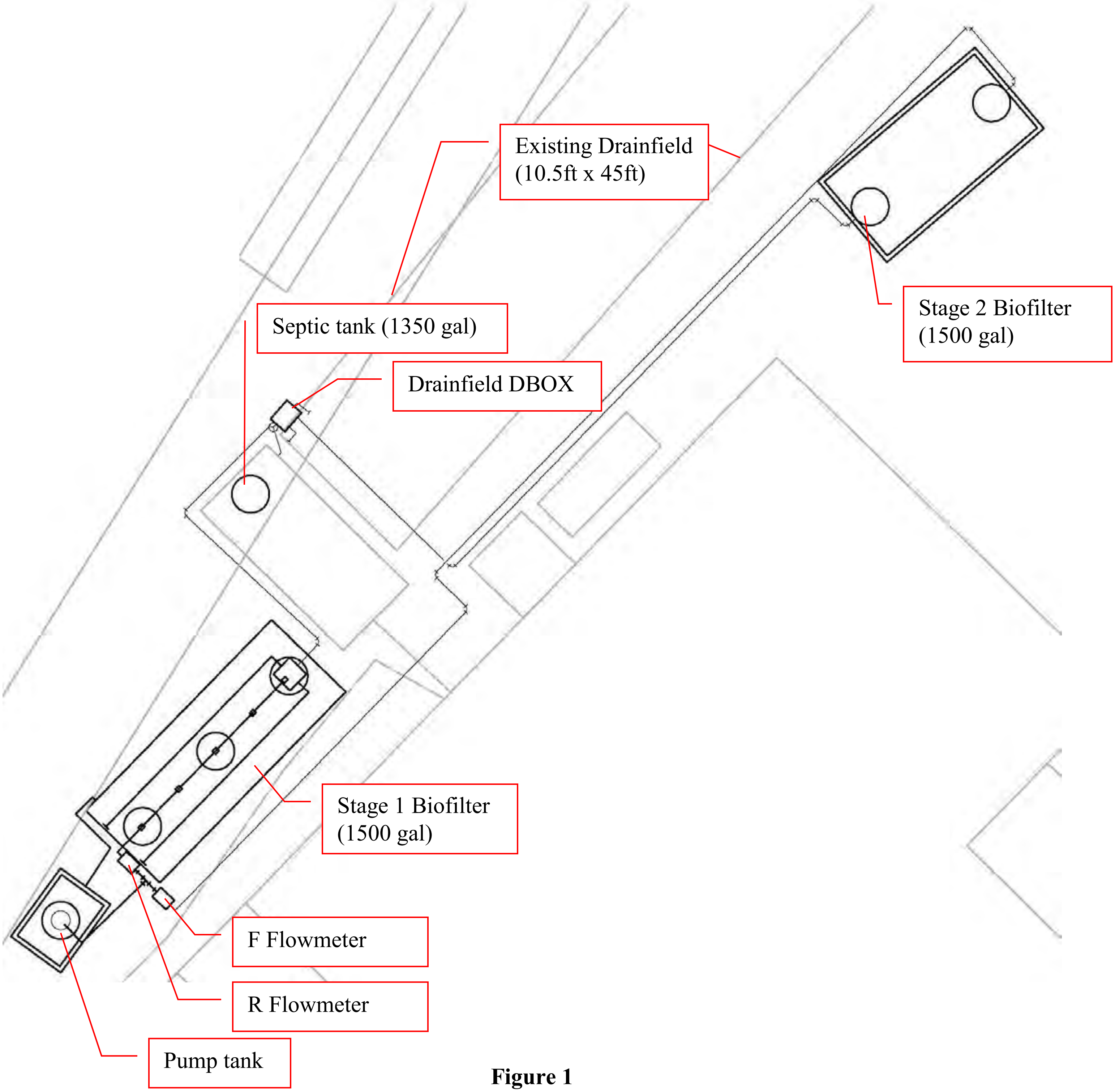

Figure 1
Schematic of B-HS5 PNRS installed in Seminole county

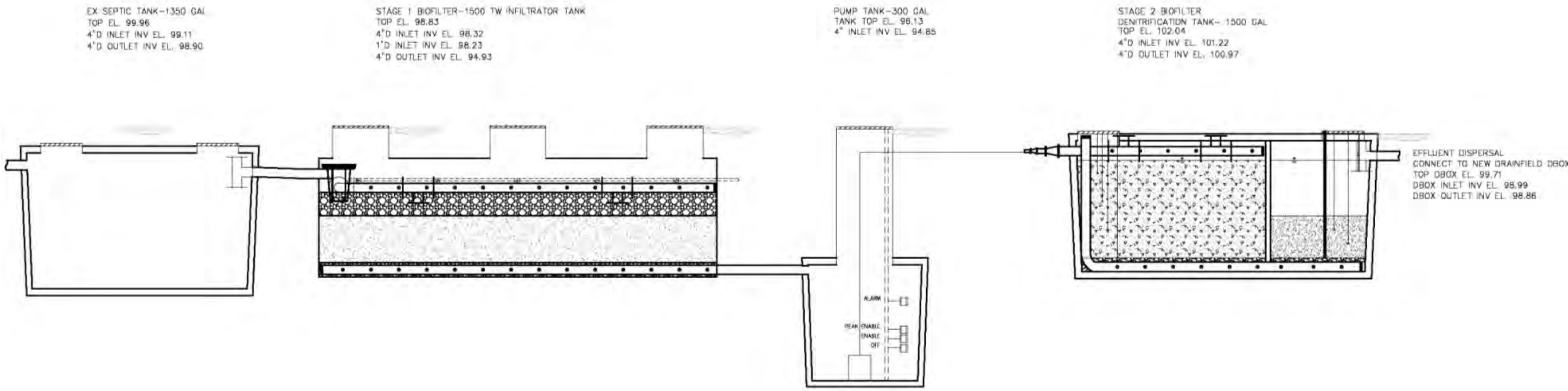

Figure 2
Flow Schematic of B-HS5 PNRS installed in Seminole county

Installation

Installation of the system commenced June 24, 2013 and was completed on June 28, 2013. The installation began with removing the existing concrete sidewalk (Figure 3) which was covering the existing septic tank outlet and existing concrete d-box for the drainfield (Figure 4). A new distribution box was installed (Figure 5). A two-way valve (Bull Run^{TM}) (Figure 5) was installed following the septic tank outlet to allow the flow to either be completely directed to the new passive system (to the Stage 2 biofilter) or to the distribution box (to the existing drainfield). A riser pipe was installed to grade over the valve, so that the valve can be turned after installation is complete. The valve is turned with a wrench on a rod which is long enough to reach with the riser installed.

Figure 3
Concrete sidewalk removed

Figure 4
Existing drainfield distribution box

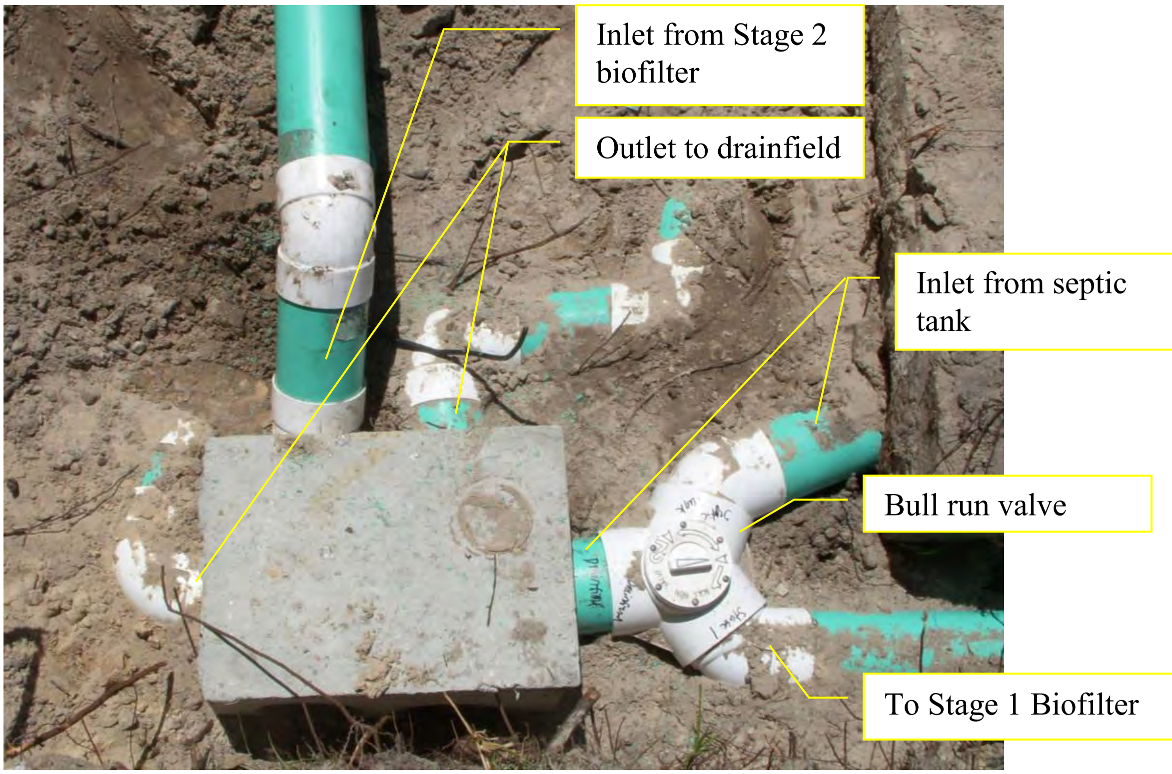

Figure 5
New drainfield distribution box

An effluent screen (Polylok^{TM}, PL-68) was installed in the outlet tee of the second chamber (Figure 6).

Figure 6
1,350 gallon, primary Tank effluent screen

The remaining passive nitrogen reduction system components were installed (Table 1). A single chamber (1,500 gallon) plastic Infiltrator™ tank was installed beside the primary tank (Figure 7). The purpose of this tank is to hold the Stage 1 expanded clay media. The 4"D inlet of the tank is connected (gravity flow) to the septic tank outlet. The 1"D inlet, installed through the standard outlet, is connected (pressurized flow) to the recirculation pipe from the pump tank (Figure 8). The 3"D outlet (Figure 8) of the pipe is located near the bottom of the tank to allow for unsaturated operation. Following gravel installation and leveling (Figure 9), 21-inches of fine (3/16 Riverlite™) expanded clay media was installed (Figure 10). Above the fine media, 12-inches of coarse (1/4 Riverlite™) expanded clay media was installed (Figure 11). Following media installation and leveling, the influent distribution network was installed (Figure 11). The 4"D influent pipe, connected to the septic tank discharge, discharges into a distribution box which flows to two 3"D perforated pipes across the top of the media (Figure 11). The 1"D influent pipe was installed along the centerline with five spray nozzles attached to distribute the recirculated effluent (Figure 12). The spray nozzles are removable for cleaning in the event clogging occurs (Figure 12).

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	1,350	55	none
Stage 1 Biofilter	1,500	78	• 12" Riverlite 1/4 • 21" Riverlite 3/16
Pump Tank	300	12	none
Stage 2a Biofilter, downflow	1,000 (1,500 total)	36 (54 total)	42" lignocellulosic (Southern yellow pine)
Stage 2b Biofilter, upflow	500 (1,500 total)	18 (54 total)	18" Elemental sulfur (90%) & oyster shell mixture (10%)

Figure 7
1500 gallon, single chamber, stage 1 biofilter tank

Figure 8
Stage 1 biofilter 3”D outlet pipe, with cleanout

Figure 9
Stage 1 biofilter gravel underdrain

Figure 10
Stage 1 biofilter 21-inches of fine media (3/16 Riverlite^{TM})

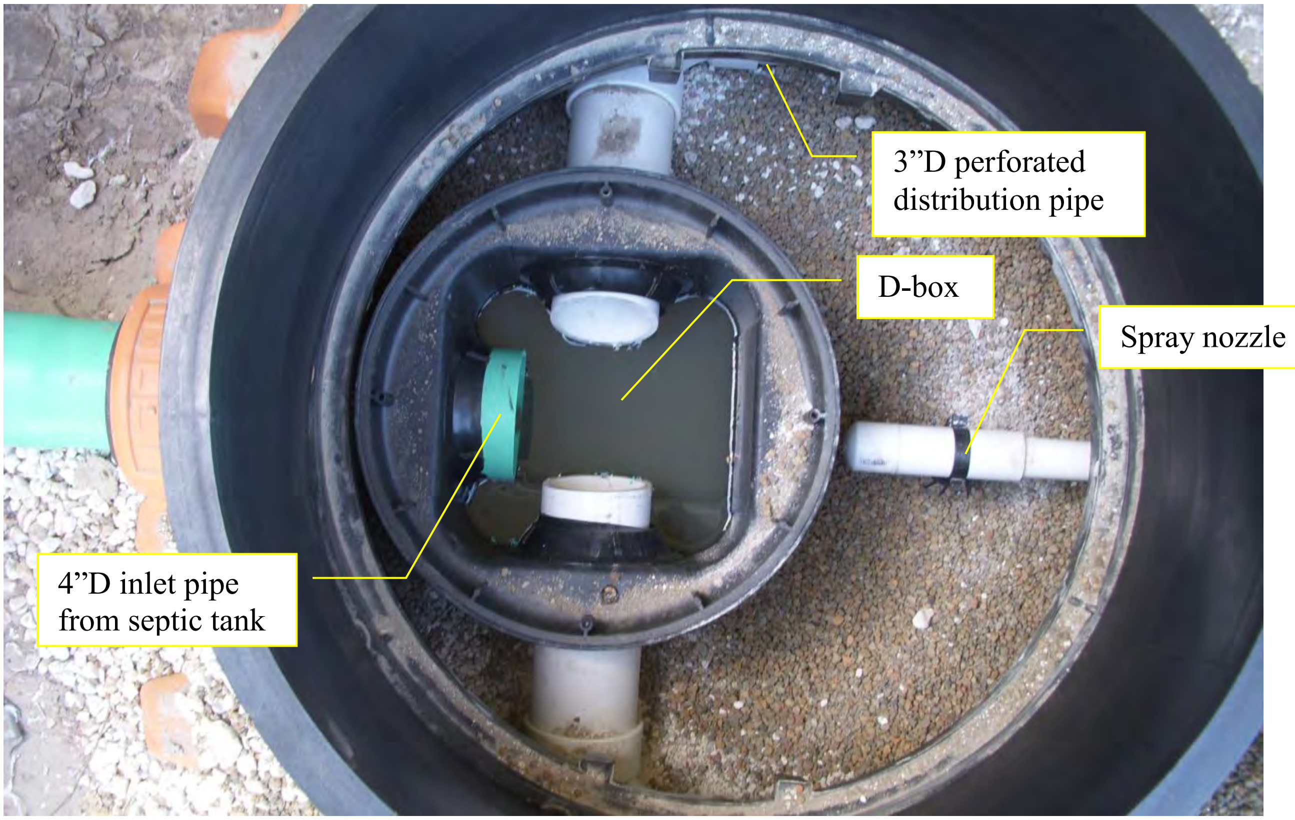

Figure 11
Stage 1 biofilter 12-inches of coarse media (1/4 Riverlite™)

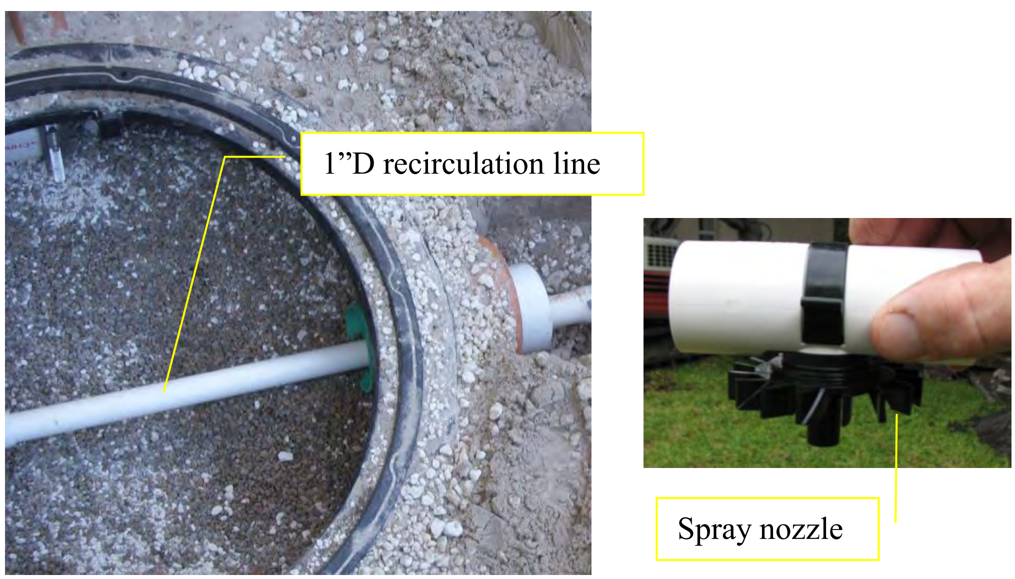

Figure 12
Stage 1 biofilter 1"D influent recirculation line

Next, the 300 gallon concrete pump tank was installed downgradient of the Stage 1 biofilter (Figure 13). The standard outlet pipe connection was plugged since the pump discharge pipe is installed through the riser. The pump was installed within a holding bracket which also supports the float tree (Figure 14). Three float switches were installed to maintain the effluent level in the pump tank and are attached to a float tree installed in the pump tank and connected to the control panel. The height of the floats is adjustable and once the proper heights were established, screws were used to secure the floats to the float tree.

Two inline flow meters were installed following the pump discharge (Figure 15). The pump discharge line was split so that a portion of the flow could be recirculated back to the Stage 1 biofilter while the rest of the flow proceeded to the Stage 2 biofilter. Two throttling gate valves were installed to allow for the adjustment of forward flow (F) and recirculated flow (R) to achieve the target recirculation ratio. The first inline flow meter installed downstream of the F globe valve measures the forward wastewater flow to the Stage 2 biofilter (Figure 15). The second flowmeter installed downstream of the R gate valve, to record the recirculated flow to the Stage 1 biofilter in gallons pumped from the pump tank (Figure 15). As previously discussed, the design includes two modes of operation. The first option (which will initially be tested) is to have the gate valves set so that there is no recirculation (100 percent F flow). Therefore, all the Stage 1 effluent is discharged to the Stage 2 biofilter. The second option is to have the recirculated effluent return to the top of the Stage 1 biofilter, dispersed by five spray nozzles. The recirculated effluent would have an opportunity to mix with incoming septic tank effluent discharged by the distribution box.

Figure 13
300 gallon pump tank

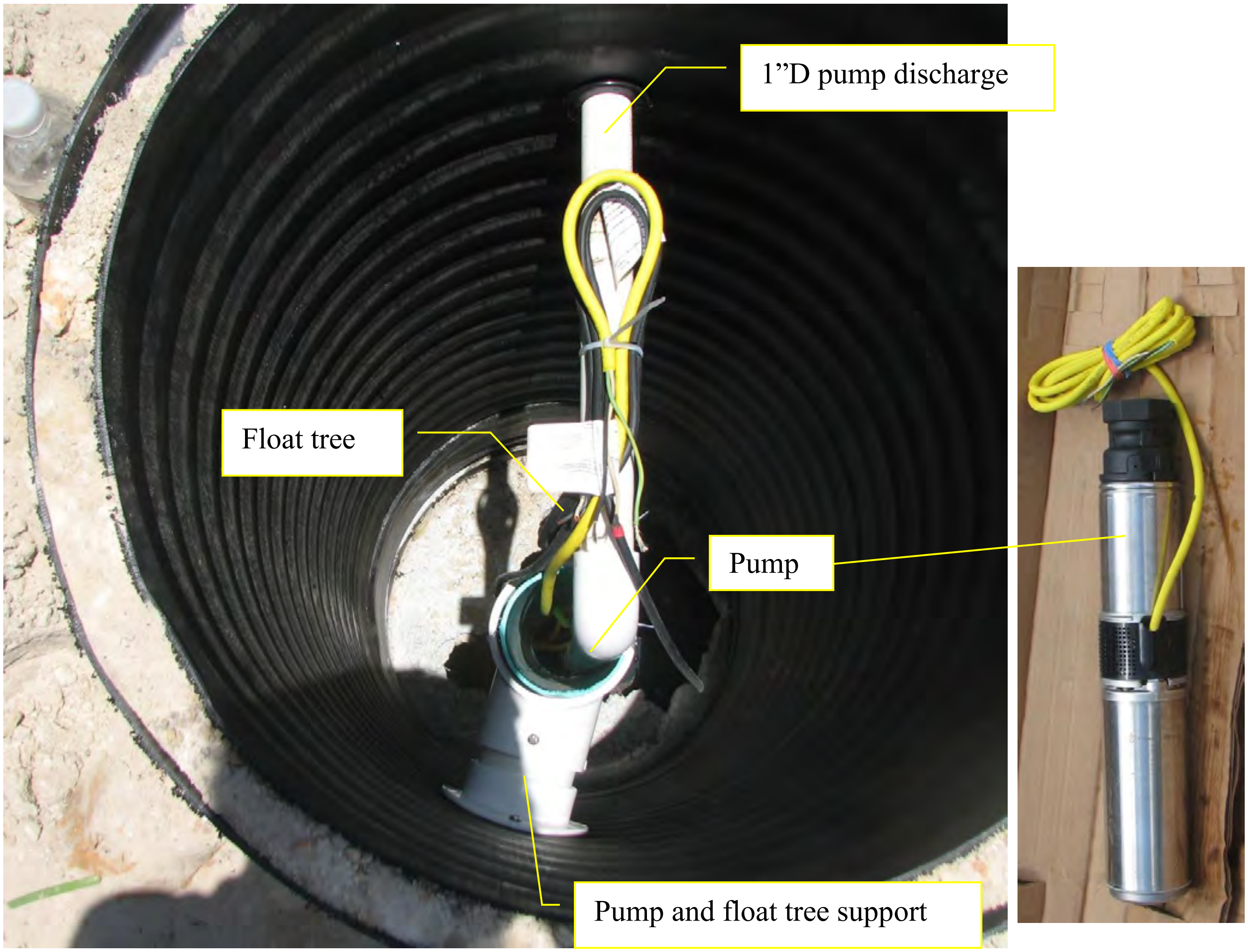

Figure 14
300 gallon pump tank (pump and float tree)

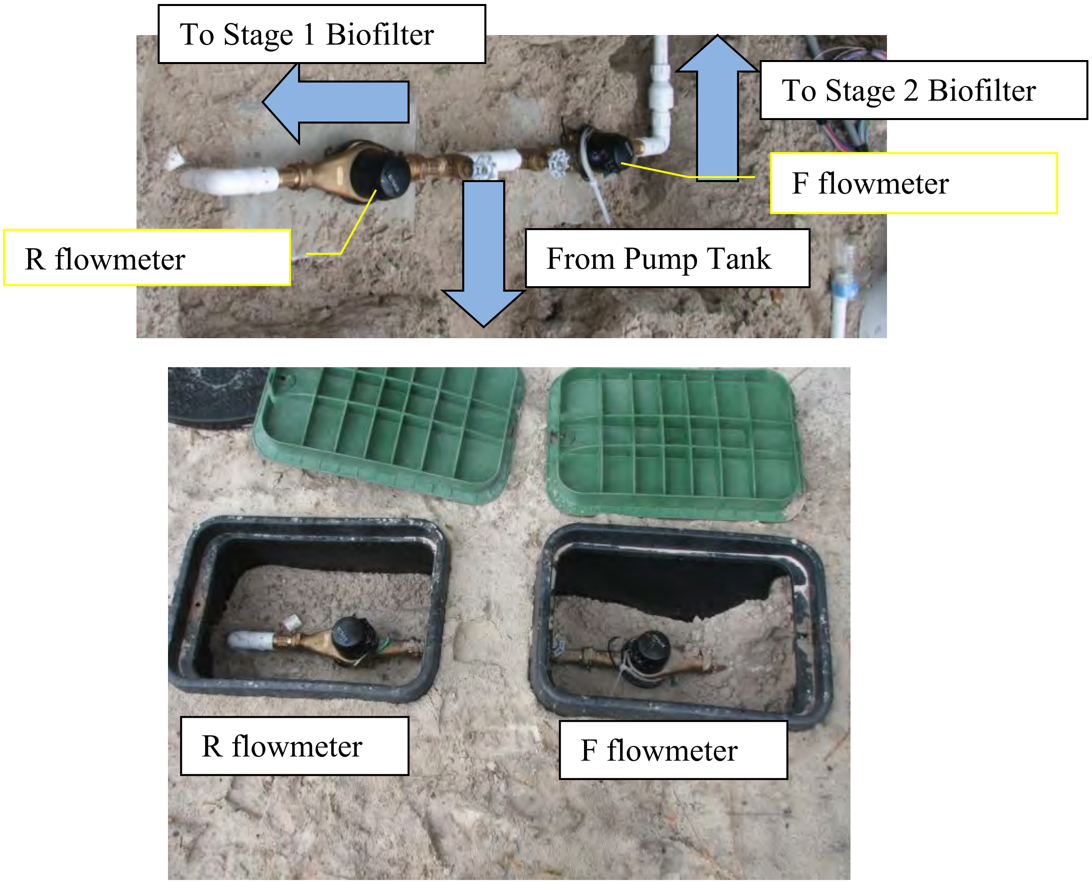

Figure 15
Flowmeters and flow split

The last tank installed was a two chamber (1,500 gallon) concrete tank (Figure 16). The purpose of this tank is to hold the Stage 2 lignocellulosic and sulfur media. The 1”D pipe downstream of the F flowmeter is expanded to 4”D and connects to a perforated pipe which distributes nitrified effluent over the lignocellulosic media within the first chamber of the Stage 2 biofilter. The nitrified effluent flows downward through the lignocellulosic media (within first chamber) and upward through the sulfur media mixture (within second chamber).

A 4”D underdrain pipe (perforated) with gravel surrounding was installed along the centerline of the bottom of the tank for transfer from the first chamber to the second chamber. The tank arrived with a coupling cast into the baffle wall near the bottom to connect both chambers of the tank. Following the underdrain gravel installation (Figure 17) and leveling, 18-inches of elemental sulfur and oyster shell media was installed and mixed (Figure 18) within the second chamber. A stainless steel drivepoint sampler tree (Figure 19) was installed for sampling at 6 and 12-inches above the bottom of the sulfur media mixture.

Above the gravel underdrain within the first chamber of the tank, 42-inches of lignocellulosic media was installed (Figure 19). A stainless steel drivepoint sampler tree was installed for sampling at 0, 12, 24 and 36-inches above the bottom of the lignocellulosic media (Figure 19). A 4”D perforated pipe was connected to the inlet of the tank for effluent dispersal above the lignocellulosic media (Figure 19). The 4”D outlet is connected to the distribution box to the existing drainfield.

Figure 16
1,500 gallon stage 2 biofilter tank

Figure 17
Stage 2 biofilter tank gravel underdrain covering perforated pipe along bottom

Figure 18
Stage 2 biofilter tank (sulfur mixed with oyster shell)

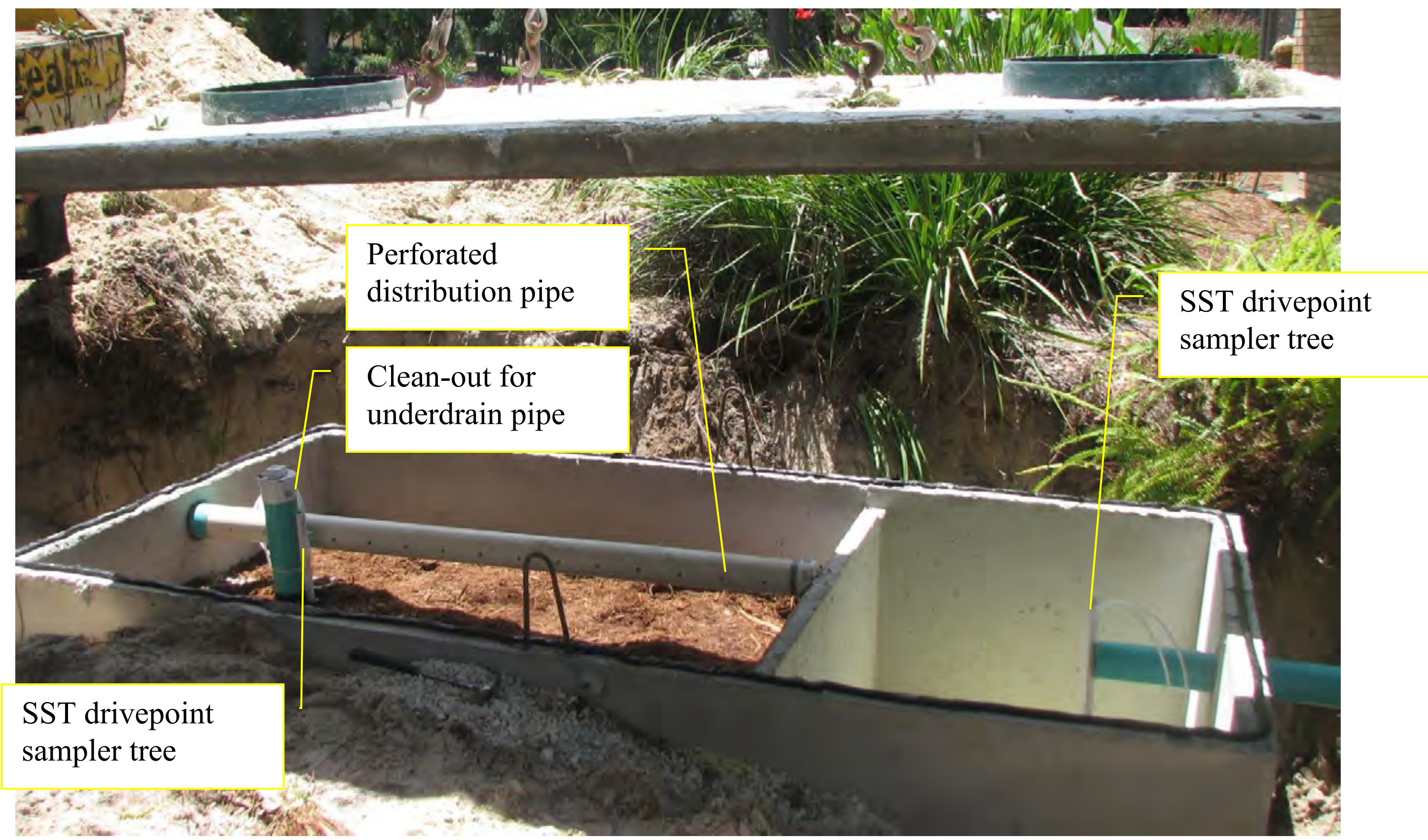

Figure 19
Stage 2 biofilter tank (lignocellulosic media)

A power meter was installed between the main power box of the house and the control panel to record cumulative power usage of the system in kilowatts. The equipment connected to the power meter are the pump and the control panel. Figure 20 shows the power meter installed inside the control panel.

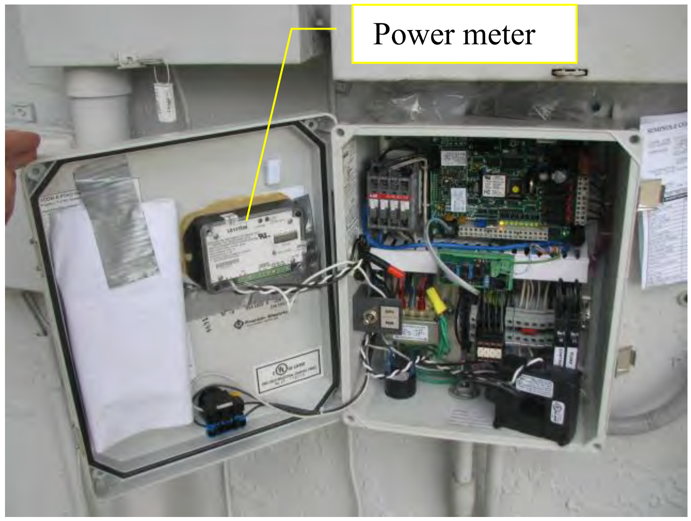

Figure 20
Control Panel

The system control panel (Figure 20) allows for a timed pump cycle which can be overridden if the effluent levels are too low or too high in the pump tank. If the floats indicate a low effluent level in the tank, the timed cycle is turned off to protect the pump. If the floats indicate a high effluent tank level, then the pump cycles faster (off cycle reduced) until the water level reaches the optimal range. An alarm will indicate if the water level goes above a critical level. The control panel is connected to a phone line which transmits data to Vericomm for monitoring.

During final testing of the system, the system operated with no visible signs of leaks, etc. The system area was filled and all disturbed areas on the property were graded (Figure 21).

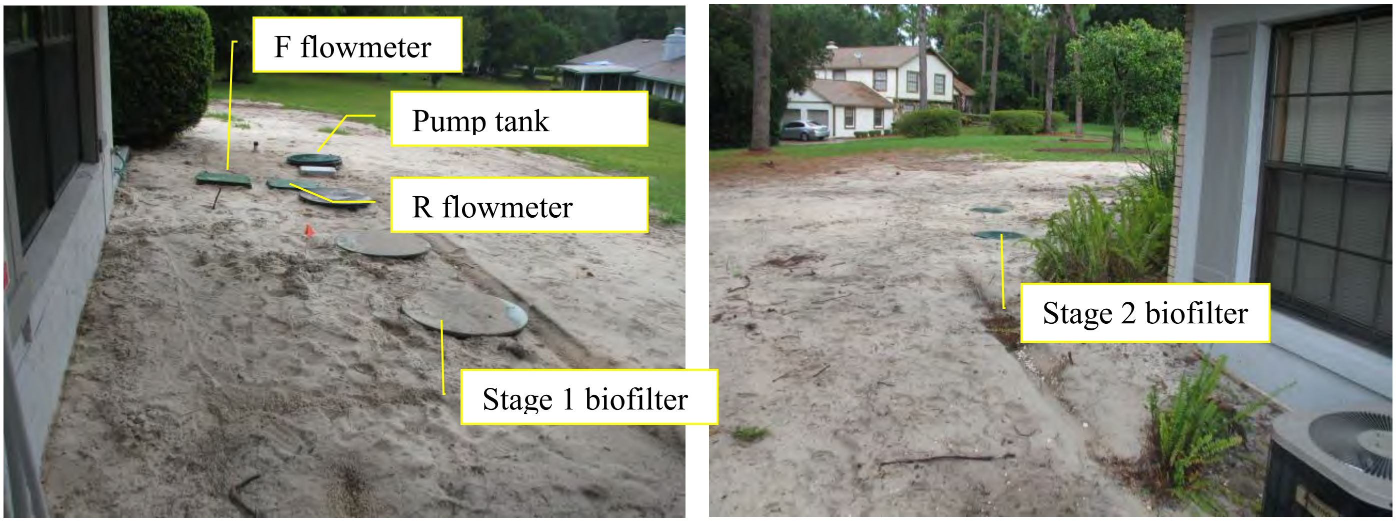

Figure 21
Overall PNRS system installed

Estimated Cost

The final construction cost for the installed system was $22,361.55 as detailed in Appendix B.

System Start-up

The system was started up July 8, 2013, when all flow was diverted to the new passive system. Routine checks of the system will be made to ensure the system is functioning as intended.

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Florida Department of Health
Onsite Nitrogen Reduction Strategies Study

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TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS6

November 2013

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Wakulla County, Florida (B-HS6).

System Overview

The B-HS6 passive nitrogen reduction system (PNRS) was installed in Wakulla County, Florida in November 2013. The new system replaced the previously installed PNRS system installed at field site B-HS1. The previously installed Aerocell™ unsaturated media filter chamber, Nitrex™ media and split recirculation device were removed from the system. The existing 1,500 gallon dual chamber septic tank will continue to provide primary treatment for the new PNRS system. However, the effluent screen was moved to the outlet and a vented tee was installed between the chambers per 64E-6.013(2)(h). The existing pump and floats were moved from the second chamber of the primary tank into a new 275 gallon pump tank. A 1,650 gallon concrete combined Stage 1 and Stage 2 media biofilter was installed. The existing 1,500 gallon concrete single chamber tank which contained the Nitrex™ media was converted to a Stage 2 saturated sulfur media biofilter. Figure 1 is a site schematic showing the system components and layout of the installation. The complete as-built system drawings are included in Appendix A.

Household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen into the pump tank (which contains the pump and float switches). The pump tank contents are discharged to the top of the Stage 1 biofilter, dispersed by four spray nozzles. The Stage 1 biofilter contains 30 inches of coarse expanded clay media (Riverlite™ 1/4; 1.1 to 4.8 mm). Wastewater proceeds in downward unsaturated flow through the expanded clay media where nitrification occurs. Twelve inches of lignocellulosic media was installed underneath the expanded clay media. The tank's outlet invert was installed 4-inches above the interior bottom of the tank. Therefore, approximately 4-inches of the lignocellulosic media is saturated, promoting oxygen depletion and denitrification of the nitrified effluent. The combination Stage 1 and Stage 2a biofilter effluent then flows into the bottom of the denitrification (Stage 2b) biofilter, where it proceeds upward through the elemental sulfur and oyster shell media mixture. The Stage 2b biofilter effluent discharges near the top of the tank; therefore denitrification occurs in the saturated environment. The denitrified treated effluent is discharged into the soil via the existing drainfield (standard trenches). A flow schematic of the system is shown on Figure 2.

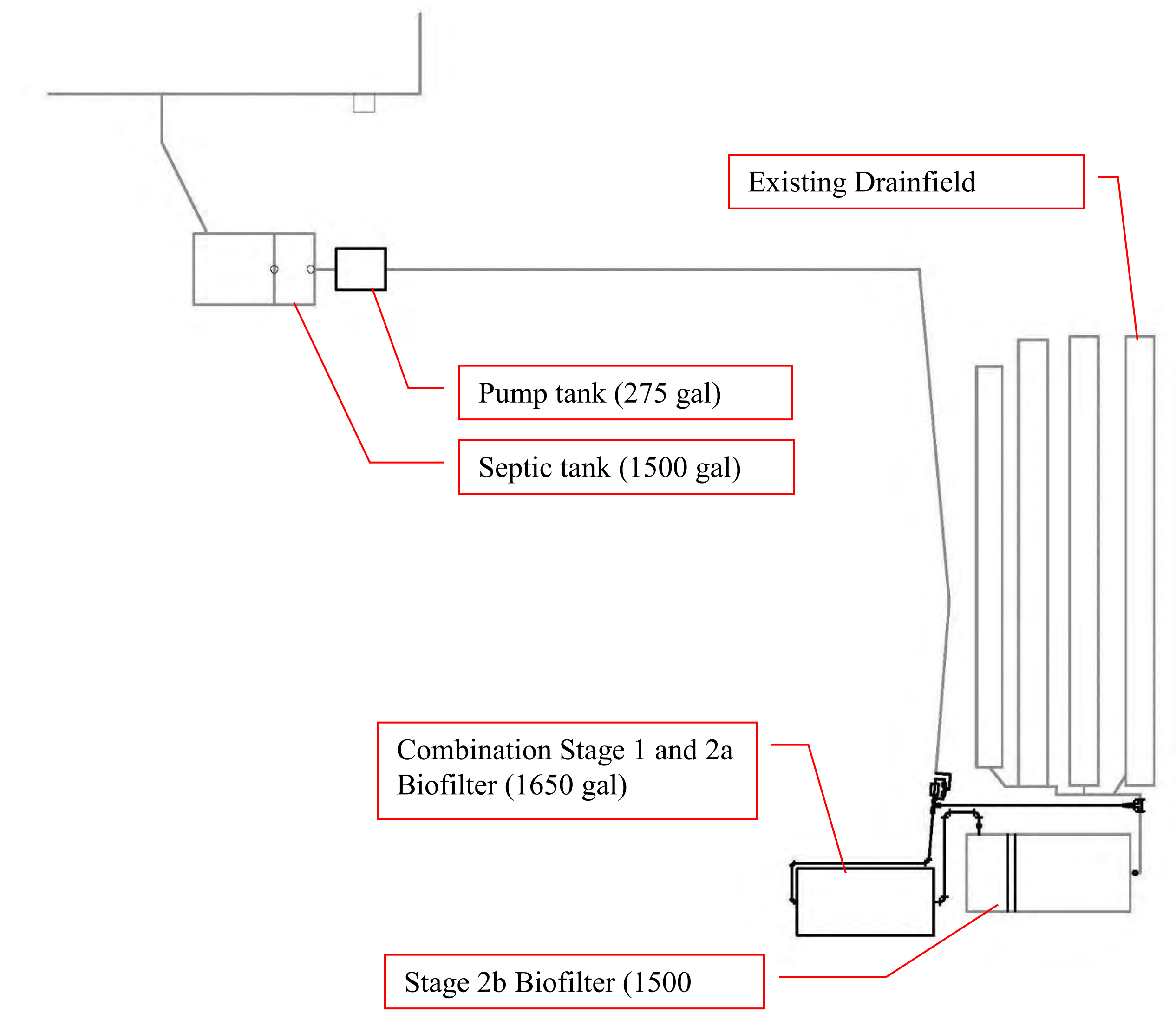

Figure 1
Schematic of B-HS6 PNRS installed in Wakulla county

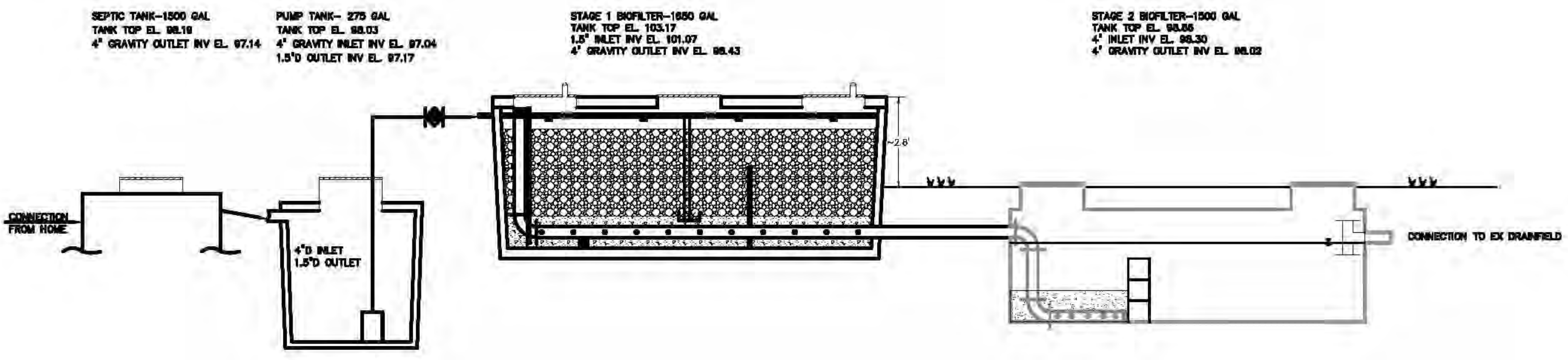

Figure 2
Flow Schematic of B-HS6 PNRS installed in Wakulla county

Installation

Installation of the system commenced November 5, 2013 and was completed on November 6, 2013. As previously discussed, the existing 1,500 gallon septic tank will continue to provide primary treatment. A vented tee was installed between the chambers (Figure 3) and the effluent screen was moved to the outlet (Figure 4).

Figure 3
Primary tank vented tee between chambers

Figure 4
Primary tank effluent screen moved to outlet

Following the primary tank modifications, the previously installed passive nitrogen reduction system components were removed. The previously installed Aerocell™ unsaturated media filter chamber (Figure 5), Nitrex™ media (Figure 6) and split recirculation device (Figure 7) were removed from the system.

Figure 5
Aerocell™ unsaturated media filter chamber removal

Figure 6
Nitrex™ media removal

Figure 7
Split Recirculation Device removal

Following the removal of the old system components, the remaining passive nitrogen reduction system components were installed (Table 1). A 275 gallon concrete pump tank was installed beside the primary tank (Figure 8). The 4"D inlet of the pump tank is connected (gravity flow) to the septic tank discharge. On the pump discharge line, the existing system flow meter was installed with a bypass line for the flowmeter (Figure 9). In addition, a PNRS system bypass for the Stage 1, 2a, and 2b biofilters was installed that connects the pump discharge directly to the drainfield (Figure 10). A single chamber (1,650 gallon) concrete tank was installed near the existing 1,500 gallon tank (Figure 11). The purpose of this tank is to hold the Stage 1 expanded clay media and Stage 2a lignocellulosic media. The Stage 1 and 2a combination tank 4"D outlet (Figure 11) is located near the bottom of the tank to allow for unsaturated operation through the expanded clay media and some saturation operation through the lignocellulosic media. The 4"D underdrain pipe (perforated) was installed along the centerline, 4-inches above the interior bottom of the tank for effluent collection. A 12-inch layer of lignocellulosic media, a blended urban waste wood from AAA Tree Experts, Tallahassee, FL, was installed in the bottom of the tank (Figure 12). Following lignocellulosic installation and leveling, 30-inches of coarse (1/4 Riverlite™) expanded clay media was installed (Figure 13) above a plastic mesh screen separating the two media layers. Following media installation and leveling, the influent distribution network was installed. The 1.5"D influent pipe, connected to the pump tank discharge, disperses the effluent through four spray nozzles (Figure 13). Vents were installed on the covers of the tank (Figure 14) to allow air into the tank promoting aerobic conditions for nitrification. The Stage 1 biofilter outlet pipe includes a sample port (Figure 15). The tank was hidden with a berm surrounding the tank (Figure 16).

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	1,500	67	none
Pump Tank	275	13	none
Stage 1 Biofilter and Stage 2a Biofilter	1,650	67	• 30" Riverlite 1/4 • 12" Lignocellulosic
Stage 2b Biofilter, upflow	~500 (1,500 total)	~20 (61 total)	12" Elemental sulfur (90%) & oyster shell mixture (10%)

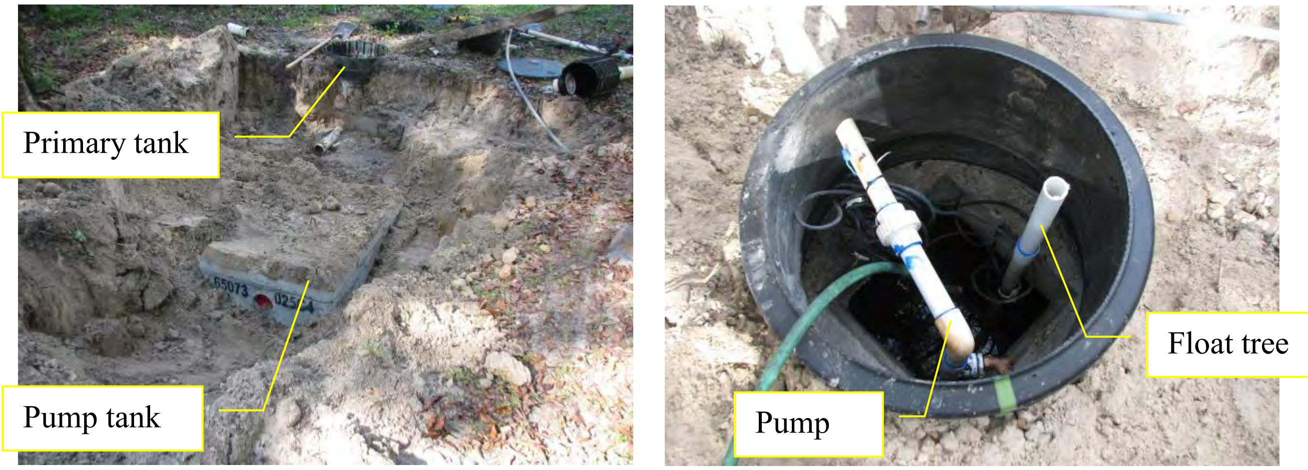

Figure 8
Pump tank (275 gallon)

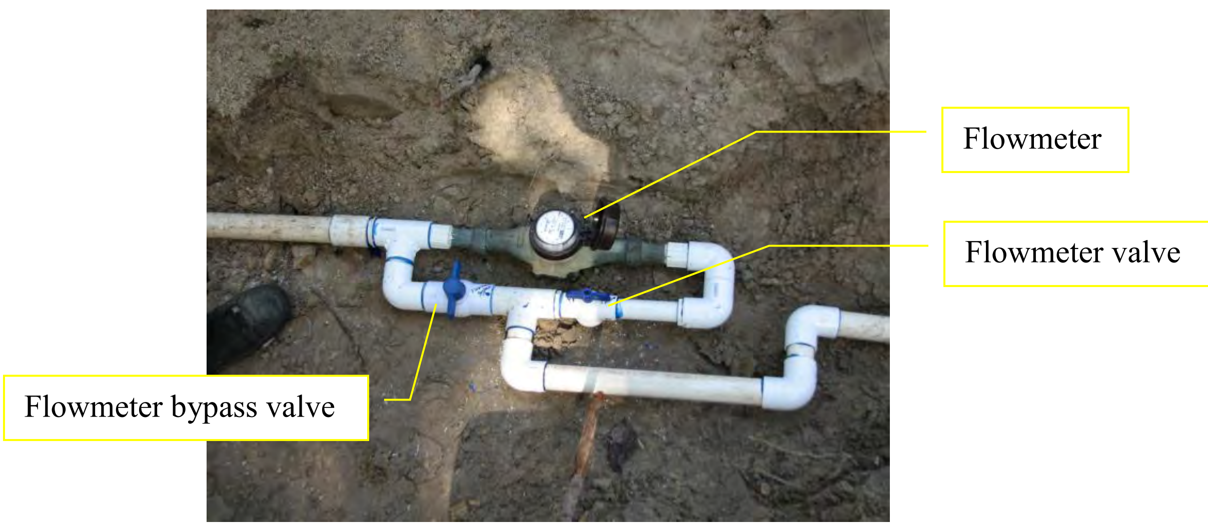

Figure 9
System flow meter

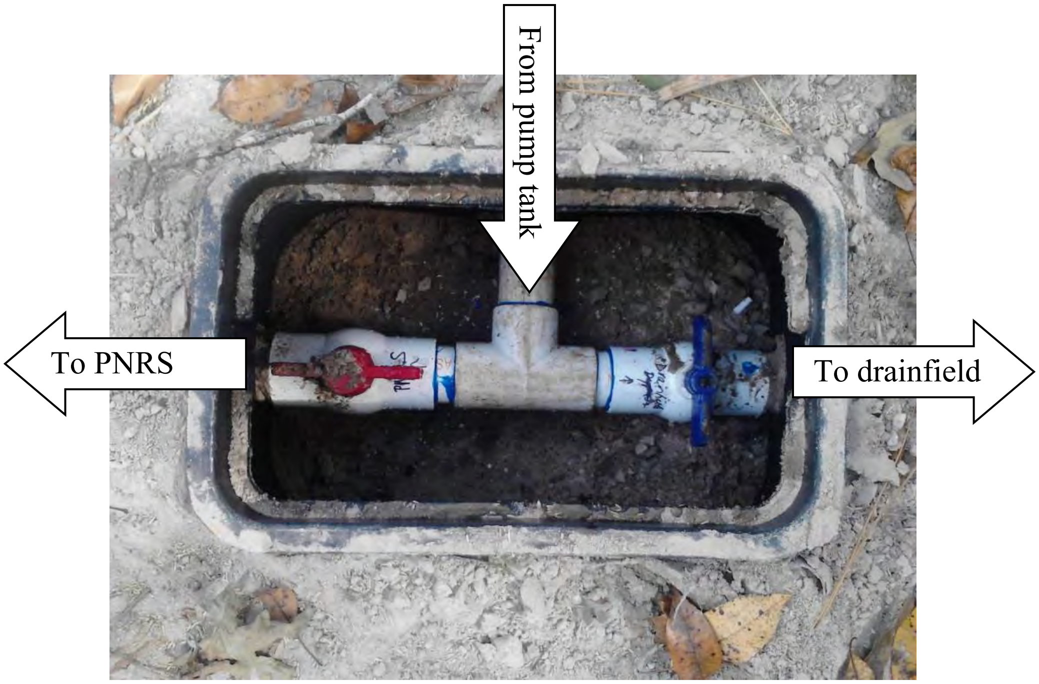

Figure 10
PNRS system bypass

Figure 11
Combination Stage 1 and 2a Biofilter (1650 gallon)

Figure 12
Lignocellulosic media installation

Figure 13
Expanded clay media installation

Figure 14
Vents on the covers

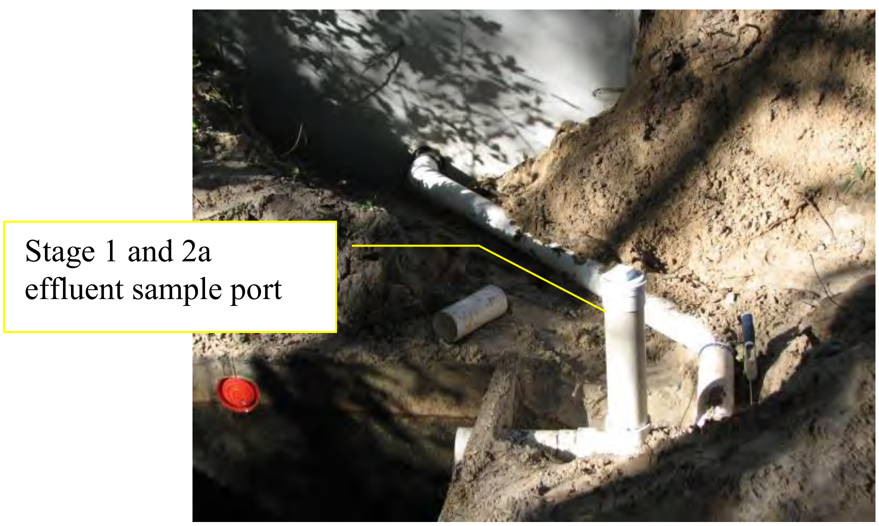

Figure 15
Stage 1 and Stage 2a effluent sample port

Figure 16
Stage 1 and Stage 2a berm hiding tank

The 1,500 gallon concrete tank that previously contained the Nitrex^{TM} media (Figure 17) was converted to the new Stage 2b tank containing 90% pastille-shaped elemental sulfur (GreenSun® ES-99) and 10% oyster shell media (Remington Feed) mixture. The volume of sulfur media required for treatment is significantly less than lignocellulosic media; therefore a cinder block wall (3 blocks in height) was installed inside the tank to create two chambers. The inlet chamber created with the wall holds the sulfur media mixture and is approximately one-third of the tank volume (Figure 18). The 4"D pipe from the Stage 1 and 2a biofilter connects to a perforated pipe along the bottom of the inlet chamber (Figure 18). Above the perforated pipe, 12-inches of elemental sulfur and oyster shell media was installed and mixed (Figure 18). The outlet pipe is connected to the existing drainfield and contains a new sample port (Figure 19).

Figure 17
Cleaned Stage 2b tank (1500 gallon)

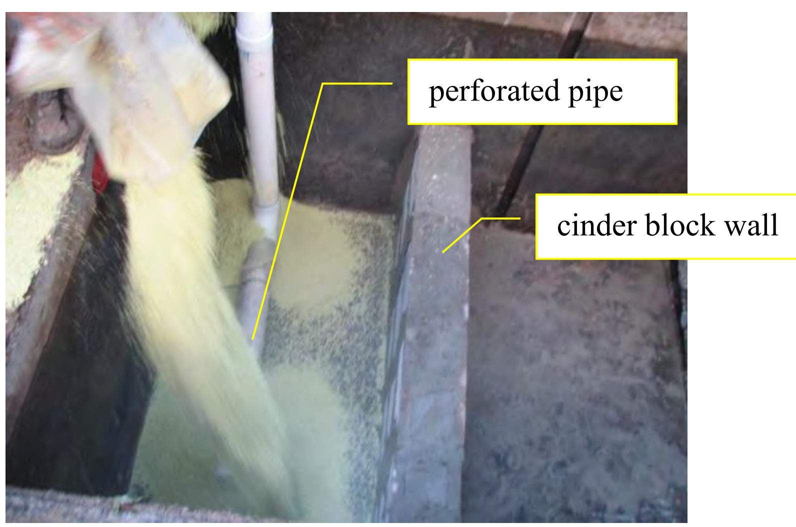

Figure 18
Stage 2b tank (1500 gallon)

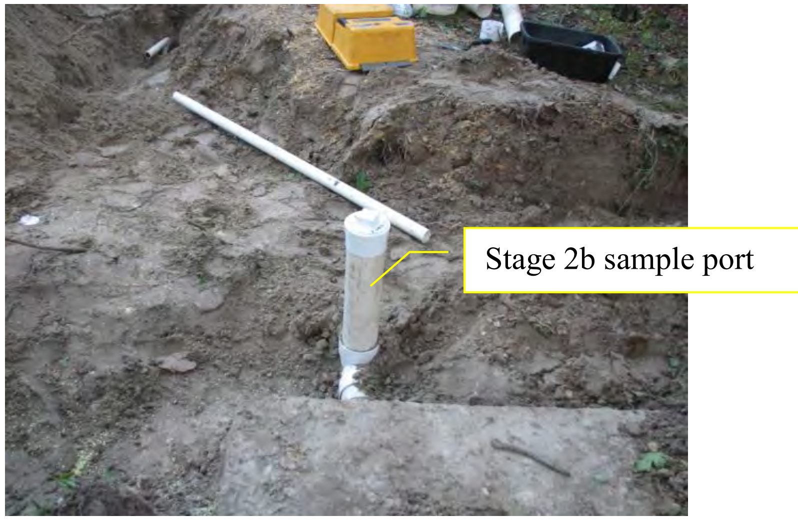

Figure 19
Stage 2b tank (1500 gallon) sample port

The previously installed power meter between the main power box of the house and the Vericomm control panel remains to record cumulative power usage of the pump in kilowatt-hours. Figure 20 shows the power meter installed inside an outdoor enclosure above the control panel.

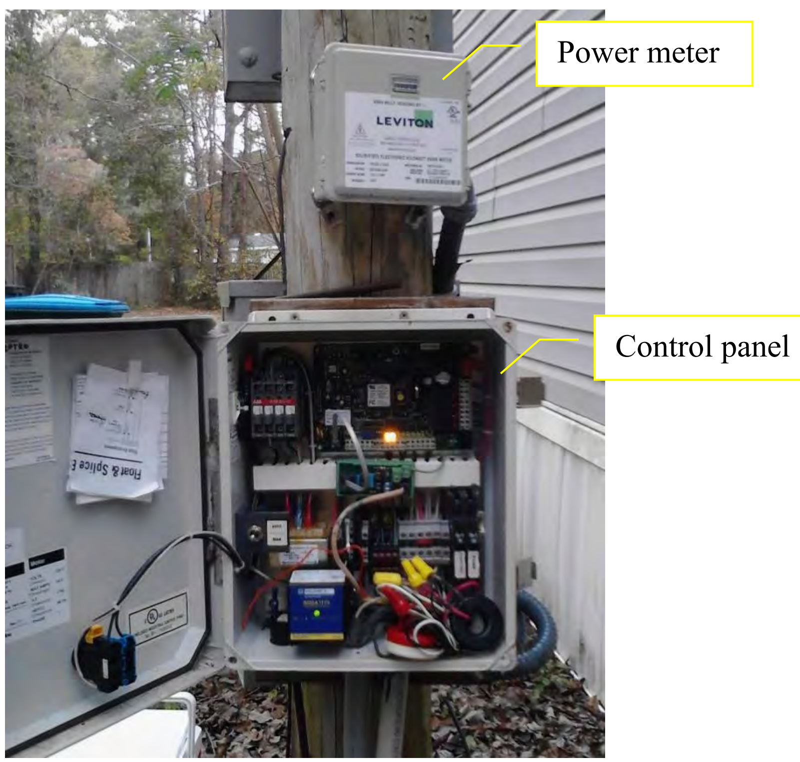

Figure 20
Power meter and Control Panel

During final testing of the system, the system operated with no visible signs of leaks, etc. The system area was filled and all disturbed areas on the property were graded (Figure 21).

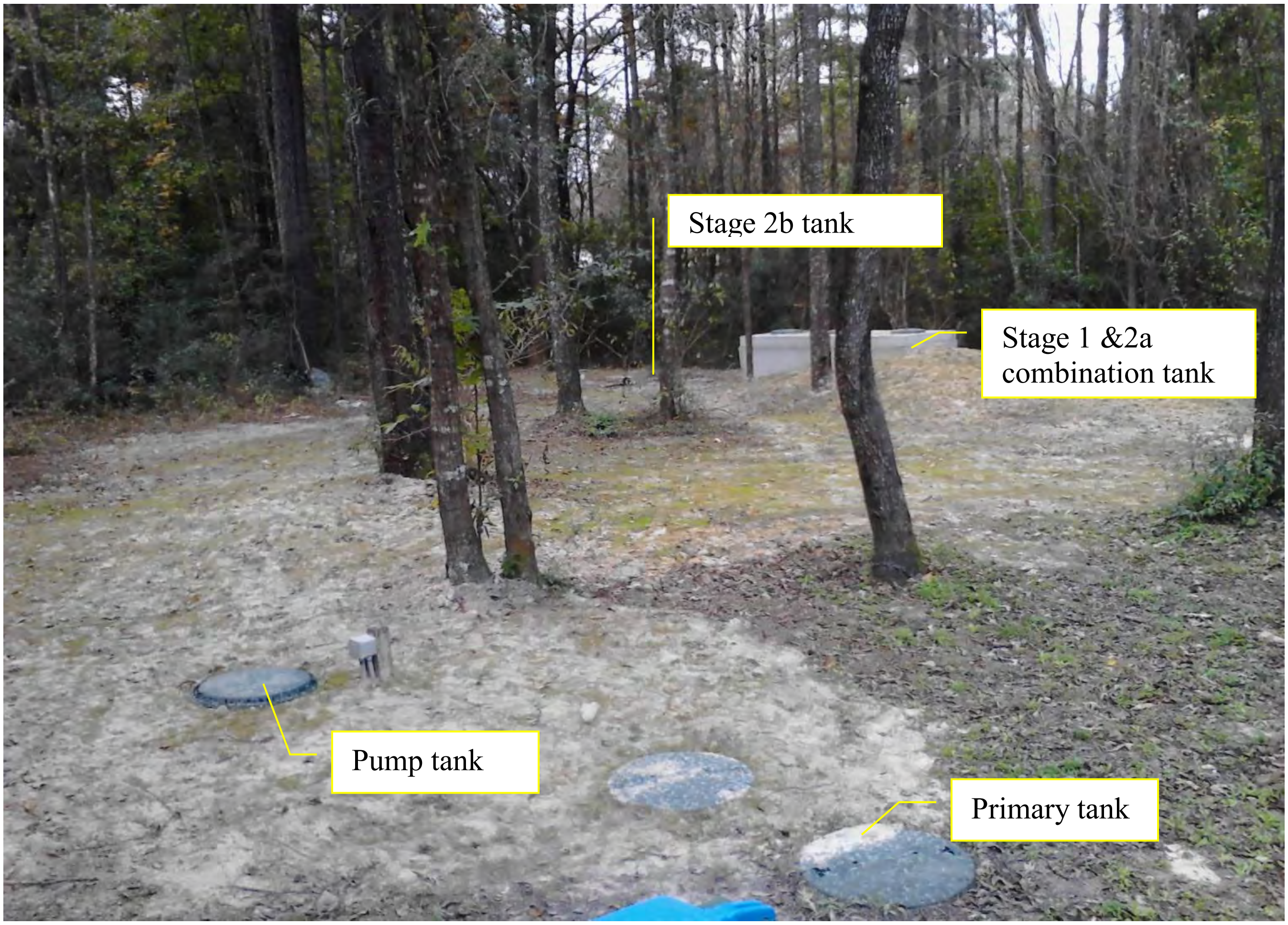

Figure 21
Overall PNRS system installed

Estimated Cost

The final construction cost for the installed system was $13,727.12 as detailed in Appendix B.

System Start-up

The system was started up November 6, 2013, when all flow was diverted to the new passive system. Routine checks of the system were made for the first two weeks to ensure the system was functioning as intended. Preliminary sampling will begin in November to monitor nitrification.

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TASK B.6

Installation Report for Passive Nitrogen Reduction System B-HS7

November 2013

Task B of the Florida Onsite Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified and pilot tested in FOSNRS Task A. To meet this objective, full scale treatment systems will be installed at various residential sites in Florida, operated on septic tank effluent under actual onsite conditions, and monitored over an extended timeframe. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the installation of a passive nitrogen reduction system at a home site in Marion County, Florida (B-HS7).

System Overview

The B-HS7 passive nitrogen reduction 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 drainfield. The existing 900 gallon dual chamber septic tank will continue to provide primary treatment for the new PNRS system. Figure 1 is a plan view showing the system components and layout of the installation. The complete as-built system drawings are included in Appendix A.

Household wastewater enters the 1st 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 Infiltrator EQ36-LP^{TM} chambers. 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 flow schematic of the system is shown in Figure 2.

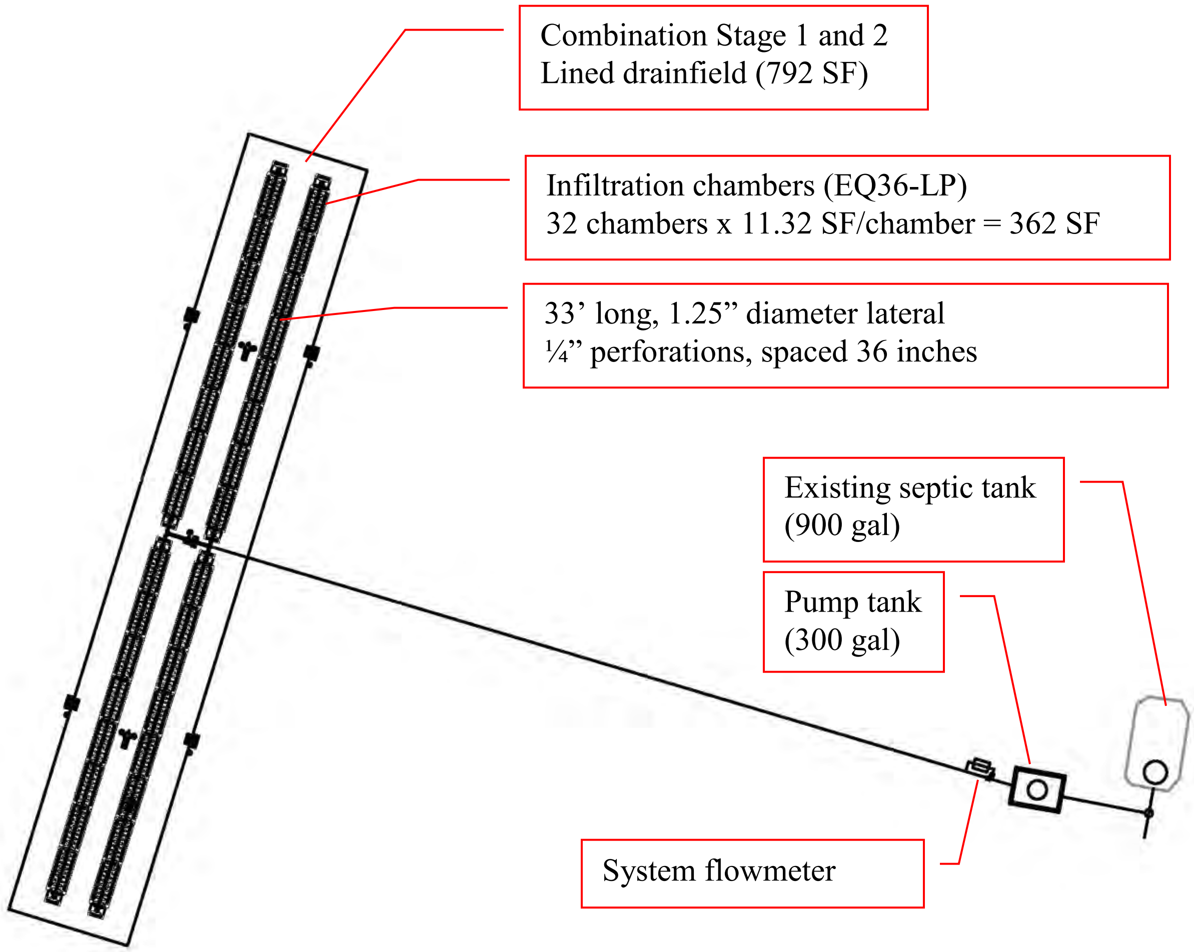

Figure 1
Plan view of B-HS7 PNRS layout installed in Marion county

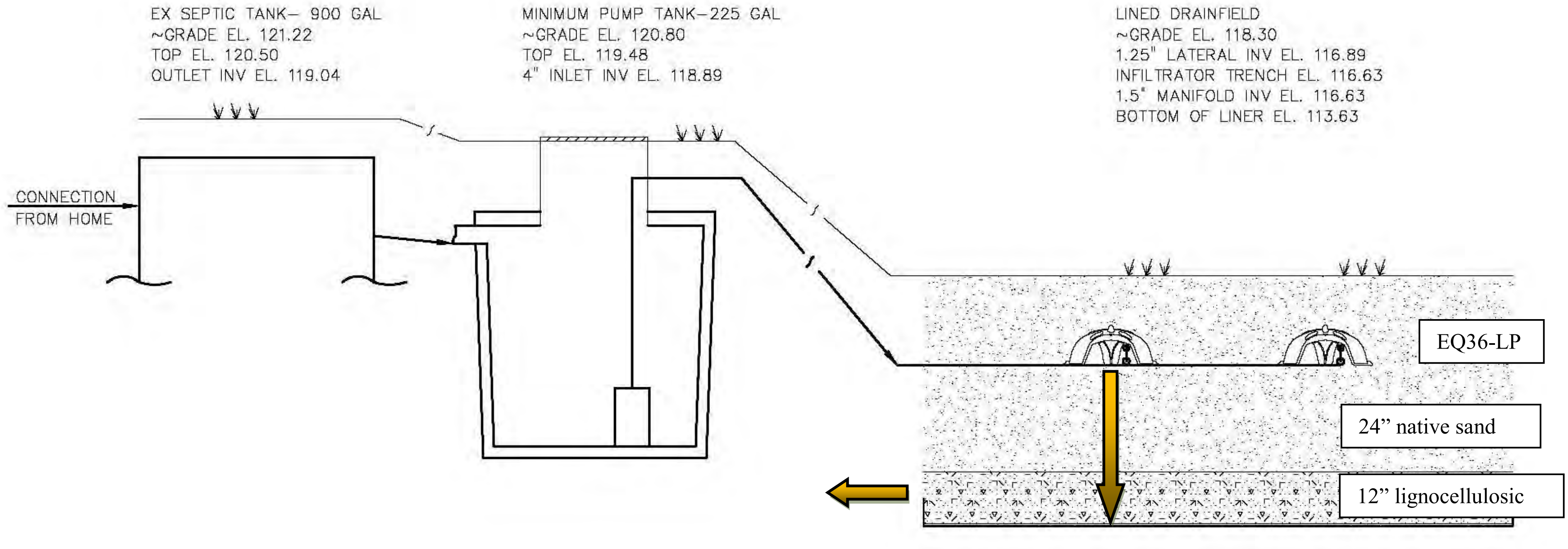

Figure 2
Flow Schematic of B-HS7 PNRS installed in Marion county

Installation

Installation of the system commenced November 13, 2013 and was completed on November 18, 2013. As previously discussed, the existing 900 gallon septic tank will continue to provide primary treatment. An access riser was installed above the second chamber of the primary tank (Figure 3) to allow for ease in maintenance of the existing outlet effluent screen. A two-way valve (Bull Run™) (Figure 4) was installed following the septic tank outlet to allow the flow to either be completely directed to the new passive system (to the pump tank) or to the existing drainfield. A riser pipe was installed to grade over the valve, so that the valve can be turned after installation is complete. The valve is turned with a wrench on a rod which is long enough to reach within the riser installed.

Figure 3
Primary tank access riser and cover

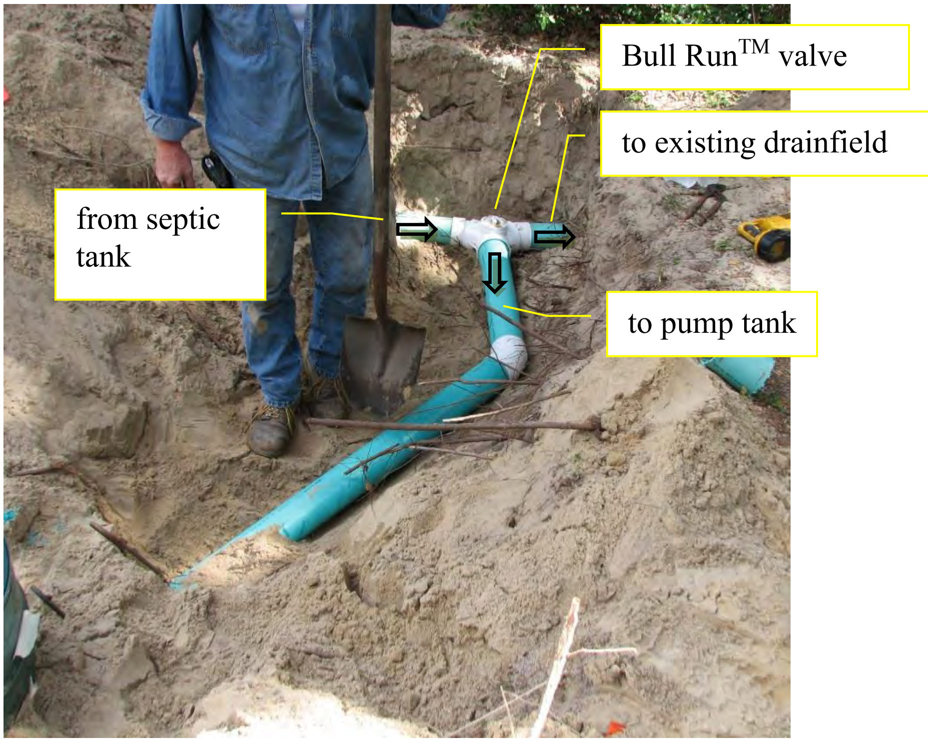

Figure 4
Bull Run™ valve

The remaining passive nitrogen reduction system components were installed (Table 1).

Table 1
Passive Nitrogen Reduction System Components

	Tank Volume (gal)	Surface Area (ft^2)	Media
Primary Tank	900		none
Pump Tank	300	12	none
Lined Drainfield Area		11' x 72' (792)	• 24" native sand • 12" lignocellulosic

The 300 gallon concrete pump tank was installed downgradient of the primary tank (Figure 5). The standard outlet pipe connection was plugged since the pump discharge pipe was installed through the riser. A Liberty LE51A-2 submersible pump was installed (Figure 6). One wide-angle piggyback float switch attached to the pump controls the effluent level in the pump tank. The height of the float is adjustable to calibrate a target dose volume. An additional float switch is connected to an audible/visual alarm (Figure 7) installed next to the power meter box to alarm for a high water level in the pump tank (pump failure). One inline flowmeter was installed following the pump discharge (Figure 8) with a bypass for maintenance/cleaning of the flowmeter.

Figure 5
Pump tank (300 gallon)

Figure 6
Submersible Liberty pump

Figure 7
High water level alarm

Figure 8
PNRS system flowmeter

The new treatment drainfield area was prepared for the 30 mil PVC liner installation (Figure 9). The liner was installed with a 6 inch lip around the outside perimeter. Above the liner, approximately a ½-inch sand layer (Figure 9) was installed to protect the liner during construction. Above the liner a 12-inch layer of lignocellulosic media, a blended urban waste wood from Wood Resource Recovery, Ocala, FL, was installed (Figure 9). Monitoring equipment surrounding the liner lip and inside the lignocellulosic media were installed (Figure 10). The various types of monitoring equipment installed include: stainless steel drivepoints, stainless steel suction lysimeters and ceramic cup suction lysimeters (Figure 11). To separate the top of the lignocellulosic media and bottom of the native sand layer a plastic mesh screen (1/16-inch) was installed above the lignocellulosic media (Figure 10). Following placement of the plastic mesh screen, a 24-inch native sand layer was installed (Figure 12). Ceramic cup suction lysimeters were installed above the mesh screen to represent water quality just after downward passage through the sand layer.

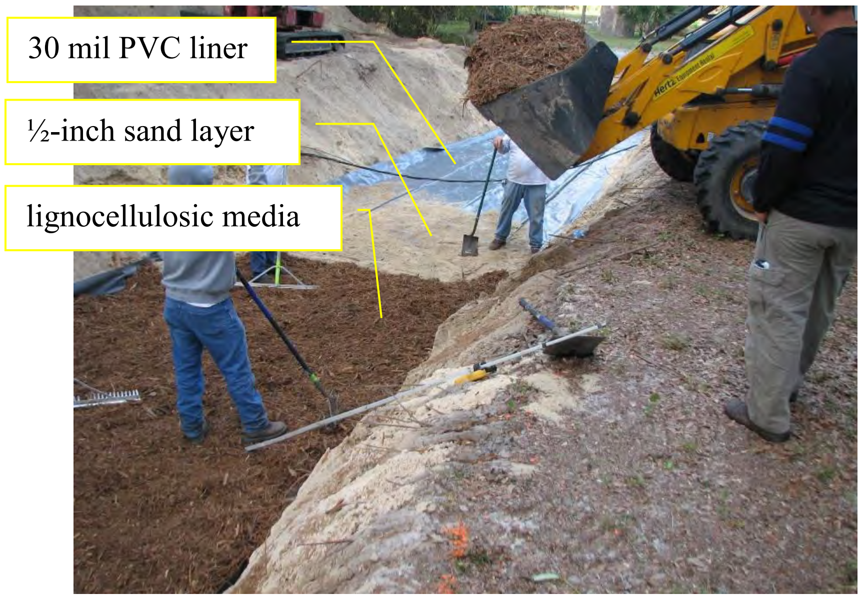

Figure 9
Lined area

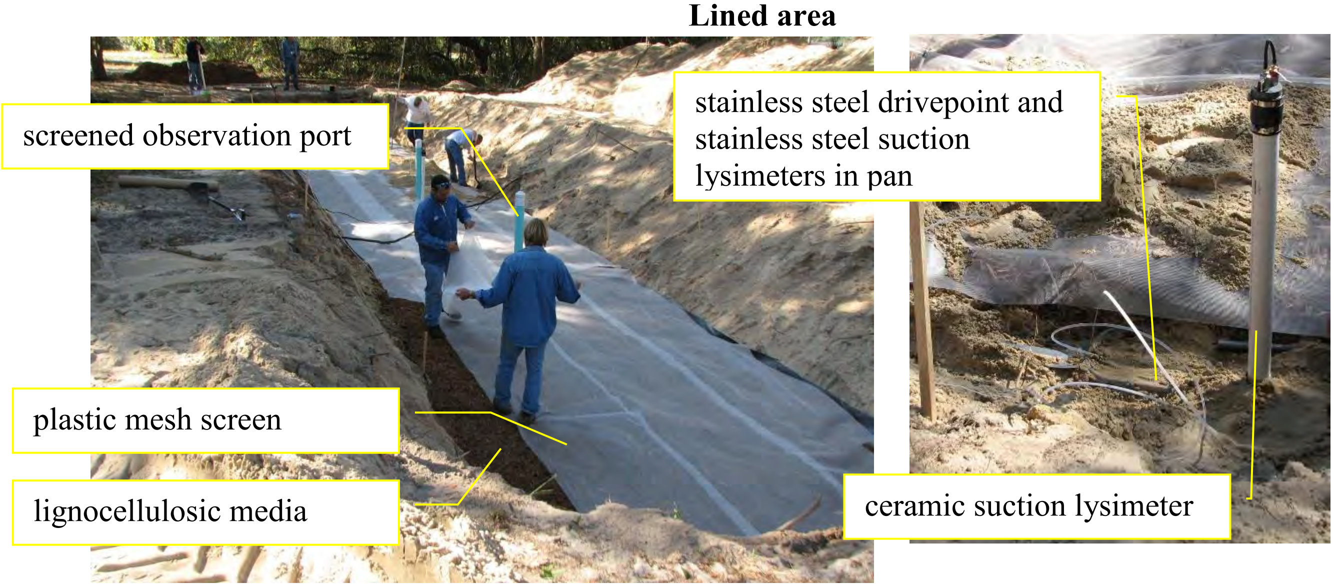

Figure 10
Lignocellulosic media monitoring equipment

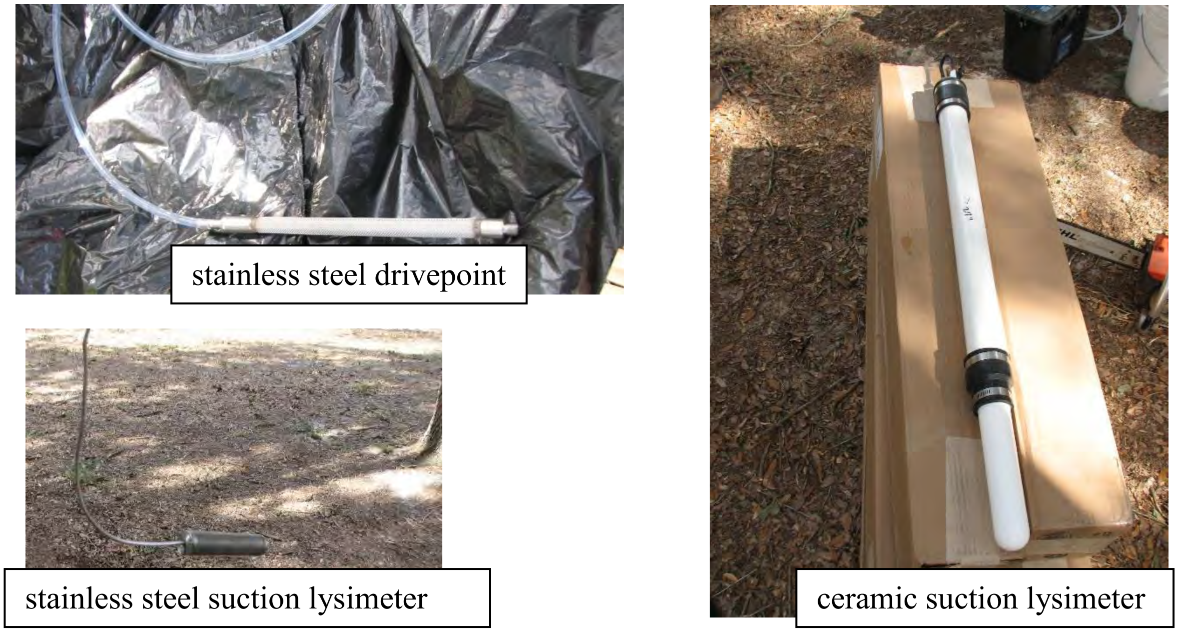

Figure 11
Lignocellulosic media monitoring equipment

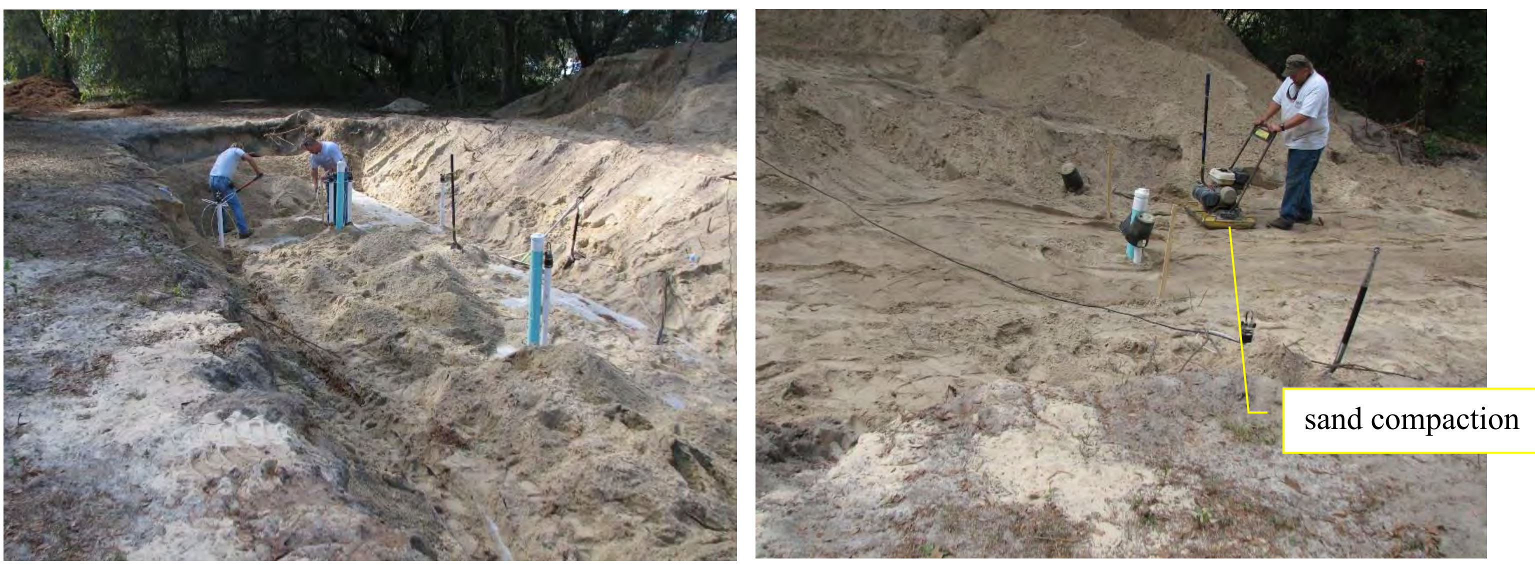

Figure 12
Native sand media

The 2"D pipe downstream of the flowmeter is reduced to 1.5"D in the center manifold of the low pressure distribution network (Figure 13). The manifold is connected to 4 laterals of perforated pipe (Figure 13) which distribute septic tank effluent over native sand inside Infiltrator EQ36-LP™ low profile chambers. The laterals were installed using pressure dosing pipe supports, so that a wet pressure test could be conducted (Figure 14) prior to installing the chambers over the laterals. Following the wet pressure test, the Infiltrator EQ36-LP™ low profile chambers were installed (Figure 15). Above the chambers, 12-inches of native sand cover (Figure 16) was installed to support wheel loads of 16,000 lbs per axle per the manufacturer. This will allow the homeowner to continue to operate a small tractor in the area. Hay and grass seed mix was placed above the sand (Figure 17).

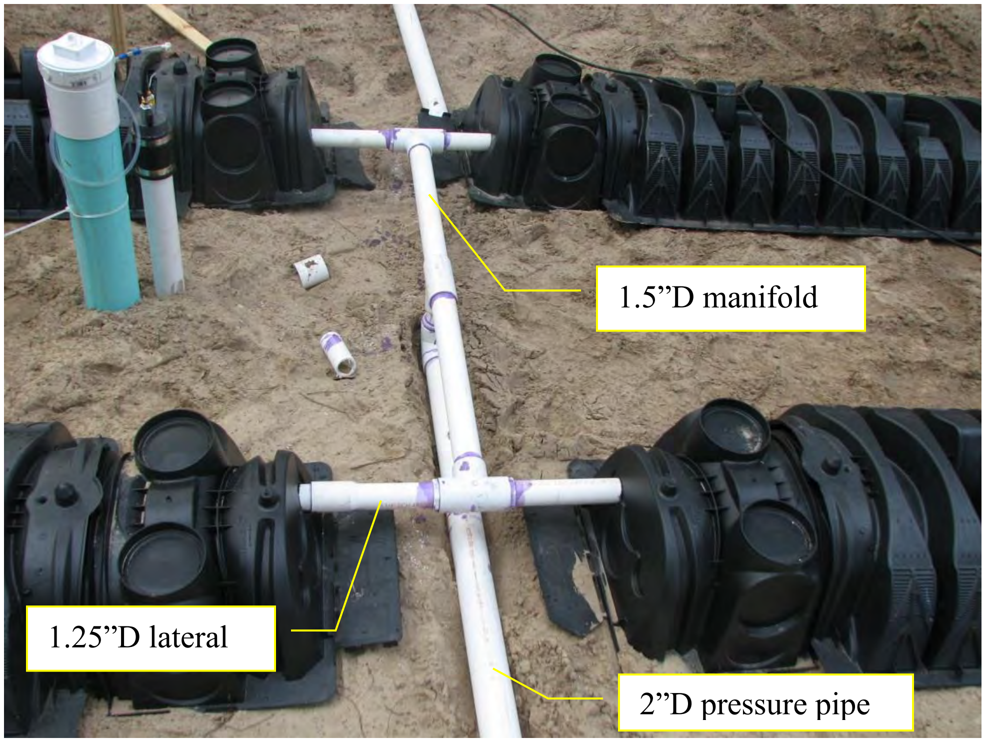

Figure 13
Center manifold of low pressure distribution network

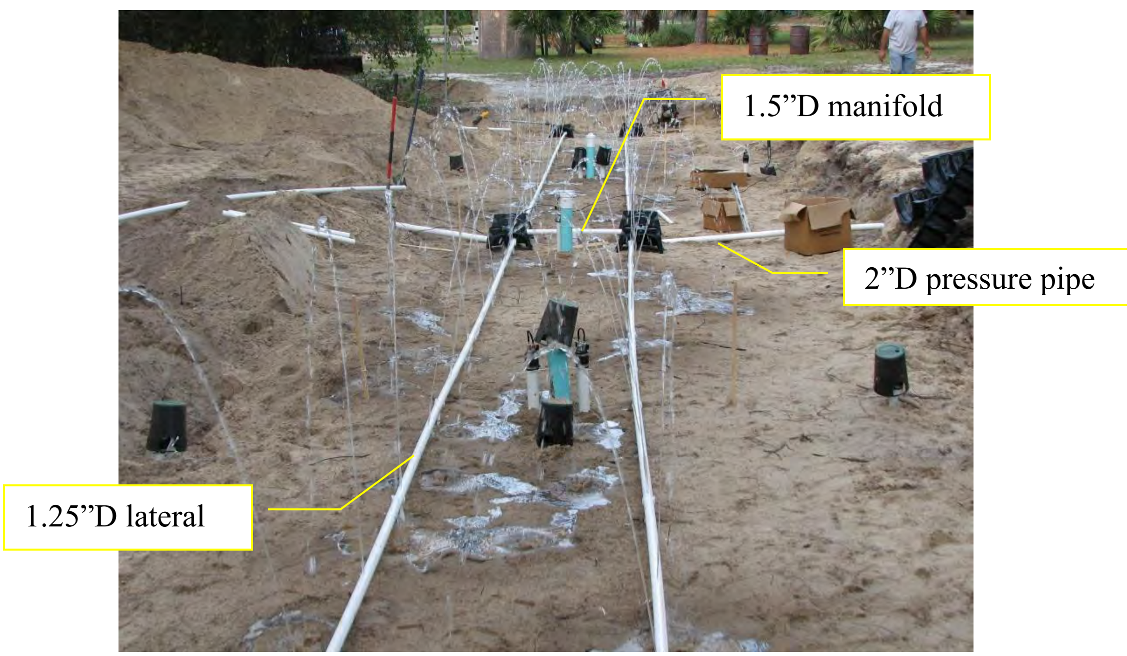

Figure 14
Wet pressure test

Figure 15
Infiltrator chambers

Figure 16
Sand cover

Figure 17
Hay and grass seed mix

Estimated Cost

The final construction cost for the installed system was $13,836.66 as detailed in Appendix B.

System Start-up

The system was started up November 19, 2013, when all flow was diverted to the new passive system. Preliminary sampling will begin in December to monitor nitrification.

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APPENDIX B FINAL FIELD SYSTEM MONITORING REPORTS

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS1 Field System
Monitoring Report No. 8

Prepared for:

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

FDOH Contract CORCL

February 2013

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

AET
Applied Environmental Technology

B-HS1 Field System Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth, and final sample event of a passive nitrogen reduction system at a home site in Wakulla County, Florida (site B-HS1).

2.0 Purpose

This monitoring report documents data collected from the eighth B-HS1 monitoring and sampling event conducted on January 24, 2013. This monitoring event consisted of collecting flow measurements from the household water use meter and the treatment system internal water meter, recording electricity use, monitoring of field parameters, collection of water samples from four points in the treatment system, and sample analyses by NELAC certified laboratories.

3.0 Materials and Methods

3.1 Project Site

The B-HS1 field site is located in Wakulla County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in June 2011. Design and construction details were presented previously in the Task B.6 document. The B-HS1 system consists of a 1,500 gallon two chamber concrete tank with a 1,000 gallon primary treatment tank (primary chamber) and a 500 gallon pump chamber (pump chamber); an Aerocell™ unsaturated media filter; and a 1,500 gallon single chamber up flow tank containing Nitrex™ media. Treated effluent from the Nitrex™ unit is discharged to a soil dispersal system (drainfield) consisting of four Infiltrator trenches. Three of the four Infiltrator trenches are 40 feet in length, and the fourth is 36 feet. Based on measured average wastewater flow and tank volumes, there is over a ten day transit time through the treatment system prior to dispersal. Figure 1 is a site schematic showing the system components and layout of the installation.

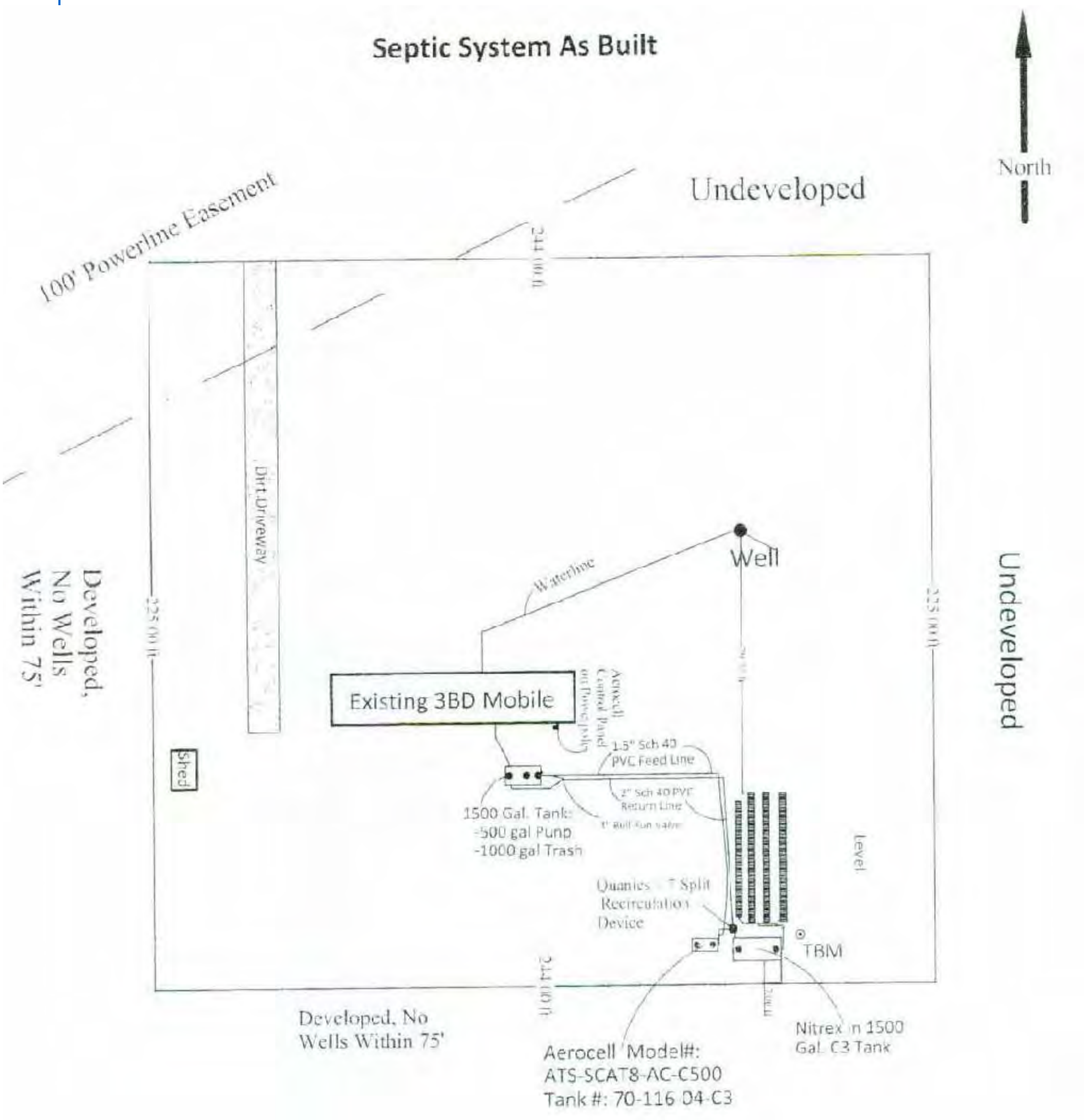


Figure 1
B-HS1 Site Schematic

3.2 Monitoring and Sample Locations and Identification

The four monitoring points for this sample event are shown in Figure 2. The first monitoring point, B-HS1-STE, is the effluent sampled approximately 1.5 feet below the surface of the first chamber of the primary tank, which is referred to as primary effluent or septic tank effluent (STE). Samples from monitoring point B-HS1-STE represent the whole household wastewater and are the influent to the remainder of the onsite nitrogen reduction system. The STE chamber is accessed from the middle tank lid of the primary treatment tank. The second sampling point (B-HS1-PUMP) was taken approximately 1.5 feet below the surface of the second chamber of the primary tank, which serves as the pump chamber and contains a mixture of primary effluent (STE) and recirculated effluent from the Aerocell™ unsaturated biofilter.

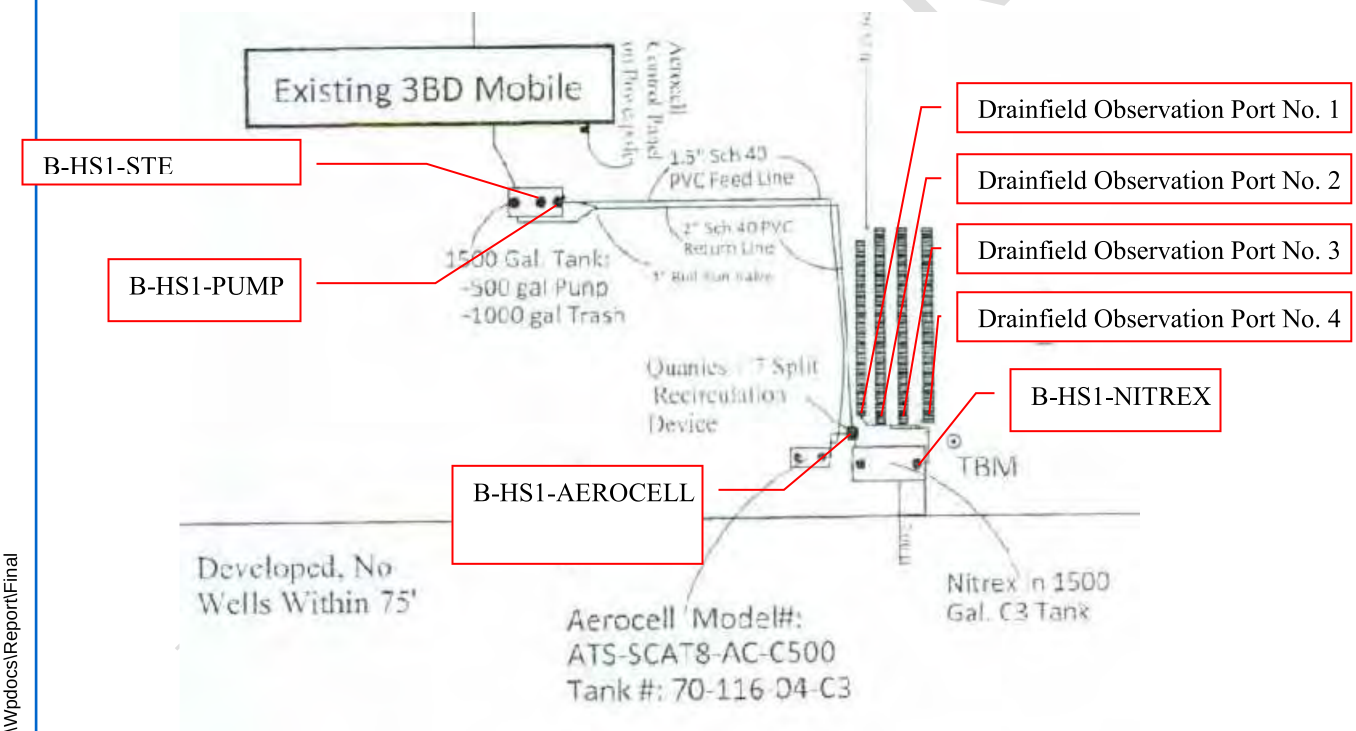


Figure 2
B-HS1 Sample and Monitoring Locations

The pump discharges wastewater to the top of the unsaturated Aerocell™ chamber. The Aerocell™ effluent flows into an adjustable split recirculation device which allows for a portion of the effluent to be sent back to the pump chamber. The remainder of the Aerocell™ effluent proceeds to the Nitrex™ tank. Samples from the third monitoring location are taken from the middle of the split recirculation device (B-HS1-AEROCELL) and represent Aerocell™ effluent (Figure 3).

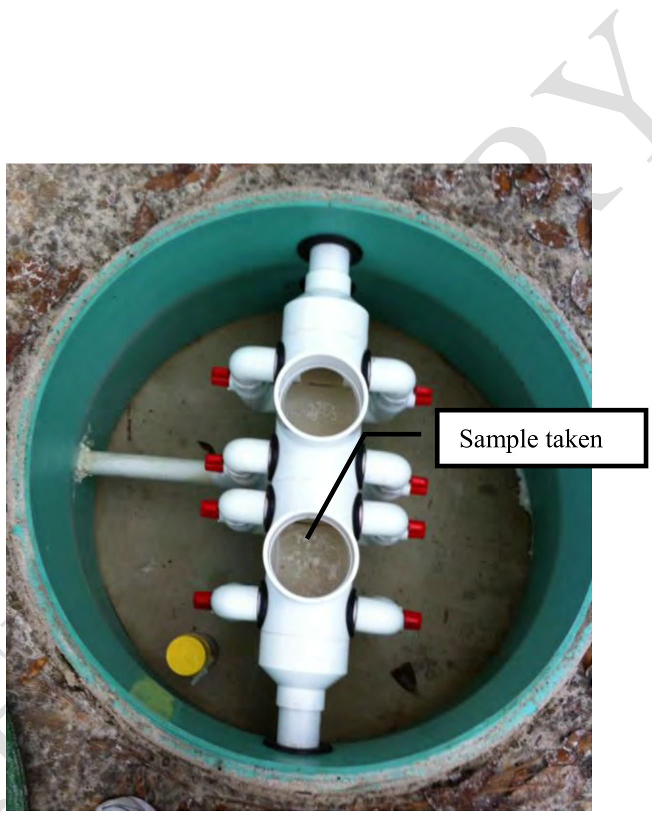


Figure 3
Recirculation Device (B-HS1-AEROCELL sample)

The fourth monitoring location is the Nitrex™ tank sample tube that is connected to the Nitrex™ effluent pipe (Figure 4). This sample represents the Nitrex™ effluent, which is the final effluent from the treatment system prior to being discharged to the soil infiltration system, or drainfield. Each drainfield line has an observation port installed at the end near the Nitrex system for monitoring (see Figure 2)

Figure 4
Nitrex™ Tank (B-HS1-NITREX sample)

3.3 Operational Monitoring

Start-up of the system occurred on June 10, 2011 and the system has operated continually since that date. For this eighth sampling event, the water meter for the house and the Aerocell™ flow meter were read and recorded on January 24, 2013. The Aerocell™ flow meter is located on the line leading from the pump/recirculation tank to the Aerocell™ chamber and records the cumulative flow in gallons pumped from the pump chamber. The measurement of the Aerocell™ flow meter includes both the forward wastewater flow from the household and the recirculation flow. The control panel includes telemetry where reports are generated regarding alarms, pump cycles, and other information using a Vericomm panel system.

3.4 Energy, Chemical and/or Additives Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. The power usage of the system is primarily due to the single recirculation pump in the pump chamber, although a small amount of power is used by the control panel itself. There are no chemicals added to the system. However, the Nitrex™ media is a "reactive" media which will be consumed during operation. The Nitrex™ tank was initially filled with 42 inches of media, which ostensibly will last for many years without replenishment or replacement.

3.5 Water Quality Sample Collection and Analyses

Influent, intermediate, and effluent water quality samples from the system were collected January 24, 2013 for water quality analysis. Samples were collected at each of the four monitoring points described in Section 3.2: B-HS1-STE, B-HS1-PUMP, B-HS1-AEROCELL, and B-HS1-NITREX. A duplicate sample was also taken at B-HS1 AERO-CELL. Additionally, laboratory split samples were collected immediately subsequent to the regular samples for analysis of the nitrogen species. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded. The sampling tube was placed approximately 1.5 feet below the surface in the STE and pump chamber samples and at mid-depth in the split recirculation device.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratory. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent samples were analyzed by the laboratory for: total alkalinity, total Kjeldahl nitrogen (TKN-N), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (Ortho P), total suspended solids (TSS), fecal coliform (fecal), and E.coli. All analyses were performed by independent and fully NELAC certified analytical laboratories (Southern Analytical Laboratory and Ackuritlabs, Inc.). For this sample event, both laboratories analyzed total Kjeldahl nitrogen (TKN-N), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N) in order to assure analytical quality. Table 1 lists the analytical parameters, analytical methods, and detection limits for these analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	EPA 300.0	0.01 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Solids (TS)	EPA 160.3	.01 % by wt
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Volatile Suspended Solids (VSS)	SM 2540E	1 mg/L
Fecal Coliform (fecal)	SM9222D	2 ct/100mL
E.coli	EPA1603	2 ct/100mL
Additional Analysis performed by Ackuritlabs, Inc.		
Total Kjeldahl Nitrogen (TKN-N)	SM 4500-NH_3 D	0.071 mg/L
Ammonia Nitrogen (NH_3-N)	SM 4500-NH_3 D	0.067 mg/L
Nitrate Nitrogen (NO_3-N)	SM 4500-NO_3 E	0.012 mg/L
Nitrite Nitrogen (NO_2-N)	SM 3500-NO_2 B	0.012 mg/L

4.0 Results and Discussion

4.1 Operational Monitoring

The flow meter readings, recycle ratio, and average daily water use for the B-HS1 field site are summarized in Table 2. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B. Summary tables of the Vericomm PLC recorded data are provided in Appendix C. These include daily and cumulative pump runtime and system alarms that are used to check general pump operation and performance.

Table 2
Summary of System Flow Rates

Date and Time Read	House Water Meter Reading	Average Daily Household Flow, Q	Aerocell™ Flow Meter Reading	Average Daily Flow Total Q + R[1]	Average Recycle Ratio
	Cumulative Volume (gallons)	Gallons/ day	Cumulative Volume (gallons)	Gallons/ Day	Recycle: Forward Flow
6/8/2011 14:10	0.0	0.0	0.0	0.0	
6/9/2011 17:10	87.3	77.6	2.1	0.0	0.0 : 1
6/10/2011 12:25	148.2	75.9	629.2	668.9	7.8 : 1
7/6/2011 11:20	2,884.8	105.4	35,025.2	1,325.2	11.6 : 1
7/7/2011 17:10	3,088.6	164.0	38,272.2	2,612.1	14.9 : 1
7/19/2011 10:30	4,254.0	99.4	40,756.0	212.0	1.1 : 1
9/13/2011	9904.0	101.7	60,840.0	361.5	2.6 : 1
10/26/2011 8:24	13804.7	90.0	118,640.9	1333.3	13.8 : 1
11/30/2011	17673.0	111.6	125,260.0	191.0	0.7 : 1
Total average prior to SRD[2] replacement		101.3		722.3	6.1 : 1
12/23/2011	20,280.0	113.3	153,930.0	1,246.5	10.0 : 1
1/25/2012 9:00	23,871.3	107.6	192,410.5	1,154.4	9.7 :1
1/30/2012 10:10	24,443.3	113.3	198,874.8	1,268.5	10.2: 1
2/24/2012 11:08	27,458.0	120.4	231,640.5	1,308.7	9.9 : 1
3/27/2012 9:56	30,820.2	105.2	267,763.0	1,130.4	9.7 : 1
4/20/2012 11:45	33,379.8	106.3	291,392.5	981.6	8.2 : 1
5/24/2012 8:55	36,914.4	104.3	323,118.2	936.4	8.0 : 1
6/22/2012 9:13	39,954.4	104.8	351,626.7	982.6	8.4 : 1
8/6/2012 8:52	45,137.0	115.2	413,985.7	1,386.2	11.0 : 1
8/30/2012 11:16	47,678.9	105.6	444,252.0	1,257.3	10.9 : 1
9/26/2012 11:19	51,047.0	124.7	478,626.3	1,271.7	9.2 : 1
10/26/2012 12:39	54,348.4	109.8	505,821.1	904.8	7.2 : 1
11/28/2012 9:37	58,471.2	125.4	540,715.2	1,061.3	7.5 : 1
12/27/2012 10:42	61,641.0	109.1	570,706.9	1,032.7	8.5 : 1
1/24/2013 10:52	64,779.2	112.1	606,945.4	1,293.9	10.5 : 1
Total average after SRD[2] replacement		111.7		1,136.9	9.2 : 1
Total average start-up to 1/24/13		108.7		1,020.3	8.4 : 1

[1]Household (Q) + Recirculation (R)

[2]Split recirculation device (SRD) was replaced December 9, 2011.

The split recirculation device (SRD) controls the fraction of Aerocell™ effluent that is re-circulated and the fraction sent to the Nitrex™ tank. The SRD was initially set so that 5 parts went back to the pump chamber and 1 part went to the Nitrex™ tank (5:1 recycle ratio). While calibrating the replacement SRD, the vendor increased the recycle ratio target to 10:1 to improve performance of the nitrification unit. The recycle ratio drifted downward towards 8:1 from April through June. In August and September the recycle ratio was close to the manufacturer's set point. The calculated recycle ratio was 7.2:1 for the October monthly monitoring and for the November 28, 2012 sampling event was 7.5:1. The December monthly monitoring showed an increase in the recirculation ratio to 8.5:1 and a further increase to 10.5:1 for the January 24, 2013 sampling event. The cause for the fluctuation observed in recirculation is not clear as the flow splitter device was not adjusted and the household water usage has remained fairly consistent (Table 2).

Prior to the SRD replacement, the household flow average was 101.3 gallons per day with periods of higher and lower flows. The average flow to the Aerocell™ unit was 722.3 gallons per day with a corresponding average recycle ratio of 6.1:1. Following the SRD replacement, the household flow average was 111.7 gallons per day, and the average flow to the Aerocell™ unit was 1,136.9 gallons per day with a corresponding average recycle ratio of 9.2:1. The household flow average between start-up and January 24, 2013 was 108.7 gallons per day, and the average flow to the Aerocell™ unit was 1,020.3 gallons per day with a corresponding average recycle ratio of 8.4:1.

4.2 Energy, Chemical and/or Additives Consumption

Energy consumption is monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 3.

Table 3
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use	Average Electrical Use per Gallon Treated
	Cumulative (kWh)	(kWh/day)	(kWh/gal)
6/9/2011 17:10	1		
6/10/2011 12:25	2	1.25	0.0164
7/6/2011 11:30	40	1.46	0.0139
7/7/2011 19:30	44	3.00	0.0183
7/19/2011 11:00	49	0.43	0.0043
9/13/2011	74	0.45	0.0044
10/26/2011 8:27	80	0.14	0.0015
Total average prior to SRD[1] replacement		0.57	0.0098
1/25/2012 8:30	268	2.07	0.0192
1/30/2012 10:26	286	3.54	0.0313
2/24/2012 11:15	378	3.67	0.0305
3/27/2012 10:06	486	3.38	0.0321
4/20/2012 11:46	558	2.99	0.0281
5/24/2012 8:58	652	2.77	0.0266
6/22/2012 9:14	734	2.83	0.0270
8/6/2012 8:50	910	3.91	0.0340
8/30/2012 11:14	994	3.49	0.0330
9/26/2012 11:21	1,088	3.48	0.0279
10/26/2012 12:40	1,162	2.46	0.0224
11/28/2012 9:40	1,262	3.04	0.0243
12/27/2012 10:43	1,353	3.13	0.0287
1/24/2013 10:52	1,470	4.18	0.0373
Total average after SRD[1] replacement		3.29	0.0295
Total average start-up to 1/24/13		2.47	0.0227

[1]Split recirculation device (SRD) was replaced December 9, 2011.

The total average electrical use through January 24, 2013 was 2.47 kWh per day. The higher readings, following the SRD replacement, are attributed to the increased pump runtime due to the increased target recycle ratio. The average electrical use following the SRD replacement was 3.29 kWh per day. The average electrical use per gallon treated following the SRD replacement is 0.0295 kWh per gallon and this parameter appears fairly stable in the period of January 30, 2012 to January 24, 2013. Figure 5 shows a plot of the average electrical use per gallon treated versus time of experiment.

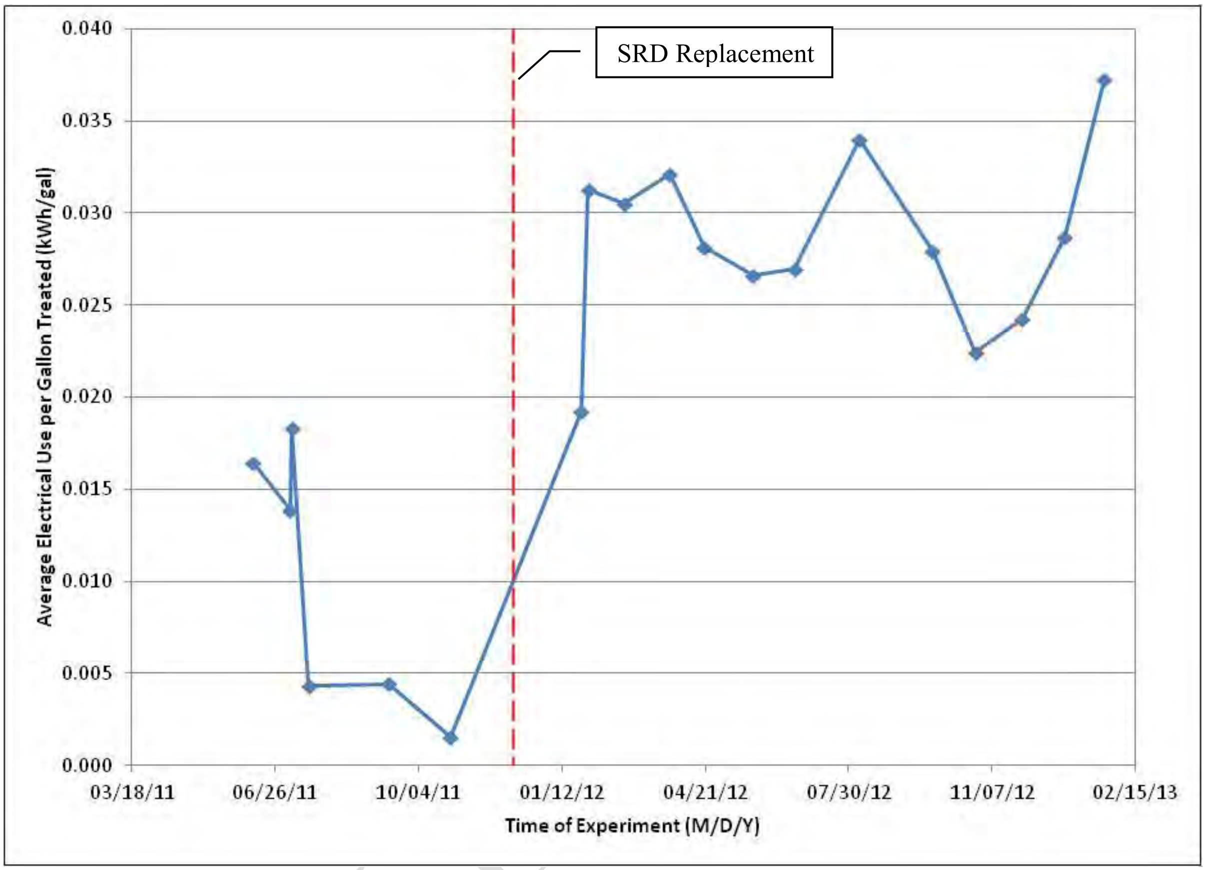
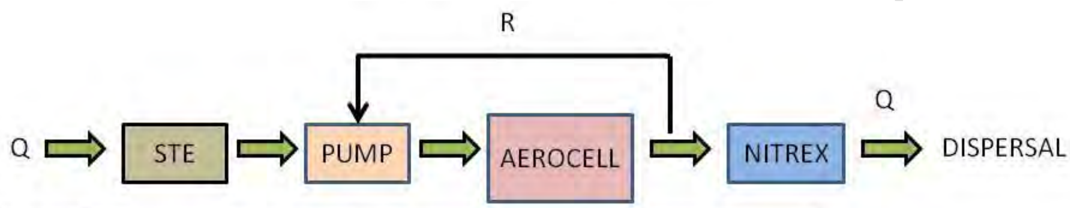


Figure 5
Plot of Average Electrical Use per Gallon Pumped

4.3 Water Quality Results, Sample Event No. 8

Water quality analytical results for Sample Event No. 8 are listed in Table 4. The laboratory reports containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results. The performance of the various system components were compared by considering the changes through treatment of nitrogen species (TKN-N, NH_3-N, and NO_X-N), as well as supporting water quality parameters. The nitrogen and other key parameter results for this sampling event are graphically displayed in Figure 6.



$CBOD_5$ mg/L	190	20	140[a]	2
TKN mg N/L	97	13	6.1	4.7
NH_3 mg N/L	85	8.5	2.3	2.5
NO_x mg N/L	0.08	20	25.4	0.03
TN mg N/L	97.1	33.0	31.5	4.7
Fecal Coliform (Ct/100 mL)	90,000	6,700	410	4

[a]$CBOD_5$ result suspect, likely lab error, results to be checked by lab.

Figure 6
Graphical Representation of Nitrogen Results

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured STE total nitrogen (TN) concentration was 97 mg/L, which is in the upper range of values typically reported for Florida single family residence STE. The residence has relatively low water usage for a family of four, likely resulting in the higher concentration of nitrogen in the STE.

Pump Chamber and Aerocell™ Effluent: The pump chamber and Aerocell™ effluent NH_3-N levels were 8.5 mg/L and 2.3 mg/L, respectively with a DO level at 3.0 mg/L in the Aerocell™ effluent (Table 4). The pump chamber TSS was 8 mg/L and $CBOD_5$ was 20 mg/L. The Aerocell™ effluent TSS was 2 mg/L and $CBOD_5$ was 140 mg/L. This $CBOD_5$

result is higher than previously measured at this site, and also significantly higher than the COD, which is very unlikely. Laboratory error is suspect, and a request to the laboratory to check calculations has been requested. The pump chamber effluent NO_x-N was 20.0 mg/L, and Aerocell^{TM} effluent NO_x-N was 25.4 mg/L. These results indicate significant denitrification (approximately 66% reduction of STE nitrogen) was occurring as the effluent was recirculated back into the pump chamber. The Aerocell^{TM} unit continued to show significant nitrification as seen in the previous sampling event with an NH_3-N concentration of 2.3 mg/L and TKN of 6.1 mg/L.

Nitrex^{TM} Effluent: Effluent NO_x-N from the Nitrex^{TM} unit was 0.04 mg/L. The low NO_x-N was accompanied by a measured 0.25 mg/L DO and -241 mV ORP. The DO sampling methodology was the same as the previous sampling event, using the method of taking the sample field readings in a secondary container. Extra care was taken to assure no bubbles were present in the sample tubing with a steady overflow of fresh sample during the multiple recorded readings. The Nitrex^{TM} system was effective in producing a reducing environment and achieving the NO_x-N reduction goals. Final total nitrogen (TN) in the treatment system effluent was 4.7 mg/L, primarily TKN. The Nitrex^{TM} unit effluent $CBOD_5$ and E. coli were effectively reduced to below the method detection limit. Fecal coliform was low at 4 colonies/100mL.

External QC Laboratory Results: As previously discussed, external QC laboratory samples were collected immediately subsequent to the regular samples for analysis of the nitrogen species. Table 6 shows the results of the QC sampling for this sample event, and a calculation of the percent difference between the sample value and the duplicate/split samples. The calculated TN results from the two laboratories were within 10% agreement except for the lower value Nitrex samples, which were 4.7 mg/L-N for Southern Analytical Laboratory and 2.6 mg/L-N for Ackuritlabs, Inc. However, there was less agreement with the individual nitrogen species, especially with ammonia nitrogen (NH_3-N). This is thought to be a result from the different analytical methods used by each laboratory (Table 1).

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 5. Figure 7 presents the mean and median values of key parameter results over the 594 day monitoring period. Figure 8 provides a time series of influent and effluent TN over the study period. Figures 9 through 14 show box and whisker plots of the various monitoring points for the key parameters measured during the study period.

Table 4
Water Quality Analytical Results

Sample ID	Analytical Laboratory	Sample Date/Time	Sample Type	Temp (°C)	pH	Total Alkalinity (mg/L)	DO (mg/L)	ORP (mV)	Specific Conductance (µS)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)
B-HS1-STE	Southern	1/24/2013 13:20	G			660				22	14	190	370	97.1	97	12.0	85	0.08	0.01	0.09	85.1	11	3.8		
B-HS1-STE-SP	Ackurit	1/24/2013 13:20	G	18.4	6.80		0.12	-262	1312					104.4	104	66.9	37.1	0.424	0.017	0.44	37.5			90,000	83,000
B-HS1-PUMP	Southern	1/24/2013 13:04	G			310				8	3	20	49	33.0	13	4.5	8.5	19	1.00	20.0	28.5	9.2	1.7		
B-HS1-PUMP-SP	Ackurit	1/24/2013 13:04	G	16.9	6.91		1.01	92	885					32.5	7.00	1.1	5.92	24.3	1.17	25.47	31.4			6,700	5,700
B-HS1-AEROCELL	Southern	1/24/2013 12:46	G			260				2	2	140	36	31.5	6.1	3.8	2.3	25	0.39	25.39	27.7	9.1	1.7		
B-HS1-AEROCELL-DUP	Southern	1/24/2013 12:47	G			260				2	2	130	32	31.9	5.6	3.4	2.2	26	0.34	26.34	28.5	9	1.5		
B-HS1-AEROCELL-SP	Ackurit	1/24/2013 12:46	G	16.5	7.05		3.01	77	846					31.9	1.88	0.3	1.54	29.6	0.423	30.02	31.6			410	410
B-HS1-AEROCELL-SP-DUP	Ackurit	1/24/2013 12:47	G	16.5	7.05		3.01	77	846					35.0	1.60	1.5	0.067	33.0	0.405	33.41	33.5			440	420
B-HS1-NITREX	Southern	1/24/2013 12:22	G			380				1	1	2	51	4.7	4.7	2.2	2.5	0.03	0.01	0.04	2.5	11	3.8		
B-HS1-NITREX-SP	Ackurit	1/24/2013 12:22	G	17.0	6.43		0.25	-241	809					2.6	2.60	1.1	1.49	0.012	0.012	0.02	1.5			4	2

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

D.O. - Dissolved oxygen

G - Grab sample

SP - split sample; DUP - duplicate sample

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Orange-shaded data points indicate results based upon colony counts exceeded the ideal range of 20-60 (fecal coliform) or 20-80 (*E. coli*) colonies per plate.

Result suspect, likely lab error, result to be checked by lab.

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Table 5
Summary of Water Quality Data

Sample ID	Statistical Parameter	Temp (°C)	pH[4]	Total Alkalinity (mg/L)	DO (mg/L)	ORP (mV)	Specific Conductance (µS)	TSS (mg/L)	VSS (mg/L)	TVS (mg/L)	$CBOD_5$ (mg/L)	COD	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal[4] (Ct/100 mL)	E-coli[4] (Ct/100 mL)
B-HS1-STE	n	8	8	8	8	8	8	8	7	2	8	8	8	8	8	8	7	7	8	8	8	8	8	8
	MEAN	21.79	6.95	610.00	0.25	-168.64	1187.75	48.63	42.71	210.00	108.00	297.50	82.74	82.63	18.50	64.13	0.07	0.12	0.12	64.24	8.65	4.30	151,088	96,893
	STD. DEV.	2.71		129.17	0.39	163.53	85.33	13.04	15.88	28.28	51.97	99.68	10.96	10.98	7.89	9.72	0.09	0.17	0.11	9.72	1.49	0.94		
	MIN	18.40	6.77	530.00	0.00	-298.10	1019.00	22.00	14.00	190.00	30.00	170.00	71.13	71.00	10.00	55.00	0.01	0.01	0.01	55.01	6.60	2.60	36,000	20,000
	MAX	26.10	7.11	910.00	1.19	192.00	1312.00	63.00	64.00	230.00	190.00	420.00	97.09	97.00	29.00	85.00	0.26	0.46	0.30	85.09	11.00	5.50	800,000	740,000
B-HS1-PUMP	n	8	8	8	7	8	8	8	7	2	8	8	8	8	8	8	7	7	8	8	8	8	8	8
	MEAN	21.06	6.82	247.50	1.69	68.63	884.38	7.25	5.14	195.00	12.88	47.00	46.20	18.10	3.95	14.15	31.29	0.79	28.10	42.25	8.15	2.46	2,703.11	2,100.78
	STD. DEV.	3.37		110.42	0.95	46.13	61.65	4.62	3.93	134.35	7.14	20.25	11.87	12.85	2.28	12.77	9.53	0.65	14.18	12.89	1.34	0.91		
	MIN	16.90	6.16	110.00	0.71	-24.00	756.00	1.00	3.00	100.00	3.00	26.00	33.00	6.30	1.30	5.00	19.00	0.42	0.27	28.50	6.00	1.30	8	6
	MAX	26.30	7.03	470.00	3.31	109.00	951.00	14.00	13.00	290.00	22.00	90.00	70.20	41.00	8.90	38.00	47.00	2.20	47.53	67.20	9.50	4.10	80,000	50,000
B-HS1-AEROCELL	n	8	8	8	8	8	8	8	7	2	8	8	8	8	8	8	7	7	8	8	8	8	8	8
	MEAN	20.61	6.71	214.50	2.80	28.46	862.25	4.75	3.36	200.00	26.50	34.63	44.51	12.14	3.81	8.32	36.00	0.54	32.38	40.70	8.13	1.93	435.68	369.07
	STD. DEV.	3.61		87.19	1.02	52.70	55.88	5.73		42.43	47.01	13.74	11.55	9.71	3.04	9.12	9.80	0.35	14.81	12.28	1.33	0.79		
	MIN	16.50	5.82	86.00	1.12	-93.30	754.00	1.00	1.50	170.00	2.00	18.00	26.20	2.40	1.60	0.08	24.00	0.27	3.20	23.20	6.10	0.66	18	18
	MAX	26.10	7.07	380.00	4.42	77.00	939.00	18.00	6.00	230.00	140.00	61.00	62.30	28.00	11.10	25.00	52.00	1.30	52.27	59.30	9.60	3.30	35,000	31,000
B-HS1-NITREX	n	8	8	8	7	8	8	8	7	2	8	8	8	8	8	8	7	7	8	8	8	8	8	8
	MEAN	20.28	6.52	370.00	1.12	-170.24	792.75	3.50	4.93	101.50	27.25	75.38	7.11	7.03	2.51	4.52	0.09	0.01	0.09	4.60	7.64	2.63	5.93	4.68
	STD. DEV.	3.40		52.92	1.21	126.28	73.64	2.07	3.54	54.45	35.07	40.01	5.72	5.75	1.77	4.56	0.09	0.00	0.09	4.52	1.70	0.79		
	MIN	16.90	5.75	310.00	0.19	-284.90	669.00	1.00	1.00	63.00	2.00	47.00	2.97	2.70	0.80	0.94	0.02	0.01	0.01	1.21	5.90	1.60	2	2
	MAX	25.40	7.33	470.00	3.46	126.00	882.00	7.00	9.50	140.00	110.00	170.00	20.03	20.00	5.60	15.00	0.26	0.01	0.27	15.03	11.00	3.80	600	600

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Geometric mean provided rather than arithmetic mean.

D.O. - Dissolved oxygen

G - Grab sample

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Orange-shaded data points indicate results based upon colony counts exceeded the ideal range of 20-60 (fecal coliform) or 20-80 (*E. coli*) colonies per plate.

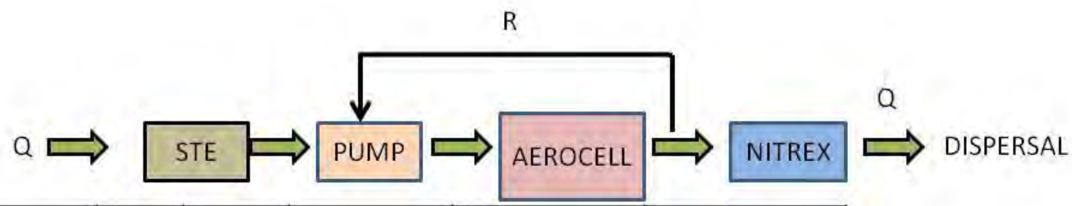
Table 6
Sample Event No. 8 External QC Sample Results

Sample ID	Analytical Laboratory	TN (mg/L N)		TKN (mg/L N)		NH_3-N (mg/L N)		NO_3-N (mg/L N)		NO_2-N (mg/L N)		NOx (mg/L N)	
		Value	% diff	Value	% diff	Value	% diff	Value	% diff	Value	% diff	Value	% diff
B-HS1-STE	Southern	97.1		97.0		85.0		0.1		0.01		0.09	
B-HS1-STE-SP	Ackurit	104.4	7.0%	104.0	6.7%	37.1	-129.1%	0.4	81.1%	0.02	MDL	0.44	79.6%
B-HS1-PUMP	Southern	33.0		13.0		8.5		19.0		1.00		20.00	
B-HS1-PUMP-SP	Ackurit	32.5	-1.6%	7.0	-85.7%	5.9	-43.6%	24.3	21.8%	1.17	14.5%	25.47	21.5%
B-HS1-AEROCELL	Southern	31.5		6.1		2.3		25.0		0.39		25.39	
B-HS1-AEROCELL-DUP	Southern	31.9	1.4%	5.6	-8.9%	2.2	-4.5%	26.0	3.8%	0.34	-14.7%	26.34	3.6%
B-HS1-AEROCELL-SP	Ackurit	31.9	1.3%	1.9	-224.5%	1.5	-49.4%	29.6	15.5%	0.42	7.8%	30.02	15.4%
B-HS1-AEROCELL-SP-DUP	Ackurit	35.0	8.9%	1.6	-17.5%	0.1	MDL	33.0	10.3%	0.41	-4.4%	33.41	10.1%
B-HS1-NITREX	Southern	4.7		4.7		2.5		0.03		0.01		0.04	
B-HS1-NITREX-SP	Ackurit	2.6	-80.6%	2.6	-80.8%	1.5	-67.8%	0.01	MDL	0.01	MDL	0.02	-66.7%

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Result suspect, likely lab error, result to be checked by lab.



n		8	8	8	8
$CBOD_5$ mg/L	mean	108.0	12.9	26.5	27.3
	median	115.0	11.5	7.5	18.0
TKN mg N/L	mean	82.6	18.1	12.1	7.0
	median	79.0	12.5	7.2	4.8
NH_3 mg N/L	mean	64.1	14.2	8.3	4.5
	median	63.5	8.3	4.1	3.0
NO_x mg N/L	mean	0.1	28.1	32.4	0.1
	median	0.1	31.3	35.9	0.1
TN mg N/L	mean	82.7	46.2	44.5	7.1
	median	79.3	43.7	45.4	4.9
Fecal Coliform (Ct/100 Ml)	mean	151,088	2,703	436	5.9
	median	164,000	4,750	375	3.0

[1]594 day monitoring period

Figure 7

Graphical Representation of Mean and Median Values of Key Parameter Results

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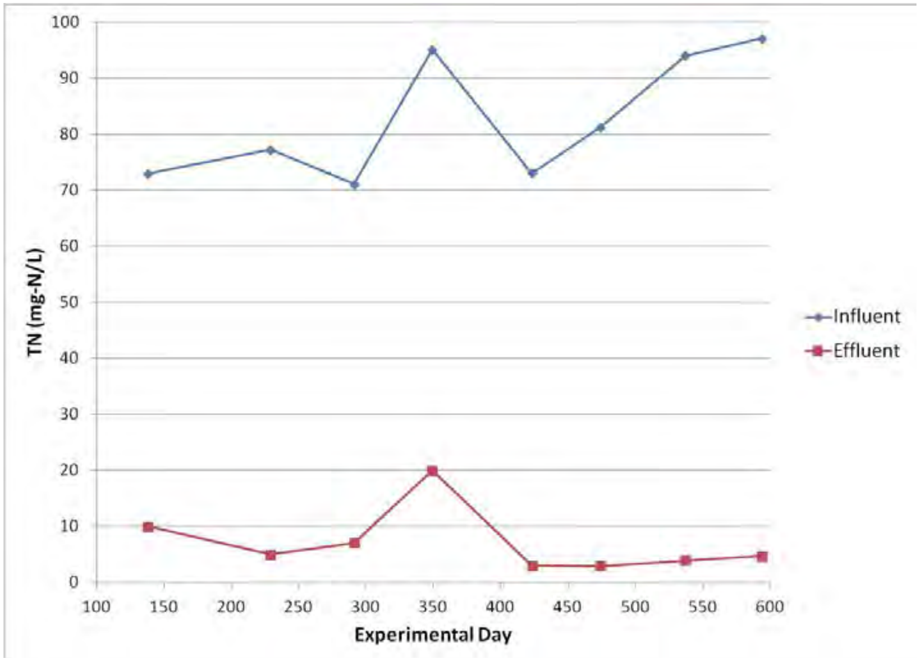

Figure 8
Influent and Effluent TN Time Series Plot

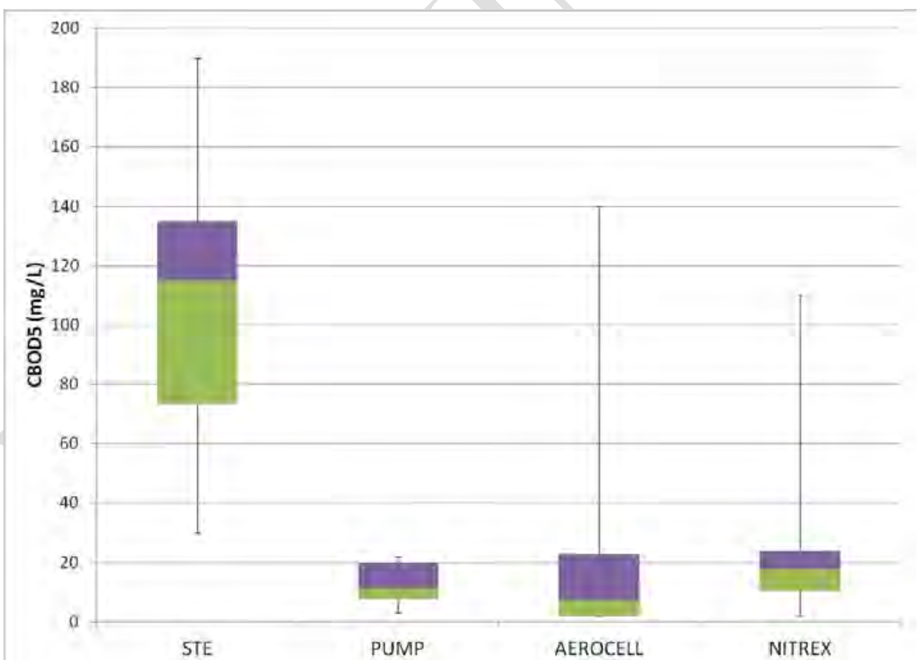

Figure 9
$CBOD_5$ Box and Whisker Plot

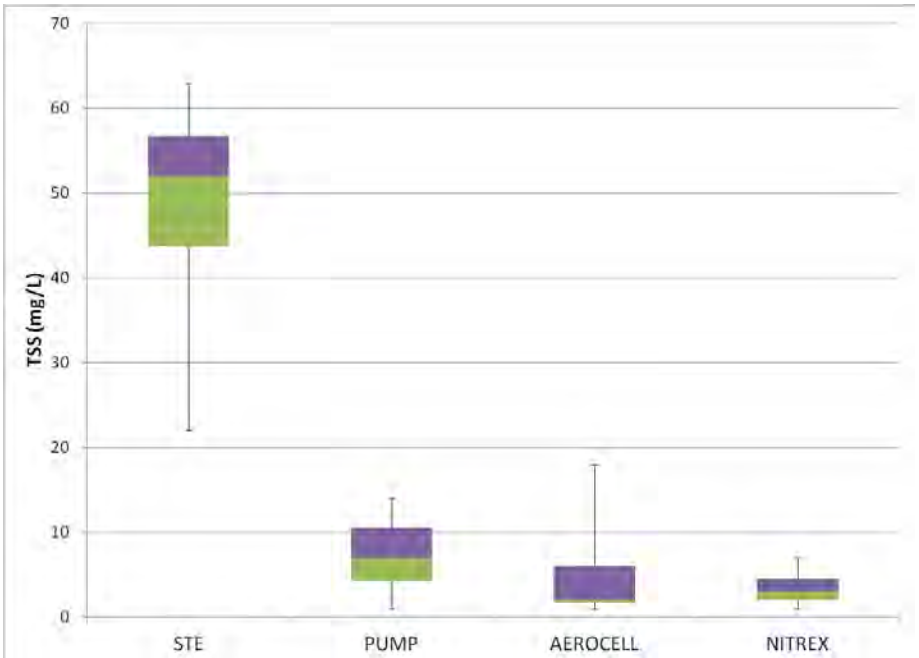

Figure 10
TSS Box and Whisker Plot

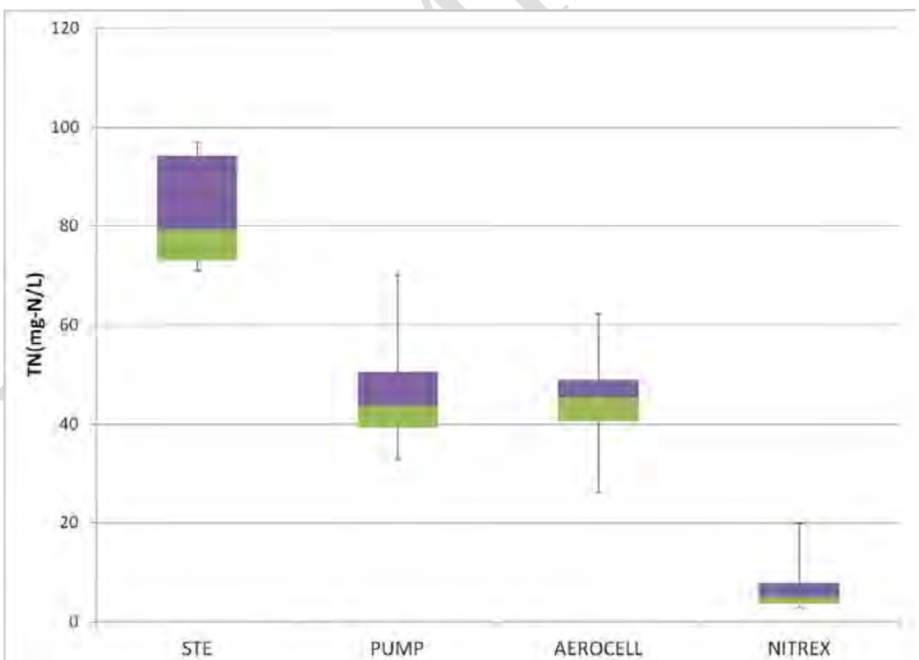

Figure 11
TN Box and Whisker Plot

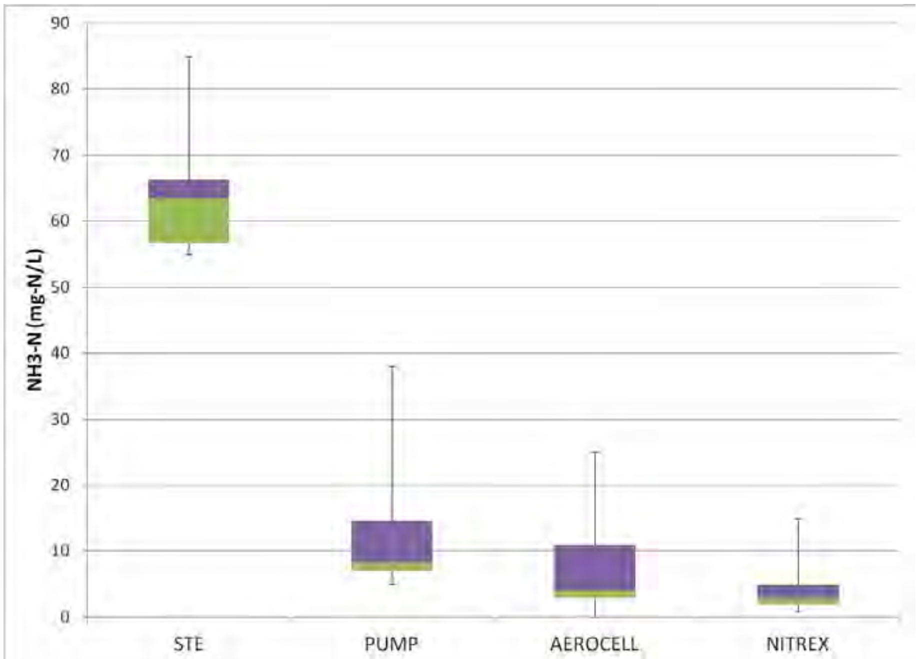

Figure 12
Ammonia N Box and Whisker Plot

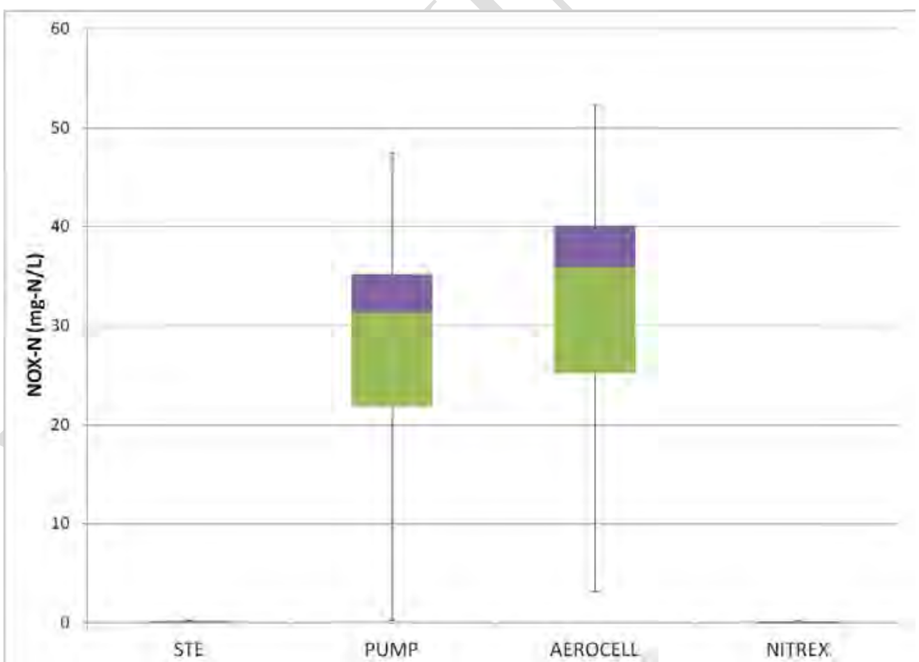

Figure 13
NOx-N Box and Whisker Plot

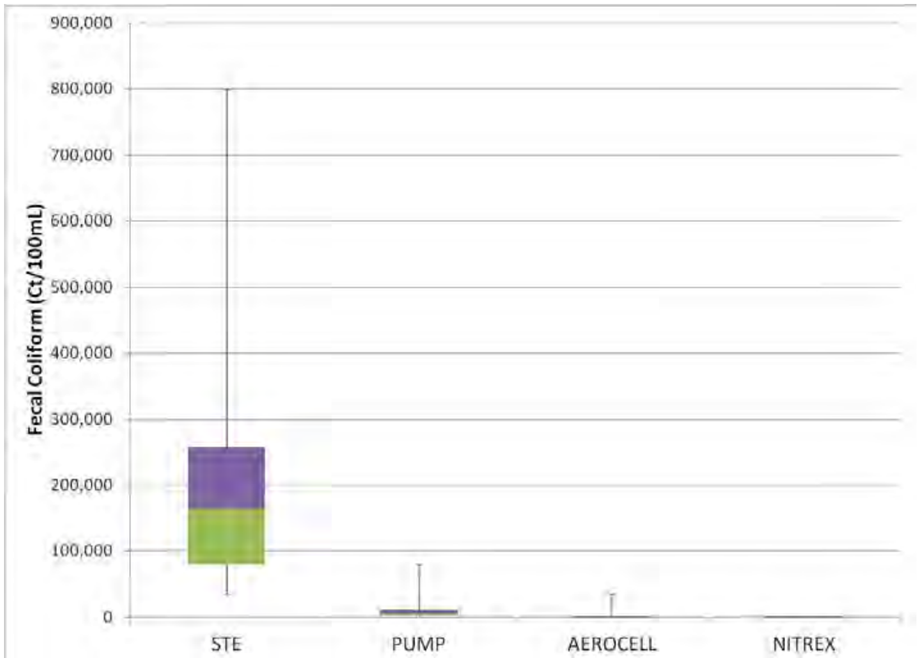

Figure 14
Fecal Coliform Box and Whisker Plot

5.0 B-HS1 Sample Event No. 8: Summary and Conclusions

5.1 Summary

The eighth and final sampling event results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of 97 mg/L is in the upper range of values typically reported for Florida single family residence STE.
- The Aerocell™ biofilter was effective in converting ammonia N to oxidized nitrogen; effluent contained 6.1 mg/L TKN, of which 2.3 mg/L was ammonia N.
- The Nitrex™ system was effective in producing a reducing environment and achieving the NO_x-N reduction goals. The Nitrex™ unit effluent fecal coliform was reduced to 4 colonies/100ml and E. coli were effectively reduced to below method detection levels.
- The total nitrogen concentration in the final effluent from the total treatment system was 4.7 mg/L, an approximately 95% reduction from STE.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS1 treatment system. Section 4.4 summarized the water quality data collected over the 1.6 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 82.7 mg/L is in the upper range of values typically reported for Florida single family residence STE.
- The pump chamber effluent average NO_x-N was 28.1 mg/L, and Aerocell™ effluent average NO_x-N was 32.4 mg/L. These results indicate significant denitrification was occurring as the effluent was recirculated back into the pump chamber.
- The Aerocell™ unit provided significant nitrification with an average NH_3-N concentration of 8.3 mg/L and average TKN of 12.1 mg/L.
- The Nitrex™ system was effective in producing a reducing environment and achieving the NO_x-N reduction goals (average NO_x-N concentration of 0.1 mg/L).

> The average final total nitrogen (TN) in the treatment system effluent was 7.1 mg/L, primarily TKN (average TKN concentration of 7.0 mg/L). The Nitrex^{TM} unit effluent average TSS and fecal coliform concentrations were effectively reduced to below 10.

Further analysis of the results obtained at this site will occur as Task B results are compiled and summarized. The results of the data collected to date have provided insights into the performance of a full-scale passive nitrogen reduction system monitored over an extended timeframe (594 experimental days) under actual onsite conditions.

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Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS2 Field System
Monitoring Report No. 8

Prepared for:

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

FDOH Contract CORCL

April 2014

Prepared by:

HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association With:

AET
Applied Environmental Technology

B-HS2 Field System
Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in PNRS II. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth sample event of the passive nitrogen reduction system at a home site B-HS2 in Hillsborough County, Florida.

2.0 Purpose

This monitoring report documents data collected from the eighth B-HS2 monitoring and sampling event conducted on March 10, 2014 (Experimental Day 531). This monitoring event consisted of conducting flow measurements from the household water use meter and the treatment system internal water meters, recording electricity use, monitoring of field parameters, collection of water samples from five points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory. In addition, daily samples were collected March 11th through March 14th, 2014 to evaluate daily variation of the treatment system.

3.0 Materials and Methods

3.1 Project Site

The B-HS2 field site is located in Hillsborough County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in September 2012. Design and construction details were presented previously in the Task B.6 document. Figure 1 is a system schematic showing the system components and layout of the installation. A flow schematic of the system is shown in Figure 2. The B-HS2 system tankage consists of a 1,050 gallon two chamber concrete primary tank; 300 gallon concrete recirculation tank; 900 gallon concrete Stage 1 unsaturated media biofilter; 300 gallon concrete pump tank; and 1,500 gallon two chamber concrete Stage 2 saturated media biofilter. Based on measured average wastewater flow and tank volumes, there is over a ten day transit time through the treatment system prior to dispersal. The denitrified treated effluent is discharged into the soil via the existing mounded drainfield (P.T.I.™ bundles).

3.2 PNRS System Modification

As recommended in the fifth sample event report, the recirculation mode of operation was modified prior to the sixth sample event. The pump tank discharge is split via two throttling globe valves which allow for a portion of the Stage 1 biofilter effluent to be sent back for recirculation with the rest proceeding to the Stage 2 biofilter. The system was designed with two recirculation modes of operation. The first option (which was initially tested) is to have the recirculated effluent return to the recirculation tank for mixing with incoming septic tank effluent. Following the fifth sample event, the recirculation mode of operation was modified to test the second option. In the second option, recirculated effluent does not pass through the recirculation tank, but is dispersed by three spray nozzles directly to the top of the Stage 1 biofilter along with recirculation tank effluent (STE).

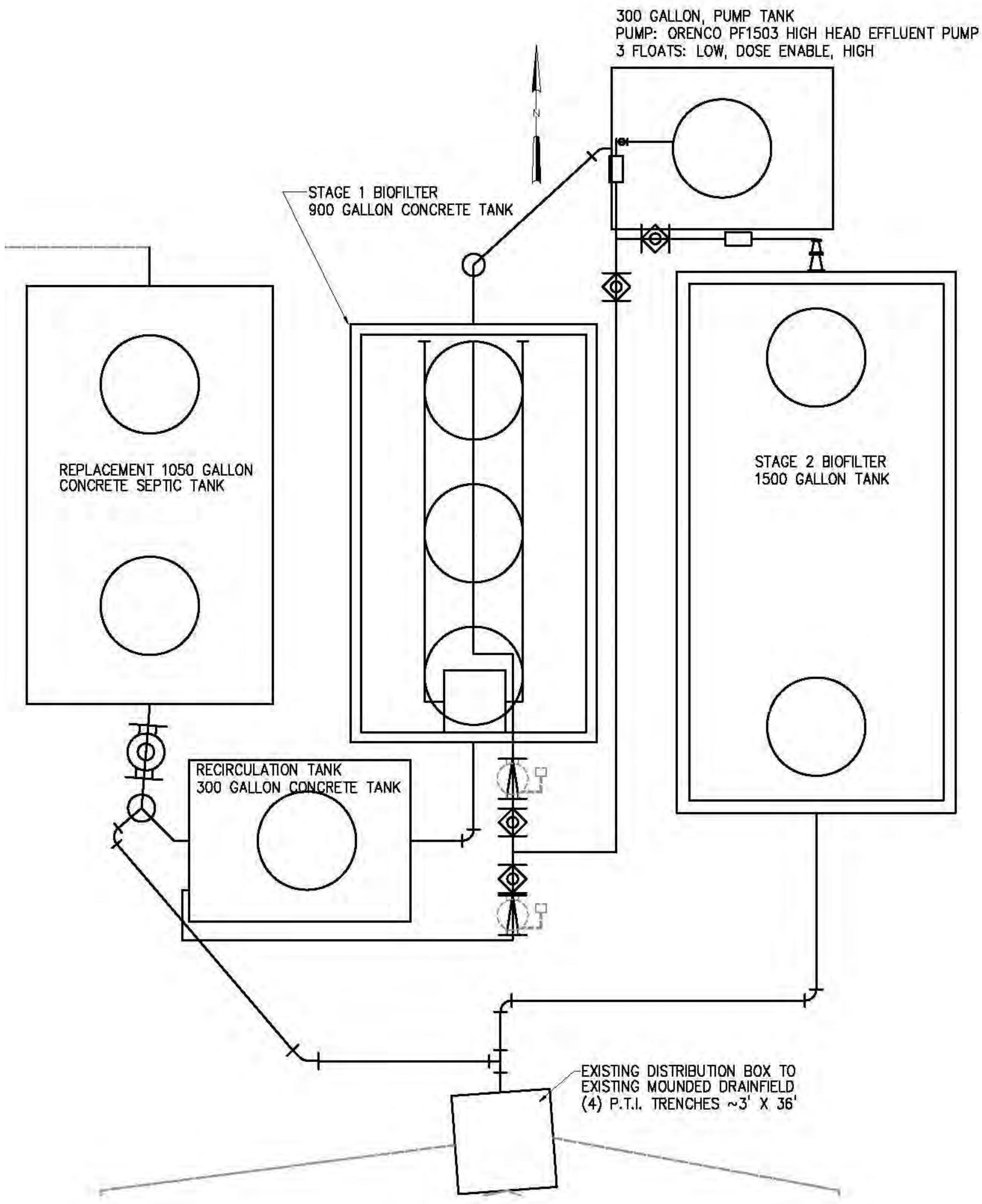


Figure 1
Plan view of B-HS2 System Layout

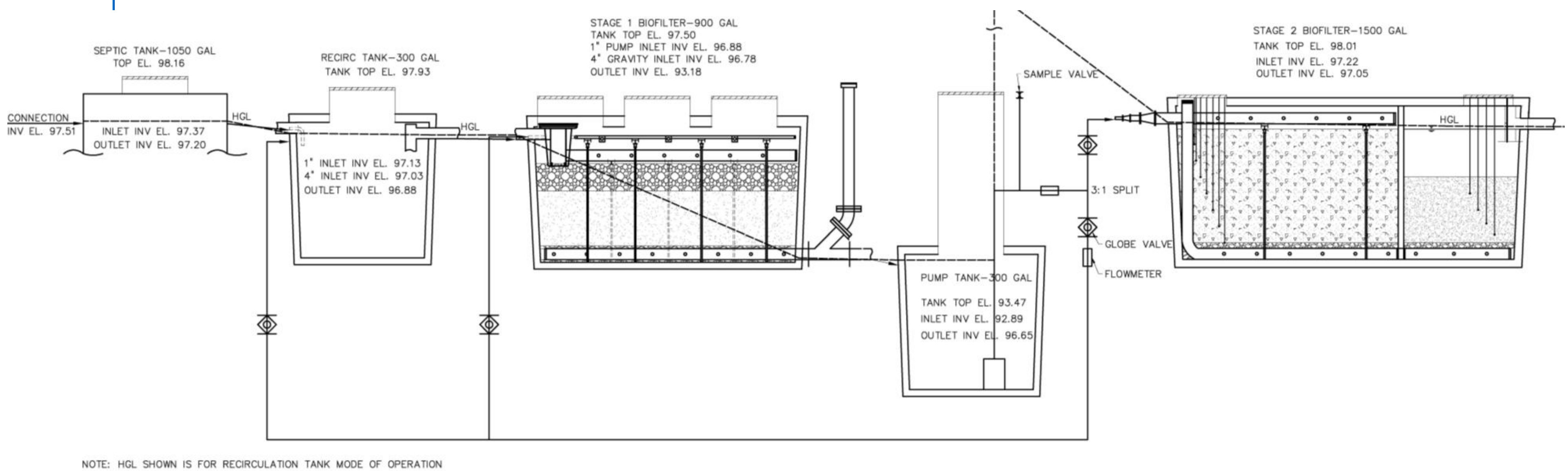


Figure 2
Flow Schematic of B-HS2 PNRS Installed in Hillsborough County

3.3 Monitoring and Sample Locations and Identification

The five primary monitoring points for this sample event are shown in Figure 3. Household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen into the recirculation tank. The first primary monitoring point, B-HS2-STE, is the effluent sampled approximately 1.5 feet below the surface of the second chamber of the primary tank (Figure 4), which is referred to as primary effluent or septic tank effluent (STE). Samples from monitoring point B-HS2-STE are the whole household wastewater after it has had some residence time in the primary tank.

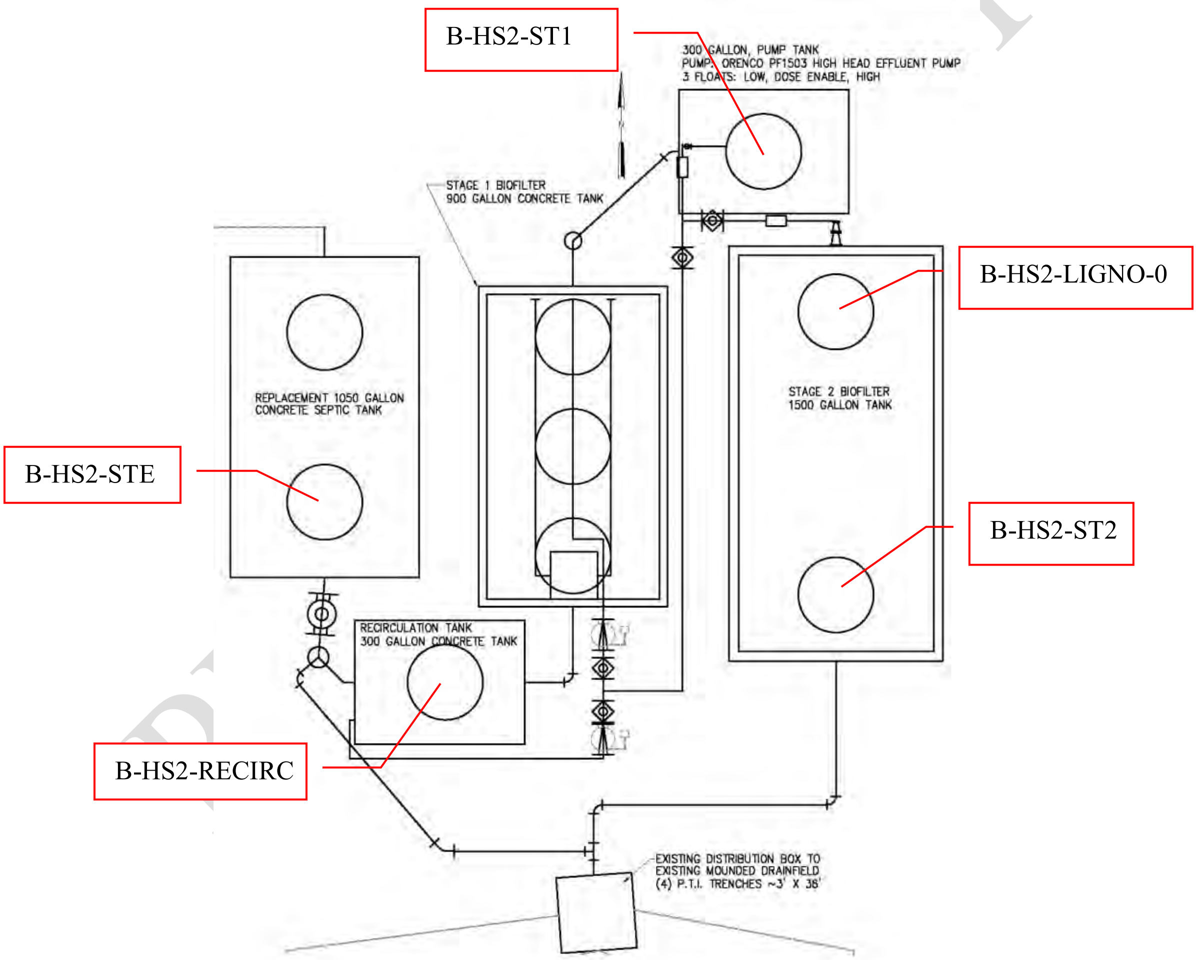


Figure 3
B-HS2 Sample and Monitoring Locations

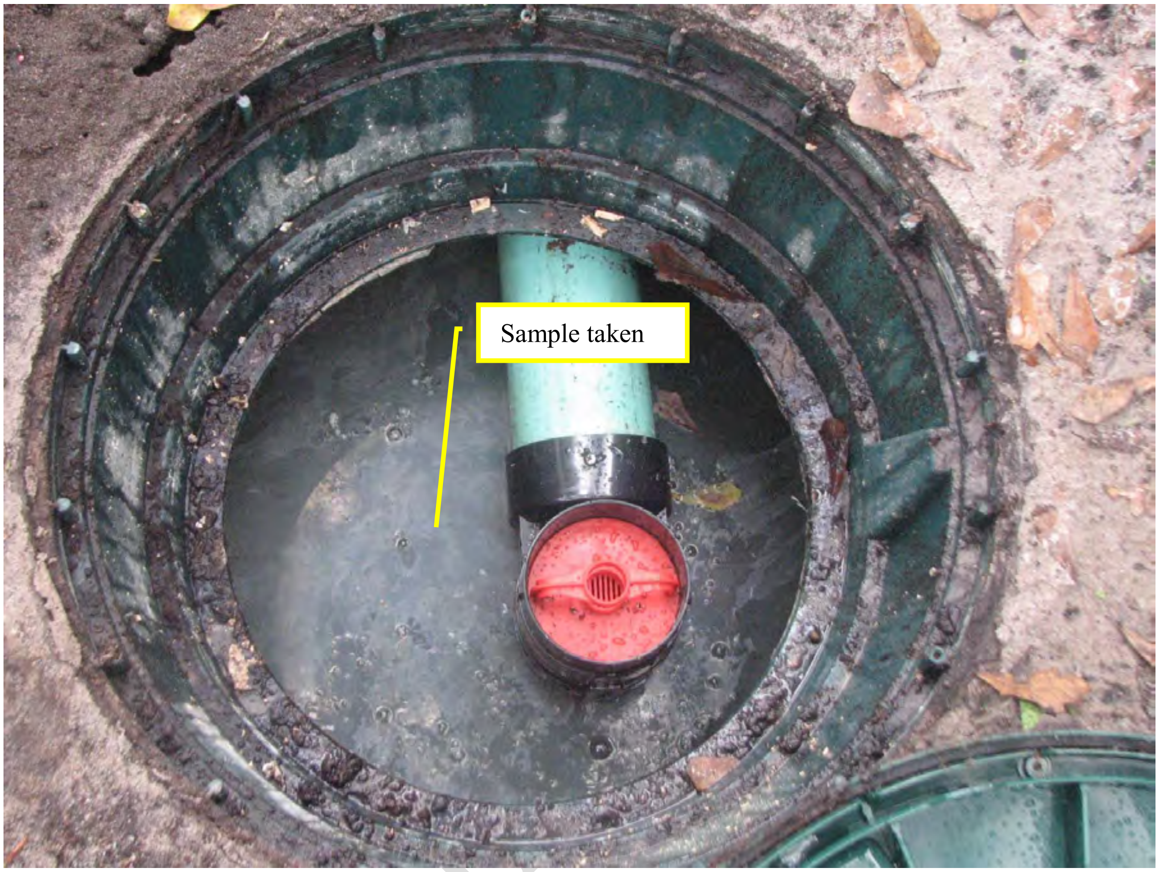


Figure 4
Second chamber of Primary Tank (B-HS2-STE sample)

Following the modification to the recirculation mode of operation, the recirculation tank only receives septic tank effluent. Therefore, the recirculation tank currently provides additional residence time for STE, before it enters the Stage 1 biofilter. The second primary monitoring point, B-HS2-RECIRC, represents the household wastewater after passage through the septic tank and recirculation tank.

Recirculation tank effluent is discharged by gravity to a distribution box located inside the Stage 1 biofilter, which splits the flow between two perforated distribution pipes along the top of the unsaturated Stage 1 biofilter media. In the Stage 1 biofilter, wastewater percolates downward through the unsaturated expanded clay media where nitrification occurs. Stage 1 biofilter effluent flows into the pump tank (which contains the pump and float switches). The third primary monitoring point, B-HS2-ST1, is the Stage 1 effluent sampled approximately 1.5 feet below the surface of the pump tank (Figure 5).

Figure 5
Stage 1 effluent sample taken in pump tank (B-HS2-ST1 sample)

The pump tank discharge is split via two throttling globe valves which allow for a portion of the Stage 1 biofilter effluent to be sent back for recirculation with the rest proceeding to the Stage 2 biofilter. The system was designed with two recirculation modes of operation. The first option (which was initially tested) is to have the recirculated effluent return to the recirculation tank for mixing with incoming septic tank effluent. The second option, which is currently being tested, is to have the recirculated effluent return to the top of the Stage 1 biofilter, dispersed by three spray nozzles. Effluent from the unsaturated (Stage 1) media tank enters the saturated denitrification (Stage 2) biofilter into a standing water column lying above the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally in a perforated 4-inch pipe through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell).

The first chamber of the Stage 2 biofilter contains 42-inches of lignocellulosic media. Stainless steel samplers are positioned at 6-inch increments for vertical profiling throughout the lignocellulosic media. The fourth primary sampling point is a stainless steel sampler positioned at the bottom of the lignocellulosic media (B-HS2-LIGNO-0). The B-HS2-LIGNO-0 sample represents the lignocellulosic media effluent (Figure 6).

A collection pipe along the bottom transfers the first chamber (lignocellulosic media) effluent to the second chamber, which contains 24-inches of elemental sulfur mixed with oyster shell media. The fifth primary sampling point, B-HS2-ST2, is the second chamber of the Stage 2 biofilter effluent which is sampled approximately 1 foot below the surface of the effluent baffle tee. This sample location is after passage through the sulfur media; it is the final effluent from the treatment system prior to being discharged to the existing soil infiltration system, or drainfield (Figure 7).

Figure 6
First Chamber of Stage 2 Biofilter (B-HS2-LIGNO-0 Sample)

Figure 7
Second Chamber of Stage 2 Biofilter (B-HS2-ST2 Sample)

3.4 Operational Monitoring

Start-up of the system occurred on September 25, 2012 (Experimental Day 0) and the system has operated continually since that date. For this eighth formal sampling event, the water meter for the house and the treatment system flow meters were read and recorded on March 10, 2014 (Experimental Day 531). As previously discussed, the pump tank discharge is split via two throttling globe valves which allow for a portion of the Stage 1 biofilter effluent to be sent back for recirculation with the rest proceeding to the Stage 2 biofilter. The combined flow meter is located on the pump tank discharge line prior to the split, and records the cumulative flow in gallons pumped from the pump chamber. Therefore the measurement of the combined flow meter includes both the forward wastewater flow from the household and the recirculation flow. The Stage 2 flow meter is located following the split on the line from the pump tank to the Stage 2 biofilter and records the cumulative forward flow in gallons pumped to the Stage 2 biofilter. The control panel includes telemetry where reports are generated regarding alarms, pump cycles, and other information using a Vericomm control panel system.

3.5 Energy Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. The power usage of the system is primarily due to the single recirculation pump in the pump chamber, although a small amount of power is used by the control panel itself. There are no chemicals added to the system. However, the Stage 2 biofilter media (lignocellulosic and sulfur) are “reactive” media which will be consumed during operation. The Stage 2 biofilter was initially filled with 42 inches of lignocellulosic media and 24 inches of sulfur media, which ostensibly will last for many years without replenishment or replacement.

3.6 Water Quality Sample Collection and Analyses

A full suite of influent, intermediate and effluent water quality samples from the system were collected for the eighth formal sample event on March 10, 2014 for water quality analysis. Samples were collected at each of the five monitoring points described in Section 3.2: B-HS2-STE, B-HS2-RECIRC, B-HS2-PUMP, B-HS2-LIGNO-0, and B-HS2-ST2. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded.

In addition, equipment blank (B-HS2-EB) sample was taken. The equipment blank was collected by pumping deionized water through the cleaned pump tubing. This sample was then analyzed for the same parameters as the monitoring samples.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent samples were analyzed by the laboratory for: total alkalinity, chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (Ortho P), total suspended solids (TSS), volatile suspended solids (VSS), total organic carbon (TOC), fecal coliform (fecal), and E.coli. The influent and sulfur media samples included sulfate, sulfide, and hydrogen sulfide (unionized). All analyses were performed by independent and fully NELAC certified analytical laboratory (Southern Analytical Laboratory). Table 1 lists the analytical parameters, analytical methods, and detection limits for laboratory analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	EPA 300.0	0.01 mg/L
Nitrate+Nitrite Nitrogen (NOX-N)	EPA 300.0	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Solids (TS)	EPA 160.3	.01 % by wt
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Volatile Suspended Solids (VSS)	SM 2540E	1 mg/L
Total Organic Carbon (TOC)	SM5310B	0.06 mg/L
Sulfate	EPA 300.0	2.0 mg/L
Sulfide	SM 4500SF	0.10 mg/L
Hydrogen Sulfide (unionized)	SM 4550SF	0.01 mg/L
Fecal Coliform (fecal)	SM9222D	2 ct/100mL
E.coli	SM9223B	2 ct/100mL

Similar methods were used for the daily sample collection and analysis that was conducted on March 11th through March 14th, 2014.

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since water meter installation on March 6, 2012. The treatment system flow meter readings and corresponding recirculation ratio for the B-HS2 field site are summarized in Table 3. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B. Summary tables of the Vericomm PLC recorded data are provided in Appendix C. These include daily and cumulative pump runtime and system alarms that are used to check general pump operation and performance.

Table 2
Summary of Household Water Use

Date	Cumulative Volume (gallons)	Average Daily Household Flow btwn readings, Q (gpd)
3/6/2012	7,790	INSTALLED
4/3/2012	11,490	132
5/1/2012	14,960	124
6/5/2012	19,560	131
7/3/2012	23,120	127
8/7/2012	26,730	103
9/4/2012	29,800	110
10/2/2012	33,240	123
11/6/2012	36,510	93
12/4/2012	40,080	128
1/1/13	43,240	113
2/5/13	47,741	129
3/5/2013	50,000	81
4/16/2013	54,010	95
5/7/2013	55,940	92
5/28/2013	57,620	80
6/11/2013	58,620	71
7/24/2013	62,422	88
8/7/2013	63,964	109
Avg. during R to recirc tank operation		108.1
9/7/2013	66,830	94
10/7/2013	69,070	73
11/5/2013	71,600	89
11/27/2013	73,925	106
12/3/2013	75,360	239
12/5/2013	75,674	157
12/17/2013	76,646	81
12/24/2013	77,600	136
1/7/2014	79,020	101
1/14/2014	79,870	121
1/21/2014	80,390	74
1/28/2014	81,000	87
2/4/2014	81,610	87
2/13/2014	82,588	109
3/10/2014	84,541	78
3/14/2014	84,884	86
Avg. during R to Stage 1 sprayers operation		95.8
Total average start-up to 3/14/14		104.5

Table 3
Summary of System Flow

Date and Time Read	Combined Pumped Flow, Q+R Water Meter Reading	Average Daily Com-bined, Q+R Flow, btwn readings	Stage 2, Q Flow Meter Reading	Average Daily Stage 2, Q Flow, btwn readings	Aver-age Daily, R Flow btwn read-ings	Average Recycle Ratio
	Cumulative Volume (gallons)	gpd	Cumula-tive Volume (gallons)	gpd	gpd	Recycle: Forward Flow
Recirculation mode of operation: to recirculation tank						
9/25/2012 11:00	351.9	Installed	102.2	Installed		
9/27/2012 9:45	570.5	Valves set	149.5	Valves set		
10/5/2012 8:07	3,898.3	419.5	880.6	92.2	327.4	3.55
10/11/2012 7:55	7,888.5	666.0	1,716.6	139.5	526.4	3.77
10/23/2012 9:00	15,092.9	598.1	3,228.2	125.5	472.6	3.77
10/30/2012 14:30	18,090.1	414.6	3,904.7	93.6	321.0	3.43
11/13/2012 14:00	22,944.4	347.3	5,007.3	78.9	268.4	3.40
12/3/2012 8:00	35,555.0	638.5	7,886.8	145.8	492.7	3.38
1/3/2013 8:00	51,563.3	516.4	11,542.3	117.9	398.5	3.38
2/5/2013 8:23	72,069.0	621.1	16,185.3	140.6	480.5	3.42
2/27/2013 11:00	81,937.3	446.3	18,441.6	102.1	344.3	3.37
4/16/13 10:15	105,376.0	488.6	23,809.3	111.9	376.7	3.37
6/4/13 7:30	126,085.7	423.6	28,513.7	96.2	327.4	3.40
7/8/2013 8:30	140,549.5	424.9	31,800.5	96.6	328.3	3.40
7/24/2013 8:39	145,987.7	339.8	33,032.0	76.9	262.8	3.42
8/7/2013 7:45	152,531.6	468.7	34,570.7	110.2	358.5	3.25
Average when R to recirc tank op-eration (8/7/13)		484.1		109.7	374.4	3.41:1
Recirculation mode of operation: to Stage 1 sprayers						
8/7/2013 13:04	152,720.1		34,616.4			
9/6/2013 9:15	163,910.2	375.0	37,404.3	93.4	281.6	3.01
10/7/2013 10:10	174,601.7	344.5	40,102.7	86.9	257.5	2.96
11/27/2013 9:40	195,934.7	418.5	45,595.0	107.7	310.7	2.88
12/3/2013 11:37	201,887.3	978.8	47,181.4	260.9	718.0	2.75
12/5/2013 8:50	203,129.2	659.2	47,518.9	179.1	480.1	2.68
12/30/2013 12:15	215,153.5	478.2	50,799.2	130.5	347.8	2.67
2/13/2014 8:20	231,849.7	372.4	55,393.9	102.5	269.9	2.63
3/10/2014 8:30	239,504.8	306.1	57,528.7	85.4	220.8	2.59
3/11/2014 10:15	239,723.5	203.8	57,589.8	57.0	146.8	2.58
3/12/2014 7:50	239,903.2	199.9	57,640.1	55.9	144.0	2.58

Table 3 (continued)
Summary of System Flow

3/13/2014 9:00	240,262.8	342.9	57,741.0	96.2	246.7	2.56
3/14/2014 9:30	240,604.5	334.7	57,836.8	93.9	240.8	2.56
Average when R to Stage 1 sprayers operation (3/14/14)		401.6		106.1	295.5	2.78:1
Total average start-up to 3/14/14		450.4		108.2	342.1	3.16:1

The two throttling globe valves control the fraction of Stage 1 effluent that is recirculated and the fraction sent to the Stage 2 biofilter. As previously discussed, the recirculation mode of operation was modified following the fifth sample event (August 7, 2013). The globe valves were set so that 3 parts went back to the Stage 1 sprayers and 1 part went to the Stage 2 tank (3:1 recycle ratio). From start-up to March 14, 2014, the household flow average was 104.5 gallons per day with periods of higher and lower flows (Table 2). The average combined pumped flow (recirculation and forward flow to the Stage 2 biofilter) following the modification to the recirculation mode of operation to the Stage 1 sprayers was 401.6 gallons per day, and the average forward flow to the Stage 2 biofilter was 106.1 gallons per day. Therefore, the average recirculation flow was 305.4 gallons per day, with a corresponding average recirculation ratio of 2.88:1 following the modification to the recirculation mode of operation.

4.2 Energy Consumption

Energy consumption is monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 4.

Table 4
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use btwn readings	Average Electrical Use per Gallon Treated	Average Electrical Use per 1,000 Gallon Treated
	Cumulative (kWh)	(kWh/day)	(kWh/gal)	(kWh/ 1,000 gal)
Recirculation mode of operation: to recirculation tank				
9/25/2012 11:05	0.2	Installed		
9/27/2012 9:58	0.3	Start-up		
10/5/2012 8:07	2.6	0.29	0.0031	3.15
10/11/2012 7:55	5.0	0.40	0.0029	2.87
10/23/2012 9:00	9.5	0.37	0.0030	2.98
10/30/2012 14:30	11.8	0.32	0.0034	3.40
11/13/2012 14:00	14.8	0.21	0.0027	2.72
12/3/2012 8:00	22.8	0.41	0.0028	2.78
1/3/2013 8:00	33.0	0.33	0.0028	2.79
2/5/2013 7:45	45.5	0.38	0.0027	2.69
2/27/2013 11:00	51.5	0.27	0.0027	2.66
4/16/2013 10:15	65.8	0.30	0.0027	2.66
6/4/2013 9:00	78.3	0.26	0.0027	2.66
7/8/2013 8:30	86.9	0.25	0.0026	2.62
7/24/2013 8:39	90.2	0.21	0.0027	2.68
8/7/2013 7:45	94.1	0.28	0.0025	2.53
Average when R to recirc tank (8/7/13)		0.30	0.0028	2.80
Recirculation mode of operation: to Stage 1 sprayers				
9/6/2013 9:15	101.2	0.24	0.0025	2.53
10/7/2013 10:10	107.8	0.21	0.0024	2.45
11/27/2013 9:40	121.2	0.26	0.0024	2.44
12/3/2013 11:37	124.8	0.59	0.0023	2.27
12/5/2013 8:50	125.6	0.42	0.0024	2.37
12/30/2013 12:15	133.1	0.30	0.0023	2.29
2/13/2014 8:20	143.5	0.23	0.0023	2.26
3/10/2014 8:30	148.3	0.19	0.0022	2.25
3/11/2014 10:15	148.5	0.19	0.0033	3.27
3/12/2014 7:50	148.6	0.11	0.0020	1.99
3/13/2014 9:00	148.8	0.19	0.0020	1.98
3/14/2014 9:30	149.0	0.20	0.0021	2.09
Average when R to Stage 1 sprayers (3/14/14)		0.25	0.0024	2.36
Total average start-up to 3/14/14		0.28	0.0027	2.58

The total average electrical use through March 14, 2014 was 0.28 kWh per day. The higher daily electrical use, prior to changing the recirculation operating mode from tank to the Stage 1 sprayers is attributed to the higher recirculation ratio. The average electrical use per gallon treated since start-up was 0.0027 kWh per gallon treated, and this parameter has been fairly stable since start-up. Figure 8 shows a plot of the average electrical use per gallon treated versus time of experiment.

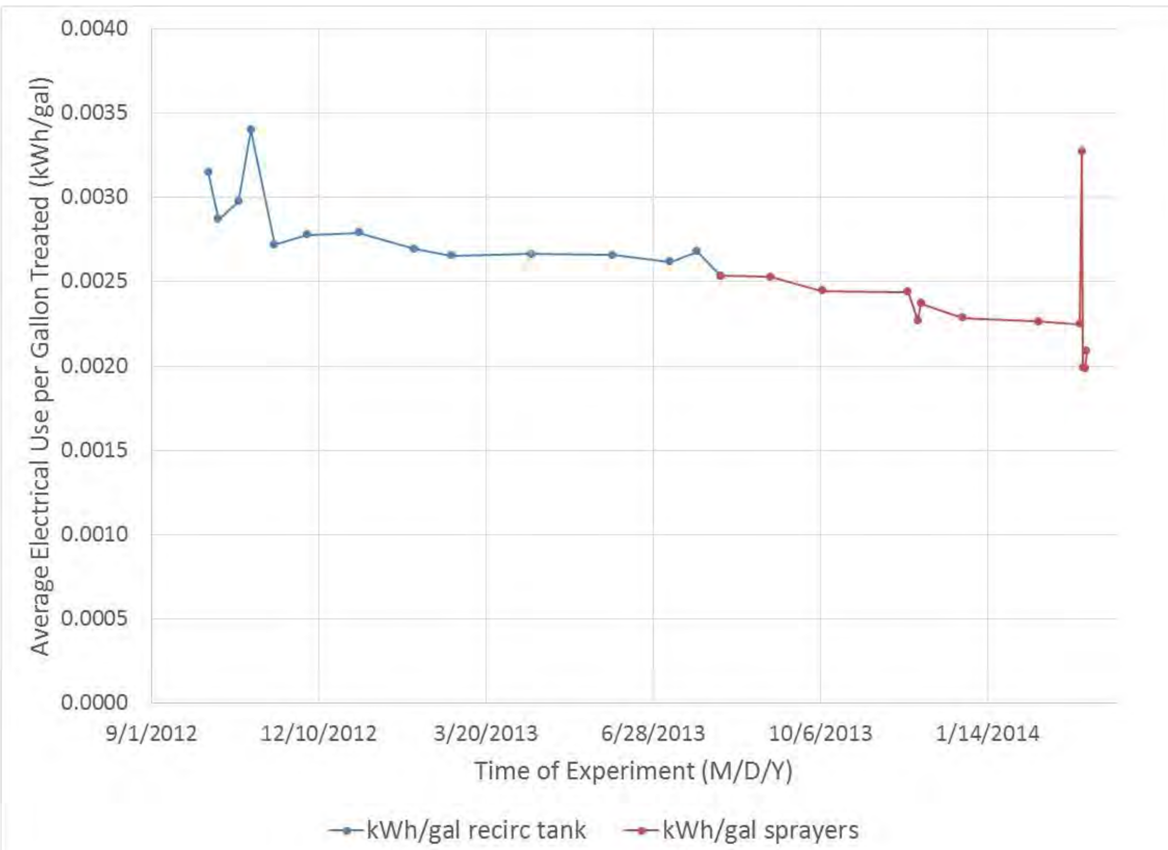
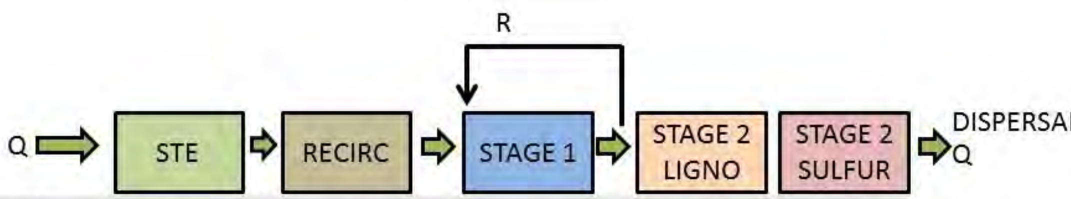


Figure 8
Plot of Average Electrical Use per Gallon Treated

4.3 Water Quality

Water quality analytical results for Sample Event No. 8 (Experimental Day 531) are listed in Table 5. Nitrogen results are graphically displayed in Figure 9. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.



	STE	RECIRC	STAGE 1	STAGE 2 LIGNO	STAGE 2 SULFUR
$CBOD_5$ mg/L	290	190	ND	4	42
TKN mg N/L	60	58	2.2	2.2	1.6
NH_3 mg N/L	49	50	0.2	0.6	0.5
NO_x mg N/L	0.06	0.1	37	7.6	0.04
TN mg N/L	60	58	39	9.8	1.6
Sulfate mg/L	3.8	3.1	160	160	160
Fecal Coliform (Ct/100mL)	62,000	73,000	710	8	100

Figure 9
Graphical Representation of Nitrogen Results
Sample Event No. 8, March 10, 2014 (Experimental Day 531)

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured STE total nitrogen (TN) concentration was 60 mg/L, which is within the range that has been typically reported for Florida single family residence STE.

Recirculation Tank (RECIRC): As previously discussed, following the modification to the recirculation mode of operation, the recirculation tank only receives septic tank effluent. Therefore, the recirculation tank currently provides some additional residence time for the STE. The measured total nitrogen (TN) concentration in the recirculation tank effluent was 58 mg/L, which was similar to TN in the STE sample.

Stage 1 Effluent (ST1): The Stage 1 effluent NH_3-N levels was 0.2 mg/L with a DO level at 4.8 mg/L in the Stage 1 effluent (Table 5). The Stage 1 effluent TSS and $CBOD_5$ concentrations were below the method detection limit of 2 mg/L. The Stage 1 biofilter showed fairly complete nitrification with an effluent NH_3-N concentration of 0.2 mg/L and TKN of 2.2 mg/L. The Stage 1 effluent NO_x-N was 37 mg/L. The Stage 1 effluent TN of 39 mg/L was 35% lower than that in STE, suggesting denitrification in the Stage 1 biofilter.

Stage 2 Biofilter Effluent (LIGNO-0 and ST2): The Stage 2 system produced a highly reducing environment and achieved essentially complete NO_x-N reduction. Effluent NO_x-N from the Stage 2 biofilter monitoring point was 0.04 mg/L. The low NO_x-N was accompanied by a measured 0.22 mg/L DO and -332.70 mV ORP. The lignocellulosic media effluent NO_x-N was 7.6 mg/L. Final total nitrogen (TN) in the treatment system effluent was 1.64 mg/L. The Stage 2 biofilter lignocellulosic media effluent $CBOD_5$ was 4 mg/L and the sulfur media effluent was 42 mg/L. The Stage 2 effluent sulfate concentration was 160 mg/L.

Equipment Blank (EB): The equipment blank (EB) was collected by pumping deionized water through the cleaned pump tubing. This sample was then analyzed for the same parameters as the monitoring samples. As expected, all parameters measured were at or below the method detection limit.

In addition during this monitoring event, daily samples were collected from the nitrogen reducing onsite treatment system to evaluate the variability of daily data. Water quality analytical results, for Sample Events No. 9 through 12 are summarized in Appendix A, Table A.1 through Table A.4. Key parameter mean and standard deviations for these five sample events are provided in Figure 10. In addition, the total nitrogen time series for these five sample events are graphically displayed in Figure 11 for the treatment sample locations.

Table 5
Water Quality Analytical Results

Sample ID	Sample Date/Time	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
BHS2-STE	3/10/14 10:00	22.0	7.18	1410	0.03	-364.9	560	30	12	290	410	60.06	60	11	49	0.06	0.01	0.06	49.06	7.4	3.2	3.8	28	66	62000	10000	120
BHS2-STE-FILTERED	3/10/14 10:05	22.0	7.18	1410	0.03	-364.9				160		55.06	55	10	45	0.06	0.01	0.06	45.06								
BHS2-RECIRC	3/10/14 9:50	21.5	7.34	1432	0.08	-366.5	600	20	18	190	270	58.1	58	8	50	0.1	0.01	0.1	50.1	6.8	6	3.1	19	56	73000	10000	59
BHS2-ST1	3/10/14 9:21	20.3	7.05	1216	4.80	83.5	220	1	1	2	18	39.2	2.2	1.99	0.21	37	0.01	37	37.21	4	3.8	160	0.4	0.8	710	610	10
BHS2-ST1-DUP	3/10/14 9:26	20.3	7.05	1216	4.80	83.5	220	1	1	2	20	39	2	1.78	0.22	37	0.01	37	37.22	4	3.8	150	0.3	0.6	740	730	11
BHS2-ST1-FILTERED	3/10/14 9:26	20.3	7.05	1216	4.80	83.5				2		40.7	2.7	2.5	0.2	38	0.01	38	38.2								
BHS2-LIGNO-0	3/10/14 9:02	20.6	7.01	1217	0.35	-267.7	330	2	1	4	25	9.77	2.2	1.65	0.55	6.7	0.87	7.57	7.5	3.5	3.3	160	1.2	2.2	8	7.5	14
BHS2-LIGNO-0-FILTERED	3/10/14 9:07	20.6	7.01	1217	0.35	-267.7				3		11.08	2.7	2.43	0.27	7.7	0.68	8.38	8.65								
BHS2-ST2	3/10/14 8:45	20.5	7.04	1209	0.22	-332.7	340	3	3	42	100	1.64	1.6	1.12	0.48	0.04	0.01	0.04	0.52	3.7	3.6	160	17	34	100	2	15
BHS2-ST2-FILTERED	3/10/14 8:50	20.5	7.04	1209	0.22	-332.7				14		1.22	1.2	0.84	0.36	0.01	0.01	0.02	0.38			160					
BHS2-EB	3/10/14 10:15	18.7	7.09	1.24	7.68	91.7	2	1	1	2	10	0.07	0.05	0.041	0.009	0.01	0.01	0.02	0.029	0.01	0.012	0.2	0.01	0.1	1	2	0.06

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

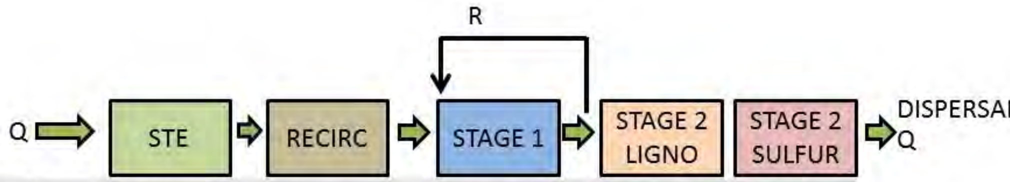
Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Too many colonies were present. The numeric value represents the filtration volume.

Results based on colony counts outside the ideal range.

Recirculation mode = to Stage 1 sprayers



$CBOD_5$ mg/L	308 ± 79	180 ± 24	10 ± 7	8.4 ± 7	46 ± 9
TKN mg N/L	61 ± 2	61 ± 3	4.7 ± 3.2	2.0 ± 0.7	1.3 ± 0.4
NH_3 mg N/L	41 ± 4.5	43 ± 4	1.2 ± 1	0.3 ± 0.1	0.4 ± 0.1
NO_x mg N/L	0.04 ± 0.02	0.06 ± 0.02	35 ± 3	5 ± 2	0.03 ± 0.01
TN mg N/L	61 ± 2	61 ± 3	39.5 ± 3	7 ± 2	1.4 ± 0.4
Sulfate mg/L	11.5 ± 7	6 ± 2	154 ± 6	152 ± 5	190 ± 27
Fecal Coliform (Ct/100mL)	54,170	72,587	6,481	3.2	6.0

Figure 10
Mean and Standard Deviations from Daily Sample Events
March 10th through March 14th, 2014

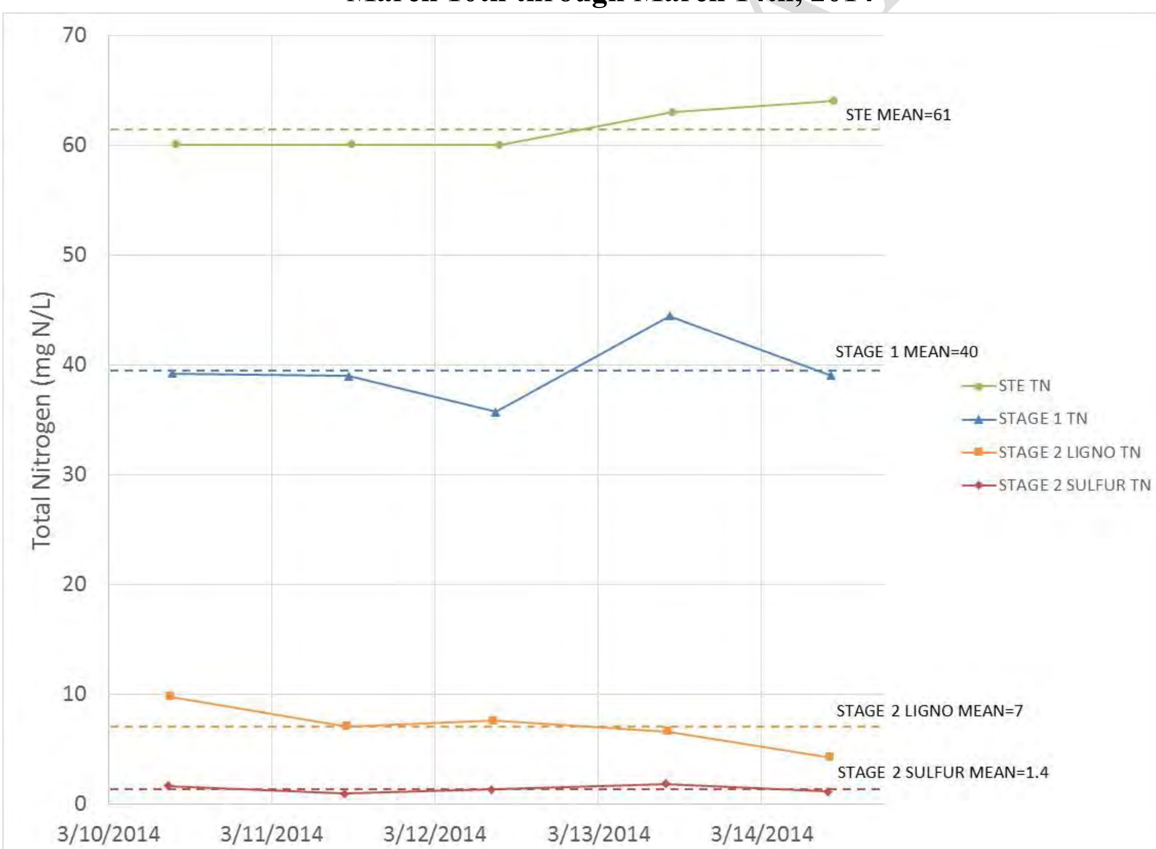


Figure 11
Graphical Representation of Total Nitrogen Time Series
March 10th through March 14th, 2014

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 6. Figure 12 provides a time series of influent and effluent TN over the study period. Figures 13 through 19 show box and whisker plots of the various monitoring points for the key parameters measured during the study period.

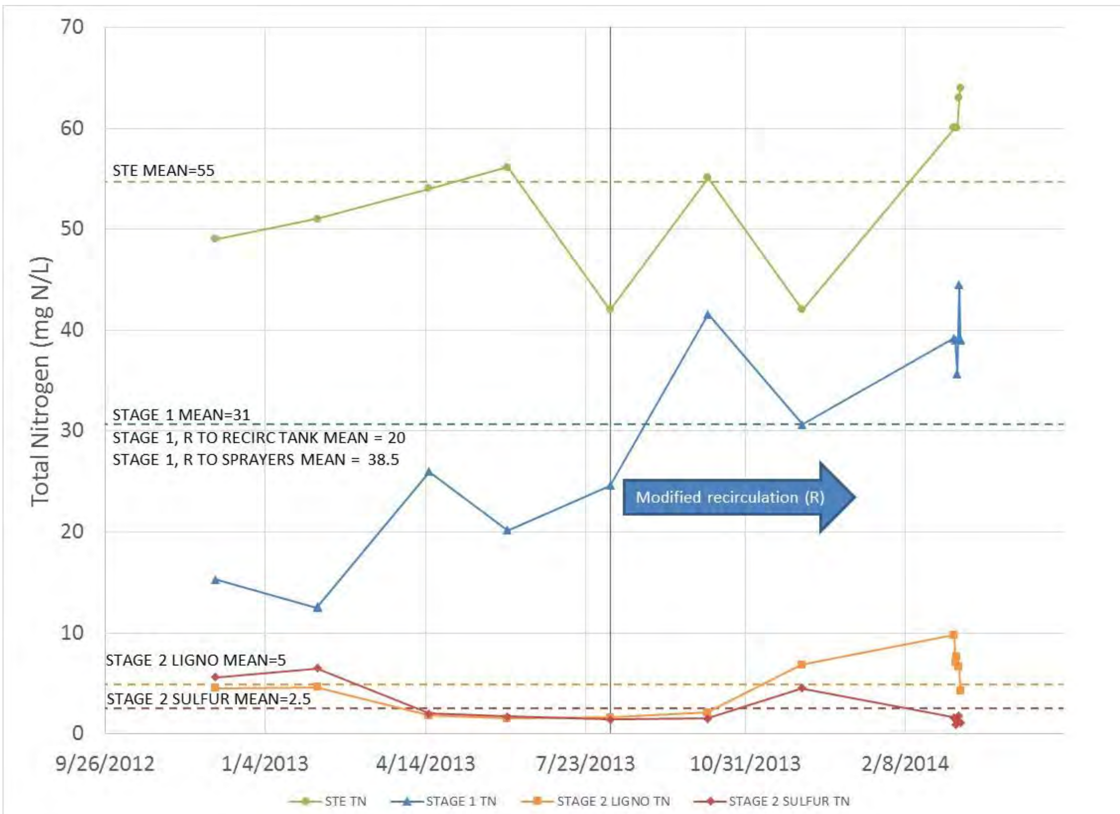


Figure 12
Total Nitrogen Time Series Graph
Sample Events No. 1 through 12
December 3, 2012 through March 14, 2014

Table 6
Summary of Water Quality Analytical Results

Sample ID	Statistical Parameter	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
Septic tank effluent (STE)	n	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	10
	MEAN	23.3	7.2	1381.4	0.1	-371.0	568.3	64.3	21.3	192.3	338.3	54.7	54.7	13.3	41.3	0.05	0.01	0.05	41.4	8.5	3.8	53.6	18.1	50.0	90159.5	59313.8	79.7
	STD. DEV.	2.7		59.9	0.2	10.6	206.1	147.6	14.2	114.1	99.3	7.5	7.5	8.8	6.5	0.04	0.00	0.03	6.5	4.4	1.6	48.5	5.6	12.4			35.1
	MIN	18.8	7.0	1248.0	0.0	-392.5	410.0	10.0	8.0	73.0	150.0	42.0	42.0	1.0	30.0	0.01	0.01	0.02	30.0	4.8	0.7	3.8	9.5	26.0	800	2,420	31.0
	MAX	27.8	7.6	1430.0	0.6	-360.0	1200.0	532.0	58.0	390.0	450.0	64.0	64.0	25.0	53.0	0.13	0.01	0.13	53.1	18.0	6.6	150.0	28.0	66.0	1,600,000	1,200,000	120.0
Stage 1 effluent (all events)	n	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	5	5	5	11	11	10
	MEAN	22.3	6.9	1,212	4.0	-48.6	225.8	12.4	6.3	11.3	19.9	30.7	3.9	3.0	0.9	26.5	0.3	26.8	27.7	5.5	2.8	154.0	0.10	0.3	1,297	762	13.2
	STD. DEV.	2.8		34.2	1.2	78.9	18.8	21.5	9.8	12.7	7.8	10.8	2.4	1.6	1.1	10.5	0.3	10.4	10.1	2.6	1.4	5.5	0.17	0.3			3.5
	MIN	16.1	6.5	1,137	2.0	-180.0	190.0	1.0	1.0	2.0	10.0	12.5	1.6	1.3	0.1	6.3	0.01	6.3	9.9	3.5	0.7	150.0	0.01	0.1	6	3	8.3
	MAX	26.9	7.2	1,267	5.7	83.5	250.0	68	35	45	36	44.5	10.0	7.6	3.6	38.0	0.8	38.0	38.2	12.0	5.8	160.0	0.40	0.8	68,000	24,000	19.0
Stage 2 lignocellulosic effluent (LIGNO-0)	n	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11	12	12	12	9
	MEAN	22.5	7.0	1165.3	0.5	-288.8	361.7	8.1	7.8	27.5	69.9	4.9	2.5	1.5	1.1	2.1	0.2	2.3	3.3	4.8	2.6	155.5	5.8	13.9	18.9	13	59.4
	STD. DEV.	2.2		50.9	0.4	53.9	42.2	9.1	9.3	26.8	56.6	2.7	1.3	0.5	1.1	2.5	0.3	2.7	2.4	2.8	1.0	32.8	7.0	15.7			131.5
	MIN	18.7	6.7	1112.0	0.1	-362.1	290.0	1.0	1.0	2.0	22.0	1.5	1.4	1.0	0.3	0.01	0.01	0.02	0.4	2.6	0.7	86.0	0.3	0.6	1.0	1.0	12.0
	MAX	26.7	7.1	1230.0	1.2	-207.3	440.0	30.0	30.0	96.0	220.0	9.8	4.6	2.8	3.3	6.7	0.9	7.6	7.5	12.0	4.9	220.0	19.0	40.0	8,000	7,800	410
Stage 2 sulfur effluent (ST2)	n	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11	12	12	12	10
	MEAN	21.9	6.9	1,211	0.1	-335.5	337.5	4.3	3.0	60.2	123	2.5	2.5	1.2	1.3	0.01	0.01	0.02	1.3	4.5	2.8	202	19.2	36.6	30.50	14.86	17.7
	STD. DEV.	2.8		47.9	0.1	45.5	47.3	4.0	2.1	27.8	78	1.9	1.9	0.4	1.7	0.01	0.00	0.01	1.7	2.4	1.2	44.1	11.2	22.2			4.1
	MIN	16.5	6.3	1,134	0.1	-372.0	220.0	1.0	1.0	32.0	10	0.9	0.9	0.6	0.3	0.01	0.01	0.02	0.3	2.4	0.9	160	6	7	1	1	13.0
	MAX	26.1	7.1	1,303	0.2	-218.8	410.0	15.0	8.0	110	260	6.5	6.5	1.8	5.0	0.04	0.01	0.04	5.0	11.0	5.1	320	40	83	20,000	9,600	25.0

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

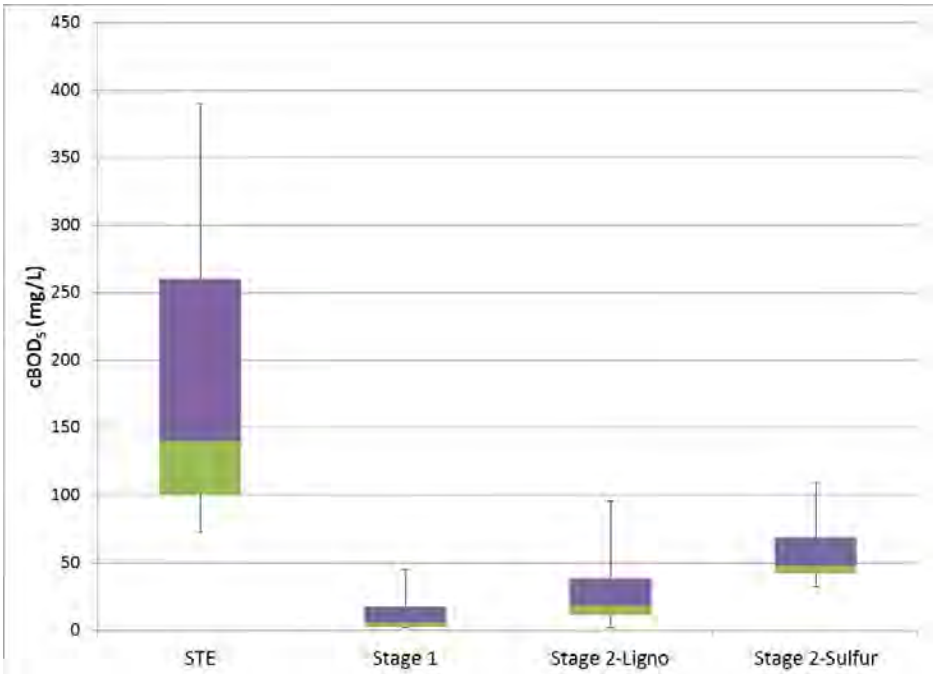


Figure 13
CBOD5 Box and Whisker Plot

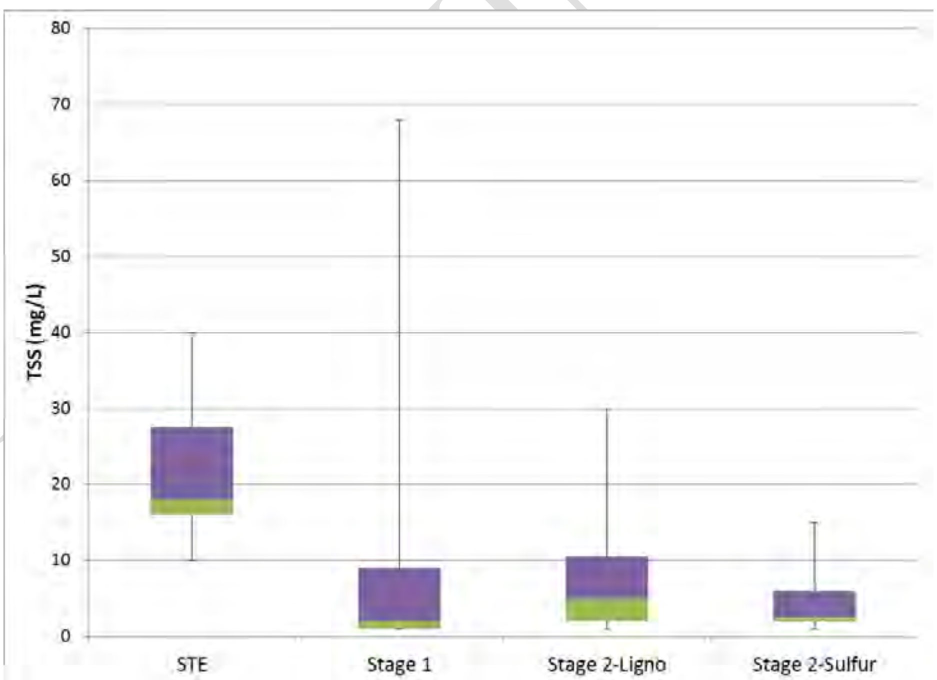


Figure 14
TSS Box and Whisker Plot

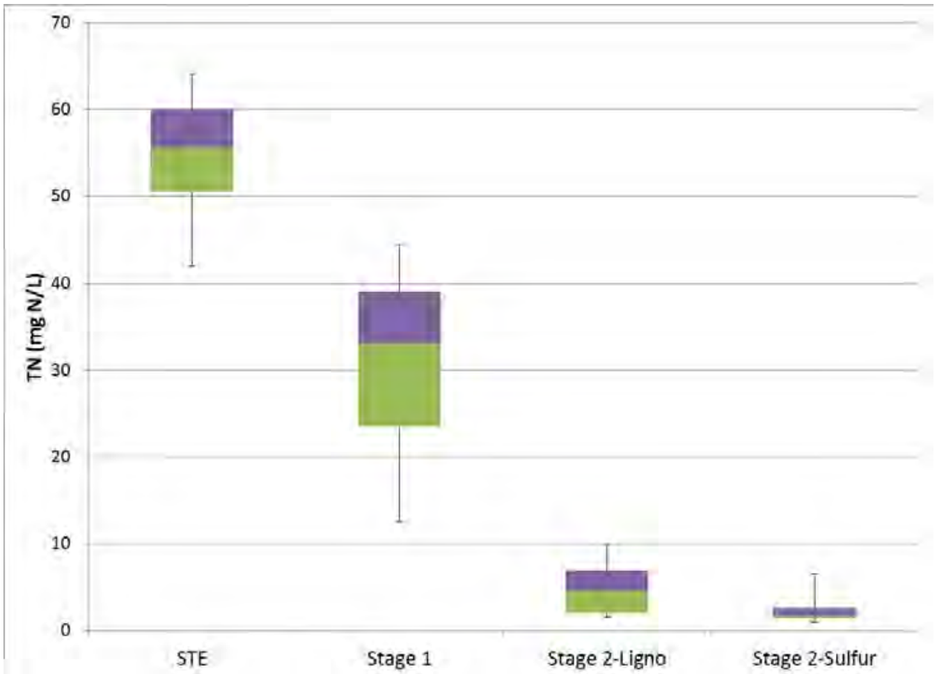


Figure 15
Total Nitrogen (TN) Box and Whisker Plot

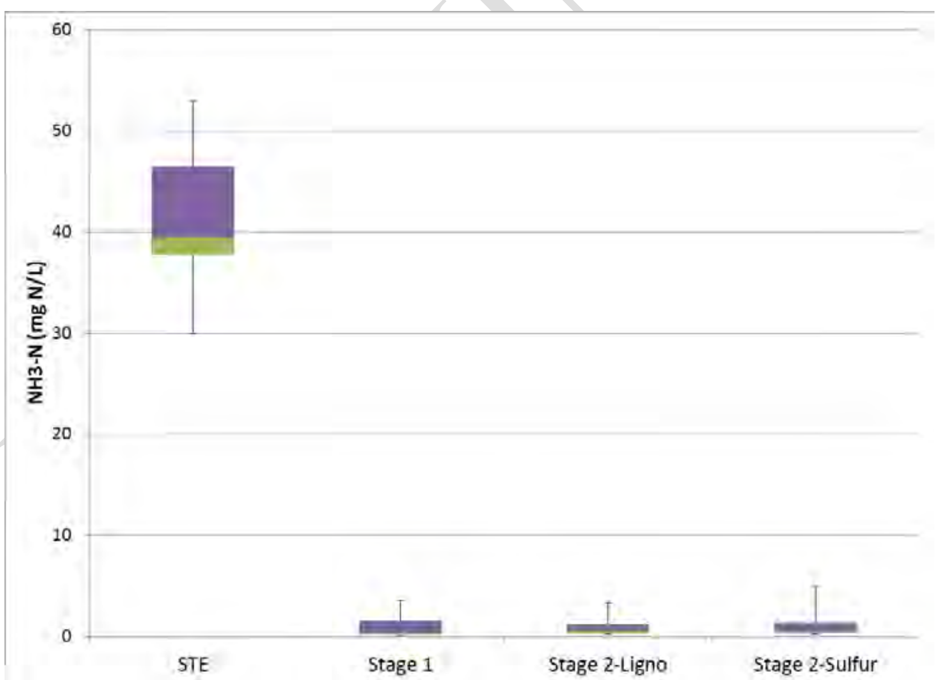


Figure 16
Ammonia N (NH3-N) Box and Whisker Plot

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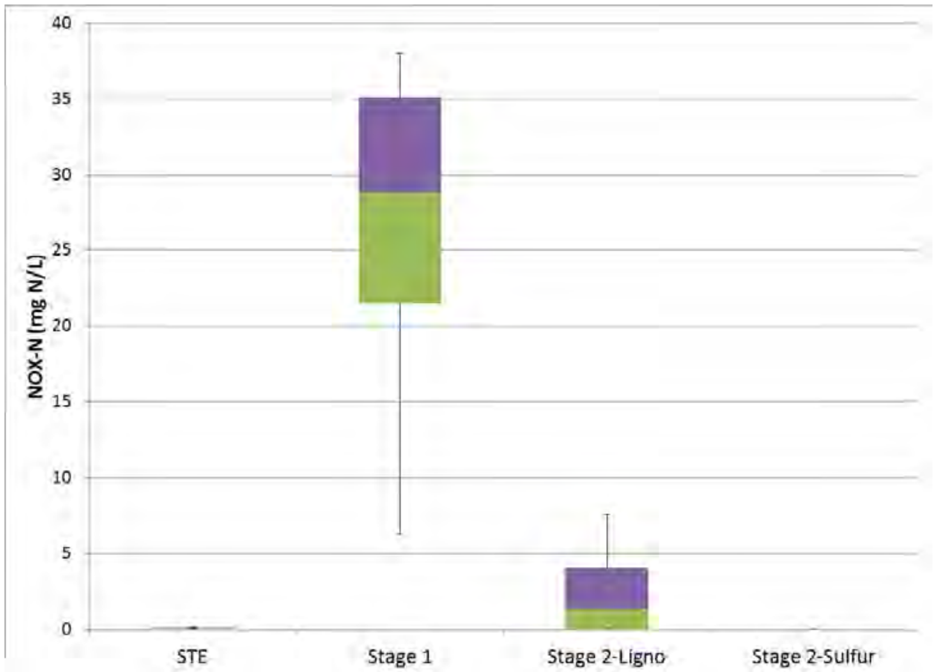

Figure 17
Nitrate+Nitrite Nitrogen (NO_x-N) Box and Whisker Plot

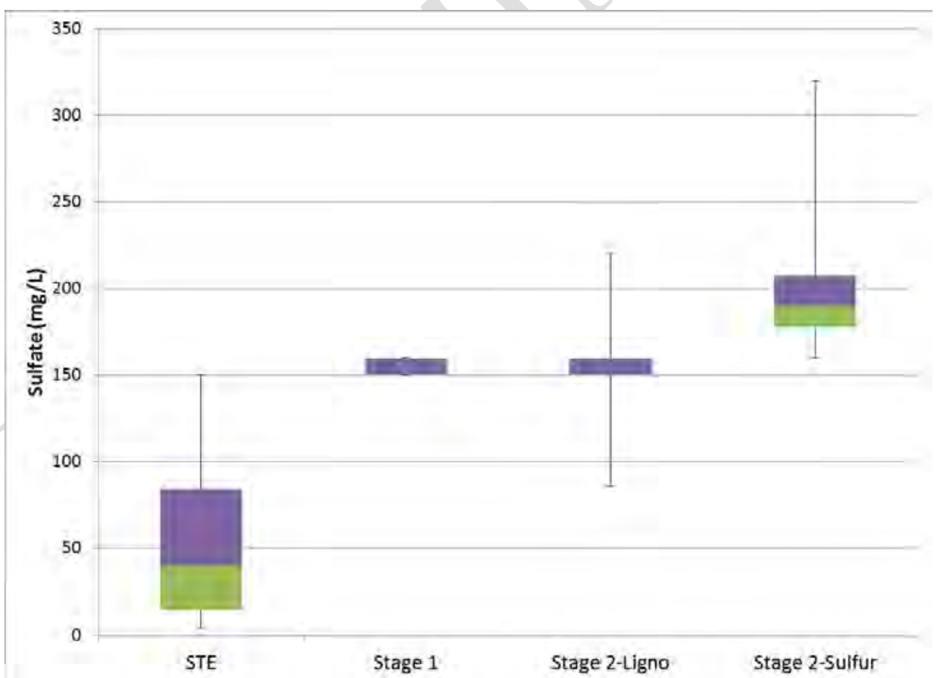

Figure 18
Sulfate (SO_4) Box and Whisker Plot

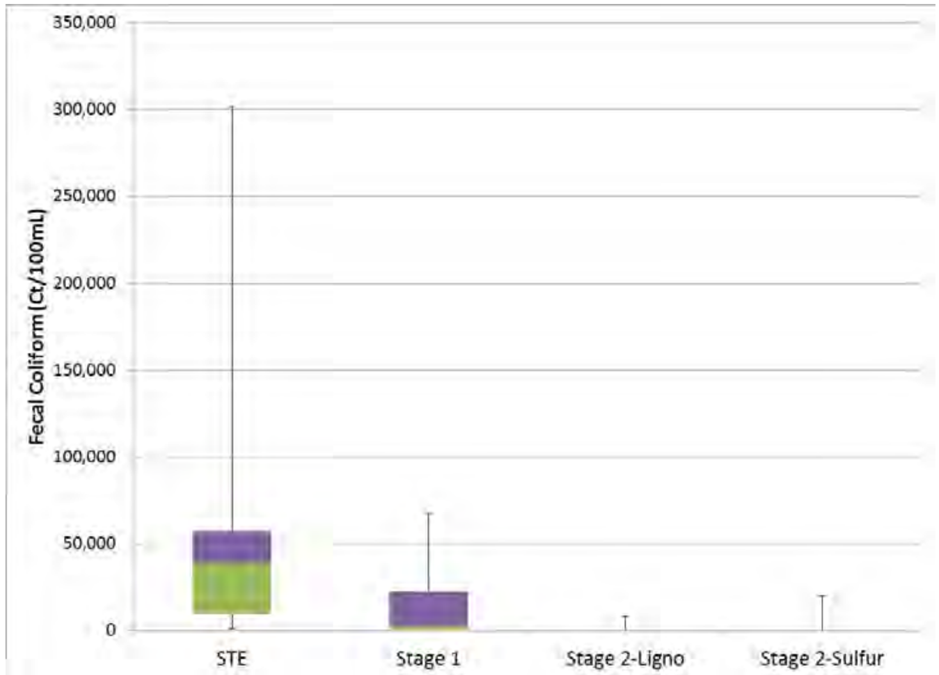

Figure 19
Fecal Coliform Box and Whisker Plot

4.5 Performance Comparison of Recirculation Mode of Operation

As previously discussed, the recirculation mode of operation was modified prior to the sixth sample event. The system was designed with two recirculation modes of operation. The first option (which was initially tested) is to have the recirculated effluent return to the recirculation tank for mixing with incoming septic tank effluent. A summary of the water quality data collected for the test system during testing of the first option (which was initially tested) is presented in Table 7. Following the fifth sample event, the recirculation mode of operation was modified to test the second option. In the second option, recirculated effluent does not pass through the recirculation tank, but is dispersed by three spray nozzles directly to the top of the Stage 1 biofilter along with recirculation tank effluent (STE). A summary of the water quality data collected for the test system during testing of the second option is presented in Table 8. A comparison of the two re-circulation modes of operation for key parameters is provided in Table 9.

Table 7
Summary of Water Quality Data
Option 1: Recirculation to Recirc Tank

Sample ID	Statistical Parameter	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
Septic tank effluent (STE)	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4
	MEAN	23.8	7.3	1,360.0	0.2	(370.1)	462.0	28.2	24.6	105.6	320.0	50.5	50.4	8.8	41.6	0.05	0.01	0.05	41.7	8.2	3.9	83.4	14.8	53.4	115,416	118,949	48.3
	STD. DEV.	3.3	-	48.3	0.2	13.2	39.6	9.4	8.5	25.5	109.3	5.4	5.4	7.7	5.3	0.05	-	0.04	5.3	5.5	0.4	44.6	2.9	10.0			23.4
	MIN	18.8	7.2	1,296.0	0.1	(392.5)	410.0	18.0	15.0	73.0	150.0	42.0	42.0	1.0	36.0	0.01	0.01	0.02	36.0	4.8	3.5	31.0	10.0	41.0	800	2,420	31.0
	MAX	27.8	7.6	1,398.0	0.6	(360.0)	510.0	40.0	35.0	140.0	430.0	56.1	56.0	18.0	48.0	0.13	0.01	0.13	48.0	18.0	4.3	150.0	17.0	65.0	1,600,000	1,200,000	82.0
Recirculation tank (DBOX)	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	5	5	4
	MEAN	23.2	7.0	1,217.6	1.0	(127.9)	286.0	20.6	16.0	25.2	69.6	18.9	12.8	3.8	9.0	5.52	1.08	6.13	15.1	6.0	2.3	-	-	-	38,350	34,064	19.3
	STD. DEV.	3.8	0.2	32.1	0.8	43.2	18.2	11.2	13.8	31.9	40.9	5.3	2.8	1.8	1.9	5.97	1.26	6.34	4.6	4.0	1.1	-	-	-			8.4
	MIN	17.4	6.8	1,173.0	0.1	(181.8)	270.0	12.0	6.0	2.0	10.0	14.4	8.8	0.7	7.1	0.01	0.01	0.02	11.0	3.7	1.1	-	-	-	1,000	2,420	11.0
	MAX	27.7	7.2	1,245.0	1.8	(71.2)	310.0	40.0	40.0	77.0	110.0	26.0	16.0	5.0	11.0	14.00	2.80	14.00	21.1	13.0	3.6	-	-	-	790,000	345,000	31.0
Stage 1 effluent (ST1 and PUMP)	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	4	4	4
	MEAN	22.7	6.8	1,209.4	3.6	(86.1)	232.0	27.2	12.8	15.2	22.8	19.7	3.1	2.1	0.9	16.26	0.28	16.66	17.6	5.6	1.6	-	-	-	269	141	12.3
	STD. DEV.	4.0	0.2	47.5	1.7	88.0	14.8	28.4	13.1	18.6	10.6	5.8	1.9	0.6	1.5	7.26	0.30	7.33	6.2	3.6	0.7	-	-	-			3.6
	MIN	16.1	6.7	1,137.0	2.0	(180.0)	210.0	1.0	1.0	2.0	11.0	12.5	1.6	1.3	0.1	6.30	0.01	6.30	9.9	3.5	0.7	-	-	-	6	3	8.3
	MAX	26.9	7.1	1,259.0	5.7	50.8	250.0	68.0	35.0	45.0	36.0	26.0	6.2	2.7	3.6	24.00	0.77	24.00	24.1	12.0	2.6	-	-	-	4,200	4,611	17.0
Stage 2 lignocellulosic effluent (LIGNO-0)	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	3
	MEAN	22.9	7.0	1,193.2	0.5	(332.4)	386.0	9.2	8.8	47.6	118.6	2.8	2.8	1.3	1.5	0.01	0.01	0.02	1.5	5.0	2.0	159.2	12.8	28.9	38	21	18.7
	STD. DEV.	3.0	-	45.1	0.3	33.2	56.8	11.8	11.9	30.1	57.9	1.6	1.6	0.3	1.4	0.01	-	0.00	1.4	4.0	0.8	53.8	7.0	13.1	-	-	2.3
	MIN	18.7	6.8	1,141.0	0.2	(362.1)	290.0	1.0	1.0	20.0	81.0	1.5	1.5	1.0	0.4	0.01	0.01	0.02	0.4	2.6	0.7	86.0	4.2	7.3	10	1	16.0
	MAX	26.7	7.1	1,230.0	0.8	(279.4)	440.0	30.0	30.0	96.0	220.0	4.6	4.6	1.8	3.3	0.03	0.01	0.03	3.3	12.0	2.7	220.0	19.0	40.0	1,300	1,986	20.0
Stage 2 sulfur effluent (ST2)	n	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	4
	MEAN	22.5	6.8	1,222.0	0.1	(323.3)	334.0	6.8	4.2	67.6	170.0	3.5	3.4	1.3	2.2	0.01	0.01	0.02	2.2	4.9	2.5	192.0	24.8	41.8	53	25	22.0
	STD. DEV.	3.7	-	65.5	0.1	61.5	76.7	5.2	2.5	32.3	101.7	2.4	2.4	0.2	2.2	-	-	-	2.2	3.5	1.3	27.7	12.5	21.2			2.2
	MIN	16.5	6.5	1,135.0	0.1	(372.0)	220.0	2.0	2.0	32.0	10.0	1.4	1.4	1.0	0.4	0.01	0.01	0.02	0.4	2.4	0.9	170.0	14.0	23.0	10	1	20.0
	MAX	26.1	7.0	1,303.0	0.2	(218.8)	410.0	15.0	8.0	110.0	260.0	6.5	6.5	1.5	5.0	0.01	0.01	0.02	5.0	11.0	4.1	240.0	40.0	73.0	300	155	25.0

Table 8
Summary of Water Quality Data
Option 2: Recirculation to Stage 1 Sprayers

Sample ID	Statistical Parameter	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
Septic tank effluent (STE)	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	MEAN	22.9	7.2	1,396.7	0.0	(371.6)	644.3	90.0	18.9	254.3	351.4	57.8	57.7	16.6	41.1	0.05	0.01	0.05	41.2	8.7	3.7	32.4	20.5	47.6	75,579	36,082	100.7
	STD. DEV.	2.4	0.1	66.1	0.0	9.5	246.4	195.0	17.5	112.7	98.2	7.5	7.5	8.5	7.6	0.03	-	0.03	7.6	3.8	2.2	41.5	6.0	14.1	-	-	23.8
	MIN	20.7	7.0	1,248.0	0.0	(390.9)	500.0	10.0	8.0	100.0	190.0	42.0	42.0	2.0	30.0	0.01	0.01	0.02	30.0	6.5	0.7	3.8	9.5	26.0	27,000	10,000	56.0
	MAX	27.0	7.2	1,430.0	0.1	(363.4)	1,200.0	532.0	58.0	390.0	450.0	64.0	64.0	25.0	53.0	0.11	0.01	0.11	53.1	17.0	6.6	120.0	28.0	66.0	302,000	240,000	120.0
Recirculation tank	n	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	MEAN	21.8	7.2	1,398.2	0.1	(370.9)	585.0	13.5	12.8	171.7	273.3	58.6	58.5	17.2	41.3	0.05	0.01	0.06	41.4	6.0	4.5	8.1	20.7	49.7	92,508	24,760	69.2
	STD. DEV.	1.4	0.2	53.1	0.0	6.0	28.8	6.4	6.1	29.3	32.0	5.8	5.8	5.7	4.9	0.03	-	0.03	4.9	0.7	1.8	5.3	10.1	13.4	-	-	15.5
	MIN	20.5	6.9	1,292.0	0.0	(382.5)	530.0	4.0	4.0	130.0	230.0	48.0	48.0	8.0	35.0	0.01	0.01	0.02	35.0	4.7	1.6	3.1	15.0	39.0	51,000	10,000	53.0
	MAX	24.5	7.3	1,432.0	0.1	(366.5)	610.0	21.0	21.0	200.0	310.0	63.1	63.0	23.0	50.0	0.10	0.01	0.10	50.1	6.8	6.0	18.0	41.0	74.0	311,000	240,000	93.0
Stage 1 effluent (ST1 and PUMP)	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	5	5	5	7	7	6
	MEAN	22.0	7.0	1,213.1	4.2	(21.7)	221.4	1.9	1.6	8.4	17.9	38.5	4.5	3.6	0.9	33.86	0.24	34.05	35.0	5.4	3.6	154.0	0.1	0.3	4,997	2,548	13.8
	STD. DEV.	2.0	0.2	25.1	0.7	65.1	21.2	1.1	0.8	6.6	5.1	4.4	2.7	1.9	0.9	4.22	0.26	4.03	4.0	1.8	1.2	5.5	0.2	0.3	-	-	3.6
	MIN	20.3	6.5	1,197.0	3.3	(80.7)	190.0	1.0	1.0	2.0	10.0	30.7	2.0	1.8	0.2	26.00	0.01	26.65	26.9	3.8	2.2	150.0	0.0	0.1	100	31	9.9
	MAX	25.6	7.2	1,267.0	4.9	83.5	250.0	4.0	3.0	18.0	23.0	44.5	10.0	7.6	2.4	38.00	0.65	38.00	38.2	7.6	5.8	160.0	0.4	0.8	68,000	24,000	19.0
Stage 2 lignocellulosic effluent (LIGNO-0)	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	MEAN	22.2	6.9	1,145.4	0.5	(257.6)	344.3	7.3	7.1	13.1	35.1	6.3	2.4	1.6	0.7	3.54	0.42	3.96	4.6	4.6	3.0	152.9	1.9	3.2	11	9	79.8
	STD. DEV.	1.7	0.1	47.7	0.4	43.1	16.2	7.7	7.8	11.8	16.0	2.5	1.1	0.6	0.9	2.26	0.26	2.50	2.2	2.0	1.0	4.9	2.5	4.0	-	-	161.8
	MIN	20.6	6.7	1,112.0	0.1	(323.7)	330.0	1.0	1.0	2.0	22.0	2.1	1.4	1.1	0.3	0.40	0.01	0.40	1.1	3.4	1.9	150.0	0.3	0.6	1	1	12.0
	MAX	25.5	7.1	1,217.0	1.2	(207.3)	370.0	18.0	18.0	36.0	67.0	9.8	4.6	2.8	2.7	6.70	0.87	7.57	7.5	7.9	4.9	160.0	7.4	12.0	8,000	7,800	410.0
Stage 2 sulfur effluent (ST2)	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	MEAN	21.4	6.9	1,203.7	0.1	(344.1)	340.0	2.4	2.1	54.9	88.7	1.8	1.8	1.1	0.7	0.02	0.01	0.02	0.8	4.3	3.0	208.6	16.1	32.8	21	10	14.8
	STD. DEV.	2.1	0.3	34.5	0.1	32.7	12.9	1.7	1.5	25.4	30.1	1.2	1.2	0.4	0.9	0.01	-	0.01	0.9	1.5	1.2	54.0	9.9	23.8	-	-	1.6
	MIN	20.0	6.3	1,134.0	0.1	(368.6)	320.0	1.0	1.0	38.0	35.0	0.9	0.9	0.6	0.3	0.01	0.01	0.02	0.3	3.0	1.7	160.0	5.7	6.8	1	1	13.0
	MAX	25.8	7.1	1,250.0	0.2	(275.5)	360.0	6.0	5.0	110.0	130.0	4.5	4.5	1.8	2.7	0.04	0.01	0.04	2.7	6.5	5.1	320.0	37.0	83.0	20,000	9,600	17.0

Table 9
Comparison of Water Quality Data

Sample ID	Statistical Parameter	Total Alkalinity (mg/L)		TSS (mg/L)		CBOD5 (mg/L)		TN (mg/L N)		TKN (mg/L N)		Organic N (mg/L N)		NH3-N (mg/L N)		NOx (mg/L N)		TIN (mg/L N)		TP (mg/L)		Sulfate (mg/L)	
		Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers	Recirc tank	Sprayers
Septic tank effluent (STE)	n	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
	MEAN	462.0	644.3	28.2	90.0	105.6	254.3	50.5	57.8	50.4	57.7	8.8	16.6	41.6	41.1	0.05	0.05	41.7	41.2	8.2	8.7	83.4	32.4
	STD. DEV.	39.6	246.4	9.4	195.0	25.5	112.7	5.4	7.5	5.4	7.5	7.7	8.5	5.3	7.6	0.04	0.03	5.3	7.6	5.5	3.8	44.6	41.5
	MIN	410.0	500.0	18.0	10.0	73.0	100.0	42.0	42.0	42.0	42.0	1.0	2.0	36.0	30.0	0.02	0.02	36.0	30.0	4.8	6.5	31.0	3.8
	MAX	510.0	1,200.0	40.0	532.0	140.0	390.0	56.1	64.0	56.0	64.0	18.0	25.0	48.0	53.0	0.13	0.11	48.0	53.1	18.0	17.0	150.0	120.0
Recirculation tank	n	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	5	6	0	6
	MEAN	286.0	585.0	20.6	13.5	25.2	171.7	18.9	58.6	12.8	58.5	3.8	17.2	9.0	41.3	6.13	0.06	15.1	41.4	6.0	6.0	-	8.1
	STD. DEV.	18.2	28.8	11.2	6.4	31.9	29.3	5.3	5.8	2.8	5.8	1.8	5.7	1.9	4.9	6.34	0.03	4.6	4.9	4.0	0.7	-	5.3
	MIN	270.0	530.0	12.0	4.0	2.0	130.0	14.4	48.0	8.8	48.0	0.7	8.0	7.1	35.0	0.02	0.02	11.0	35.0	3.7	4.7	-	3.1
	MAX	310.0	610.0	40.0	21.0	77.0	200.0	26.0	63.1	16.0	63.0	5.0	23.0	11.0	50.0	14.00	0.10	21.1	50.1	13.0	6.8	-	18.0
Stage 1 effluent	n	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	0	5
	MEAN	232.0	221.4	27.2	1.9	15.2	8.4	19.7	38.5	3.1	4.5	2.1	3.6	0.9	0.9	16.66	34.05	17.6	35.0	5.6	5.4	-	154.0
	STD. DEV.	14.8	21.2	28.4	1.1	18.6	6.6	5.8	4.4	1.9	2.7	0.6	1.9	1.5	0.9	7.33	4.03	6.2	4.0	3.6	1.8	-	5.5
	MIN	210.0	190.0	1.0	1.0	2.0	2.0	12.5	30.7	1.6	2.0	1.3	1.8	0.1	0.2	6.30	26.65	9.9	26.9	3.5	3.8	-	150.0
	MAX	250.0	250.0	68.0	4.0	45.0	18.0	26.0	44.5	6.2	10.0	2.7	7.6	3.6	2.4	24.00	38.00	24.1	38.2	12.0	7.6	-	160.0
Stage 2 lignocellulosic effluent	n	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
	MEAN	386.0	344.3	9.2	7.3	47.6	13.1	2.8	6.3	2.8	2.4	1.3	1.6	1.5	0.7	0.02	3.96	1.5	4.6	5.0	4.6	159.2	152.9
	STD. DEV.	56.8	16.2	11.8	7.7	30.1	11.8	1.6	2.5	1.6	1.1	0.3	0.6	1.4	0.9	0.00	2.50	1.4	2.2	4.0	2.0	53.8	4.9
	MIN	290.0	330.0	1.0	1.0	20.0	2.0	1.5	2.1	1.5	1.4	1.0	1.1	0.4	0.3	0.02	0.40	0.4	1.1	2.6	3.4	86.0	150.0
	MAX	440.0	370.0	30.0	18.0	96.0	36.0	4.6	9.8	4.6	4.6	1.8	2.8	3.3	2.7	0.03	7.57	3.3	7.5	12.0	7.9	220.0	160.0
Stage 2 sulfur effluent	n	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7	5	7
	MEAN	334.0	340.0	6.8	2.4	67.6	54.9	3.5	1.8	3.4	1.8	1.3	1.1	2.2	0.7	0.02	0.02	2.2	0.8	4.9	4.3	192.0	208.6
	STD. DEV.	76.7	12.9	5.2	1.7	32.3	25.4	2.4	1.2	2.4	1.2	0.2	0.4	2.2	0.9	-	0.01	2.2	0.9	3.5	1.5	27.7	54.0
	MIN	220.0	320.0	2.0	1.0	32.0	38.0	1.4	0.9	1.4	0.9	1.0	0.6	0.4	0.3	0.02	0.02	0.4	0.3	2.4	3.0	170.0	160.0
	MAX	410.0	360.0	15.0	6.0	110.0	110.0	6.5	4.5	6.5	4.5	1.5	1.8	5.0	2.7	0.02	0.04	5.0	2.7	11.0	6.5	240.0	320.0

5.0 B-HS2 Sample Event No. 8: Summary and Recommendations

5.1 Summary

The eighth and final sampling results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of 60 mg/L is within the range of values typically reported for Florida single family residence STE.
- The Stage 1 biofilter converted most of the ammonia N to oxidized nitrogen; effluent contained 2.2 mg/L TKN, of which 0.21 mg/L was ammonia.
- The Stage 2 biofilter effluent NO_x-N was 0.04 mg N/L.
- The total nitrogen concentration in the final effluent from the total treatment system was 1.64 mg/L, an approximately 97% reduction in STE TN.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS2 treatment system. Section 4.4 summarized the water quality data collected over the 1.5 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 54.7 mg/L is in the upper range of values typically reported for Florida single family residence STE.
- The Stage 1 biofilter with recirculation provided significant nitrification with an average NH_3-N concentration of 0.9 mg/L and average TKN of 3.9 mg/L. The Stage 1 biofilter effluent average NO_x-N was 26.8 mg/L. These results indicate significant denitrification (approximately 44% total nitrogen reduction) was occurring.
- The Stage 2 biofilter was effective in producing a reducing environment and achieving the NO_x-N reduction goals (average NO_x-N concentration of 0.02 mg/L). The average final total nitrogen (TN) in the treatment system effluent was 2.5 mg/L, primarily TKN (average TKN concentration of 2.5 mg/L).

Further analysis of the results obtained at this site will occur as Task B results are compiled and summarized. The results of the data collected to date have provided insights into the performance of a full-scale passive nitrogen reduction system monitored over an extended timeframe (535 experimental days) under actual onsite conditions.

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS3 Field System Monitoring Report No. 8

Prepared for:

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

FDOH Contract CORCL

December 2014

Prepared by:

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Applied Environmental Technology

B-HS3 Field System
Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in PNRS II. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth and final sample event of a passive nitrogen reduction system at home site B-HS3 in Seminole County, Florida.

2.0 Purpose

Operation of the B-HS3 system was initiated on July 12, 2013. This monitoring report documents data collected from the eighth monitoring and sampling event conducted on December 17, 2014 (Day 523). The monitoring event consisted of collecting flow measurements from the household water use meter and the treatment system flow meters, recording electricity use, monitoring of field parameters, collection of water samples from eleven points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory.

3.0 Materials and Methods

3.1 Project Site

The B-HS3 field site is located in Seminole County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in June 2013. Design and construction details were presented previously in the Task B.6 document. A system schematic identifying the system components and layout of the installation is shown in Figure 1. A flow schematic of the system is shown in Figure 2. The B-HS3 system consists of a 1,500 gallon two chamber concrete primary treatment (septic) tank that replaced the former septic tank; a 600 gallon concrete septic tank effluent (STE) dose tank; a two zone drip system; and a 1,050 gallon concrete tank enclosing a Stage 2 saturated sulfur media biofilter. The two zone drip system consists of a Stage 1&2a lined drip zone (Zone 1), that receives primary effluent and a drip zone that receives treated effluent from the Stage 2b biofilter (Zone 2).

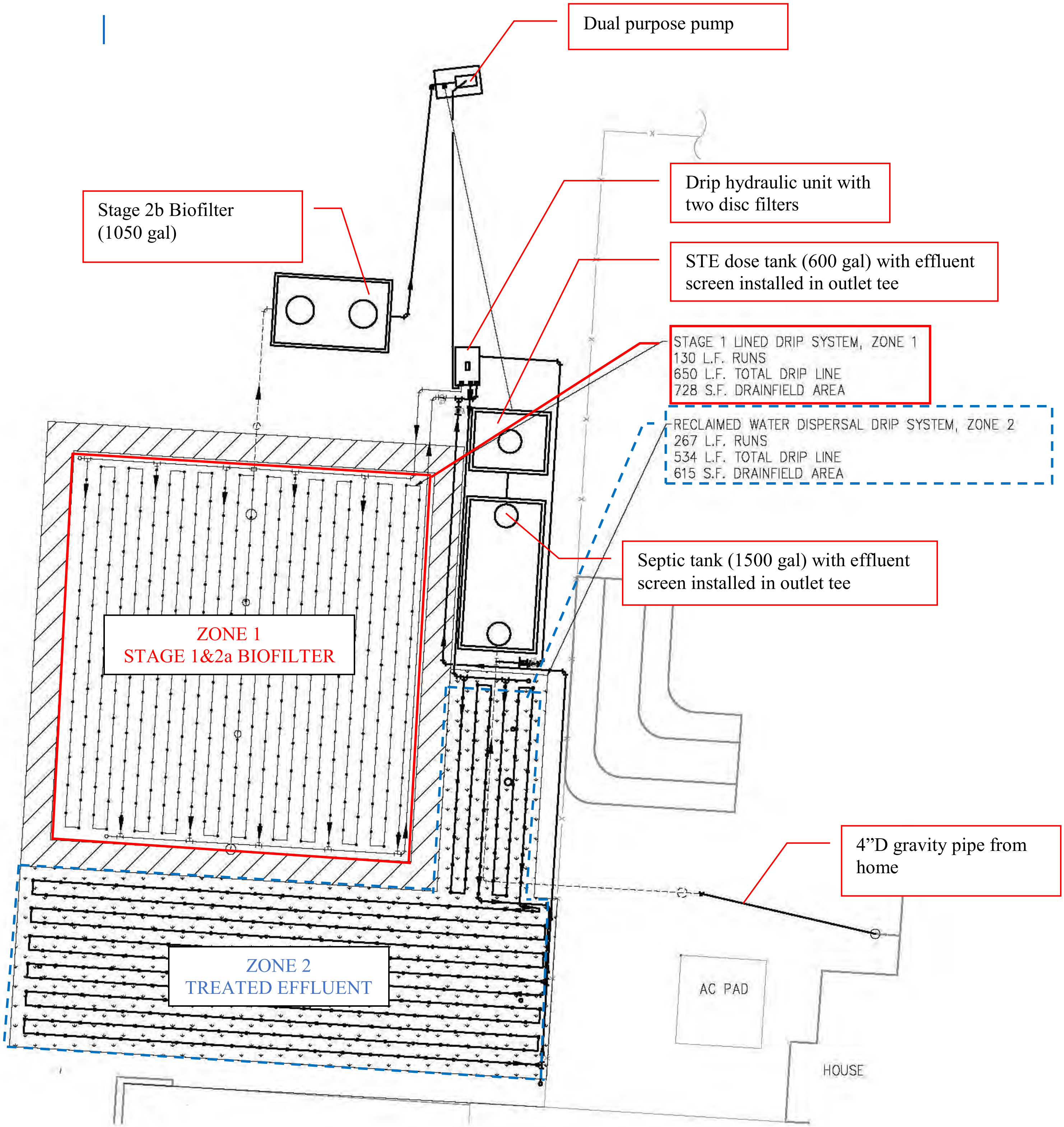

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Figure 1
Plan View of B-HS3 System Layout

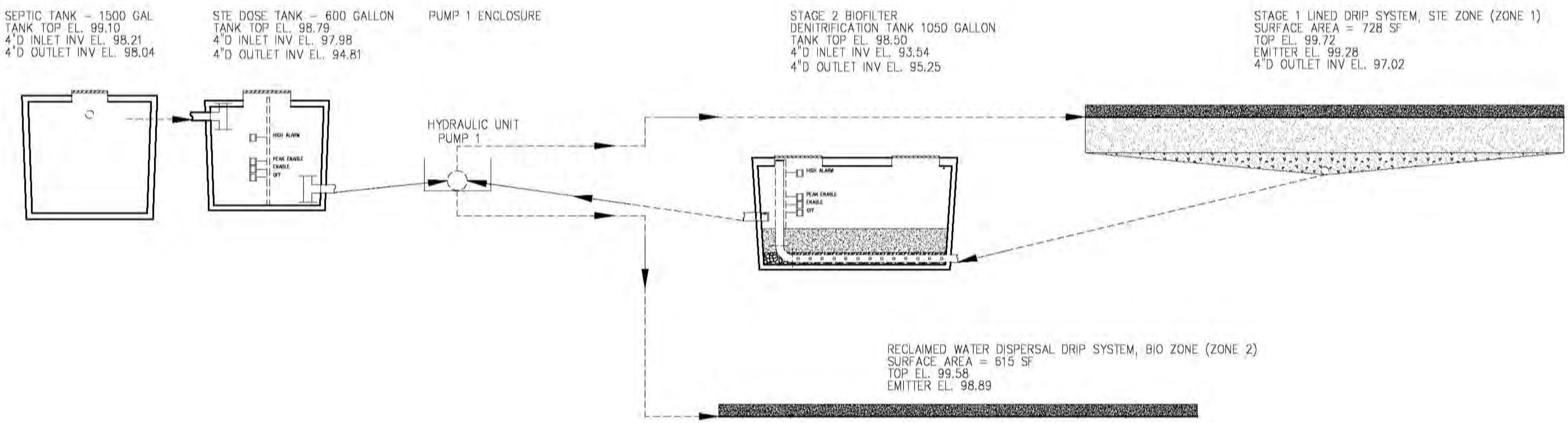

Figure 2
Flow Schematic of B-HS3 PNRS Installed in Seminole County

3.2 Monitoring and Sample Locations and Identification

3.2.1 Treatment System Monitoring Points

This monitoring event included sample collection from eleven points within the treatment system (Figure 3). In the treatment system, household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent through an effluent screen into the STE dose tank. The first monitoring point, B-HS3-STE, is the effluent sampled approximately 1.5 feet below the surface of the second chamber of the primary tank (Figure 4) before the effluent filter, which is referred to as primary effluent or septic tank effluent (STE). Samples from monitoring point B-HS3-STE are of whole household wastewater after it has had some residence time in the primary tank and represent the influent to the remainder of the onsite nitrogen reduction system.

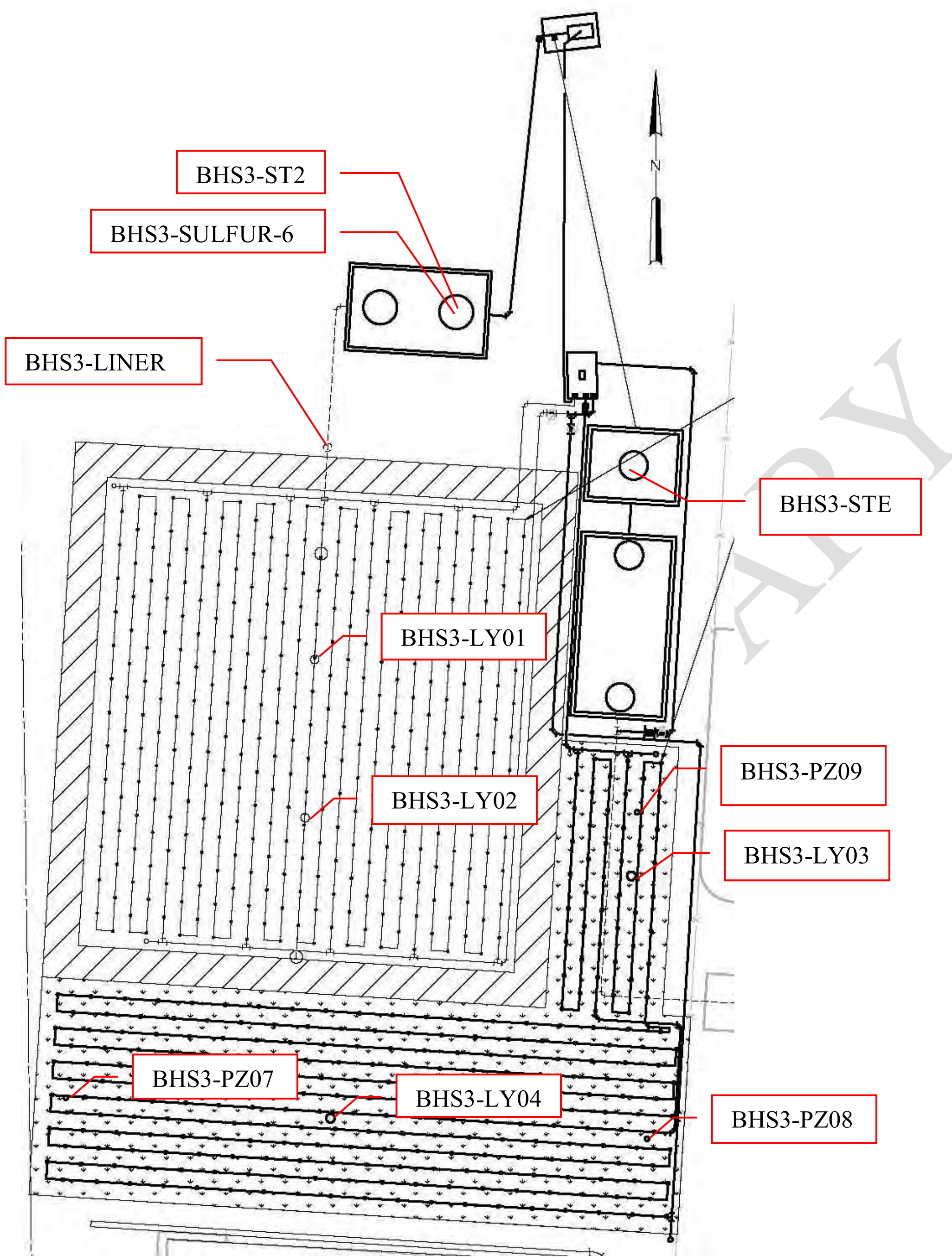

Figure 3
B-HS3 Treatment System Sampling and Monitoring Locations

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Figure 4
Second Chamber of Primary Tank (B-HS3-STE Sample)

The STE dose tank effluent is pumped through the drip system hydraulic unit and discharged to the Stage 1&2a drip system (Zone 1). In the Stage 1&2a drip area, wastewater percolates downward through an 18-inch layer of unsaturated sand and a layer of lignocellulosic and sand media (9-inch maximum thickness) placed above a 30 mil PVC liner. The second and third sampling points are two suction lysimeters (BHS3-LY01 and BHS3-LY02) located at the interface of the overlying sand (Stage 1) and underlying lignocellulosic/sand mixture (Stage 2a). The suction lysimeters were installed with the bottom of the 9-inch ceramic placed at the interface of the two media layers. These sample locations ostensibly represent wastewater that has been nitrified by passage through the overlying sand layer (Figure 5).

Figure 5
Stage 1 Suction Lysimeter (BHS3-LY01 and –LY02)

The Stage 1&2a drip system area was prepared by grading a V-shape so that effluent would collect on the liner and flow to the center where a perforated pipe within a gravel underdrain conveys the effluent to the Stage 2b denitrification tank through a pipe boot within the liner. The fourth sampling point (BHS3-LINER) is a sample port of the Stage 1&2a lined area effluent prior to the Stage 2b sulfur biofilter. At the BHS3-LINER sample point, wastewater should be denitrified by passage through the lignocellulosic media mixture (Stage 2a).

The liner effluent is conveyed to a Stage 2b biofilter, a concrete 1,050 gallon tank, containing elemental sulfur reactive media for additional treatment (denitrification). Wastewater flow is in an upward direction. The fifth sampling point, BHS3-SULFUR-6, is a stainless steel drivepoint sampler positioned 6-inches above the bottom of the sulfur media. The sixth sampling point, B-HS3-ST2, is the Stage 2b sulfur media biofilter effluent which is sampled approximately 6 inches below the water surface of the Stage 2b biofilter tank (Figure 6).

Figure 6
Second Chamber of Stage 2b Biofilter (B-HS3-ST2 Sample)

The Stage 2b biofilter effluent is pumped through the drip system hydraulic unit and discharged through the treated effluent drip system emitters (Zone 2) to natural soil. Monitoring points 7 through 11 were placed below the Zone 2 drip emitters. Their locations are shown in Figure 3. Sampling points seven and eight are suction lysimeters (BHS3-LY03 and BHS3-LY04) located in the treated effluent drip area with the top of the 9 inch ceramic cup located 24 inches below the drip emitters to represent treatment through 24-inches of unsaturated soil (Figure 7). Sampling points nine, ten and eleven are also located within the treated effluent drip area; these are standpipe piezometers (BHS3-PZ07, BHS3-PZ08, and BHS3-PZ09) positioned so that the top of the 5-foot screen is 24-inches below the drip emitters (Figure 8).

Figure 7
Treated Effluent Suction Lysimeter (B-HS3-LY03 and –LY04 sample)

Figure 8
Treated Effluent Area Standpipe Piezometers (B-HS3-PZ07, -PZ08 and –PZ09)

3.2.2 Groundwater Monitoring Points

For this monitoring event, five of the sixty-seven downgradient groundwater monitoring points that were installed as part of the C-HS2 groundwater monitoring network were included. A sampling grid for groundwater screening was developed downgradient of the original OSTDS as depicted in Figure 9. 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 increase (higher letter identification) moving southward from the mound. Transect lines 0 through 15 were located parallel to the groundwater flow direction and increase moving from southeast to northwest. Groundwater monitoring points were installed in June and July 2011. One type of monitoring point was installed using either hand or drilling methods: standpipe piezometers. Standpipe piezometers consist of either ¾-inch or 2-inch diameter PVC with a 1-foot, 2-foot, or 4-foot screen (0.010-inch slots) and riser extending to the ground surface (refer to the Task C QAPP and Task C.23 C-HS2 Instrumentation Report for additional detail).

Each monitoring location was assigned a unique identification indicating grid location (self explanatory), and depth below ground surface (bottom of the drive point or well screen in feet). For example A07-6 is a standpipe piezometer sampler located on the grid at A07 at approximately 6-feet below ground surface.

Groundwater level measurements are used to determine hydraulic gradients and directions of flow. Groundwater levels were measured using a flat tape water level meter graduated in feet (measurement accuracy is 0.01 feet). The groundwater level within the standpipe piezometers sampled was measured for this sampling event. Figure 10 illustrates the surficial groundwater contours as measured within the standpipe piezometers during this sample event.

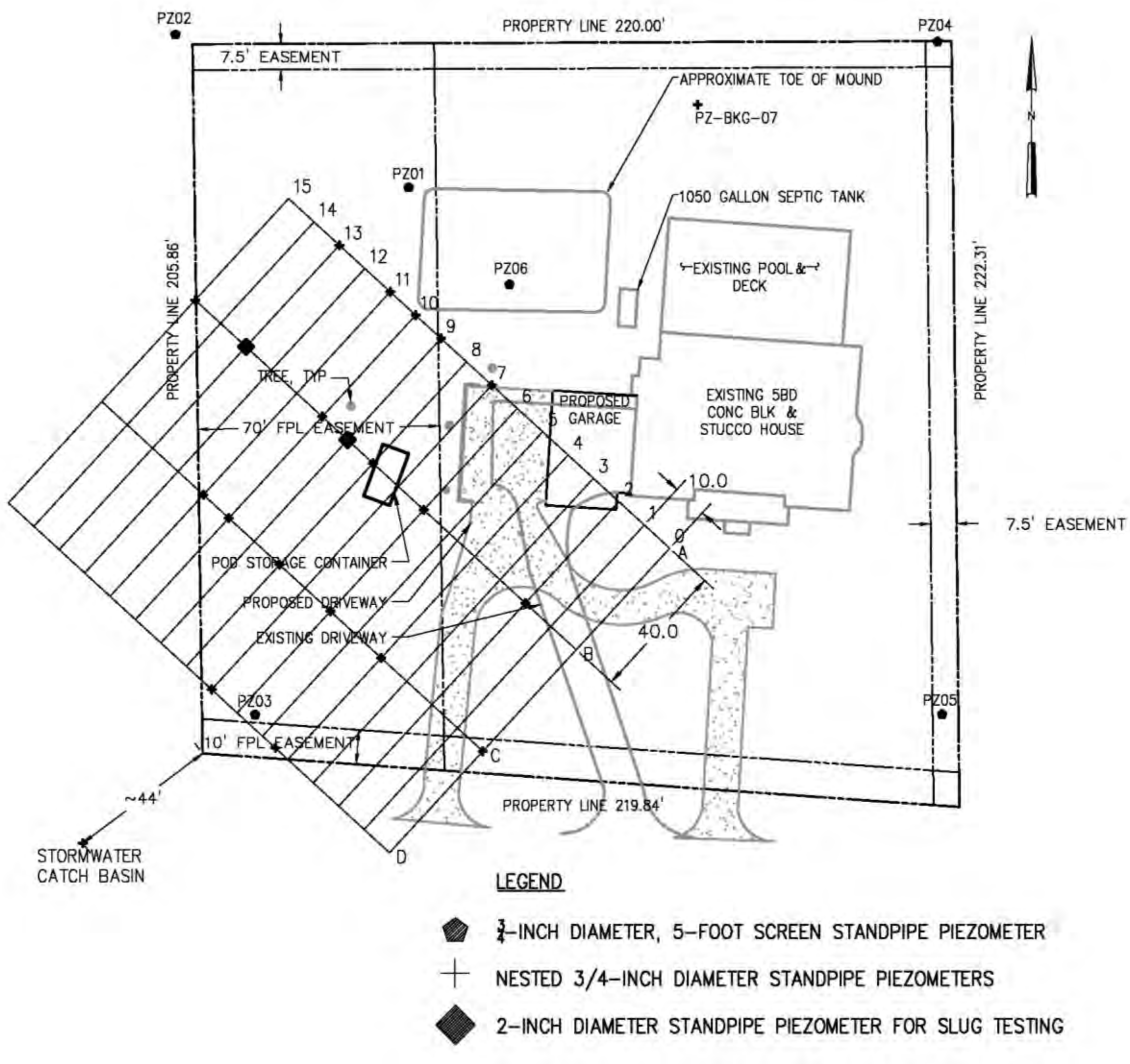

Figure 9
C-HS2 Monitoring Network

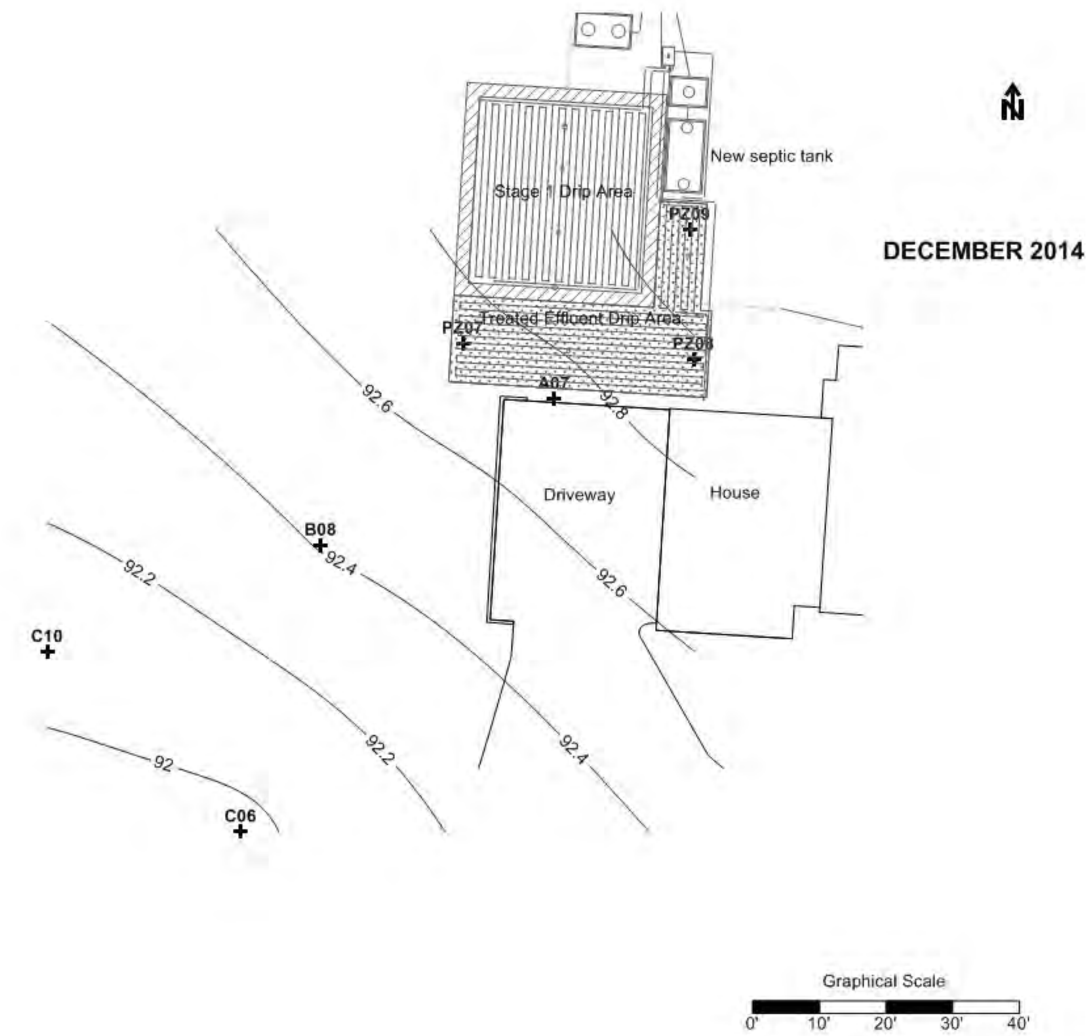

Figure 10
Groundwater Sampling Locations and
Surficial Groundwater Contours December 17, 2014

3.3 Operational Monitoring

Start-up of the system occurred on July 12, 2013 (Experimental Day 0) and the system has operated almost continually since that date. Between September 10, 2013 and September 17, 2013 the system was not operating because a replacement part for the hydraulic unit was required.

Regular maintenance includes checking and cleaning, as necessary, the primary tank effluent screen and the STE dose tank effluent screen installed within the outlet tees. During sample event site visits, this is done after sampling. The cleaning of the disc filters in the hydraulic unit is an automated process. A backflush of the filters occurs at the beginning of each dose cycle, and the backflush flow is directed to the primary tank.

3.4 Flow Monitoring

The eighth formal sampling event was conducted December 17, 2014 (Experimental Day 523). For the eighth formal sampling event, the water meter for the house and the treatment system flow meters were read and recorded on December 17, 2014. The household potable water use is recorded via a water meter (Meter 1) located in the front yard which includes indoor and outdoor water use. The household has a separate irrigation well which supplies the irrigation system; however the metered potable water use includes filling the pool, car washing, etc. The combined pump flow meter is located inside the hydraulic unit following the hydraulic unit filters prior to the split between the two zones, and records the cumulative pumped flow in gallons pumped from both the STE dose tank and Stage 2b biofilter tank (Meter 2). Therefore, the measurement of the combined flow meter includes both the STE flow from the household and the treated effluent flow from the Stage 2b biofilter. The Stage 2b treated effluent flow meter (Meter 3) is located following the split on the line from the pump to the treated effluent drip system and records the cumulative flow in gallons pumped from the Stage 2b biofilter tank. The control panel includes telemetry which logs alarms, cumulative pump cycles, and cumulative field flush cycles.

The daily wastewater volume supplied to the passive nitrogen removal system was the volume that was pumped to the lined Stage 1&2a biofilter (Drip Zone 1); it was estimated by calculating the difference between the volume readings of Meter 2 and Meter 3. This calculation does not account for water entering or leaving the Stage 1/2a biofilter (Drip Zone 1) through hydrologic processes such as precipitation, irrigation, and evapotranspiration.

Flow calculations using the metered data:

Combined pumped flow = Meter 2

Treated effluent flow (Zone 2) = Meter 3

Stage 1&2a biofilter wastewater flow (Zone 1) = Meter 2 – Meter 3

Additional Zone 1 inputs/outputs = Meter 3 - [Meter 2- Meter 3]

3.5 Energy, Chemical and/or Additives Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. 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. There are no chemicals added to the system. However, the denitrification media (lignocellulosic and sulfur) are “reactive” media which will be consumed during operation. The Stage 1&2a lined area was initially filled with 9 inches of lignocellulosic and sand media mixture and the Stage 2b biofilter was initially filled with 12 inches of sulfur and oyster shell media mixture, which ostensibly will last for many years without replenishment or replacement.

3.6 Water Quality Sample Collection and Analyses

The eighth formal sample event was conducted on December 17, 2014 and included a full suite of influent, intermediate and effluent water quality samples from the system. Samples were collected at each of the sixteen monitoring points described previously in Section 3.2 and illustrated in Figures 3 and 10: eleven treatment system monitoring points and six groundwater sampling points. A peristaltic pump was used to collect the treatment system samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded.

Groundwater samples were obtained using a peristaltic pump, which was attached directly to dedicated standpipe piezometer tubing. Samples were collected after sufficient purging (the sample was clear and field readings had stabilized) had occurred.

In addition, a field blank, equipment blank (EB), and field sample duplicates were taken. The field blank was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. The equipment blank was collected by pumping deionized water through the cleaned pump tubing. The field sample duplicates (B-HS3-ST2 and PZ-B8-5) were collected immediately subsequent to the regular samples. These samples were then analyzed for the same parameters as the monitoring samples.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent samples were analyzed by the laboratory for: total alkalinity, chemical oxygen demand (COD), Carbonaceous Biological Oxygen Demand ($CBOD_5$), total Kjeldahl nitrogen (TKN-N), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (Ortho P), total suspended solids (TSS), volatile suspended solids (VSS), total organic carbon (TOC), chloride, fecal coliform (fecal), and E. coli. The influent and sulfur media samples included sulfate, sulfide, and hydrogen sulfide (unionized). All analyses were performed by an independent and fully NELAC certified analytical laboratory (Southern Analytical Laboratory). Table 1 lists the analytical parameters, analytical methods, and detection limits for these analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	EPA 300.0	0.01 mg/L
Nitrate+Nitrite Nitrogen (NOX-N)	EPA 300.0	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Volatile Suspended Solids (VSS)	SM 2540E	1 mg/L
Total Organic Carbon (TOC)	SM5310B	0.06 mg/L
Chloride	EPA 300.0	0.50 mg/L
Sulfate	EPA 300.0	2.0 mg/L
Sulfide	SM 4500SF	0.10 mg/L
Hydrogen Sulfide (unionized)	SM 4550SF	0.01 mg/L
Fecal Coliform (fecal)	SM 9222D	2 ct/100mL
E.coli	SM 9223B	2 ct/100mL

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since July 13, 2011. The treatment system flow meter readings for the B-HS3 field site are summarized in Table 3. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B.

Table 2
Summary of Household Water Use

Date	Cumulative Volume (gallons)	Average Daily Household Flow, Q Between read-ings (gpd)	Comments
7/13/2011 14:45	5302677.9		Installed
7/20/2011 17:50	5304207.8	214.6	
7/26/2011 15:19	5305257.9	178.1	
10/27/2011 15:19	5327920.4	243.7	
11/30/2011 8:00	5355610.4	821.8	
3/13/2012 8:10	5378780.2	222.8	
7/10/2012 16:15	5453899.3	629.5	
10/18/2012 15:30	5470593.1	167.0	
3/7/2013 14:00	5488517.4	128.1	
6/7/2013 14:00	5504725.9	176.2	
7/9/2013 12:50	5508873.0	129.8	
7/12/13			PNRS start-up
7/12/13 14:01	5509172.1	98.1	
7/17/13 13:55	5509884.1	142.5	
7/29/13 9:50	5510830.9	80.0	
8/6/13 10:40	5511588.8	94.3	
8/12/13 11:07	5512244.8	109.0	
8/15/13 8:48	5513128.8	304.5	Prelim Event No. 1
9/5/13 15:31	5514810.2	79.0	
9/10/13			Septic tank pumped
9/17/13			System running again
9/27/13 8:00	5517331.9	116.3	
9/30/13 8:00	5517622.5	96.9	Sample Event No. 1
10/11/13 8:30	5518421.6	72.5	
10/17/13 11:00	5519187.0	125.4	
11/15/2013 10:00	5524455.0	181.9	
11/27/2013 9:10	5525784.8	111.1	
12/2/2013 8:30	5527623.5	369.8	Several guests stayed in the home over the Thanksgiving holiday
12/4/2013 8:51	5527809.2	92.2	Sample Event No. 2
12/23/2013 11:45	5529755.3	101.8	
1/23/2014 11:00	5532487.5	88.2	
1/30/2014 9:00	5533156.8	96.8	
2/3/2014 8:00	5533482.0	82.2	Sample Event No. 3
2/4/2014 8:15	5533499.6	17.4	Sample Event No. 4

Table 2
Summary of Household Water Use

Date	Cumulative Volume (gallons)	Average Daily Household Flow, Q Between readings (gpd)	Comments
2/5/2014 10:45	5533558.4	53.3	Sample Event No. 5
2/6/2014 10:45	5533690.6	132.2	Sample Event No. 6
2/7/2014 8:00	5533788.6	110.7	Sample Event No. 7
2/12/14 10:00	5534282.7	97.2	
3/14/14 8:24	5537363.8	102.9	
4/3/14 8:45	5539932.0	128.3	Sample Event No. 8 (formal No. 4)
4/29/14 10:10	5544794.2	186.6	
5/29/14 10:00	5549396.9	153.5	Sample Event No. 9 (formal No. 5)
6/9/14 12:45	5550719.1	119.0	
7/29/14 9:30	5555927.1	104.4	
8/22/14 7:30	5557593.9	69.7	Sample Event No. 10 (formal No. 6)
9/19/2014 12:48	5560271.5	94.9	
10/23/2014 15:45	5564131.1	113.1	Sample Event No. 11 (formal No. 7)
12/17/2014 8:00	5570112.8	109.4	Sample Event No. 12 (formal No. 8)
Total average PNRS start-up to 12/17/14		116.6	

Table 3
Summary of System Flow

Date and Time Read	Meter 2 Combined Pumped Flow	Average Daily Combined Pumped Flow between readings	Calc Flow to Stage 1&2a [Meter 2 – Meter 3] [2]	Average Daily Calculated Flow to Stage 1&2a between readings[2]	Meter 3 Treated Effluent Flow	Average Daily Treated Effluent Flow between readings	Stage 1&2a Area Water Input or Output[1]
	Cum Vol. (gal)	Gal/ Day	Cum Vol. (gal)	Gal/ Day	Cum Vol. (gal)	Gal/ Day	Gal/ Day
7/12/13 14:01	206.9	Start-up	Start-up	Start-up	58.6	Start-up	Start-up
7/17/13 11:57	423.0	44.0	40.6		234.2	35.7	
7/29/13 9:52	3,345.1	245.3	765.3	60.8	2,431.6	184.5	123.6
8/6/13 9:45	6,541.1	399.7	1,045.1	35.0	5,347.8	364.8	329.8
8/12/13 11:07	8,953.1	398.2	2,360.0	217.1	6,444.9	181.1	-36.0
8/15/13 8:48	10,131.2	405.8	3,084.3	249.4	6,898.7	156.3	-93.1
9/5/13 15:31	18,696.5	402.5	7,734.4	218.5	10,813.8	184.0	-34.5
9/9/13 9:00	19,884.6	318.7	8,287.6	148.4	11,448.8	170.3	22.0
9/17/13 10:12	20,912.4	127.7	8,785.2	61.8	11,979.0	65.9	4.0
9/27/13 8:00	22,142.0	124.1	9,239.3	45.8	12,754.5	78.3	32.4
9/30/13 8:00	22,885.0	247.7	9,692.2	151.0	13,044.6	96.7	-54.2
10/11/13 8:30	26,428.9	321.6	11,417.0	156.5	14,863.7	165.1	8.5
10/17/13 11:00	28,781.4	385.4	12,823.8	230.5	15,809.4	154.9	-75.5
11/8/13 12:30	34,278.1	249.1	15,844.0	136.9	18,285.9	112.2	-24.6
11/27/13 9:10	39,031.1	252.0	18,656.6	149.1	20,226.3	102.9	-46.2
12/2/13 8:30	42,081.5	613.5	20,437.6	358.2	21,495.7	255.3	-102.9
12/4/13 8:51	42,599.8	257.3	20,729.5	144.9	21,722.1	112.4	-32.6
12/23/13 11:45	47,135.0	237.2	23,346.3	136.9	23,640.5	100.3	-44.3
1/23/14 11:00	54,702.9	244.4	27,486.2	133.7	27,068.4	110.7	-23.0
1/30/14 9:00	56,954.9	325.6	28,619.7	163.9	28,187.0	161.7	-2.2
2/3/14 8:00	58,390.4	362.7	29,205.1	147.9	29,037.1	214.8	66.9
2/4/14 8:15	58,688.7	295.2	29,298.1	92.0	29,242.4	203.2	111.1
2/5/14 10:45	58,870.7	164.8	29,393.9	86.7	29,328.6	78.1	-8.6
2/6/14 10:45	59,118.7	248.0	29,553.8	159.9	29,416.7	88.1	-71.9
2/7/14 8:00	59,354.0	265.8	29,704.7	170.4	29,501.1	95.4	-75.0

Table 3 (con't)
Summary of System Flow

Date and Time Read	Meter 2 Combined Pumped Flow	Average Daily Combined Pumped Flow between readings	Calc Flow to Stage 1&2a [Meter 2 – Meter 3][2]	Average Daily Calculated Flow to Stage 1&2a between readings[2]	Meter 3 Treated Effluent Flow	Average Daily Treated Effluent Flow between readings	Stage 1&2a Area Water Input or Output[1]
	Cum Vol. (gal)	Gal/ Day	Cum Vol. (gal)	Gal/ Day	Cum Vol. (gal)	Gal/ Day	Gal/ Day
2/12/14 10:00	61,023.9	328.5	30,135.7	84.8	30,739.9	243.7	158.9
3/14/14 8:24	67,901.2	229.8	34,391.1	142.2	33,361.9	87.6	-54.6
4/3/14 8:45	73,953.4	302.4	37,466.0	153.6	36,339.2	148.8	-4.9
4/29/14 10:10	81,273.0	280.9	41,710.4	162.9	39,414.4	118.0	-44.9
5/29/14 10:00	86,833.4	185.4	44,628.2	97.3	42,057.0	88.1	-9.2
6/9/14 12:45	90,633.4	341.9	46,511.8	169.5	43,973.4	172.4	3.0
7/11/14 14:45	98,858.8	256.4	50,797.4	133.6	47,913.2	122.8	-10.8
7/29/14 9:30	105,444.4	370.4	54,191.1	190.9	51,105.1	179.5	-11.3
8/22/14 7:30	110,175.4	197.8	56,565.4	99.3	53,461.8	98.5	-0.7
9/19/2014 12:48	118,258.6	286.4	60,754.3	148.4	57,356.1	138.0	-10.4
10/23/2014 15:45	130,079.5	346.4	65,886.9	150.4	64,044.4	196.0	45.6
11/21/2014 9:30	139,036.3	311.7	71,279.4	187.6	67,608.7	124.0	-63.6
12/17/2014 8:00	147,921.6	342.6	75,970.7	180.9	71,802.7	161.7	-19.2
Avg start-up to 12/17/14		282.6		145.3		137.2	-8.1

[1]This value is the difference between the calculated flow to Stage 1&2a and metered Treated Effluent flow (Meter 3) from the Stage 2b biofilter. A positive value indicates an additional water input to the Stage 1&2a area (precipitation, irrigation, etc.) whereas a negative value indicates a water output (evapotranspiration, etc.).

[2]The additional volume in the Stage 1&2a flow as compared to the household water use meter is the volume returned to the septic tank during field flushing of the drip lines.

The average household water use since the PNRS system start-up was 116.6 gallons per day with periods of higher and lower flows. Since the PNRS system start-up, the average combined pumped flow (flow to the Stage 1&2a drip system and treated effluent drip system) was 282.6 gallons per day, the average calculated Stage 1&2a drip system (STE) flow was 145.3 gallons per day and the average treated effluent drip system (Stage 2b biofilter effluent) flow was 137.2 gallons per day. The calculated Stage 1&2a drip system (STE) flow includes pumped water used for field flushing of the drip lines, which is returned to the septic tank after flushing. This is the reason that the calculated STE flow is considerably higher than the flow measured by the household potable water meter. Actual system treated flow is probably closer to the potable water meter flow value.

The difference between the flow to the Stage 1&2a drip system (STE) and the treated effluent drip system (Stage 2b biofilter effluent) are due to water inputs and outputs. Water inputs include precipitation, applied STE, and any lawn irrigation water collected in the Stage 1&2a lined area. Water outputs include evapotranspiration. The last column in Table 3 summarizes the difference in the Stage 1&2a and treated effluent flows for each time period. The positive values indicate higher treated effluent flow (water inputs) which are likely attributed to precipitation and irrigation water collected in the lined area. The negative values indicate higher Stage 1&2a flow (water outputs) which is likely attributed to evapotranspiration. Overall, there was a net loss of water equal to approximately 8.1 gallons per day.

A weather station (Lake Wayman Heights, Longwood, FL) is located approximately 5 miles from the site. Data from this weather station is available at the following website: http://www.wunderground.com. Recorded meteorological data is provided in Appendix C, Table C.1 from this weather station. Table 4 provides daily precipitation totals leading up to and during the sample event. There was approximately 0.01 inches of rain in the 5 days ending on December 17th.

Table 4
Precipitation Data Daily Totals Measured December 1, 2014 through December 17, 2014
Sample Event No. 8

Date	Precipitation (inches)
12/1/2014	0
12/2/2014	0.01
12/3/2014	0
12/4/2014	0
12/5/2014	0.01
12/6/2014	0.01
12/7/2014	0.11
12/8/2014	0.11
12/9/2014	0
12/10/2014	0
12/11/2014	0
12/12/2014	0
12/13/2014	0.01
12/14/2014	0
12/15/2014	0
12/16/2014	0
12/17/2014	0

4.2 Energy, Chemical and/or Additives Consumption

Energy consumption is monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 5. The total average electrical use through December 17, 2014 was 0.90 kWh per day. The average electrical use per 1,000 gallons treated was 6.168 kWh per 1,000 gallons, and this parameter varies based on the amount of additional pumped flow attributed to precipitation.

Table 5
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use between readings	Average Electrical Use Per Treated Gallon between readings	Average Electrical Use Per 1,000 Gallons Treated between readings
	Cumulative (kWh)	(kWh/day)	(kWh/gal)	(kWh/ 1,000 gal)
7/12/13 14:01	0.6	Start-up	Start-up	Start-up
7/17/13 11:57	1.1	0.10	0.011	10.763
7/29/13 9:52	8.9	0.65	0.036	36.456
8/6/13 9:45	19.1	1.28	0.007	6.692
8/12/13 11:07	27.9	1.45	0.006	6.351
8/15/13 8:48	32.5	1.58	0.008	7.978
9/5/13 15:31	69.6	1.74	0.023	22.959
9/9/13 9:00	82.3	3.41	0.008	7.838
9/17/13 10:12	86.2	0.48	0.006	5.725
9/27/13 8:00	88.8	0.26	0.004	3.975
9/30/13 8:00	90.6	0.60	0.005	4.580
10/11/13 8:30	98.5	0.72	0.004	4.407
10/17/13 11:00	104.7	1.02	0.005	5.430
11/8/13 12:30	121.1	0.74	0.005	5.155
11/27/13 9:10	135.6	0.77	0.005	5.334
12/2/13 8:30	145.1	1.91	0.006	5.823
12/4/13 8:51	146.8	0.84	0.000	0.000
1/23/14 11:00	185.1	0.76	0.006	5.720
1/30/14 9:00	192.3	1.04	0.006	6.352
2/3/14 8:00	197.0	1.19	0.008	8.029
2/4/14 8:15	198.0	0.99	0.011	10.753
2/5/14 10:45	198.6	0.54	0.006	6.266
2/6/14 10:45	199.3	0.73	0.005	4.556
2/7/14 8:00	200.2	0.98	0.006	5.776
2/12/14 10:00	205.7	1.08	0.013	12.760
3/14/14 8:24	228.2	0.75	0.005	5.287
4/3/14 8:45	248.3	1.00	0.007	6.537
4/29/14 10:10	272.5	0.93	0.006	5.702
5/29/14 10:00	290.2	0.59	0.006	6.066
6/9/14 12:45	302.0	1.06	0.006	6.265
7/11/14 14:45	327.3	0.79	0.006	5.903
7/29/14 9:30	347.3	1.12	0.006	5.893
8/22/14 7:30	361.4	0.59	0.006	5.939
9/19/14 12:48	385.1	0.84	0.006	5.658

Table 5 (con't)
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use between readings	Average Electrical Use Per Treated Gallon between readings	Average Electrical Use Per 1,000 Gallons Treated between readings
	Cumulative (kWh)	(kWh/day)	(kWh/gal)	(kWh/ 1,000 gal)
10/23/14 15:45	420.7	1.04	0.007	6.936
11/21/14 9:30	442.5	0.76	0.004	4.043
12/17/14 8:00	469.2	1.03	0.006	5.691
Total average start-up to 12/17/14		0.90	0.006	6.168

4.3 Water Quality

Water quality analytical results, for Sample Event No. 8 are listed in Table 6 and graphically displayed in Figure 11. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results for the Sample Event No. 8. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.

Parameter	STE	Stage 1 effluent LY01	Stage 1 effluent LY02	Stage 1/2a lignocellulosic effluent	Stage 2b sulfur effluent
$CBOD_5$ mg/L	57	24	4	Non-detect	15
TKN mg N/L	52	3.6	4.9	4.2	1.5
NH_3 mg N/L	43	Non-detect	Non-detect	0.7	0.43
NO_x mg N/L	0.4	30.0	40.0	11.0	0.03
TN mg N/L	52.4	33.6	44.9	15.2	1.5
Sulfate mg/L	22	68	77	69	250
Fecal Coliform (Ct/100mL)	68,000	Not analyzed	Not analyzed	3	7

Figure 11
Graphical Representation of Water Quality Results
Sample Event No. 8, December 17, 2014

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured STE total nitrogen (TN) concentration was 52 mg/L, which is within the range that has been typically reported for Florida single family residence STE. The measured STE $CBOD_5$ was 57 mg/L which is in the low end of the typical range.

Stage 1 (Bottom of Sand Layer) Soil Suction Lysimeters (LY01 and LY02): The soil suction lysimeters LY01 and LY02 effluent NH_3-N levels were below the method detection limit of 0.009 mg/L (Table 6). The NO_x-N was 30 mg/L and 40 mg/L for LY01 and LY02, respectively. The Stage 1 biofilter sand layer showed nearly complete ammonium removal and significant removal of total nitrogen with an effluent concentration equal to or less than: NH_3-N below the method detection limit of 0.009 mg/L, NO_x-N of 40 mg/L and TKN of 4.9 mg/L.

Stage 1&2a (Bottom of Lignocellulosic Layer) Liner Effluent (Liner): The lignocellulosic (Stage 1&2a) effluent NH_3-N level was 0.66 mg/L with a DO level at 2.00 mg/L (Table 6). TSS was 2 mg/L, and $CBOD_5$ was below the method detection limit of 2 mg/L. The Stage 1&2a effluent NO_x-N was 11 mg/L. These results indicate nitrate removal by passage through the lignocellulosic/sand layer in the Stage 1&2a lined area (between 63 and 73% reduction of NO_x-N). The combined Stage 1&2a liner area biofilter showed ammonium removal and removal of NO_x-N with an effluent NH_3-N of 0.66 mg/L, NOx-N of 11 mg/L and TKN of 4.2 mg/L.

Stage 2b Biofilter (Sulfur) Effluent (ST2): Effluent NO_x-N from the Stage 2b sulfur media biofilter was 0.03 mg/L with a DO level at 0.1 mg/L and ORP at -215 mV. Final total nitrogen (TN) in the passive nitrogen removal system effluent was 1.53 mg/L. The Stage 2b biofilter effluent $CBOD_5$ concentration was 15 mg/L, TSS was below the method detection limit of 1 mg/L and sulfate was 250 mg/L.

As previously discussed in Section 3.3, Sample Event 8 also included a Stage 2b biofilter sample taken 6 inches within the sulfur media. The BHS3-SULFUR-6 stainless steel drivepoint sampler results from this event indicate that the NO_x-N was effectively reduced to 0.08 mg/L and sulfate concentration was 170 mg/L after passage through 6 inches of the sulfur media.

Treated Effluent Soil Suction Lysimeters (LY03 and LY04): The treated effluent drip system monitoring devices LY03 and LY04 NO_x-N concentrations were 5.6 mg/L and 2 mg/L, respectively, which is higher than the Stage 2b effluent concentration. This has been noted in each sampling event since system start-up. It appears that there must be another source of nitrogen to the effluent irrigation area, and it is suspected that fertilizer from the new sod installed in the area is still contributing to this result. The NO_x-N concentrations did appear to decrease with time following sod installation and in the winter months with less rainfall; however in March and June the NO_x-N concentrations increased possibly from sod fertilizer runoff in the rainy season (Figure 12).

Field Blank and Equipment Blank (FB & EB): Described in Section 3.5, the equipment blank (EB) and field blank (FB) results for most of the parameters measured were at or below the method detection limit. The slightly elevated parameters were TKN, total phosphorus and total organic carbon in both samples.

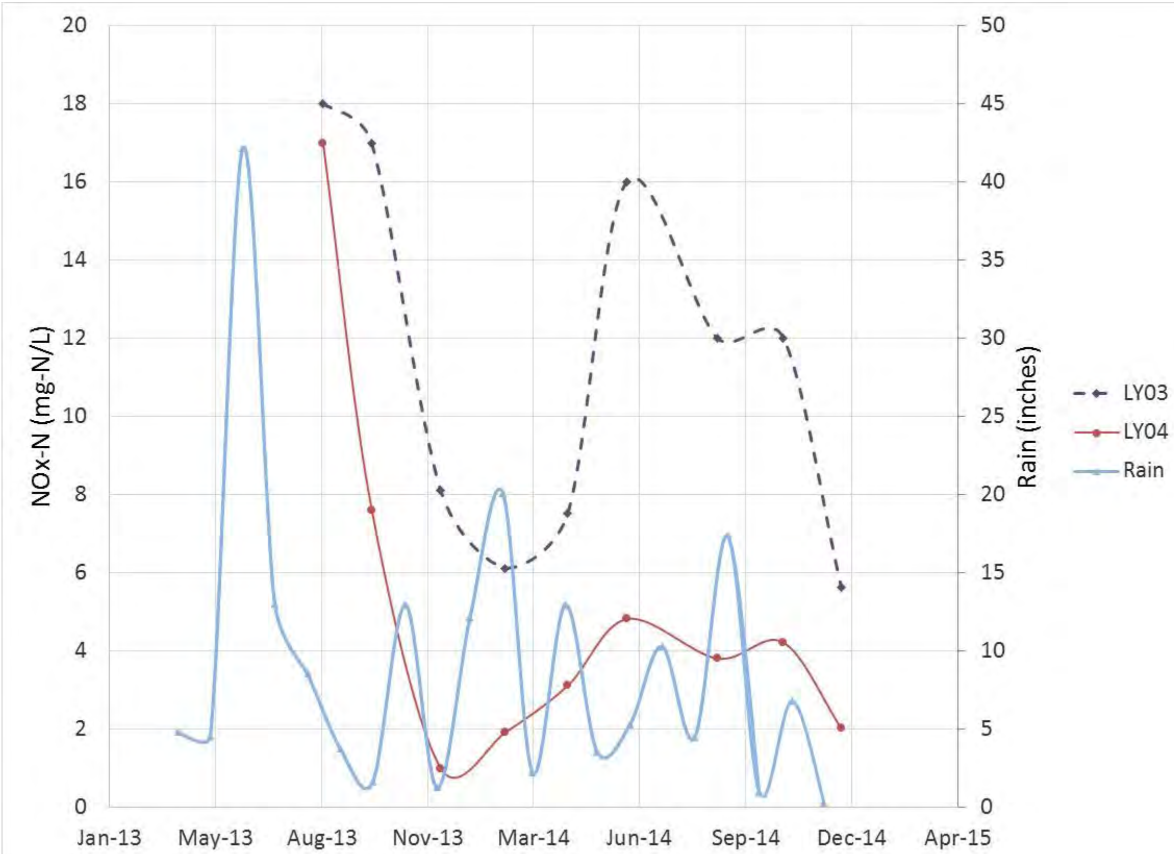

Figure 12
LY03 and LY04 NO_x-N Time Series

Table 6
Sample Event 8 Water Quality Results

Sample ID	Sample Date/Time	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	TSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
BHS3-STE	12/17/2014 9:26	18.27	7.26	1055	0.19	-244.3	18	57	140	52.4	52	9	43	0.34	0.06	0.4	43.4	4.6		22	0.5	1.4	68000	61000	33
BHS3-ST1-LY01	12/17/2014 9:05	15.00	6.90	652	5.73	95.4	1	24	16	33.61	3.6	3.591	0.009	30	0.01	30.01	30.019	0.92		68					15
BHS3-ST1-LY02	12/17/2014 9:20	16.20	6.41	737	6.23	129.9	1	4	31	44.92	4.9	4.891	0.009	40	0.02	40.02	40.029	2.7		77					
BHS3-ST1&2a-LINER	12/17/2014 8:35	18.50	6.80	810	2.00	89.5	2	2	22	15.24	4.2	3.54	0.66	11	0.04	11.04	11.7	0.46		69			3	2	12
BHS3-ST2b-SULFUR-6	12/17/2014 9:06	18.96	6.53	986	1.11	-241.6		38		2.58	2.5	1.77	0.73	0.06	0.02	0.08	0.81			170					
BHS3-ST2b	12/17/2014 8:20	18.49	6.39	1067	0.10	-214.5	1	15	47	1.53	1.5	1.07	0.43	0.02	0.01	0.03	0.46	0.62	39	250	0.57	0.82	7	6.3	15
BHS3-ST2b-DUP	12/17/2014 8:40	18.49	6.39	1067	0.10	-214.5	3	14	56	1.53	1.5	0.92	0.58	0.02	0.01	0.03	0.61	0.66	42	240	0.57	0.82	4	3.1	12
BHS3-LY03	12/17/2014 11:10	18.30	6.64	760	6.05	181.0	1	2	16	7.21	1.6	1.18	0.42	5.6	0.01	5.61	6.03	0.33	25	160		0.1			
BHS3-LY04	12/17/2014 9:30	15.40	6.80	753	6.75	153.8	1	2	12	2.92	0.91	0.901	0.009	2	0.01	2.01	2.019	0.33	27	160		0.1			
BHS3-PZ07	12/17/2014 10:28	18.33	6.29	596	6.61	62.2	2	2	27	2.36	0.95	0.941	0.009	1.4	0.01	1.41	1.419	0.3	20	99	0.01	0.1	1	2	23
BHS3-PZ08	12/17/2014 10:04	18.54	6.56	658	4.01	55.9	91	2	33	1.65	0.83	0.821	0.009	0.81	0.01	0.82	0.829	0.59	24	140	0.01	0.1	1	2	19
BHS3-PZ09	12/17/2014 10:00	18.80	6.41	268	6.08	171.1	150	2	60	6.91	2.1	2.091	0.009	4.8	0.01	4.81	4.819	1.7	5.2	16	1.2	1.4	1	2	46
PZ-A7-6	12/17/2014 11:22	20.14	6.45	702	2.39	64.8				1.88	1.4	1.391	0.009	0.44	0.04	0.48	0.489		22	120					
PZ-A7-8	12/17/2014 11:34	20.85	6.38	461	0.81	26.7				3.23	3.2	2.76	0.44	0.02	0.01	0.03	0.47		11	30					
PZ-B8-5	12/17/2014 11:25	19.70	6.19	507	1.22	-2.8				1.64	1.6	1.43	0.17	0.03	0.01	0.04	0.21		23	55					
PZ-B8-5-DUP	12/17/2014 11:30	20.00	6.13	505	1.22	-2.8				1.65	1.6	1.48	0.12	0.04	0.01	0.05	0.17		21	51					
PZ-C06-5	12/17/2014 12:24	21.25	5.67	478	3.16	70.7				1.53	1.5	1.28	0.22	0.02	0.01	0.03	0.25		21	59					
PZ-C10-6	12/17/2014 12:06	21.91	6.00	276	1.22	37.2				4.62	2.8	2.716	0.084	1.8	0.02	1.82	1.904		5.8	15					
EB	12/17/2014 10:40	17.50	6.00	1.94	8.41	155.0	1	2	10	0.23	0.2	0.191	0.009	0.02	0.01	0.03	0.039	0.18		0.2	0.01	0.1	1	2	3.1
FB	12/17/2014 10:50	18.40	6.01	2.47	8.29	144.8	1	2	10	0.18	0.15	0.141	0.009	0.02	0.01	0.03	0.039	0.2		0.2	0.01	0.1	1	2	0.64

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Groundwater Monitoring Standpipe Piezometers: As discussed in Section 3.2.2, five downgradient groundwater monitoring points installed as part of the C-HS2 groundwater monitoring network were sampled during this event. Figure 13 depicts a site plan of maximum TN concentrations at all locations where groundwater samples were obtained during the four sample events (July 2011 through July 2012) conducted as part of the C-HS2 monitoring events (taken prior to PNRS installation). In addition, illustrated in Figure 13 are two transect cross sections A-A' and B-B'. For comparison, Figure 14 depicts the maximum TN concentration at all locations where groundwater samples were obtained during this sample event (December 17, 2014) along with similar transect cross section A-A'. Figure 15 is a time series plot of total nitrogen concentrations measured at PZ-A7-08, PZ-B8-5 and PZ-C10-6 which shows the highest concentrations during the Task C monitoring. A significant decrease in total nitrogen concentration in the groundwater plume downgradient of the PNRS system has occurred since PNRS system installation (Figure 15).

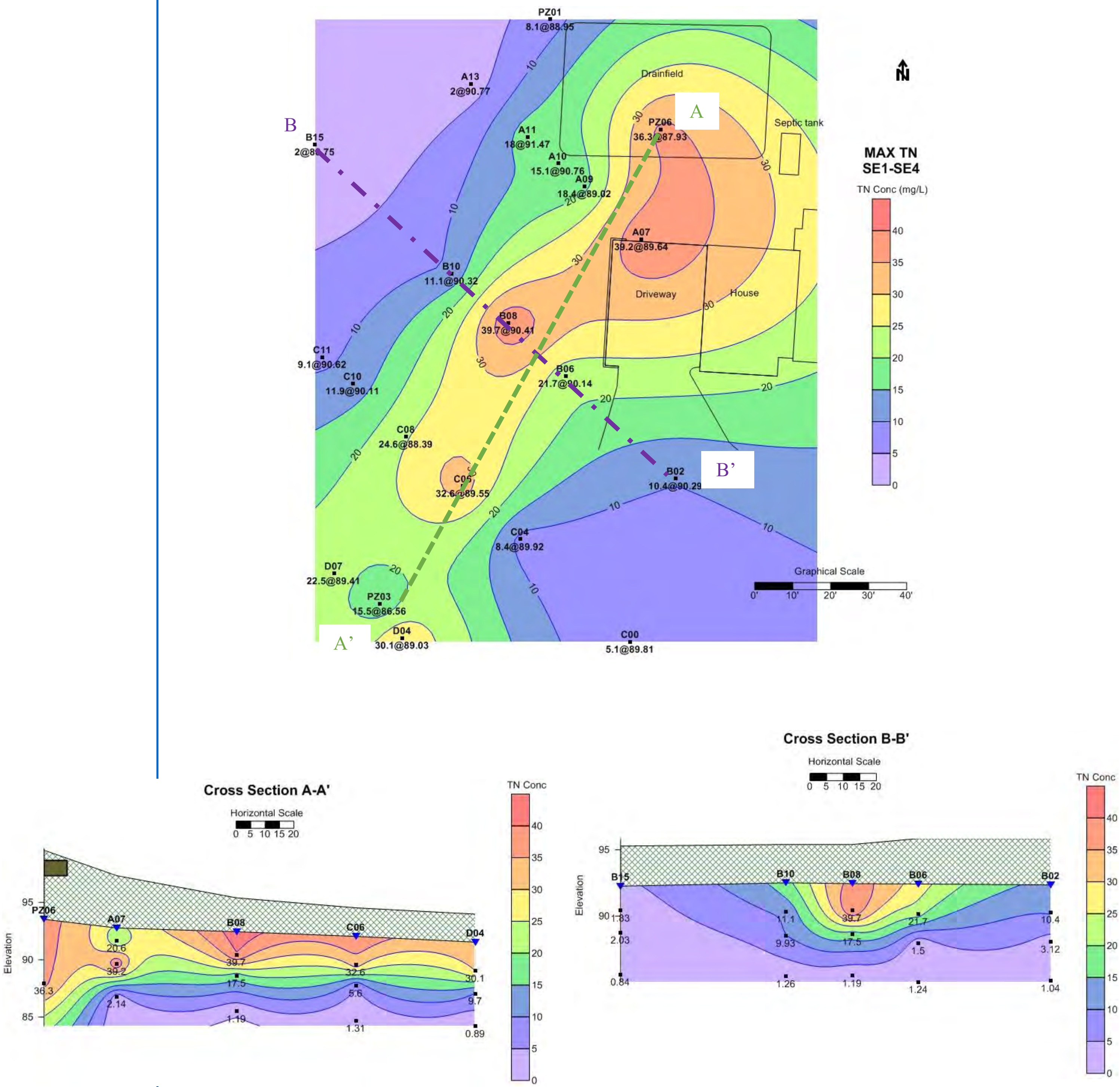

Figure 13
C-HS2 Maximum TN Concentrations (July 2011 through July 2012)

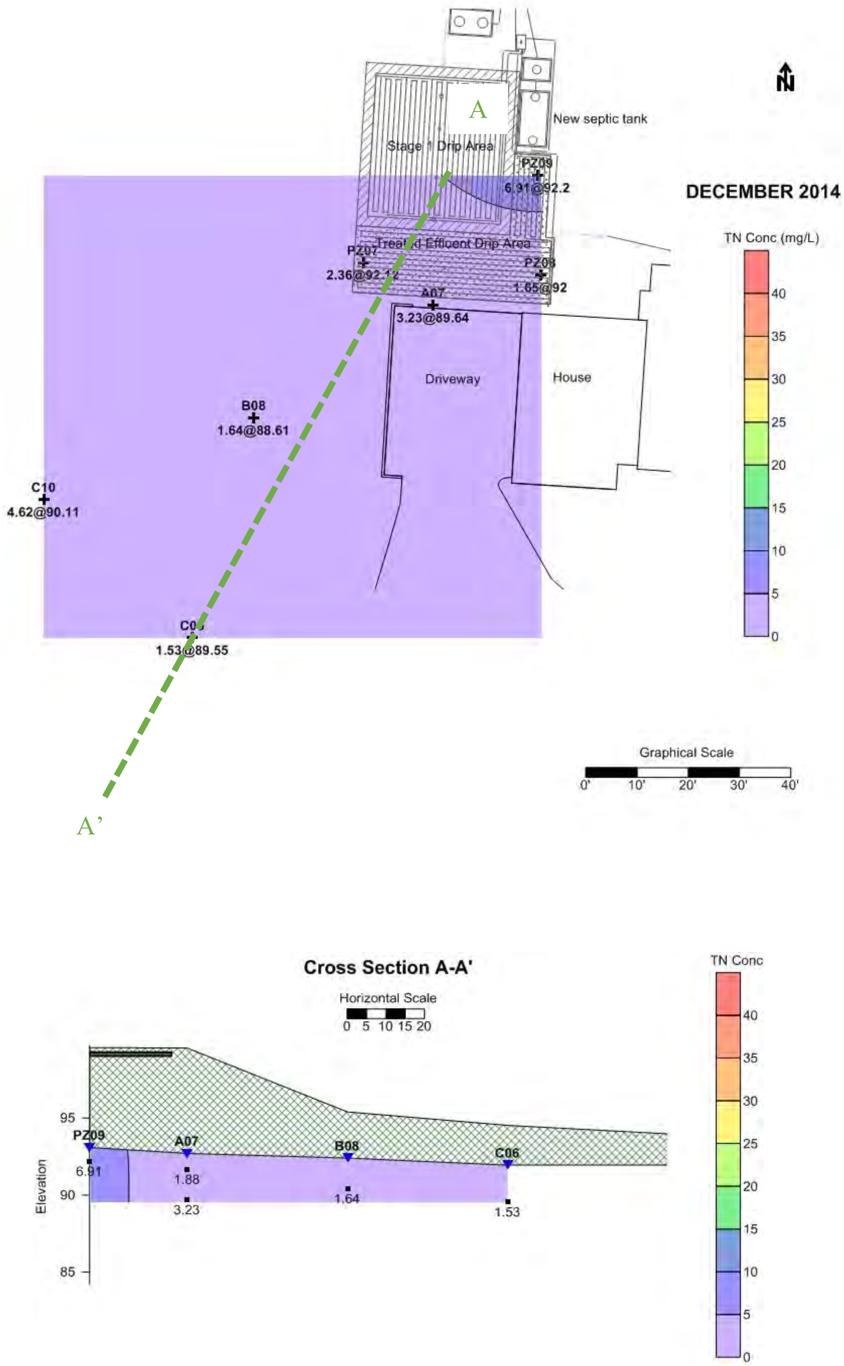

Figure 14
B-HS3 TN Concentrations (December 17, 2014)

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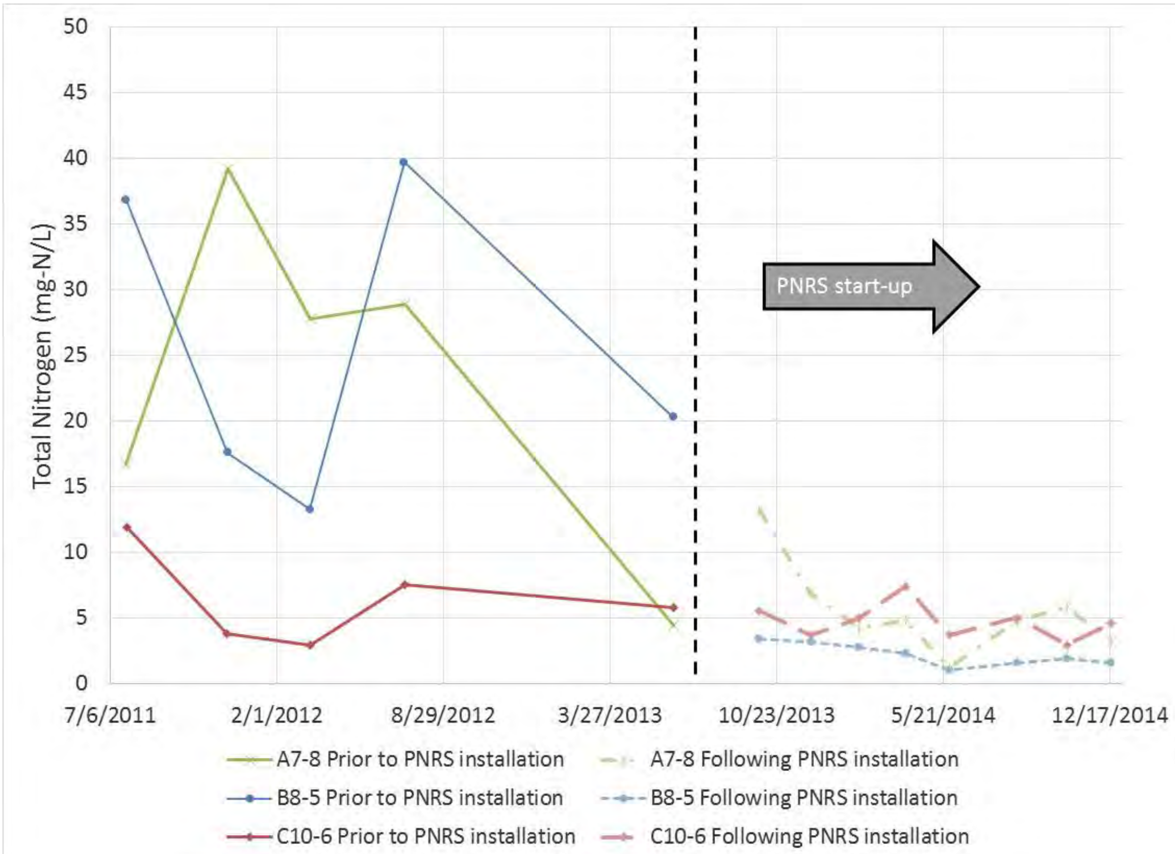

Figure 15
TN Time Series for Various Groundwater Wells

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4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 7. Figure 16 provides a time series of influent and effluent TN over the study period. Figures 17 through 22 show box and whisker plots of the various monitoring points for the key parameters measured during the study period. Both Stage 1 monitoring points (LY01 and LY02) are shown separately, because the total nitrogen and NO_x-N results indicate consistent differences. The reason for the difference is unknown but could be attributed to the location of the ceramic cup relative to the lignocellulosic media, vicinity to a drip emitter, distribution of effluent, or other factors.

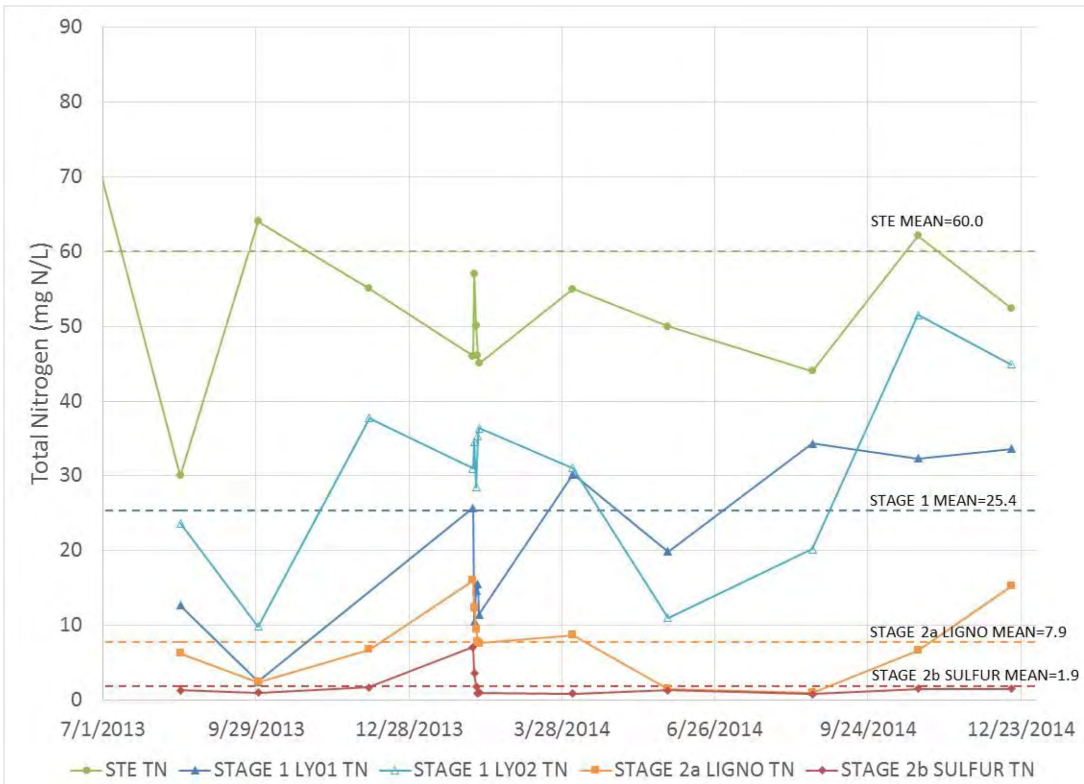

Figure 16
Total Nitrogen Time Series Graph
August 15, 2013 through December 17, 2014

Table 7
Summary of Water Quality Analytical Results

Sample ID	Statistic	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Chloride	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)
STE	n	18	18	18	18	13	16	14	11	14	13	18	18	18	18	16	15	18	18	14	13	15	15	13	13	14	7
	MEAN	23.60	7.27	1090.17	0.30	-288.82	414.38	24.64	21.27	78.29	178.46	59.99	59.83	10.78	49.06	0.09	0.08	0.16	49.22	5.59	4.10	54.20	20.75	3.28	7.91	62,180	28,671
	STD. DEV.	4.00		135.66	0.44	32.22	39.66	13.90	12.60	45.51	72.44	19.01	18.89	11.07	14.80	0.21	0.24	0.42	14.87	1.74	1.51	12.70	12.68	2.80	3.67		
	MIN	18.27	6.88	868.00	0.00	-341.70	330.00	12.00	9.00	42.00	120.00	30.05	30.00	0.00	27.00	0.01	0.01	0.02	27.05	3.50	2.20	39.00	0.82	0.01	1.00	20,000	10,000
	MAX	29.60	7.82	1322.00	1.20	-244.30	490.00	61.00	55.00	210.00	400.00	110.06	110.00	45.00	85.00	0.82	0.94	1.80	85.06	9.00	7.50	87.00	40.00	8.90	12.00	420,000	240,000
Stage 1 LY01	n	12	12	12	11	11	4	6	5	6	11	12	12	12	12	12	12	12	12	11	10	10	11	0	0	0	0
	MEAN	22.54	6.81	553.83	5.97	125.80	91.00	1.50	1.40	9.50	37.64	20.31	1.89	1.84	0.06	18.39	0.02	18.42	18.47	0.27	0.12	38.10	40.64				
	STD. DEV.	4.71		116.88	2.71	93.86	31.84	0.84	0.55	9.07	48.42	10.64	0.73	0.73	0.08	10.31	0.03	10.29	10.30	0.29	0.21	11.92	14.62				
	MIN	15.00	6.33	330.00	0.54	-75.00	55.00	1.00	1.00	2.00	10.00	2.50	0.99	0.93	0.01	1.30	0.01	1.30	1.38	0.05	0.01	15.00	21.00				
	MAX	30.90	7.24	711.00	9.92	301.90	130.00	3.00	2.00	24.00	180.00	34.30	3.60	3.59	0.30	33.00	0.13	33.00	33.01	0.92	0.52	61.00	68.00				
Stage 1 LY02	n	13	13	13	13	13	5	9	8	9	12	13	13	13	13	13	13	13	13	12	11	11	12	0	0	1	1
	MEAN	22.59	6.55	756.62	4.48	113.04	134.80	2.00	1.63	6.00	24.25	30.45	2.34	2.16	0.17	27.99	0.08	28.12	28.29	2.10	1.56	42.27	45.00			1,000	2
	STD. DEV.	4.56		90.31	2.84	79.46	45.88	1.50	1.41	6.87	11.92	12.04	1.27	1.41	0.43	11.69	0.15	11.76	11.82	0.97	0.95	7.70	14.27				
	MIN	14.60	6.18	559.00	0.73	-25.30	74.00	1.00	1.00	2.00	10.00	9.90	1.00	0.10	0.01	7.10	0.01	7.10	7.12	0.18	0.01	23.00	26.00			1,000	2
	MAX	30.20	6.99	871.00	10.23	279.20	180.00	5.00	5.00	23.00	49.00	51.56	4.90	4.89	1.60	47.00	0.47	47.06	47.10	3.20	2.80	52.00	77.00			1,000	2
Stage 1&2a Lignoceullosic Effluent (Liner)	n	13	13	13	13	13	11	12	11	12	12	13	13	13	13	13	13	13	13	12	11	11	11	5	5	12	11
	MEAN	22.91	6.72	730.54	2.66	-1.43	269.09	16.25	8.55	3.83	26.58	7.85	2.07	1.90	0.18	5.76	0.02	5.78	5.96	0.49	0.03	35.09	31.02	0.42	0.66	32	3
	STD. DEV.	4.44		101.04	2.43	93.98	42.06	34.47	12.34	3.66	13.53	4.72	0.82	0.68	0.21	4.36	0.02	4.36	4.44	0.83	0.06	7.78	18.15	0.42	0.60		
	MIN	18.10	6.39	552.00	0.31	-199.70	210.00	1.00	1.00	2.00	10.00	0.99	0.93	0.89	0.04	0.01	0.01	0.02	0.07	0.01	0.01	15.00	5.50	0.01	0.10	1	2
	MAX	31.80	7.15	925.00	9.09	124.50	360.00	125.00	45.00	14.00	60.00	16.01	4.20	3.54	0.66	14.00	0.08	14.01	14.07	2.90	0.22	43.00	69.00	1.10	1.60	6,800	310
Stage 2b Sulfur Effluent (ST2)	n	13	13	13	13	13	11	12	11	12	12	13	13	13	13	13	13	13	13	12	11	12	13	13	13	12	11
	MEAN	22.40	6.79	860.15	0.25	-215.02	274.55	4.33	3.36	14.33	35.25	1.91	1.30	0.97	0.33	0.35	0.26	0.61	0.93	0.21	0.07	36.00	113.85	2.51	4.96	5	3
	STD. DEV.	4.05		100.48	0.26	82.66	27.34	3.23	2.06	21.63	13.01	1.72	0.36	0.33	0.22	0.89	0.64	1.52	1.48	0.24	0.16	7.77	56.50	3.40	5.23		
	MIN	18.49	6.39	653.00	0.01	-299.90	240.00	1.00	1.00	2.00	10.00	0.84	0.82	0.44	0.02	0.01	0.01	0.02	0.04	0.01	0.01	15.00	27.00	0.01	0.10	1	2
	MAX	29.70	7.15	1067.00	0.91	38.20	310.00	12.00	6.00	81.00	50.00	7.10	1.80	1.58	0.87	3.20	2.10	5.30	5.52	0.62	0.51	45.00	250.00	12.00	16.00	300	10
Treated Effluent LY03	n	9	9	9	9	9	4	6	5	6	8	9	9	9	9	9	9	9	9	8	7	8	9	4	5	1	1
	MEAN	24.05	6.47	723.19	5.14	146.46	182.40	2.17	2.40	21.00	40.75	13.64	2.27	2.17	0.10	11.37	0.01	11.37	11.47	0.18	0.06	26.50	96.56	0.24	0.28	1	2
	STD. DEV.	3.06		257.32	1.90	46.10	116.06	1.47	1.52	43.67	45.91	5.23	0.63	0.71	0.14	4.80	0.01	4.80	4.77	0.07	0.06	9.24	34.27	0.29	0.27		
	MIN	18.30	6.27	75.70	2.05	103.30	9.60	1.00	1.00	2.00	10.00	7.21	1.60	1.18	0.01	5.60	0.01	5.61	6.03	0.09	0.01	13.00	50.00	0.01	0.10	1	2
	MAX	29.00	6.64	934.00	9.09	248.70	250.00	4.00	4.00	110.00	150.00	21.60	3.60	3.57	0.42	18.00	0.05	18.00	18.04	0.33	0.13	38.00	160.00	0.60	0.71	1	2
Treated Effluent LY04	n	9	9	9	9	9	6	6	5	7	8	9	9	9	9	9	9	9	9	8	7	8	9	3	4	1	1
	MEAN	24.12	6.49	767.89	4.69	128.40	220.00	1.17	1.20	3.43	25.88	6.64	1.59	1.55	0.04	5.04	0.01	5.05	5.09	0.13	0.02	25.51	95.78	0.28	0.30	1	2
	STD. DEV.	3.93		68.47	2.52	58.10	38.99	0.41	0.45	2.70	13.87	5.89	1.03	1.01	0.04	4.89	0.00	4.89	4.91	0.11	0.02	13.49	37.48	0.24	0.25		
	MIN	15.40	6.21	619.00	1.41	66.20	160.00	1.00	1.00	2.00	12.00	1.79	0.80	0.79	0.01	0.99	0.01	0.99	1.00	0.01	0.01	0.05	40.00	0.01	0.10	1	2
	MAX	29.40	6.80	821.00	9.98	265.50	270.00	2.00	2.00	9.00	56.00	21.00	4.00	3.91	0.10	17.00	0.01	17.00	17.09	0.33	0.06	42.00	160.00	0.48	0.60	1	2
Groundwater PZ07	n	7	7	7	7	7	4	5	4	6	6	7	7	7	7	7	7	7	7	6	5	6	6	5	5	4	4
	MEAN	25.01	6.39	713.00	3.99	37.89	225.00	5.40	4.25	2.83	29.50	6.10	1.83	1.67	0.16	4.24	0.03	4.27	4.43	0.21	0.08	22.00	75.50	0.23	0.30	1	2
	STD. DEV.	5.40		120.08	2.06	145.50	60.28	4.72	2.75	1.33	10.99	4.08	1.09	0.87	0.26	3.24	0.05	3.21	3.32	0.12	0.07	9.06	30.12	0.15	0.14		
	MIN	18.33	6.18	516.00	0.59	-248.70	160.00	1.00	1.00	2.00	10.00	2.36	0.84	0.83	0.01	1.40	0.01	1.41	1.42	0.04	0.01	15.00	35.00	0.01	0.10	1	2
	MAX	34.70	6.74	833.00	6.61	189.60	290.00	11.00	7.00	5.00	43.00	12.30	4.00	3.26	0.74	10.00	0.15	10.00	10.08	0.37	0.17	40.00	120.00	0.35	0.41	1	2

Table 7 (con't)
Summary of Water Quality Analytical Results

Sample ID	Statistic	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Chloride	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)
Groundwater PZ08	n	7	7	7	7	7	4	5	4	6	6	7	7	7	7	7	7	7	7	6	5	6	6	6	6	5	5
	MEAN	23.65	6.26	655.86	3.57	73.56	167.50	30.00	7.25	4.33	31.67	7.34	1.47	1.24	0.23	5.86	0.01	5.87	6.10	0.44	0.23	21.12	81.67	0.09	0.17	2	2
	STD. DEV.	4.12		157.71	1.36	64.30	26.30	35.80	5.74	3.83	14.50	7.04	0.74	0.92	0.56	6.39	0.01	6.39	6.41	0.12	0.18	10.89	43.79	0.13	0.12		
	MIN	18.54	5.67	492.00	2.12	-21.90	130.00	4.00	2.00	2.00	10.00	1.65	0.83	0.00	0.01	0.81	0.01	0.82	0.83	0.29	0.05	7.70	35.00	0.01	0.10	1	2
	MAX	29.70	6.56	962.00	5.67	186.00	190.00	91.00	14.00	11.00	50.00	21.50	2.50	2.48	1.50	19.00	0.04	19.00	19.02	0.59	0.48	40.00	140.00	0.32	0.41	10	2
Groundwater PZ09	n	6	6	6	6	6	3	4	3	4	5	6	6	6	6	6	6	6	6	5	4	5	5	5	5	4	4
	MEAN	24.88	5.83	462.17	4.08	137.18	116.67	60.25	13.33	2.00	97.00	10.88	2.05	2.02	0.03	8.82	0.01	8.83	8.86	2.04	1.72	17.56	49.50	0.66	0.76	1	2
	STD. DEV.	3.92		153.60	1.95	98.85	5.77	67.36	9.71	0.00	113.83	5.67	0.71	0.69	0.03	5.08	0.00	5.07	5.10	1.42	1.31	15.03	44.93	0.34	0.38		
	MIN	18.80	5.09	268.00	0.62	38.30	110.00	6.00	5.00	2.00	35.00	1.86	1.00	0.99	0.01	0.84	0.01	0.86	0.87	1.00	0.73	3.60	4.50	0.37	0.41	1	2
	MAX	28.90	6.41	629.00	6.08	256.40	120.00	150.00	24.00	2.00	300.00	17.10	3.10	3.03	0.07	14.00	0.02	14.00	14.07	4.50	3.50	41.00	110.00	1.20	1.40	1	2
Groundwater PZA7-6	n	12	12	12	12	8	9	0	0	0	3	12	12	12	12	9	8	12	12	2	1	10	9	0	0	1	1
	MEAN	23.23	6.09	516.25	2.22	43.09	114.67				186.67	4.07	1.77	1.62	0.15	0.41	0.02	2.30	2.45	0.62	1.00	22.17	58.24			1	2
	STD. DEV.	3.23		178.44	1.87	99.17	49.59				15.28	5.80	1.07	1.03	0.11	0.57	0.02	5.03	5.07	0.51		10.05	40.90				
	MIN	18.50	5.80	242.00	0.09	-51.40	58.00				170.00	0.58	0.56	0.44	0.01	0.01	0.01	0.02	0.04	0.26	1.00	5.70	0.20			1	2
	MAX	28.00	6.45	702.00	5.50	249.90	190.00				200.00	20.60	3.60	3.30	0.35	1.70	0.06	17.00	17.30	0.98	1.00	42.00	120.00			1	2
Groundwater PZA7-8	n	13	13	13	13	8	10	0	0	0	4	13	13	13	13	11	11	13	13	2	2	11	10	0	0	1	1
	MEAN	23.49	6.02	548.69	0.81	-14.08	108.30				90.50	12.42	3.05	2.27	0.78	6.07	0.03	9.38	10.16	5.00	3.00	22.45	46.90			1	2
	STD. DEV.	2.28		149.25	0.81	97.12	102.79				57.88	12.16	1.48	1.24	1.19	8.25	0.04	11.85	11.97	0.42	1.41	11.53	21.05				
	MIN	20.00	5.60	186.00	0.11	-200.20	2.00				36.00	1.24	0.89	0.58	0.01	0.02	0.01	0.03	0.47	4.70	2.00	3.90	14.00			1	2
	MAX	26.90	6.38	784.00	2.91	115.30	270.00				150.00	39.20	5.80	4.87	4.10	23.00	0.12	37.00	37.01	5.30	4.00	40.00	84.00			1	2
Groundwater PZB8-5	n	13	13	13	13	8	10	0	0	0	5	13	13	13	13	12	11	13	13	2	3	11	12	0	0	1	1
	MEAN	23.52	5.85	468.00	0.97	61.89	81.10				86.20	11.20	2.62	2.48	0.15	5.87	0.05	8.58	8.73	0.75	0.70	23.27	43.67			1	2
	STD. DEV.	2.84		80.98	0.94	86.19	46.30				51.74	13.67	1.09	1.18	0.16	9.16	0.06	12.84	12.77	0.92	0.26	6.50	22.01				
	MIN	19.70	5.50	296.00	0.10	-41.10	21.00				0.00	1.02	1.00	0.72	0.03	0.01	0.01	0.02	0.10	0.10	0.49	13.00	0.00			1	2
	MAX	29.00	6.19	586.00	3.51	213.30	180.00				130.00	39.70	4.70	4.67	0.64	28.00	0.18	35.00	35.03	1.40	0.99	34.00	76.00			1	2
Groundwater PZB8-7	n	12	12	12	11	7	9	0	0	0	4	12	12	12	12	8	8	12	12	2	0	10	7	0	0	1	1
	MEAN	23.76	5.88	349.92	1.03	104.07	51.89				55.25	5.79	1.60	1.46	0.15	2.34	0.06	4.19	4.34	0.50		28.99	16.14			1	2
	STD. DEV.	2.24		87.33	1.75	68.30	25.17				23.82	6.38	0.57	0.60	0.21	5.54	0.10	5.92	5.93	0.38		11.60	10.68				
	MIN	20.84	5.46	249.00	0.10	32.10	2.00				36.00	0.77	0.75	0.60	0.01	0.01	0.01	0.02	0.10	0.23		6.90	4.00			1	2
	MAX	27.80	6.14	518.00	6.19	207.00	93.00				90.00	18.00	2.50	2.36	0.73	16.00	0.30	16.00	16.02	0.77		44.00	30.00			1	2
Groundwater PZC10-6	n	13	13	13	13	8	10	0	0	0	4	13	13	13	13	10	9	13	13	2	1	11	9	0	0	1	1
	MEAN	24.15	5.92	364.90	1.18	26.61	119.20				97.75	5.40	3.48	2.86	0.62	1.19	0.02	1.92	2.54	0.10	0.01	15.83	13.93			1	2
	STD. DEV.	2.85		147.63	1.19	100.70	97.54				17.75	2.45	0.73	0.76	0.47	1.10	0.04	2.52	2.54	0.02		8.83	6.81				
	MIN	19.19	5.10	200.70	0.10	-70.70	15.00				77.00	2.98	2.70	1.50	0.08	0.01	0.01	0.02	0.21	0.08	0.01	5.80	4.00			1	2
	MAX	29.00	6.30	689.00	3.78	230.00	270.00				120.00	11.90	5.00	4.75	1.40	2.80	0.12	9.20	9.51	0.11	0.01	32.00	23.00			1	2

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

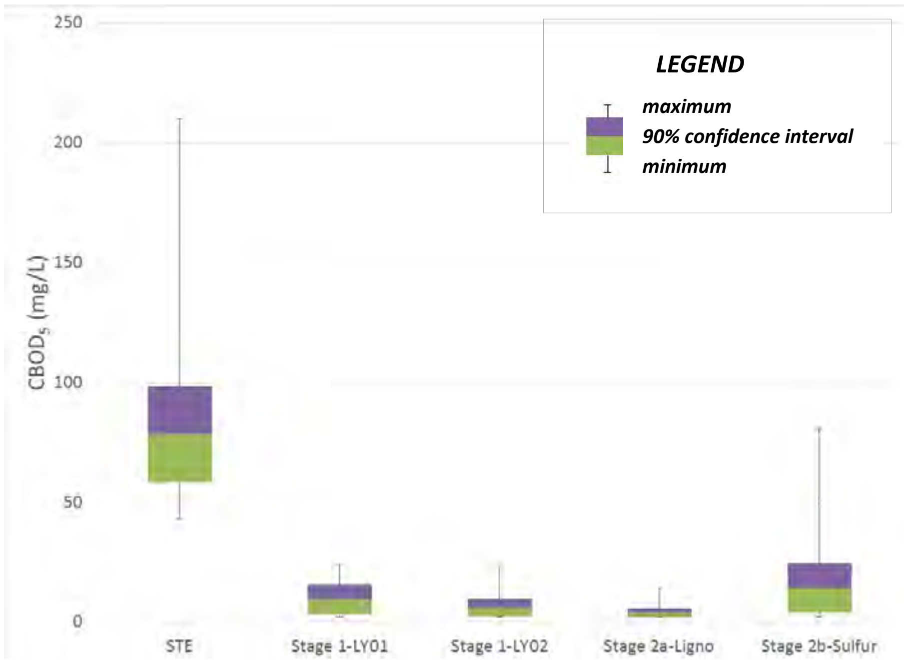

Figure 17
CBOD5 Box and Whisker Plot

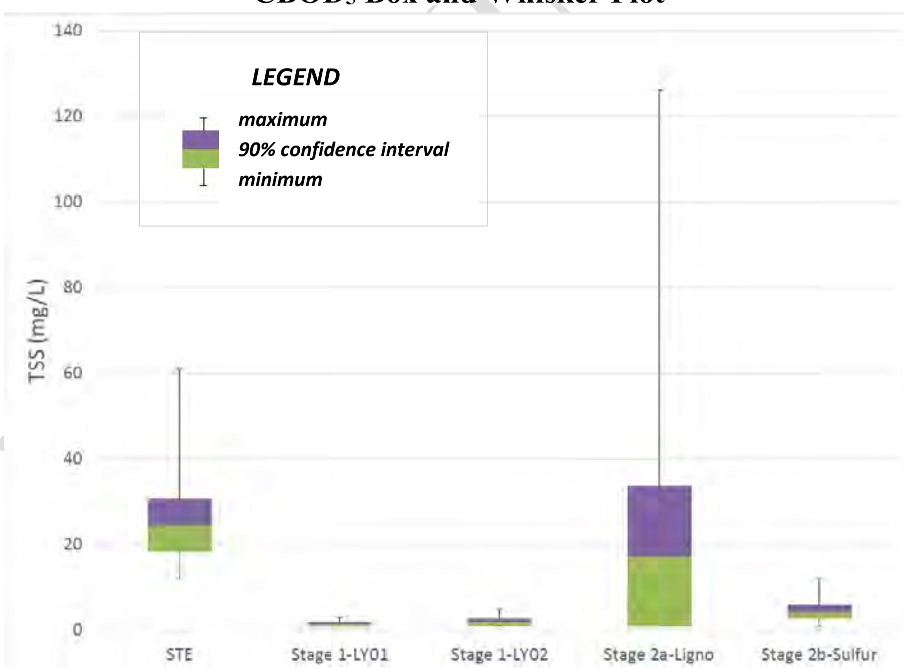

Figure 18
TSS Box and Whisker Plot

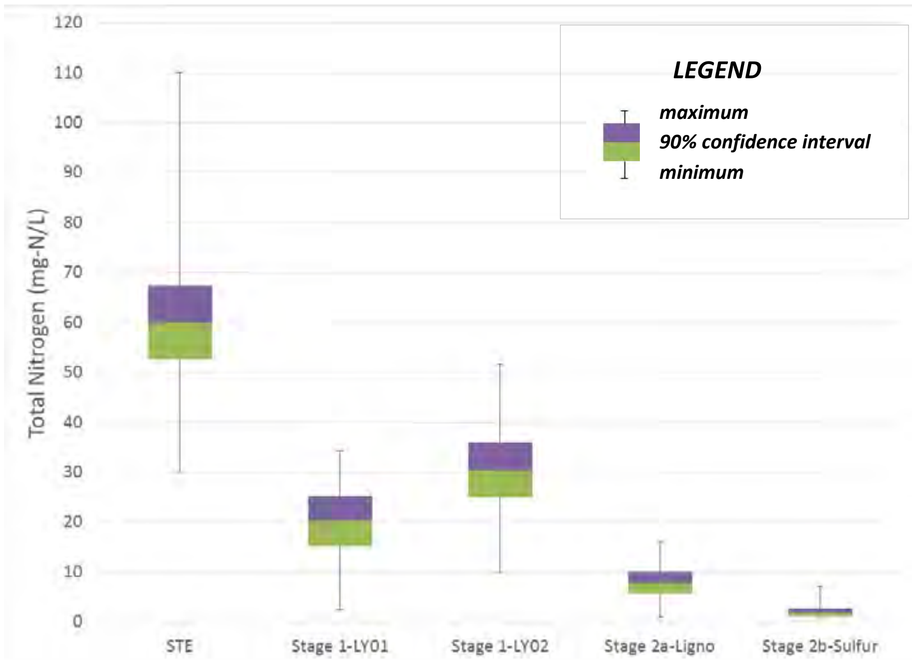

Figure 19
Total Nitrogen (TN) Box and Whisker Plot

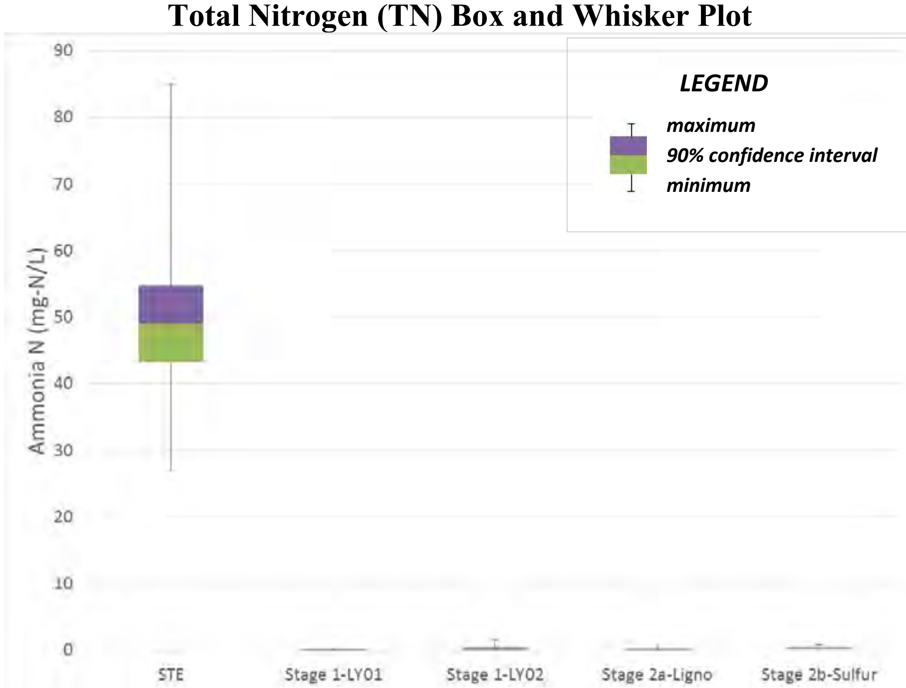

Figure 20
Ammonia N (NH3-N) Box and Whisker Plot

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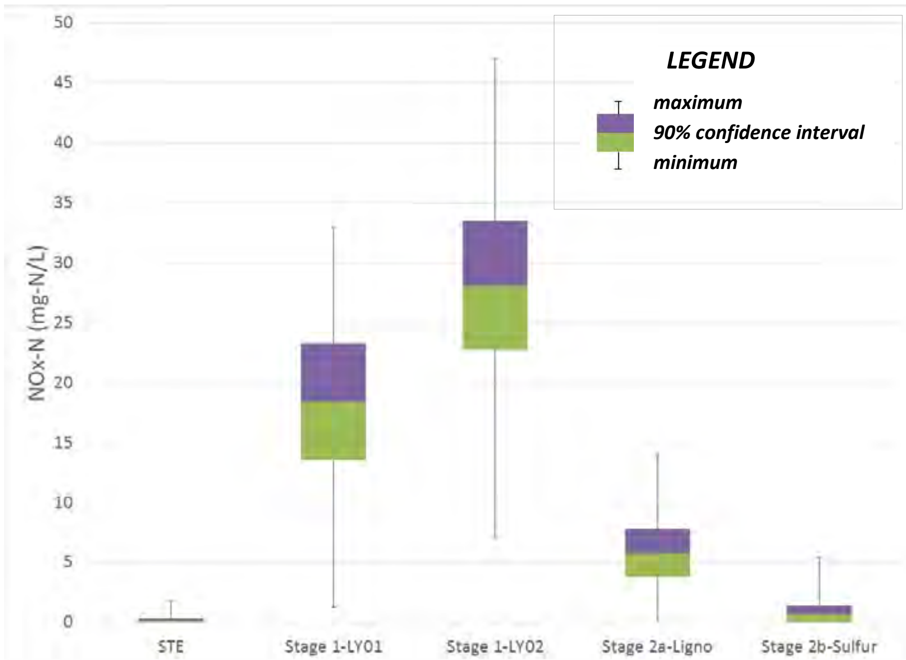

Figure 21
Nitrate+Nitrite Nitrogen (NO_X-N) Box and Whisker Plot

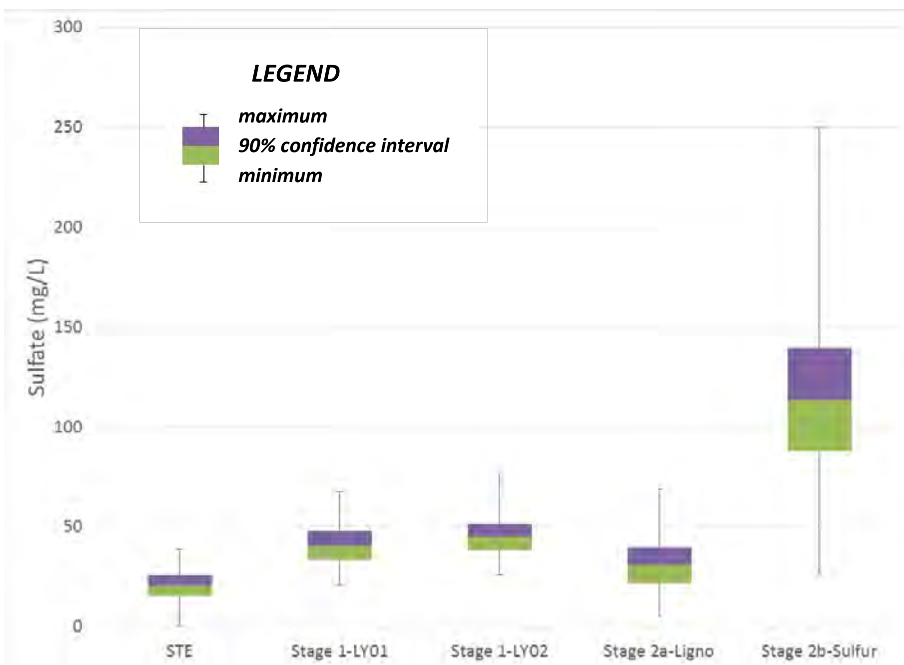

Figure 22
Sulfate (SO_4) Box and Whisker Plot

5.0 B-HS3 Sample Event No. 8: Summary and Recommendations

5.1 Summary

The results of the eighth sampling event indicate that the system is operating well and no adjustments are recommended at this time. The Sample Event No. 8 results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of 52 mg/L is within the range of values typically reported for Florida single family residence STE. However, the $CBOD_5$ concentration of 57 mg/L is in the low end of the typical range of values.

- The combined Stage 1&2a lined drip system with lignocellulosic media was effective in converting ammonium to oxidized nitrogen; effluent contained 4.2 mg/L TKN, of which 0.66 mg/L was ammonia. The Stage 2a layer of lignocellulosic media produced a reducing environment and effluent NO_x-N was 11 mg/L.

- The Stage 2b sulfur media biofilter effluent NO_x-N was 0.03 mg/L.

- The total nitrogen concentration in the final effluent from the total treatment system was approximately 1.5 mg/L, an approximately 97% reduction from STE.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS3 treatment system. Section 4.4 summarized the water quality data collected over the 1.4 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 60 mg/L is in the range of values typically reported for Florida single family residence STE.

- The combined Stage 1&2a lined drip system with lignocellulosic media provided significant ammonia removal with an average NH_3-N concentration of 0.2 mg/L and average TKN of 2.1 mg/L. The average Stage 1&2a biofilter effluent NO_x-N was 5.8 mg/L. These results indicate significant NO_x-N removal (approximately 87% total nitrogen reduction) was occurring.

- The Stage 2b biofilter with sulfur media was effective in producing a reducing environment and achieving significant NO_x-N removal (average NO_x-N concentration of 0.61 mg/L). The average final total nitrogen (TN) in the treatment system effluent was 1.9 mg/L, primarily TKN (average TKN concentration of 1.3 mg/L). This represents a 96 percent average reduction in total nitrogen from STE for this PNRS system over the study period.

- Additional monitoring of the downgradient groundwater monitoring points installed as part of the C-HS2 groundwater monitoring network showed a significant decrease in total nitrogen concentration in the groundwater plume downgradient of the PNRS system following PNRS system installation.

Further analysis of the results obtained at this site will occur as Task B results are compiled and summarized. The results of the data collected to date have provided insights into the performance of a full-scale passive single pass nitrogen reduction system monitored over an extended timeframe (523 experimental days) under actual onsite conditions.

Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS4 Field System
Monitoring Report No. 8

Prepared for:

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

FDOH Contract CORCL

December 2014

Prepared by:

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AET
Applied Environmental Technology

B-HS4 Field System Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in Task A.26. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth and final sample event of the passive nitrogen reduction system at home site B-HS4 in Seminole County, Florida.

2.0 Purpose

Operation of the B-HS4 system was initiated on July 9, 2013. This monitoring report documents data collected from the eighth B-HS4 monitoring and sampling event conducted on December 16, 2014 (Experimental Day 525). This monitoring event consisted of conducting flow measurements from the household water use meter, recording electricity use, monitoring of field parameters, collection of water samples from nine points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory.

3.0 Materials and Methods

3.1 Project Site

The B-HS4 field site is located in Seminole County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in June 2013. Design and construction details were presented previously in the Task B.6 document. Figure 1 is a system schematic showing the system components and layout of the installation. A flow schematic of the system is shown in Figure 2. Prior to the installation of the nitrogen removal system, the property had two existing onsite sewage treatment and disposal systems. The pre-existing 1,200 gallon concrete septic tank, located on the west side of the property, continues to provide primary treatment, now as part of the PNRS system. The pre-existing 900 gallon septic tank, located on the northeast side of the property, was converted to a lift station. In the new configuration, raw sewage is pumped from the 900 gallon lift station to the head end of the new gravity flow PNRS. All subsequent flow through the PNRS is by gravity. The passive nitrogen reduction system consists of the septic tank, two treatment tanks and a new drainfield that replaced the two existing permitted systems. The B-HS4 PNRS tankage includes a 2,800 gallon concrete tank that houses a Stage 1 unsaturated media biofilter and 1,500 gallon two chamber concrete tank that houses a Stage 2 saturated media biofilter. Based on measured average wastewater flow and tank volumes, there is over a ten day transit time through the treatment system prior to dispersal. The treated effluent from the Stage 2 biofilter is discharged into the soil via the new drainfield (EQ36-LP™ chambers).

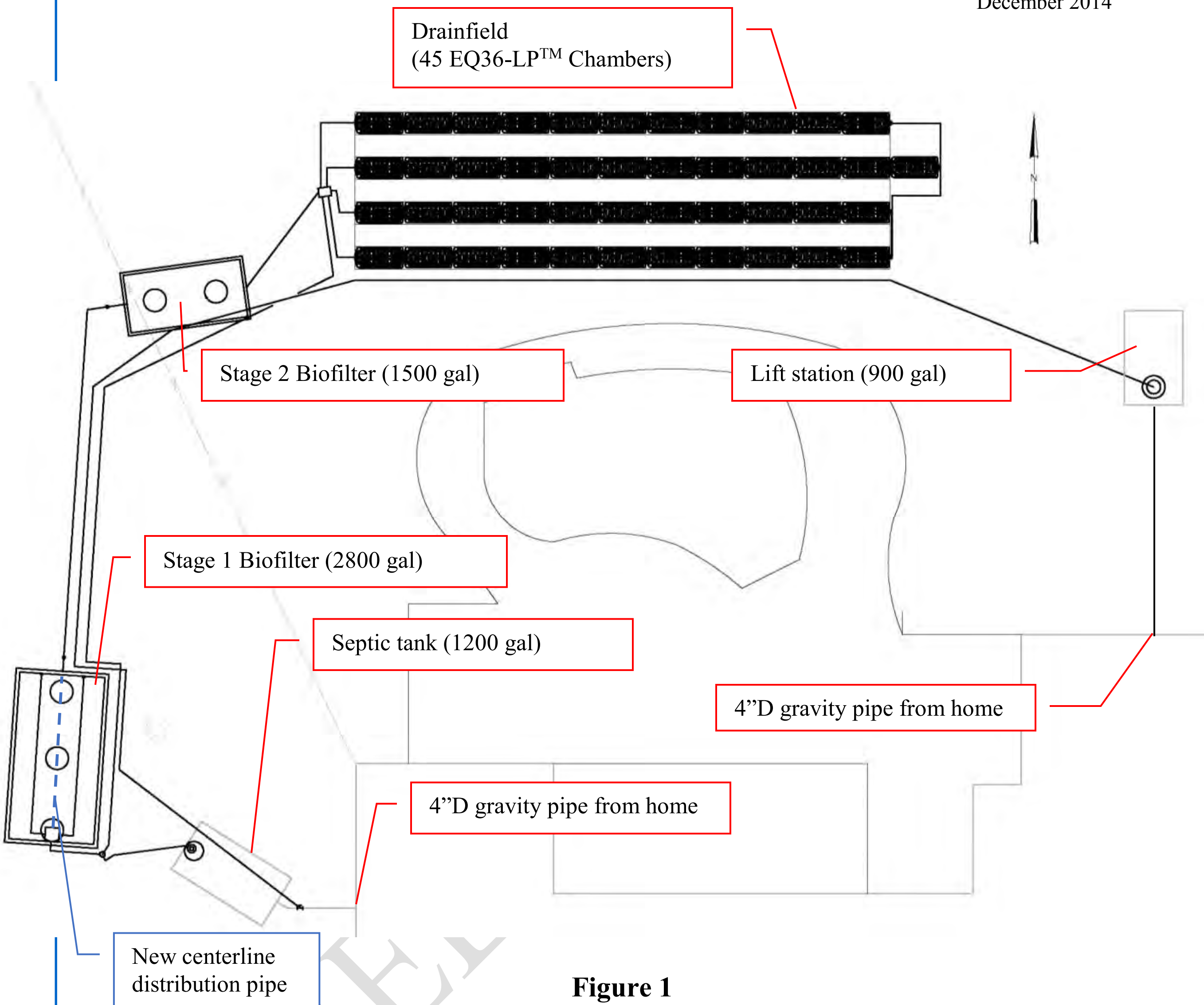

Figure 1
Plan View of B-HS4 System Layout

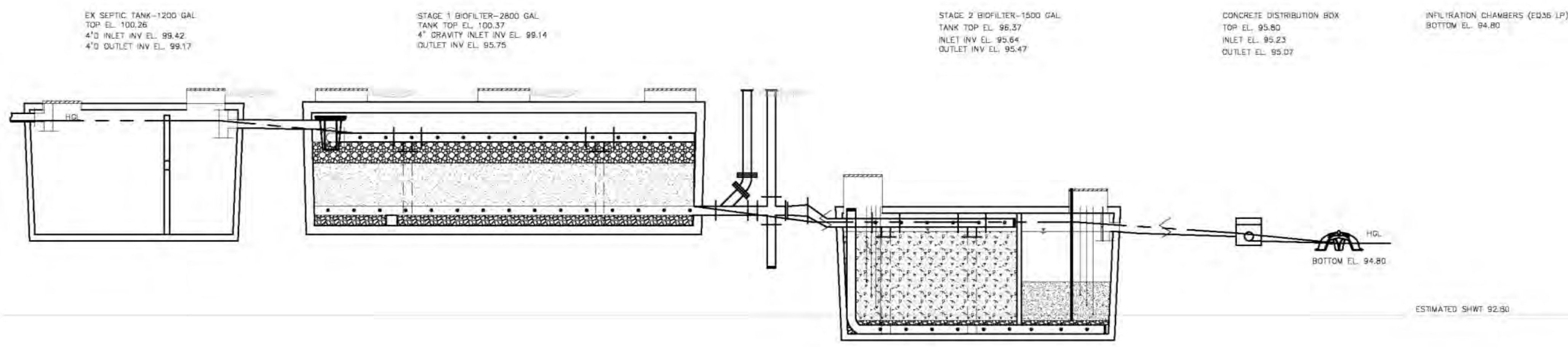

Figure 2
Flow Schematic of B-HS4 PNRS

3.2 Monitoring and Sample Locations and Identification

The nine monitoring points are shown in Figure 3. Household wastewater enters the primary tank and exits as septic tank effluent through an effluent filter screen into the Stage 1 biofilter. The first monitoring point, B-HS4-STE, is the effluent sampled approximately 1.5 feet below the surface of the primary tank before the effluent filter screen (Figure 4), which is referred to as primary effluent or septic tank effluent (STE). The lift station wastewater is pumped into the inlet side of the primary tank; therefore, samples from monitoring point B-HS4-STE are representative of the whole household wastewater and are the influent to the remainder of the onsite nitrogen reduction system.

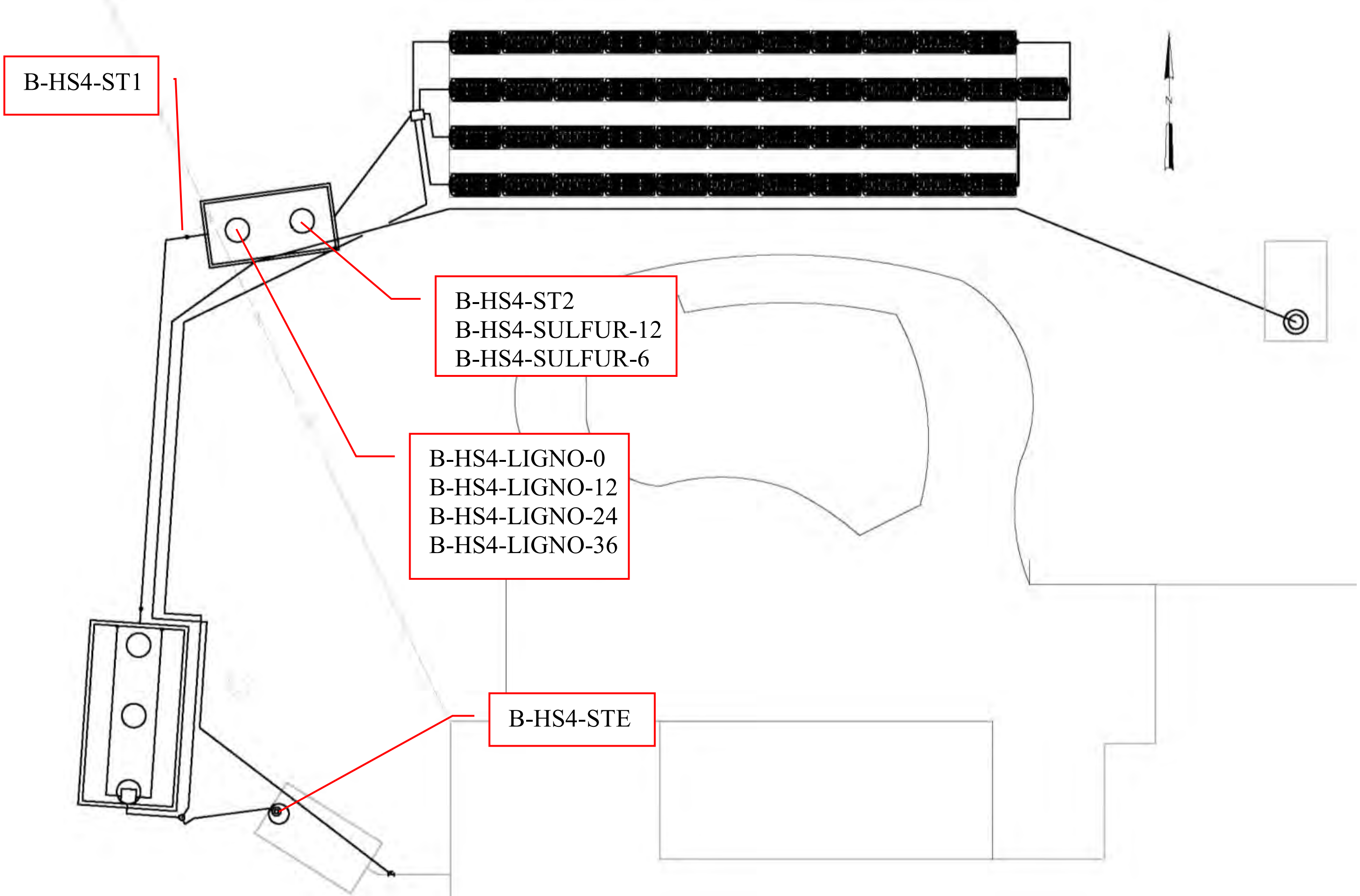

Figure 3
B-HS4 Sample and Monitoring Locations

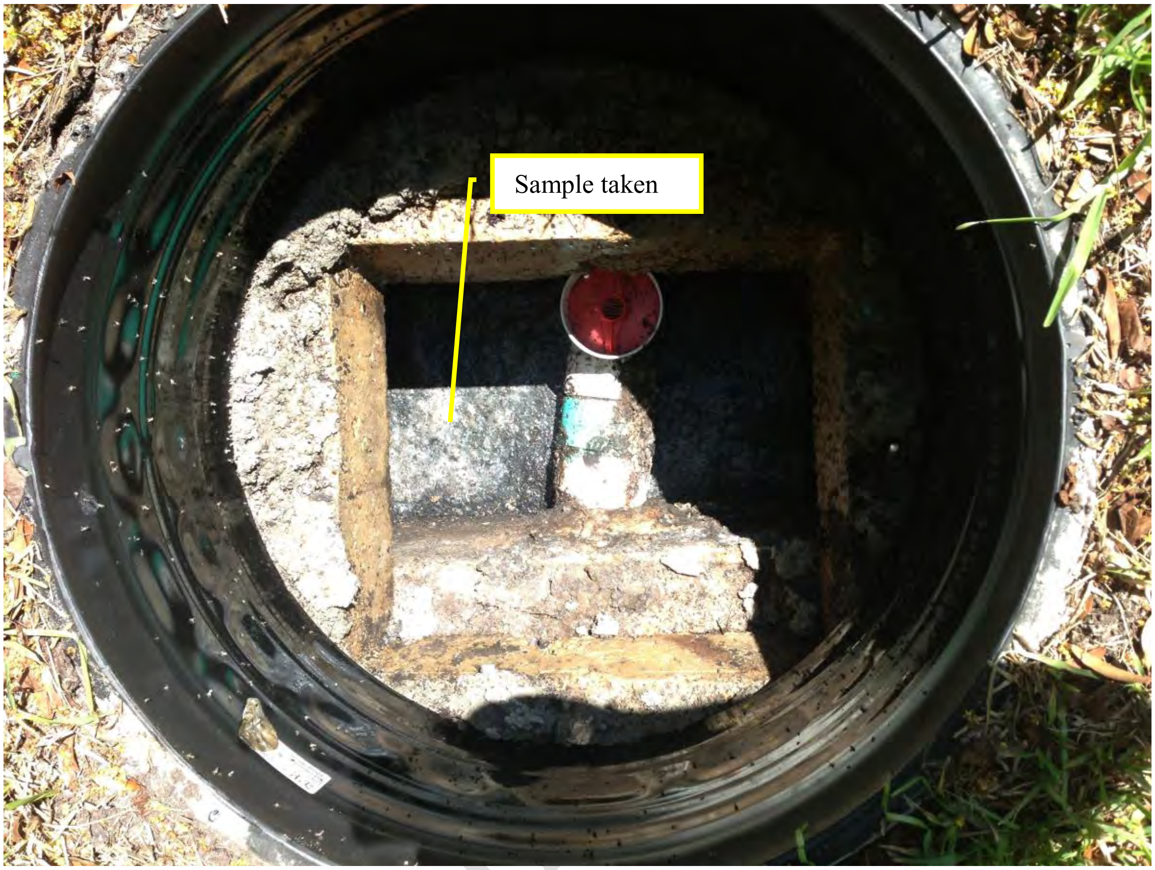

Figure 4
Primary Tank (B-HS4-STE Sample)

The primary tank contents are discharged by gravity to a distribution box, located inside the Stage 1 biofilter, which splits the flow between three perforated distribution pipes which run along the top of the unsaturated Stage 1 biofilter media. In the Stage 1 biofilter, wastewater percolates downward through 30-inches of unsaturated expanded clay media where nitrification occurs. Stage 1 biofilter effluent flows into the Stage 2 biofilter by gravity. The second sampling point (B-HS4-ST1) represents the Stage 1 biofilter effluent, and is taken from a sample port in the gravity pipe connecting the Stage 1 biofilter outlet to the Stage 2 biofilter inlet (Figure 3).

Effluent from the unsaturated (Stage 1) media tank enters the saturated denitrification (Stage 2) biofilter above the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally in a perforated 4-inch pipe through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell).

The first chamber of the Stage 2 biofilter contains 42-inches of lignocellulosic media (Southern Yellow Pine (SYP)). Stainless steel samplers are positioned at 12-inch increments for vertical profiling throughout the lignocellulosic media. The third primary sampling point is a stainless steel sampler positioned at the bottom of the lignocellulosic media (B-HS4-LIGNO-0) with tubing to the surface. Twelve inches above B-HS4-LIGNO-0 is another stainless steel drivepoint sampler B-HS4-LIGNO-12, and so forth (B-HS4-LIGNO-24 and B-HS4-LIGNO-36). The B-HS4-LIGNO-0 sample represents the lignocellulosic media effluent (Figure 5).

Figure 5
First Chamber of Stage 2 Biofilter (B-HS4-LIGNO-0 Sample)

A collection pipe along the bottom transfers the first chamber (lignocellulosic media) effluent to the second chamber, which contains 18-inches of elemental sulfur mixed with oyster shell media. Similar to the lignocellulosic media chamber, stainless steel drive-point samplers are positioned to create a vertical profile. B-HS4-SULFUR-6 and B-HS4-SULFUR-12 are positioned 6-inches and 12-inches, respectively, above the bottom of the sulfur media. The fourth primary sampling point, B-HS4-ST2, is the second chamber of the Stage 2 biofilter effluent which is sampled approximately 1 foot below the surface of the effluent baffle tee. This sample location is after passage through the sulfur media; it is the final effluent from the treatment system prior to being discharged to the soil infiltration system, or drainfield (Figure 6).

Figure 6
Second Chamber of Stage 2 Biofilter (B-HS4-ST2 Sample)

3.3 Operational Monitoring

Start-up of the system occurred on July 9, 2013 (Experimental Day 0). Preliminary sampling for several key parameters was conducted July 29, 2013 (Experimental Day 20) to evaluate start-up performance. It was noted during sampling that the incoming lift station wastewater flow into the primary tank was causing mixing in the primary tank and the carryover of solids into the Stage 1 biofilter d-box. Therefore, the PNRS system was bypassed on August 15, 2013. On September 5, 2013 a smaller pump (lower horsepower) was installed in the lift station with a mechanical float switch. This modification results in more frequent and lower volume doses from the lift station to the primary tank and reduced mixing within the primary tank. The PNRS system has operated continually since September 5, 2013 (Experimental Day 58). For the eighth formal sampling event, Sample Event No. 8, the water meter for the house was read and recorded on December 16, 2014. The household water meter is located on the potable water line from the onsite well prior to entering the household plumbing. The water meter does not include the irrigation water use. Therefore, the water meter reading should be indicative of the wastewater flow to the system.

3.4 Energy Consumption

The new PNRS system at this site is a gravity flow system and uses no energy for wastewater treatment. As indicated previously however, a small lift station pump was required to transfer a fraction of the total wastewater flow from the second existing OSTDS to the new gravity PNRS. Energy consumption by this lift station pump was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. There are no chemicals added to the system. However, the Stage 2 biofilter media (lignocellulosic and sulfur) are “reactive” media which will be consumed during operation. The Stage 2 biofilter was initially filled with 42 inches of lignocellulosic media and 18 inches of sulfur and oyster shell mixture media, which ostensibly will last for many years without replenishment or replacement.

3.5 Water Quality Sample Collection and Analyses

The eighth formal sample event was conducted on December 16, 2014. A full suite of samples were collected for water quality analysis, including influent, intermediate and effluent points. Samples were collected at each of the nine monitoring points described in Section 3.3: B-HS4-STE, B-HS4-ST1, B-HS4-LIGNO-36, B-HS4-LIGNO-24, B-HS4-LIGNO-12, B-HS4-LIGNO-0, B-HS4-SULFULR-6, B-HS4-SULFULR-12, and B-HS4-ST2. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded.

Lastly, field blank (FB) and field duplicate samples were taken. The field blank was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. The field sample duplicate (B-HS4-ST2) was collected immediately subsequent to the regular samples. These samples were then analyzed for the same parameters as the monitoring samples.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent primary monitoring samples were analyzed by the laboratory for: carbonaceous biological oxygen demand ($CBOD_5$), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN-N), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), total suspended solids (TSS), sulfate, sulfide, hydrogen sulfide (unionized), total organic carbon (TOC), fecal coliform (fecal), and E.coli. The Stage 2 intermediate drivepoint samples were analyzed for: Carbonaceous Biological Oxygen Demand ($CBOD_5$), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), and sulfate. All analyses were performed by an independent and fully NELAC certified analytical laboratory (Southern Analytical Laboratory). Table 1 lists the analytical parameters, analytical methods, and detection limits for laboratory analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	SM 4500NO2-B	0.01 mg/L
Nitrate+Nitrite Nitrogen (NOX-N)	EPA 353.2	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Total Organic Carbon (TOC)	SM 5310B	0.06 mg/L
Sulfate	EPA 300.0	2.0 mg/L
Sulfide	SM 4500SF	0.10 mg/L
Hydrogen Sulfide (unionized)	SM 4550SF	0.01 mg/L
Fecal Coliform (fecal)	SM 9222D	1 ct/100mL
E.coli	SM 9223B	2 ct/100mL

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since the water meter installation on February 8, 2013. The average daily household water use since start-up is 310 gallons per day. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B.

Table 2
Summary of Household Water Use

Date and Time Read	Cumulative Volume (gallons)	Avg. Daily Household Flow between readings, Q (gpd)	Avg. Household Flow since PNRS start-up, Q (gpd)
2/8/2013 13:45	0.0	INSTALLED	
2/21/2013 11:25	4,391.0	340.3	
2/28/2013 12:00	6,292.5	270.7	
6/7/2013 8:00	34,417.4	284.6	
6/14/2013 8:00	36,179.5	251.7	
6/20/2013 12:40	37,981.2	290.9	
7/9/2013 15:35	42334.44	227.7	PNRS start-up
7/17/2013 14:30	45,422.8	388.2	388.2
7/23/2013 13:32	47,051.9	273.4	339.0
7/29/2013 11:25	48,658.8	271.8	319.0
8/6/2013 12:15	50,922.9	281.8	308.3
8/12/2013 10:24	52,614.2	285.6	304.3
8/15/2013 8:20	53,328.4	245.1	299.6
8/27/2013 10:20	56,550.0	266.6	291.4
9/5/2013 9:59	58,748.1	244.6	284.1
9/30/2013 13:15	65,633.7	273.9	281.0
11/8/2013 11:00	76,559.6	280.8	281.0
11/27/2013 11:15	82,039.9	288.3	282.0
12/2/2013 13:30	83,048.8	198.1	279.0
12/23/2013 13:00	88,271.2	248.9	275.2
1/23/2014 10:30	98,116.0	318.6	282.0
1/31/2014 10:48	100,521.0	300.2	282.7
2/3/2014 11:20	101,475.3	315.8	283.2
2/4/2014 10:05	101,844.6	389.6	283.7
2/5/2014 8:05	102,095.7	273.9	283.6
2/6/2014 9:25	102,275.2	170.1	283.1
2/7/2014 9:11	102,557.9	285.5	283.1
2/12/2014 11:30	103,986.0	280.2	283.0
3/14/2014 9:00	112,449.7	283.1	283.0
4/3/2014 12:00	118,146.5	283.1	283.0
4/25/2014 8:50	124,728.7	301.0	284.4
4/29/2014 11:15	125,962.6	300.9	284.6
5/29/2014 11:20	136,114.3	338.4	289.6
6/9/2014 11:15	138,848.1	248.6	288.3
7/11/2014 10:30	147,011.9	255.4	285.4
7/29/2014 14:15	152,624.1	309.1	286.5
8/22/2014 9:30	166,932.8	601.2	304.8
9/19/14 11:20	175,287.4	297.6	304.4
10/23/2014 8:00	187,775.5	368.8	309.0
11/21/2014 10:00	197,976.1	350.7	311.4
12/16/2014 9:22	204,946.0	279.1	309.9

4.2 Energy Consumption

As mentioned previously, the PNRS at this site is a gravity system and uses no electrical energy for treatment. However, energy is required to transfer a fraction of the total wastewater from the second existing OSTDS to the head end of the PNRS system. The energy consumption by the lift station pump that transfers flow from the second existing OSTDS is monitored using an electrical meter installed between the main power box for the house and the lift station pump outlet to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 3. The total average electrical use through December 16, 2014 was 0.150 kWh per day. The cause for the increase in electrical use between the March 14th and April 3rd, 2014 readings is attributed to a clog in the lift station throttling valve (ball valve). The clog was causing the pump to run longer with a very slow flow rate.

Table 3
Summary of System Electrical Use

Date and Time Read	Cumulative Electrical Meter Reading (kWh)	Average Daily Electrical Use btwn readings (kWh/day)
6/20/2013 14:00		Installed
7/9/2013 15:45	0.3	PNRS start-up
7/17/2013 10:41	0.5	0.026
7/23/2013 13:34	0.6	0.016
7/29/2013 11:30	0.8	0.034
8/6/2013 11:42	0.9	0.012
8/12/2013 10:24	1.2	0.050
8/15/2013 8:20	1.3	0.034
8/27/2013 10:20	1.8	0.041
9/5/2013 9:59	2.2	0.045
9/30/2013 13:15	5.8	0.143
11/8/2013 11:00	12.3	0.167
11/27/2013 11:15	14.1	0.095
12/2/2013 12:55	14.5	0.079
12/23/2013 13:00	17.3	0.133
1/23/2014 10:30	21.1	0.123
1/31/2014 10:48	22.2	0.137
2/3/2014 11:20	22.7	0.165
2/4/2014 10:05	22.9	0.211
2/5/2014 8:05	23.0	0.109
2/6/2014 9:25	23.1	0.095
2/7/2014 9:11	23.1	0.000
2/12/2014 11:30	23.9	0.157
3/14/2014 9:00	29.7	0.194
4/3/2014 12:00	62.2	1.615
4/25/2014 8:50	66.8	0.210
4/29/2014 11:15	68.4	0.390
5/29/2014 11:20	73.7	0.177
6/9/2014 11:15	73.9	0.018
7/11/2014 10:30	74.7	0.025
8/22/2014 9:30	75.9	0.029
9/19/2014 11:20	76.6	0.025
10/23/2014 8:00	77.5	0.027
11/21/2014 10:00	78.3	0.028
12/16/2014 9:22	79.1	0.032
Total average through 12/16/14		0.150

4.3 Water Quality

Water quality analytical results, for Sample Event No. 8 are listed in Table 4 and key results are graphically displayed in Figure 7. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.

	STE	STAGE 1	STAGE 2 LIGNO	STAGE 2 SULFUR
$CBOD_5$ mg/L	170	10	8	11
TKN mg N/L	78	8.2	3.3	4.8
NH_3 mg N/L	74	2.9	0.3	2.7
NO_x mg N/L	0.12	49.0	6.3	9.4
TN mg N/L	78.1	57.2	9.6	14.2
Sulfate mg/L	1.6	26	28	68
Fecal Coliform (Ct/100mL)	200,000	200	570	2900

Figure 7
Graphical Representation of Nitrogen Results
Sample Event No. 8 December 16, 2014 (Experimental Day 525)

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE for all parameters. The measured STE total nitrogen (TN) concentration was 78.1 mg/L, which is within the high end of the range that has been typically reported for Florida single family residence STE. The measured $CBOD_5$ concentration was 170 mg/L.

Stage 1 Effluent (ST1): The Stage 1 effluent NH_3-N level was 2.9 mg/L with a DO level at 1.11 mg/L (Table 4). The Stage 1 effluent TSS and $CBOD_5$ concentrations were 7 and 10 mg/L, respectively. The Stage 1 biofilter effluent NH_3-N concentration was 2.9 mg/L and effluent TKN was 8.2 mg/L. The Stage 1 effluent NO_x-N was 49.0 mg/L. The Stage 1 effluent TN of 57.2 mg/L was 27% lower than that in the STE, suggesting denitrification in the Stage 1 biofilter.

Stage 2 Biofilter Effluent (LIGNO-0" and ST2): The Stage 2 system produced a reducing environment and NO_x-N removal occurred. Effluent NO_x-N from the Stage 2 biofilter monitoring point was 9.4 mg/L and was accompanied by a measured DO of 0.07 mg/L. The effluent NO_x-N of the lignocellulosic media biofilter was 6.3 mg/L. The cause for the higher concentration of NO_x-N in the final effluent (9.4 mg/L) as compared to the lignocellulosic effluent NO_x-N concentration (6.3 mg/L) is unknown. It does not appear to be a laboratory issue, since a duplicate sample of BHS4-ST2 was taken and showed a similar NO_x-N concentration (9.1 mg/L). This is the first sample event that the final effluent had a NO_x-N concentration greater than 0.07 mg/L. This result may indicate a sampling problem with the BHS4-ST2 sample. As a result, final total nitrogen (TN) in the treatment system effluent was 14.2 mg/L. The Stage 2 biofilter lignocellulosic media effluent and sulfur media effluent $CBOD_5$ were 8 and 11 mg/L, respectively. The Stage 2 effluent sulfate concentration was 68 mg/L.

As previously discussed in Section 3.3, Sample Event 8 also included Stage 2 biofilter profile samples. As depicted in Figure 8, the unsaturated Stage 1 biofilter effluent is pumped to the top of the first chamber of the Stage 2 biofilter which contains lignocellulosic media. The effluent flows downward through the lignocellulosic media, moves laterally in a perforated 4-inch pipe through the baffle wall to the bottom of the second chamber, and upward through the sulfur media mixture in the second chamber. The nitrogen results at the various depths of the Stage 2 biofilter are graphically displayed in Figure 8. Each stainless steel drivepoint sampler was assigned a unique identification indicating the depth (in inches) the sampler was placed above the bottom of the media. For example LIGNO-36 is a stainless steel drivepoint sampler located at 36 inches above the bottom of the lignocellulosic media. The profile results from this event indicate that the NO_x-N was effectively reduced below the method detection limit at profile sampler SULFUR-6; however, as previously discussed, it is unclear why the final sulfur media effluent NO_x-N concentration was 9.4 mg/L. The NO_x-N concentration progressively decreased with passage through the lignocellulosic media in the downflow biofilter, which accounted for approximately 87 percent of the NO_x-N reduction. Residual NO_x-N in the effluent of the downflow lignocellulosic biofilter was reduced to 0.05 mg/L at the 6-inch depth through the sulfur media.

2A Lignocellulosic Compartment					2B Sulfur Compartment			
FROM PUMP	TKN	NH3-N	NOX-N	Tank Wall		TKN	NH3-N	NOX-N
Influent	8.2	2.9	49.0		Effl. Sulfur	4.8	2.7	9.4
LIGNO-36	5.5	1.3	41.0					
LIGNO-24	5.0	0.17	28.0					
LIGNO-12	3.0	0.32	5.9		SULFUR-12	1.6	0.2	0.04
LIGNO-0	3.3	0.27	6.3		SULFUR-6	1.8	0.5	0.05

Figure 8
Graphical Representation of Stage 2 Biofilter Profile Nitrogen Results

Field Blank (EB): Described in Section 3.5, the field blank (FB) results for most of the parameters measured were at or below the method detection limit. The slightly elevated parameters were TKN 0.2 mg/L and total phosphorus 0.033 mg/L.

Table 4
Water Quality Analytical Results

Sample ID	Sample Date/Time	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
BHS4-STE	12/16/2014 11:20	21.8	7.25	1291	0.08	-262.4		58		170	270	78.12	78	4.00	74	0.02	0.1	0.12	74.12	8.3		1.6	0.5	1.4	200000	200000	57
BHS4-ST1	12/16/2014 10:55	19.8	6.68	1412	1.11	-23.8		7		10	23	57.23	8.2	5.30	2.9	49	0.03	49.03	51.93	0.35		26	0.01	0.1	200	160	10
BHS4-LIGNO-36	12/16/2014 10:50	19.7	6.66	1284	0.4	-86.1				2		46.51	5.5	4.20	1.3	41	0.01	41.01	42.31			25					
BHS4-LIGNO-24	12/16/2014 10:45	20.6	6.64	1259	0.14	-105.5				6		33.03	5	4.83	0.17	28	0.03	28.03	28.20			26					
BHS4-LIGNO-12	12/16/2014 10:40	21.1	6.68	1211	0.2	-123.4				8		8.94	3	2.68	0.32	5.3	0.64	5.94	6.26			28					
BHS4-LIGNO-0	12/16/2014 10:30	21.1	6.68	1214	0.2	-218.4		6		8	20	9.57	3.3	3.03	0.27	5.7	0.57	6.27	6.54	1.4		28	0.01	0.1	570	480	9.6
BHS4-SULFUR-6	12/16/2014 10:20	21.8	6.57	1232	0.16	-280				22		1.85	1.8	1.31	0.49	0.02	0.03	0.05	0.54			77					
BHS4-SULFUR-12	12/16/2014 10:15	22.0	6.73	1227	0.24	-241.5				23		1.64	1.6	1.36	0.24	0.03	0.01	0.04	0.28			73					
BHS4-ST2	12/16/2014 9:40	21.0	6.66	1229	0.07			5		11	25	14.20	4.8	2.10	2.7	6.9	2.5	9.4	12.10	1.6		68	0.01	0.1	2900	2400	11
BHS4-ST2-DUP	12/16/2014 9:55	21.0	6.66	1229	0.07			8		10	29	14.10	5	2.20	2.8	6.3	2.8	9.1	11.90	1.6		64	0.01	0.1	3000	2400	11
BHS4-FB	12/16/2014 11:30	18.4	5.37	1.54	8.79	75.3		1		2	10	0.23	0.2	0.19	0.009	0.02	0.01	0.03	0.04	0.033		0.2	0.01	0.1	1	2	0.06

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 5. Figure 9 provides a time series of influent and effluent TN over the study period. Figures 10 through 16 show box and whisker plots of the various monitoring points for the key parameters measured during the study period.

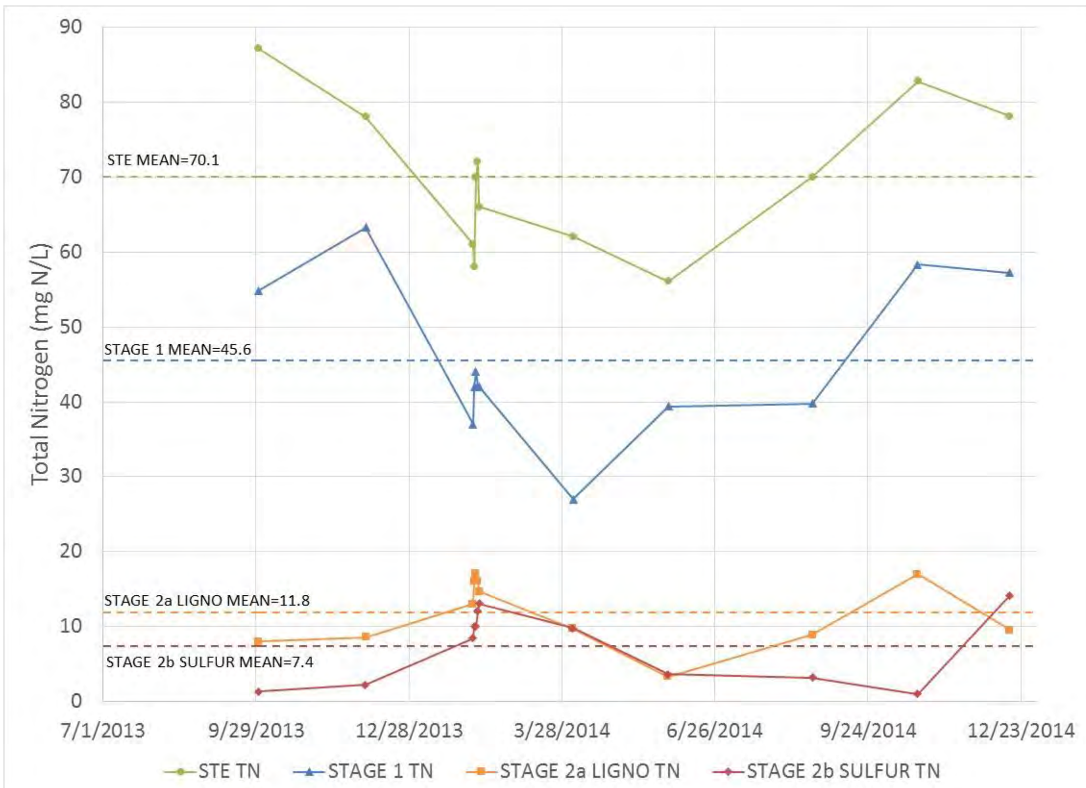

Figure 9
Total Nitrogen Time Series Graph
September 30, 2013 through December 16, 2014

Table 5
Summary of Water Quality Analytical Results

Sample ID	Statistical Parameter	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
STE	n	12	12	12	12	12	11	12	11	12	12	12	12	12	12	12	12	12	12	12	11	12	12	12	12	11	12
	MEAN	22.80	6.83	1185.00	0.15	-221.22	442.73	61.08	58.18	136.92	218.17	70.11	70.00	7.67	62.33	0.09	0.03	0.11	62.44	9.44	6.42	1.66	2.92	4.82	48,499	17,916	64.50
	STD. DEV.	3.15		117.36	0.21	54.88	30.69	20.97	20.71	53.04	108.56	9.94	9.84	7.54	7.32	0.18	0.04	0.21	7.36	2.06	2.29	1.50	1.23	1.79			15.51
	MIN	19.50	6.52	1027.00	0.01	-321.80	400.00	38.00	38.00	23.00	10.00	56.06	56.00	-5.00	49.00	0.01	0.01	0.02	49.07	7.60	0.01	0.20	0.50	1.40	21,000	690	34.00
	MAX	28.32	7.25	1329.00	0.79	-131.40	490.00	118.00	111.00	220.00	330.00	87.14	87.00	23.00	75.00	0.66	0.10	0.76	75.02	14.00	9.20	5.40	4.50	6.80	200,000	200,000	85.00
Stage 1	n	12	12	12	12	12	11	12	11	12	12	12	12	12	12	11	11	12	12	12	11	10	9	9	12	11	12
	MEAN	22.34	6.82	1190.42	2.55	85.86	321.82	9.42	8.55	8.75	40.58	45.58	11.98	3.92	8.06	33.36	0.16	33.60	41.66	3.33	2.86	19.70	0.27	0.54	2,764	1,452	14.95
	STD. DEV.	3.22		154.62	1.54	150.18	37.10	6.10	5.34	6.20	32.20	10.58	7.50	3.86	8.18	16.45	0.30	15.55	10.51	1.46	0.96	3.13	0.32	0.60			5.83
	MIN	19.00	6.42	978.00	0.87	-69.70	270.00	3.00	3.00	2.00	10.00	27.00	3.20	0.00	0.38	12.00	0.01	12.00	27.00	0.35	1.50	16.00	0.01	0.10	100	41	6.50
	MAX	27.60	7.39	1412.00	5.16	508.20	390.00	22.00	18.00	18.00	120.00	63.30	25.00	14.44	23.00	57.00	0.85	57.00	58.80	5.50	4.10	26.00	1.00	1.80	32,000	24,000	24.00
Stage 2a Ligno	n	12	12	12	12	12	11	12	11	12	12	12	12	12	12	12	12	12	12	12	11	11	9	9	12	11	12
	MEAN	22.83	6.64	1113.00	0.59	-155.59	426.36	5.33	5.00	12.67	44.33	11.83	8.67	3.07	5.60	3.10	0.08	3.17	8.76	2.71	2.24	14.67	1.13	1.68	1,150	607	14.39
	STD. DEV.	3.49		85.66	0.64	94.52	22.03	3.65	3.46	6.64	17.32	4.42	6.15	3.36	6.24	4.01	0.17	4.11	4.83	1.36	1.19	7.50	0.65	0.94			4.29
	MIN	18.20	6.46	956.00	0.13	-238.00	400.00	1.00	1.00	2.00	20.00	3.30	2.00	0.70	0.13	0.03	0.01	0.03	1.21	0.42	0.18	5.70	0.01	0.10	30	10	6.20
	MAX	28.51	6.80	1247.00	2.16	58.20	460.00	12.00	12.00	23.00	79.00	17.04	17.00	13.49	15.00	13.00	0.57	13.27	15.04	4.10	3.30	28.00	2.10	3.00	17,200	6,100	19.00
Stage 2b Sulfur	n	12	12	12	12	11	11	12	11	12	12	12	12	12	12	12	12	12	12	12	11	12	12	12	12	11	12
	MEAN	22.34	6.73	1167.92	0.17	-222.68	462.73	4.08	3.45	12.25	43.08	7.42	6.61	2.25	4.36	0.60	0.22	0.82	5.17	2.64	2.23	37.17	4.18	5.93	409	264	13.74
	STD. DEV.	2.99		88.79	0.11	59.91	24.53	2.31	2.58	8.15	13.39	4.83	4.36	3.09	4.02	1.98	0.72	2.70	4.55	1.11	1.02	17.61	2.68	3.44			3.89
	MIN	19.60	5.79	1054.00	0.04	-348.90	440.00	2.00	1.00	3.00	25.00	1.03	0.99	0.29	0.51	0.01	0.01	0.02	0.53	0.70	0.32	21.00	0.01	0.10	1	2	6.50
	MAX	27.60	7.66	1306.00	0.44	-132.60	510.00	9.00	8.00	30.00	64.00	14.20	13.00	11.70	10.00	6.90	2.50	9.40	12.10	4.10	3.50	71.00	9.90	11.00	5,400	2,400	18.00
Well	n	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	MEAN	27.90	7.32	529.00	5.10	101.30	150.00	1.00	1.00	2.00	10.00	1.58	0.18	0.16	0.02	1.40	0.01	1.40	1.42	0.49	0.20	8.70	0.13	0.41	1	2	2.10
	STD. DEV.																										
	MIN	27.90	7.32	529.00	5.10	101.30	150.00	1.00	1.00	2.00	10.00	1.58	0.18	0.16	0.02	1.40	0.01	1.40	1.42	0.49	0.20	8.70	0.13	0.41	1	2	2.10
	MAX	27.90	7.32	529.00	5.10	101.30	150.00	1.00	1.00	2.00	10.00	1.58	0.18	0.16	0.02	1.40	0.01	1.40	1.42	0.49	0.20	8.70	0.13	0.41	1	2	2.10

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Fecal coliform and pH values are reported as geometric mean.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

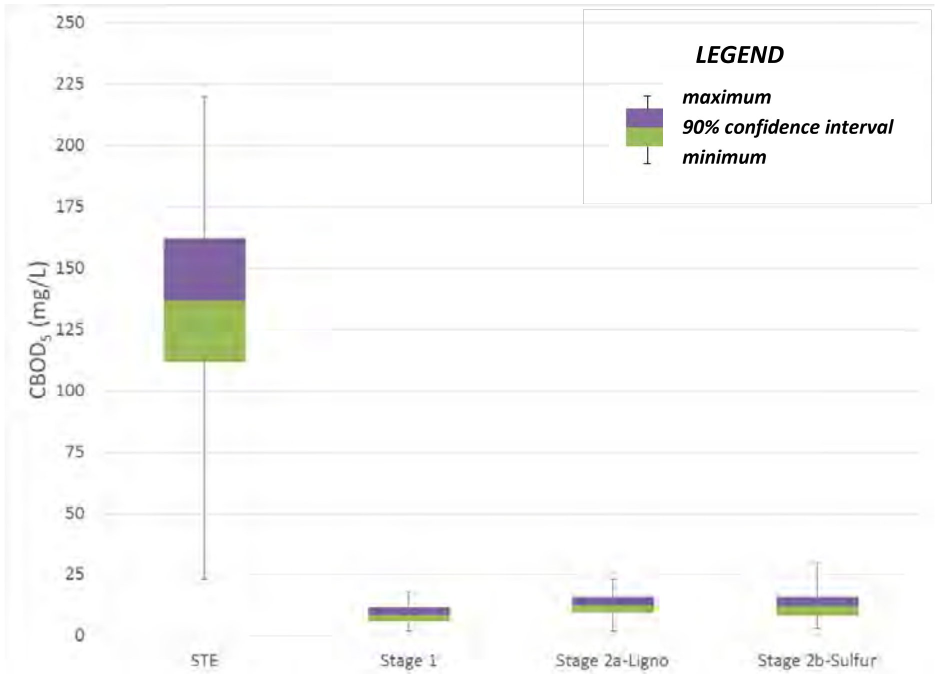

Figure 10
CBOD5 Box and Whisker Plot

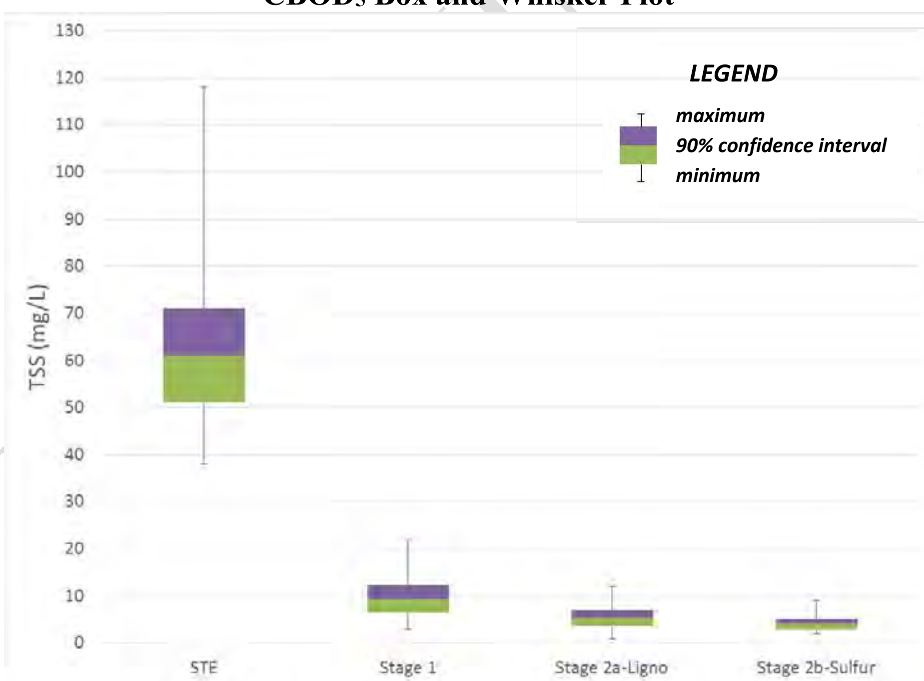

Figure 11
TSS Box and Whisker Plot

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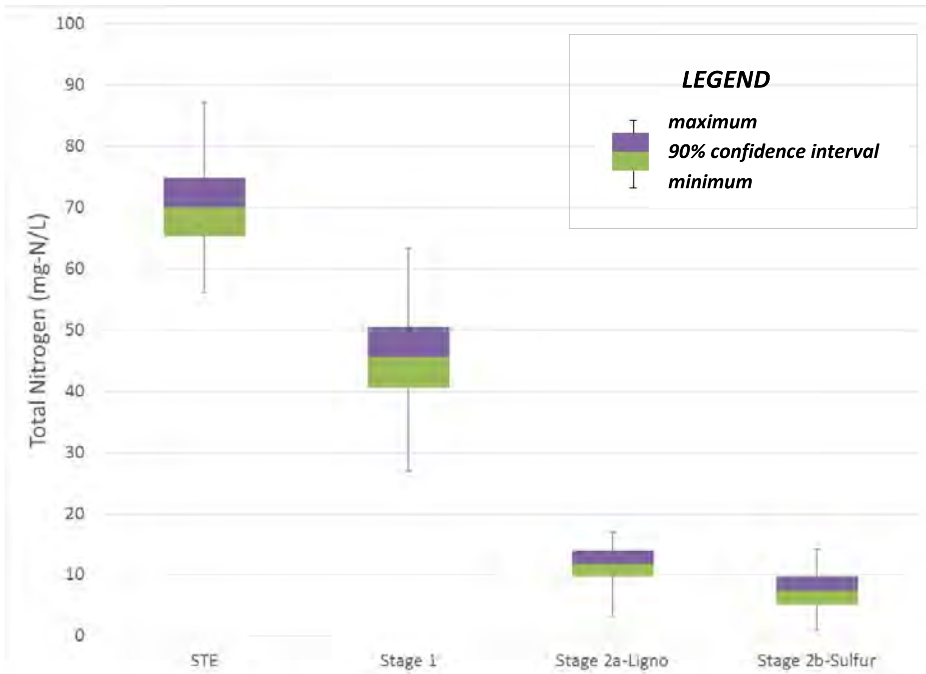

Figure 12
Total Nitrogen (TN) Box and Whisker Plot

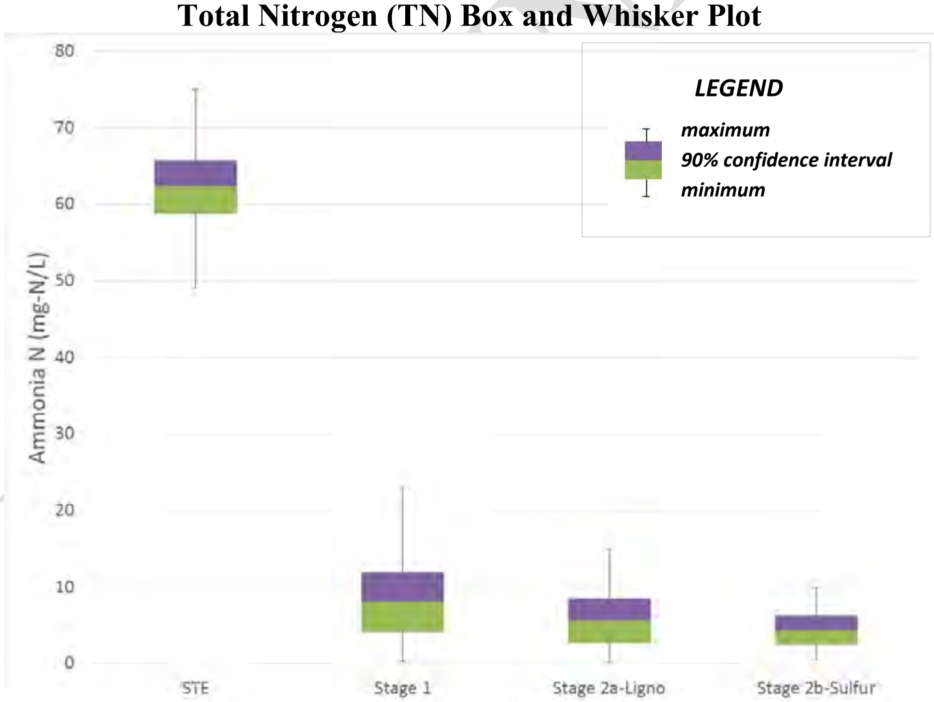

Figure 13
Ammonia N (NH3-N) Box and Whisker Plot

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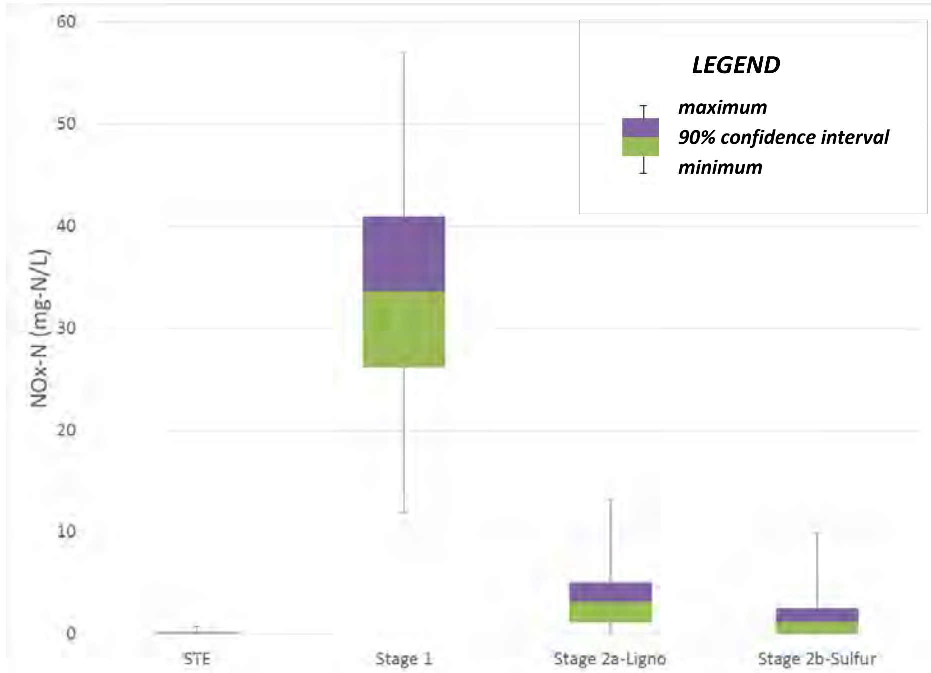

Figure 14
Nitrate+Nitrite Nitrogen (NO_x-N) Box and Whisker Plot

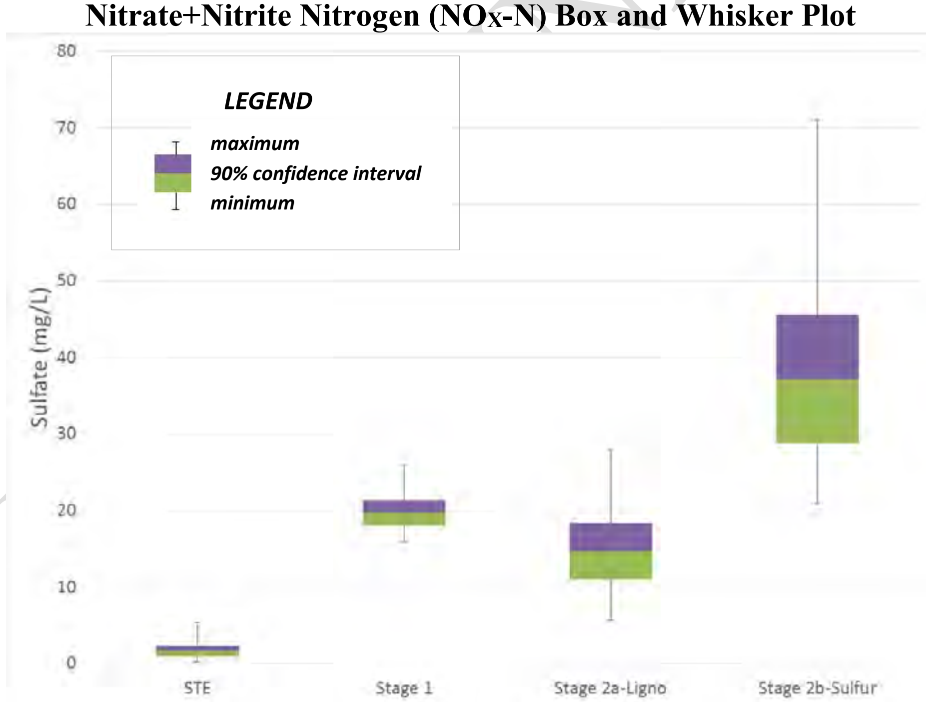

Figure 15
Sulfate (SO_4) Box and Whisker Plot

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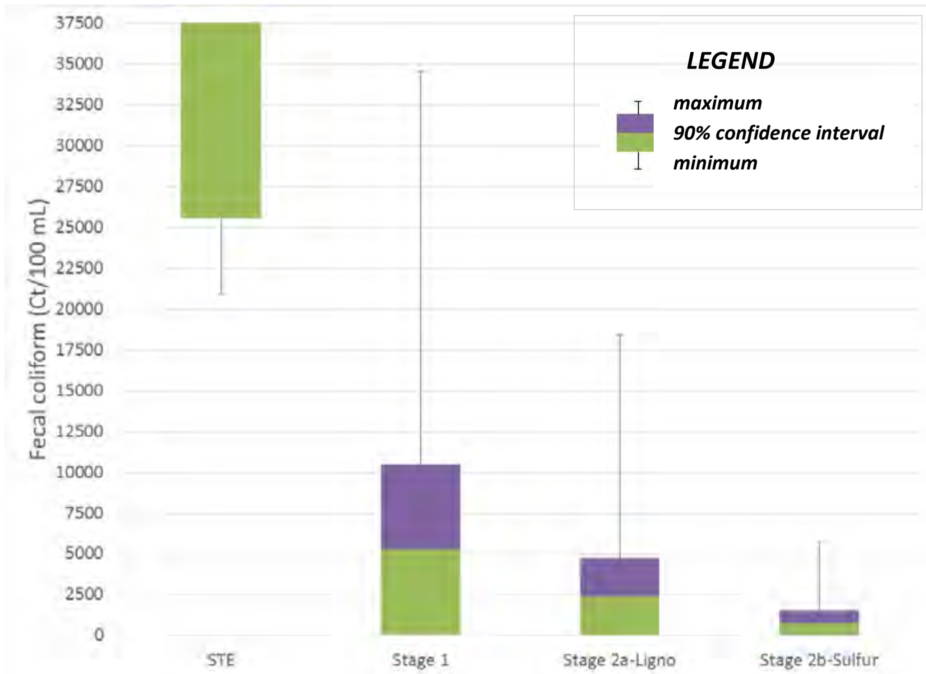

Figure 16
Fecal Coliform Box and Whisker Plot

5.0 B-HS4 Sample Event No. 8: Summary and Recommendations

5.1 Summary

The eighth and final sampling results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of 78.1 mg/L is within the high end of the range of values typically reported for Florida single family residence STE.

- The Stage 1 biofilter reduced TN and TKN by 27 and 89%, respectively.

- The Stage 1 biofilter reduced TKN and ammonium; effluent TKN and ammonia N were 8.2 and 2.9 mg/L, respectively.

- The Stage 2 biofilter effluent NO_x-N was 9.4 mg N/L, which was unusually high and may indicate a sampling problem.

- The total nitrogen concentration in the final effluent from the total treatment system was 14.2 mg/L, an approximately 82% reduction in STE TN.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS4 treatment system. Sections 4.4 summarized the water quality data collected over the 1.4 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 70.1 mg/L is in the upper range of values typically reported for Florida single family residence STE.
- The Stage 1 biofilter provided significant ammonia removal with an average NH_3-N concentration of 8.1 mg/L and average TKN of 12.0 mg/L. The Stage 1 biofilter effluent average NO_x-N was 33.6 mg/L. These results indicate denitrification (approximately 35% total nitrogen reduction) was likely occurring in the Stage 1 biofilter.
- The Stage 2 biofilter was effective in producing a reducing environment and achieving significant NO_x-N removal (average NO_x-N concentration of 0.82 mg/L). The average final total nitrogen (TN) in the treatment system effluent was 7.4 mg/L, primarily TKN (average TKN concentration of 6.6 mg/L), which represents an 89 percent average total nitrogen reduction from this PNRS.

Further analysis of the results obtained at this site will occur as Task B results are compiled and summarized. The results of the data collected to date have provided insights into the performance of a full-scale passive single pass nitrogen reduction system monitored over an extended timeframe (525 experimental days) under actual onsite conditions.

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Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS5 Field System
Monitoring Report No. 8

Prepared for:

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

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December 2014

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AET
Applied Environmental Technology

B-HS5 Field System
Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in Task A.26. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth and final sample event of the passive nitrogen reduction system at home site B-HS5 in Seminole County, Florida.

2.0 Purpose

Operation of the B-HS5 system was initiated on July 9, 2013. This monitoring report documents data collected from the eighth B-HS5 monitoring and sampling event conducted on December 15, 2014 (Experimental Day 524). This monitoring event consisted of collecting flow measurements from the household water use meter, treatment system flow meters, recording electricity use, monitoring of field parameters, collection of water samples from nine points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory.

3.0 Materials and Methods

3.1 Project Site

The B-HS5 field site is located in Seminole County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in June 2013. Design and construction details were presented previously in the Task B.6 document. Figure 1 is a system schematic showing the system components and layout of the installation. A flow schematic of the system is shown in Figure 2. The passive nitrogen reduction system (PNRS) consists of three process tanks that were added to the existing permitted onsite system: a 1500 gallon plastic tank housing a Stage 1 unsaturated media filter; a 300 gallon concrete pump tank; and a 1,500 gallon two chamber concrete tank housing a Stage 2 saturated media biofilter. The existing 1,350 gallon concrete septic tank continues to provide primary treatment prior to the PNRS system. Based on measured average wastewater flow and tank volumes, there is over a ten day transit time through the treatment system prior to dispersal. The denitrified treated effluent is discharged into the soil via the existing drainfield which is a standard bed.

3.2 PNRS System Modification

The PNRS system was designed with two operational modes for Stage 1: single pass and recirculation. In single pass mode, 100 percent of the Stage 1 effluent was discharged to the Stage 2 biofilter. In recirculation mode the pump tank discharge is split via two throttling gate valves to provide for recycling of a portion of the Stage 1 biofilter effluent to Stage 1 influent, with the balance of Stage 1 effluent proceeding to the Stage 2 biofilter.

The Stage 1 biofilter was operated in single pass mode since system startup, but was switched to recirculation mode on April 25, 2014 (Experimental Day 290) following the fourth sample event. In recirculation mode, a portion (3:1 target ratio) of the Stage 1 effluent was recirculated to the top of the Stage 1 biofilter and dispersed via five spray nozzles. The recirculated, nitrified effluent would have an opportunity to mix with incoming septic tank effluent discharged by the distribution box. In recirculation mode, the Stage 1 biofilter received both forward wastewater flow and recirculated Stage 1 effluent, and overall hydraulic loading on the Stage 1 biofilter is increased.

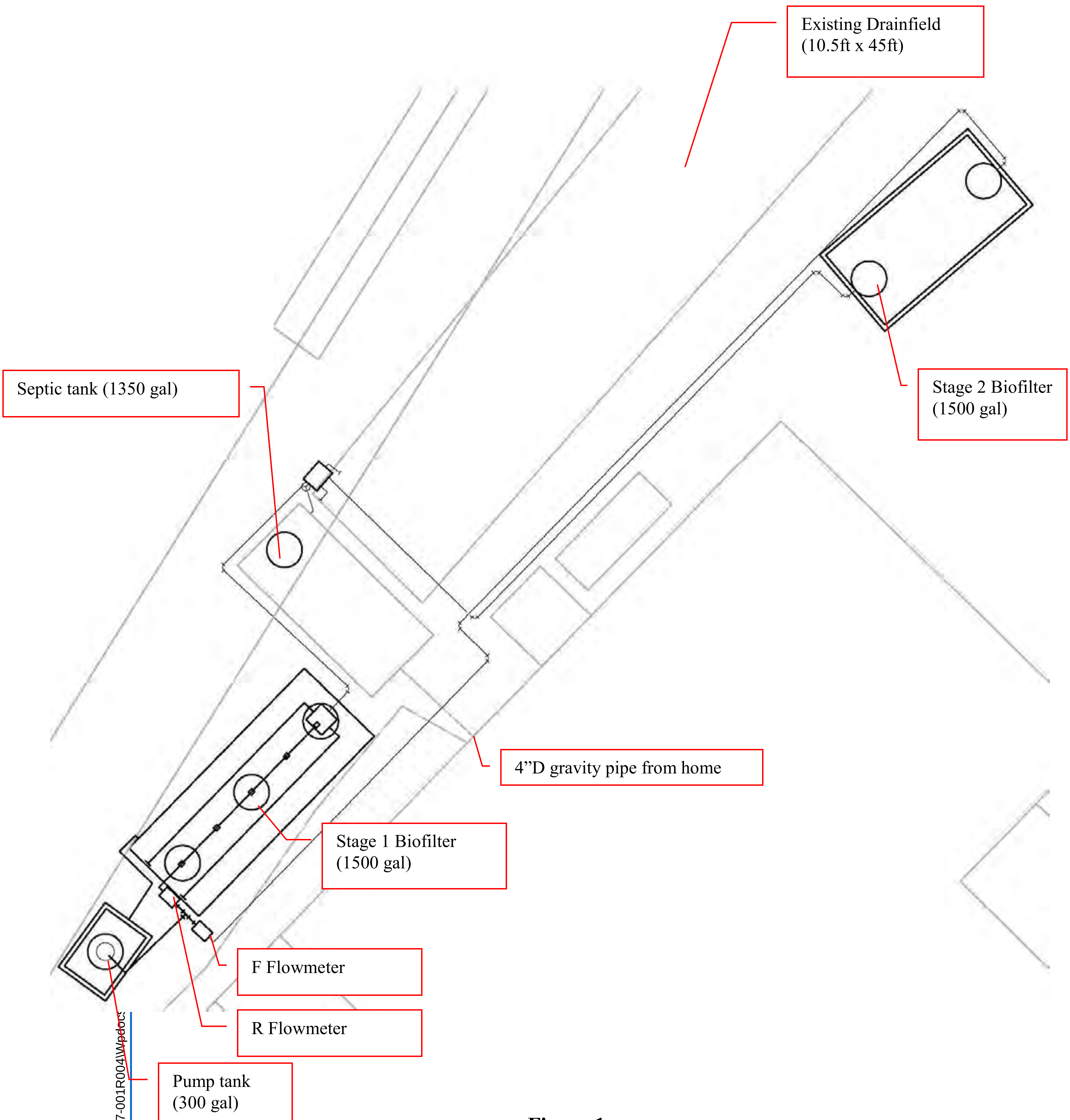

Figure 1
Plan View of B-HS5 System Layout

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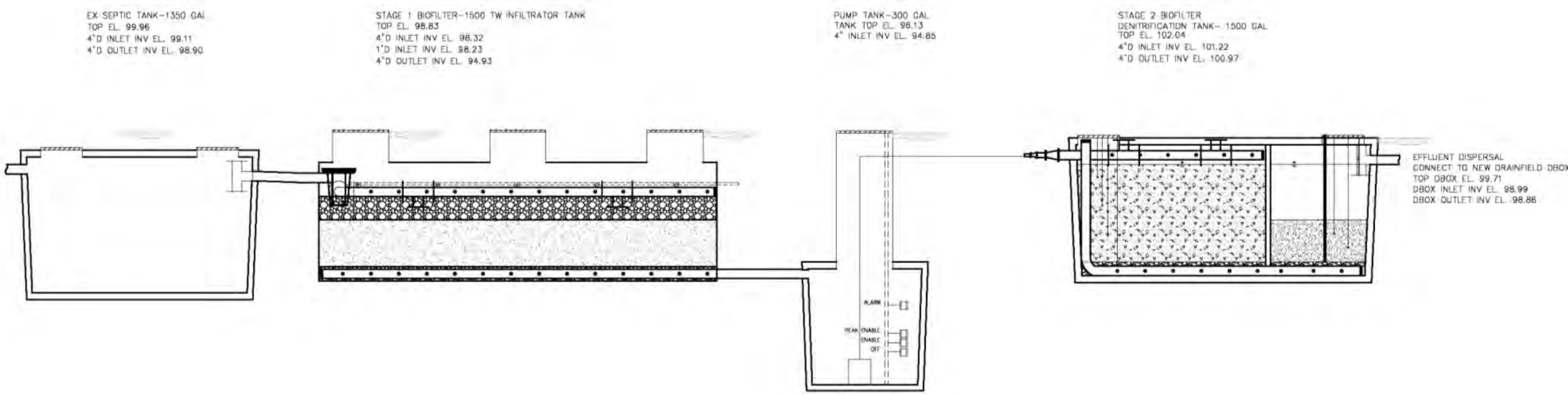

Figure 2
Flow Schematic of B-HS5 PNRS

3.3 Monitoring and Sample Locations and Identification

This monitoring event included sample collection from nine points within the treatment system (Figure 3). Household wastewater enters the primary tank and exits as septic tank effluent (STE) through an effluent filter screen into the Stage 1 biofilter. The first monitoring point, B-HS5-STE, is the STE sampled approximately 1.5 feet below the surface of the primary tank prior to the effluent filter (Figure 4). Samples from monitoring point B-HS5-STE are representative of the whole household wastewater and represent the influent to the passive nitrogen reduction system.

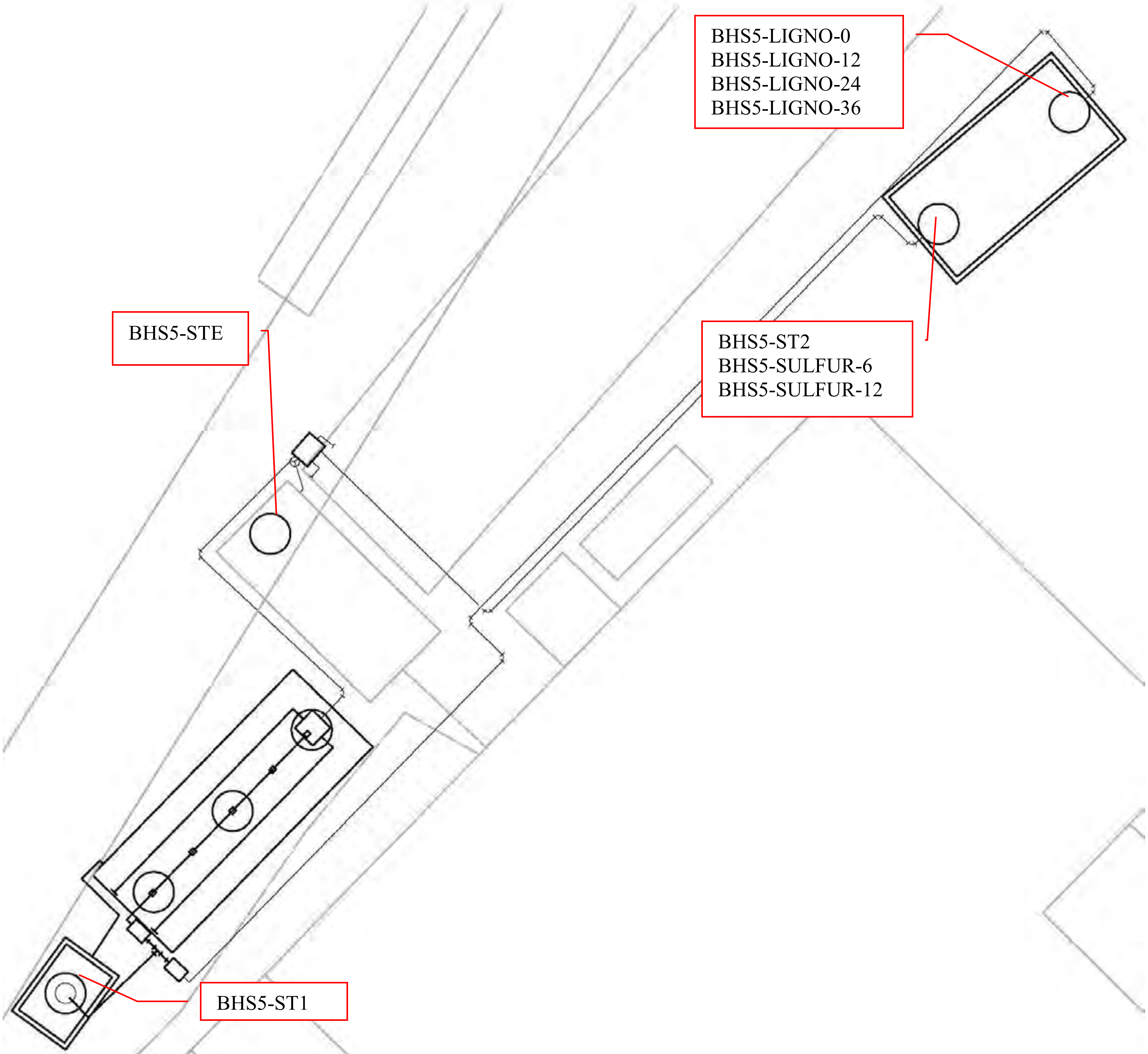

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Figure 3
B-HS5 Sample and Monitoring Locations

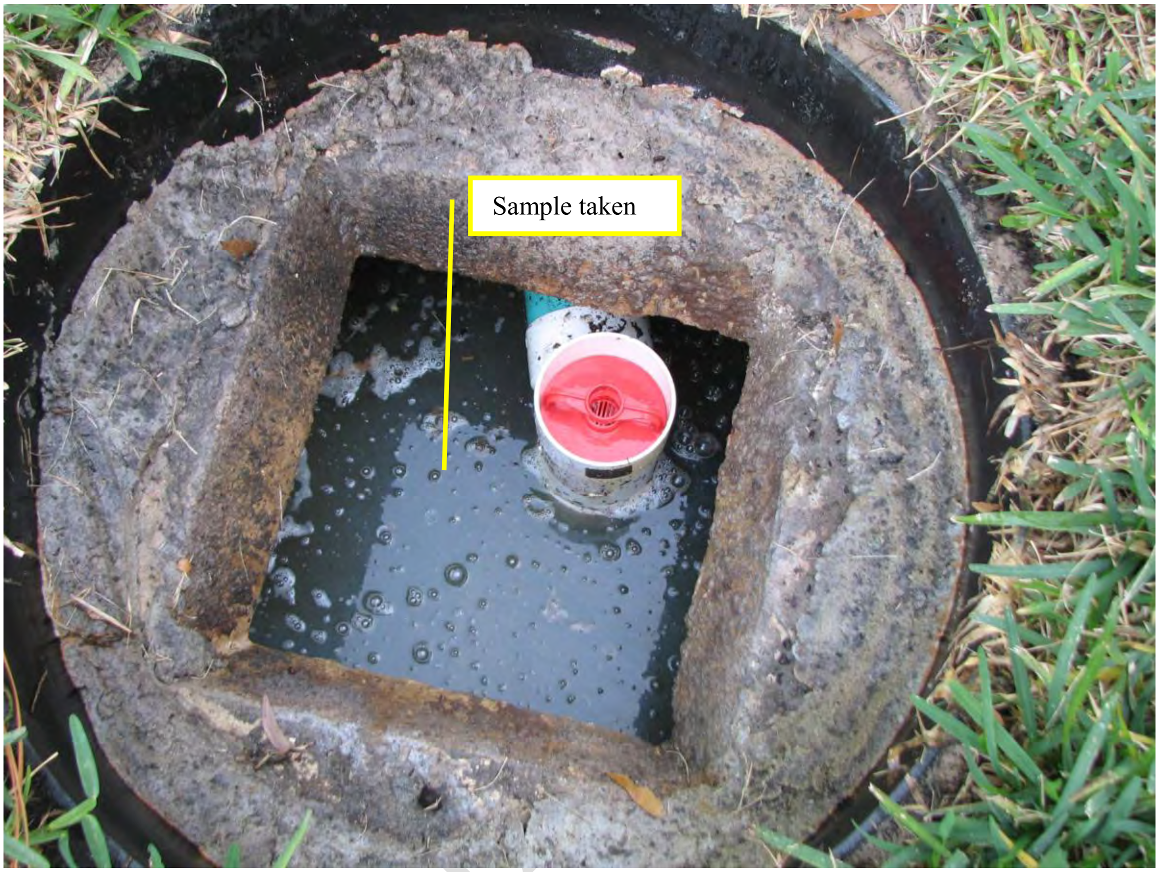

Figure 4
Primary Tank (B-HS5-STE sample)

The primary tank contents are discharged by gravity to a distribution box, located inside the Stage 1 biofilter, which splits the flow between three perforated distribution pipes that run along the top of the unsaturated Stage 1 biofilter media. In the Stage 1 biofilter, wastewater percolates downward through the unsaturated expanded clay media where nitrification occurs. The Stage 1 biofilter contains 12.8 inches of coarse expanded clay media (Riverlite^{TM} 1/4; 1.1 to 4.8 mm) above 21 inches of finer expanded clay media (Riverlite^{TM} 3/16; 0.6 to 2.4 mm). Stage 1 biofilter effluent flows into the pump tank by gravity. The second sampling point (B-HS5-ST1), is sampled approximately 1.5 feet below the surface of the pump tank representing the Stage 1 biofilter effluent (Figure 5).

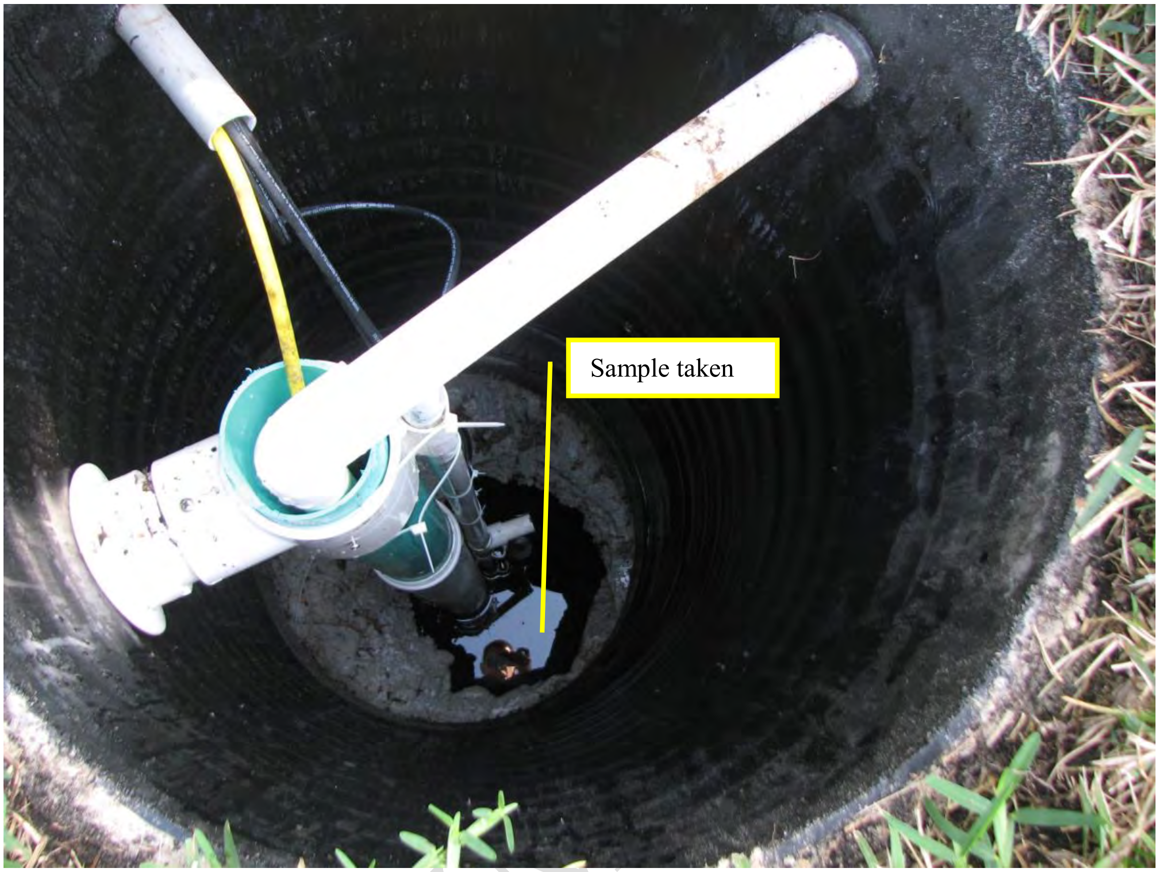

Figure 5
Stage 1 Effluent in Pump Tank (B-HS5-ST1 sample)

The pump tank discharge is split via two throttling gate valves which allow for optional recycling of a portion of the Stage 1 biofilter effluent with the balance proceeding to the Stage 2 biofilter. As described previously, the system was designed with two operational modes. In the first mode, 100 percent of the Stage 1 effluent is discharged to the Stage 2 biofilter. Initial operation of B-HS5 was in the non-recirculation mode, which was in effect from system start-up through Experimental Day 290. The system was switched thereafter to the second operating mode in which a portion of Stage 1 effluent is recirculated to the top of the Stage 1 biofilter and dispersed via five spray nozzles. The recirculated, nitrified effluent has an opportunity to mix with incoming septic tank effluent discharged by the distribution box. Recirculation back to the Stage 1 biofilter increases the overall hydraulic loading on the Stage 1 biofilter.

Effluent from the unsaturated (Stage 1) media tank enters the denitrification (Stage 2) biofilter at the top of the media in the first chamber (lignocellulosic media), flows downward through the media, moves laterally through the baffle wall to the bottom of the second chamber, and upward through the media in the second chamber (elemental sulfur and oyster shell).

The first chamber of the Stage 2 biofilter contains 42-inches of lignocellulosic media as a supplemental carbon source for denitrification, a blended urban waste wood from Mother's Organics, Inc., Thonotosassa, FL. Stainless steel samplers are positioned at 12-inch increments for vertical profiling throughout the lignocellulosic media. The third primary sampling point is a stainless steel sampler positioned at the bottom of the lignocellulosic media (B-HS5-LIGNO-0) with tubing to the surface. Twelve inches above B-HS5-LIGNO-0 is another stainless steel drivepoint sampler B-HS5-LIGNO-12, and so forth (B-HS5-LIGNO-24 and B-HS5-LIGNO-36). The B-HS5-LIGNO-0 sample represents the lignocellulosic media effluent (Figure 6).

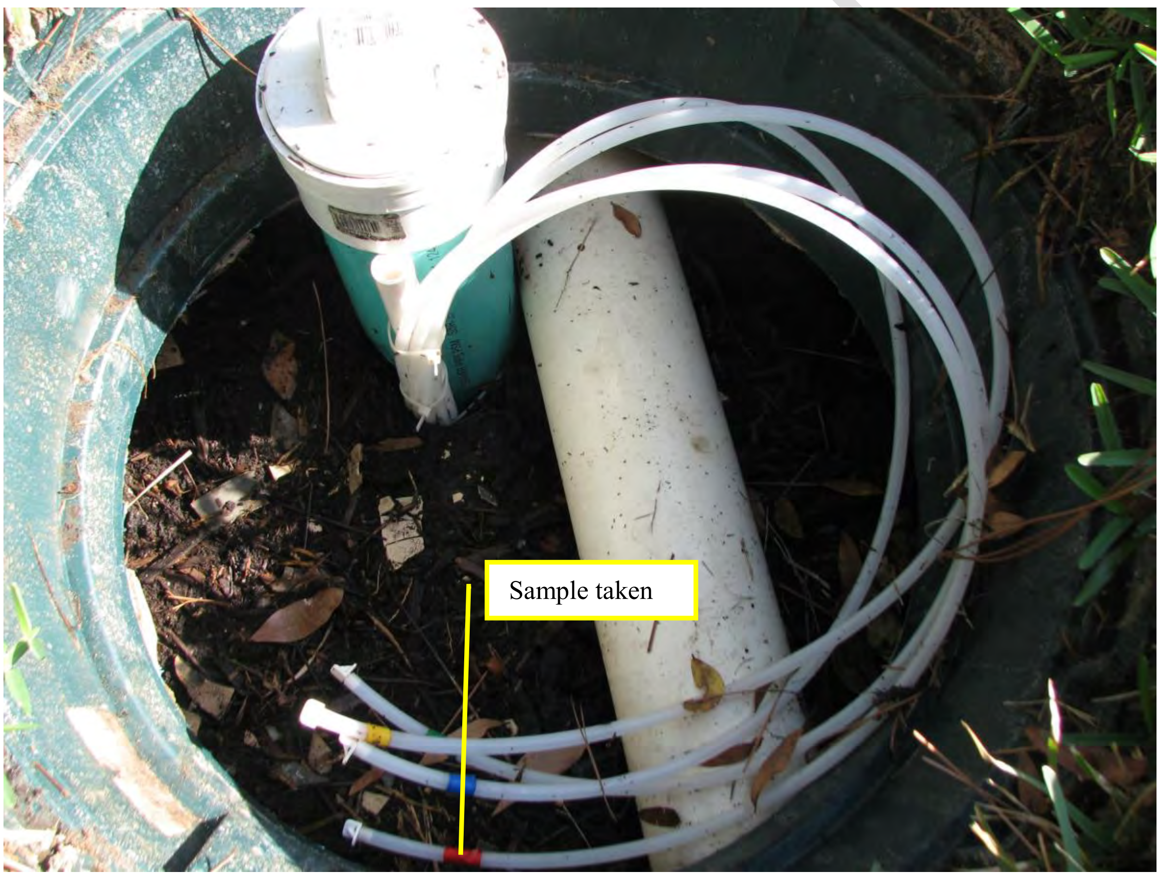

Figure 6
First chamber of Stage 2 biofilter (B-HS5-LIGNO-0" sample)

A collection pipe along the bottom transfers the first chamber (lignocellulosic media) effluent to the second chamber, which contains 18-inches of elemental sulfur mixed with oyster shell media. Similar to the lignocellulosic media chamber, stainless steel drivepoint samplers are positioned to create a vertical profile. B-HS5-SULFUR-6 and B-HS5-SULFUR-12 are positioned 6-inches and 12-inches, respectively, above the bottom of the sulfur media. The fourth primary sampling point, B-HS5-ST2, is the second chamber of the Stage 2 biofilter effluent which is sampled approximately 1 foot below the surface of the effluent baffle tee. This sample location is after passage through the sulfur media; it is the final effluent from the treatment system prior to being discharged to the soil infiltration system, or drainfield (Figure 7).

Figure 7
Second chamber of Stage 2 biofilter (B-HS5-ST2 sample)

3.4 Operational Monitoring

Start-up of the system occurred on July 9, 2013 (Experimental Day 0). The PNRS system has operated continually since that date. For this eighth formal sampling event, the water meter for the house and treatment system flow meters were read and recorded on December 15, 2014. The household water meter is located on the potable water line from the onsite well prior to entering the household plumbing. The water meter does not include the irrigation water use. Therefore, the water meter reading should be indicative of the wastewater flow to the system.

As previously discussed in Section 3.2, the pump tank discharge is split via two throttling gate valves which allow for a portion of the Stage 1 biofilter effluent to be sent back to the Stage 1 biofilter spray nozzles (for recirculation) with the rest proceeding to the Stage 2 biofilter. The treatment system flow meters (Figure 1) are located on the pump tank discharge lines following the flow split, and record the cumulative flow in gallons pumped from the pump chamber to the Stage 1 biofilter (R flowmeter) and Stage 2 biofilter (F flowmeter).

3.5 Energy Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. The power usage of the system is primarily due to the single lift station pump installed within the pump tank, although a small amount of power is used by the control panel itself. There are no chemicals added to the system. However, the Stage 2 biofilter media (lignocellulosic and sulfur) are "reactive" media which will be consumed during operation. The Stage 2 biofilter was initially filled with 42 inches of lignocellulosic media and 18 inches of sulfur and oyster shell mixture media, which ostensibly will last for many years without replenishment or replacement.

3.6 Water Quality Sample Collection and Analyses

The eighth formal sample event was conducted on December 15, 2014 (Experimental Day 524). A full suite of influent, intermediate and effluent water quality samples were collected from the system for water quality analysis. Samples were collected at each of the nine monitoring points described in Section 3.3: B-HS5-STE, B-HS5-ST1, B-HS5-LIGNO-0, BHS5-LIGNO-12, BHS5-LIGNO-24, BHS5-LIGNO-36, BHS5-SULFUR-6, BHS5-SULFUR-12 and B-HS5-ST2. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded.

A field sample duplicate was taken of B-HS5-ST1 which was collected immediately subsequent to the regular samples.

A field blank (FB), equipment blank (EB) and field duplicate sample were taken. The field blank was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. In addition, an equipment blank (B-HS7-EB) sample was taken by pumping deionized water through the cleaned pump tubing. Lastly, the field sample duplicate (B-HS4-ST1) was collected immediately subsequent to the regular samples. These samples were then analyzed for the same parameters as the monitoring samples.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent primary monitoring samples were analyzed by the laboratory for: Carbonaceous Biological Oxygen Demand ($CBOD_5$), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), sulfate, sulfide, hydrogen sulfide (unionized), total suspended solids (TSS), total organic carbon (TOC), fecal coliform (fecal), and E.coli. The Stage 2 intermediate drivepoint samples were analyzed for: Carbonaceous Biological Oxygen Demand ($CBOD_5$), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), and sulfate. All analyses were performed by an independent and fully NELAC certified analytical laboratory (Southern Analytical Laboratory). Table 1 lists the analytical parameters, analytical methods, and detection limits for laboratory analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	SM 4500NO2-B	0.01 mg/L
Nitrate+Nitrite Nitrogen (NOX-N)	EPA 353.2	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Total Organic Carbon (TOC)	SM 5310B	0.06 mg/L
Sulfate	EPA 300.0	2.0 mg/L
Sulfide	SM 4500SF	0.10 mg/L
Hydrogen Sulfide (unionized)	SM 4550SF	0.01 mg/L
Fecal Coliform (fecal)	SM 9222D	1 ct/100mL
E.coli	SM 9223B	2 ct/100mL

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since the water meter installation on February 12, 2013. The treatment system flow meter readings for the B-HS5 field site are summarized in Table 3. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B. Summary tables of the Vericomm PLC recorded data are provided in Appendix C, Table C.1 and Table C.2. These include daily and cumulative pump runtime and system alarms that are used to check general pump operation and performance. From PNRS start-up through October 21, 2014, the average household water use was 132.3 gallons per day with periods of higher and lower flows (Table 2).

Table 2
Summary of Household Water Use Flowmeter

Date and Time Read	Cumulative Volume (gallons)	Average Daily Household Flow between readings, Q (gpd)	Average Daily Household Flow Since start-up, Q (gpd)
2/12/2013 10:30	166.0	INSTALLED	INSTALLED
2/21/2013 10:45	1,130.3	107.0	107.0
2/28/2013 11:45	2,323.9	169.5	134.4
3/7/2013 10:25	2,832.1	73.2	115.9
6/14/2013 13:00	13,460.9	107.2	108.9
6/25/2013 8:53	14,860.1	129.2	110.5
7/9/2013 15:20	PNRS start-up		
7/23/2013 8:31	17,659.4	100.0	
7/29/2013 11:10	18,769.2	181.6	181.6
8/15/2013 12:28	21,078.4	135.4	147.6
8/27/2013 9:15	22,427.8	113.7	136.1
9/27/2013 10:40	25,738.3	106.6	122.2
11/8/2013 10:30	31,992.8	148.9	132.6
11/27/2013 11:12	34,400.8	126.5	131.7
12/4/2013 14:34	35,292.8	124.9	131.3
12/23/2013 12:38	37,649.1	124.5	130.5
1/23/2014 10:00	42,526.6	157.9	135.1
1/31/2014 13:00	43,688.6	143.0	135.4
2/3/2014 8:40	43,688.6	0.0	133.5
2/4/2014 11:45	43,841.1	135.1	133.5
2/5/2014 9:45	43,928.5	95.3	133.3
2/6/2014 8:20	44,029.1	106.9	133.2
2/7/2014 10:30	44,175.2	134.0	133.2
2/12/2014 11:00	44,987.4	161.8	133.9
3/14/2014 9:50	48,684.9	123.5	132.6
4/11/2014 9:00	52,272.6	128.3	132.1
4/25/2014 10:05	54,087.0	128.9	131.9
4/29/2014 11:45	54,618.0	131.5	131.9
5/28/2014 10:00	59,552.4	170.6	135.5
6/11/2014 9:45	65,290.1	410.1	147.4
8/18/2014 11:00	69,750.1	65.5	133.2
9/19/2014 9:00	73,358.2	113.0	131.7
10/21/2014 12:21	77,223.0	120.3	130.9
11/21/2014 9:45	81,164.2	127.6	130.7
12/15/2014 12:22	85,132.8	164.6	132.3

Table 3
Summary of Treatment System Flowmeters

Date	Recirculation Pumped Flow, R Water Meter Reading	Recirculation Pumped Flow, R Water Meter Reading	Average Recirc Ratio	Stage 2 Biofilter Pumped Flow, Q Water Meter Reading	Average Daily Stage 2, Q between readings
	Cumulative Volume (gal)	Gallons/Day	R:Q	Cumulative Volume (gal)	Gallons/Day
7/5/2013 12:00	286.1	0.0	0.0		Installed
7/9/2013 15:20	286.1	0.0	0.0	167.5	Start-up
7/12/2013 14:13	286.1	0.0	0.0	207.4	13.5
7/17/2013 9:02	286.1	0.0	0.0	995.6	164.8
7/23/2013 8:31	286.1	0.0	0.0	1,642.9	108.3
7/29/2013 11:10	286.1	0.0	0.0	2,733.4	178.5
8/6/2013 8:51	286.1	0.0	0.0	3,894.7	146.9
8/15/2013 11:40	286.1	0.0	0.0	4,884.6	108.6
8/27/2013 9:15	286.1	0.0	0.0	6,135.4	105.1
9/27/2013 10:40	286.1	0.0	0.0	9,035.2	93.4
11/8/2013 10:30	286.1	0.0	0.0	14,347.7	126.5
11/27/2013 10:55	286.1	0.0	0.0	16,591.6	118.0
12/4/2013 13:45	286.1	0.0	0.0	17,474.0	124.0
12/23/2013 12:38	286.1	0.0	0.0	19,610.1	112.7
1/23/2014 10:00	286.1	0.0	0.0	24,359.1	153.7
1/31/2014 13:00	286.1	0.0	0.0	25,506.3	141.2
2/3/2014 8:40	286.1	0.0	0.0	25,551.0	15.9
2/4/2014 11:45	286.1	0.0	0.0	25,659.1	95.7
2/5/2014 9:45	286.1	0.0	0.0	25,737.2	85.3
2/6/2014 8:20	286.1	0.0	0.0	25,836.3	105.3
2/7/2014 10:30	286.1	0.0	0.0	25,952.1	106.2
2/12/2014 11:00	286.1	0.0	0.0	26,756.2	160.2
3/14/2014 9:50	286.1	0.0	0.0	30,148.2	113.3
4/11/2014 9:00	286.1	0.0	0.0	33,578.8	122.7
4/25/2014 10:50	286.1	0.0	0.0	35,326.6	124.2
Total average start-up to 4/25/14		0.0	0.0		121.3
Switched to recirculation mode of operation: Stage 1 sprayers					
4/25/2014 12:00	314.1	0.0		35,355.0	
4/29/2014 13:00	1,626.0	324.6	3.2:1	35,768.8	102.4
5/28/2014 10:22	13,966.4	427.1	3.4:1	39,443.6	127.2
7/11/2014 9:45	30,112.5	367.2	3.2:1	44,416.3	113.1
8/18/2014 11:00	43,938.8	363.4	3.2:1	48,763.1	114.2
9/19/2014 9:00	56,562.2	395.5	3.1:1	52,793.5	126.3

Table 3 (con't)
Summary of Treatment System Flowmeters

Date	Recirculation Pumped Flow, R Water Meter Reading	Recirculation Pumped Flow, R Water Meter Reading	Average Recirc Ratio	Stage 2 Biofilter Pumped Flow, Q Water Meter Reading	Average Daily Stage 2, Q between readings
	Cumulative Volume (gal)	Gallons/Day	R:Q	Cumulative Volume (gal)	Gallons/Day
10/21/2014 12:20	69,070.3	389.2	3.0:1	56,912.7	128.2
11/21/2014 9:45	79,362.6	333.2	3.1:1	60,198.4	106.4
12/15/2014 12:22	92,433.8	542.2	3.2:1	64,303.6	170.3
Total average 4/25/2014 to 12/15/14		393.6	3.2:1		123.7

The two throttling gate valves control the fraction of Stage 1 effluent that is recirculated and the fraction sent to the Stage 2 biofilter. As previously discussed, the recirculation mode of operation was modified following the fourth sample event. The gate valves were set so that 3 parts went back to the Stage 1 sprayers and 1 part went to the Stage 2 tank (3:1 recycle ratio). The average recirculated pumped flow (to the Stage 1 biofilter), following the modification to the recirculation mode of operation, was 393.6 gallons per day, and the average forward flow to the Stage 2 biofilter was 123.7 gallons per day. Following the switch to the recirculation mode of operation, the average recirculation ratio was 3.2:1 (Table 3).

4.2 Energy Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 4.

Table 4
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use between readings	Average Electrical Use per Gallon Treated	Average Electrical Use Per 1,000 Gallons Treated
	Cumulative (kWh)	(kWh/day)	(kWh/gal)	(kWh/1000 gal)
7/5/2013 12:00		Installed		
7/9/2013 15:20	0.3	Start-up		
7/12/2013 14:13	0.4	0.03	0.0025	2.5063
7/17/2013 9:02	0.6	0.04	0.0003	0.2537
7/23/2013 8:32	0.8	0.03	0.0003	0.3089
7/29/2013 11:10	1.2	0.07	0.0004	0.3669
8/6/2013 8:51	1.5	0.04	0.0003	0.2583
8/15/2013 11:40	1.8	0.03	0.0003	0.3030
8/27/2013 9:15	2.2	0.03	0.0003	0.3198
9/27/2013 10:40	3.1	0.03	0.0003	0.3104
11/8/2013 10:30	4.8	0.04	0.0003	0.3200
11/27/2013 10:55	5.5	0.04	0.0003	0.3119
12/4/2013 13:45	5.8	0.04	0.0003	0.3400
12/23/2013 12:38	6.5	0.04	0.0003	0.3277
1/23/2014 10:00	8.0	0.05	0.0003	0.3159
1/31/2014 13:00	8.4	0.05	0.0003	0.3487
2/3/2014 8:40	8.4	0.00	0.0000	0.0000
2/12/2014 11:00	8.8	0.04	0.0002	0.2487
3/14/2014 9:50	9.9	0.04	0.0003	0.3243
4/11/2014 9:00	11.0	0.04	0.0003	0.3206
4/25/2014 10:50	11.6	0.04	0.0003	0.3433
Total average start-up to 4/25/14		0.04	0.0003	0.3214
Switched to recirculation mode of operation: Stage 1 sprayers				
4/25/2014 12:00	11.6			
4/29/2014 13:00	12.1	0.12	0.0012	1.2083
5/28/2014 10:22	16.5	0.15	0.0012	1.1973
7/11/2014 9:45	22.1	0.13	0.0011	1.1261
8/18/2014 11:00	27.1	0.13	0.0012	1.1503
9/19/2014 9:00	31.6	0.14	0.0011	1.1165
10/21/2014 12:20	36.2	0.14	0.0011	1.1167
11/21/2014 9:45	39.9	0.12	0.0011	1.1261
12/15/2014 12:22	44.5	0.19	0.0011	1.1205
Total average 4/25/14 to 12/15/14		0.14	0.0011	1.1365

The total average electrical use prior to switching to the recirculation mode of operation (through April 25, 2014) was 0.04 kWh per day, corresponding to an average electrical use of 0.3214 kWh per 1,000 gallons treated. Following the switch from single pass to recirculation mode, the average electrical use increased, as expected. Average electrical use after switching to the recirculation mode of operation was 0.14 kWh per day, corresponding to an average electrical use of 1.1365 kWh per 1,000 gallons treated.

4.3 Water Quality

Water quality analytical results for Sample Event No. 8 are listed in Table 5. Key results are graphically displayed in Figure 8. A summary of the water quality data collected to date for the test system is presented in Table 6. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.

	STE	STAGE 1	STAGE 2 LIGNO	STAGE 2 SULFUR
$CBOD_5$ mg/L	170	3	Non-detect	14
TKN mg N/L	73	4.7	2.8	2.1
NH_3 mg N/L	58	0.1	Non-detect	1.3
NO_x mg N/L	0.07	62	34	0.05
TN mg N/L	73	67	37	2.2
Sulfate mg/L	19	27	25	270
Fecal Coliform (Ct/100mL)	105,000	500	70	60

Figure 8
Graphical Representation of Nitrogen Results
Sample Event No. 8, December 15, 2014 (Experimental Day 524)

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured STE total nitrogen (TN) concentration was 73 mg/L, which is within the high end of the range that has been typically reported for Florida single family residence STE.

Stage 1 Effluent (ST1): The Stage 1 effluent NH_3-N level was 0.1 mg/L with a DO level at 5.4 mg/L (Table 5). The Stage 1 effluent TSS concentration was below the method detection limit of 1 mg/L and $CBOD_5$ concentration was 3 mg/L. The Stage 1 biofilter showed nearly complete nitrification with an effluent NH_3-N concentration of 0.1 mg/L and TKN of 4.7 mg/L. The Stage 1 effluent NO_x-N was 62.1 mg/L. The Stage 1 effluent TN was 66.8 mg/L, a nine percent reduction in nitrogen.

Stage 2 Biofilter Effluent (LIGNO-0" and ST2): The Stage 2 system produced a reducing environment and achieved essentially complete NO_x-N reduction. Effluent NO_x-N from the Stage 2 biofilter monitoring point was 0.05 mg/L. The low NO_x-N was accompanied by a measured 0.2 mg/L DO and -232 mV ORP. The lignocellulosic media effluent NO_x-N was 34.2 mg/L. The total nitrogen (TN) in the treatment system final effluent was 2.15 mg/L, a 97 percent reduction in nitrogen relative to the influent STE. The Stage 2 biofilter lignocellulosic media effluent $CBOD_5$ concentration was below the method detection limit of 2 mg/L and was 14 mg/L in the sulfur biofilter effluent. The Stage 2 effluent sulfate concentration was 270 mg/L.

As previously discussed in Section 3.3, Sample Event 8 also included Stage 2 biofilter profile samples. As depicted in Figure 9, the unsaturated Stage 1 biofilter effluent is pumped to the top of the first chamber of the Stage 2 biofilter which contains lignocellulosic media. The effluent flows downward through the lignocellulosic media, moves laterally in a perforated 4-inch pipe through the baffle wall to the bottom of the second chamber, and upward through the sulfur media mixture in the second chamber. The nitrogen results at the various depths of the Stage 2 biofilter are graphically displayed in Figure 9. Each stainless steel drivepoint sampler was assigned a unique identification indicating the depth (in inches) the sampler was placed above the bottom of the media. For example LIGNO-36 is a stainless steel drivepoint sampler located at 36 inches above the bottom of the lignocellulosic media. The profile results from this event indicate that the NO_x-N was effectively reduced below the method detection limit at profile sampler SULFUR-6. The NO_x-N concentration progressively decreased with passage through the lignocellulosic media in the downflow biofilter, which accounted for approximately 44.8 percent of the NO_x-N reduction. Residual NO_x-N in the effluent of the downflow biofilter was reduced to 0.03 mg/L at the 6-inch depth through the sulfur media.

2A Lignocellulosic Compartment					2B Sulfur Compartment			
FROM PUMP	TKN	NH3-N	NOX-N	Tank Wall		TKN	NH3-N	NOX-N
Influent	4.7	0.10	62.1		Effl. Sulfur	2.1	1.3	0.05
LIGNO-36	5.1	0.05	41.1					
LIGNO-24	4.1	0.01	32.1					
LIGNO-12	3.3	0.01	33.0		SULFUR-12	1.9	1.0	0.03
LIGNO-0	2.8	0.01	34.2		SULFUR-6	2.3	1.2	0.03

Figure 9
Graphical Representation of Stage 2 Biofilter Profile Nitrogen Results

Blanks (FB and EB): The field blank (FB) was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. The equipment blank (EB) was collected by pumping deionized water through the cleaned pump tubing. Both samples were then analyzed for the same parameters as the monitoring samples. As expected, most parameters measured were at or below the method detection limit. However the TKN was 0.1 and 0.08 mg/L and the total phosphorus was 0.48 and 0.49 mg/L for FB and EB, respectively.

Table 5
Sample Event No. 8 Water Quality Results

Sample ID	Sample Date/Time	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
BHS5-STE	12/15/2014 11:10	19.8	7.43	1222	0.05	-293.7		31		170	240	73.07	73	15.00	58	0.02	0.05	0.07	58.07	0.63		19	0.01	5.6	105000	100000	28
BHS5-ST1	12/15/2014 10:55	20.2	6.93	1187	5.43	120.7		1		3	10	66.75	4.7	4.60	0.1	62	0.05	62.05	62.15	3.3		27	0.01	0.2	500	420	3.4
BHS5-LIGNO-36	12/15/2014 10:35	20	6.87	1122	1.26	24				2		46.15	5.1	5.05	0.054	41	0.05	41.05	41.10			26					
BHS5-LIGNO-24	12/15/2014 10:25	20.1	6.97	1107	1.75	-17.2				2		36.15	4.1	4.09	0.009	32	0.05	32.05	32.06			25					
BHS5-LIGNO-12	12/15/2014 10:20	19.8	6.92	1110	0.23	-122.3				5		36.34	3.3	3.29	0.009	33	0.04	33.04	33.05			26					
BHS5-LIGNO-0	12/15/2014 10:05	19.6	6.94	1111	0.38	-190.1		1		2	12	37.03	2.8	2.79	0.009	34	0.23	34.23	34.24	2.8		25	0.01	0.1	70	56	4.6
BHS5-SULFUR-6	12/15/2014 9:55	19.7	6.62	1209	0.3	-264.4				19		2.33	2.3	1.10	1.2	0.02	0.01	0.03	1.23			240					
BHS5-SULFUR-12	12/15/2014 9:50	19.2	6.33	1301	0.5	-265.4				28		1.93	1.9	0.92	0.98	0.02	0.01	0.03	1.01			260					
BHS5-ST2	12/15/2014 9:25	19.1	6.77	1306	0.2	-231.8		5		14	41	2.15	2.1	0.80	1.3	0.02	0.03	0.05	1.35	2.5		270	0.01	6.8	60	41	5.5
BHS5-ST2-DUP	12/15/2014 9:30	19.1	6.77	1306	0.2	-231.8		1		13	37	2.05	2	0.60	1.4	0.02	0.03	0.05	1.45	2.5		310	0.01	6.6	60	37	5.5
BHS5-FB	12/15/2014 11:35	18.1	6.59	4.36	8.41	106.4		1		2	10	0.13	0.1	0.09	0.009	0.02	0.01	0.03	0.04	0.48		0.2	0.01	0.1	1	2	0.06
BHS5-EB	12/15/2014 11:45	18.3	6.23	2.06	8.42	110.4		1		2	10	0.11	0.08	0.07	0.009	0.02	0.01	0.03	0.04	0.49		0.2	0.01	0.1	1	2	0.06

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 6. Figure 12 provides a time series of influent and effluent TN over the study period. Figures 13 through 19 show box and whisker plots of the various monitoring points for the key parameters measured during the study period.

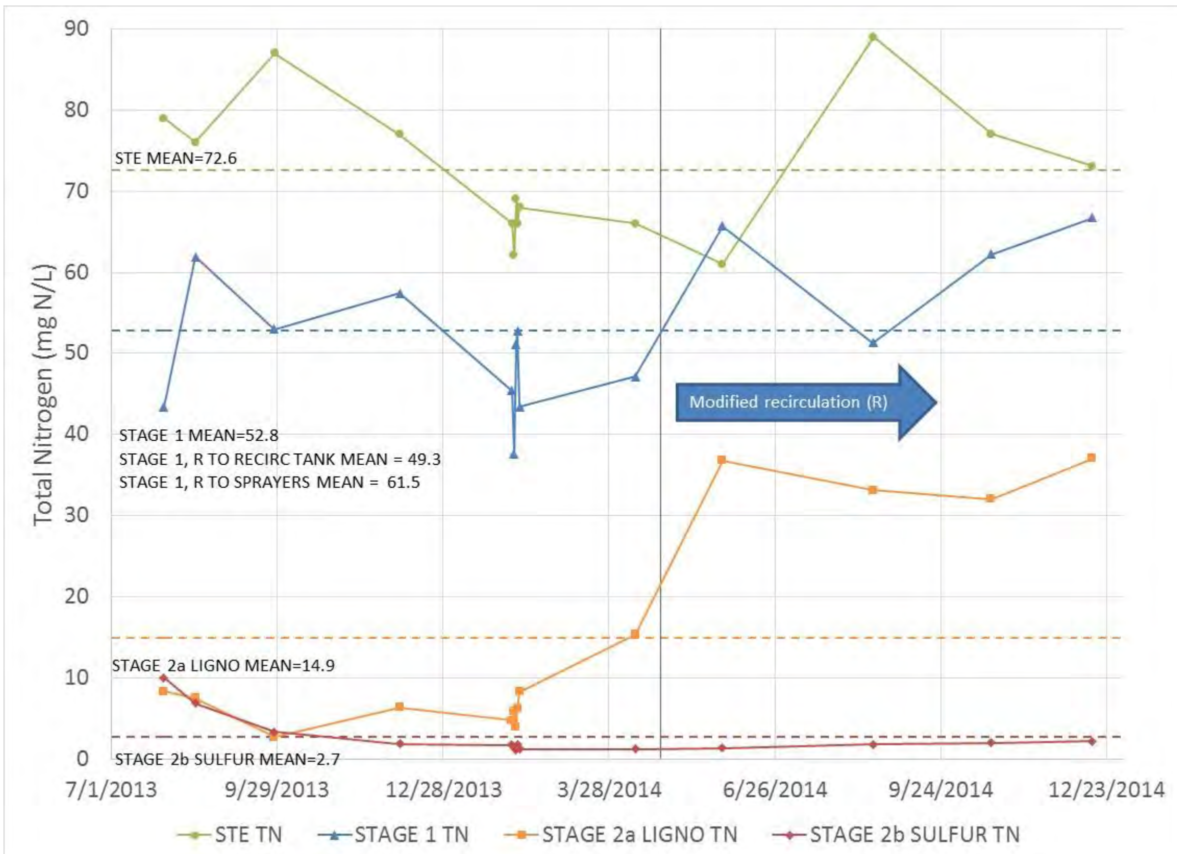

Figure 12
Total Nitrogen Time Series Graph
July 29, 2013 through December 15, 2014

Table 6
Summary of Water Quality Analytical Results

Sample ID	Statistics	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
STE	n	14	14	14	14	14	11	14	11	14	12	14	14	14	14	14	14	14	14	12	11	14	14	14	12	12	12
	MEAN	23.67	7.26	1200.21	0.06	-285.88	411.82	38.07	33.55	86.14	156.50	72.60	72.57	12.41	60.16	0.02	0.02	0.03	60.19	6.85	5.27	6.27	3.10	7.71	51,361	10,730	37
	STD. DEV.	3.80		65.64	0.03	37.96	20.89	12.68	13.68	32.51	68.19	8.68	8.68	15.41	19.00	0.02	0.01	0.02	19.00	2.65	0.80	6.24	1.82	2.73			10
	MIN	19.10	6.99	1048.00	0.01	-341.90	370.00	22.00	12.00	32.00	37.00	61.02	61.00	0.00	0.26	0.01	0.01	0.02	0.28	0.63	3.70	1.30	0.01	1.40	3,100	1,700	20
	MAX	28.90	7.63	1305.00	0.11	-226.80	440.00	60.00	56.00	170.00	270.00	89.02	89.00	60.74	79.00	0.08	0.05	0.08	79.02	12.00	6.50	19.00	6.90	12.00	160,000	120,000	51
Stage 1	n	14	14	14	14	14	11	12	11	12	12	14	14	14	14	13	13	14	14	12	11	10	9	9	12	12	12
	MEAN	23.39	6.87	1157.50	3.00	14.84	202.73	1.83	1.73	8.17	14.50	52.79	6.07	3.40	2.67	45.38	0.35	46.72	49.39	2.54	1.70	29.30	0.18	0.33	1,003	117	6
	STD. DEV.	3.23		70.10	1.29	95.76	18.49	1.03	1.10	5.24	7.20	9.00	2.47	1.42	2.69	8.73	0.49	9.26	8.48	0.45	0.23	5.08	0.26	0.35			2
	MIN	20.11	6.65	1057.00	1.64	-127.90	170.00	1.00	1.00	2.00	10.00	37.60	3.60	1.60	0.10	33.00	0.01	34.00	34.39	2.00	1.30	21.00	0.01	0.10	82	2	3
	MAX	28.20	7.18	1249.00	5.43	134.50	230.00	4.00	4.00	18.00	33.00	66.75	10.00	6.50	7.50	62.00	1.80	62.05	62.15	3.30	1.90	37.00	0.79	1.20	8,100	3,600	12
Stage 2a Ligno	n	14	14	14	14	14	11	14	11	14	12	14	14	14	14	13	13	14	14	12	11	11	10	10	12	12	12
	MEAN	23.74	6.65	1082.21	0.54	-104.66	344.55	4.86	2.91	11.57	35.08	14.86	3.04	2.31	0.73	9.21	0.83	11.82	12.55	1.41	0.73	25.36	0.17	0.29	212	25	11
	STD. DEV.	4.27		69.08	0.64	92.87	56.28	6.00	1.87	9.38	35.57	13.41	2.11	1.22	1.34	12.89	0.78	13.74	13.21	0.67	0.45	3.26	0.23	0.28			6
	MIN	18.40	6.25	946.00	0.03	-230.80	260.00	1.00	1.00	2.00	12.00	2.70	0.88	0.00	0.01	0.01	0.01	0.02	0.42	0.51	0.13	18.00	0.01	0.10	43	2	5
	MAX	30.20	7.38	1182.00	2.50	63.10	410.00	24.00	6.00	38.00	140.00	37.03	8.30	4.32	4.60	34.00	2.00	35.00	35.07	2.80	1.60	30.00	0.63	0.81	1,000	740	29
Stage 2b Sulfur	n	14	14	14	14	14	11	12	11	12	12	14	14	14	14	14	14	14	14	12	12	14	14	14	12	12	12
	MEAN	23.08	6.71	1218.86	0.15	-257.90	353.64	2.58	2.36	11.42	34.58	2.68	2.64	1.32	1.32	0.03	0.01	0.04	1.36	1.25	0.65	128.79	6.93	10.78	27	9	10
	STD. DEV.	4.51		208.09	0.10	49.84	71.03	1.44	1.29	8.82	7.98	2.57	2.58	0.97	1.70	0.04	0.01	0.04	1.69	0.50	0.38	93.18	11.69	16.54			5
	MIN	18.30	6.41	991.00	0.03	-357.00	200.00	1.00	1.00	2.00	23.00	1.12	1.00	0.65	0.16	0.01	0.01	0.02	0.18	0.42	0.00	29.00	0.01	0.40	1	2	6
	MAX	30.40	7.04	1781.00	0.38	-195.40	480.00	5.00	5.00	33.00	50.00	10.02	10.00	4.20	5.80	0.17	0.03	0.18	5.82	2.50	1.40	330.00	45.00	64.00	1,000	74	25

Notes:

Includes first two preliminary sample events which appear to be during maturation of the system.

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Fecal coliform and pH values are reported as geometric mean.

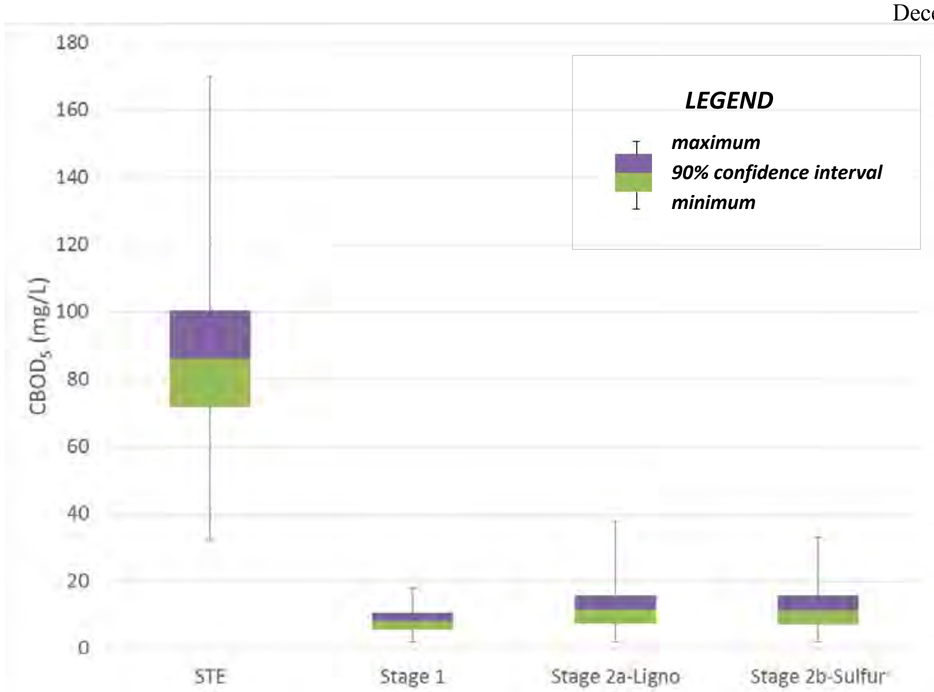

Figure 13
CBOD5 Box and Whisker Plot

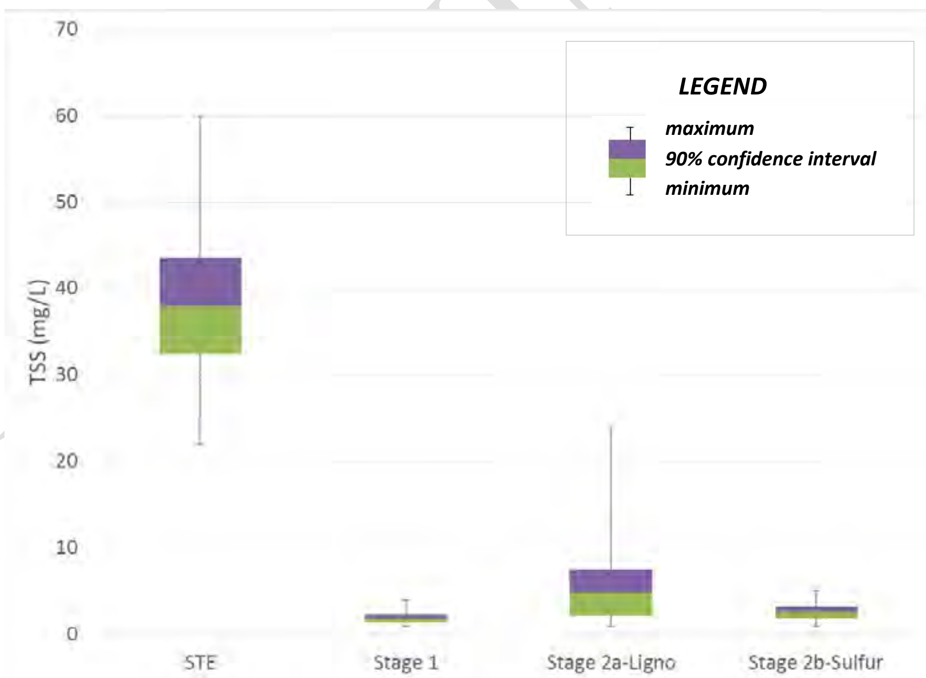

Figure 14
TSS Box and Whisker Plot

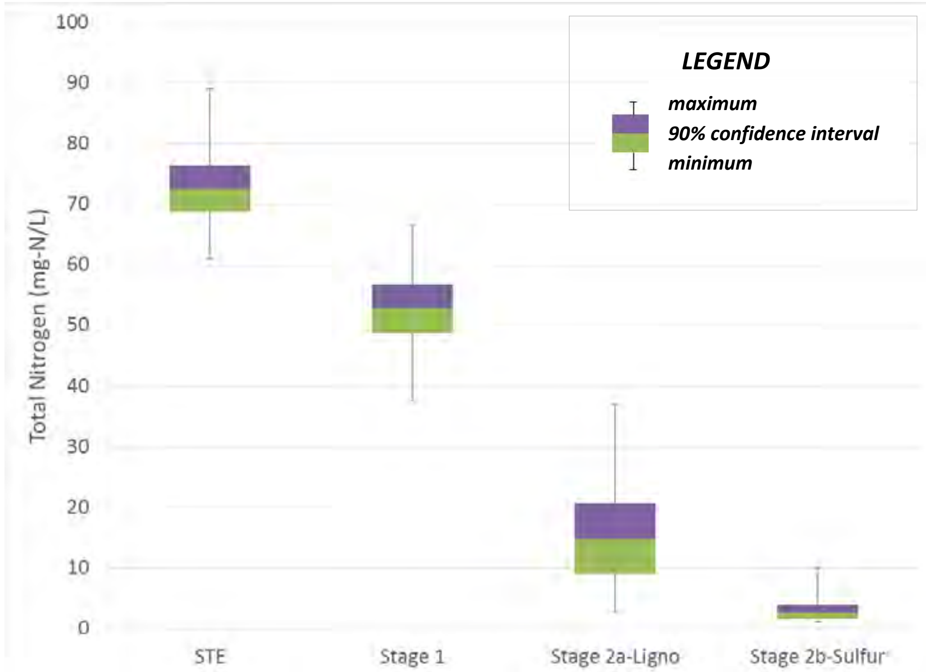

Figure 15
Total Nitrogen (TN) Box and Whisker Plot

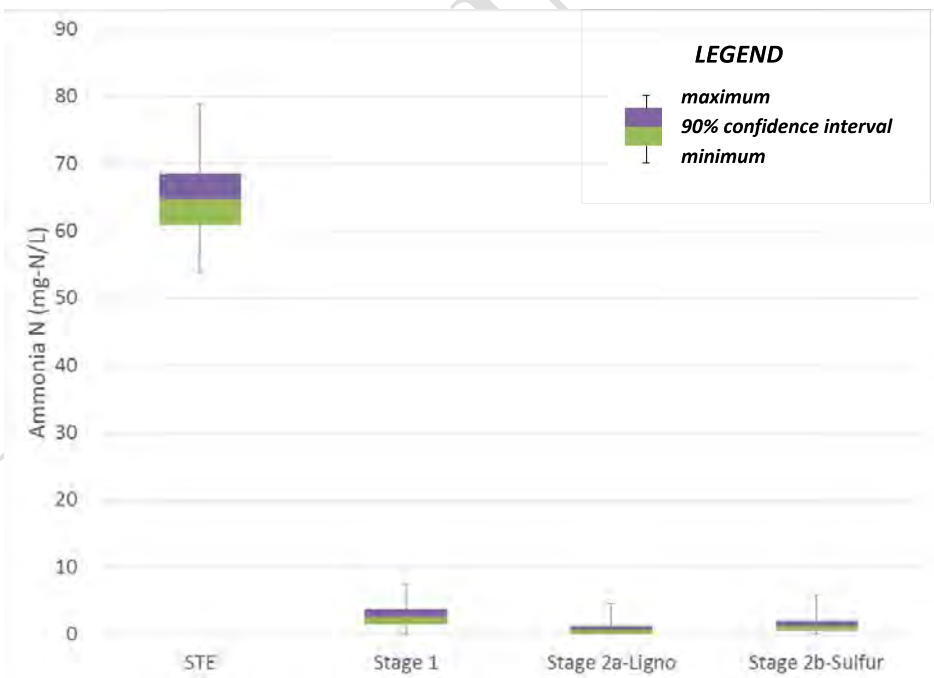

Figure 16
Ammonia N (NH3-N) Box and Whisker Plot

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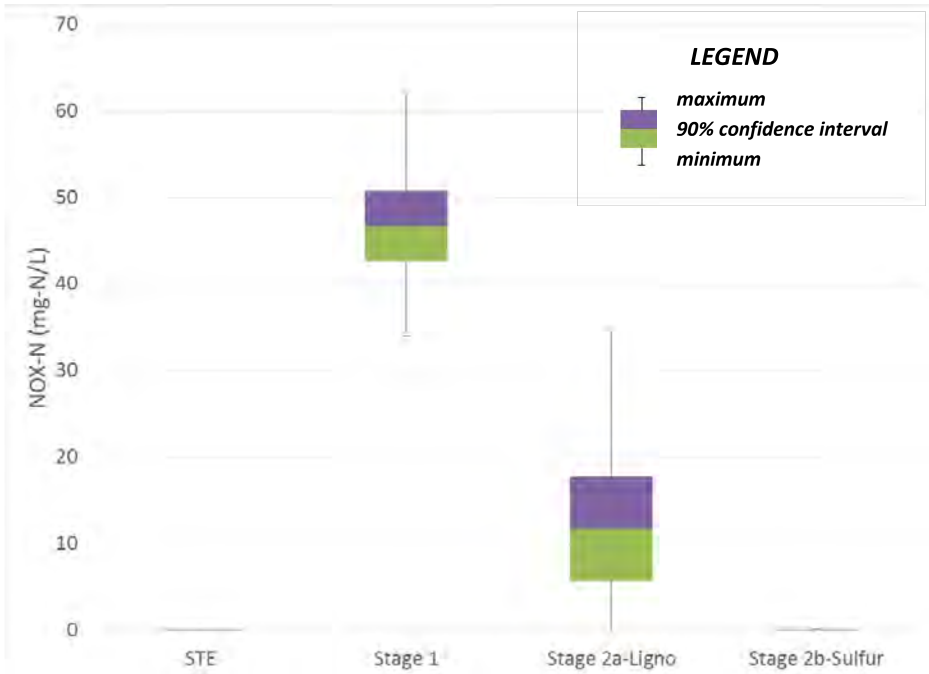

Figure 17
Nitrate+Nitrite Nitrogen (NOx-N) Box and Whisker Plot

Figure 18
Sulfate (SO_4) Box and Whisker Plot

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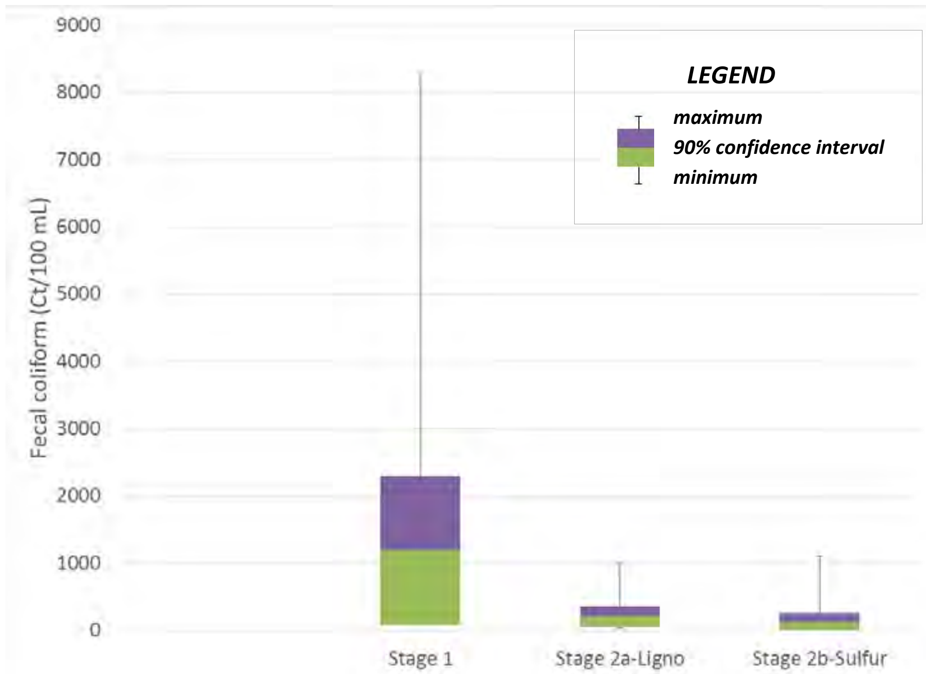

Figure 19
Fecal Coliform Box and Whisker Plot

4.5 Mode of Operation Performance Comparison

As previously discussed, the recirculation mode of operation was modified following the fourth sample event. Single pass mode was initially tested, where 100 percent of the Stage 1 effluent was discharged to the Stage 2 biofilter. A summary of the water quality data collected for the test system during testing of single pass operation (which was initially tested) is presented in Table 7. Following the fourth sample event, the recirculation mode was initiated. In recirculation mode, a portion (3:1 target ratio) of the Stage 1 effluent was recirculated to the top of the Stage 1 biofilter and dispersed via five spray nozzles. The recirculated, nitrified effluent would have an opportunity to mix with incoming septic tank effluent discharged by the distribution box. A summary of the water quality data collected for the test system during testing of the second option is presented in Table 8. A comparison of the two modes of operation for key parameters is provided in Table 9.

Table 7
Summary of Water Quality Data
Option 1: Single Pass Operation

Sample ID	Statistics	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
STE	n	10	10	10	10	10	8	10	8	10	8	10	10	10	10	10	10	10	10	8	8	10	10	10	8	8	8
	MEAN	23.1	7.3	1180.7	0.1	-286.2	406.3	39.8	35.4	77.2	141.0	71.6	71.6	8.7	62.9	0.02	0.01	0.03	62.9	7.5	5.0	3.8	3.4	8.5	42034.7	4908.3	35.5
	STD. DEV.	3.9		64.7	0.0	40.7	20.7	14.3	13.6	24.8	76.6	7.8	7.8	7.2	6.8	0.02	0.00	0.02	6.8	2.0	0.7	3.7	1.6	2.1			9.6
	MIN	19.1	7.0	1048.0	0.0	-341.9	370.0	22.0	22.0	32.0	37.0	62.1	62.0	0.0	54.0	0.01	0.01	0.02	54.0	5.9	3.7	1.3	1.6	5.1	3100.0	1700.0	20.0
	MAX	28.9	7.6	1294.0	0.1	-226.8	430.0	60.0	56.0	120.0	270.0	87.0	87.0	25.0	76.0	0.08	0.01	0.08	76.0	12.0	5.5	14.0	6.9	12.0	160000.0	24000.0	49.0
Stage 1	n	10	10	10	10	10	8	8	8	8	8	10	10	10	10	10	10	10	10	8	8	6	5	5	8	8	8
	MEAN	23.1	6.9	1145.4	2.3	-13.2	212.5	2.3	2.0	10.3	16.3	49.3	6.7	3.0	3.7	42.3	0.4	42.6	46.3	2.5	1.7	29.3	0.3	0.4	2406.3	171.1	6.8
	STD. DEV.	3.4		77.1	0.7	96.6	8.9	1.0	1.2	5.1	8.3	7.3	2.7	1.5	2.5	6.5	0.5	6.5	7.1	0.5	0.2	6.5	0.3	0.5			2.2
	MIN	20.1	6.8	1057.0	1.6	-127.9	200.0	1.0	1.0	2.0	10.0	37.6	3.6	1.6	0.4	33.0	0.0	34.0	34.4	2.0	1.4	21.0	0.0	0.1	1000.0	10.0	5.3
	MAX	28.2	7.2	1249.0	3.4	130.0	230.0	4.0	4.0	18.0	33.0	61.9	10.0	6.5	7.5	52.0	1.8	52.0	57.1	3.1	1.9	37.0	0.8	1.2	8100.0	3600.0	12.0
Stage 2a Ligno	n	10	10	10	10	10	8	10	8	10	8	10	10	10	10	10	10	10	10	8	8	7	6	6	8	8	8
	MEAN	23.1	6.6	1064.6	0.7	-107.9	373.8	5.9	3.0	14.6	44.1	6.9	3.2	2.2	1.0	2.7	1.0	3.7	4.7	1.1	0.5	24.1	0.1	0.3	416.1	35.9	13.4
	STD. DEV.	4.4		71.4	0.7	83.5	30.7	6.8	1.6	9.5	41.2	3.5	2.5	1.4	1.5	3.8	0.8	3.6	3.2	0.4	0.3	3.3	0.2	0.3			6.5
	MIN	18.4	6.3	946.0	0.1	-230.8	310.0	2.0	1.0	2.0	12.0	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.1	18.0	0.0	0.1	200.0	2.0	9.3
	MAX	30.2	7.4	1182.0	2.5	9.7	410.0	24.0	6.0	38.0	140.0	15.3	8.3	4.3	4.6	12.0	2.0	12.0	12.5	1.6	1.0	27.0	0.5	0.8	1000.0	740.0	29.0
Stage 2b Sulfur	n	10	10	10	10	10	8	8	8	8	8	10	10	10	10	10	10	10	10	8	8	10	10	10	8	8	8
	MEAN	22.6	6.8	1191.0	0.2	-259.5	381.3	2.3	2.3	9.4	33.0	3.0	3.0	1.5	1.5	0.04	0.01	0.04	1.5	1.1	0.7	81.3	8.3	12.6	23.4	8.7	11.6
	STD. DEV.	4.9		243.5	0.1	54.8	43.9	1.4	1.4	6.1	7.0	3.0	3.0	1.1	2.0	0.05	0.00	0.05	2.0	0.3	0.3	45.6	13.7	19.5			5.7
	MIN	18.3	6.6	991.0	0.0	-357.0	350.0	1.0	1.0	2.0	23.0	1.1	1.0	0.7	0.2	0.01	0.01	0.02	0.2	0.4	0.2	29.0	0.3	0.4	1.0	2.0	7.1
	MAX	30.4	7.0	1781.0	0.4	-195.4	480.0	5.0	5.0	19.0	43.0	10.0	10.0	4.2	5.8	0.17	0.01	0.18	5.8	1.5	1.0	200.0	45.0	64.0	1000.0	52.0	25.0

Notes:

Includes first two preliminary sample events which appear to be during maturation of the system.

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Fecal coliform and pH values are reported as geometric mean.

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Table 8
Summary of Water Quality Data
Option 2: Recirculation to Stage 1 Sprayers

Sample ID	Statistics	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	Hydrogen Sulfide (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	TOC (mg/L)
STE	n	4	4	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4
	MEAN	25.08	7.25	1249.00	0.04	-285.05	426.67	33.75	28.67	108.50	187.50	75.05	75.00	21.69	53.32	0.02	0.03	0.05	53.36	5.63	6.00	12.48	2.32	5.83	76,681	51,274	40.50
	STD. DEV.	3.63		41.01	0.02	35.56	15.28	6.80	15.63	42.38	37.75	11.55	11.55	26.67	36.57	0.01	0.02	0.03	36.58	3.63	0.78	7.43	2.41	3.43			10.47
	MIN	19.80	7.09	1215.00	0.02	-319.10	410.00	27.00	12.00	74.00	150.00	61.02	61.00	1.00	0.26	0.01	0.01	0.02	0.28	0.63	5.10	3.30	0.01	1.40	48,000	24,000	28.00
	MAX	28.10	7.43	1305.00	0.05	-235.00	440.00	43.00	43.00	170.00	240.00	89.02	89.00	60.74	79.00	0.02	0.05	0.07	79.02	8.50	6.50	19.00	4.60	9.70	140,000	120,000	51.00
Stage 1	n	4	4	4	4	4	3	4	3	4	4	4	4	4	4	3	3	4	4	4	3	4	4	4	4	4	4
	MEAN	24.08	6.83	1187.75	4.61	84.85	176.67	1.00	1.00	4.00	11.00	61.50	4.48	4.34	0.13	55.67	0.04	57.03	57.16	2.60	1.70	29.25	0.08	0.20	174.16	55.16	4.90
	STD. DEV.	3.17		42.06	0.82	50.81	5.77	0.00	0.00	2.16	2.00	7.07	0.26	0.28	0.03	7.77	0.02	6.89	6.90	0.50	0.35	2.63	0.14	0.14			2.50
	MIN	20.20	6.65	1137.00	3.48	29.10	170.00	1.00	1.00	2.00	10.00	51.30	4.20	4.03	0.10	47.00	0.01	47.00	47.12	2.10	1.30	27.00	0.01	0.10	82.00	2.00	3.40
	MAX	27.80	6.98	1240.00	5.43	134.50	180.00	1.00	1.00	7.00	14.00	66.75	4.70	4.60	0.17	62.00	0.05	62.05	62.15	3.30	1.90	33.00	0.28	0.39	500.00	420.00	8.60
Stage 2a Ligno	n	4	4	4	4	4	3	4	3	4	4	4	4	4	4	3	3	4	4	4	3	4	4	4	4	4	4
	MEAN	25.43	6.69	1126.25	0.23	-96.70	266.67	2.25	2.67	4.00	17.00	34.73	2.60	2.58	0.02	31.00	0.18	32.13	32.16	2.13	1.26	27.50	0.22	0.35	55.04	12.82	6.83
	STD. DEV.	4.01		42.08	0.15	127.90	5.77	2.50	2.89	2.16	4.16	2.56	0.56	0.59	0.03	2.65	0.15	2.90	2.92	0.50	0.43	2.08	0.29	0.33			3.48
	MIN	19.60	6.44	1074.00	0.03	-209.30	260.00	1.00	1.00	2.00	12.00	32.00	1.80	1.73	0.01	29.00	0.01	29.30	29.31	1.60	0.78	25.00	0.01	0.10	43.00	2.00	4.60
	MAX	28.50	6.94	1166.00	0.38	63.10	270.00	6.00	6.00	7.00	22.00	37.03	3.10	3.09	0.07	34.00	0.30	35.00	35.07	2.80	1.60	30.00	0.63	0.79	70.00	56.00	12.00
Stage 2b Sulfur	n	4	4	4	4	4	3	4	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	MEAN	24.39	6.58	1288.50	0.12	-253.98	280.00	3.25	2.67	15.50	37.75	1.79	1.75	0.86	0.89	0.02	0.02	0.04	0.93	1.57	0.64	247.50	3.45	6.18	34.64	10.50	7.98
	STD. DEV.	3.76		26.59	0.07	41.72	85.44	1.50	1.15	12.87	9.98	0.35	0.34	0.17	0.49	0.01	0.01	0.01	0.50	0.68	0.60	71.36	3.27	2.84			3.48
	MIN	19.10	6.41	1249.00	0.05	-302.40	200.00	2.00	2.00	2.00	27.00	1.32	1.30	0.70	0.21	0.01	0.01	0.02	0.23	0.89	0.00	160.00	0.01	2.00	1.00	2.00	5.50
	MAX	28.00	6.77	1306.00	0.20	-208.90	370.00	5.00	4.00	33.00	50.00	2.15	2.10	1.09	1.30	0.04	0.03	0.05	1.35	2.50	1.40	330.00	6.30	8.20	300.00	74.00	13.00

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Fecal coliform and pH values are reported as geometric mean.

Table 9
Comparison of Water Quality

Sample ID	Statistical Parameter	Total Alkalinity (mg/L)		TSS (mg/L)		CBOD5 (mg/L)		TN (mg/L N)		TKN (mg/L N)		Organic N (mg/L N)		NH3-N (mg/L N)		NOx (mg/L N)		TIN (mg/L N)		TP (mg/L)		Sulfate (mg/L)	
		Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers	Single Pass	Recirc to Sprayers
Septic tank effluent (STE)	n	8	3	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4
	MEAN	406.3	426.7	38.3	33.8	70.9	108.5	70.2	75.0	70.1	75.0	7.8	21.7	62.4	53.3	0.03	0.05	62.4	53.4	7.5	5.6	3.9	12.5
	STD. DEV.	20.7	15.3	14.4	6.8	21.8	42.4	8.1	11.5	8.1	11.5	4.2	26.7	4.9	36.6	0.02	0.03	4.9	36.6	2.0	3.6	4.2	7.4
	MIN	370.0	410.0	22.0	27.0	32.0	74.0	62.1	61.0	62.0	61.0	2.0	1.0	56.0	0.3	0.02	0.02	56.0	0.3	5.9	0.6	1.3	3.3
	MAX	430.0	440.0	60.0	43.0	110.0	170.0	87.0	89.0	87.0	89.0	16.0	60.7	71.0	79.0	0.08	0.07	71.0	79.0	12.0	8.5	14.0	19.0
Stage 1 effluent	n	8	3	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	6	4
	MEAN	212.5	176.7	2.3	1.0	10.3	4.0	48.5	61.5	6.0	4.5	2.9	4.3	3.0	0.1	42.5	57.0	45.5	57.2	2.5	2.6	29.3	29.3
	STD. DEV.	8.9	5.8	1.0	0.0	5.1	2.2	6.3	7.1	2.5	0.3	1.6	0.3	2.4	0.0	5.5	6.9	6.6	6.9	0.5	0.5	6.5	2.6
	MIN	200.0	170.0	1.0	1.0	2.0	2.0	37.6	51.3	3.6	4.2	1.6	4.0	0.4	0.1	34.0	47.0	34.4	47.1	2.0	2.1	21.0	27.0
	MAX	230.0	180.0	4.0	1.0	18.0	7.0	57.4	66.8	10.0	4.7	6.5	4.6	7.5	0.2	49.5	62.1	54.6	62.2	3.1	3.3	37.0	33.0
Stage 2 lignocellulosic effluent	n	8	3	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	7	4
	MEAN	373.8	266.7	3.3	2.3	11.4	4.0	6.7	34.7	2.2	2.6	1.8	2.6	0.4	0.0	4.5	32.1	4.8	32.2	1.1	2.1	24.1	27.5
	STD. DEV.	30.7	5.8	1.6	2.5	5.0	2.2	3.9	2.6	1.3	0.6	1.3	0.6	0.5	0.0	3.7	2.9	3.6	2.9	0.4	0.5	3.3	2.1
	MIN	310.0	260.0	2.0	1.0	2.0	2.0	2.7	32.0	0.9	1.8	0.0	1.7	0.0	0.0	0.0	29.3	0.4	29.3	0.5	1.6	18.0	25.0
	MAX	410.0	270.0	6.0	6.0	17.0	7.0	15.3	37.0	4.7	3.1	4.3	3.1	1.4	0.1	12.0	35.0	12.5	35.1	1.6	2.8	27.0	30.0
Stage 2 sulfur effluent	n	8	3	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4	8	4
	MEAN	381.3	280.0	2.3	3.3	9.4	15.5	1.7	1.8	1.7	1.8	1.0	0.9	0.6	0.9	0.05	0.04	0.7	0.9	1.1	1.6	67.1	247.5
	STD. DEV.	43.9	85.4	1.4	1.5	6.1	12.9	0.7	0.4	0.7	0.3	0.3	0.2	0.7	0.5	0.06	0.01	0.7	0.5	0.3	0.7	20.6	71.4
	MIN	350.0	200.0	1.0	2.0	2.0	2.0	1.1	1.3	1.0	1.3	0.7	0.7	0.2	0.2	0.02	0.02	0.2	0.2	0.4	0.9	29.0	160.0
	MAX	480.0	370.0	5.0	5.0	19.0	33.0	3.3	2.2	3.3	2.1	1.5	1.1	2.4	1.3	0.18	0.05	2.4	1.4	1.5	2.5	98.0	330.0

Note: Nitrification and denitrification was still being established during the first two preliminary sample events; therefore the start-up period results were not included in the single pass data set.

5.0 B-HS5 Sample Event No. 8: Summary and Recommendations

5.1 Summary

The eighth and final sampling results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of 73 mg/L is within the high end of the range of values typically reported for Florida single family residence STE.

- The Stage 1 biofilter converted most of the ammonia N to oxidized nitrogen; effluent contained 4.7 mg/L TKN, of which 0.1 mg/L was ammonia.

- The Stage 2 biofilter effluent NO_x-N was 0.05 mg N/L.

- The total nitrogen concentration in the final effluent from the total treatment system was 2.15 mg/L, an approximately 97% reduction from STE.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS5 treatment system. Sections 4.4 and 4.5 summarized the water quality data collected over the 1.4 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 72.4 mg/L is in the upper range of values typically reported for Florida single family residence STE.

- Stage 1 recirculation mode of operation resulted in generally overall similar treatment performance as single pass mode.

- Both modes of operation showed that the Stage 1 biofilter provided significant nitrification with an average NH_3-N concentration of 3.0 and 0.1 mg/L and average TKN of 6.0 and 4.5 mg/L for single pass and recirculation, respectively. The Stage 1 biofilter effluent average NO_x-N was 42.5 and 57.0 mg/L for single pass and recirculation, respectively. These results indicate denitrification (approximately 31% and 18% total nitrogen reduction, respectively) was occurring.

- The time series plot (Figure 12) shows a trend in increasing total nitrogen in the lignocellulosic effluent with time which indicates less NO_x-N removal. The cause for the reduction in NO_x-N removal effectiveness in the lignocellulosic chamber is unclear; it could be related to the change in operation to recirculation, loss in reactivity of the media, or other factors.

- However, the Stage 2 biofilter sulfur media was effective in producing a reducing environment and achieving the NO_x-N reduction goals throughout the study period (average NO_x-N concentration of 0.04 mg/L). The average final total nitrogen (TN) in the treatment system effluent was 2.68 mg/L, primarily TKN (average TKN concentration of 2.64 mg/L), representing a 96 percent average reduction in total nitrogen from this PNRS.

Further analysis of the results obtained at this site will occur as Task B results are compiled and summarized. The results of the data collected to date have provided insights into the performance of a full-scale passive nitrogen reduction system monitored over an extended timeframe (524 experimental days) under actual onsite conditions.

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Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS6 Field System
Monitoring Report No. 8

Prepared for:

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Division of Disease Control and Health Protection
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B-HS6 Field System
Monitoring Report No. 8

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in PNRS II. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth and final sample event of the passive nitrogen reduction system at home site B-HS6 in Wakulla County, Florida.

2.0 Purpose

This monitoring report documents data collected from the eighth B-HS6 monitoring and sampling event conducted on January 29, 2015 (Experimental Day 441). This monitoring event consisted of collecting flow measurements from the household water use meter, treatment system flow meter, recording electricity use, monitoring of field parameters, collection of water samples from four points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory.

3.0 Materials and Methods

3.1 Project Site

The B-HS6 field site is located in Wakulla County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in November 2013. Operation commenced on November 14, 2013. Design and construction details were presented previously in the Task B.6 document. Figure 1 is a system schematic showing the system components and layout of the installation. A flow schematic of the system is shown in Figure 2. The new system replaced the previously installed PNRS system installed at field site B-HS1. The previously installed components that were removed

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were the Aerocell^{TM} unsaturated media filter chamber, Nitrex^{TM} media and split recirculation device. The existing 1,500 gallon dual chamber septic tank will continue to provide primary treatment for the new PNRS system. However, the effluent screen was moved to the outlet from the hole in the wall between the two chambers and a vented tee was installed between the chambers per 64E-6.013(2)(h). The existing pump and floats were moved from the second chamber of the primary tank into a new 275 gallon pump tank. A 1,650 gallon concrete tank was installed to house a combined Stage 1 and Stage 2a media biofilter. The existing 1,500 gallon concrete single chamber tank which had contained the Nitrex^{TM} media was converted to a Stage 2b saturated sulfur media biofilter. The denitrified treated effluent is discharged into the soil via the existing drainfield (standard Infiltrator EQ36 Quick 4 trenches).

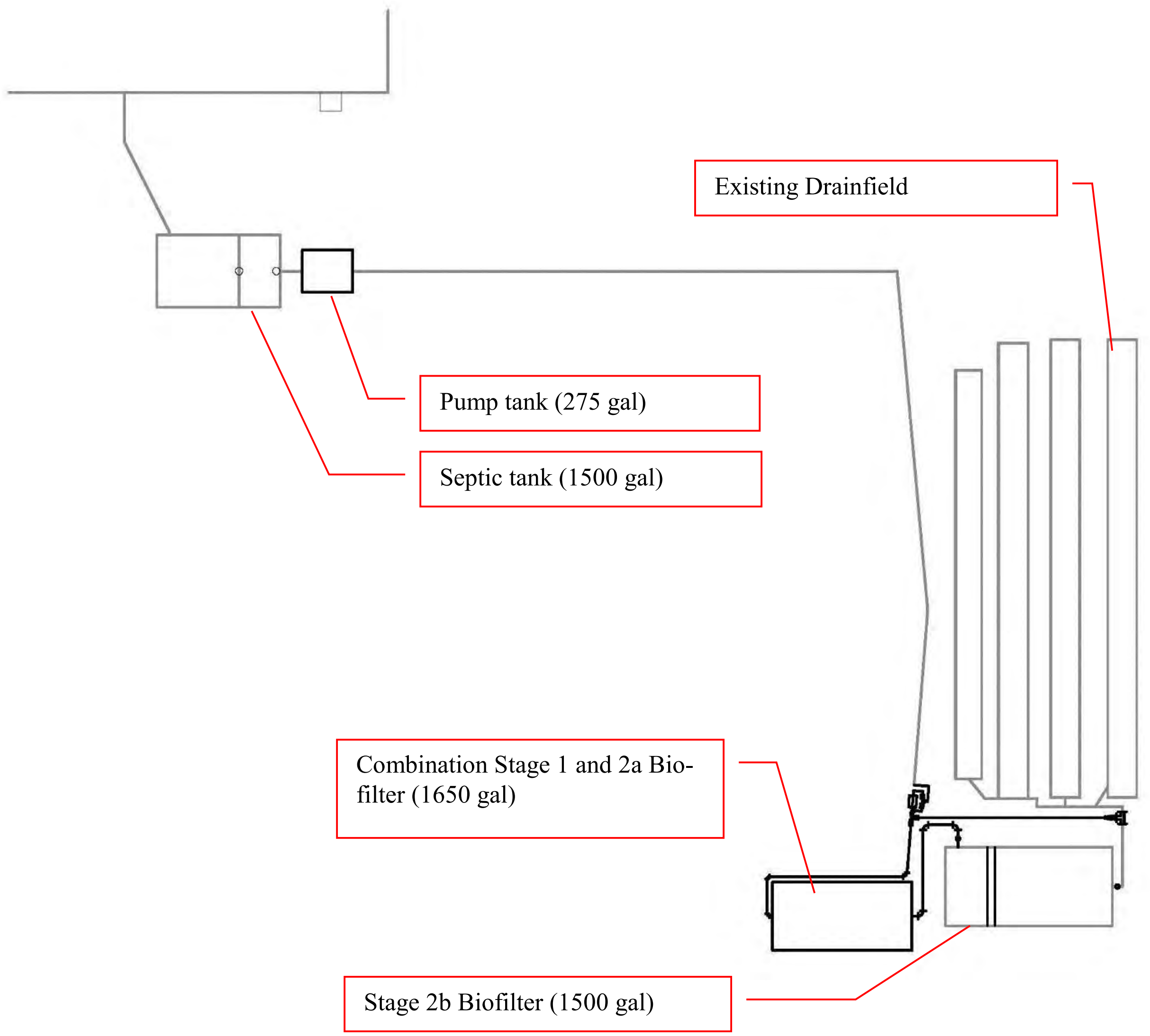

Figure 1
Plan view of B-HS6 system layout installed in Wakulla County

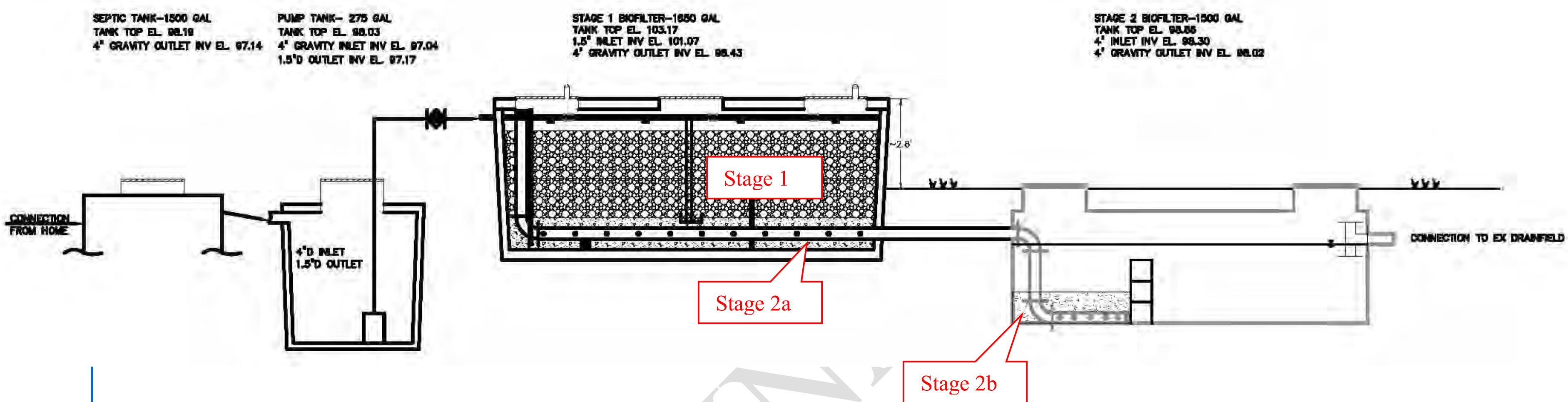

Figure 2
Flow Schematic of B-HS6 PNRS installed in Wakulla County

3.2 Monitoring and Sample Locations and Identification

Four of the eight monitoring points shown in Figure 3 (B-HS6-STE; B-HS6-DP2; B-HS6-ST1&2a; and B-HS6-ST2b-P) were sampled for this sample event. Monitoring point B-HS6-ST2b-T was not sampled as the water quality was very similar to the adjacent monitoring point B-HS6-ST2b-P. B-HS6-DP1, B-HS6-DP3, B-HS6-DP4 located in the Stage 1&2a tank were also not sampled during this sample event.

Household wastewater enters the 1st chamber of the primary tank and exits the second chamber through an effluent screen into the pump tank (which contains the pump and float switches). The first monitoring point, B-HS6-STE, is the effluent sampled from a sample port on the pump discharge line (Figure 4), which is downstream of the effluent screen and referred to as primary effluent or septic tank effluent (STE). Samples from monitoring point B-HS6-STE are representative of the whole household wastewater and represent the influent to the remainder of the onsite nitrogen reduction system.

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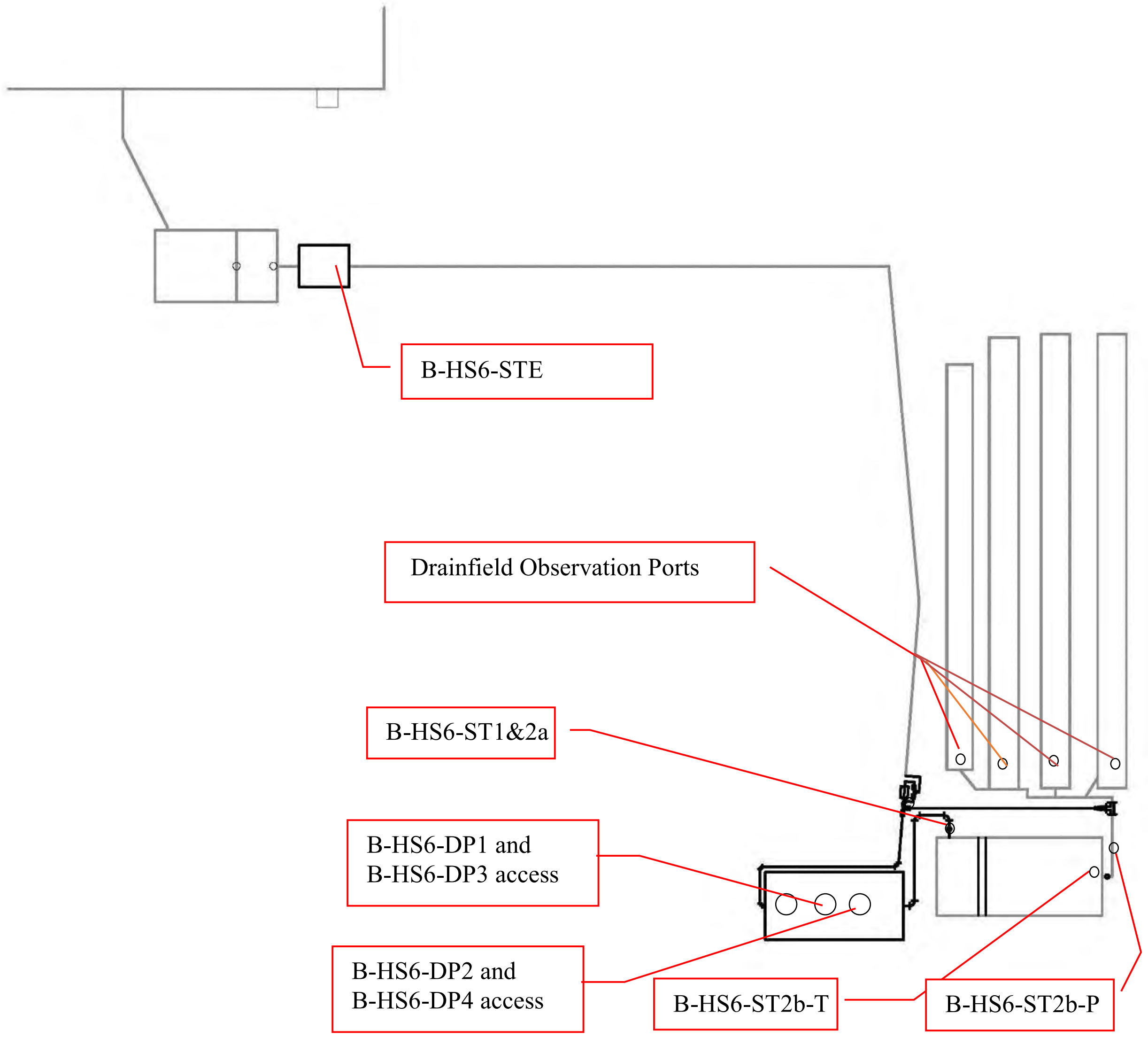

Figure 3
B-HS6 Treatment System Sampling and Monitoring Locations

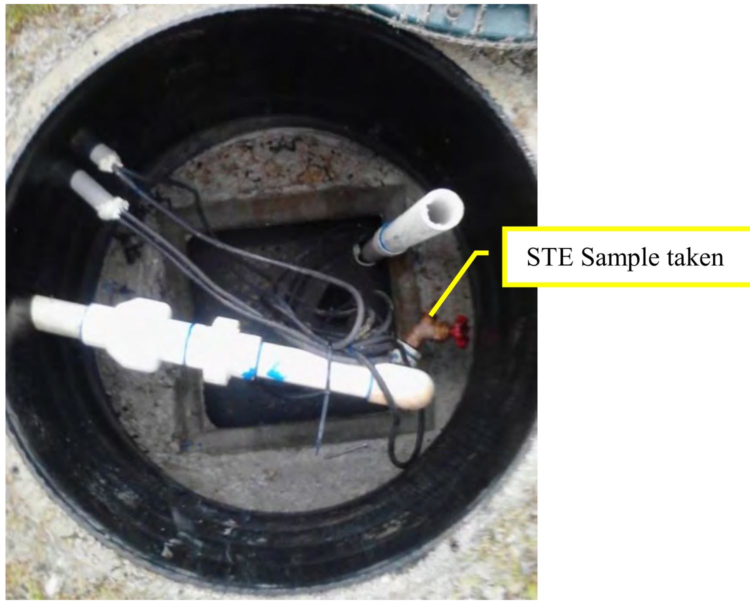

Figure 4
Primary Effluent (B-HS6-STE sample)

The pump tank contents are discharged to the top of the Stage 1 biofilter through three Orenco™ spin nozzles. The spin nozzles visually appear to adequately cover the surface area of the biofilter and provide relatively uniform flow distribution. The four spray nozzles that were originally installed were replaced with the three spin nozzle sprayers on March 20, 2014. In the Stage 1 biofilter, wastewater percolates downward through expanded clay media where unsaturated conditions provide for ammonium oxidation and nitrification. The Stage 1 biofilter contains 30 inches of coarse expanded clay media (Riverlite™ 1/4; 1.1 to 4.8 mm). Two shallow pans, each containing a drive point sampler, were installed underneath the expanded clay layer and on top of the Stage 2a lignocellulosic media (see Figure 5). The second and third sampling points (B-HS6-DP1 and B-HS6-DP2) are sampled by connecting a peristaltic pump to the drivepoint tubing of each pan. Each sample represents effluent from the unsaturated Stage 1 biofilter.

Figure 5
Stage 1 Unsaturated Biofilter Effluent (B-HS6-DP1 and B-HS6-DP2 sample)

Twelve inches of lignocellulosic media, a blended waste wood from AAA Tree Experts, Tallahassee, FL, was installed underneath the expanded clay media as a supplemental carbon source for denitrification. A single 4-inch diameter outlet pipe connected the Stage 1&2a tank to the Stage 2b tank. The pipe was installed along the centerline of the Stage 1&2a tank with the invert at 4-inches above the interior bottom of the tank. Therefore, approximately 4-inches of the lignocellulosic media is saturated, promoting oxygen depletion and denitrification of the nitrified effluent. Two additional stainless steel drive points were installed at the bottom of the Stage 2a saturated lignocellulosic media (see Figure 6). These drive points sampled water from near the very bottom of the tank. The fourth and fifth sampling points (B-HS6-DP3 and B-HS6-DP4) are each sampled by connecting a peristaltic pump to the drive point tubing. Samples from each of the two monitoring points possibly represent the effluent from the Stage 2a saturated biofilter.

Figure 6
Stage 2a Saturated Biofilter Effluent (B-HS6-DP3 and B-HS6-DP4) sample tubing

The tubing for sample points B-HS6-DP1 and B-HS6-DP3 are accessed via the middle tank cover (Figure 7), and B-HS6-DP2 and B-HS6-DP4 are accessed through the tank cover on the outlet side of the tank.

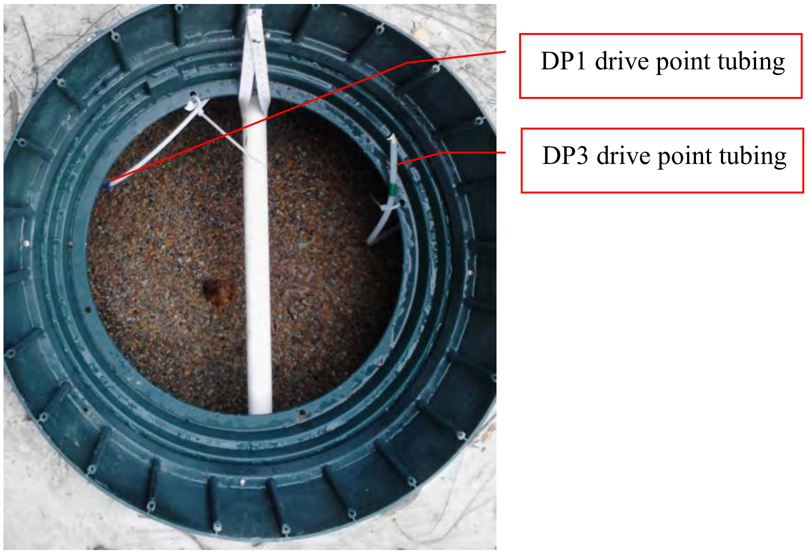

Figure 7
Drivepoint tubing access (B-HS6-DP1 and B-HS6-DP3 sample)

The effluent from the Stage 1&2a biofilter flows into the Stage 2b biofilter by gravity. The sixth sampling point (B-HS6-ST1&2a) is taken from a sample port in the gravity pipe connecting the Stage 1&2a biofilter outlet to the Stage 2b biofilter inlet representing the Stage 1&2a biofilter effluent (see Figure 8).

Figure 8
Stage 1&2a Biofilter Effluent Sample Port (B-HS6-ST1&2a sample)

Effluent from the Stage 1&2a biofilter enters the saturated denitrification (Stage 2b) biofilter at the bottom of the tank through a 4-inch diameter perforated pipe, flows upward through the 12-inches of elemental sulfur and oyster shell media mixture, and moves laterally over a concrete block wall to the second chamber. The Stage 2b biofilter effluent discharges near the top of the tank; therefore denitrification occurs in the saturated environment. The seventh primary sampling point, (B-HS6-ST2b-T) is the second chamber of the Stage 2 biofilter effluent, which is sampled approximately 1 foot below the surface of the effluent baffle tee. This sample location is after passage through the sulfur media; it is the final effluent from the treatment system prior to being discharged to the soil infiltration system, or drainfield (Figure 9).

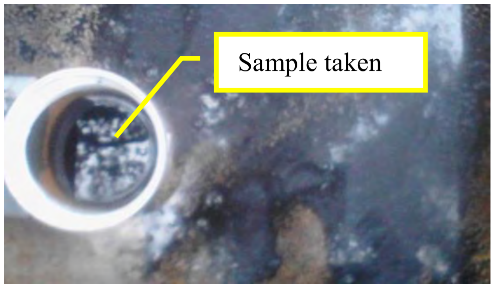

Figure 9
Stage 2b Biofilter Effluent (B-HS6-ST2b-T sample)

The eighth sampling point (B-HS6-ST2b-P) is from a sample port in the gravity pipe connecting the Stage 2b biofilter outlet to the drainfield inlet also representing the treated effluent (Figure 10).

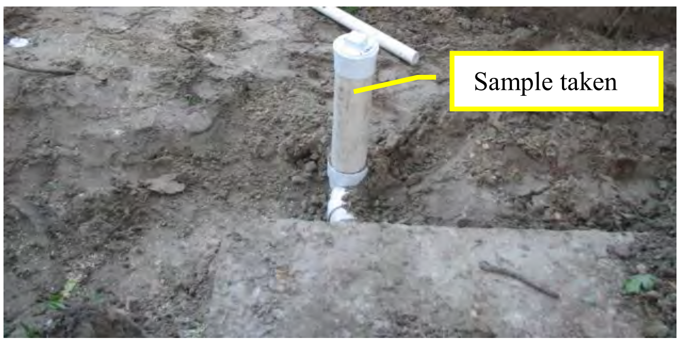

Figure 10
Stage 2b Biofilter Effluent (B-HS6-ST2b-P sample)

Treated effluent is discharged to a soil dispersal system (drainfield) consisting of four Infiltrator trenches. Three of the four Infiltrator trenches are 40 feet in length, and the fourth is 36 feet. The layout of the system and a flow schematic are shown in Figures 1 and 2, respectively.

3.3 Operational Monitoring

Start-up of the system occurred on November 14, 2013 (Experimental Day 0). The PNRS system has operated continually since that date. For this seventh formal sampling event, the water meter for the house and treatment system flow meter were read and recorded on January 29, 2015 (Experimental Day 441).

The household water meter is located on the potable water line from the onsite well prior to entering the household plumbing. The water meter does not include the irrigation water use. Therefore, the water meter reading should be indicative of the wastewater flow to the PNRS system.

The PNRS treatment system flow meter (Figure 11) is located on the pump tank discharge line and records the cumulative flow in gallons pumped from the pump chamber to the combined Stage 1&2a biofilter. The control panel includes telemetry where reports are generated regarding alarms, pump cycles, and other information using a Vericomm control panel system.

Figure 11
Treatment system flow meter

3.4 Energy Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. The power usage of the system is primarily due to the single lift station pump installed within the pump tank, although a small amount of power is used by the control panel itself. There are no chemicals added to the system. However, the Stage 2 biofilter media (lignocellulosic and sulfur) are “reactive” media which will be consumed during operation. The Stage 1&2a biofilter was initially filled with 12 inches of lignocellulosic media. The Stage 2b biofilter was filled with 12 inches of sulfur and oyster shell mixture media, which ostensibly will last for many years without replenishment or replacement.

3.5 Water Quality Sample Collection and Analyses

The eighth formal sample event (Sample Event No. 8), which is the subject of this report, was conducted on January 29, 2015 (Experimental Day 441). A full suite of influent, intermediate and effluent water quality samples were collected from the system for water quality analysis. Samples were collected at four monitoring points described in Section 3.2: B-HS6-STE, B-HS6-DP2, B-HS6-ST1&2a, B-HS6-ST2b-P. A duplicate sample was also taken at B-HS6-ST1&2a. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded. For sample B-HS6-STE, the system pump was briefly turned on to collect sample from the spigot. In addition, a field blank and equipment blank (EB) were taken. The field blank was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. The equipment blank was collected by pumping deionized water through the cleaned pump tubing.

The analysis-specific containers were supplied by the analytical laboratories and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. Field parameters were measured directly in the tank/port for the B-HS6-STE, B-HS6-ST1, and B-HS6-ST2b-P samples. Due to the design of the probe, ORP was measured in a container overflowing with sample water. Due to low sample volume, no field parameters were taken during sampling of B-HS6-DP2.

The influent, intermediate, and effluent samples were analyzed by the laboratory for: total alkalinity, chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (Ortho P), total suspended solids (TSS), volatile suspended solids

(VSS), total organic carbon (TOC), fecal coliform (fecal), and E. coli. The influent and sulfur media samples included sulfate, sulfide, and hydrogen sulfide (unionized). Due to the small sample volume, B-HS6-DP2 was only analyzed for the nitrogen species and $CBOD_5$. All analyses were performed by independent and fully NELAC certified analytical laboratories (Southern Analytical Laboratory and Ackuritlabs, Inc.). Table 1 lists the analytical parameters, analytical methods, and detection limits for laboratory analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	EPA 300.0	0.01 mg/L
Nitrate+Nitrite Nitrogen (NO_X-N)	EPA 300.0	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Solids (TS)	EPA 160.3	.01 % by wt
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
Sulfate	EPA 300.0	2.0 mg/L
Sulfide	SM 4500SF	0.10 mg/L
Hydrogen Sulfide (unionized)	SM 4550SF	0.01 mg/L
Fecal Coliform (fecal)	SM9222D	1 ct/100mL
E.coli	EPA1603	2 ct/100mL

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since the new treatment system installation on November 6, 2013. The treatment system flow meter readings for the B-HS6 field site are summarized in Table 2. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B. Summary tables of the Vericomm PLC recorded data are provided in Appendix C. These include daily and cumulative pump runtime and system alarms that are used to check general pump operation and performance.

Table 2
Summary of Flowmeters

Date and Time Read	Household Water Meter Reading	Average Daily Household Flow between readings	PNRS Flow Meter Reading	Average PNRS Flow between readings	Ratio PNRS flow to Household flow
	Cumulative Volume (gallons)	gallons/ day	Cumulative Volume (gallons)	gallons/ day	PNRS:HH
11/6/2013 12:15	99,030.4	Installed	1,027,435.3	Installed	Installed
11/14/2013 12:30	100,113.9	Start-up	1,027,435.3	Start-up	Start-up
11/20/2013 8:04	100,925.7	139.6	1,028,375.4	161.7	1.16
12/4/2013 7:52	102,616.8	120.9	1,030,645.4	162.3	1.34
12/20/2013 12:46	104,570.6	120.6	1,033,374.2	168.4	1.40
1/9/2014 11:49	107,163.1	129.9	1,036,306.1	146.9	1.13
1/22/2014 8:55	109,061.5	147.4	1,038,248.5	150.8	1.02
3/7/2014 10:30	115,093.0	136.9	1,045,302.0	160.1	1.17
3/20/2014 11:45	116,543.0	111.1	1,047,111.1	138.6	1.25
3/24/2014 10:50	116,979.0	110.1	1,047,597.8	122.9	1.12
4/10/2014 9:29	118,873.3	111.8	1,050,015.7	142.7	1.28
4/14/2014 19:15	119,370.5	112.8	1,050,622.9	137.8	1.22
4/16/2014 14:29	119,594.6	124.4	1,050,904.4	156.3	1.26
4/28/2014 12:47	120,956.3	114.1	1,052,696.0	150.2	1.32
5/7/2014 9:33	122,109.1	130.0	1,054,174.5	166.8	1.28
5/27/2014 12:26	124,623.2	125.0	1,057,401.8	160.4	1.28
5/30/2014 9:45	124,853.9	79.9	1,057,698.3	102.6	1.28
6/23/2014 9:00	127,482.8	109.7	1,060,658.0	123.5	1.13
7/21/2014 11:34	130,874.8	120.7	1,064,238.6	127.4	1.06
8/26/2014 8:54	135,223.9	121.2	1,068,857.5	128.7	1.06
8/27/2014 10:05	135,334.0	104.9	1,069,055.3	188.4	1.80
9/26/2014 11:27	139,560.0	140.6	1,074,161.6	169.9	1.21
10/3/2014 9:59	140,410.5	122.6	1,075,072.1	131.2	1.07
10/16/2014 11:36	142,525.8	161.9	1,077,527.8	187.9	1.16
10/30/2014 9:30	144,872.7	168.7	1,080,135.5	187.4	1.11
11/26/2014 12:38	148,920.8	149.2	1,084,870.1	174.5	1.17
12/29/2014 12:46	153,837.0	149.0	1,090,591.4	173.3	1.16
1/16/2015 14:37	155,830.5	110.3	1,092,977.0	132.0	1.20
1/29/2015 9:52	157,836.0	156.7	1,095,321.6	183.1	1.17
Average since start-up to January 29, 2015		130.9		154.0	1.18

On November 14, 2013, an alarm indicated a pump failure and upon inspection loose wiring was discovered and repaired. PNRS flow readings indicated that the pump had not run since installation until the time the wiring was repaired, therefore the official start-up of the PNRS system was November 14, 2013 (Experimental Day 0). From system start-up through January 29, 2015, the household water use average was 130.9 gallons per day with periods of higher and lower flows (Table 2). The average pumped flow to the PNRS was 154.0 gallons per day from start-up through January 29, 2015. The metered PNRS flow is continuously reading higher (by approximately 20 percent) than the household water meter. The reason for the difference in the two meter readings is not known. There is a possibility that there is some drainage back to the pump tank following each dose cycle, because a check valve was not installed on the pump discharge line.

Based on the hydraulic design of the system, a normally expected water level in the Stage 1&2a tank would be approximately 98.52 ft. elevation, or a depth above tank bottom of 4.8 inches. The normal operation level in the Stage 1&2a tanks therefore could be expected to vary between 4 and 6 inches above the tank bottom. Water levels above these values could adversely affect treatment performance and would suggest hydraulic blockages in the system. While purging the Stage 1 effluent drive points DP1 and DP2 during Sample Event No. 2, it was observed that the water level in the Stage 1&2a tank was elevated above the pans holding the drive points. The water level in the Stage 1&2a tank was found to be elevated approximately 10-inches above the invert of the collection pipe during that sample event. This water level would saturate all 12-inches of the ligno-cellulosic media and approximately 2-inches of the expanded clay media. The elevated water level could quite possibly have affected the performance of the system as monitored in Sample Event 2. A piezometer was installed within the Stage 1&2a tank on April 10, 2014 to provide better access to water level observations (Figure 12).

Figure 12
Piezometer installed on April 19, 2014 in the Stage 1&2a Tank

Table 3 summarizes the water level readings recorded. On April 14, 2014, it was determined the clog in the system was in the inlet pipe on the Stage 2b sulfur tank. An unsuccessful attempt was made with a plumbing snake to clear the clog. On April 16, 2014, the clog was cleared using compressed air and a 4-inch rubber bladder; the water level in the Stage 1&2a tank was restored to normal operational levels. During the following monitoring event, Sample Event No. 3, the water level in the Stage 1&2a tank was at normal operational levels. A system check on May 27, 2014 indicated that the water level was elevated approximately 8 inches above the tank bottom. A repair on the inlet pipe to the Stage 2b sulfur tank was completed on May 31, 2014. The repair included drilling additional holes in the inlet pipe and replacing the mesh material surrounding the pipe with a different type with larger mesh size to prevent future clogging. During a system check on September 26, 2014, the water level in the Stage 1&2a tank piezometer was again elevated by approximately 8 inches. This could have resulted in greater saturation of lignocellulosic media in Stage 2a, but submergence of the pans holding drive points DP1 and DP2 would not be expected. It was determined that the outflow pipe of the Stage 1&2a tank was partially clogged. A clean out was installed on the outflow pipe, just downgradient of the Stage 1&2a tank on October 9, 2014 which allowed access to clean the perforations from inside the effluent collection pipe. In addition, additional holes were drilled in the effluent collection pipe (from inside the pipe) inside the tank.

During Sample Event No. 8, which is the subject of this report, the water level in the Stage 1&2a tank was at normal operational levels.

Table 3
Summary of Stage 1&2a Water Level

Date and Time Read	Water level In Stage1&2a PZ from TOC	Water Elev	Water level above bottom of tank[1]	Water level above outlet invert
	(ft)	(ft)	(in)	(in)
4/14/2014 19:20	3.74	99.57	17.63	13.63
4/14/2014 19:35	3.75	99.56	17.51	13.51
4/16/2014 14:35	3.77	99.54	17.27	13.27
4/16/2014 16:16	4.76	98.55	5.39	1.39
4/16/2014 16:25	4.79	98.52	5.03	1.03
4/16/2014 16:49	4.81	98.50	4.79	0.79
5/6/2014 9:35	4.71	98.60	5.99	1.99
5/6/2014 9:58	4.66	98.65	6.59	2.59
5/7/2014 9:39	4.68	98.63	6.35	2.35
5/7/2014 10:51	4.70	98.61	6.11	2.11
5/27/2014 12:00	4.02	99.29	14.27	10.27
5/30/2014 9:51	4.09	99.22	13.43	9.43
5/30/2014 15:10	4.79	98.52	5.03	1.03
5/31/2014 19:03	4.79	98.52	5.03	1.03
6/23/2014 9:06	4.61	98.70	7.19	3.19
6/23/2014 12:25	4.52	98.79	8.27	4.27
7/21/2014 11:43	4.49	98.82	8.63	4.63
8/26/2014 9:05	4.36	98.95	10.19	6.19
8/27/2014 10:13	4.33	98.98	10.55	6.55
9/26/2014 12:32	4.04	99.27	14.03	10.03
10/3/2014 10:03	4.11	99.20	13.19	9.19
10/20/2014 15:58	4.70	98.61	6.11	2.11
10/29/2014 13:19	4.71	98.60	5.99	1.99
10/30/2014 9:33	4.71	98.60	5.99	1.99
11/26/2014 12:42	4.65	98.66	6.71	2.71
12/29/2014 12:44	4.66	98.65	6.59	2.59
1/16/2015 14:42	4.71	98.60	5.99	1.99
1/29/2015 9:50	4.72	98.59	5.87	1.87

[1]Stage 1&2a tank interior bottom elev = 98.10

4.2 Energy Consumption

Energy consumption is monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kilowatt-hours. The recorded electrical use for the system is summarized in Table 4 and has been fairly consistent through system operation.

Table 4
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use	Average Electrical Use per Gallon Treated	Average Electrical Use per 1,000 Gallons Treated
	Cumulative (kWh)	(kWh/day)	(kWh/gal)	(kWh/ 1,000 gal)
11/6/2013 12:22	2,749	0.00		
11/14/2013 12:32	2,749	0.00		
11/20/2013 8:08	2,751	0.34	0.0021	2.127
12/4/2013 7:54	2,757	0.43	0.0026	2.643
12/20/2013 12:48	2,764	0.43	0.0026	2.565
1/9/2014 11:53	2,772	0.40	0.0027	2.729
1/22/2014 8:57	2,777	0.39	0.0026	2.574
3/7/2014 10:32	2,797	0.45	0.0028	2.836
3/20/14 11:47	2,802	0.38	0.0028	2.764
3/24/2014 10:51	2,803	0.25	0.0021	2.054
4/10/2014 9:32	2,811	0.47	0.0033	3.309
4/14/2014 19:17	2,813	0.45	0.0033	3.293
4/16/2014 14:31	2,814	0.56	0.0036	3.552
4/28/2014 12:48	2,820	0.50	0.0033	3.349
5/7/2014 9:34	2,825	0.99	0.0034	3.382
5/27/2014 12:27	2,835	0.50	0.0031	3.099
5/30/2014 9:47	2,836	0.35	0.0034	3.373
6/23/2014 9:01	2,846	0.42	0.0034	3.379
7/21/2014 11:36	2,857	0.39	0.0031	3.072
8/27/2014 10:03	2,876	0.51	0.0024	2.417
9/26/2014 11:25	2,897	0.70	0.0041	4.113
10/3/2014 9:57	2,901	0.58	0.0044	4.393
10/16/2014 11:35	2,910	0.69	0.0037	3.665
10/30/2014 9:28	2,918	0.58	0.0031	3.068
11/26/2014 12:36	2,932	0.52	0.0030	2.957
12/29/2014 12:44	2,951	0.58	0.0033	3.321
1/16/2015 14:35	2,959	0.44	0.0034	3.353
1/29/2015 9:50	2,967	0.62	0.0034	3.412
Total average start-up to 1/29/2015		0.49	0.0032	3.211

The total average electrical use through January 29, 2015 was 0.49 kWh per day. The average electrical use per 1,000 gallons treated was 3.21 kWh per 1,000 gallons treated, and this parameter has been fairly stable since start-up.

4.3 Water Quality

As discussed in the Sample Event No. 1 (SE1) report, the preliminary sampling results indicated that ammonia reduction through the Stage 1 biofilter was limited. During preliminary sampling, it was observed that the sprayers were not spraying uniformly over the Stage 1 media surface. Therefore on December 21, 2013, the sprayers were rotated to spray up on the tank lid rather than straight down for better distribution over the media surface. The results from the SE1 DP1 and DP2 samples indicated significant nitrification was occurring with this sprayer set-up; however, the long-term operation and maintenance of the sprayers in this set-up was a concern. Therefore, on March 20, 2014, the four originally installed spray nozzles were replaced by three Orenco™ spin nozzles positioned under the tank lids allowing for easy maintenance and maximum spray coverage. During a system check on October 3, 2014, two of the Orenco™ spin nozzles were observed to be spinning slowly and not providing full coverage. New nozzles were installed on October 20, 2014 prior to SE6 and were working prior to and during SE8.

Water quality results for the eighth full sampling event (Sample Event No. 8) are listed in Table 5. Nitrogen results are graphically displayed in Figure 13. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results for Sample Event No. 8. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.

	STE	STAGE 1 DP1 & DP2	STAGE 2a LIGNO DP3 & DP4	STAGE 1&2a	STAGE 2b SULFUR
$CBOD_5$ mg/L	96	5		7	5
TKN mg N/L	62	6.2		2.9	8.3
NH_3 mg N/L	55	5.7		1.8	6.2
NO_x mg N/L	0.3	50		45	23
TN mg N/L	62	56		48	31
Sulfate mg/L	12	NA		22	110
Fecal Coliform (Ct/100mL)	210,000	NA		12,000	108

NA = not analyzed

Figure 13
Graphical Representation of Nitrogen Results
Sample Event 8 January 29, 2015 (Experimental Day 441)

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured TN concentration for this sample event was approximately 62 mg-N/L, which is in the range typically seen for this household.

Stage 1 Unsaturated Effluent (DP2): Stage 1 effluent NO_x-N concentration was 50 mg/L for sample DP2. The TKN and NH_3-N concentrations were 6.2 mg/L and 5.7 mg/L, respectively. These results indicate incomplete nitrification in the Stage 1 unsaturated media biofilter.

Stage 2a Saturated Effluent (DP3 and DP4): Not sampled for Sample Event 8.

Stage 1&2a Tank Effluent (ST1&2a): The sample port between the Stage 1&2a combination tank and the Stage 2b sulfur tank represents the effluent from the Stage 1&2a tank and the influent to the Stage 2b biofilter. The Stage 1&2a sample port effluent TKN was 2.9 mg/L of which 1.8 mg/L was NH_3-N. The NO_x-N concentration was 45 mg/L and was accompanied by a measured DO of 1.78 mg/L DO and ORP of 88 mV. The Stage 1&2a effluent TSS concentration was 2 mg/L and $CBOD_5$ was 6 mg/L. The ST1&2a sample indicates incomplete ammonia removal and limited nitrate removal in the Stage 1&2a biofilter.

Stage 2b Tank Effluent (ST2b): In Sample Events 1 and 2 the monitoring points, B-HS6-ST2b-T and B-HS6-ST2b-P had nearly identical nitrogen concentrations. For this sample event, B-HS6-ST2b-T was not sampled. B-HS6-ST2b-P was chosen as the preferred sample point as it is located in the pipe leading from the PNRS system to the drainfield.

Effluent NO_x-N from the Stage 2b biofilter was approximately 23 mg/L. The NO_x-N was accompanied by a measured DO of 1.70 mg/L and ORP of 138 mV. The Stage 2b biofilter achieved incomplete NO_x-N reduction. The NH_3-N concentration was 6.2 mg/L and TKN was 8.3 mg/L. Final total nitrogen (TN) in the treatment system effluent was 31 mg/L. The Stage 2b effluent sulfate concentration was 110 mg/L.

Lastly, the Stage 1 sample (DP2) showed incomplete nitrification with an NH_3-N concentration 5.7 mg/L. However, the NH_3-N concentration at the following monitoring point (ST1&2a) was lower at 1.8 mg/L. Interestingly, the NH_3-N concentration in the ST2b effluent was slightly higher than the DP2 sample with a concentration of 6.2 mg/L. The unexpected differences in water quality at the various sample locations as discussed above cannot be explained at this time; however, could be attributed to hydraulic residence time, sampling methodology, an artifact from hydraulic issues previously discussed, or other factors.

Field Blank and Equipment Blank (FB & EB): Described in Section 3.5, the equipment blank (EB) and field blank (FB) results for most of the parameters measured were at or below the method detection limit. The only slightly elevated parameters was total Kjeldahl nitrogen and total phosphorous in the equipment blank sample (0.08 and 0.071 mg/L, respectively), and total phosphorus in the field blank sample (0.055 mg/L).

Table 5
Water Quality Analytical Results

Sample ID	Sample Date/Time	Sample Type	Temp (°C)	pH	Total Alkalinity (mg/L)	DO (mg/L)	ORP (mV)	Specific Conductance (µS)	TSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Sulfate (mg/L)	H_2S (mg/L)	Sulfide (mg/L)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)
BHS6-STE	1/29/15 10:36	G	16.4	7.35	520	0.33	-237	1137	27	96	140	62.3	62	7.0	55	0.25	0.08	0.33	55.33	7.3	12	0.2	0.72	210,000	180,000
BHS6-DP02	1/29/15 11:22	G			150				66	5	16	56.2	6.2	0.5	5.7	50	0.03	50	55.7						
BHS6-ST1&2a	1/29/15 10:48	G	14.3	6.31	180	1.78	88	865	2	7	23	47.9	2.9	1.1	1.8	45	0.09	45	46.8	2.7	22	0.34	0.41	12,000	11,000
BHS6-ST1&2a-DUP	1/29/15 10:50	G	14.2	6.31	160	1.64	88	864	8	9	22	48.9	2.9	1.1	1.8	45	0.09	46	47.8	2.7	20	0.34	0.41	8,000	7,300
BHS6-ST2b-Port	1/29/15 10:24	G	13.9	6.51	210	1.70	138	938	2	5	25	31.3	8.3	2.1	6.2	23	0.05	23	29.2	5	110	0.15	0.21	108	98
BHS6-EB	1/29/15 11:04	G	16.5	7.44	3.5	9.26	102	3.2	1	2	10	0.1	0.08	0.1	0.009	0.02	0.01	0.01	0.019	0.071	0.2	0.01	0.1	2.0	2.0
BHS6-FB	1/29/15 11:14	G	16.9	7.19	2.5	9.17	190	2.1	1	2	10	0.1	0.05	0.0	0.009	0.02	0.01	0.01	0.019	0.055	0.2	0.01	0.1	2.0	2.0

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X

D.O. - Dissolved oxygen

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 6. Figure 14 provides a time series of influent and effluent TN over the study period. Figures 15 through 20 show box and whisker plots of the various monitoring points for the key parameters measured during the study period. The preliminary sample events conducted November 20, 2013 (Experimental Day 6) and December 4, 2013 (Experimental Day 20) were not included in the long term analyses as the system was still in the start-up period.

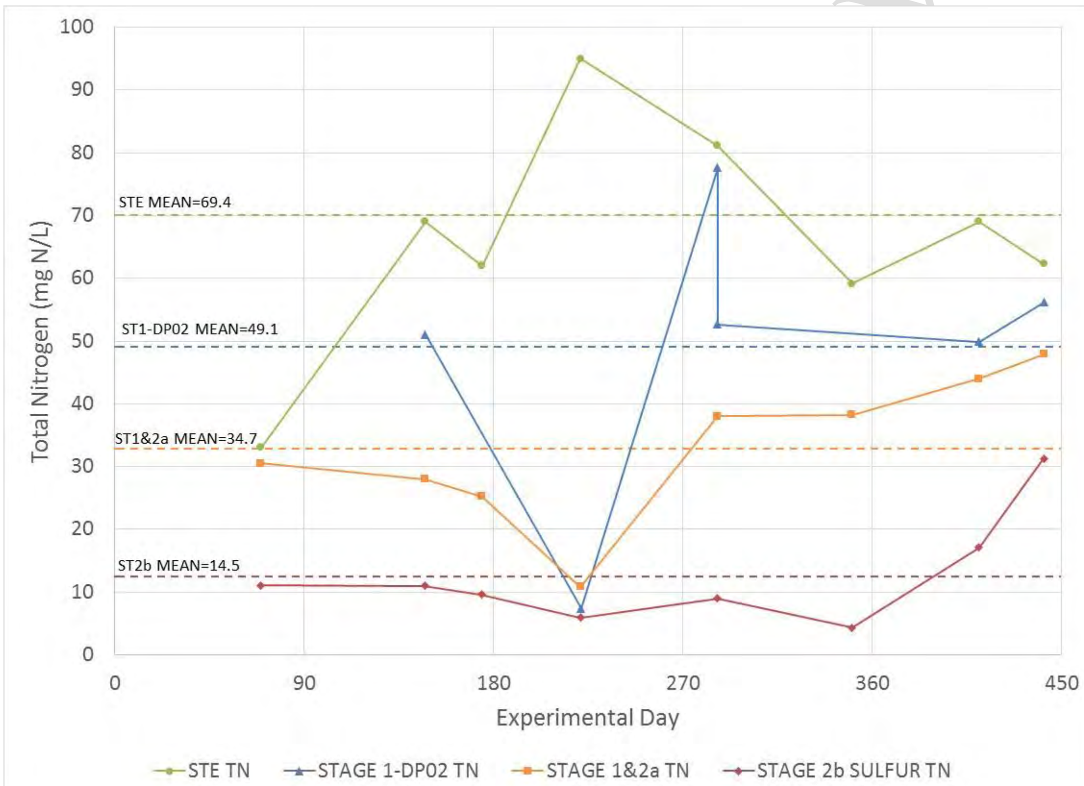

Figure 14
Total Nitrogen Time Series Graph

Table 6
Summary of Water Quality Analytical Results

Sample ID	Statistical Parameter	Temp (°C)	pH[4]	Total Alkalinity (mg/L)	DO (mg/L)	ORP (mV)	Specific Conductance (µS)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Sulfate (mg/L)	H2S (mg/L)
BHS6-STE	n	8	8	8	8	8	8	8	6	8	8	8	7	7	8	8	8	8	8	8	6	8	8
	MEAN	20.3	7.2	512.5	0.2	-189.8	1,148.8	27.8	23.3	80.0	168.8	66.3	62.1	9.3	58.1	0.1	0.1	0.1	58.2	8.1	5.4	5.3	1.2
	STD. DEV.	3.6		43.0	0.1	57.3	91.1	9.4	7.9	26.8	27.5	17.9	14.8	3.2	20.7	0.1	0.0	0.1	20.7	1.9	0.7	3.9	1.1
	MIN	16.1	7.1	460.0	0.0	-245.0	1,018.0	16.0	15.0	61.0	140.0	33.0	33.0	5.0	23.0	0.0	0.0	0.0	23.0	6.3	4.5	1.1	0.0
	MAX	25.9	7.4	600.0	0.4	-98.0	1,278.0	42.0	38.0	140.0	200.0	95.0	81.0	15.0	95.0	0.3	0.1	0.3	95.0	12.0	6.3	12.0	2.6
BHS6-ST1&2a	n	8	8	8	8	8	8	8	6	8	8	8	8	8	8	8	8	8	8	8	6	8	8
	MEAN	19.1	6.4	251.3	1.0	-31.6	875.3	4.9	5.8	24.5	49.0	32.8	8.0	2.1	5.9	24.4	0.6	24.8	30.8	4.1	2.6	18.0	0.6
	STD. DEV.	4.2		58.7	0.8	108.4	46.0	3.6	3.6	24.1	24.2	11.8	4.9	1.6	4.0	14.8	0.5	14.4	12.5	1.0	0.8	5.3	1.2
	MIN	13.8	6.2	180.0	0.2	-146.0	790.0	1.0	1.0	6.0	23.0	10.8	2.9	0.3	1.8	0.0	0.1	0.9	9.6	2.7	1.4	9.0	0.0
	MAX	26.5	6.7	350.0	2.1	167.0	926.0	10.0	10.0	69.0	97.0	47.9	18.0	5.0	13.0	45.0	1.5	45.0	46.8	5.2	3.4	27.0	3.5
BHS6-ST2b-Port	n	8	8	8	8	8	8	8	6	8	8	8	8	8	8	8	8	8	8	8	6	8	8
	MEAN	18.9	6.6	310.0	0.5	-73.3	1014.9	3.6	3.5	8.3	41.8	12.4	8.0	2.2	5.8	4.4	0.0	4.4	10.2	4.1	2.5	135.5	1.5
	STD. DEV.	4.4		74.6	0.5	191.5	80.1	1.3	0.8	9.5	11.8	8.5	2.6	1.0	2.8	8.6	0.0	8.6	8.2	0.8	0.4	37.1	1.7
	MIN	13.6	6.5	210.0	0.2	-219.0	895.0	2.0	2.0	2.0	25.0	4.3	4.2	1.0	0.9	0.0	0.0	0.0	3.1	3.0	2.0	64.0	0.1
	MAX	25.7	6.9	430.0	1.7	300.0	1133.0	6.0	4.0	31.0	58.0	31.3	11.0	4.2	9.5	23.0	0.1	23.0	29.2	5.0	3.0	190.0	4.5
BHS6-ST2b-Tee	n	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	MEAN	15.8	6.7	365.0	0.1	-153.0	1015.5	12.5	11.0	20.0	49.5	11.5	11.5	2.4	9.1	0.0	0.0	0.0	9.1	3.3	2.5	96.5	3.4
	STD. DEV.	3.0		91.9	0.0	116.0	167.6	14.8	14.1	7.1	0.7	0.7	0.7	1.3	0.6	0.0	0.0	0.0	0.5	0.4	0.7	47.4	3.4
	MIN	13.7	6.6	300.0	0.1	-235.0	897.0	2.0	1.0	15.0	49.0	11.0	11.0	1.5	8.7	0.0	0.0	0.0	8.8	3.0	2.0	63.0	1.0
	MAX	17.9	6.9	430.0	0.1	-71.0	1134.0	23.0	21.0	25.0	50.0	12.1	12.0	3.3	9.5	0.1	0.0	0.1	9.5	3.6	3.0	130.0	5.8
BHS6-DP01	n	1	1	3	1	1	1	2	2	4	3	5	5	5	6	5	6	6	6	0	0	0	0
	MEAN	19.7	6.9	119.0	2.5	40.0	929.0	41.0	28.0	55.8	32.3	49.7	6.0	2.6	3.2	51.2	0.4	43.0	46.1				
	STD. DEV.			28.2				46.7	33.9	96.2	18.8	28.4	5.9	2.2	4.5	15.4	0.6	25.0	24.5				
	MIN	19.7	6.9	87.0	2.5	40.0	929.0	8.0	4.0	5.0	20.0	3.3	0.5	0.1	0.1	38.0	0.0	0.1	3.2				
	MAX	19.7	6.9	140.0	2.5	40.0	929.0	74.0	52.0	200.0	54.0	81.0	16.0	5.1	12.0	76.0	1.6	76.0	77.5				
BHS6-DP02	n	1	1	4	1	1	1	4	2	5	3	6	6	6	7	6	7	7	7	0	0	0	0
	MEAN	19.8	7.0	148.8	2.2	55.0	918.5	112.0	65.0	5.0	19.3	49.1	7.4	2.5	5.2	47.1	0.3	41.5	46.7				
	STD. DEV.			37.9				55.5	29.7	3.1	3.1	22.9	3.9	2.6	3.5	11.0	0.3	20.9	21.0				
	MIN	19.8	7.0	95.0	3.4	12.0	917.0	66.0	44.0	2.0	16.0	7.4	0.5	0.4	0.1	38.0	0.0	0.0	5.6				
	MAX	19.8	7.0	180.0	3.4	12.0	917.0	192.0	86.0	10.0	22.0	77.6	12.0	7.5	9.7	68.0	0.6	68.0	75.3				
BHS6-DP03	n	5	5	3	5	5	5	3	3	5	2	5	5	5	5	5	5	5	5	1	0	0	0
	MEAN	21.1	6.5	374.3	0.4	-133.8	900.4	3.8	3.5	22.6	49.5	20.9	8.9	2.4	6.4	11.6	0.7	12.1	18.5	0.2			
	STD. DEV.	5.0		81.9	0.2	35.8	77.9	2.5	2.6	14.7	6.4	11.8	6.4	1.8	5.4	9.3	0.8	8.8	10.5				
	MIN	14.4	6.3	310.0	0.2	-184.0	795.0	2.0	2.0	2.0	45.0	5.6	0.5	0.1	0.4	1.8	0.0	1.8	3.8	0.2			
	MAX	26.8	6.8	470.0	0.8	-93.0	1015.0	7.0	7.0	33.0	54.0	34.0	16.0	4.6	14.0	22.0	2.1	22.0	29.4	0.2			
BHS6-DP04	n	5	5	3	5	5	5	3	3	5	3	5	5	5	5	5	5	5	5	0	0	3	0
	MEAN	21.1	6.4	353.3	0.4	-155.2	941.6	4.0	4.0	41.6	99.3	10.9	7.0	2.1	4.9	3.5	0.4	3.9	8.8			8.0	
	STD. DEV.	5.1		56.9	0.3	36.7	51.7	4.4	4.4	34.6	27.6	8.1	6.6	1.2	6.1	3.6	0.5	3.7	7.6			7.8	
	MIN	14.2	6.4	290.0	0.2	-184.0	888.0	1.0	1.0	13.0	68.0	3.8	0.5	0.3	0.2	0.6	0.0	0.8	1.2			3.4	
	MAX	26.7	6.5	400.0	0.9	-92.0	1015.0	9.0	9.0	100.0	120.0	21.0	16.0	3.7	14.0	8.3	1.1	9.0	17.3			17.0	

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

[4]Geometric mean provided rather than arithmetic mean.

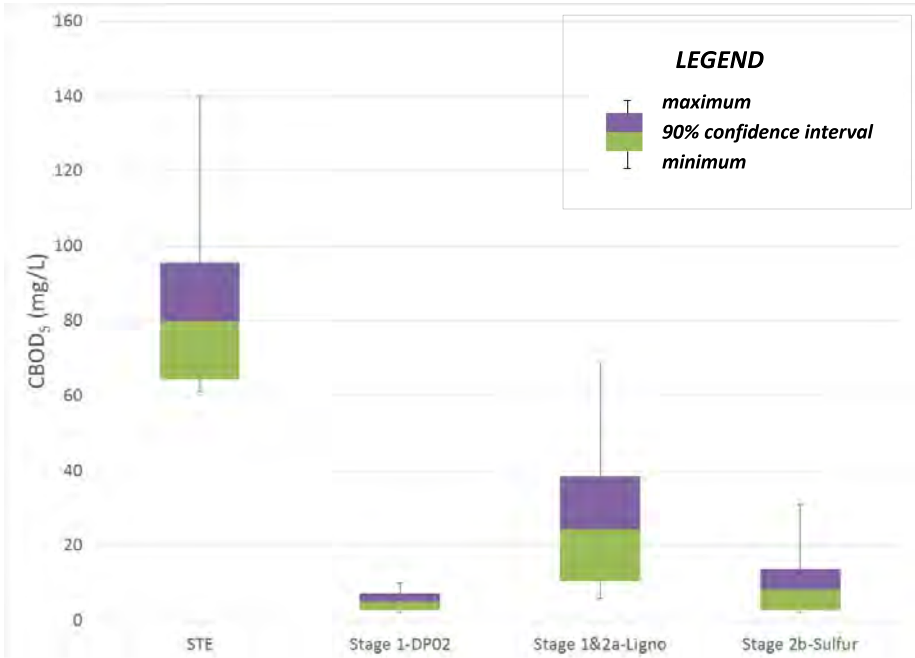

Figure 15
CBOD5 Box and Whisker Plot

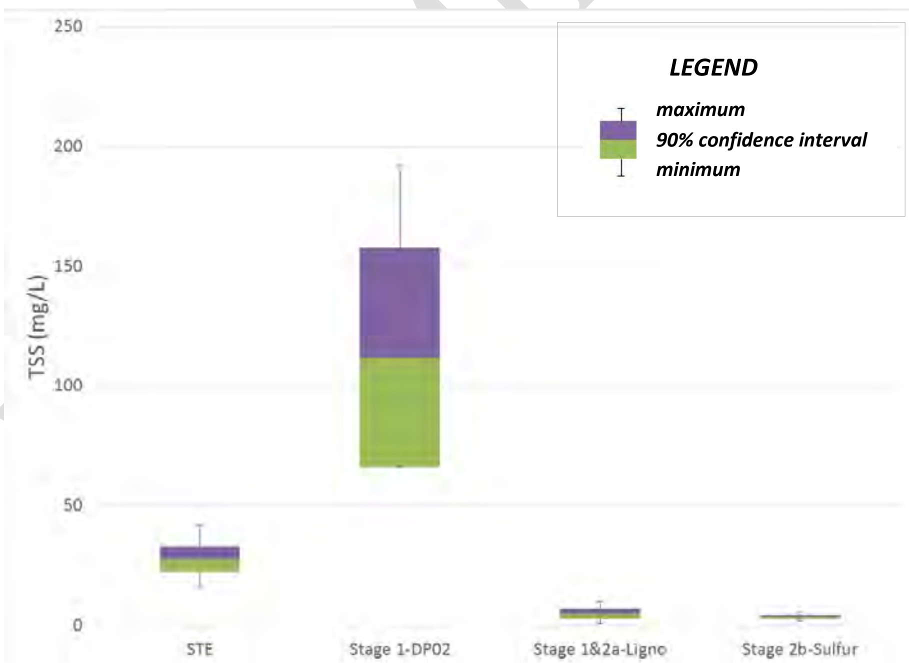

Figure 16
TSS Box and Whisker Plot

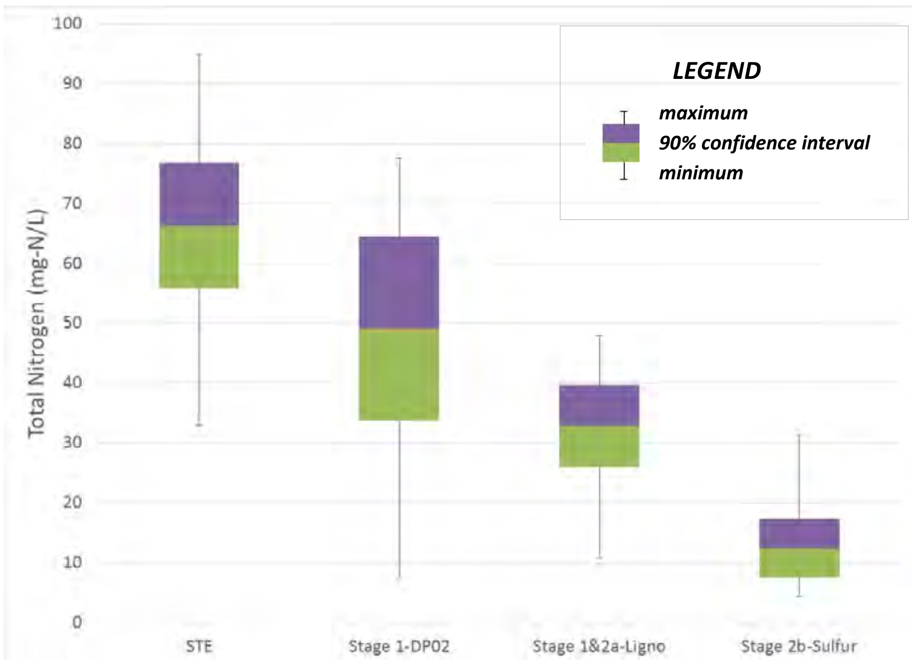

Figure 17
Total Nitrogen (TN) Box and Whisker Plot

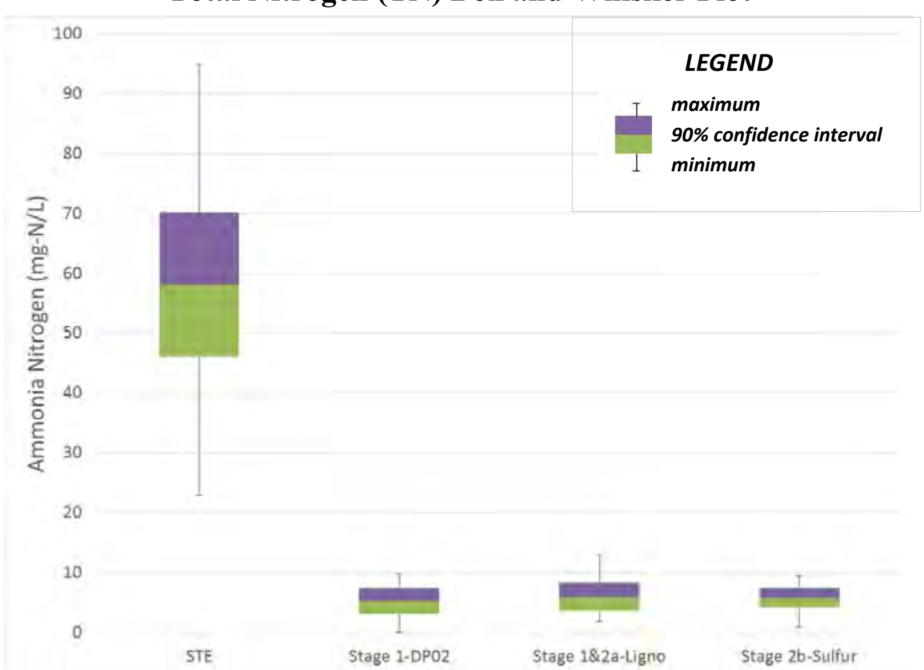

Figure 18
Ammonia N (NH3-N) Box and Whisker Plot

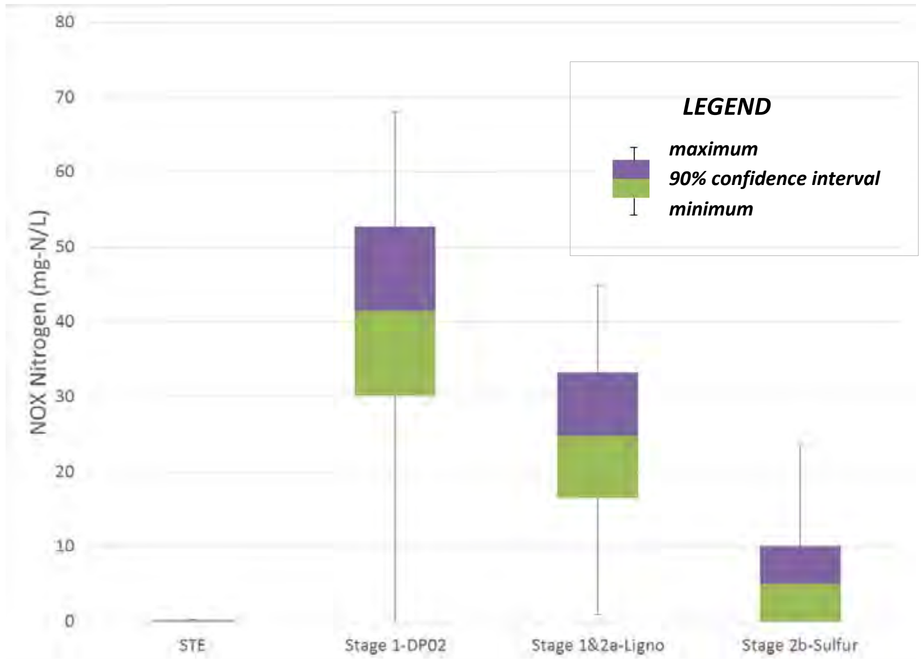

Figure 19
Nitrate+Nitrite Nitrogen (NO_X-N) Box and Whisker Plot

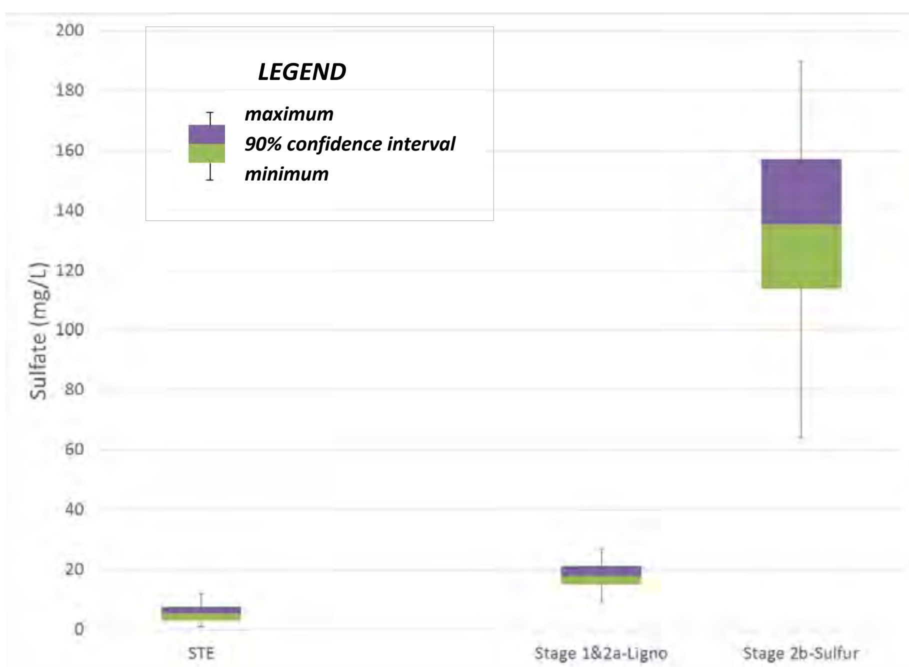

Figure 20
Sulfate (SO_4) Box and Whisker Plot

5.0 B-HS6 Sample Event No. 8: Summary

5.1 Summary

The Sample Event No. 8 results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality, and within the range previously measured at this household. The TKN of 62 mg/L is in the range of values typically reported for Florida single family residence STE.

- The Stage 1 biofilter sample DP2 showed 90% reduction in ammonia concentration; effluent in the DP2 sample had an ammonia-N concentration of 5.7 mg/L.

- The Stage 1&2a effluent sample port (ST1&2a) between the Stage 1&2a combination tank outlet and the Stage 2b sulfur tank inlet, showed 97% reduction in ammonium concentration from STE. The ammonia-N concentration in both the ST1&2a sample and duplicate were 1.8 mg/L.

- The Stage 2b sulfur biofilter (ST2b) effluent NO_x-N was 23 mg/L. The NO_x-N removal was not as high as typically seen through this system, and the reasons for this are unknown.

- The total nitrogen concentration in the final effluent from the total treatment system was 31 mg/L, an approximately 50% reduction from STE.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS6 treatment system. Sections 4.4 summarized the water quality data collected over the 1.2 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 66.3 mg/L is in the upper range of values typically reported for Florida single family residence STE.
- The Stage 1 biofilter sample DP2 showed significant ammonia removal with an average NH_3-N concentration of 5.2 mg/L and average TKN of 7.4 mg/L. The DP2 average NO_x-N was 41.5 mg/L.

- The Stage 1&2a effluent sample port (ST1&2a) between the Stage 1&2a combination tank outlet and the Stage 2b sulfur tank inlet, showed similar ammonia removal with an average NH_3-N concentration of 5.9 mg/L and average TKN of 8.0 mg/L. The ST1&2a average NO_x-N was 24.8 mg/L.
- The Stage 2b biofilter was effective in producing a reducing environment and achieving significant NO_x-N removal (average NO_x-N concentration of 4.4 mg/L). The average final total nitrogen (TN) in the treatment system effluent was 12.4 mg/L, primarily TKN (average TKN concentration of 8.0 mg/L), which represents an 81.3 percent average total nitrogen reduction from this PNRS.

The results of the data collected to date have provided insights into the performance of a full-scale passive single pass nitrogen reduction system monitored over an extended timeframe (441 experimental days) under actual onsite conditions.

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Florida Onsite Sewage Nitrogen Reduction Strategies Study

TASK B.7
PROGRESS REPORT

B-HS7 Field System Monitoring Report No. 8

Prepared for:

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

FDOH Contract CORCL

Revised May 2015

Prepared by:

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In Association With:

AET
Applied Environmental Technology

B-HS7 Field System
Monitoring Report No. 8 (Revised)

1.0 Background

Task B of the Florida Onsite Sewage Nitrogen Reduction Strategies Study (FOSNRS) includes performing field experiments to critically evaluate the performance of nitrogen removal technologies that were identified in FOSNRS Task A.9 and pilot tested in Task A.26. To meet this objective, full scale treatment systems are being installed at various residential sites in Florida and monitored over an extended timeframe under actual onsite conditions. The Task B Quality Assurance Project Plan (Task B.5) documents the objectives, monitoring framework, sample frequency and duration, and analytical methods to be used at the home sites. This report documents the eighth sample event of the passive nitrogen reduction system at a home site B-HS7 in Marion County, Florida.

2.0 Purpose

This monitoring report documents data collected from the eighth B-HS7 monitoring and sampling event conducted on February 4, 2015 (Experimental Day 442). This monitoring event consisted of conducting flow measurements from the household water use meter and the treatment system internal water meters, recording electricity use, monitoring of field parameters, collection of water samples from fifteen points in the treatment system, and chemical analyses of water samples by a NELAC certified laboratory.

3.0 Materials and Methods

3.1 Project Site

The B-HS7 field site is located in Marion County, FL. The nitrogen reducing onsite treatment system for the single family residence was installed in November 2013. Design and construction details were presented previously in the Task B.6 document. Figure 1 is a system schematic showing the system components and layout of the installation. A flow schematic of the system is shown in Figure 2. The existing 900 gallon dual chamber septic tank will continue to provide primary treatment for the new PNRS system. The PNRS system consists of a 300 gallon concrete pump tank, low-pressure distribution network, and an in-ground Stage 1 nitrification biofilter directly over a lined Stage 2 denitrification biofilter. There were no changes to the physical configuration of the treatment system or system operation since the last monitoring report.

The anticipated hydraulics of the system were that nitrified Stage 1 effluent would percolate into the liner filled with lignocellulosic media for denitrification. The denitrified effluent would then discharge into the soil around the perimeter of the liner. As discussed, later in this revised report, this hydraulic scenario was not fully realized, and it appears much of the nitrified effluent did not flow into the liner media.

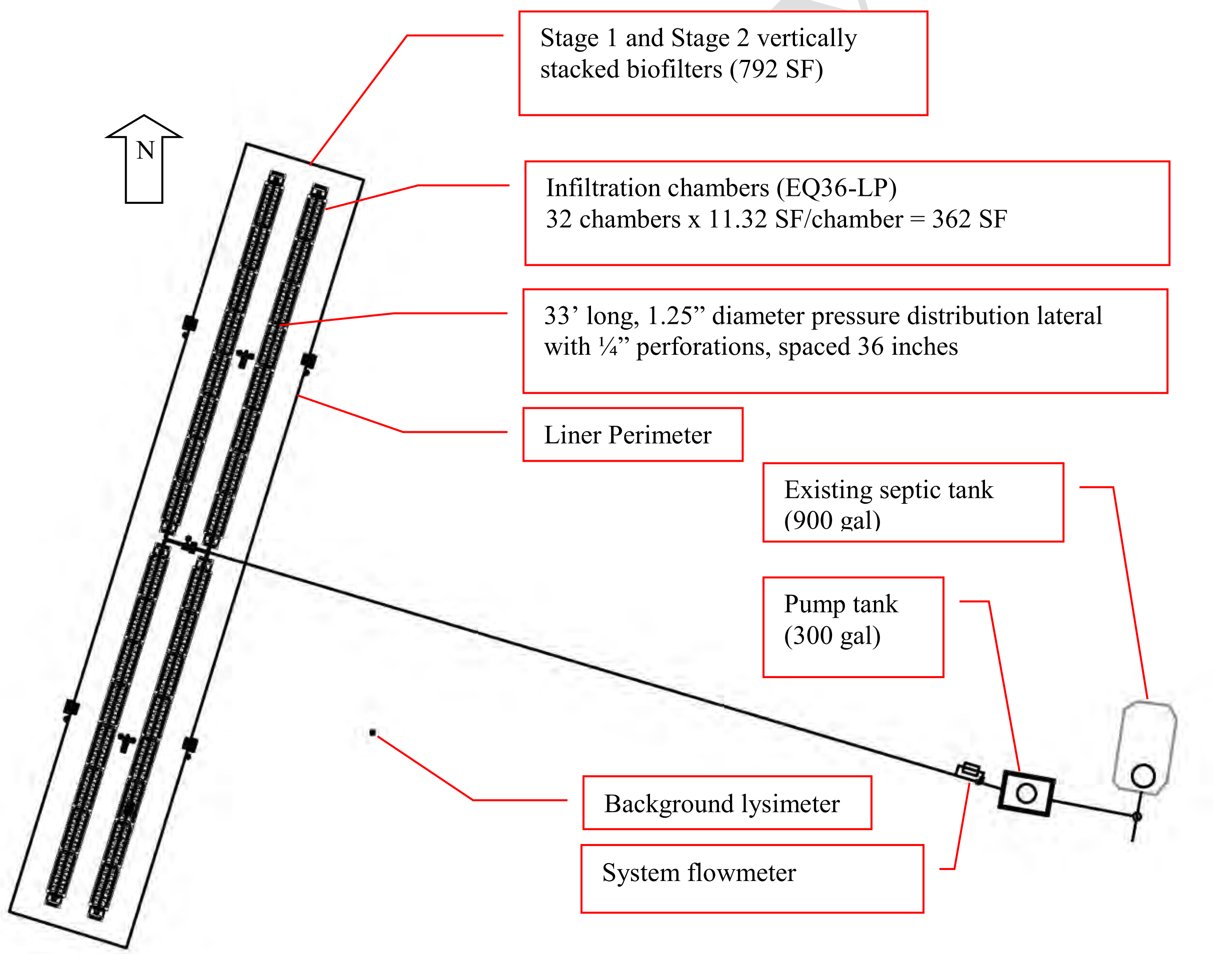


Figure 1
Plan view of B-HS7 System Layout

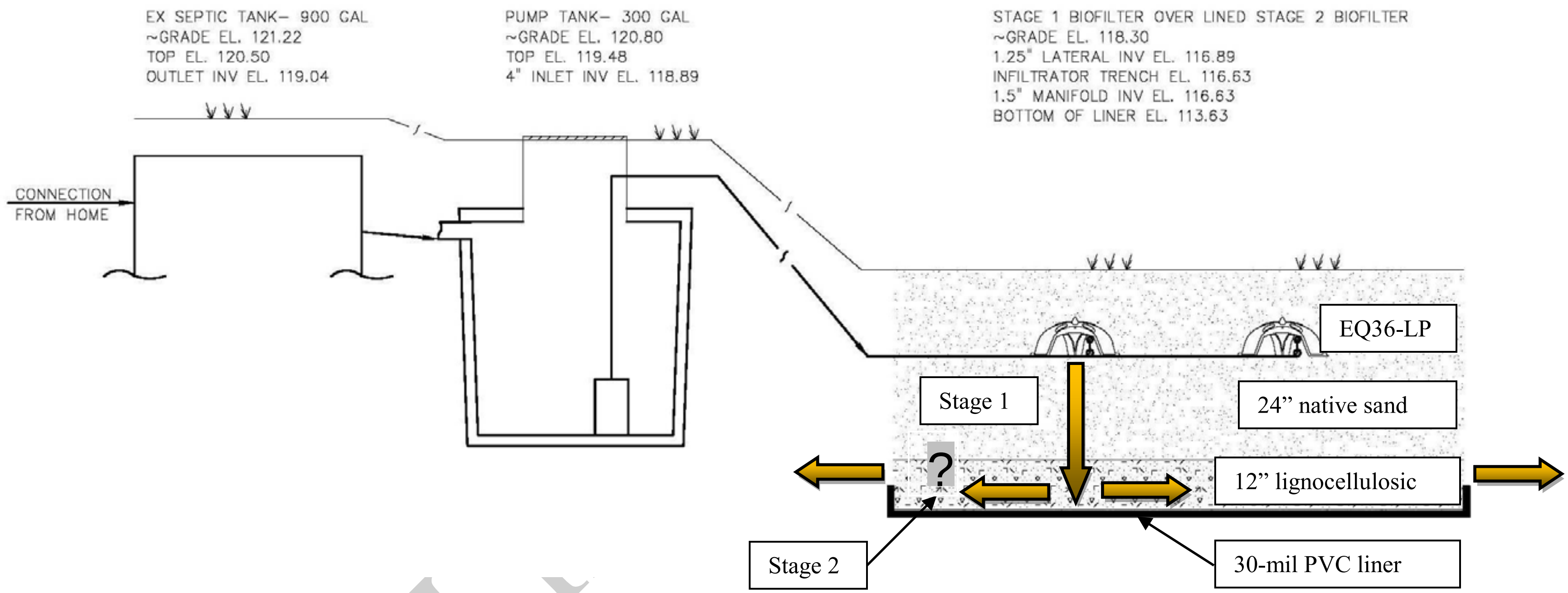
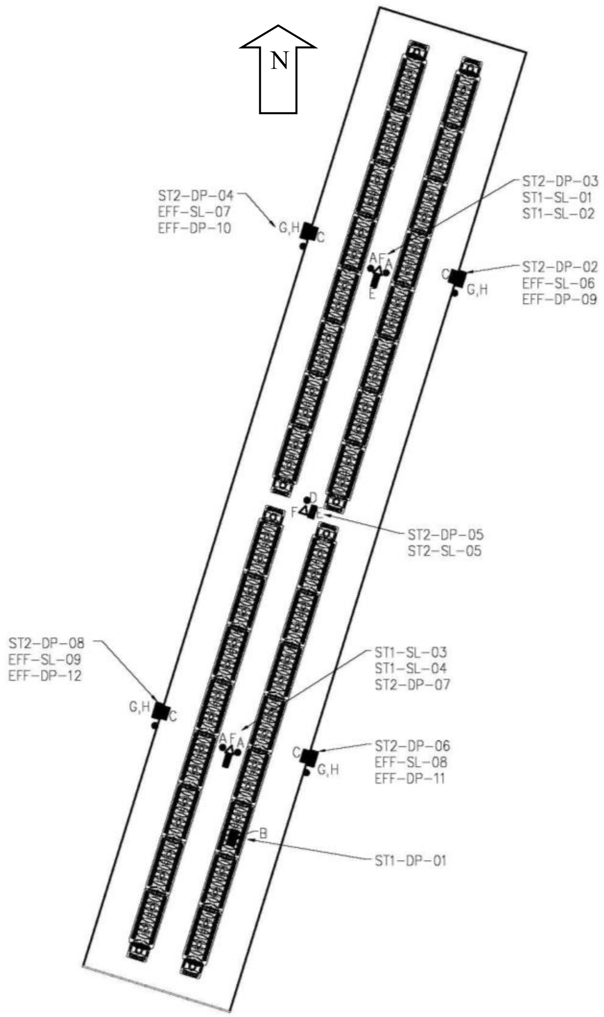
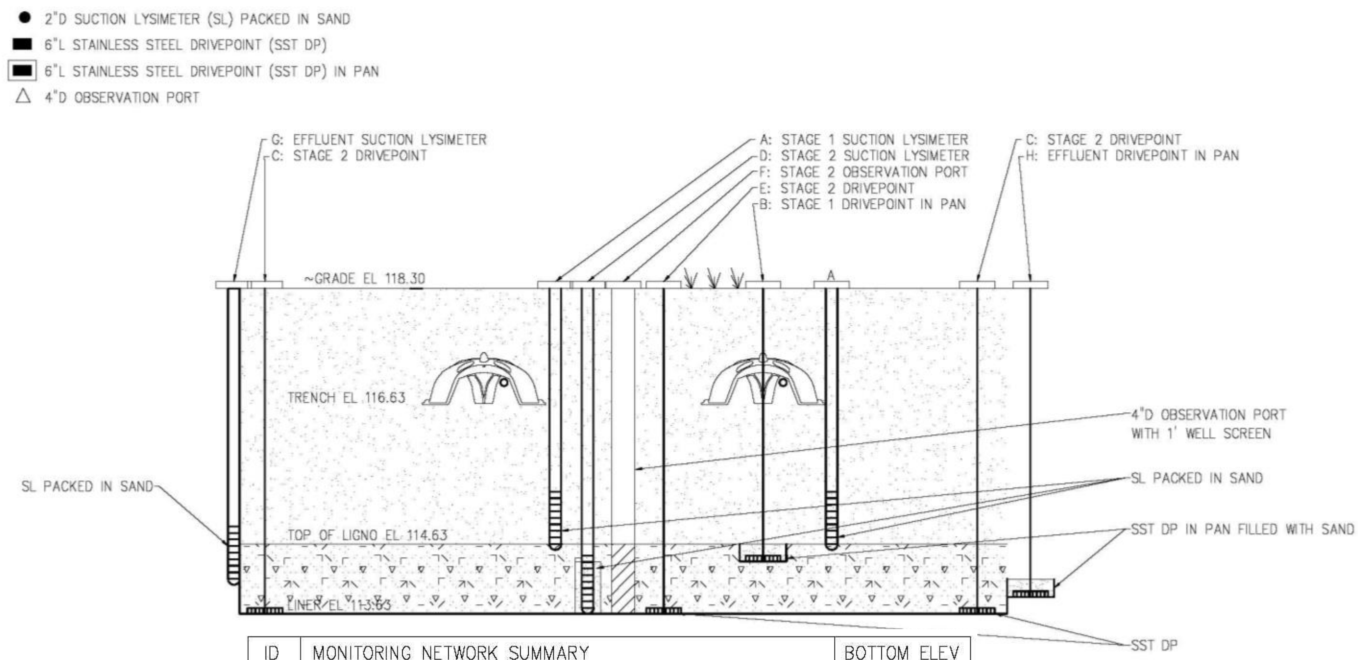


Figure 2
Flow Schematic of B-HS7 PNRS Installed in Marion County

3.3 Monitoring and Sample Locations and Identification

The monitoring points are shown in Figure 3. The monitoring points used for treatment evaluation include STE, Stage 1 effluent sample points, liner sample points, and perimeter sample points.





ID	MONITORING NETWORK SUMMARY	BOTTOM ELEV
	STE	
	(1) PUMP TANK	
	STAGE 1, NITRIFICATION	
	CENTER OF EACH TRENCH	
A	(4) SL PACKED IN SAND	114.63
B	(1) SST DP & LY IN PAN PACKED WITH SAND	114.38
	STAGE 2, DENITRIFICATION	
	EDGE OF LINED AREA	
C	(4) SST DP	113.63
	CENTER OF LINED AREA	
D	(1) SL PACKED IN SAND	113.63
E	(3) SST DP	113.63
F	(3) OBERVATION PORT TO LINER	113.63
	TREATED EFFLUENT	
	OUTSIDE LINER PERIMETER	
G	(4) SL	114.13
H	(4) SST DP & LY IN PAN PACKED WITH SAND	113.88

Figure 3
B-HS7 Sample and Monitoring Locations

Primary Effluent: Household wastewater enters the 1st chamber of the primary tank and exits the second chamber as septic tank effluent (STE) through an effluent screen. Screened effluent is directed to the pump tank which contains the pump and float switches. The first monitoring point, B-HS7-STE, is the STE sampled approximately 1.5 feet below the surface of the pump tank (Figure 5). Samples from monitoring point B-HS7-STE are the whole household wastewater after it has had some residence time in the primary tank.

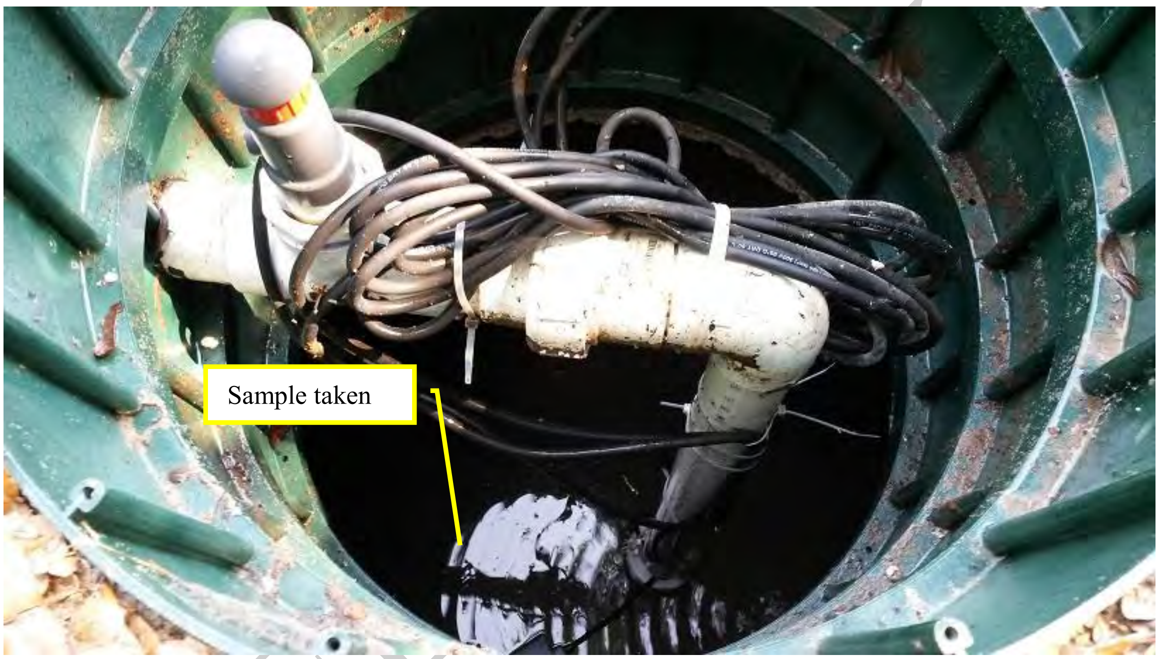


Figure 5
Pump Tank (B-HS7-STE sample)

Stage 1 Effluent: STE in the pump tank is discharged through a low-pressure distribution network installed inside Infiltrator EQ36-LP™ chambers. The low-pressure distribution network consists of a central manifold design with (4) 33-foot long, 1.25-inch diameter perforated laterals installed along the top of the 24-inch native sand media (unsaturated Stage 1 biofilter). In the Stage 1 biofilter, wastewater percolates downward through the unsaturated native sand media where nitrification occurs. Ceramic cup suction lysimeters (BHS7-ST1-SL-01, BHS7-ST1-SL-02, BHS7-ST1-SL-03, and BHS7-ST1-SL-04) were installed with the cup at the bottom of the native sand layer to represent water quality after downward passage through the sand layer (see Figure 6). In addition, one stainless steel drivepoint (BHS7-ST1-DP-01) was installed in a shallow pan at the bottom of the native sand layer (see Figure 7). However, this sample point often contained no water, and during this sample event the drivepoint was not sampled. The four suction lysimeters formed the basis for Stage 1 performance evaluation.

Figure 6
Stage 1 biofilter effluent sample taken from suction lysimeter (BHS7-ST1-SL samples)

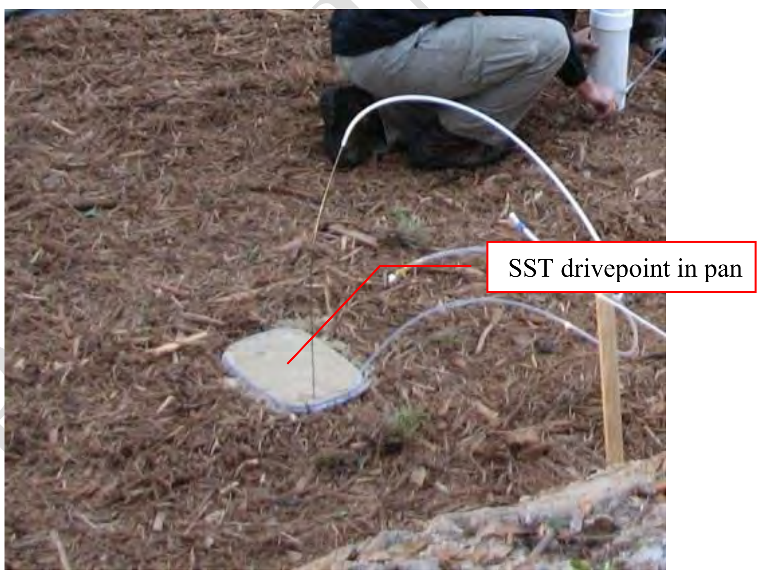


Figure 7
Stage 1 biofilter effluent sample taken from drivepoint in pan
(BHS7-ST1-DP-01 sample)

Line Water Samples (Perceived Stage 2 Effluent): Directly below the 24-inch native sand Stage 1 biofilter is a 12-inch layer of lignocellulosic media as a supplemental carbon source for denitrification (Stage 2 biofilter). This material is a blended urban waste wood from Wood Resource Recovery, Ocala, FL. The Stage 2 biofilter treatment area was prepared with a 30 mil PVC liner installed below the lignocellulosic media. The liner was installed with a 6 inch lip around the outside perimeter. Therefore, approximately 6-inches of the lignocellulosic media can reach saturation from applied wastewater, promoting oxygen depletion and denitrification of the nitrified effluent. At the bottom of the Stage 2 biofilter lignocellulosic media, directly above the liner, stainless steel drivepoint samplers were installed (see Figure 8) including: BHS7-ST2-DP-02, BHS7-ST2-DP-03, BHS7-ST2-DP-04, BHS7-ST2-DP-05 BHS7-ST2-DP-06, BHS7-ST2-DP-07, and BHS7-ST2-DP-08. DP03, DP05, DP06, DP07 and DP08 were sampled regularly and formed the basis for the liner samples mean. As discussed, it appeared that much of the Stage 1 effluent did not flow into/through the liner, so these sample points may not be representative of system effluent.

Figure 8
Stage 2 biofilter effluent sample taken from drivepoint (BHS7-ST2-DP samples)

Perimeter Monitoring Points: As discussed previously, it was anticipated that the treated effluent would be discharged from the liner under saturated conditions by flowing over the lip of the liner and into the soil surrounding the perimeter of the lined area. Ceramic cup suction lysimeters (BHS7-EFF-SL-06, BHS7-EFF-SL-07, BHS7-EFF-SL-08, and BHS7-EFF-SL-09) were installed around the perimeter of the liner, with the bottom of the cup approximately 6-inches below the lip of the liner within the native sand (see Figure 9) to represent this treated effluent. In addition, stainless steel drivepoints (BHS7-EFF-DP-09, BHS7-EFF-DP-10, BHS7-EFF-DP-11, BHS7-EFF-DP-12) were installed in shallow pans adjacent to the lip of the liner (see Figure 10). Based on liner water levels and other data, it appeared that much of the Stage 1 effluent did not flow into the liner, rather, soil moisture appeared to move laterally out from the treatment area to the surrounding unsaturated soil. Perimeter water quality therefore may be more representative of system performance. DP10, DP11, DP12, SL06, SL07, SL08 and SL09 were sampled regularly and formed the basis for perimeter water quality.

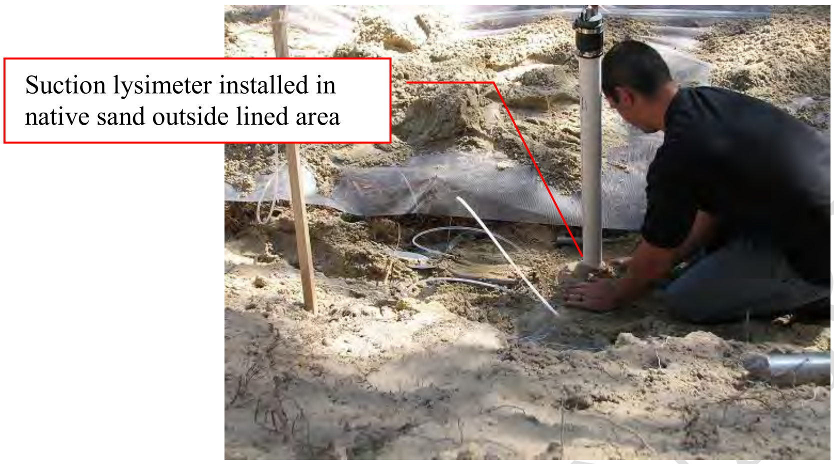


Figure 9
Treated effluent sample taken from suction lysimeter (BHS7-EFF-SL samples)

Figure 10
Treated effluent sample taken from drivepoint in pan (BHS7-EFF-DP samples)

3.4 Operational Monitoring

Start-up of the system occurred on November 19, 2013 (Experimental Day 0). However, during the 2013 Thanksgiving holiday, the homeowners projected having between thirty and forty additional people staying at the home. Therefore, since this was so soon after start-up, on November 26, 2013, the Bull Run™ diversion valve was flipped so that all the wastewater flow was diverted to the old drainfield. The diversion valve was flipped back to the PNRS system on December 2, 2013. Shortly thereafter, the homeowners planned a holiday party with a projected eighty people in attendance. Therefore on December 6, 2013, the diversion valve was flipped again so that all the wastewater flow was diverted to the old drainfield. The diversion valve was flipped back to the PNRS system on December 9, 2013, and the PNRS system has operated almost continually since that date. During July 2014, it was observed that the power breaker to the system had been flipped. This was likely due to a severe thunderstorm. With no power to the system, the pump had not run for several days, and the water elevation within the primary tank and pump tank was very high. Upon further inspection, the breaker that was installed within the panel was a GFI breaker. The contractor was contacted and came to the site to install a non-GFI breaker for the pump.

The eighth formal sampling event was conducted February 4, 2015 (Experimental Day 442). For this eighth formal sampling event, the water meter for the house and treatment system flow meters were read and recorded on February 4, 2015. The household water meter is located on the potable water line from the onsite well prior to entering the household plumbing following the water softener. The water meter does not include the irrigation water use. Therefore, the water meter reading should be relatively close to the wastewater flow to the system. Differences could occur due to water used for drinking, cooking, car washing, etc.

The PNRS treatment system flow meter (Figure 11) is located on the pump tank discharge line and records the cumulative flow in gallons pumped from the pump chamber to the low-pressure distribution network.

Three observation ports are installed along the centerline of the Stage 2 biofilter lined area (north, center and south). The observation ports are 4-inch diameter well screens that were installed with the bottom positioned on the liner. Therefore, the water level within the lined area can be monitored within the observation ports.

Figure 11
PNRS system flow meter

3.5 Energy Consumption

Energy consumption was monitored using an electrical meter installed between the main power box for the house and the control panel. The electrical meter records the cumulative power usage of the system in kilowatt-hours. The power usage of the system is primarily due to the single pump in the pump tank. There are no chemicals added to the system. However, the Stage 2 biofilter media (lignocellulosic) is “reactive” media which will be consumed during operation. The Stage 2 biofilter was initially filled with 12 inches of lignocellulosic media, which ostensibly will last for many years without replenishment or replacement.

3.6 Water Quality Sample Collection and Analyses

The eighth formal sample event (Sample Event No. 8), which is the subject of this report, was conducted on February 4, 2015 (Experimental Day 442). A full suite of influent, intermediate and effluent water quality samples were collected from the system for water quality analysis. Samples were collected at each of the monitoring points described in Section 3.2. A peristaltic pump was used to collect samples and route them directly into analysis-specific containers after sufficient flushing of the tubing had occurred. Field parameters were then recorded.

In addition, a field blank (FB), equipment blank (EB), and field sample duplicates were taken. The field blank was collected by filling sample containers with deionized water that had been transported into the field along with other sample containers. The equipment blank was collected by pumping deionized water through the cleaned pump tubing. The field sample duplicates (BHS7-PUMP and SC-BHS7-ST1-SL-03) were collected immediately subsequent to the regular samples. These samples were then analyzed for the same parameters as the monitoring samples.

The analysis-specific containers were supplied by the analytical laboratory and contained appropriate preservatives. The analysis-specific containers were labeled, placed in coolers and transported on ice to the analytical laboratories. Each sample container was secured in packing material as appropriate to prevent damage and spills, and was recorded on chain-of-custody forms supplied by the laboratory. Chain of custody forms, provided in Appendix A, were used to document the transfer of samples from field personnel to the analytical laboratory.

Field parameters were measured using portable electronic probes and included temperature (Temp), dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductance. The field parameters were measured by placing the analytical probes in a container overflowing with sample water. The influent, intermediate, and effluent samples were analyzed by the laboratory for: total alkalinity, chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total phosphorus (TP), orthophosphate (Ortho P), total suspended solids (TSS), volatile suspended solids (VSS), total organic carbon (TOC), fecal coliform (fecal), and E.coli. All analyses were performed by independent and fully NELAC certified analytical laboratory (Southern Analytical Laboratory). Table 1 lists the analytical parameters, analytical methods, and detection limits for laboratory analyses.

Table 1
Analytical Parameters, Method of Analysis, and Detection Limits

Analytical Parameter	Method of Analysis	Method Detection Limit (mg/L)
Total Alkalinity as $CaCO_3$	SM 2320B	2 mg/L
Chemical Oxygen Demand (COD)	EPA 410.4	10 mg/L
Total Kjeldahl Nitrogen (TKN-N)	EPA 351.2	0.05 mg/L
Ammonia Nitrogen (NH_3-N)	EPA 350.1	0.005 mg/L
Nitrate Nitrogen (NO_3-N)	EPA 300.0	0.01 mg/L
Nitrite Nitrogen (NO_2-N)	EPA 300.0	0.01 mg/L
Nitrate+Nitrite Nitrogen (NOX-N)	EPA 300.0	0.02 mg/L
Total Phosphorus (TP)	SM 4500P-E	0.01 mg/L
Orthophosphate as P (Ortho P)	EPA 300.0	0.01 mg/L
Carbonaceous Biological Oxygen Demand ($CBOD_5$)	SM5210B	2 mg/L
Total Suspended Solids (TSS)	SM 2540D	1 mg/L
Volatile Suspended Solids (VSS)	SM 2540E	1 mg/L
Chloride	EPA 300.0	0.50 mg/L
Fecal Coliform (fecal)	SM9222D	2 ct/100mL
E.coli	SM9223B	2 ct/100mL

4.0 Results and Discussion

4.1 Operational Monitoring

Table 2 provides a summary of the household water use since the household water meter installation on October 15, 2013. The treatment system flow meter readings for the B-HS7 field site are also summarized in Table 2. The operation and maintenance log which includes actions taken since start-up is provided in Appendix B.

Table 2
Summary of Flowmeters

Date and Time Read	Household Water Meter Reading	Average Daily Household Flow between readings	PNRS Flow Meter Reading	Average Daily PNRS Flow between readings
	Cumulative Volume (gallons)	gallons/ day	Cumulative Volume (gallons)	gallons/ day
10/15/2013 13:51	2.9	XX		
10/23/2013 12:20	1,186.9	149.2		
11/14/2013 8:50	3,602.5	110.5		
11/15/2013 14:40	3,800.0	158.9		
11/19/2013 14:18	4,997.5	300.5	652.0	PNRS Start-up
11/26/2013 10:30	7,901.4	424.4	2,480.0	267.2
11/26/2013	Flow to old drainfield			
12/2/2013	Flow to PNRS			
12/2/2013 9:45	9,148.6	209.0	2,480.0	0.0
12/6/2013 9:00	10,470.4	333.1	3,134.0	164.8
12/6/2013	Flow to old drainfield			
12/9/2013	Flow to PNRS			
12/10/2013 10:00	11,218.9	185.2	3,302.0	0.0
12/12/2013 9:00	11,519.1	153.3	3,635.0	170.0
1/3/2014 10:50	14,722.0	145.1	6,774.0	142.2
1/17/2014 10:00	16,940.8	158.9	8,621.0	132.3
1/20/2014 12:37	17,483.4	174.5	9,134.0	165.0
3/5/2014 12:00	26,166.5	197.5	11,575.0	55.5
3/13/2014 13:30	27,382.4	150.8	12,609.0	128.2

Table 2 (con't)
Summary of Flowmeters

Date and Time Read	House-hold Water Meter Reading	Average Daily Household Flow between readings	PNRS Flow Meter Reading	Average Daily PNRS Flow between readings
	Cumula-tive Volume (gallons)	gallons/ day	Cumulative Volume (gallons)	gallons/ day
3/19/2014 11:30	28,122.6	125.1	13,167.5	94.4
3/20/2014 12:30	28,281.8	152.8	13,318.0	144.5
4/28/2014 10:05	34,294.9	154.6	18,259.0	127.0
5/8/2014 9:00	36,055.4	176.9	19,521.0	126.8
5/27/2014 11:00	39,320.1	171.1	22,272.0	144.2
6/19/2014 12:00	43,520.7	182.3	25,837.0	154.7
7/16/2014 9:45	47,666.8	154.1	26,991.0	42.9
8/20/2014 12:20	53,342.4	161.7	32,037.0	143.7
9/23/2014 9:25	58,882.6	163.5	36,743.0	138.9
10/22/2014 8:45	62,854.7	137.1	40,005.0	112.6
11/24/2014 9:30	67,695.7	146.6	44,290.0	129.7
12/18/2014 10:00	71,528.4	159.6	47,851.0	148.2
1/14/2015 9:30	75,239.6	137.6	50,655.0	103.9
2/4/2015 8:35	77,920.5	127.9	52,826.0	103.6
Average since December 10, 2013 through February 4, 2015		158.5		117.7

As discussed in Section 3.4, there were two periods during the 2013 holidays when the wastewater was diverted to the old drainfield. Following these interruptions in flow, the household water use average was 158.5 gallons per day through February 4, 2015 with periods of higher and lower flows (Table 2). The average pumped flow to the PNRS system for the same time period was 117.7 gallons per day. The difference in flow could be due to outdoor water use such as filling the pool, car washing, hose bibbs for hand watering the garden, flowmeter error, etc. The irrigation system is not part of the metered flow.

An additional water input to consider for evaluation of the system treatment performance is precipitation. A weather station was installed at the site on the roof of the home on January 6, 2014. Data from this weather station is available from the homeowner. Recorded meteorological data is provided in Appendix C, Table C.1. A summary of monthly precipitation is provided in Appendix C, Figure C.1. Table 3 provides daily precipitation totals leading up to and during the sample event.

Table 3
Precipitation Data Daily Totals Measured
January 5, 2015 through February 4, 2015

Date	Precipitation (inches)
January 5, 2015	0.00
January 6, 2015	0.00
January 7, 2015	0.01
January 8, 2015	0.00
January 9, 2015	0.02
January 10, 2015	0.00
January 11, 2015	0.06
January 12, 2015	2.39
January 13, 2015	0.01
January 14, 2015	0.00
January 15, 2015	0.21
January 16, 2015	0.02
January 17, 2015	0.01
January 18, 2015	0.00
January 19, 2015	0.01
January 20, 2015	0.00
January 21, 2015	0.00
January 22, 2015	0.01
January 23, 2015	1.60
January 24, 2015	0.52
January 25, 2015	0.01
January 26, 2015	0.09
January 27, 2015	0.00
January 28, 2015	0.00
January 29, 2015	0.00
January 30, 2015	0.00
January 31, 2015	0.00
February 1, 2015	0.00
February 2, 2015	0.24
February 3, 2015	0.00
February 4, 2015	0.16

As discussed in Section 3.4, three observation ports are installed along the centerline of the Stage 2 biofilter lined area (north, center and south). The observation port measurements are summarized in Table 4 which indicate that the monitored liner water level is continuously below the overflow elevation (114.03 ft). During this sample event, the water elevation was at a range between 5.3 and 6.1 inches below the overflow elevation. This data seems to indicate that much of the Stage 1 effluent flow is not reaching the liner.

Table 4
Liner Water Level within Observation Ports

Date Read	North Observation Port water elevation		Center Observation Port water elevation		South Observation Port water elevation		Range
	Water elevation (ft)	Depth below overflow (in)	Water elevation (ft)	Depth below overflow (in)	Water elevation (ft)	Depth below overflow (in)	Depth below overflow (in)
11/26/2014	113.65	4.6	113.70	4.0	113.69	4.1	4.0-4.6
12/2/2014	113.60	5.2	113.63	4.8	113.59	5.3	4.8-5.3
12/6/2014	113.64	4.7	113.67	4.3	113.64	4.7	4.3-4.7
12/12/2014	113.65	4.5	113.67	4.4	113.59	5.3	4.4-5.3
1/3/2014	113.67	4.3	113.69	4.1	113.61	5.0	4.1-5.0
1/17/2014	113.67	4.3	113.73	3.6	113.65	4.5	3.6-4.5
3/20/2014	113.67	4.3	113.73	3.6	113.76	3.3	3.3-4.3
4/28/2014	113.72	3.8	113.69	4.1	113.69	4.0	3.8-4.1
5/8/2014	113.74	3.5	113.73	3.6	113.69	4.0	3.5-4.0
5/27/2014	113.67	4.3	113.73	3.6	113.69	4.0	3.6-4.3
6/18/2014	113.69	4.0	113.69	4.1	113.65	4.5	4.0-4.5
6/19/2014	113.67	4.3	113.67	4.4	113.63	4.8	4.3-4.8
7/16/2014	113.74	3.5	113.71	3.9	113.65	4.5	3.5-4.5
8/19/2014	113.59	5.3	113.58	5.4	113.59	5.3	5.3-5.4
9/23/2014	113.58	5.4	113.59	5.2	113.59	5.3	5.2-5.5
10/22/2014	DRY	DRY	113.54	5.9	113.57	5.5	5.5-5.9
11/24/2014	DRY	DRY	DRY	DRY	DRY	DRY	
12/18/2014	113.57	5.5	113.52	6.1	113.59	5.3	5.3-6.1
1/14/2015	113.75	3.4	113.73	3.6	113.74	3.5	3.4-3.6
2/2/2015	113.61	5.0	113.59	5.2	113.57	5.5	5.0-5.5
2/4/2015	113.59	5.3	113.57	5.5	DRY	DRY	5.3-5.5

Overflow elevation is 114.03 ft which is approximately 6 inches above the liner.

4.2 Energy Consumption

Energy consumption is monitored using an electrical meter installed between the main power box for the house and the control panel to record cumulative power usage of the pump in kWh. The recorded electrical use for the system is summarized in Table 5.

Table 5
Summary of System Electrical Use

Date and Time Read	Electrical Meter Reading	Average Daily Electrical Use	Average Electrical Use per Gallon Treated
	Cumulative (kWh)	(kWh/day)	(kWh/ 1000 gal)
11/19/2013 14:18	0.2	0.03	PNRS Start-up
11/26/2013 10:30	0.6	0.06	0.219
11/26/2013	Flow to old drainfield		
12/2/2013	Flow to PNRS		
12/2/2013 9:45	0.6	0.00	No flow
12/6/2013 9:00	0.8	0.05	0.306
12/6/2013	Flow to old drainfield		
12/9/2013	Flow to PNRS		
12/10/2013 10:00	0.8	0.00	0.000
12/12/2013 9:00	0.9	0.05	0.300
1/3/2014 10:50	1.7	0.04	0.255
1/17/2014 10:00	2.3	0.04	0.325
1/20/2014 12:37	2.4	0.03	0.195
3/5/2014 12:00	3.1	0.02	0.287
3/13/2014 13:30	3.5	0.05	0.387
3/19/2014 11:30	3.7	0.03	0.358
3/20/2014 12:30	3.7	0.00	0.000
4/28/2014 10:05	5.5	0.05	0.364
5/8/2014 9:00	6.0	0.05	0.396
5/27/2014 11:00	6.9	0.05	0.327
6/19/2014 12:00	8.0	0.05	0.309
7/16/2014 9:45	8.1	0.00	0.087
8/20/2014 12:20	9.6	0.04	0.297
9/23/2014 9:25	11.1	0.04	0.319
10/22/2014 8:45	12.0	0.03	0.276
11/24/2014 9:30	13.3	0.04	0.303
12/18/2014 10:00	14.4	0.05	0.309
1/14/2015 9:30	16.1	0.06	0.606
2/4/2015 8:35	17.0	0.05	0.461
Average since December 10, 2013 through February 4, 2015		0.04	0.329

The total average electrical use through February 4, 2015 was 0.04 kWh per day. The average electrical use per 1,000 gallons treated since start-up was 0.329 kWh per 1,000 gallons treated, and this parameter has been fairly stable since start-up.

4.3 Water Quality

Water quality results for the eighth sampling event (Sample Event No. 8) are listed in Table 6. A summary of the water quality data collected for the test system since start-up is presented in Table 7. Mean nitrogen results for performance evaluation points are graphically displayed in Figure 12. The laboratory report containing the raw analytical data is included in Appendix A. The following discussion summarizes the water quality analytical results for Sample Event No. 8. The performance of the various system components was compared by considering the changes through treatment of nitrogen species (TKN, NH_3-N, and NO_X-N), as well as supporting water quality parameters.

	Sample ID	$CBOD_5$ mg/L	TKN mg N/L	NH_3 mg N/L	NO_x mg N/L	TN mg N/L	Fecal Coliform (Ct/100 mL)
STE	PUMP	110.0	64.0	45.0	0.02	64.0	33,000
24" Sand	SL01, SL02, SL03, SL04	2.0	3.6	0.20	12.5	16.0	1
12" Ligno/Liner	DP03, DP05, DP06, DP07, DP08	2.0	2.6	0.06	0.06	2.7	3
Perimeter soil water	SL06, SL07, SL08, SL09	4.5	1.4	0.04	3.1	4.5	1

DISPERSAL

NA = not analyzed

Figure 12
Graphical Representation of Water Quality Results

Septic Tank Effluent (STE) Quality: The water quality characteristics of STE collected in Sample Event 8 were within the typical range generally expected for domestic STE. The measured STE total nitrogen (TN) concentration was approximately 64 mg/L, which is within the upper range that has been typically reported for Florida single family residence STE.

Stage 1 Effluent (native sand): The sample points considered representative of Stage 1 effluent included: BHS7-ST1-SL-01, BHS7-ST1-SL-02, BHS7-ST1-SL-03, and BHS7-ST1-SL-04. Based on these samples (n=4), the mean concentration ± the standard deviation are evaluated. Stage 1 effluent mean NH_3-N level was 0.20 ± 0.18 mg/L with a mean DO level of 6.47 ± 0.24 mg/L in the Stage 1 effluent (Table 6). These results indicate a substantial reduction of ammonia through the Stage 1 biofilter and nearly complete nitrification. The Stage 1 effluent mean NO_x-N concentration was 12.49 ± 4.39 mg/L, implying significant denitrification may also be occurring in the 24-inch sand layer based on comparison with the applied STE total nitrogen concentration.

Liner Water (Perceived Stage 2 Biofilter Lignocellulosic Effluent): The sample points considered representative of the Stage 2 biofilter (lignocellulosic media) liner water included: BHS7-ST2-DP-03, BHS7-ST2-DP-05, BHS7-ST2-DP-06, BHS7-ST2-DP-07, and BHS7-ST2-DP-08. Based on these samples (n=5), the mean concentration ± the standard deviation are evaluated. The Stage 2 effluent mean NO_x-N concentration was 0.06 ± 0.04 mg/L with a mean DO level at 3.0 ± 1.1 mg/L. The effluent that ended up in the liner achieved nearly complete NO_x-N reduction. The mean total nitrogen (TN) concentration was 2.7 ± 1.1 mg/L, and was comprised primarily of organic nitrogen; however, as discussed these samples are not likely representative of overall system performance.

Perimeter Monitoring Points: The perimeter monitoring points included: BHS7-EFF-SL-06, BHS7-EFF-SL-07, BHS7-EFF-SL-08, BHS7-EFF-SL-09. Based on these samples (n=4), the mean concentration ± the standard deviation are evaluated. The perimeter monitoring points mean TN was 4.5 ± 6.1 mg/L of which mean TKN was 1.4 ± 0.3 and mean NO_x-N was 3.1 ± 5.9 mg/L.

As has often been the case for this system, NO_x-N levels in one or more of the perimeter monitoring points is higher than NO_x-N levels in samples collected within the Stage 2 media. The observation port measurements at the time of sampling showed that the water level within the liner was between 5.3 and 5.5 inches below the periphery overflow elevation, which indicate that the lined area is nearly dry. The water sampled at the perimeter points is therefore not likely to be water that was recently discharged off of the lined area. One hypothesis is that the NO_x-N plume beneath the wastewater application zone extends laterally past the width of the Stage 2 biofilter liner area. The overlying Stage 1 biofilter is a 24-inch layer of native sand media which is classified as Candler fine sand. During site reconnaissance, two soil profiles indicated that the water table was below 72 inches, which would provide a free drainage condition for the Stage 1 domain. As depicted in the Task D.7 Hydrus 2-D Simulation, Scenario 45 graphic (Figure 13), it is possible that the nitrate plume may extend approximately +100 cm (3.28 ft) from the exterior trench wall. The Stage 2 biofilter was designed to extend only 2.5 ft from the exterior trench wall, therefore a portion of the unsaturated plume could be missing the liner and causing the high NO_x-N results along the perimeter. In addition, the soil moisture profile below Stage 1 relative to the surrounding perimeter soil (Figure 13) and the abrupt change in texture from fine sand to coarse lignocellulosic (wood chips) allows a high soil moisture content to develop at the sand/wood chip interface, allowing soil water to move laterally away from the system, into the drier surrounding soil. It is likely that much of the Stage 1 effluent does not make it into the liner area.

Therefore, the perimeter soil water samples are probably the most representative of system performance as currently operating. Several design revisions could likely correct or improve this operation. First, a larger liner would aid in capturing the effluent plume that that may be missing the liner. Second, a liner media mixture consisting of a sand/wood mix at a 50/50 or higher ratio would allow better fluid movement into the liner. Another design revision could be to design a liner with sides that extends upward near the infiltrative surface and then provide effluent collection in the Stage 2 media directed out through the liner into a soil dispersal system.

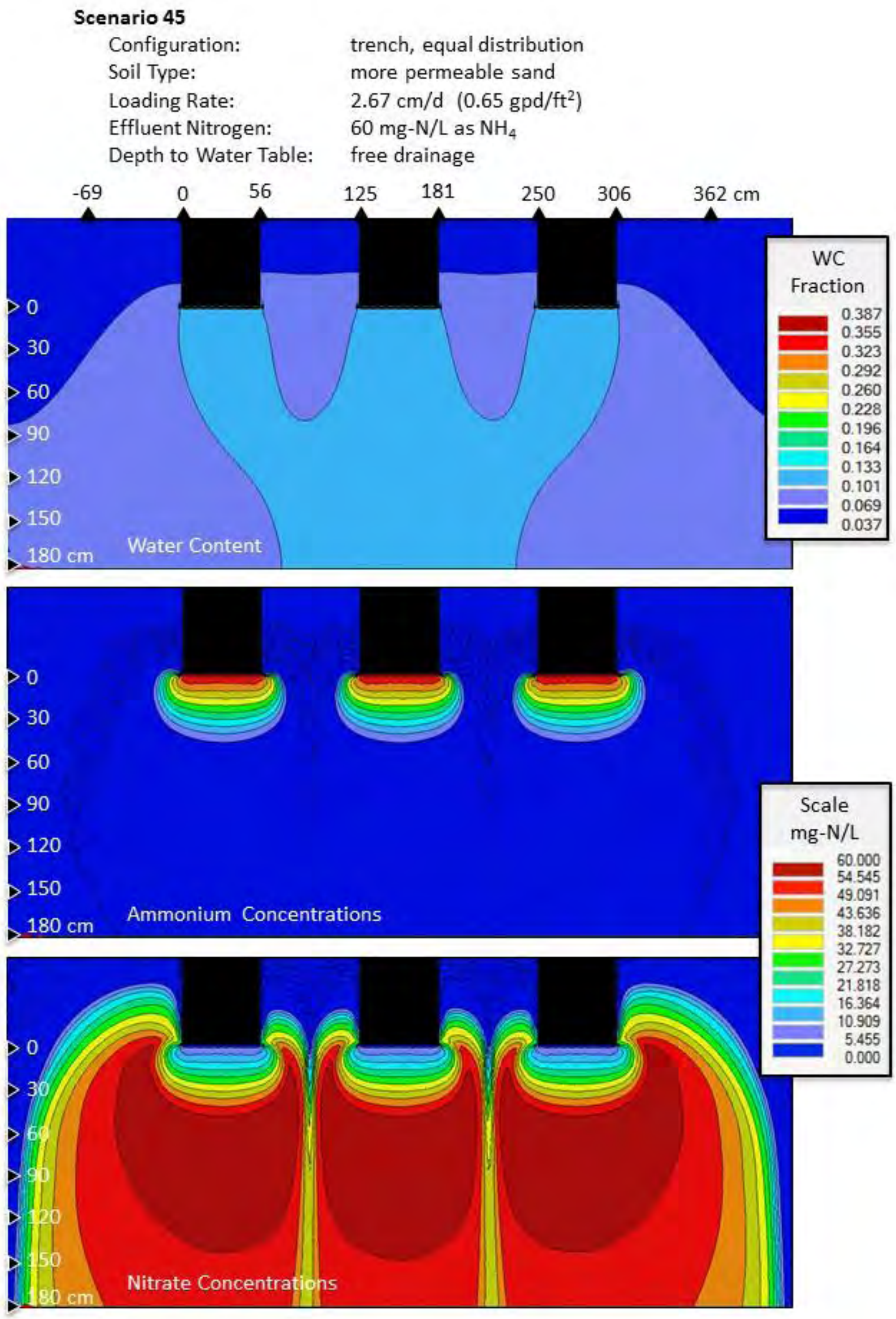


Figure 13
Graphic Representation of Task D.7 Hydrus 2-D Simulation, Scenario 45

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Field Blank (FB) and Equipment Blank (EB): Described in Section 3.5, the field blank and equipment blank (EB) results for most of the parameters measured were at or below the method detection limit. The slightly elevated parameter was total phosphorus in the equipment blank sample.

It still unclear why chloride concentrations vary greatly across the system with several very high concentrations during the previous sample events. During this sample event (Sample Event No. 8), one sample location (SW-BHS7-EFF-SL-09) continued to show a relatively high chloride concentration of 1,200 mg/L. Historically the average STE chloride concentration is 401 mg/L with a maximum concentration of 700 mg/L. Based on water level measurements in the liner, it appears that there is significant evaporation and/or transpiration of the applied wastewater. If this is the case, the increased chloride concentrations could result from this evaporation.

Table 6
Water Quality Analytical Results

Sample ID	Sample Date/Time	Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	Chloride (mg/L)
BHS7-PUMP	2/4/2015 11:15	18.3	7.52	2102	0.16	-247.2	310	60	53	110	180	64.03	64	19	45	0.02	0.01	0.03	45.03	6.3	5.1	33000	28000	420
BHS7-PUMP-DUP	2/4/2015 11:20	18.3	7.52	2102	0.16	-247.2	310	65	51	100	200	61.03	61	23	38	0.02	0.01	0.03	38.03	6.7	5.1	26000	25000	380
NC-BHS7-ST1-SL-01	2/4/2015 8:40	13.9	5.74	2220	6.66	149.8						13.01	3.9	3.46	0.44	9.1	0.01	9.11	9.55					560
NC-BHS7-ST1-SL-02	2/4/2015 8:55	13.9	5.8	2034	6.3	173.9						12.91	4.1	3.89	0.21	8.8	0.01	8.81	9.02					540
SC-BHS7-ST1-SL-03	2/4/2015 9:15	13.9	4.56	2081	6.69	218.5						22.11	4.1	3.98	0.12	18	0.01	18.01	18.13					740
SC-BHS7-ST1-SL-03-DUP	2/4/2015 9:20	13.9	4.56	2081	6.69	218.5						20.91	1.9	1.817	0.083	19	0.01	19.01	19.09					720
SC-BHS7-ST1-SL-04	2/4/2015 9:30	13.9	5.39	1625	6.23	216.9	15	7	7	2	22	16.11	2.1	2.075	0.025	14	0.01	14.01	14.04	0.9	0.3	1		490
NC-BHS7-ST2-DP-03	2/4/2015 9:55	17.2	6.16	1774	1.96	152.4						4.3	4.2	4.148	0.052	0.07	0.03	0.10	0.15					450
C-BHS7-ST2-DP-05	2/4/2015 10:05	16.2	6.07	1773	1.94	109.1						3.19	3.1	2.94	0.16	0.07	0.02	0.09	0.25					470
SE-BHS7-ST2-DP-06	2/4/2015 10:28	16.9	6.06	1685	2.68	111.4						2.03	2	1.965	0.035	0.02	0.01	0.03	0.07					430
SC-BHS7-ST2-DP-07	2/4/2015 10:25	16.4	6.06	1649	4.12	110.4	140	1	1	2	99	1.93	1.9	1.891	0.009	0.02	0.01	0.03	0.04	1.1	0.47	8	5.1	460
SW-BHS7-ST2-DP-08	2/4/2015 10:08	16.1	6.05	1763	4.29	113.4	150	6	6	2	91	1.93	1.9	1.87	0.03	0.02	0.01	0.03	0.06	0.56	0.24	1		490
N-BHS7-ST2-OB-01	2/4/2015 10:56	16	6.19	1535	3.34	139.2						6.95	6.9	6.826	0.074	0.02	0.03	0.05	0.12					440
NE-BHS7-EFF-SL-06	2/4/2015 8:46	15.6	5.49	79.9	8.02	141						1.25	0.98	0.86	0.12	0.26	0.01	0.27	0.39					10
NW-BHS7-EFF-SL-07	2/4/2015 9:06	15.4	6	2270	8.35	174.3						1.44	1.4	1.382	0.018	0.03	0.01	0.04	0.06					730
SE-BHS7-EFF-SL-08	2/4/2015 9:22	15	5.15	1889	7.41	215.2	8.2	1	1	7	12	13.61	1.6	1.577	0.023	12	0.01	12.01	12.03	0.093	0.012	1		590
SW-BHS7-EFF-SL-09	2/4/2015 9:44	15.5	5.71	4050	8.24	206.2	2.2			2	41	1.51	1.4	1.391	0.009	0.1	0.01	0.11	0.12	0.094	0.012	1		1200
BHS7-FB	2/4/2015 10:45	14.4	6.25	2.09	9.18	99.3	2	1	1	2	10	0.08	0.05	0.041	0.009	0.02	0.01	0.03	0.04	0.01	0.012	1	2	1
BHS7-EB	2/4/2015 11:00	14.3	5.77	1.33	9.57	77.4	2	1	1	2	10	0.08	0.05	0.041	0.009	0.02	0.01	0.03	0.04	0.016	0.012	1	2	1
BHS7-TAP	2/4/2015 11:30	17.3	7.71	181.7	6.32	86.9																		3.3

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and NO_X.

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and NH_3.

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and NO_X.

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

4.4 Water Quality Monitoring Summary

A summary of the water quality data collected for the test system is presented in Table 7. As discussed in Section 4.3 and depicted in Figure 14, the perimeter monitoring points (EFF) NO_x-N concentrations significantly varied throughout time and often had higher NO_x-N levels than in samples collected within the Stage 2 media. It appears that the NO_x-N plume beneath the wastewater application zone extends laterally past the width of the Stage 2 biofilter liner area, and also moves laterally into the surrounding soil, and that much of the Stage 1 effluent does not flow into the liner media. Therefore, the perimeter monitoring points may be the most representative of the water quality leaving the system as currently operating.

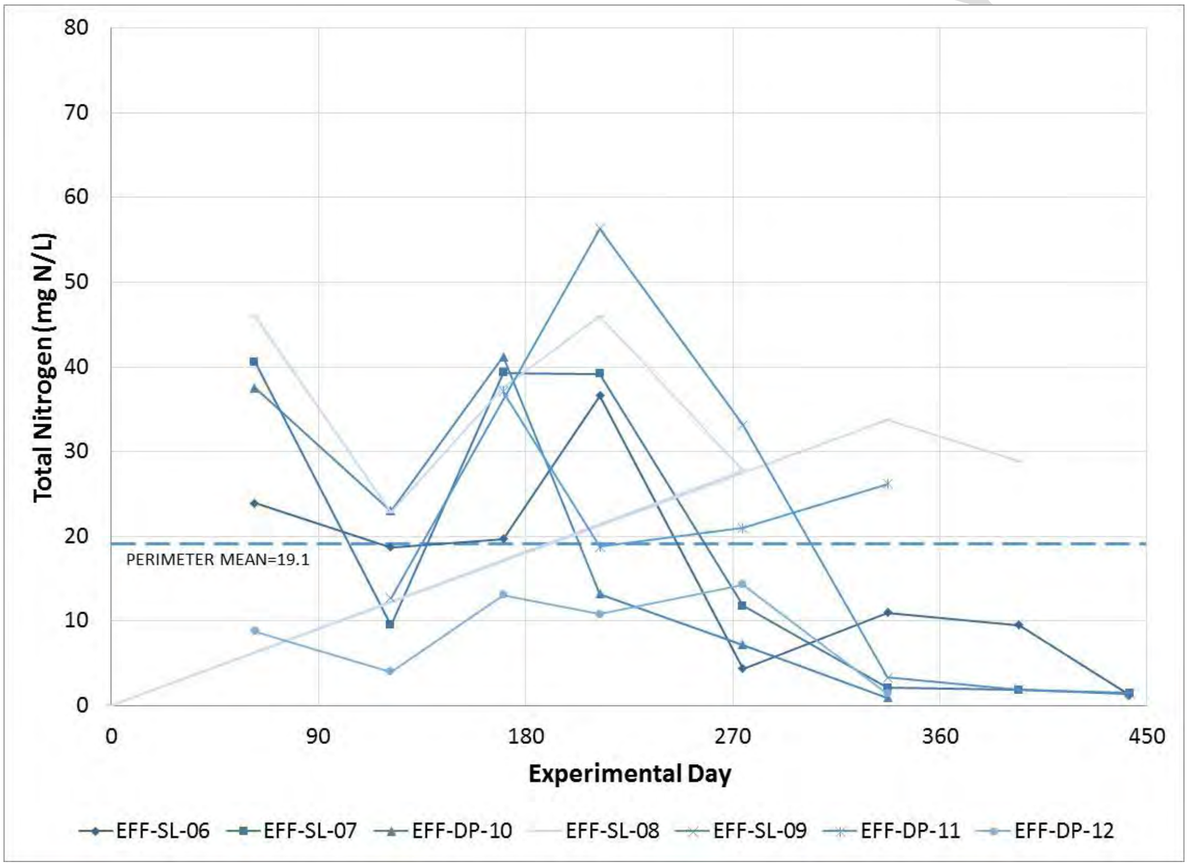

Figure 14
Perimeter Monitoring Points - Total Nitrogen Time Series Graph

Table 7
Summary of Water Quality Analytical Results

Sample ID		Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	Cl (mg/L)
BHS7-PUMP	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	MEAN	21.98	7.26	1987.25	0.11	-182.28	296.25	35.50	32.63	98.75	177.75	54.93	54.88	11.01	43.86	0.03	0.03	0.05	43.92	6.93	5.01	31754	2250	401.25
	STD. DEV.	3.65		247.06	0.09	62.98	35.43	12.44	10.88	34.21	75.71	9.79	9.78	14.63	15.97	0.02	0.03	0.03	15.99	1.24	1.12			156.79
	MIN	18.22	6.92	1609.00	0.01	-247.20	250.00	22.00	22.00	38.00	22.00	46.02	46.00	0.00	6.90	0.01	0.01	0.02	6.92	5.70	3.90	20000	96	190.00
	MAX	27.82	7.63	2454.00	0.25	-95.20	370.00	60.00	53.00	150.00	250.00	72.10	72.00	43.10	62.00	0.07	0.08	0.10	62.10	9.30	7.40	51000	28000	700.00
BHS7-ST1-SL-01	n	8	8	8	8	7	0	0	0	0	0	8	8	8	8	7	8	8	8	0	0	0	0	6
	MEAN	21.00	5.49	1881.38	5.54	169.01						25.92	3.15	2.76	0.39	21.16	0.01	22.77	23.16					795.00
	STD. DEV.	5.76		473.36	1.09	30.09						15.68	1.27	1.02	0.62	15.36	0.00	14.93	15.18					938.82
	MIN	13.90	5.23	1077.00	4.34	128.90						2.42	1.60	1.57	0.03	0.01	0.01	0.02	0.06					270.00
	MAX	28.90	5.74	2370.00	7.55	203.40						50.21	5.20	4.90	1.90	45.00	0.01	45.01	45.31					2700.00
BHS7-ST1-SL-02	n	8	8	8	8	8	0	0	0	0	0	8	8	8	8	8	8	8	8	0	0	0	0	6
	MEAN	20.90	5.46	1593.13	4.86	156.04						19.65	3.41	2.79	0.62	16.23	0.01	16.24	16.86					661.67
	STD. DEV.	5.52		395.62	1.28	34.53						20.22	2.02	1.61	1.08	19.44	0.00	19.44	19.53					810.59
	MIN	13.90	5.04	1156.00	3.04	92.20						1.32	1.30	1.25	0.01	0.01	0.01	0.02	0.05					220.00
	MAX	28.60	5.91	2062.00	6.67	196.70						53.20	7.40	6.20	3.10	51.00	0.02	51.00	51.35					2300.00
BHS7-ST1-SL-03	n	8	8	8	8	8	0	0	0	0	0	8	8	8	8	7	8	8	8	0	0	0	0	5
	MEAN	20.90	5.13	1933.75	5.21	182.19						36.95	3.56	2.96	0.61	30.57	0.55	33.38	33.99					472.00
	STD. DEV.	6.27		372.26	1.19	41.08						17.68	1.97	1.22	1.34	16.76	1.52	16.92	17.27					160.53
	MIN	13.70	4.55	1348.00	3.95	115.20						2.22	1.60	1.49	0.02	0.01	0.01	0.02	0.10					310.00
	MAX	29.10	5.87	2360.00	6.69	231.80						55.91	7.10	5.36	3.90	50.00	4.30	50.01	50.55					740.00
BHS7-ST1-DP-01	n	2	2	2	2	2	0	0	0	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0
	MEAN	17.85	5.08	1556.50	5.21	138.95						27.56	5.05	3.31	1.74	22.51	0.01	22.51	24.25					
	STD. DEV.	1.48		675.29	0.23	73.19						36.68	4.88	2.53	2.35	31.81	0.00	31.81	34.15					
	MIN	16.80	5.04	1079.00	5.05	87.20						1.62	1.60	1.52	0.08	0.01	0.01	0.02	0.10					
	MAX	18.90	5.12	2034.00	5.37	190.70						53.50	8.50	5.10	3.40	45.00	0.01	45.00	48.40					
BHS7-ST1-SL-04	n	8	8	8	8	8	6	7	7	8	8	8	8	8	8	7	8	8	8	8	8	5	5	7
	MEAN	20.54	5.35	1537.38	4.79	176.01	21.17	3.71	3.29	9.13	43.38	33.12	3.49	2.84	0.65	26.72	0.01	29.63	30.28	0.24	0.05	2	2	367.14
	STD. DEV.	6.42		407.67	1.14	42.63		2.81	2.50	18.55	52.18	18.27	2.62	1.10	1.72	16.38	0.00	17.25	17.79	0.28	0.10			86.74
	MIN	12.80	5.11	635.00	3.16	106.90	15.00	1.00	1.00	2.00	14.00	2.62	1.40	1.39	0.01	0.01	0.01	0.02	0.10	0.04	0.01	1	2	230.00
	MAX	29.50	5.80	1933.00	6.34	221.00	31.00	8.00	7.00	55.00	170.00	52.20	9.70	4.80	4.90	48.00	0.01	50.00	50.03	0.90	0.30	10	2	490.00

o:\44237-0

Table 7 (continued)
Summary of Water Quality Analytical Results

Sample ID		Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	Cl (mg/L)
BHS7-ST2-DP-02	n	2	2	2	2	2	0	0	0	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0
	MEAN	19.25	6.00	1732.50	0.12	24.70						10.74	10.40	9.73	0.68	0.34	0.06	0.34	1.02					
	STD. DEV.	0.35		369.82	0.01	142.69						8.00	7.92	8.27	0.35	0.08	0.06	0.08	0.26					
	MIN	19.00	5.99	1471.00	0.11	-76.20						5.08	4.80	3.88	0.43	0.28	0.01	0.28	0.83					
	MAX	19.50	6.01	1994.00	0.12	125.60						16.40	16.00	15.57	0.92	0.40	0.10	0.40	1.20					
BHS7-ST2-DP-03	n	8	8	8	8	8	0	0	0	0	0	8	8	8	8	8	8	8	8	0	0	0	0	6
	MEAN	21.10	6.08	1573.38	1.91	69.61						4.10	3.94	3.83	0.11	0.13	0.03	0.16	0.27					272.00
	STD. DEV.	4.24		356.89	1.96	96.91						1.55	1.58	1.55	0.05	0.13	0.04	0.14	0.16					154.48
	MIN	14.10	5.88	1059.00	0.13	-109.60						1.73	1.70	1.62	0.03	0.01	0.01	0.02	0.06					32.00
	MAX	27.28	6.44	2068.00	5.87	196.50						5.81	5.70	5.56	0.17	0.39	0.12	0.39	0.47					450.00
BHS7-ST2-DP-04	n	2	2	2	2	2	0	0	0	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0
	MEAN	19.80	6.02	1828.50	0.08	-5.45						3.77	3.75	3.66	0.09	0.01	0.01	0.02	0.11					
	STD. DEV.	0.71		375.47	0.00	208.38						1.34	1.34	1.35	0.01	0.00	0.00	0.00	0.01					
	MIN	19.30	5.94	1563.00	0.08	-152.80						2.82	2.80	2.71	0.08	0.01	0.01	0.02	0.10					
	MAX	20.30	6.10	2094.00	0.08	141.90						4.72	4.70	4.62	0.09	0.01	0.01	0.02	0.11					
BHS7-ST2-DP-05	n	7	7	7	7	7	0	0	0	0	0	7	7	7	7	7	7	7	7	0	0	0	0	5
	MEAN	21.06	6.13	1659.86	1.81	28.07						2.95	2.90	2.81	0.09	0.04	0.01	0.05	0.14					332.00
	STD. DEV.	5.48		332.25	2.01	105.35						0.50	0.50	0.50	0.04	0.03	0.01	0.03	0.05					102.08
	MIN	12.80	6.05	1183.00	0.08	-147.60						2.22	2.20	2.09	0.05	0.01	0.01	0.02	0.10					220.00
	MAX	28.31	6.20	2133.00	4.65	126.30						3.52	3.50	3.40	0.16	0.07	0.03	0.09	0.25					470.00
BHS7-ST2-SL-05	n	2	2	2	2	2	0	0	0	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0
	MEAN	19.25	6.02	1585.50	2.30	97.20						8.80	3.45	3.36	0.09	5.35	0.01	5.35	5.44					
	STD. DEV.	4.60		651.25	1.56	59.40						2.26	1.63	1.66	0.03	0.64	0.00	0.64	0.61					
	MIN	16.00	5.94	1125.00	1.20	55.20						7.20	2.30	2.19	0.07	4.90	0.01	4.90	5.01					
	MAX	22.50	6.10	2046.00	3.40	139.20						10.40	4.60	4.53	0.11	5.80	0.01	5.80	5.87					
BHS7-ST2-DP-06	n	7	7	7	7	7	0	0	0	0	0	7	7	7	7	7	7	7	7	0	0	1	1	5
	MEAN	20.70	6.12	1665.00	1.74	54.29						4.20	4.13	4.03	0.10	0.05	0.03	0.07	0.17			1.00	2.00	286.40
	STD. DEV.	3.54		425.76	1.85	89.76						1.94	1.96	1.91	0.07	0.06	0.03	0.08	0.10					176.71
	MIN	16.20	5.95	1092.00	0.06	-120.40						2.03	2.00	1.97	0.01	0.01	0.01	0.02	0.06			1.00	2.00	32.00
	MAX	25.99	6.63	2280.00	4.31	153.50						7.92	7.90	7.76	0.20	0.14	0.10	0.21	0.34			1.00	2.00	430.00
BHS7-ST2-DP-07	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7
	MEAN	22.11	6.22	1777.38	2.11	49.01	192.50	11.50	8.63	26.25	172.38	3.05	3.01	2.94	0.07	0.02	0.02	0.04	0.11	10.63	6.51	14	5	395.71
	STD. DEV.	4.86		361.01	2.28	95.12	29.64	7.33	5.40	28.88	129.42	1.88	1.90	1.86	0.06	0.02	0.02	0.04	0.05	20.28	11.88			106.12
	MIN	16.40	5.99	1201.00	0.10	-117.30	140.00	1.00	1.00	2.00	50.00	1.42	1.40	1.36	0.01	0.01	0.01	0.02	0.04	1.10	0.47	1	2	190.00
	MAX	29.36	6.44	2350.00	6.60	181.50	240.00	27.00	17.00	79.00	380.00	7.22	7.20	7.07	0.15	0.06	0.08	0.14	0.17	60.00	35.00	1200	200	470.00
BHS7-ST2-DP-08	n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7	7
	MEAN	21.38	6.09	1584.00	1.74	39.04	185.00	9.50	6.88	30.38	261.50	2.45	2.40	2.33	0.07	0.04	0.02	0.05	0.12	7.58	4.42	1	2	350.00
	STD. DEV.	4.94		330.95	1.73	108.79	25.63	4.72	4.39	29.94	347.85	1.11	1.11	1.09	0.04	0.05	0.01	0.05	0.06	12.82	7.25			106.93
	MIN	14.80	5.97	1067.00	0.08	-161.00	150.00	1.00	1.00	2.00	91.00	1.35	1.30	1.27	0.01	0.01	0.01	0.02	0.06	0.56	0.24	1	2	190.00
	MAX	28.07	6.17	2070.00	4.29	151.10	220.00	16.00	13.00	78.00	1100.00	4.72	4.70	4.61	0.13	0.15	0.04	0.15	0.26	37.00	20.00	10	3	490.00

Table 7 (continued)
Summary of Water Quality Analytical Results

Sample ID		Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	Cl (mg/L)
BHS7-EFF-SL-06	n	8	8	8	8	8	0	0	0	0	0	8	8	8	8	7	8	8	8	0	0	0	0	6
	MEAN	20.13	5.68	572.99	6.12	173.08						15.64	1.99	1.82	0.16	10.59	0.01	13.65	13.81					76.67
	STD. DEV.	5.82		375.48	1.18	32.69						11.50	0.90	0.96	0.16	7.78	0.00	11.24	11.16					56.24
	MIN	12.40	5.49	79.90	4.94	124.10						1.25	0.98	0.86	0.03	0.26	0.01	0.27	0.39					10.00
	MAX	27.50	5.94	1073.00	8.02	215.80						36.60	3.90	3.84	0.46	20.00	0.02	35.00	35.05					170.00
BHS7-EFF-DP-09	n	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0
	MEAN	17.70	6.06	431.00	6.36	131.50						7.20	2.50	1.59	0.91	4.70	0.01	4.70	5.61					
	STD. DEV.																							
	MIN	17.70	6.06	431.00	6.36	131.50						7.20	2.50	1.59	0.91	4.70	0.01	4.70	5.61					
	MAX	17.70	6.06	431.00	6.36	131.50						7.20	2.50	1.59	0.91	4.70	0.01	4.70	5.61					
BHS7-EFF-SL-07	n	8	8	8	8	8	0	0	0	0	0	8	8	8	8	7	8	8	8	0	0	0	0	6
	MEAN	20.39	5.59	1753.25	6.70	169.04						18.23	1.61	1.17	0.44	13.70	0.01	16.61	17.05					895.00
	STD. DEV.	5.06		1140.86	1.06	27.11						18.17	0.34	0.66	0.72	17.40	0.00	18.09	17.81					1143.25
	MIN	13.40	4.61	367.00	5.51	126.70						1.44	1.20	0.10	0.01	0.03	0.01	0.04	0.06					230.00
	MAX	27.30	6.59	3970.00	8.35	199.80						40.60	2.20	2.15	1.60	39.00	0.01	39.00	39.01					3200.00
BHS7-EFF-DP-10	n	6	6	6	6	6	0	0	0	0	0	6	6	6	6	6	6	6	6	0	0	0	0	4
	MEAN	21.57	5.97	1646.50	5.76	141.05						20.51	2.05	1.89	0.16	18.46	0.01	18.46	18.61					807.50
	STD. DEV.	4.96		411.77	1.21	31.44						16.35	0.75	0.91	0.22	15.85	0.00	15.85	15.73					873.82
	MIN	13.30	5.74	1147.00	4.40	85.30						0.93	0.89	0.29	0.02	0.03	0.01	0.04	0.64					220.00
	MAX	27.30	6.18	2187.00	7.18	182.80						41.20	3.00	2.88	0.60	39.00	0.01	39.00	39.06					2100.00
BHS7-EFF-SL-08	n	8	8	8	8	8	1	1	1	1	1	8	8	8	8	7	8	8	8	1	1	1	0	6
	MEAN	20.65	5.25	1673.63	6.10	171.61	8.20	1.00	1.00	7.00	12.00	32.03	2.53	2.37	0.15	27.43	0.01	29.50	29.66	0.09	0.01	1.00		758.33
	STD. DEV.	4.93		230.56	1.05	41.89						11.20	0.94	0.79	0.30	9.74	0.00	10.75	10.90					908.83
	MIN	15.00	4.88	1331.00	4.49	110.70	8.20	1.00	1.00	7.00	12.00	13.61	1.60	1.58	0.01	12.00	0.01	12.01	12.03	0.09	0.01	1.00		280.00
	MAX	27.60	6.25	1898.00	7.43	215.20	8.20	1.00	1.00	7.00	12.00	46.00	4.00	3.79	0.88	42.00	0.01	44.00	44.03	0.09	0.01	1.00		2600.00
BHS7-EFF-SL-09	n	8	8	8	8	8	5	5	5	7	7	6	6	6	8	7	8	8	8	7	8	1	1	7
	MEAN	21.15	5.76	2729.38	6.24	146.73	1101.24	1.00	1.40	14.43	54.57	18.15	2.03	1.87	0.15	15.66	0.01	20.46	20.61	0.13	0.04		2.00	1085.57
	STD. DEV.	5.74		2353.65	1.45	67.94	2088.00	0.00	0.89	23.59	38.27	22.22	0.49	0.56	0.16	16.80	0.01	20.63	20.65	0.10	0.08			1176.54
	MIN	14.60	5.09	269.00	4.58	53.80	2.20	1.00	1.00	2.00	10.00	1.51	1.40	1.29	0.01	0.04	0.01	0.05	0.12	0.01	0.01		2.00	34.00
	MAX	29.10	6.57	6120.00	8.51	219.20	4800.00	1.00	3.00	64.00	120.00	56.30	2.80	2.77	0.41	40.00	0.03	54.00	54.06	0.29	0.24		2.00	3300.00
BHS7-EFF-DP-11	n	4	4	4	4	4	0	0	0	0	0	4	4	4	4	5	5	5	4	0	0	0	0	4
	MEAN	24.58	5.88	1665.00	5.23	168.40						25.78	3.03	2.81	0.22	25.40	0.01	25.40	22.97					380.00
	STD. DEV.	3.41		350.21	0.72	31.36						8.16	0.17	0.41	0.35	9.15	0.00	9.15	7.92					111.65
	MIN	19.90	5.75	1356.00	4.34	137.20						18.80	2.80	2.26	0.03	16.00	0.01	16.00	16.07					280.00
	MAX	28.00	6.06	2151.00	6.02	202.40						37.10	3.20	3.17	0.74	36.00	0.02	36.00	34.04					500.00
BHS7-EFF-DP-12	n	6	6	6	6	6	4	4	4	4	4	6	6	6	6	6	6	6	6	4	4	2	2	4
	MEAN	22.78	6.12	1751.17	4.31	112.62	1255.00	12.25	9.00	20.00	87.00	8.74	2.95	2.85	0.10	5.79	0.01	5.79	5.89	1.84	0.77	1.00	2.00	410.00
	STD. DEV.	4.31		289.72	0.47	91.12	2230.06	6.45	6.73	21.66	20.77	5.10	1.05	1.02	0.05	4.65	0.00	4.64	4.66	0.72	0.24			76.16
	MIN	17.20	5.90	1309.00	3.66	-36.30	120.00	3.00	1.00	4.00	56.00	1.44	1.40	1.39	0.01	0.02	0.01	0.04	0.05	0.96	0.44	1.00	2.00	330.00
	MAX	28.20	6.25	2173.00	5.01	211.90	4600.00	18.00	17.00	52.00	100.00	14.30	4.60	4.47	0.15	11.00	0.02	11.00	11.08	2.60	1.00	1.00	2.00	480.00

Table 7 (continued)
Summary of Water Quality Analytical Results

Sample ID		Temp (°C)	pH	Specific Conductance (uS/cm)	DO (mg/L)	ORP (mV)	Total Alkalinity (mg/L)	TSS (mg/L)	VSS (mg/L)	$CBOD_5$ (mg/L)	COD (mg/L)	TN (mg/L N)[1]	TKN (mg/L N)	Organic N (mg/L N)[2]	NH_3-N (mg/L N)	NO_3-N (mg/L N)	NO_2-N (mg/L N)	NOx (mg/L N)	TIN (mg/L N)[3]	TP (mg/L)	Ortho P (mg/L P)	Fecal (Ct/100 mL)	E-coli (Ct/100 mL)	Cl (mg/L)
BHS7-BKG-LY	n	3	3	3	3	3	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	1	1	2
	MEAN	27.07	5.71	78.87	5.92	182.07	11.00	1.00	8.50	16.00	30.50	3.25	0.89	0.82	0.08	2.36	0.01	2.36	2.44	0.05	0.01	1.00	2.00	3.90
	STD. DEV.	2.74		37.47	0.35	24.52		0.00	10.61		26.16	3.18	0.16	0.14	0.02	3.03	0.00	3.03	3.04	0.01	0.00			0.99
	MIN	24.10	5.43	35.80	5.67	155.60	11.00	1.00	1.00	16.00	12.00	1.00	0.78	0.72	0.06	0.22	0.01	0.22	0.28	0.04	0.01	1.00	2.00	3.20
	MAX	29.50	5.96	104.00	6.32	204.00	11.00	1.00	16.00	16.00	49.00	5.50	1.00	0.91	0.09	4.50	0.01	4.50	4.59	0.05	0.01	1.00	2.00	4.60
BHS7-TAP	n	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	MEAN	20.03	7.37	178.30	6.43	95.47	82.50	2.00	2.00	2.00	10.00	0.24	0.05	0.04	0.01	0.11	0.08	0.19	0.20	0.15	0.12	1.00	2.00	3.65
	STD. DEV.	2.70		3.99	0.67	54.95	6.36	1.41	1.41	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.01	0.04	0.04	0.04	0.04			
	MIN	17.30	7.14	173.90	5.83	45.30	78.00	1.00	1.00	2.00	10.00	0.21	0.05	0.04	0.01	0.09	0.07	0.16	0.17	0.12	0.10	1.00	2.00	3.30
	MAX	22.70	7.71	181.70	7.15	154.20	87.00	3.00	3.00	2.00	10.00	0.27	0.05	0.04	0.01	0.13	0.09	0.22	0.23	0.17	0.15	1.00	2.00	4.00
BHS7-EB	n	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6
	MEAN	21.54	6.08	1.69	8.13	111.96	2.41	1.00	1.00	2.00	10.00	0.10	0.07	0.06	0.01	0.01	0.01	0.02	0.03	0.02	0.01	1.00	2.00	0.53
	STD. DEV.	6.80		0.44	1.56	55.80	0.97	0.00	0.00	0.00	0.00	0.06	0.06	0.05	0.01	0.01	0.00	0.01	0.01	0.01	0.00			0.52
	MIN	14.30	4.62	1.20	5.16	43.10	2.00	1.00	1.00	2.00	10.00	0.06	0.05	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	1.00	2.00	0.05
	MAX	30.90	7.39	2.26	9.57	181.20	4.60	1.00	1.00	2.00	10.00	0.24	0.22	0.18	0.04	0.02	0.01	0.03	0.06	0.04	0.01	1.00	2.00	1.00

Notes:

[1]Total Nitrogen (TN) is a calculated value equal to the sum of TKN and $NO_{X.}$

[2]Organic Nitrogen (ON) is a calculated value equal to the difference of TKN and $NH_{3.}$

[3]Total Inorganic Nitrogen (TIN) is a calculated value equal to the sum of NH_3 and $NO_{X.}$

Gray-shaded data points indicate values below method detection level (mdl), mdl value used for statistical analyses.

Yellow-shaded data points indicate the reported value is between the laboratory method detection limit and the laboratory practical quantitation limit, value used for statistical analysis.

Figure 15 provides a time series of influent and effluent TN over the study period for the performance evaluation results described previously. Figures 16 through 20 show box and whisker plots of the various monitoring points for the key parameters measured during the study period. The Stage 1 monitoring points include the suction lysimeters located with the cup at the bottom of the native sand layer at the sand and lignocellulosic interface: ST1-SL-01, ST1-SL-02, ST1-SL-03, and ST1-SL-04. The Stage 2 monitoring points include the drivepoints installed within the lignocellulosic media on the liner: ST2-DP-03, ST2-DP-04, ST2-DP-05, ST2-DP-06, ST2-DP-07 and ST2-DP-08. The preliminary sample event conducted December 12, 2013 (Experimental Day 23) was not included in the long term analyses as the system was still in the start-up period.

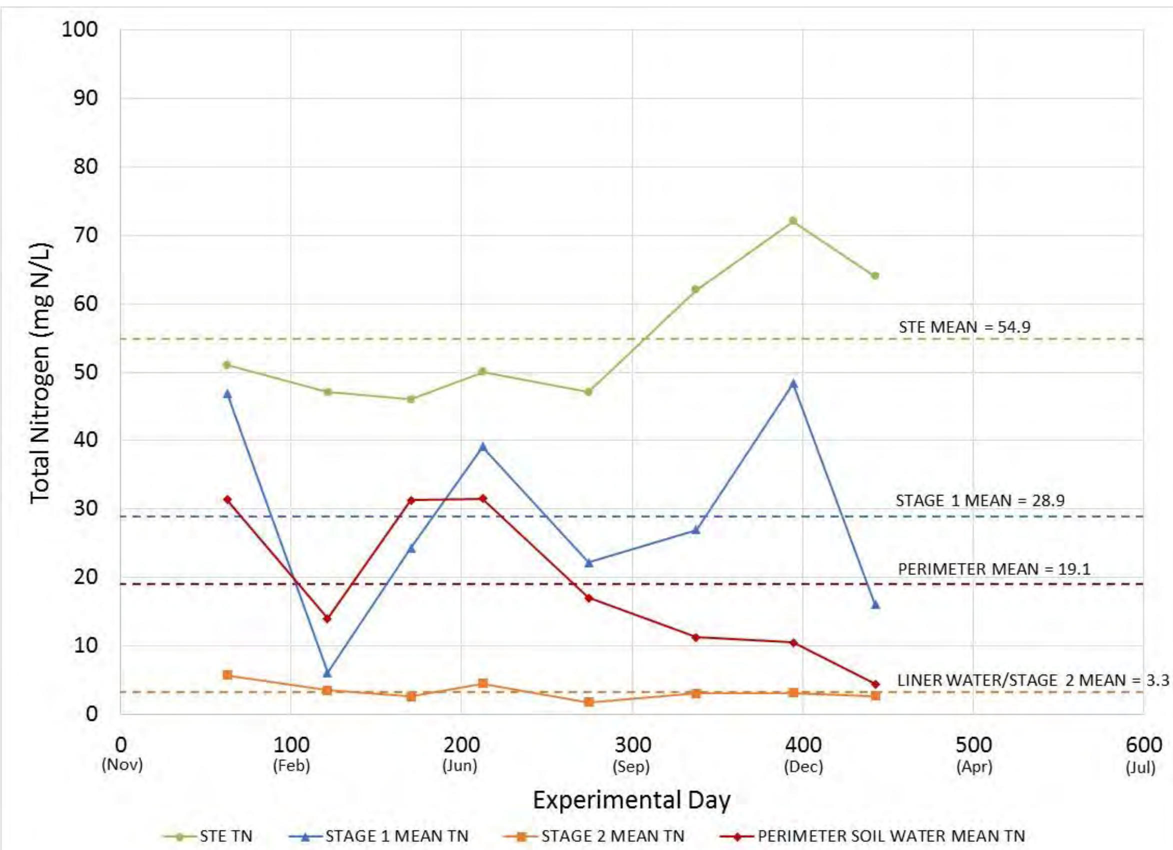

Figure 15
Total Nitrogen Time Series Graph

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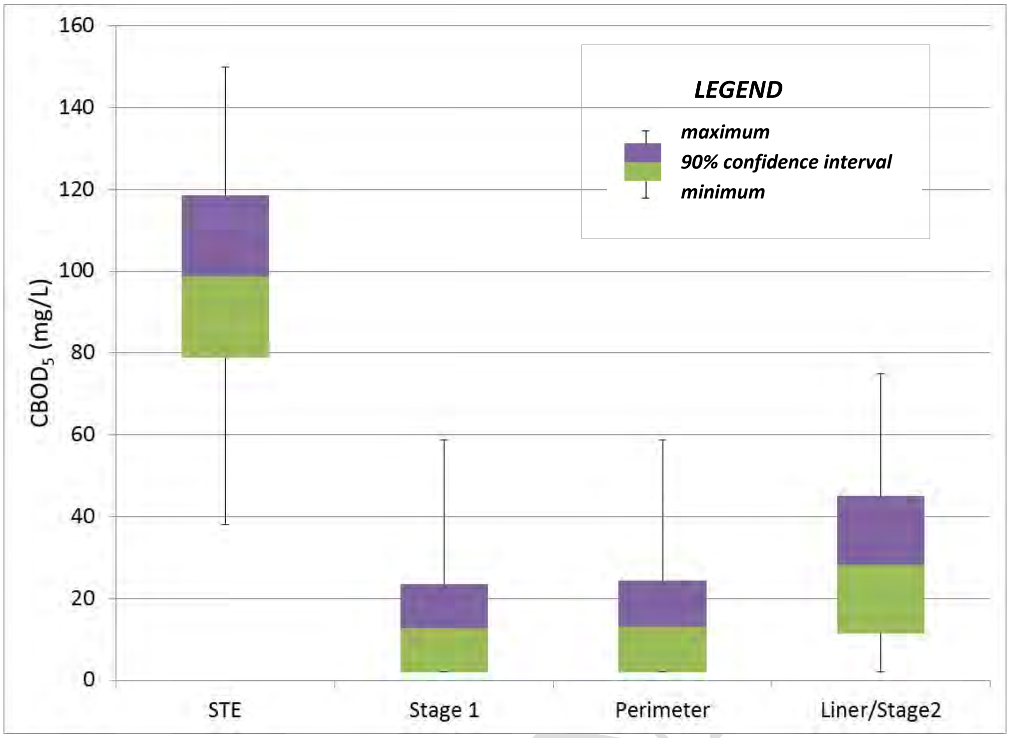

Figure 16
$CBOD_5$ Box and Whisker Plot

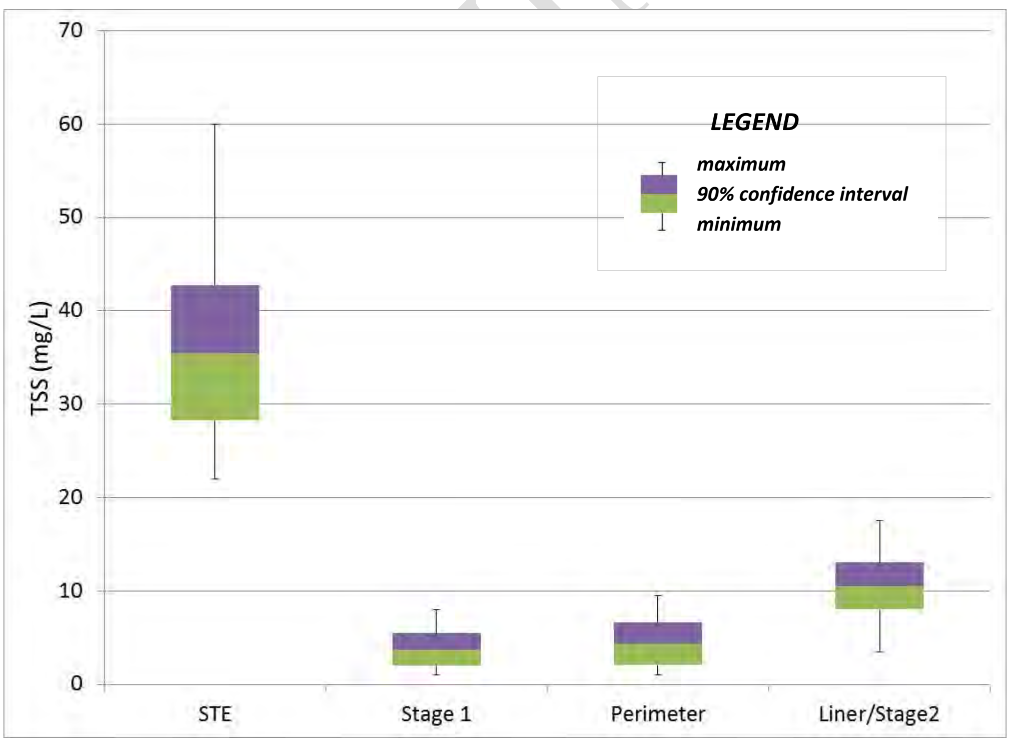

Figure 17
TSS Box and Whisker Plot

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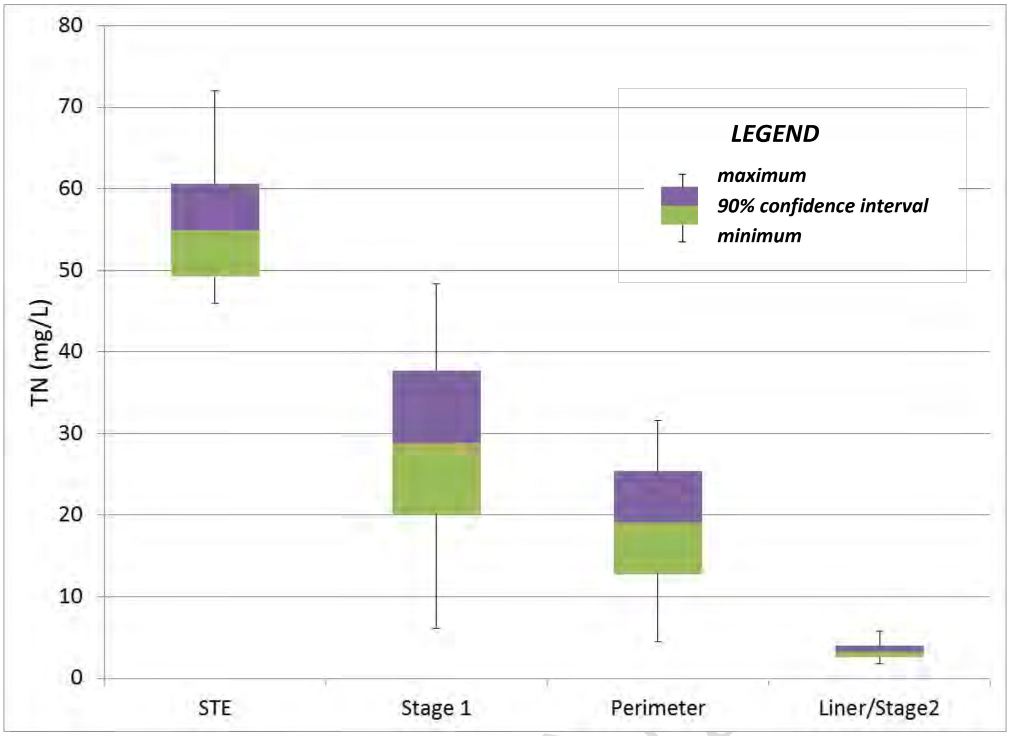

Figure 18
Total Nitrogen (TN) Box and Whisker Plot

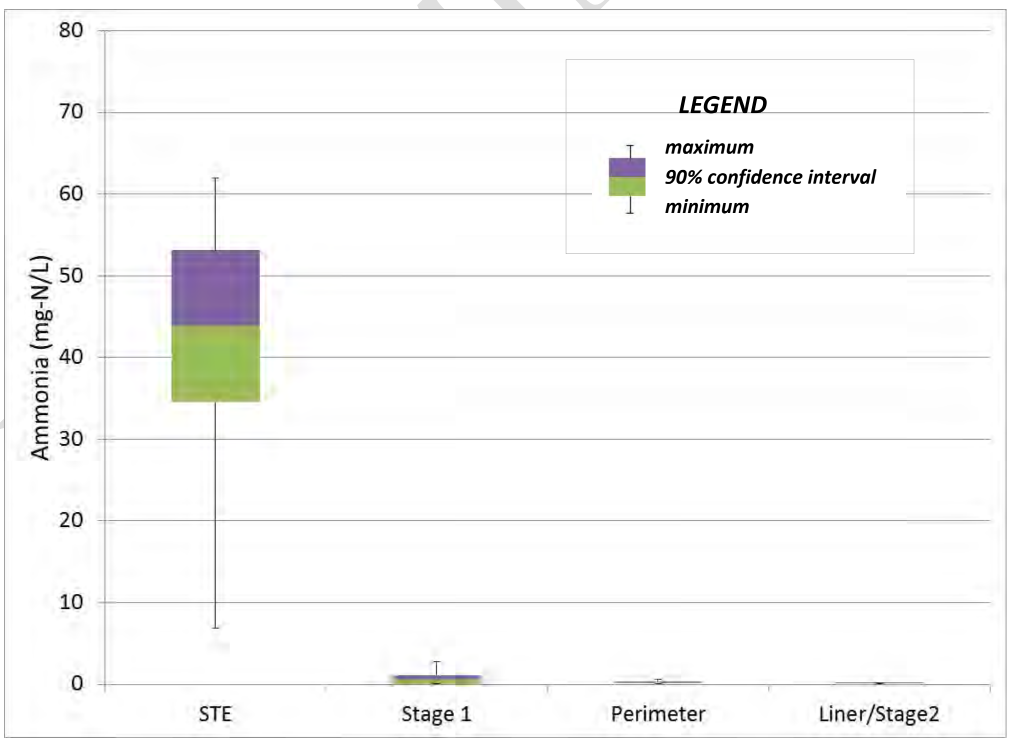

Figure 19
Ammonia N (NH3-N) Box and Whisker Plot

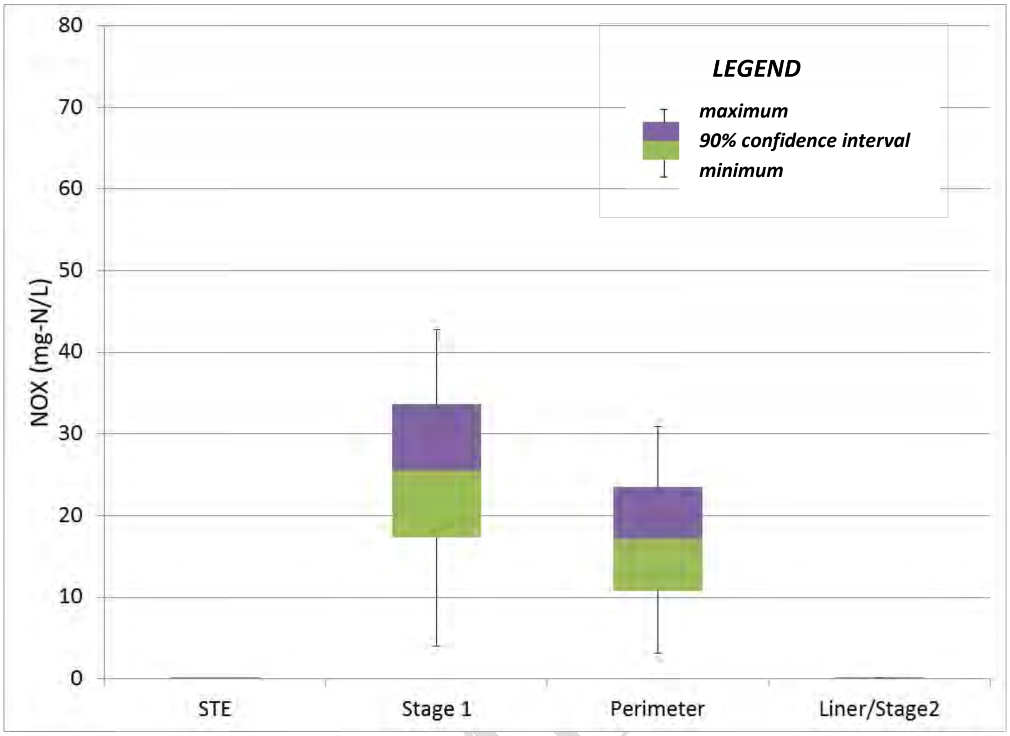

Figure 20
Nitrate+Nitrite Nitrogen (NO_X-N) Box and Whisker Plot

5.0 B-HS7 Sample Event No. 8: Summary and Recommendations

5.1 Summary

The Sample Event No. 8 results indicate that:

- Septic tank effluent (STE) quality is characteristic of typical household STE quality. The total nitrogen concentration of approximately 64 mg/L is within the range of values typically reported for Florida single family residence STE.

- The Stage 1 biofilter converted the majority of ammonium to oxidized nitrogen; mean effluent values contained 3.6 ± 1.0 mg/L TKN, of which 0.2 ± 0.2 mg/L was ammonia.

- The Stage 2 biofilter mean lignocellulosic effluent NO_x-N within the biofilter media was 0.06 ± 0.04 mg N/L; however, this is most likely not representative of water leaving the system.

- The total nitrogen concentration in the perimeter monitoring points surrounding the treatment system was 4.5 ± 6.1 mg/L of which mean TKN was 1.4 ± 0.3 and mean NO_x-N was 3.1 ± 5.9 mg/L. The perimeter monitoring points often have higher NO_x-N levels than samples taken from within the Stage 2 media. Since the observation port measurements indicated that the liner water level was between 5.3 and 5.5 inches below the overflow elevation at the time of sampling, the water sampled at the perimeter points is not likely to be water that was recently discharged off of the lined area, but water that is moving laterally away from the Stage 1 soil into the surrounding soil. Therefore, the perimeters samples are likely most representative of water leaving the system as currently operating.

5.2 Conclusions

Sample Event 8 was the last funded sample event for the B-HS7 treatment system. Section 4.4 summarized the water quality data collected over the 1.2 year monitoring period for this system. These results indicate that:

- The septic tank effluent average total nitrogen concentration of 54.9 mg/L is in the range of values typically reported for Florida single family residence STE.

- The Stage 1 monitoring points located at the sand and lignocellulosic interface (ST1-SL-01, ST1-SL-02, ST1-SL-03, and ST1-SL-04) showed significant ammonia removal with an average NH_3-N concentration of 0.6 mg/L and average TKN of 3.4 mg/L. The average NO_x-N was 25.5 mg/L.

- The Stage 2 monitoring points located within the lignocellulosic media on the liner (ST2-DP-03, ST2-DP-05, ST2-DP-06, ST2-DP-07 and ST2-DP-08) showed similar ammonia removal with an average NH_3-N concentration of 0.09 mg/L and average TKN of 3.2 mg/L. The Stage 2 biofilter was effective in producing a reducing environment and achieving significant NO_x-N removal (average NO_x-N concentration of 0.07 mg/L). The average final total nitrogen (TN) was 3.3 mg/L, primarily TKN (average TKN concentration of 3.2 mg/L). However, as discussed in Section 4, it is likely that much of the Stage 1 effluent did not reach the liner media, and therefore the liner water samples are not representative of effluent leaving the system.
- As discussed, the perimeter monitoring points (EFF samples) NO_x-N concentrations significantly varied throughout time and often had higher NO_x-N levels than in samples collected within the Stage 2 media. The water sampled at the perimeter points is not likely to be water that was recently discharged off of the lined area. It is suspected that the NO_x-N plume beneath the wastewater application zone extends laterally past the width of the Stage 2 biofilter liner area, and that water from Stage 1 also moves laterally away from the system into the surrounding soil. Therefore, the perimeter monitoring points are likely most representative of water leaving the system as currently operating. Based on the perimeter monitoring results, the BHS-7 PNRS achieved approximately 65% mean reduction in total nitrogen leaving the system.

The results of the data collected to date have provided insights into the performance of an in-ground full-scale passive single pass nitrogen reduction system monitored over an extended timeframe (442 experimental days) under actual onsite conditions. Based on the results from this system evaluation, several potential design revisions for the Stage 2 liner system have been formulated, which could correct the hydraulic limitations discussed and greatly improve the performance of the system.

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