Wakulla County Septic Tank Study

Phase II Report on Performance Based Treatment Systems

FDEP AGREEMENT NO: WM926

The Florida State University
Department of Earth, Ocean and Atmospheric Science

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Prepared by

Harmon Harden[1], Jeffrey Chanton[2], Richard Hicks[3] and Edgar Wade[4]

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[1] Corresponding authors, Jeff Chanton and Richard Hicks.
[2] Florida State University Department of EOAS, jchanton@fsu.edu
[3] Florida Department of Environmental Protection Ground Water Protection Section, richard.w.hicks@dep.state.fl.us
[4] Florida Department of Environmental Protection Ground Water Protection Section, edgar.wade@dep.state.fl.us

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Results at a Glance

1. The average total nitrogen (TN) input value for raw sewage inputs to septic systems was 72.8 ± 39.2 mg-N/L, n=17 from five households served by Performance Based Treatment Systems (PBTS). A companion study by the Colorado School of the Mines (CSM, Lowe et al., 2009) focused on anther six households, with an average of 73.1 ± 50.3 mg-N/L, n = 24. The data indicates that 70 mg-N/L is a reasonable estimate of total nitrogen concentration in wastewater being discharged from households in Wakulla County to their septic systems.

2. The average of monthly septic tank effluent concentration in samples from the 8 PBTS sites monitored in Phase II two of the study was 30 ± 11 mg-N/L. This average effluent concentration is consistent with the effluent concentrations in 27 other PBTS that were also sampled in Wakulla County during this study, which had a average effluent concentration of 29 ± 21 mg-N/L. For all 35 PBTS that were sampled, the average TN concentration was 29 ± 19 mg-N/L. While this is a 50-60% N reduction relative to wastewater inputs, the PBTS effluent concentration is greater than the 10 mg-N/L target effluent concentration included in Wakulla County Ordinance 2006-58. This ordinance was based on testing of treatment systems under controlled conditions, with much lower nitrogen concentrations in the influent than observed during this study.

3. The results of this study indicate that Performance Based Treatment Systems (PBTS) installed in Wakulla County reduced nitrogen 50-60% from input concentrations when properly maintained. Using a raw wastewater input concentration of 70 mg-N/L and the effluent results in bullet number 2 above; the 8 primary study sites yield a TN reduction of 57 ± 16%. For the 27 sites sampled only once, we calculated a TN reduction of 59 ± 30%.
4. In a previous Wakulla County study, conducted by the Colorado School of the Mines (CSM, Lowe et al., 2009), the average conventional septic tank effluent (STE) TN concentration was 64 ± 13 mg-N/L. For all 35 PBTS that were sampled in this study, the average TN concentration was 29 ± 19 mg-N/L. The effluent from PBTS is thus less than half (45%) of the effluent from a conventional septic system.
5. Compliance, operation and maintenance issues in Wakulla County were responsible for a large percentage of systems that were found to be non-operational or performing poorly.
6. Lysimeters and wells placed within pressurized drip drainfield systems and conventional drainfield systems captured roughly 50% septic tank effluent based upon Cl concentration data. In other words, the water collected from these samplers was diluted by 50%, and contained 50% septic water. Median effluent nitrogen attenuation by denitrification, adsorption and plant uptake was 30% in these systems, similar to the 25% reduction observed for conventional systems during Phase I of this study (Katz et a. 2010). Four drip systems and five conventional systems were evaluated. Due to high variability, our results do not indicate a significant difference in TN removal between the drip and the conventional drain fields.
7. As stated above, a previous Wakulla County study (Lowe et al., 2009), found that the average conventional septic tank effluent (STE) TN concentration was 64 ± 13 mg-N/L (Fig. ES-2). For all 35 PBTS that were sampled in this study, the average TN concentration was 29 ± 19 mg-N/L. Our results indicate that N-attenuation in the drainfield is 30%. These results thus indicate that for Wakulla County , a typical conventional septic tank input to the aquifer is

$$(1-0.3) * 64 \pm 13 \text{ mg-N/L} = \quad 45 \pm 9 \text{ mg-N/L}.$$

Similarly, a typical PBTS system TN input to the aquifer may be calculated as

$$(1-0.3) * 29 \pm 19 \text{ mg-N/L} = \quad 20 \pm 13 \text{ mg-N/L}.$$

PBTS systems reduce TN input to the watershed by 55%. The effluent from a PBTS is only 45% that of a conventional septic system. Average daily water use for the 11 residences in the Phase I and Phase II study was 988±492 L/d (261±130 gallons per day, Appendix A). Thus the typical N-flux to the aquifer from a conventional septic tank is 44 ± 24 grams N per day (32±17 lbs/yr). For a PBTS the value is 20 ± 16 grams N per day (16±14 lbs/yr).

Executive Summary

A conventional onsite sewage treatment and disposal system (OSTDS) includes a septic tank and drainfield to treat wastewater. Under normal conditions, conventional septic tanks provide minimal treatment of nitrogen. Most of the nitrogen removal associated with a conventional OSDS occurs within and beneath the drainfield. However, in karst regions of Florida the soil can be very well drained and low in organic carbon. These conditions result in a nitrogen flux to ground water. Advanced pre-dispersal treatment may need to be provided when soil conditions cannot provide adequate overall treatment. Performance based treatment systems (PBTS) are engineered to provide this additional treatment of nitrogen from the wastewater before it is discharged. The purpose of this study is to evaluate the effectiveness of PBTS installed and operated at residences in the Wakulla Springs basin.

Advanced treatment of nitrogen for new and repaired OSTDS became a requirement for Wakulla County residents in County Ordinance 2006-58, passed in October 2006, and is being considered by Leon County as well as other counties with karst features. The Wakulla County 2006 ordinance states that "only performance-based septic systems that *can* produce a treatment standard of 10 mg/L nitrogen shall be installed in new construction and as replacements when

older systems fail or are replaced" (Wakulla County Ordinance, 2006). This ordinance applies to the entire county. Approved PBTS from the following three manufacturers have been installed in Wakulla County: MicroFAST by Bio-Microbics, Inc., HOOT Series-AND by HOOT Aerobics Inc, and Singulair 960 by Norweco, Inc. For simplicity they will be referred to hereafter in this report as FAST, HOOT, and Norweco. As of July 2010, approximately 200 PBTS have been installed in Wakulla County under the new ordinance. The general distribution of PBTS installed in Wakulla County by manufacturer is shown in Figure ES-1.

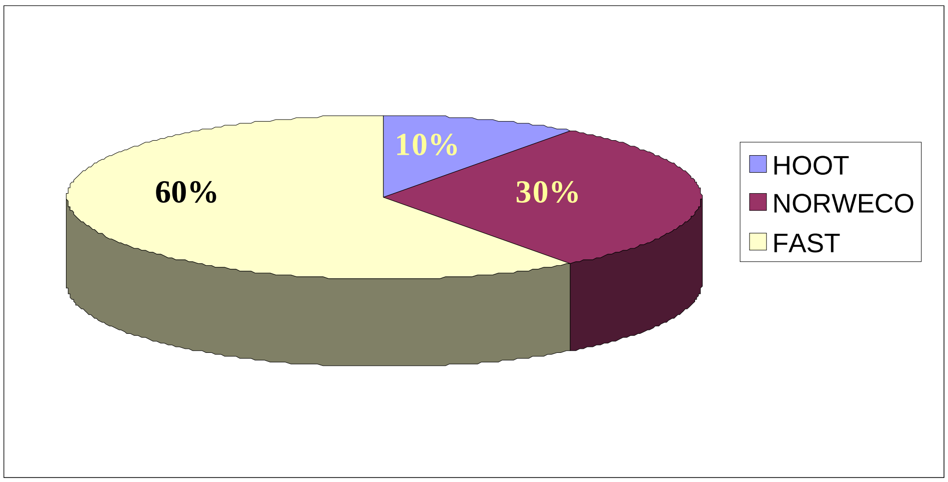


Figure ES-1. The distribution of performance based treatment systems by manufacturer installed in Wakulla County, 10% Hoot, 30% Norweco, 60% Fast.

In May 2007, the Florida State University Department of Oceanography entered into an agreement with the Florida Department of Environmental Protection (FDEP) Ground Water Protection Section and worked cooperatively with the United States Geological survey to evaluate the fate of nutrients discharged by conventional OSTDS in the Wakulla Springs Basin by measurement of nutrients in the septic tank effluent, drainfield pore water and underlying groundwater. This contract was amended in June 2008 to include a second phase, a 1-year-long study of PBTS that were installed under the new ordinance. The scope of work for Phase II used a similar study design, with monthly monitoring of the PBTS and additional sampling of the raw sewage inputs to the systems. The initial results from the 8 PBTS tank effluent indicated the systems were not achieving the 10 mg-N/L goal of the Wakulla County ordinance. Although significant reduction of total nitrogen (TN) was observed, the initial results indicated that the average effluent concentration was approximately 30 mg-N/L. To determine whether the 8 systems being studied were representative of PBTS installed in the area, the study was expanded to include the sampling of effluent from 27 additional PBTS and resulted in the inspection of 59 PBTS in Wakulla County.

This report was prepared to convey results of the Phase II study, and to specifically

1. provide information on the TN removal effectiveness of the treatment systems being evaluated;
2. provide the findings of the wider inspection and sampling of PBTS, which included over half of the systems installed in Wakulla County as of October 2008; and
3. provide results on the attenuation of nutrients by conventional drainfields and drip systems.

Effectiveness of the systems being monitored in this study was measured as a percent (%) reduction in the TN concentration of the septic tank effluent, comparing average OSTDS influent concentrations obtained in the county against tank effluent concentrations from the PBTS included in the project, as shown below in Equation 1.

$$\textbf{\% N-reduction} = \textbf{(1 - PBTS effluent /PBTS influent) * 100} \qquad \textbf{(1)}$$

Characterizing the amount of nitrogen going into an individual residential OSTDS (influent) requires multiple samples over a period of time due to the high variability in the composition of the raw sewage. However, understanding the characteristics of the waste stream is crucial in the design of treatment systems, management decisions, and accessing PBTS performance and environmental impacts. As this study was commencing, the Colorado School of Mines (CSM, Lowe et al,. 2009) was finishing a large study focusing on the raw sewage inputs and effluent from conventional septic tanks in three regions of the United States, and a portion of the work was conducted in Wakulla County by a Department of Oceanography researcher. The Phase II raw sewage samples were collected using the same methodology and equipment used for the CSM work.

In this study, raw sewage samples from five households served by PBTS had an average influent concentration of 72.8 ± 39.2 mg-N/L, n=17. The CSM study (Lowe et al., 2009) focused on six other households which produced an average raw TN concentration of 73.1 ± 50.3, mg-N/L, n = 24 (Figure ES-2). As mentioned previously, a large range in raw wastewater TN concentrations is to be expected due to the variety of daily water use activities that can significantly dilute or strengthen the waste stream TN composition for a particular household. Additionally, the number and age of household members and their life styles can affect the TN concentration in the wastewater. For ease of subsequent calculations, a value of 70 mg-N/L was chosen to represent raw wastewater input of TN to septic tanks in Wakulla County.

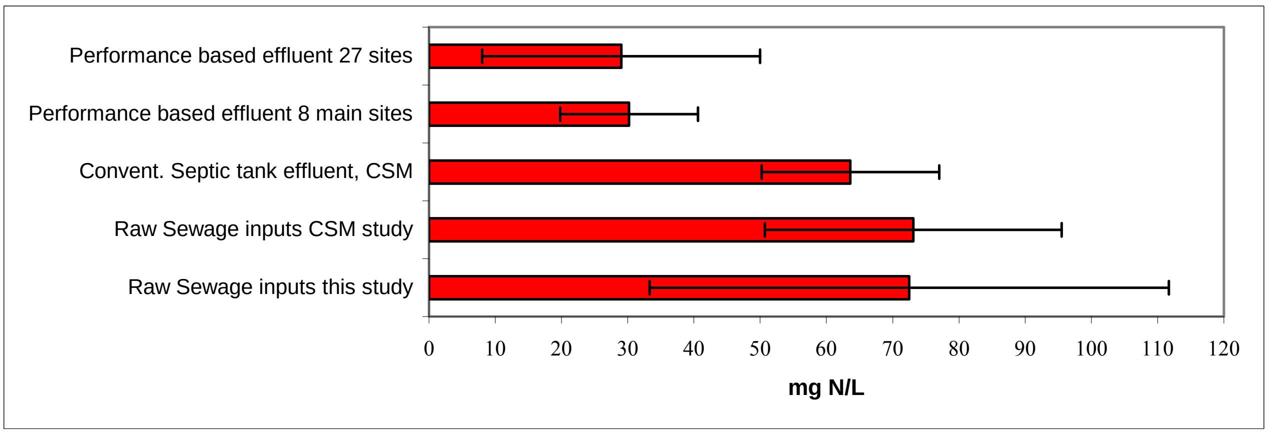


Figure ES-2. Concentration of total nitrogen in septic tank inputs and effluent from conventional and performance based systems.

In the CSM study, the average conventional septic tank effluent (STE) concentration was 64 ± 13 mg-N/L (Fig. ES-2). If 70 mg-N/L is used as a raw wastewater input value, this results in a TN-reduction of 9 ± 19% (Eq. 1) for these conventional septic tanks (Figure ES-3). A conventional OSTDS provides for some attenuation of nitrogen through ammonia volatilization and the removal of solids. According to Anderson (2006), estimates of up to 17% reduction in TN content have been reported by the U.S. Environmental Protection Agency and others. Anderson (2006) as a rule of thumb recommended a figure of 10% reduction for a conventional septic tank. In another study, Xuan et al. (2009) reported a of 24% reduction in TN for a conventional system during the first few months of operation. The La Pine, Oregon survey of 40 conventional systems with 427 samples reported a median TN concentration of 63 mg-N/L for conventional septic tank effluent (La Pine Oregon Demonstration Project, 2006), which is similar to the CSM value of 64 ± 13 mg-N/L.

The average TN concentration from monthly effluent samples collected during the Phase II study of 8 PBTS sites was 30 ± 11 mg-N/L. The results of the Phase II study of the 8 PBTS sites are consistent with the average concentration from 27 PBTS randomly sampled in Wakulla County (29 ± 21 mg-N/L, inFigure ES-2). For all 35 PBTS that were sampled, the average TN concentration was 29 ± 19 mg-N/L. The results are 55% lower than the average TN concentration from conventional OSTDS effluent. However, the observed PBTS TN concentration is greater than the 10 mg-N/L treatment goal in the county ordinance. Using a raw wastewater input concentration of 70 mg-N/L; and the mean effluent value determined in this study, the 8 primary study sites provided a TN reduction of 57 ± 16%. For the 27 sites sampled only once, we calculated a TN reduction of 59 ± 30% (Figure ES-3). From direct measurements of PBTS inputs (raw sewage) and effluent on 5 sites, we calculated an average reduction of 49.2 ± 17.8% (Table 15). These results are similar to results obtained in the larger La Pine National Demonstration Project conducted in Oregon (La Pine Oregon Demonstration Project, 2006).

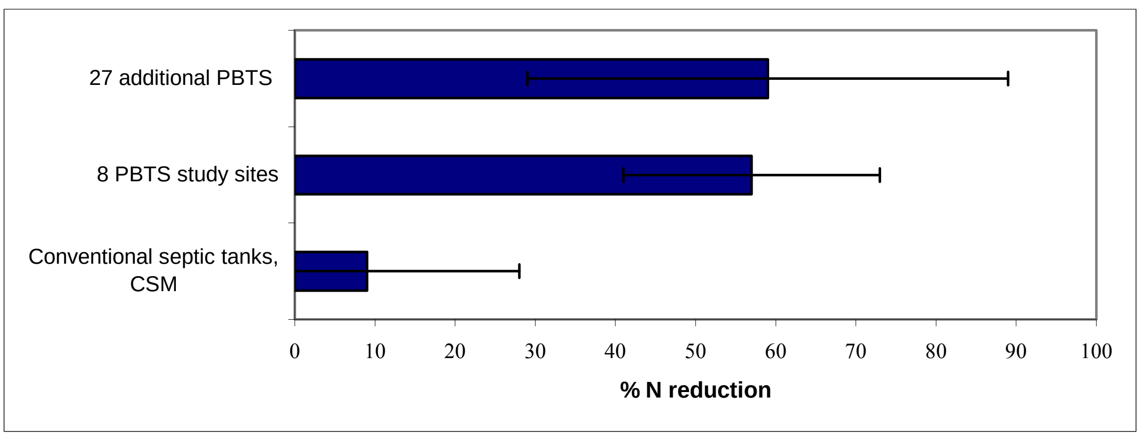


Figure ES-3. Percent Nitrogen reduction from conventional and performance based septic systems. An influent value of 70 mg-N/L was used in calculations.

The average TN effluent concentration of approximately 30 mg-N/L may seem high for systems that achieved a 10 mg-N/L effluent concentration standard during testing, but the percent reduction value of 50-60% is consistent with other studies. The technology employed by all of these three systems has been shown to consistently achieve 50-70% nitrogen reduction when the systems are installed and maintained correctly. The discrepancy between the test-center based design concentration standard (10 mg/L) and actual in-the-field results is due to the influent concentrations used in the testing facility. In the test centers measurments (for NSF and others where the testing occurred) from which performance-based designs are based, TN concentrations in the influent was 25-35 mg-N/L, less than half of the actual concentrations in raw sewage measured in these studies specific to Wakulla County and in other studies (approximately 70 mg-N/L). Higher effluent concentrations in septic waters relative to the testing water may be due to water saving devices such as low flush toilets and low volume showerheads.

The sampling of the 27 PBTS sites in addition to the 8 study sites, was conducted with the assistance of the Wakulla County Health Department (health department) and the FDOH Bureau of Onsite Sewage Programs. All of the PBTS systems visited were installed prior to October 2008, to insure at least 6 months between installation and sampling. The distribution of types of PBTS in Wakulla County (ES-1) was also taken into consideration while selecting site candidates. The sampling team encountered several issues of concern regarding the installation, operation and maintenance of many systems. A total of 59 systems were inspected to obtain the 27 samples from properly functioning systems. More site visits would have been required to collect the samples had not health department staff pre-checked sites to eliminate non-operating systems during the last three days due to time constraints of the sampling team. Although not in the study plan, this survey included over half of the systems installed in Wakulla County.

Of a total of 59 PBTS inspected, 23 (39%) of these systems were not operating as designed (Figure ES-4).

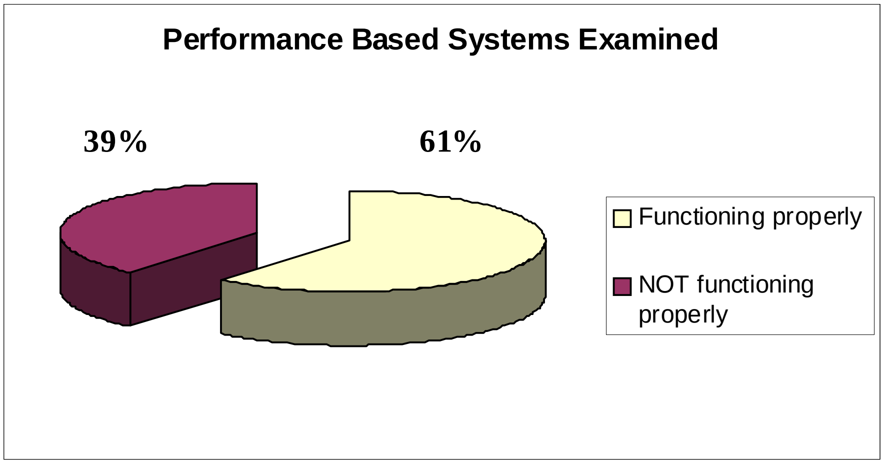


Figure ES-4. Of 59 performance based systems examined in Wakulla County, 36 (61%) were in compliance. 23 systems (39%) were not functioning as performance based systems due to electrical issues, being turned off or other problems.

One widespread problem identified in this study was that many of the systems (22) were not in operation, either because their electrical switches had been turned off or (in three cases) because the wires to the control boxes had never been connected. Not operating or installing the systems as designed could be in violation of the homeowners' septic tank permits with the county health department.

At another non-compliant site, a plug was missing from the bottom of the system's holding tank, resulting in effluent seeping into the ground and not going to the drainfield. Sampling was further complicated at several sites by the lack of ports or other access points to enable sampling of the system effluent, which is a requirement of the engineering design and necessary for periodic inspections required under their permits. For some systems that were sampled, extraordinary efforts were required to access suitable sampling points. This lack of accessibility seemed to contradict their maintenance records which indicated that effluent was being periodically being inspected by contractors for clarity and odor.

Of the 59 sites visited, it appeared that only 36 (61%) were operating. Of the 36 functioning systems inspected, 27 (75%) were sampled, 3 (8%) had no sampling access, and 6 (17%) were simply not chosen for system type distribution considerations. As a requirement of its permit, a PBTS in Wakulla County is supposed to receive initial and periodic inspections by the septic tank contractor. However, the rigor of some of these inspections would appear to be questionable.

Lysimeters and wells placed beneath pressurized drip drainfield systems and conventional drainfield systems captured roughly 50% septic tank effluent, based upon Cl concentration data. In other words the samples collected by these devices contained 50% waste water and were diluted by groundwater by 50%. Median nitrogen attenuation due to denitrification, adsorption and plant uptake was 30% in these systems. Four drip systems and five conventional systems were evaluated. Due to high variability, our results did not indicate that either of the wastewater disposal methods (conventional drainfield or drip irrigation) had a significant advantage over the other as far as nitrogen removal was concerned. A drip system with unchecked unruly vegetation appeared to perform better than did systems where there was a conventional lawn. We hypothesize that the vegetation roots were deeper in this system and that they were able to access the nitrogen released from the drip line.

For the Wakulla County sites included in the CSM study, the average conventional septic tank effluent (STE) concentration was 64 ± 13 mg-N/L (Fig. ES-2). For all 35 PBTS that were sampled in this study, the average TN concentration for effluent was 29 ± 19 mg-N/L. The PBTS systems reduced N output 57 to 59% based on a raw sewage value of 70 mg-N/L. Our results indicate that the average N-attenuation in the drainfield is an additional 30%. These results indicate that for Wakulla County, a typical conventional septic tank input is 45±9 mg-N/L of wastewater to the aquifer (64* (1-0.3)). A typical PBTS system inputs 20 ± 13 mg-N/L of wastewater to the aquifer (29* (1-0.3)). Average daily water use for the 11 residences in the Phase I and Phase II study was 988±492 L/d (261.0 ± 130.0 gallons/d)(Appendix A). Thus the typical N-flux to the aquifer from a conventional septic tank is 44 ± 24 gram N per day (0.088 lbs per day). For a PBTS the value is 20 ± 16 gram N per day (0.044 lbs/day).

1 Introduction

1.1 Background and Motivation

Onsite sewage treatment and disposal systems (OSTDS) are an important part of Florida's wastewater infrastructure, serving about a quarter of the state's households (Social Science Data Analysis Network, undated; FDOH, 2007). The proportion of homes served by OSTDS, in comparison to those on central sewer, is much higher in the rapidly growing, formerly rural areas of central and north Florida. These regions include areas where the limestone is close to the surface and characterized by karst features, such as large springs, sinkholes and solution channels that have formed in these shallow limestone layers. These karst features have been shown to rapidly transport contaminants to and in the underlying groundwater (e.g. Price, 1988; Paul et al., 2000; Dillon et al., 1999, 2000: Harden et al., 2008).

Springs in most areas, except in national forests, have experienced degradation in water quality, particularly exhibiting elevated nitrogen concentrations (Florida Springs Task Force, 2006). While other sources such as fertilizer use, stormwater runoff, atmospheric deposition, and wastewater treatment plant discharge also contribute to nitrogen in ground water, the effects of conventional OSTDS, consisting of a septic tank with a drainfield, have become a concern because of the recent trend in high-to-medium density residential development in areas not served by sewer. The EPA has stated "alternative systems may be necessary in karst areas" (EPA, 2006). In Florida, advanced treatment to reduce nitrogen is required for permanent OSTDS installed in the Florida Keys, where limestone is at the surface, lots are small, and the nearby coral reef system is threatened (FDOH, 2009). Advanced waste treatment is also required by local ordinance in Collier and a coastal area of Franklin County, Florida. Also in some karst areas of Florida, a larger drainfield is required when shallow discontinuous limestone is encountered during site evaluation (FDOH, 1999). In some cases, a mounded system is used to raise the disposal point well above the limestone, which is often the more cost effective solution. In October 2006, an ordinance was passed by the Wakulla County Commission to require performance based treatment systems (PBTS) for nitrogen removal (Ordinance 2006-58) and similar ordinances have been proposed for Leon and Marion counties.

In May 2007, the Florida State University Department of Oceanography entered into an agreement with the Florida Department of Environmental Protection (FDEP) Ground Water

Protection Section to evaluate the effectiveness and fate of nutrients discharged by conventional OSTDS in the Wakulla Springs Basin. This contract was amended in June 2008 to include a second phase, a 1-year-long field study of the effectiveness of PBTS that were installed under the new Wakulla County ordinance.

Phase I of this study focused on three residential sites with conventional septic tanks and drainfields in or near Wakulla County. Septic tank effluent (STE) samples, pore water samples from lysimeters below the drainfields; and ground water well samples from below the drainfields were collected and analyzed for nutrients, inorganic wastewater tracers, organic wastewater compounds and microorganisms (Katz, et al, 2010). Concurrent with this study, the Department of Oceanography, working with the Colorado School of Mines (CSM, Lowe et al, 2009), conducted a study characterizing raw sewage inputs into septic tanks in comparison to STE from conventional OSTDS. One of the CSM study areas was in Wakulla County and included one of the Phase I sites.

Phase II of this study was focused on assessing the effectiveness and performance issues associated with PBTS that were installed in compliance with the 2006 Wakulla County ordinance. It included collection and analysis of septic tank effluent samples, pore water samples beneath drainfields and ground water samples from adjacent to drainfields. In addition, it included collection of influent samples using the same equipment and methodology employed in the CSM study.

This report includes a comparison between raw sewage inputs to household septic systems from the three studies against the nitrogen content of effluent from both conventional and performance based treatment systems, with the goal of calculating a percent reduction for nitrogen (N) as

$$\textbf{\% N-reduction} = \textbf{(1 - septic tank effluent/septic tank influent) * 100} \qquad \textbf{(1a)}$$

or

$$\textbf{\% N-reduction} = \textbf{(1 - PBTS effluent/PBTS influent) * 100} \qquad \textbf{(1b)}$$

Additionally, Phase II includes an overall assessment of the PBTS in Wakulla County and a survey to assess compliance with the ordinance and random sampling to evaluate TN reduction and system efficiency. The findings of this survey are also included in this report.

1.2 Descriptions of PBTS Installed in Wakulla County

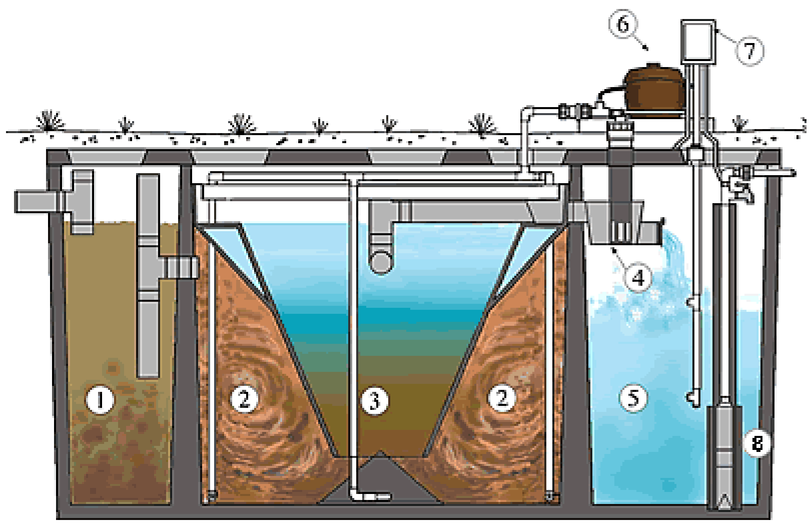
Performance based treatment systems are defined by the Florida Department of Health (FDOH) as “a specialized onsite sewage treatment and disposal system designed by a professional engineer with a background in wastewater engineering, licensed in the state of Florida, using appropriate application of sound engineering principles to achieve specified levels of CBOD5 (carbonaceous biochemical oxygen demand),TSS (total suspended solids), TN (total nitrogen), TP (total phosphorus), and fecal coliform found in domestic sewage waste, to a specific and measurable established performance standard.” (FDOH, 2009). Nitrogen reduction data for designs currently in use in Florida were obtained concurrently with testing according to the NSF/ANSI Standard 40 plus Nitrogen Reduction or Standard 245 and have been reviewed and approved by the FDOH Bureau of Onsite Septic Systems. At least five PBTS had successfully reduced effluent TN concentrations to below 10 mg-N/L during the NSF/ANSI testing as listed in the FDOH data base and are approved by FDOH for installation in Florida. Consistent with the performance expectation of the FDOH evaluation process, the Wakulla County 2006 ordinance states that “only performance-based septic systems that *can* produce a treatment standard of 10 mg/L TN shall be installed: in new construction and as replacements when older systems fail or are replaced” (Wakulla County Ordinance 2006-58). Designs based on technologies from the following three manufactures have been installed in Wakulla County: MicroFAST by Bio-Microbics, Inc., HOOT Series-AND by HOOT Aerobics Inc, and Singulair 960 by Norweco Inc. For simplicity they will be referred to as FAST, HOOT, and Norweco in this report.

Raw sewage (influent) that enters the tanks contains nitrogen in the form of mainly organic nitrogen and ammonia. The organic N component is converted to ammonia and ammonium by bacteria under anaerobic conditions. In the presence of oxygen, ammonia (NH_3) and ammonium (NH_4) are then converted to nitrate (NO_3). Nitrate can be converted to di-nitrogen gas (N_2) under sub-oxic/anaerobic conditions by bacteria in the presence of organic matter. Di-nitrogen gas is an inert form of N; all the other forms are bio-active. Thus denitrification is a goal of performance-based systems to achieve N reduction. To be effective, the septic systems should cycle the wastewater from anaerobic conditions, to aerobic, and then back to sub-oxic/anaerobic conditions. Further nitrogen removal then occurs as the wastewater enters the drainfield and percolates through the unsaturated soil column.

All three of the PBTS evaluated in this study employ similar processes and principles to achieve the three stages of the nitrogen cycle that reduce the nitrogen to acceptable levels, ammonification, nitrification and denitrification. Raw sewage flows into a pre-treatment chamber, which acts as a small septic tank. Here, solids settle out and ammonification occurs in the anaerobic conditions as bacteria convert organic nitrogen into ammonia and ammonium ion (ammonification). Total Kjeldahl nitrogen is the combination of ammonia, ammonium and organic nitrogen. The predominant form of nitrogen in the wastewater is ammonia as it flows out of the anaerobic pre-treatment chamber into the treatment chamber. A blower or aerator creates an aerobic environment in the treatment chamber, where in the presence of the proper bacteria ammonia is converted into nitrite and then nitrate. This process is called nitrification. Length of treatment time, oxygen levels and the population and health of the nitrifying bacteria determine the extent of nitrification. The design of the treatment chamber is the major difference between the three systems, but they are all engineered so the wastewater is exposed to both aerobic and anaerobic conditions to allow for nitrification followed by denitrification. Denitrification is the process of nitrate being converted to nitrogen gas in the presence of denitrifying bacteria. These bacteria require high carbon content and low dissolved oxygen. In HOOT, Norweco and some configurations of FAST systems, the treated effluent then flows into a dosing tank where it its then pumped to a conventional drainfield or drip irrigation bed. Further denitrification is accomplished by having a portion of the pumped effluent directed back to the pre-treatment chamber. This recirculation is required in HOOT and Norweco systems in order for them to achieve their performance objective. Although FAST systems can be installed with recirculation, it is not required. Each system is described in greater detail below.

1.2.1 HOOT and Aerobic Treatment System. Models H-500 and H-600 are typical for residential use and use the same tank.

Septic influent enters the anaerobic pretreatment chamber where initial settling and anaerobic treatment occurs. The wastewater then flows into the aeration chamber. A blower delivers air into the aeration chamber through bubbler stones. The wastewater enters the clarification chamber, which has an open bottom and is inside the aeration chamber. Sludge settles out of the open bottom clarification chamber back into the aeration chamber. Wastewater flows from the clarification tank into a dosing tank. The wastewater is pumped from the holding tank into the drainfield (Figure 1). If the drainfield is a drip system, the pumped effluent passes through a 120-150 micron filter. A portion of the effluent pumped to the drainfield is returned to the pre-treatment tank enhancing denitrification. The recirculation of the effluent back to the pre-treatment tank is the configuration of the HOOT system for which test center data have shown that the 10 mg N/L standard for Wakulla County can be met.



1. Pretreatment tank where influent enters.
2. Aeration chamber where oxygen is pumped into the wastewater.
3. Clarifier chamber where the clear, odorless effluent rises.
4. Chlorinator where the clear effluent passes through for disinfection. *
5. Holding tank for disinfected* effluent ready for discharge (optional).
6. Aerator and pump.
7. HOOT Control Center monitors and controls the system.
8. Discharge Pump

* Not used in the Wakulla Springs basin.

Figure 1-Diagram of the HOOT Aerobic Treatment System from HOOT website. Recirculation of the effluent exiting the system back into the pretreatment tank is not shown.

1.2.2 Norweco Singulair Model 960 with recirculation.

With the Norweco system, wastewater enters an anaerobic pretreatment chamber where settlement and ammonification occur. Wastewater flows into the aeration chamber. Aeration is achieved by a specifically designed aerator. Air enters the aerator through four vents and is drawn down into the treatment tank through the spinning aerator shaft. A control box monitors and turns the aerator on and off at adjustable time intervals which allows for alternating aerobic and anaerobic conditions. Wastewater flows from the aeration chamber to a clarification chamber. The inlet has a pipe that delivers the aerated wastewater near the bottom of the clarification chamber and sludge settles and flows back into the aeration chamber through an opening between the chambers. The remaining wastewater flows into a "Bio-Kinetic" filter, which has optional chlorination and dechlorination (Figure 2). This filter provides non-mechanical flow equalization achieved by a small hole into the filter container, which reduces incoming hydraulic surges from periods of high wastewater flow. Wastewater flows out into a separate pump tank and a pump doses the drip drainfield system after passing through another 120-150 micron filter. If the drainfield is conventional, then there is no secondary filter. As with the HOOT system, recirculation back to the pre-treatment chamber is the configuration of the Norweco system for which test center data have shown that the 10 mg N/L standard for Wakulla County can be met.

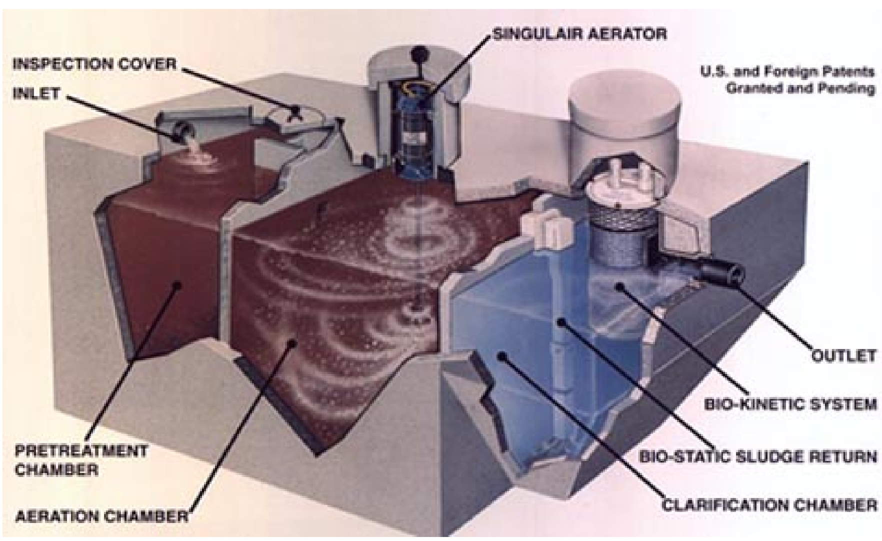


Figure 2. The *Singulair Wastewater Treatment System by Norweco, Inc. From the Norweco website. In Wakulla County a post tank housing a pump is required to allow recirculation back to the pretreatment chamber.*

1.2.3 FAST: Fixed Activated Sludge Treatment, Model MicroFAST 0.5 or 0.75 for typical residence, lager sizes available, a product of Bio-Microbics, Inc.

The FAST system differs from the Norweco and HOOT systems in that it has fixed media for the nitrifying bacteria to grow, whereas bacteria in the Norweco and HOOT systems are suspended in the wastewater. Another major difference between the FAST system and the other two is that the FAST system typically uses slightly modified two-chamber tanks manufactured locally, whereas the chambered tank is part of the HOOT and Norweco systems and supplied by the manufacturer.

Influent flows into an anaerobic settling chamber (pre-treatment chamber) in a two-compartment tank or in a separate "trash" tank. The septic water then flows into another chamber or tank that has the FAST treatment unit installed. The treatment unit sits above the bottom of the tank either on legs or it is suspended from the top. An above ground blower forces air into the FAST chamber drawing water up into the treatment unit and splashing water and air up and over the fixed media. An outlet vent allows air to escape the system to prevent pressurization of the tank. Bacteria fix themselves to the media and consume nutrients as the water circulates through the media. As the bacterial mat ages and accumulates on the media, a sloughing off occurs and dead bacteria settle to the bottom of the tank to be removed by periodic pump outs. An outlet pipe in the treatment unit sends water out to the drainfield system or a dosing tank (Figure 3).

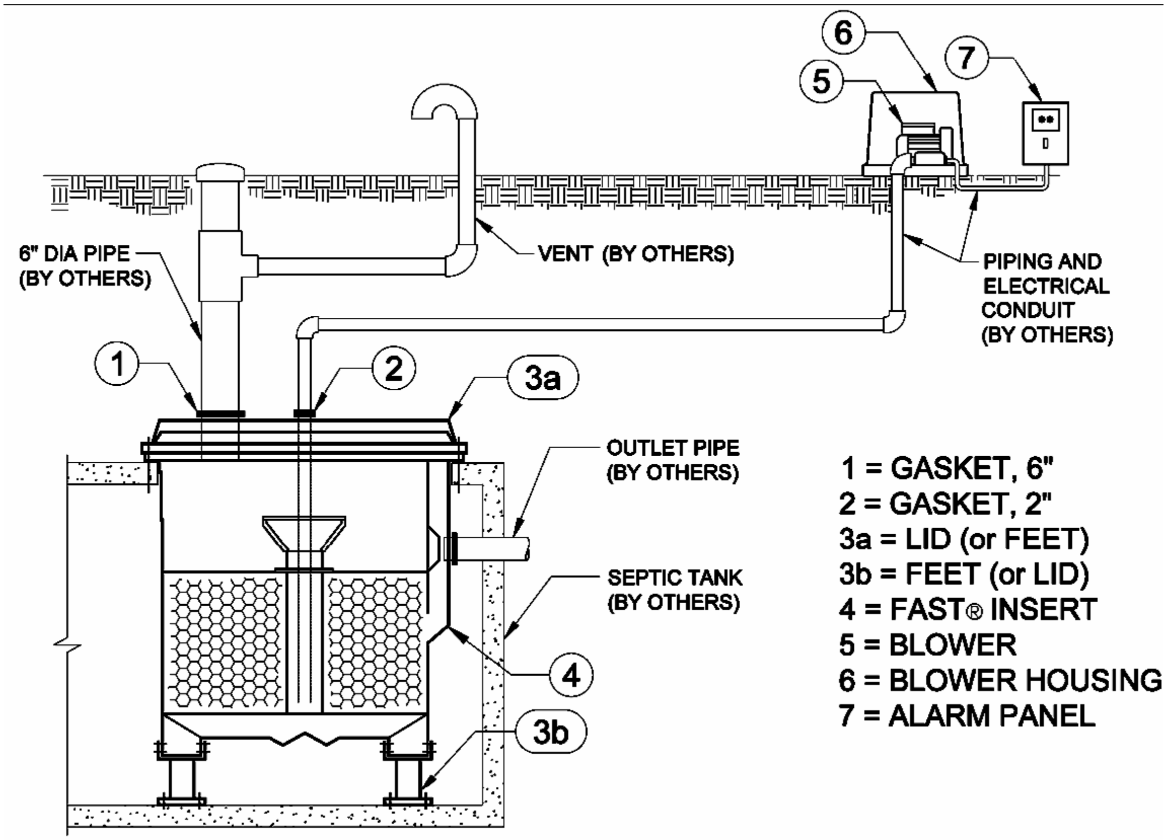


Figure 3. Cross section of the FAST treatment unit installed in the second chamber of two chamber tank or in a single chamber tank that is after a separate pre-treatment tank. The blower, vents and controls are also shown. From the Bio-Microbics website.

The recirculation step described for the HOOT and Norweco systems to enhance denitification is not required for the FAST system. A narrow spill tray allows water splashing up over the fixed media in the treatment to flow back outside the treatment unit but in the treatment chamber. The water outside the treatment unit in the treatment chamber is likely to be anaerobic, providing an environment for denitrification of the aerated wastewater from the spill tray (Figure 4).

Figure 4. A picture of FAST treatment unit being installed into the treatment chamber of a dual chambered tank. The blue fixed media and spill tray are shown.

Not having to recirculate a system's effluent back to a pretreatment chamber allows for the FAST system to be installed without a post chamber or tank housing a pump, as with the HOOT and Norweco systems. If a drip or mounded drainfield systems is necessary, a separate dosing tank or pump tank is added. An additional tank can also be added without the pump to increase the capacity of the system. Because of the added expense of the extra tank and/or pump, most FAST systems have a conventional drainfield that is fed by gravity flow (Figure 5).

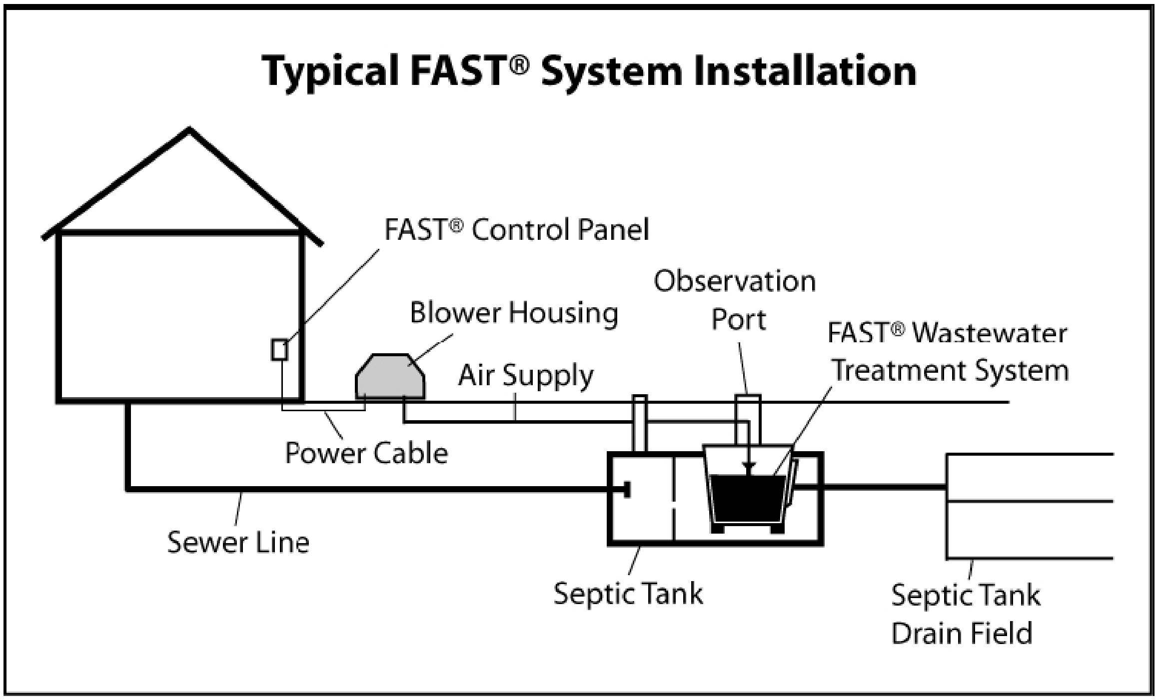


Figure 5. The most common FAST system configuration installed in Wakulla County. From the Bio-Microbics website.

Earlier FAST systems installed in Wakulla County used to include a single 1050-gallon septic tank followed by a 350-gallon pump tank. Competing interests complained to the county health department that these systems were not engineered with an anaerobic tank and therefore were in a different configuration than those certified by NSF/ANSI Standard 40 and Nitrogen Reduction. The FDOH then recommended that the systems be installed with a pre-treatment chamber or tank. As a result, FAST systems are now installed into a two chamber 850-900 gallon tank, the first approximately 350 gallon chamber being anaerobic and the second being the aeration chamber with no pump tank. In some homes, the engineer has added a separate tank post treatment unit. This is also done when drip irrigation is used and there is need for an effluent pump. The most elaborate configuration of a FAST PBTS uses three separate tanks, a pretreatment tank, a treatment tank with the FAST unit installed, and a post treatment or pump tank.

2 Methods

2.1 Phase II Study Sites.

Potential study sites were selected after a review of septic tank permit files at the Wakulla County Health Department. At that time, the files contained records for 105 PBTS systems installed as of 10/27/08 in the county. Potential sites were chosen so that the different types of PBTS systems installed in the county were represented. The drainfield type was also considered in site selection to have an equal representation of conventional and pressurized drip systems. The owners of the candidate sites were then visited by the research team and cooperating sites that were evaluated for accessibility and acceptable soil and water table conditions. Table 1 describes the 8 sites selected for the Phase II study.

Table 1. Site information for the Phase II sites, including system type, drainfield, installation date.

Site ID	PBTS	Drainfield Type	Final Inspection	Household
WSS-1-2	HOOT	Drip, Small Mound	07/03/07	2 adults, 3 children
WSS-2-2	FAST -Dual Chamber	Conventional, gravity	02/02/08	2 adults, 1 child
WSS-3-3	Norweco	Conventional, dose	04/10/08	2 adults
WSS-4-2	FAST- 3 Tanks	Drip, Large Mound	08/18/05	2 adults, 1 child
WSS-5-2	Norweco	Mounded conventional dose	08/20/07	2 adults
WSS-6-2	HOOT	Drip	8/20/07	2 adults, 2 children
WSS-7-2	Norweco	Drip	08/28/08	2 adults, 1 child
WSS-8-2	FAST-Dual & Post Tank	Conventional, gravity	02/08/08	5 adults, 5 children

The locations of the 8 sites in Wakulla County are shown in Figure 6.

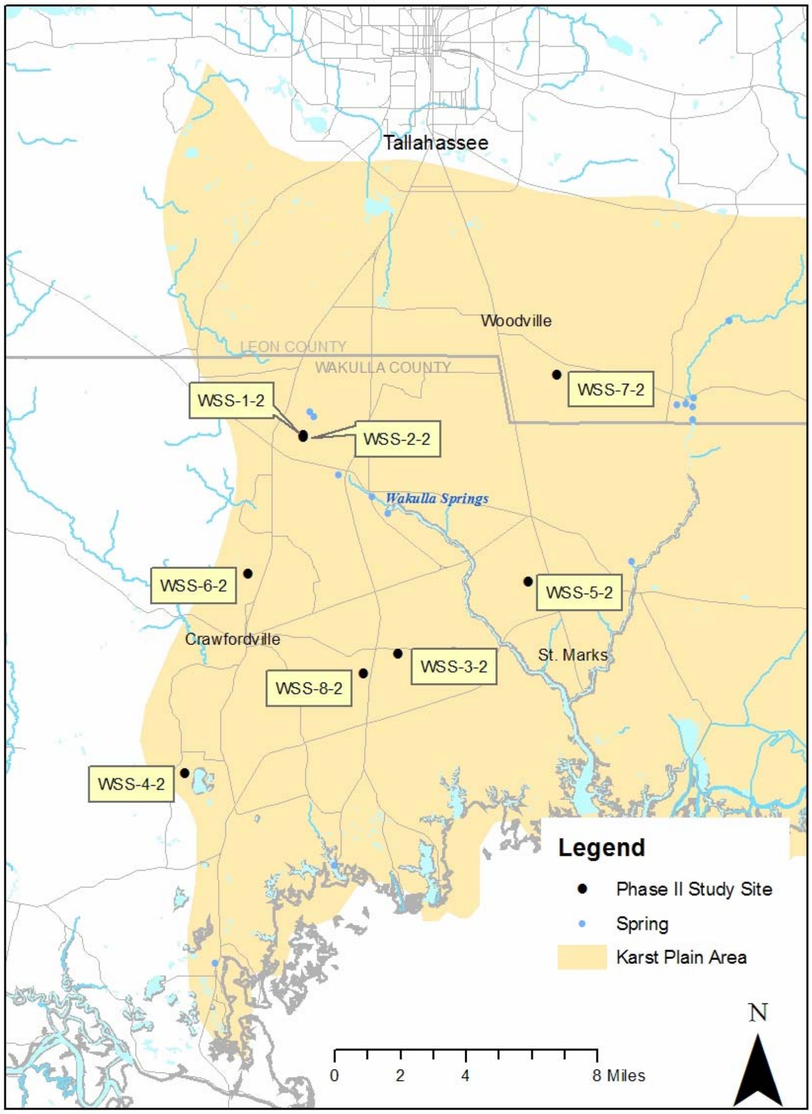


Figure 6. Study Site Locations.

2.2 Raw Sewage Sampling

Flow-weighted 24-hour composite samples of the raw sewage were collected to access the nutrient input to residential septic systems. Raw sewage was homogenized by the sampling pump that was triggered using a water sensor to capture each flow event.

Prior to the first sampling event, the raw wastewater line between the house and septic system was exposed and a collection vessel and associated plumbing installed. Two vertical PVC pipes extended from the collection vessel to the ground surface. One access port was for placement of a float switch which triggered the sampling pump and the other port was for the raw wastewater input to the pump. An additional PVC line extended to the ground surface for the return of wastewater to the septic tank a (Figure 7). After backfilling each site, two irrigation boxes were placed over the access.

Figure 7. Plumbing for sampling raw wastewater about to be installed between the house and septic tank at site WSS-4-2. The water sensor is placed in the 4 inch opening of the 4-way PVC piece. Note the inlet clean out.

The raw sewage sampling device consists of a fabricated system mounted on a wagon that includes an in-line macerating vacuum pump, a power converter, and the waste stream return line with ball valve for sample collection (Figure 8). The entire raw wastewater flow from the home passes through the collection vessel and sampling pump. A float switch in the collection vessel triggers the in-line macerating vacuum pump (Jets Standard As, vacuumerator 15MB). The pump, commonly used in Europe, is designed for collection of toilet waste and is capable of operating either continuously or intermittently at flow rates up to approximately 83 L/min. A ball valve, installed in the discharge line to control wastewater flow to the sampling container, is adjusted to collect approximately 75-150 mL of sample from each 7.5-liter sample event (1-2% of the total flow). The remainder of the homogenized wastewater flow returns to the wastewater line prior to discharge into the septic tank. Prior to collecting raw wastewater samples, the solids in the collection vessel are purged and the vessel is flushed with water. Due to the complex nature of the homogenization apparatus (i.e., vacuum pump, PVC connections and polyethylene tubing) and the variability of the waste stream being sampled (i.e., raw wastewater with high concentrations of the constituents being analyzed for), this system flush also served to decontaminate the homogenization apparatus between sites. Approximately 20 L of tap water was used during the flush. However, if the discharge stream from the wagon visually appeared “dirty”, additional clean water was flushed through the system. Finally, prior to sample collection, up to four exchanges of wastewater from the 7.5-L collection vessel were passed through the system.


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Figure 8. The sampling pump wagon set-up at a residence to sample raw sewage. The clear hose is the inlet to the pump and the white hose is the return line. The blue cooler holds a glass 2 gallon jar on ice. On the far right, the wire coming out of the PVC pipe is from the water sensor.

2.3 PBTS Effluent Sampling

The technique for sampling effluent varied depending on the type of system. Ideally, effluent would be sampled while flowing in the pipe that leads from the PBTS to the drainfield. In systems that have drip drainfields, the pump has a 120-150 micron filter and the sample is taken post filter. Sites WSS-4-2 and WSS-5-2 both had sampling ports installed in the correct location. For these sites, the pump could be turned on and after waiting at least 1 minute, the sample taken using the installed valve. At sites WSS-2-2 and WSS-8-2, both with gravity fed drainfields, the vent pipe was used as the sampling port. For these, if effluent was not flowing prior to sampling systems without an effluent pump, then flow was induced by adding water to the cleanout in the inlet pipe to the system. Site WSS-3-2 was sampled from a cleanout installed in the pipe from the pump tank to the conventional drainfield. The pump was turned on and the sample taken from then cleanout after flow was established. The remaining sites, WSS-1-2, WSS-6-2, and WSS-7-2, have pumps with filters. The sampling ports were located prior to the filter housing and were not used as the sample should be taken post filter. In addition to the inlet and outlet of the filter, there is a small (1/4 inch) line that is used to re-circulate the filtered effluent back to the pretreatment tank. To sample these systems, the line was disconnected, the pump turned on and after allowing the effluent to flow at least 1 minute, the sample taken.

Analyses and analytical methods for raw sewage and PBTS effluent samples are shown in Table 2.

Table 2. Analytical Methods for Raw Sewage and Septic Tank Effluent Samples

Analysis	Analytical Method	Laboratory Detection Limit
Ammonia Nitrogen	EPA 350.1 Rev. 20.	0.010 mg/L
Total Kjeldahl Nitrogen	EPA 351.2 Rev. 2.0	0.20 mg/L
Nitrate+Nitrite Nitrogen	EPA 353.2 Rev. 2.0	0.004 mg/L
Total Phosphorus	EPA 365.1 Rev. 2.0	0.012 mg/L

2.4 Lysimeter Construction.

Suction lysimeters were used to collect soil pore water from beneath and away from the drain field at each of the sites. Lysimeter bodies were constructed from 2-inch (5.08-cm) PVC pipe. A porous ceramic cup measuring 26 cm (Soilmoisture 0653X07-B01M3) was attached to ceramic cups were attached with epoxy to custom machined bushings made from solid 2 3/8 inch PVC stock. The cup bushing was then glued into a 2 inch PVC coupling and attached to the 2 inch pipe. Another bushing for the 2 valves and sample tube was made for the top of the lysimeter. Two ¼-inch holes were drilled through a piece of the solid PVC stock, both holes were threaded (¼-inch NPT threads) on one side to hold two ¼-inch valves which were fitted with hose barbs. On the other side of the bushing, one hole was threaded and a ¼-inch brass Swagelok connector was used to attach the sample tube, which reached to bottom of the Lysimeter cup. The outside of the top bushing was machined to fit into a 2-inch coupling. The bushing was glued into the coupling and the coupling attached to the lysimeter body. An alternative design was used for 10 of the lysimeters, due to limitations in availability of the machine shop personnel. The bushing for the ceramic cup was replaced by a 2- to 1.5-inch rubber reducer coupling with band clamps and attached with clear water proof adhesive. For the top of the lysimeter, a 2-inch rubber coupling was used to attach the valve bushing to the top of the pipe. Both designs proved effective in the field and allowed for flexibility in the depth of lysimeter placement.

2.5 Lysimeter Installation and Sampling

At each site, two shallow lysimeters were placed so the top of the cup was 2 ft (0.6 m) below the bottom of the drain field or drip irrigation line. This depth was chosen as it is the separation required between the drainfield and the seasonal high water table by the FDOH. Two deep lysimeters were also installed just above the clay or limestone layer where clay or limestone were encountered. In areas where limestone or clay was not encountered, the deep lysimeters where placed approximately 2.5 meters below land surface. In Section 4, the depths of the bottom of drainfield and the lysimeters are given for each site.

The day prior to sampling, a vacuum of 60 KPa was by applied to each of the lysimeters using a peristaltic or hand pump to create a negative pressure in the soil around the ceramic cup and extract pore water. A pore water sample was then taken by opening both valves and withdrawing water from the lysimeter using a peristaltic pump attached to the valve with sample tube.

3 Conventional Septic System and Performance Based Treatment Systems

Nitrogen in raw wastewater is predominately in the reduced forms of organic-nitrogen and ammonium-nitrogen. Conditions in septic tanks, as well as the pre-treatment tanks in PBTS, are generally anaerobic, causing ammonification, the rapid conversion of organic-nitrogen to ammonium-nitrogen, the predominate form of nitrogen in STE. Nitrification occurs with sufficient oxygen and the proper microbial population, converting ammonium-nitrogen to nitrite-nitrogen then nitrate-nitrogen. In a conventional septic system, nitrification occurs in the unsaturated soil within and beneath the drainfield. In a PBTS, the purpose of the blower or aerator is to create an aerobic environment in the treatment chamber so microbial nitrification can occur. Subsequently, if the system provides the proper anaerobic conditions for the nitrified wastewater and the required microbial populations are then present, denitrification converts nitrate-nitrogen to inert nitrogen gas. The denitrifying bacteria require a carbon source and limited dissolved oxygen.

Denitrification may be somewhat limited underneath a drainfield in the soil and the subsurface aquifer in the Wakulla County. Denitrification requires nitrate and organic matter as well as anaerobic conditions. Beneath a thin topsoil layer, the soils are sandy and very low in organic content and conditions are aerobic. As currently installed, conventional systems and most drip drainfields are below the more carbon rich layer and the root zone of plants that could utilize the nitrate. In a PBTS, denitrification may occur in the treatment tank and perhaps in the post treatment tank. Further denitrification occurs as a portion of the effluent is recirculated back to the anaerobic pretreatment tank. These nitrogen transformations are critical to reduce environmental nitrogen loading especially in sensitive receiving environments.

3.1 Raw wastewater nitrogen inputs to residential OSTDS in Wakulla County

To gauge the effectiveness of septic systems in reducing TN, input concentrations as well as system effluent concentrations must be known. In Phase I of this study, raw wastewater was not sampled. Fortunately during that time period, CSM choose Wakulla County as one of their three study regions and 6 sites were sampled quarterly for a year for both raw wastewater and STE. Phase II of this study employed the same equipment (contributed by CSM), sampling techniques, and personnel to sample the wastewater inputs at 5 of the 8 study sites.

Unfortunately, site WSS-8-2 had to be abandoned after three of the monthly sampling events and only one raw wastewater sample was obtained from the PBTS installed at it. The PBTS at Site WSS-4-2 was then outfitted with the raw wastewater sampling apparatus as a replacement. As expected, nitrogen in the raw influent was predominately total Kjeldahl nitrogen (TKN), mostly in the form of organic nitrogen with a smaller component of ammonium (Table 3).

Table 3. Phase II Study Results. Raw sewage TN-inputs to septic tanks. Units of N are in mg-N/L.

Site ID	TN Average (mg/L)	n	%TN as TKN	%TKN as $NH4^+$
WSS-1-2	**55.1 ± 28.2**	**4**	**98**	**16**
WSS-2-2	**96.5 ± 56.2**	**5**	**100**	**20**
WSS-4-2	**54.4 ± 32.7**	**4**	**96**	**16**
WSS-7-2	**77.4 ± 26.1**	**5**	**99**	**5**
WSS-8-2	**70.2**	**1**	**100**	**6**
All Samples	**72.5 ± 38.3**	**19**	**98**	**14**

Notes: Average with standard deviation and number of samples (n) for TN measured at each site. The percentage of TN in the form of TKN and the percentage of TKN in the form of ammonium ion and ammonia is also presented. TKN is the sum of organic nitrogen and ammonia species components of TN. TN is the combination of TKN and nitrate plus nitrite.

Although the TKN percentage of TN was consistently close to 100%, there was a large variability in the TN concentrations (Table 4).

Table 4. Phase II Study Results. TN statistics from the 5 sites at which raw sewage inputs were measured. Units are in mg-N/ L or percent, where noted.

Site ID	Average	Std. Dev.	Low	25th %	Median	75th %	High	IQR	n
WSS-1-2	**55.1**	28.2	**30.4**	32.0	**51.5**	74.6	**87.1**	42.6	**4**
WSS-2-2	**96.5**	56.2	**42.6**	51.0	**78.3**	140.3	**170.2**	89.2	**5**
WSS-4-2	**54.4**	32.7	**24.5**	35.7	**46.6**	65.3	**100.0**	29.6	**4**
WSS-7-2	**77.4**	26.1	**54.7**	59.6	**61.6**	100.7	**110.4**	41.1	**5**
WSS-8-2	**70.2**								**1**
All Samples									
	72.5	38.3	**24.5**	46.8	**61.6**	93.6	**170.2**	46.7	**19**
Statistics for Averages of 4 Phase II sites: WSS-1-2, WSS-2-2, WSS-4-2, WSS-7-2									
	70.9	20.1	**54.4**	54.9	**66.3**	82.2	**96.5**	27.2	**4**

Notes: Only one sample was taken at site WSS-8-2. Due to the high variability in TN values found in raw wastewater, the data from this site was not used in calculating the statistics of the averages of each site. The bottom row is the average of the means of each of the four sites where the most data was obtained. Each site is counted once in this mean, n=4.

The wide range in raw wastewater TN values is not surprising due to variety of daily water use activities that can dilute or strengthen the waste stream concentration for a particular household. Additionally, a household's number and age of members and their life styles can affect the TN concentration in the wastewater. For example, an elderly retired couple's waste stream may be very different than that of a younger couple with children. The CSM data shows a similar wide range in TN concentrations for individual sites (Table 5).

Table 5. CSM Wakulla Results for Raw Wastewater. Statistics for the TN concentrations from the 6 sites at which raw sewage inputs were measured during the portion of the Colorado School of Mines study in Wakulla County. One of the quarterly samples for site F2 is an average of 6 samples taken over a one week period. Units of N are in mg-N/ L.

Site ID	Average	Std. Dev.	Low	25th %	Median	75th %	High	IQR	n
F1	**51.1**	29.1	**22.0**	28.8	**50.3**	72.6	82.0	43.9	**4**
F2	**43.5**	30.31	**10.5**	28.9	**40.0**	54.6	83.4	25.7	**4**
F3	**96.9**	51.4	**37.0**	66.3	**97.8**	128.4	155.0	62.1	**4**
F4	**70.3**	15.1	**50.0**	65.0	**72.5**	77.8	86.0	12.8	**4**
F5	**81.8**	105.8	**23.0**	23.0	**32.0**	90.8	240.0	67.8	**4**
F6	**95.3**	15.5	**74.5**	88.0	**99.3**	106.5	108.0	18.5	**4**
All Samples									
	73.1	50.3	**10.5**	36.5	**72.3**	87.6	240.0	51.1	**24**
Statistics for Averages of 6 Sites									
	73.2	22.4	**43.5**	55.9	**76.1**	91.9	96.9	36.0	**6**.

Notes: The bottom row is the average of the means of each of the six sites. Each site is counted once in this mean, n=6. Units of N are in mg-N/ L.

The Phase II (Table 4) and CSM (Table 5) data for raw wastewater are in good agreement in regard to the averages of the means of each site where 4 or more samples were taken, 70.9 ± 20.1 mg-N/L n=4 and 73.2 ± 22.4 mg-N/L n=6, respectively. This very strong correlation is also seen if the statistics are done using all the samples taken in the Phase II study to date, 72.5 ± 38.3 mg-N/L, n=19 and 73.1 ± 50.3 mg-N/L, n=24 from the CSM study. Both studies also show the high degree of variability in samples. The low value in the Phase II data to date is 24.5 mg-N/L and the high value is 170.2 mg-N/L. The range of values was greater in the CSM study, 10.5 mg-N/L and 240.0 mg-N/L. The higher range and standard deviation of the TN values in the CSM study may be a result of the greater number of samples taken. One of the CSM sites in each region was sampled for 7 consecutive days to access daily variations. The statistics for 6 samples taken over a one week period from a Wakulla County site (F-2) are summarized Table 6.

Table 6. CSM 7 Day Intensive Results. Statistics for the raw wastewater TN inputs to the CSM site F2 which included a 7 day sampling event during the week of April 15 through 21, 2008. Units of N are in mg-N/L.

Measurement Date	**Average.**	**Standard Deviation**	**Median**	**n**
15 April	71.0	0.0		2
16 April	**No sample**			**0**
17 April	94.0	0.0		2
18 April	44.0	2.8		2
19 April	38.5	0.7		2
20 April	149.0	0.0		2
21 April.	104.0	4.2		2
April, 2008 6 days	**83.4**	41.4	**82.5**	**6**
F2-Fall	10.5	0.5		**2**
F2-Winter	35.0	0.0		**2**
F2-April, 2008	**83.4**			**6**
F2-July, 2008	45.0	0.0		**2**
Quarterly Total	**43.5**	30.3	**40.0**	**4**
All F2 samples	**65.7**	43.1	**45.0**	**9**

Notes: The sewage pump was set up on a Monday and first sample was on Tuesday. The Wednesday sample was not taken due to equipment malfunction. The statistics are presented for all samples taken at site F2 as well as the 4 quarterly events, using the average of the 6 daily samples taken during the 3rd quarterly sample even for that value.

The results presented in Table 6 show a wide range of TN values during the weeklong daily sampling and further illustrate the necessity of repeated sampling to accurately access a household's waste stream. It is difficult to sample raw wastewater on a large number of systems due to having to install special plumbing and the time and labor involved, yet having a realistic and reliable wastewater input value is crucial to evaluating the effectives of treatment. The family in this household, at Site F2, is a young working couple with a toddler. The recently released CSM report, *Characterization of Raw Wastewater and Septic Tank Effluent from*

Residential Onsite Sources, discusses regional and demographic variations in detail (Lowe et al., 2009).

3.2 Septic tank effluent (STE) from conventional septic tanks at Phase I Sites.

Normally, little nitrogen reduction occurs in a conventional septic tank. The primary processing of nitrogen is ammonification, the bacterial conversion of organic nitrogen to ammonia and ammonium ion (Washington State DOH, 2005). Some of the ammonia species are reconverted back to organic nitrogen via cell growth, but a net increase in ammonium concentration occurs in the septic tank (Table 7).

Table 7. Phase I Study Results. The STE Average (Ave.) and standard deviation (Std. Dev.), number of samples (n) for TN measured at each site. Units of N are in mg-N/L.

Site ID	TN Average.	TN Std. Dev.	TN Median	n	%TN as TKN	%TKN as $NH4^+$
HK	**30.1**	10.4	**35.0**	3	100	87
LT	**57.2**	4.6	**55.0**	3	100	94
YG (F1)	**47.8**	13.5	**43.5**	3	100	96
All Samples						
	45.0	14.8	**43.5**	9	100	93

Notes: The percentage of TN in the form of TKN and the percentage of TKN in the form of ammonium ion and ammonia is also presented. TKN is the organic nitrogen and ammonia species component of TN. TN is the combination of TKN and nitrate plus nitrite.

The nitrogen removal from wastewater in a conventional septic tank occurs through ammonia volatilization and sedimentation of undigested organic matter, which is removed by periodic septic pump outs (Washington State DOH, 2005). The low concentrations or absence of nitrate in raw wastewater and the anaerobic conditions unfavorable to nitrification result in the TN in STE to be virtually 100% TKN (Table 7). Denitrification in wastewater treatment requires anaerobic conditions followed by aerobic conditions and back to anaerobic conditions in the presence of a carbon source.

The TN concentration in STE is less variable than the TN in raw wastewater due to temporal averaging that occurs in the tank. One of the primary functions of a conventional septic tank is to equalize the flow of the wastewater stream and allow for the digestion and sedimentation of wastewater solids. The statistics for the TN concentrations found in the three sites with conventional septic tanks studied in Phase I of this study are summarized below in Table 8.

Table 8. Phase I Study Results. Septic tank effluent (STE) TN statistics for the 3 sites with conventional systems at which STE were measured at the Phase I sites. Site YG and F1 are the same. These samples are grab samples. Units of N are in mg-N/L.

Site ID	Ave.	Std. Dev.	Low	25^{th} %	Median	75^{th} %	High	IQR	N
HK	**30.1**	10.4	**18.1**	26.6	**35.0**	36.0	**37.0**	9.4	**3**
LT	**57.2**	4.6	**54.0**	54.5	**55.0**	58.8	**62.5**	4.2	**3**
YG (F1)	**47.8**	13.5	**37.0**	40.3	**43.5**	53.3	**63.0**	13.0	**3**
Statistics for Means of 3 Sites									
	45.0	13.8	**30.1**	39.0	**47.8**	`52.5	**57.2**	13.6	**3**
All Samples									
	45.0	14.8	**18.1**	37.0	**43.5**	55.0	**63.0**	18.0	**9**

Notes: The second to bottom row is the average of the means of each of the three sites, where each site is counted once, n=3. The bottom row includes the statistics for all samples taken from the three sites

In Phase I, the STE samples were grab samples. In the CSM study the STE samples were 24-hour composite samples. Site YG from Phase I is the same residence as site F1 in the CSM study. In the CSM study (Table 9) the average septic tank effluent was 64 ± 13 mg-N/L. Due to the larger sample size, we consider the CSM study results for STE for conventional septic tanks to be the more representative values. This assertion is supported by the results of the much more comprehensive La Pine study, 66 ± 22, n=427 (La Pine Oregon Demonstration Project, 2006).

Table 9. CSM Study Results. TN statistics of STE measured at the 6 CSM Wakulla County sites with conventional systems. Site YG from Phase I and F1 of the CSM study are the same septic system. Units of TN are in mg-N/L

Site ID	Average.	Std. Dev.	Low	25^{th} %	Median	75^{th} %	High	IQR	n
F1 (YG)	**43.9**	5.3	**38.0**	41.0	**43.5**	46.4	**50.5**	5.4	**4**
F2	**72.8**	7.0	**64.0**	68.1	**71.0**	78.0	**85.5**	9.9	**10**
F3	**68.3**	5.4	**61.0**	66.3	**69.0**	71.0	**74.0**	4.8	**4**
F4	**67.5**	7.9	**59.0**	62.0	**67.5**	73.0	**76.0**	11.0	**4**
F5	**44.3**	4.3	**38.0**	43.3	**45.5**	46.5	**48.0**	3.3	**4**
F6	**70.9**	5.5	**65.0**	68.0	**70.3**	73.1	**78.0**	5.1	**4**
Statistics for Averages of 6 Sites									
	61.3	13.4	**43.9**	50.1	**67.9**	70.3	**72.8**	20.2	**6**
All Samples									
	63.6	13.4	**38.0**	52.6	**68.0**	72.0	**85.5**	19.4	**30**

Notes: The second to bottom row is the average of the means of each of the six sites, where each site is counted once, n=6. The bottom row is the statistics for all samples taken from the six sites

If 70 mg-N/L is used as an input value, this results in an N-reduction of 9 ± 19% in these conventional septic tanks (using Equation 1). The results of Table 8 with an STE of 45 ± 15 mg-N/L indicate a 36 ± 21% reduction. However, the total CSM study found that on average the mean of both raw influent (n=63) and STE (n=61) was ≈ 60 mg-N/L, suggesting little removal of N by a conventional septic tank (Lowe et al, 2009).

3.3 Effluent Nitrogen data from PBTS installed in Wakulla County, Florida 8 main sites.

Effluent from 8 PBTS was sampled as many as 11 times on an approximately monthly basis for a year and analyzed for the nitrogen species, as well as TP and chloride. For this report, nitrogen is the focus. Table 10 summarizes the TN concentration in the effluent, measured at the 8 sites. Site WSS-8-2 was abandoned after the first three samples because the homeowner decided to no longer participate in the study. Only samples from functioning systems in occupied residences are reported. Other deviations from the 11-month sample set were due to system malfunctions, homeowners being on vacation or homeowners moving. During three of the sampling events, site WSS-3-2 was found to be non-functioning. The home owner was notified and the system issue was addressed. At site WSS-7-2 the home owner moved between the PTBS sampling on 09/08/09 and the quarterly sampling on 10/01/09. The homeowners at site WSS-4-2 were out of town during one sampling event and there was no access to the system.

Table 10. Phase II Study Results. TN in effluent from 8 PBTS study sites in Wakulla County, Florida. Units of TN are in mg-N/L.

Site ID	Average	Std. Dev.	Low	25th %	Median	75th %	High	IQR	n
WSS-1-2	**39.6**	17.1	10.5	28.3	**43.1**	53.0	59.0	24.8	**11**
WSS-2-2	**25.2**	2.7	20.8	23.1	**24.5**	27.3	28.9	4.2	**11**
WSS-3-2	**28.2**	13.8	12.7	17.9	**26.6**	33.0	54.2	15.1	**8**
WSS-4-2	**17.3**	9.4	1.3	11.0	**20.4**	25.0	27.2	14.0	**10**
WSS-5-2	**32.2**	10.1	13.2	26.4	**33.0**	38.7	49.4	12.3	**11**
WSS-6-2	**14.5**	9.0	5.3	9.6	**11.2**	16.8	32.1	7.2	**11**
WSS-7-2	**49.2**	17.0	16.3	45.6	**48.1**	57.6	71.3	12.0	**7**
WSS-8-2	**33.7**	3.8	31.0	31.5	**32.0**	35.0	38.0	3.5	**3**
Statistics for Averages of 8 Sites									
	30.0	11.4	14.5	23.2	**30.2**	35.2	49.2	11.9	**8**
All Samples									
	28.7	15.4	1.3	17.3	**26.7**	38.6	71.3	21.3	**72**

Notes: The second to bottom row is the average of the means of each of seven sites. Each site is counted once, n=8. The bottom row is the statistics for all samples taken from the eight sites.

3.4 Daily Variation in Effluent Nitrogen data from PBTS

The short-term fluctuation in effluent concentration was evaluated by sampling effluent from 3 of the PBTS on consecutive days. During 2 of the monthly effluent monitoring events, site WSS-4-2 was sampled on two consecutive days. The deviation between consecutive samples was small and the averages were reported as the monthly TN value Table (11). At sites

WSS-3-2 and site Wss-6-2 the effluent was measured on 5 consecutive days during the December sampling. The agreement between samples at site WSS-6-2 was very close. At site WSS-3-2 the effluent TN was more variable with a low TN of 21 mg-N/L and a high value of 38 mg-N/L. The median of the 5 values at each site was used as the monthly TN effluent measurement (Table 11).

Table 11 Phase II Study Results. Daily variation of TN in effluent from PBTS study sites in Wakulla County, Florida where samples were taken on consecutive days. TN concentration is in mg-N/L.

Site ID		Average	Median	n
WSS-3-2	5 days	26.6 ± 7.4	21.7	5
WSS-6-2	5 days	10.2 ± 0.6	10.2	5
WSS-4-2	2 days	21.9 ± 0.8		2
WSS-4-2	2 days	18.9 ± 0.8		2

3.5 TN in effluent sampled from the 3 Norweco PBTS

The sampling protocol recommended by Norweco for sampling their systems differs from the approach used in this study. We sampled all the systems from plumbing which leads from the last tank in the system and the drainfield. This approach captures the effluent that is actually entering the drainfield at that point in the treatment process. Norweco recommends that the sample be taken as the effluent leaves the ATU portion of the system and flows into the pump tank. This approach avoids any mixing from the effluent that was just treated before it mixes with the treated effluent in the pump tank. Our purpose was to determine the TN concentration as the effluent entered the drainfield at a point in time, while the Norweco approach focuses on how the system is functioning at that point in time. The procedure for collecting an effluent sample recommended by Norweco is difficult because it involves opening the pump tank and placing a bottle on a pole to reach the effluent as it falls into the pump tank. At the 3 sites with Norweco systems, samples using both approaches where taken during 3 of the monthly sampling events. Of these 9 sample comparisons, 5 differed by 5% or less (Table 12).

Table 12. Comparison of the sampling approach recommended by Norweco and the approach used in this study are presented. NOR designates samples taken according to the Norweco protocol and EFF designates samples using the standard sampling procedures followed in this study. Units of TN are in mg-N/L.

Site	Date	NOR	EFF	% Difference
WSS-3-2	**5/1/09**	30.5	54.2	44
WSS-3-2	**6/1/09**	12.7	12.7	0
WSS-3-2	**7/1/09**	39.1	37.0	5
WSS-5-2	**5/1/09**	51.6	49.4	4
WSS-5-2	**6/1/09**	40.5	33.6	17
WSS-5-2	**7/1/09**	23.0	22.3	3
WSS-7-2	**5/1/09**	36.2	44.1	18
WSS-7-2	**6/1/09**	17.1	16.3	4
WSS-7-2	**7/1/09**	56.1	48.1	14

3.6 Effluent Nitrogen data from Performance Based Treatment Systems installed in Wakulla County, Florida, sampling of additional sites in April, 2009.

In an effort to ascertain if the results from the 8 intensive sites were representative of PBTS installed in the Wakulla Springs basin, an additional 27 PBTS systems were sampled in the county in cooperation with the Wakulla County Health Department and FDOH Bureau of Onsite Sewage Programs in April, 2009. Candidate systems were selected from a survey of PBTS permits finalized as of 10/27/08. This survey indicated that of the 105 PBTS installed, approximately 10% were HOOT systems, 30% were Norweco systems and 60% were FAST systems. Sample sites were chosen to reflect this ratio and to also sample each variety of FAST system that was installed.

Of the 27 additional sites sampled during April, 2009, 3 sites had TN effluent concentrations lower than the 10 mg-N/L total nitrogen treatment goal and 5 sites had TN effluent concentrations of 60 mg-N/L or greater, similar to conventional septic system effluent (STE). However, the majority of the sites that were sampled had TN effluent concentrations very similar to those detected in the monthly samples from the PBTS study sites (Table 13).

Table 13. Phase II Study Results. TN in effluent from 27 additional PBTS sites in Wakulla County, Florida sampled in April, 2009. Units of TN are in mg-N/L.

Sample ID	System type	TN.	%TKN
WS-11	HOOT	20.2	6
WS-25	HOOT	40.5	11
WS-26	HOOT	18.1	23
WS-1	Norweco	**72.0**	**86**
WS-10	Norweco	19.2	22
WS-12	Norweco	21.1	100
WS-20	Norweco	23.0	74
WS-24	Norweco	**8.6**	**94**
WS-3	FAST Dual Chamber	26.4	68
WS-5	FAST Dual Chamber	26.1	4
WS-7	FAST Dual Chamber	**67.0**	**21**
WS-8	FAST Dual Chamber	**3.6**	**64**
WS-9	FAST Dual Chamber	**59.5**	**100**
WS-22	FAST Dual Chamber	29.3	8
WS-23	FAST Dual Chamber	14.1	22
WS-14	FAST Dual Chamber + Post Tank	**2.6**	**38**
WS-18	FAST Dual Chamber + Post Tank	20.0	98
WS-21	FAST Dual Chamber + Post Tank	16.2	7
WS-6	FAST Single Chamber +Pre Tank	37.0	100
WS-13	FAST Single Chamber +Pre Tank	**60.0**	**27**
WS-16	FAST Single Chamber +Pre Tank	13.2	24
WS-17	FAST Single Chamber +Pre Tank	32.1	19
WS-2	FAST Single Chamber +Post Tank	20.3	98
WS-15	FAST Single Chamber +Post Tank	**8.6**	**2**
WS-19	FAST Single Chamber +Post Tank	26.4	80
WS-4	FAST Three Tanks	**78.1**	**3**
WS-27	FAST Three Tanks	24.0	8
	Average	**29.2 ± 20.8**	

Notes: ***Data are grouped by system type. The FAST system with a single chamber with the treatment unit plus a post tank is no longer allowed by the FDOH. The FAST Dual Chamber configuration is the most common installation. The TN values below 10 mg-N/L and those above 60 mg-N/L, an estimate TN for conventional systems, are in bold.***

The results from the 27 additional sites confirm that the TN data from the 8 PBTS study sites are representative of functioning systems installed in Wakulla County. Table 14 compares the results from all PBTS sampled to date and also gives statistics for the three types of systems studied. The average effluent concentration for the 35 sites was 29.4 ± 18.8 mg-N/L.

Table 14. Phase II Study Results. TN in effluent from the 8 PBTS sites of Phase II and the 27 additional PBTS sites in Wakulla County, Florida sampled in April 2009. Units of N are in mg-N/L.

Sample Group	Ave.	Std. Dev.	Low	25^{th} %	Median	75^{th} %	High	IQR	n
24 Current Code**	**30.5**	21.5	2.6	17.6	**23.5**	37.9	78.1	20.3	**24**
27 Survey Sites	**29.2**	20.8	2.6	17.2	**23.0**	34.6	78.1	17.4	**27**
8 Main sites	**30.0**	11.4	14.5	23.2	**30.2**	35.2	49.2	11.9	**8**
HOOT	**26.7**	10.5	18.1	19.2	**20.2**	35.6	40.5	16.4	**5**
Norweco	**32.2**	19.9	8.6	20.6	**27.3**	37.7	72.0	17.1	**8**
FAST	**29.2**	20.2	2.6	16.5	**26.2**	33.3	78.1	16.8	**22**
Average of 35 Sites									
Total	**29.5**	18.7	2.6	18.1	**26.1**	35.0	78.1	16.9	**35**

*****Notes: Three of the 27 sites have the FAST unit in a single chamber tank with a post tank, which is no longer allowed by WDOH. These sites are excluded from the 27 Survey Sites in the Table entry "24 Current Code".***

3.7 Evidence of Nitrification and Denitrification in PBTS Effluent

In a properly functioning PBTS, the nitrogen in the wastewater flowing out of the pre-treatment chamber into the treatment chamber approaches 100% organic nitrogen + ammonia (TKN) (Table 6). In the treatment chamber, TKN is to be converted to NO_3 with oxygen through bacterial nitrification. The efficiency of this process is dependent on the amount of dissolved oxygen present as well as the health and vigor of the nitrifying bacteria. Since nitrification of the TKN to NO_3 is necessary before denitrification can occur, the extent of nitrification in this step affects the amount of the nitrogen reduction that can occur through denitrification. Denitrification then occurs as the NO_3 encounters anaerobic conditions in the presence of organic matter. The percentage of nitrogen as TKN versus NO_3 in the PBTS effluent can provide insight into how well a system is functioning, but those findings can also be misleading since the treatment processes for HOOT and Norweco systems involve the recirculation of treated water and mixing of more and less treated wastewater. The study results showed that samples with relatively low TN concentrations could have either very low or higher percentages of TKN in comparison to NO_3. However, samples with relatively high TN concentrations consistently have high percentages of nitrogen as TKN, which may indicate less efficient treatment by the PBTS (Figure 9).

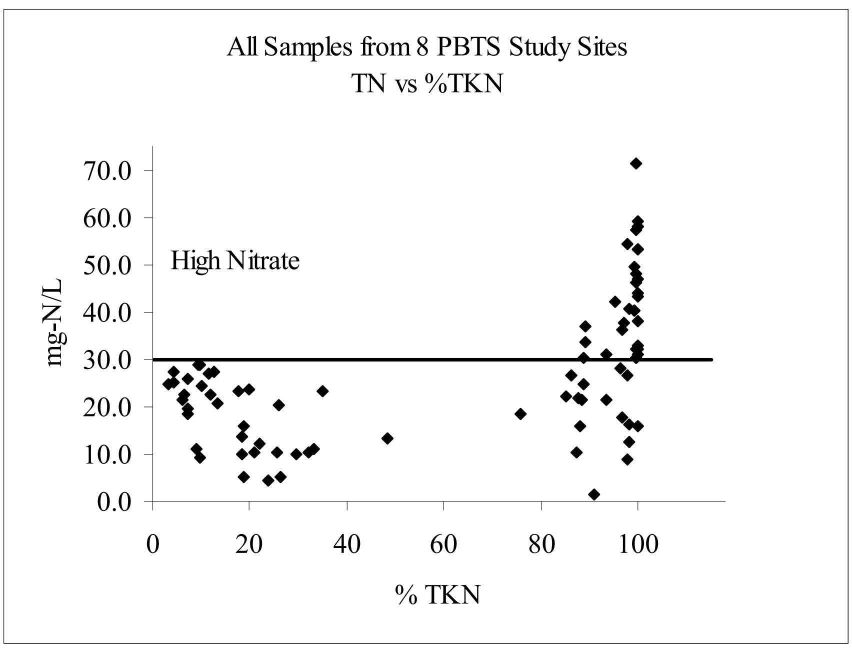

Figure 9. The TN concentrations (y-axis) of all samples from the 8 PBTS study sites plotted against the percentage of nitrogen as TKN. The samples with TN concentrations below 30 mg-N/L had TKN percentages that were either low or high. Samples with TN concentrations above 30 mg-N/L always had a high percentage of nitrogen as TKN.

Effluent samples from systems with low TN concentrations and a high percentage of the nitrogen as NO_3 indicate that these systems are achieving a high rate of nitrification. Most of the nitrogen is converted into NO_3 and as denitrification occurs, lowering the TN, the remaining effluent is predominately NO_3. Samples with low TN concentrations and a high percentage of the nitrogen as TKN indicate systems that have incomplete nitrification followed by denitrification. As denitrification occurs in the partially nitrified wastewater, the NO_3 is consumed, resulting in effluent with a high percentage of nitrogen as TKN. Samples with high TN concentrations and a higher percentage of the nitrogen as TKN in comparison to NO_3 indicate systems that have limited or no nitrification. Any NO_3 that is formed is consumed by denitrification. Since nitrification is limited, denitrification is also limited and the resulting effluent has a high TN that is mostly TKN. These results suggest that the effectiveness of these systems is limited by insufficient aeration. A balance must be struck however, for with too much aeration, denitrification is limited.

The data from site WSS-1-2 illustrates how the performance of an individual system can be improved with monitoring and subsequent adjustments to the system. After the May 2009 sample event, the pressure in the drainfield and recirculation system was reduced. Nitrification was thought to be limited as the recirculation was flushing wastewater through the system too fast. After this adjustment, the TN values were lower with a greater percentage of (NO_3 in the effluent (Figure 10). Apparently additional adjustment was needed, for in September the sytem returned to its previous poor performance.

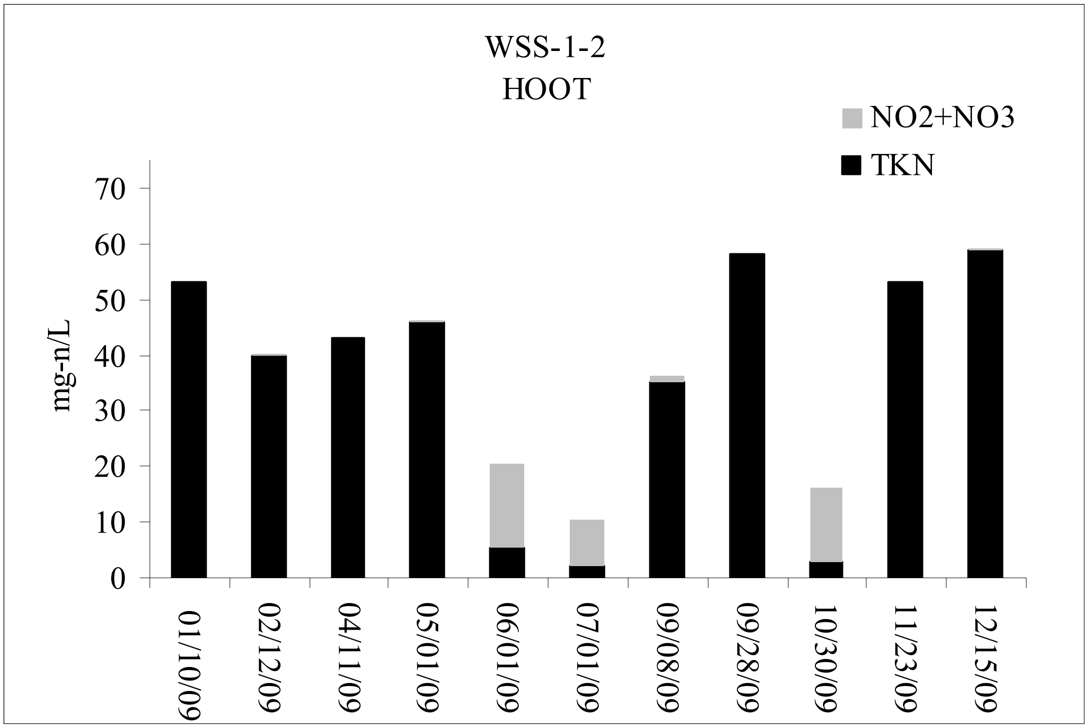

Figure 10. The TN concentrations plotted against the percentage of nitrogen as TKN at site WSS-1-2. In the first 4 samples with relatively high TN values, the nitrogen was mostly TKN. In the following two samples nitrification was apparently much more extensive and the TN concentrations were lower and predominately in the form of NO_3.

The data from the 27 additional sites sampled showed a greater degree of variability in the percentage of TKN in the TN of the systems effluent. As with the data from the 8 PBTS study sites, there are: 1)low TN concentrations with low percent as TKN indicating extensive nitrification and denitrification; 2)low TN concentrations with high percent as TKN indicating incomplete nitrification and denitrification (or mixing of treated water from different stages); and 3)high TN concentrations with a high percentage as TKN indicating limited nitrification and denitrification. Additionally, the data from the additional 27 sites shows a fourth category, 4)systems with samples with high TN with a low percentage as TKN indicating a system that is possibly too aerobic and that is nitrifying the waste stream without the subsequent denitrification step (Figure 11).

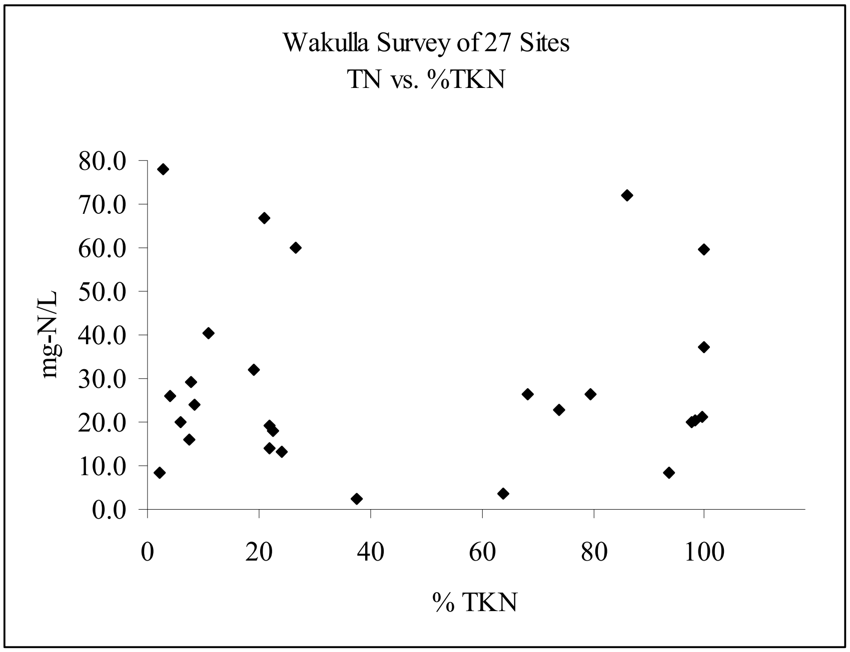

Figure 11. The TN concentrations (y axis) of all samples from the 27 PBTS study sites plotted against the percentage of nitrogen as TKN (x-axis).

3.8 Nitrogen Reduction in PBTS

The reduction of nitrogen by a system can be calculated if both the raw sewage inputs and the effluent output nitrogen concentrations are known. As discussed previously, the nitrogen content of raw sewage is highly variable depending on varying water use and lifestyle of the occupants of a household. The recent measurements suggest that a reasonable estimate for the average TN input from raw sewage in residences in Wakulla County is 70 mg-N/L (Tables 4 and 5). The percent reduction is calculated using this estimate and the actual input values for the study sites where the data is available.

The results of the Phase II study on performance based units are as follows. Effluent from eight Wakulla County PBTS units was sampled on a monthly basis during 2009. STE from the study sites averaged 30 ± 10 mg-N/L (Figure ES-2, Table 10). Of the additional 59 surveyed sites, the effluent of 27 performance based units was sampled. Their average value was 29 ± 21 mg-N/L (Figure ES-2, Table 11). The average concentration for the 35 total sites was 29 ± 19 mg-N/L (Table 12). These values are 45% of the average TN concentration in effluent from conventional septic tanks.

For the 5 sites where the TN of the raw sewage was measured, the percent reduction is calculated using both the measured input TN concentrations and the influent concentration estimate of 70mg-N/L (Table 15).

Table 15. Phase II Study Results. The percent reduction in TN achieved by the PBTS systems at sites where raw sewage inputs were measured is calculated using both the measured raw sewage values and the estimate of 70 mg-N/L. Units of N are in mg-N/L.

Site ID	Input TN Average.	Effluent TN Average.	Average % Reduction	% Reduction 70 Input
WSS-1-2	55.1 ± 28.2, n=4	39.6 ± 17.1, n=11	28.1	43.4
WSS-2-2	96.5 ± 56.2, n=5	25.2 ± 2.7, n=11	73.9	64.0
WSS-4-2	39.1 ± 20.6, n=2	17.3 ± 9.4, n=10	55.8	75.3
WSS-7-2	77.4 ± 26.0, n=5	49.2 ± 17.0, n=7	36.4	29.7
WSS-8-2	70.2, n=1	33.7 ± 3.8, n=3	52.0	51.9
5 Sites with Input Measurements				
	67.7 ±21.8, n=5	**33.0 ± 12.4, n=5**	**49.2± 17.8, n=5**	**52.9 ± 17.7, n=5**
All Samples				
	72.8 ± 39.2, n=17	31.6 ± 16.3, n=42	56.6	54.9
WSS-3-2	NA	31.6 ± 15.3, n=6	NA	54.9
WSS-5-2	NA	34.4 ± 9.5, n=6	NA	50.9
WSS-6-2	NA	19.2 ± 9.3, n=6	NA	72.6

Notes: The second to bottom row is the average of the means of each of the five sites, where each site is counted once, n=5. The bottom row is the statistics for all samples taken from the five sites

For the 27 sites sampled once, we calculate a percent N-reduction of 58.9 ± 28.5% (Figure ES-3, Table 16)

Table 16. Phase II Study Results. Nitrogen reduction at the study sites. Percentages assume an input TN concentration of 70 mg-N/L. For samples with effluent values greater than 70 mg-N/L, the % reduction was assumed to be zero. Units of N are in mg-N/L.

Sample ID	System type	TN.	%Reduction 70 mg-N/L Input
WS-11	HOOT	20.2	71
WS-25	HOOT	40.5	42
WS-26	HOOT	18.1	74
WS-1	Norweco	**72.0**	**0**
WS-10	Norweco	19.2	73
WS-12	Norweco	21.1	70
WS-20	Norweco	23.0	67
WS-24	Norweco	**8.6**	**88**
WS-3	FAST Dual Chamber	26.4	62
WS-5	FAST Dual Chamber	26.1	63
WS-7	FAST Dual Chamber	**67.0**	**4**
WS-8	FAST Dual Chamber	**3.6**	**95**
WS-9	FAST Dual Chamber	**59.5**	**15**
WS-22	FAST Dual Chamber	29.3	58
WS-23	FAST Dual Chamber	14.1	80
WS-14	FAST Dual Chamber + Post Tank	**2.6**	**96**
WS-18	FAST Dual Chamber + Post Tank	20.0	71
WS-21	FAST Dual Chamber + Post Tank	16.2	77
WS-6	FAST Single Chamber +Pre Tank	37.0	47
WS-13	FAST Single Chamber +Pre Tank	**60.0**	**14**
WS-16	FAST Single Chamber +Pre Tank	13.2	81
WS-17	FAST Single Chamber +Pre Tank	32.1	54
WS-2	FAST Single Chamber +Post Tank	20.3	71
WS-15	FAST Single Chamber +Post Tank	**8.6**	**88**
WS-19	FAST Single Chamber +Post Tank	26.4	62
WS-4	FAST Three Tanks	**78.1**	**0**
WS-27	FAST Three Tanks	24.0	66
	Average and Standard Deviation	**29.2± 20.8**	**58.9 ± 28.5**

The average TN value of near 30 mg-N/L may seem high for systems in comparison to the 10 mg-N/L expectation in FDOH and Wakulla County documentation, but the percent reduction value of near 60% indicates these systems are working as designed. This technology has been shown to consistently achieve 50-70% nitrogen reduction when installed and maintained correctly. The discrepancy with the NSF/ANSI standard is that under the controlled testing conditions these systems were fed sewage with TN influent concentrations of 25-35 mg-N/l, which is much lower than many of the influent concentrations measured for actual home septic systems (Table 17). The results of this study indicate that in field settings the PBTS tested generally achieve 50% N-reduction, but they do not achieve 10 mg-N/L in their effluent.

Table 17. Influent and effluent TN concentrations of systems during NSF/ANSI standard testing. Percent reduction of TN is also calculated. Units of N are in mg-N/L

NSF/ANSI Testing	Input TN Average	Effluent TN Average	Average % Reduction
FAST	34.5	9.4	73
HOOT	26.3	9.63	63
Norweco	25	6.8	73

3.9 Survey Results: Frequent non-compliance of PBTS systems.

During the course of sampling these additional PBTS, we encountered issues of concern regarding their installation, operation and maintenance. The most widespread problems were that a large number of systems were being turned off or were not receiving power. Also, a number of sites lacked a sampling port or other access to enable sampling of the system effluent. Out of a total of 59 PBTS inspected, 23 (39%) of these systems were not functioning as PBTS. At 22 of those systems, the treatment units were turned off or not powered. At three of these, the electrical wires were not even connected to the control boxes (Figures 12 and 13). At the other non-compliant site, the pump tank was empty due to a missing plug on the bottom (Figure 14). Other sites considered for this survey were not visited by the sampling team because pre-screening by Wakulla County Health Department staff indicated that those systems were not running (and presumably also not in compliance with their permits).

Figure 12. Picture taken on 04/16/09 of a FAST system with the unwired control box lying on the exposed tank. The system was in use with sewage, but no electricity.

Figure 13. Picture taken on 04/16/09 of Norweco system with the wiring to the control box not connected. There was power to the pump, but not to the aerator control box.

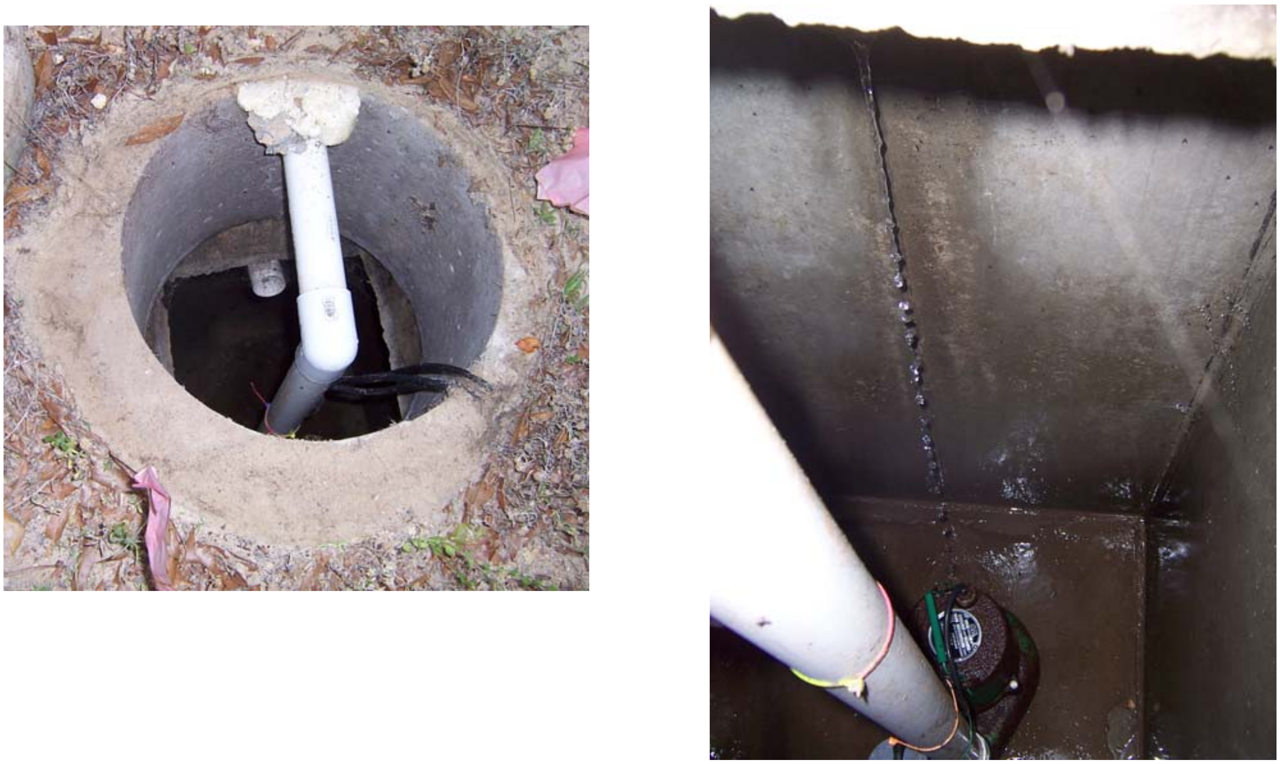

Figure 14. Pictures of the inside of an empty pump tank attached to a functioning FAST system. The installer indicated that a plug at the bottom of the tank came out and has encountered this problem at other sites.

Of the 59 sites visited, 36 (61%) were in compliance. Of the 36 functioning systems inspected, we sampled 27 (75%), 3 (8%) had no sampling access, and 6 (17%) were not sampled for other reasons.

Once a functioning system was found, sampling the effluent was often a challenge. This was unexpected because biannual maintenance that occurs under these permits includes visual inspection of the PBTS effluent, which would not be possible without an access port. For some sites, the sampling team found it very difficult to gain access to the effluent. At several sites the pump tank lid was dug up and opened. Locating the pump lid was also a challenge at a few sites. Due to the difficulty the team had in obtaining samples, it became obvious that the effluent at some sites was not being inspected by the maintenance contractors. With three systems that were visited, the sampling team could find no way to access the effluent. At one of the sites, there was no sample port and when the lid was dug up, the electrical wires were found strung across the pump tank lid making it impossible to open without, cutting or disconnecting the wires (Figure 15).


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Figure 15. Picture taken on 04/20/09 of Norweco system with wires strung across the pump tank lid preventing access. No sampling port was installed. Maintenance records indicate the effluent was visually inspected.

At other sites, the vent pipe had to be cut and then repaired in order to take a sample (Figure 16). Despite our difficulties in sampling systems, maintenance records for these sites show that the effluent from the PBTS has been visually inspected. In other instances, the team found that the systems did have sampling ports, but they had been installed in the wrong place in the system to obtain a sample complying with the manufacturer’s recommendations.

Figure 16. Picture taken on 04/14/09 of a vent pipe typical of FAST installations. Note the PVC coupling at ground level. In order to take a sample, the pipe was cut and repaired with the coupling. The black piece is a charcoal filter installed due to odor complaints. In this neighborhood, there are 5 systems in a row, backing to another 5 systems. This resulted in 10 systems on 1 ¼ acre which apparently created an odor problem.

The highest TN concentration in the effluent samples from the 27 survey sites and the 8 main study sites was 78.1 mg-N/L. This sample was collected from site WS-4, which has a FAST system configured with three separate tanks with recirculation and a mounded drip irrigation system. This configuration has a separate pretreatment tank, treatment tank, and pump tank and should have been one of the systems, based on the design, to provide optimum TN reduction. However, this system had an ongoing repair problem with a broken pipe that resulted in the system effluent filling the control box and not going to the drainfield (Figure 17). Other repair issues with this system may have been responsible for the elevated TN concentration in the effluent.

Figure 17. Pictures of site WS-4 taken on April 14, 2009. The broken plumbing evident in this picture was also reported in September 2008. The broken pipe caused the effluent to fill the control box instead of going to the drainfield.

3.10 Operation and Maintenance Issues with PBTS

Testing and field research have shown that PBTS can achieve 50 percent reduction of TN from input concentrations. The research from this locality shows that 70 mg-N/L is a reasonable estimate for residential sewage in Wakulla County. The median for all three regions investigated (Florida, Colorado, and Minnesota) in the CSM study was 60 mg-N/L, which is similar. Using the 70 mg-N/L average for influent TN, properly functioning PBTS should have on average effluent TN values below 30-35 mg-N/L. Our October 2008 inventory of septic tank permits in the Wakulla County Health Department files identified 105 PBTS installed in the county at that time. Of these systems, 63 (60%) were visited and 59 of the systems were inspected by the sampling team. Of the 59 systems inspected, 23 (39%) were not being operated properly and were therefore were not sampled because they would not provide representative performance data.. Twenty seven of the systems visited were operating and were sampled. The operational systems had an average TN concentration in the effluent of 29.2± 20.8 mg-N/L. Using 60-70 mg-N/L as an input value for TN, this translates to 50% to 60% reduction, on average.

Of the 27 systems sampled, 13 (48%) had effluent concentrations higher than 30 mg-N/L, and 9 (33%) had effluent concentrations higher than 35 mg-N/L. Five (15%) of the systems sampled appeared to not be functioning properly based on the data because they had effluent concentrations at raw sewage values (60-70 mg-N/L). The compliance issue with the systems that were not in operation is clear-cut but also the systems with elevated TN effluent concentrations could have issues that were not identified in this one sampling episode.

PBTS are not popular with some septic installers and many homeowners, which may be reflected by the high percentage of systems with non-compliance issues. Sampling many of these systems was difficult and in a few cases not possible. Tanks lids were located and dug up, vent piping cut, and some sampled with a peristaltic pump from the system. Other systems were found that were not fully installed (they were unwired) in occupied houses. Maintenance records indicate the effluent from theses systems has been inspected and system were noted as operational. It appears some holders of the maintenance contracts (installers) were not fulfilling their obligations at the time. The most prevalent issue identified in the site visits was that homeowners had simply turned off power to the systems. These homeowners may be motivated to turn off power to their PBTS because of electrical costs, noise and/or odor issues.

3.11 September, 2009 additional site visit observations

Two of the 27 sites were re-sampled in September, 2009 along with an additional 3 systems in close proximity to site WSS-3-2. The two sites were chosen for re-sampling because one was not indicating any treatment over a conventional system in April and the other was performing better than average. The TN concentrations and the percent TKN in these systems are presented in Table 18.

Table 18. Phase II Study Results. Additional PBTS sampling. Two of the 27 sites sampled in April were resampled in September, along with 3 additional sites. Percentages assume an input TN concentration of 70 mg-N/L. Units of N are in mg-N/L.

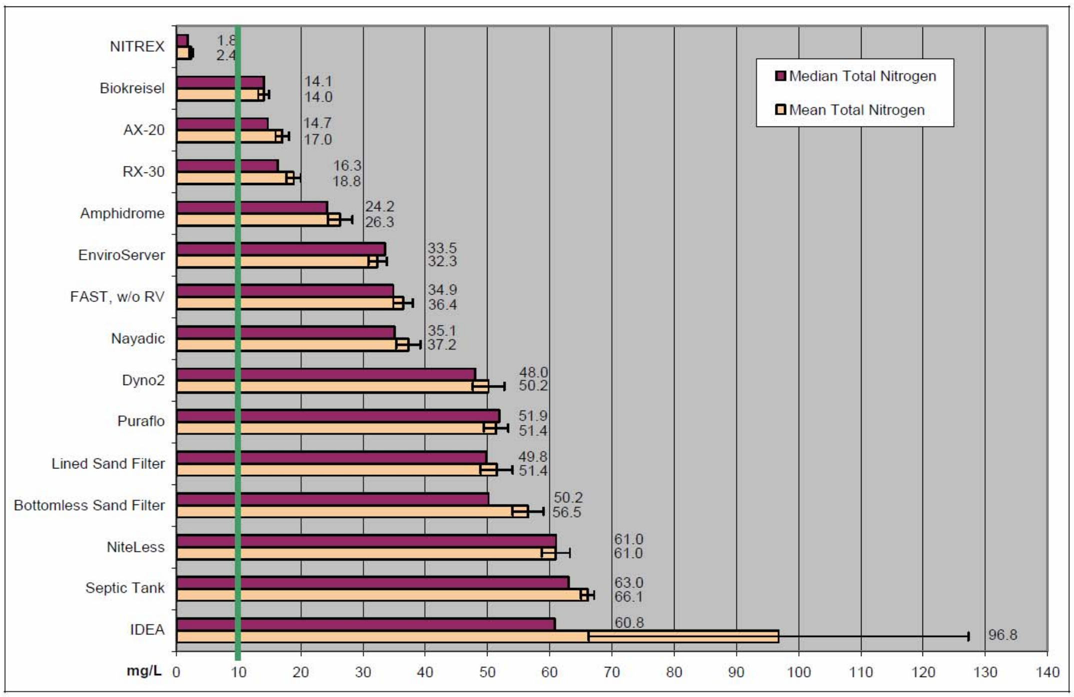
Sample ID	Date	System Type	TN	%Reduction
WS-13	April	FAST Single Chamber +Pre Tank	60.0	14.3
WS-13	September		39.6	43.4
WS-24	April	Norweco	8.6	87.8
WS-24	September		42.5	39.4
WS-28	September	Norweco	25.4	63.7
WS-29	September	FAST Dual Chamber	5.2	92.6
WS-30	September	FAST Dual Chamber	13.8	80.3

The re-sampling of the two systems illustrates the variability that can occur in the performance of nitrogen reduction in these systems. The TN reduction observed in the other three systems sampled was better than average for sites sampled in Wakulla County. Adding these five additional samples the average TN concentration changes slightly to 28.5 ± 19.9 mg-N/L, n=32.

While sampling the three additional sites, two other neighboring sites were inspected and the systems found not functioning, although the switches were turned on. Site WSS-3-2 experienced periodic maintenance issues, of the 11 sampling events, during 3 the system was found not operating. During one of these inspections, the neighboring system of the same type and installation was also not functioning.

3.12 Other research findings

The much larger La Pine National Demonstration Project conducted in Oregon by the US Geological Survey several years ago demonstrated the difficulty of attaining an effluent TN goal of 10 mg-N/L using most PBTS (Fig. 18, La Pine Oregon Demonstration Project, 2006).



Notes. The median TN concentration of 63 mg-N/L for effluent from conventional septic systems (STE) shown above is very similar to the values presented in this study. The FAST effluent TN mean concentration of 35 mg-N/L in the La Pine study compares to the FAST effluent results of this study, 26.2 mg-N/L.

Figure 18 Results of La Pine Oregon Demonstration Project, 2006. Only one of the nitrogen reducing systems examined achieved levels of 10 mg-N/L.

Raw sewage inputs were not measured in the La Pine study, instead conventional septic tank effluent and sand filters were used as controls. The effluent TN concentrations in the La Pine study for both conventional septic tanks and the FAST system are very similar to results in this report (Fig. 18). For the La Pine study, the 5 systems that consistently produced effluent concentrations lower than 30 mg-N/L used different technologies than the PBTS installed in Wakulla County. The NITREX system, the only system to meet the 10 mg-N/L goal, uses a different treatment strategy which involves the addition of a carbon source in another treatment chamber after nitrification. A chart compiled by FDOH summarizing data for PBTS and innovative systems reports nitrogen reductions ranging from 44% to 77% (FDOH, 2008). This excludes NITREX and Puraflo systems, both which utilize an added carbon source for denitrification. The Washington State Health Department also released a study on nitrogen reducing systems reporting reductions of 51% to 64% (WDOH, 2005).

One Passive Nitrogen Removal system recently proposed by the University of Central Florida also utilizes an added carbon source, a layer of reactive media that would be installed beneath the drainfield. This approach has the potential to reduce the TN concentration in the effluent by approximately 70% (Chang et al 2009). Preliminary results from a pilot test conducted by an FDOH contractor, using another form of reactive media, showed considerable nitrogen removal (Smith et al 2008). FDOH currently has a study under way that includes pilot-scale and then field scale testing of several promising passive technologies to reduce effluent TN concentrations.

4 TN attenuation downstream of the PBTS or Septic Tank: Pressurized Dripfields and Drainfields.

Once the TN loading to the drain field from either conventional or PBTS effluent is known, the treatment of the drainfield and underlying soils can be investigated by examining the TN concentrations in the soil porewater and shallow groundwater beneath the drain field or dripfield. The percent reduction of TN from the systems effluent in the porewater and groundwater can be calculated from just the nitrogen data; however this does not consider dilution effects.

$$\%\ \text{TN Reduction} = [1 - \{TN_{sample}/TN_{medianSTE}\}] \qquad 4\text{-}1$$

To determine the amount of TN attenuation due to adsorption or denitrification, it is essential to know how much the effluent in the porewater and groundwater is diluted. Chloride (Cl) is thought to act conservatively and can be used to calculate the dilution of the effluent. Although evaporation effects are not accounted for, the dilution of Cl is a reasonable estimate of dilution.

$$\% \text{ TN Attenuation} = \left(1 - \frac{\frac{TN_{sample}}{Cl_{sample - background}}}{\frac{TN_{median STE}}{Cl_{median STE}}} \right) * 100 \qquad 4\text{-}2$$

This calculation corrects for dilution of the septic effluent in the porewater and groundwater. Since the TN and Cl concentrations of the effluent are variable, the median effluent values over the 12 months were used for the loading concentration. Chloride concentrations for the porewater and groundwater samples were corrected for background concentrations. The lowest median value in either a background lysimeter or well was chosen. The source of Cl in the septic tank effluent was due either to residential use of chlorinated city water (site 3 and 6, Appendix A), household use of cleaners and detergents containing chlorine, household use of chlorine bleach and dietary salt.

It is important to know how much a sample is diluted as well as the amount of nitrogen attenuation. This can help determine whether a lysimeter or well is sampling the main effluent plume or sampling toward the edges or even outside the plume.

$$\% \text{ Cl dilution} = \left(1 - \frac{(Cl_{sample} - Cl_{background})}{Cl_{medianSTE}} \right) * 100 \qquad 4\text{-}3$$

4.1 TN Attenuation in Phase II PBTS with pressurized drip drainfields

Drainfields with pressurized drip emitters can enhance plant uptake of nitrogen by distributing the effluent closer to the root zone. Plant cover and depth of installation are critical factors that can affect the uptake of nitrogen. Without filtration, effluent from conventional septic systems tends to clog the emitters due to high BOD and thus pressurized drip systems are not used with conventional septic tanks in Florida, although they are in some states. Effluent nitrogen in a properly functioning PBTS should have a low BOD, allowing for shallow dispersal and plant uptake. Wakulla Basin PBTS study sites with drip drainfields were WSS-1-2, WSS-4-2, WSS-6-2 and WSS-7-2. Drip lines for these systems were 8 to 12 inches (20 – 30 cm) below the soil surface.

Site WSS-1-2

Site WSS-1-2 has a small mound (less than 0.5 m) with a pressurized drip system. The ground cover is part of a maintained lawn and the drip lines at the location of the lysimeters are 20-25 cm below surface. The shallow lysimeters were installed so the top of the 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drip lines (Table 19).

Table 19. The depth from surface is given for the bottom of the drainfield (DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-1-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-1	**Shallow**	8 in (20 cm)	33 in (84 cm)	42 in (107 cm)
S-L-4	**Shallow**	10 in (25 cm)	35 in (89 cm)	44 in (112 cm)
D-L-2	**Deep**	10 in (25 cm)	71 in (180 cm)	80 in (203 cm)
D-L-3	**Deep**	8 in (20 cm)	91 in (231 cm)	100 in (254 cm)
BG-L	**Background**		66 in (168 cm)	75 in (191 cm)
OM-L	**Off Mound**		53 in (135 cm)	62 in (157 cm)

The drainfield well was located approximately 6 ft (2 m) from the drainfield. The off mound lysimeter (OM-L) was located next to the drainfield well. The background well and lysimeter were located near the front of the property, up gradient from the septic system. The median Cl concentration of the background well was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations. Both the background lysimeter and the off mound lysimeter had elevated Cl concentrations during the February sampling event (Table 20).

Table 20. The Cl and TN concentrations of the background well (BG Well), the background lysimeter (BG-L), and the lysimeter located off the drainfield mound (OM-L), next to the drainfield well. Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

WSS-1-2	BG Well		BG-L		OM-L	
	Cl	**TN**	*Cl*	**TN**	*Cl*	TN
02/25/09	*2.5*	**0.2**	*6.9*	**0.2**	*9.2*	**0.2**
06/16/09	*2.9*	**0.2**	*0.61*	**0.4**	*1.5*	**0.2**
09/28/09	*3.3*	**0.3**	*1.8*	**0.4**	*0.76*	**0.2**
12/15/09	*3.4*	**0.3**	*2.5*	**0.3**	*1.5*	**0.1**
Mean	***3.0***	**0.2**	***3.0***	**0.3**	***3.2***	**0.2**
SD	*0.4*	0.0	*2.7*	0.1	*4.0*	0.0
Median	***3.1***	**0.3**	***2.2***	**0.3**	***1.5***	**0.2**

The effluent TN from the HOOT system at WSS-1-2 was variable, ranging from 11 to 59 mg-N/L. The fluctuating TN input into the drainfield makes any seasonal change in the effectiveness of the drainfield difficult to discern.

Calculations for TN reduction in the lysimeters and drainfield well are made using the median of the effluent (Eff) TN concentrations. TN reduction includes the effect of dilution, while attenuation refers to the reduction without dilution. The table below (Table 21) gives the TN concentrations and the percent reduction of TN including any dilution. The negative values for EFF indicate that on some sampling dates the sampled STE (septic tank effluent) was greater than the median STE value, as seen in Figure 19. The negative value for D-L-3 on December 15, 2009, indicates that the TN in the lysimeters was above the median STE value.

Table 21. The TN in mg-N/L and the percent TN reduction (Red) <u>including dilution</u> is given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-1, S-L-4) and the deep lysimeters (D-L-1, D-L-3). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-1-2	2/25/09		6/16/09		9/28/09		12/15/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**40.2**	*7%*	**20.3**	*53%*	**58.1**	*-35%*	**59.0**	*-37%*	**43.1**	*0%*
S-L-1	**28.7**	*33%*	**15.8**	*63%*	**34.2**	*21%*	**33.1**	*23%*	**30.9**	*28%*
S-L-4	**16.0**	*63%*	**5.4**	*87%*	**26.9**	*38%*	**11.7**	*73%*	**13.9**	*68%*
D-L-2	**33.1**	*23%*	**13.2**	*69%*	**26.9**	*38%*	**42.9**	*0%*	**30.0**	*30%*
D-L-3	**38.8**	*10%*	**12.1**	*72%*	**18.6**	*57%*	**44.5**	*-3%*	**28.7**	*33%*
DF Well	**26.4**	*39%*	**17.2**	*60%*	**11.3**	*74%*	**23.4**	*46%*	**20.3**	*53%*

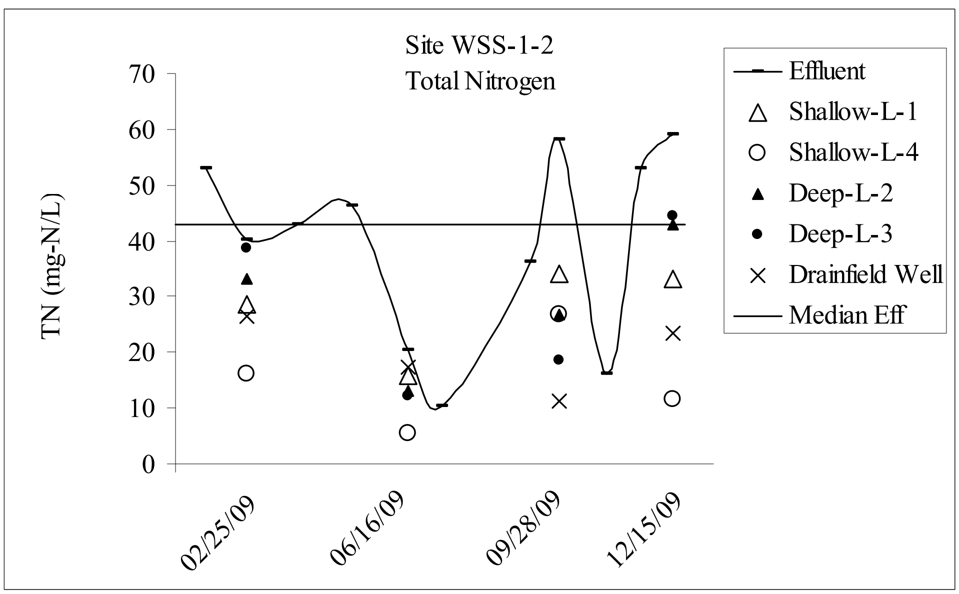


Figure 19. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-1-2. Sampling dates for effluent that included lysimeters and wells were on 02/25/09, 06/16/09, 09/28/09, and 12/15/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

The drainfield well is in the main effluent plume as indicated by the Cl dilution, ranging from 23 to 48 %, and a larger range of TN attenuation from 3 to 63 %. Little to no attenuation was observed in the lysimeters during the February sampling. In June, significant attenuation was observed in all lysimeters. In the September sampling event, attenuation was less than in June in the lysimeters and greater in the drainfield well. In December, the shallow lysimeters and drainfield well were more heavily diluted than in previous samplings and negative attenuation of TN was observed in the lysimeters and slight attenuation in the drainfield well. The negative attenuation in the lysimeters in December indicates an additional source of nitrogen besides the PBTS effluent. On possible source may be dog waste. Between the September and December sample events the homeowner fenced in their backyard, enlarging the area their two dogs could access to include the area of the drainfield. The fluctuation is shown in Figure 20.

Even with a pressurized drip system which distributes the effluent throughout the drainfield, TN attenuation can greatly differ in different locations in the drainfield. Shallow-L-1 samples that were more diluted (64% and 39%) showed no TN reduction. In the more concentrated samples, diluted by 6% and 11%, TN attenuation was observed (Table 22). The median TN attenuation via denitrification and/or adsorption at this site was 10%.

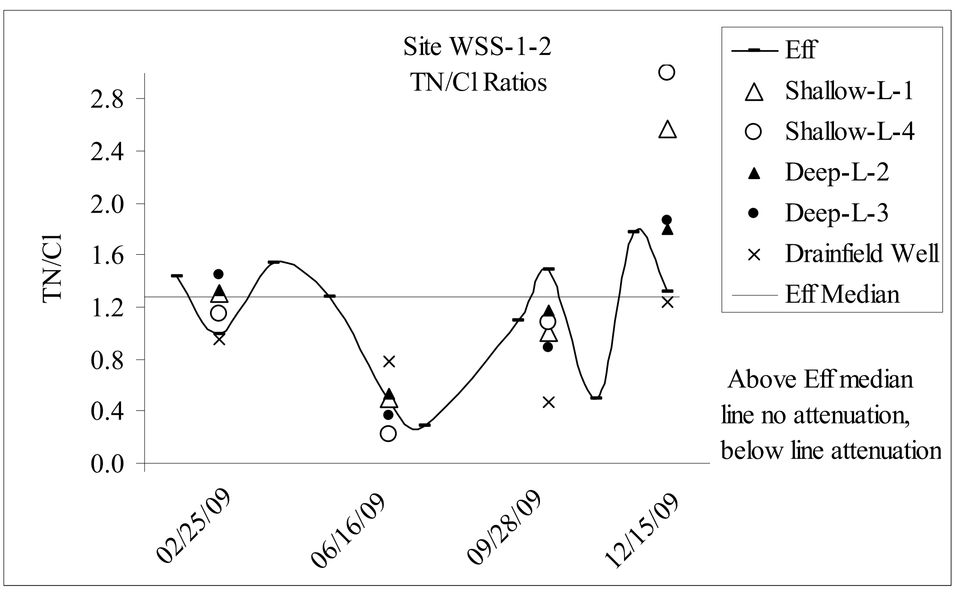


Figure 20. The TN/Cl ratios for the site WSS-1-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 22. The percent TN attenuation (TN Atten) calculated from TN/CL ratios which accounts for dilution. The percent of Cl dilution (CL dil) is also given.

WSS-1-2	2/25/09		6/16/09		9/28/09		12/15/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-1	**-2%**	*39%*	**61%**	*11%*	**21%**	*6%*	**-100%**	*64%*	**10%**	*25%*
S-L-4	**10%**	*61%*	**83%**	*31%*	**16%**	*31%*	**-134%**	*89%*	**13%**	*46%*
D-L-2	**-4%**	*31%*	**59%**	*31%*	**8%**	*36%*	**-40%**	*34%*	**2%**	*32%*
D-L-3	**-12%**	*25%*	**71%**	*9%*	**30%**	*42%*	**-45%**	*34%*	**9%**	*29%*
DF Well	**26%**	*23%*	**39%**	*39%*	**63%**	*34%*	**3%**	*48%*	**32%**	*36%*

Site WSS-4-2

Site WSS-4-2 has a large drainfield mound (greater than 1 m) with a pressurized drip effluent dispersal system. The mound is overgrown with thick untended vegetation. The drip lines are 12 in (30 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of the 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drip lines (Table 23).

Table 23. The depth from surface is given for the bottom of the drainfield (DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-4-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-1	**Shallow**	12 in (30 cm)	36 in (91 cm)	45 in (114 cm)
S-L-3	**Shallow**	12 in (30 cm)	36 in (91 cm)	45 in (114 cm)
D-L-2	**Deep**	12 in (30 cm)	63 in (160 cm)	72 in (183 cm)
D-L-4	**Deep**	12 in (30 cm)	63 in (160 cm)	72 in (183 cm)
BG-L	**Background**		59 in (150 cm)	68 in (173 cm)

The drainfield well was located on the lip of the drainfield mound. The background well and lysimeter were located near the boundary of the property, up gradient from the septic system. The median Cl concentration of the background lysimeter was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations. The background well had Cl concentrations an order of magnitude greater than the concentrations in the background lysimeter (Table 24).

Table 24. Site WSS-4-2. The Cl and TN concentrations of the background well (BG Well) and the background lysimeter (BG-L). Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

WSS-4-2	BG Well		BG-L	
	Cl	**TN**	*Cl*	**TN**
2/27/09	*7.0*	**0.1**	*NS*	**NS**
6/18/09	*6.5*	**0.1**	*2.7*	**0.1**
10/02/09	*16.0*	**0.2**	*0.7*	**0.1**
12/18/09	*17.0*	**0.1**	*1.8*	**0.1**
mean	***11.6***	**0.1**	***1.7***	**0.1**
SD	*5.7*	0.0	*1.0*	0.0
median	**11.5**	**0.1**	***1.8***	**0.1**

The effluent TN from the FAST system at WSS-4-2 was also variable but generally lower than WSS-1-2, ranging from 1.3 to 27.2 mg-N/L. The fluctuating TN input into the drainfield makes any seasonal variation in the effectiveness of the drainfield difficult to discern (Figure 22).

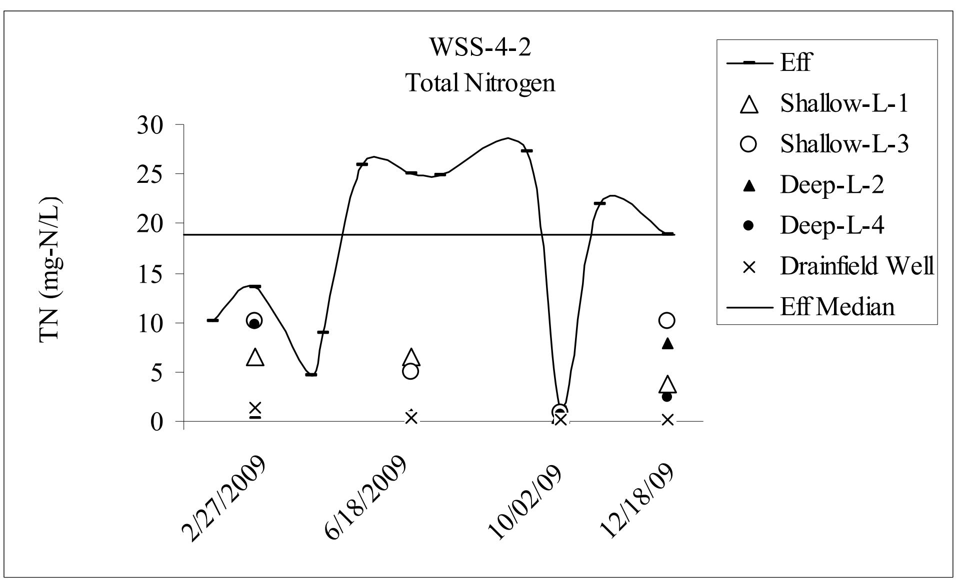


Figure 22. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and the drainfield well at site WSS-4-2. Sampling dates for effluent that included lysimeters and wells were 02/27/09, 06/18/09, 10/02/09, and 12/18/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Calculations for TN reduction were made using the median of the effluent (Eff) TN concentrations. TN reduction includes the effect of dilution, while attenuation refers to the reduction without dilution. Table 25 shows the TN concentrations and the percent reduction of TN including any dilution. It is unclear why the TN effluent was so low (1.3 mg-N/L) during the 10/02/09 sampling event. The lysimeter and drainfield well values are even smaller indicating that loading to the drainfield was also reduced compared to other sampling events.

Table 25. The TN in mg-N/L and the percent TN reduction (Red) <u>including dilution</u> is given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-1, S-L-3) and the deep lysimeters (D-L-2, D-L-4). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-4-2	2/27/09		6/18/09		10/02/09		12/18/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**13.5**	*28%*	**25.1**	*-33%*	**1.3**	*93%*	**18.9**	*0%*	**18.9**	*0%*
S-L-1	**6.5**	*66%*	**6.4**	*66%*	**0.7**	*96%*	**3.8**	*80%*	**5.1**	*73%*
S-L-3	**10.2**	*46%*	**4.9**	*74%*	**0.8**	*96%*	**10.2**	*46%*	**7.5**	*60%*
D-L-2	**0.9**	*95%*	**0.7**	*96%*	**0.4**	*98%*	**7.8**	*59%*	**0.8**	*96%*
D-L-4	**9.8**	*48%*	**0.5**	*97%*	**0.7**	*96%*	**2.4**	*87%*	**1.6**	*92%*
DF Well	**1.4**	*93%*	**0.3**	*98%*	**0.2**	*99%*	**0.1**	*99%*	**0.3**	*99%*

The TN/Cl ratios for the lysimeters and monitoring well over time are shown in Figure 23 and TN attenuation for each lysimeter and the well is summarized in Table 26. . During the February sampling event, the Cl data indicates the lysimeter samples were 0 to 10% diluted compared to the effluent and the drainfield well was diluted by 54%. Significant TN reduction was observed in all samples. Although the amount of dilution varies over the four sampling events, significant attenuation was observed in all samples. The median attenuation via denitrification and/or adsorption for this site was 78%.

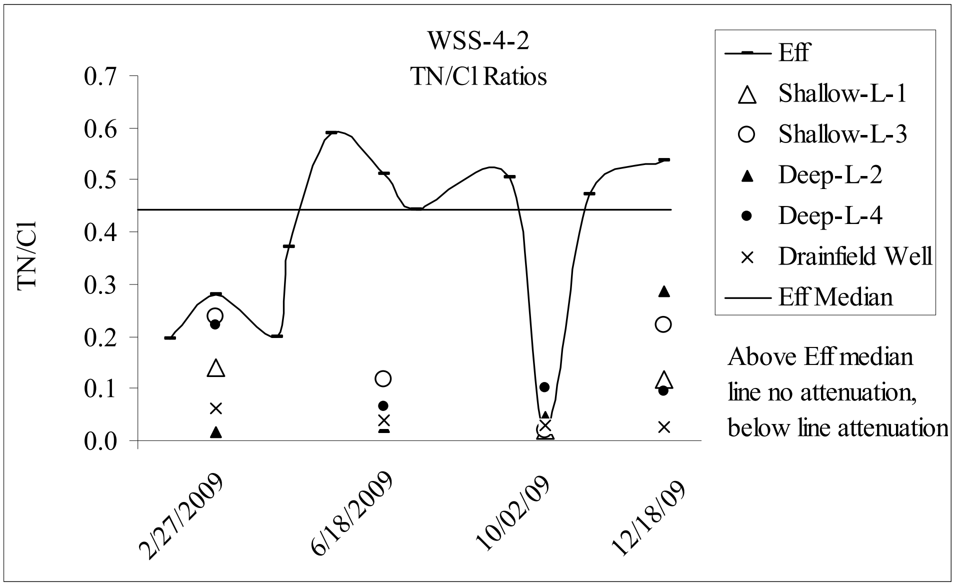


Figure 23. The TN/Cl ratios for the lysimeters and drainfield well at site WSS-4-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration of the 11 effluent samples. The graph is corrected for dilution.

Table 26. The percent TN attenuation (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. Not enough sample was available for Cl analysis in S-L-1 on 06/01/09 and is indicated by NS.

WSS-4-2	2/27/09		6/18/09		9/28/09		12/15/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-1	**69%**	*4%*	**NS**	*NS*	**96%**	*25%*	**74%**	*33%*	**74%**	*25%*
S-L-3	**47%**	*10%*	**74%**	*12%*	**96%**	*10%*	**50%**	*4%*	**62%**	*10%*
D-L-2	**96%**	*0%*	**94%**	*45%*	**90%**	*84%*	**35%**	*43%*	**92%**	*44%*
D-L-4	**50%**	*8%*	**86%**	*84%*	**77%**	*85%*	**79%**	*48%*	**78%**	*66%*
DF Well	**86%**	*54%*	**91%**	*83%*	**93%**	*87%*	**94%**	*89%*	**92%**	*85%*

Site WSS-6-2

Site WSS-6-2 has a pressurized drip drainfield that is at grade, covered by a mowed lawn. The drip lines were 11-13 in (28-33 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of 9 inch (23 cm) cups were approximately 2 ft

(0.6 m) below the drip lines. Lysimeter S-L-5 was installed after the first sampling event. Installation details of the lysimeters and well are provided in Table 27.

Table 27. The depth from surface is given for the bottom of the drainfield (DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-6-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-2	**Shallow**	13 in (33 cm)	37 in (94 cm)	46 in (117 cm)
S-L-3	**Shallow**	11 in (28 cm)	35 in (89 cm)	44 in (112 cm)
S-L-5	**Shallow**	13 in (33 cm)	37 in (94 cm)	46 in (117 cm)
D-L-1	**Deep**	13 in (33 cm)	62 in (157 cm)	71 in (180 cm)
D-L-4	**Deep**	12 in (30 cm)	91 in (231 cm)	100 in (254 cm)
BG-L	**Background**		72 in (183 cm)	81 in (206 cm)

The drainfield well was located approximately 3m off the corner of drainfield. The background well and lysimeter were located up gradient from the septic system. Since no sample was obtained in S-L-2 on 02/26/09, this lysimeter was removed, and lysimeter S-L-5 was added prior to next sampling event.

The median Cl concentration of the background well was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations. The background lysimeter had Cl concentrations that were higher and more variable (Table 28).

Table 28. Site WSS-6-2. The Cl and TN concentrations of the background well (BG Well) and the background lysimeter (BG-L). Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

WSS-6-2	BG Well		BG-L	
	Cl	**TN**	*Cl*	**TN**
02/26/09	*4.0*	**0.8**	*37*	**0.4**
06/17/09	*4.2*	**0.9**	*13*	**0.3**
09/29/09	*4.8*	**1.1**	*12*	**0.2**
12/16/09	*4.7*	**1.3**	*5.8*	**0.2**
mean	***4.4***	**1.0**	***17.0***	**0.3**
SD	*0.4*	0.2	*13.7*	0.1
median	***4.5***	**1.0**	***12.5***	**0.3**

The TN concentration in effluent from the HOOT PBTS system at WSS-6-2 was also variable but with a lower median STE TN concentration than both WSS-1-2 and WSS-4-2, ranging from 3.3 to 32.1 mg-N/L. The fluctuating TN input into the drainfield makes any seasonal variation in the effectiveness of the drainfield difficult to discern (Figure 24).

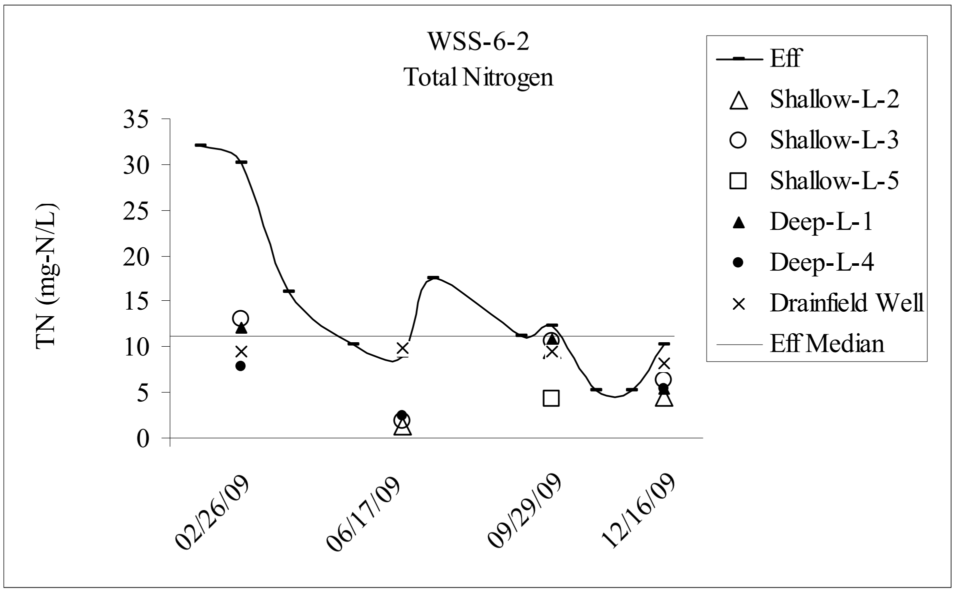


Figure 24. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-6-2. Sampling dates for effluent that included lysimeters and wells were on 02/26/09, 06/17/09, 9/29/09, and 12/16/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

The fist two effluent TN concentrations were approximately 3 times higher the median value. The higher input concentrations during and prior to the February sampling event account for the negative percent TN reduction values in these samples (Table 29). Calculations for TN reduction and attenuation were made using the median effluent (Eff) TN and Cl values.

The drainfield well TN concentrations were relatively consistent over the four sampling events, ranging from 9.9 to 8.2 mg-N/L. The June sampling event had the highest drainfield well concentration, yet the lowest lysimeter concentrations of the samples.

Table 29. The TN in mg-N/L and the percent TN reduction (Red) including dilution is given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-2, S-L-3, S-L-5), the deep lysimeters (D-L-1, D-L-4) and the drainfield well (DF Well). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events. NS indicates not enough sample was in the lysimeter for TN analysis.

WSS-6-2	02/26/09		06/17/09		09/29/09		12/16/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**30.1**	*-169%*	**9.0**	*20%*	**12.3**	*-10%*	**10.2**	*9%*	**11.2**	*0%*
S-L-2	**NS**		**1.3**	*89%*	**9.7**	*14%*	**4.5**	*59%*	**4.5**	*59%*
S-L-3	**13.1**	*-17%*	**1.9**	*83%*	**10.7**	*5%*	**6.3**	*44%*	**8.5**	*24%*
S-L-5	Not Installed		**1.0**	*91%*	**4.3**	*62%*	**NS**		**2.6**	*77%*
D-L-1	**12.1**	*-8%*	**NS**		**10.8**	*4%*	**5.5**	*51%*	**10.8**	*4%*
D-L-4	**7.9**	*29%*	**2.4**	*79%*	**9.5**	*15%*	**5.5**	*51%*	**6.7**	*40%*
DF Well	**9.4**	*16%*	**9.9**	*12%*	**9.4**	*16%*	**8.2**	*27%*	**9.4**	*16%*

The drainfield well had much higher TN/Cl ratios than the effluent and lysimeters (Figure 25). The Cl dilution percentages indicate 80% or greater dilution of the effluent (Table 30). An additional source of nitrogen, besides the septic system, may be contributing to TN in the drainfield well. Possible sources include fertilizer or the goat waste from the animal pen nearby.

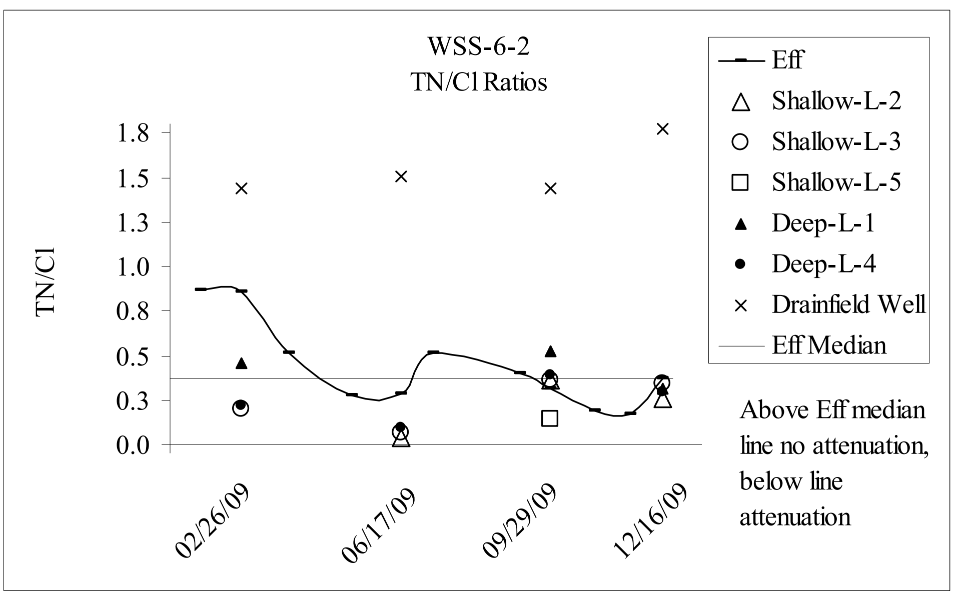


Figure 25. The TN/Cl ratios for the site WSS-6-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 30. The percent TN attenuation (TN Atten) calculated from the TN/CL ratios to account for dilution. The percent of Cl dilution (CL dil) is also given. NS indicates not enough sample was in the lysimeter for a sample.

WSS-6-2	2/26/09		6/17/09		9/29/09		12/16/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-2	NS		**89%**	*8%*	**3%**	*17%*	**31%**	*45%*	**31%**	***17%***
S-L-3	46%	*-102%*	**83%**	*11%*	**4%**	*8%*	**9%**	*42%*	**28%**	***9%***
S-L-5	**Not Installed**		**NS**		**61%**	*8%*	**NS**		**NA**	
D-L-1	**-21%**	*17%*	**NS**		**-39%**	*36%*	**17%**	*45%*	**-21%**	***36%***
D-L-4	**41%**	*-11%*	**74%**	*23%*	**-3%**	*23%*	**22%**	*42%*	**31%**	***23%***
DF Well	**-283%**	*80%*	**-301%**	*80%*	**-283%**	*80%*	**-372%**	*86%*	**-292%**	***80%***

The negative Cl dilution values observed on the 02/26/09 sampling event in two of the lysimeters indicate that the concentration of the effluent in Shallow-L-3 had twice as much Cl than the STE median. The Deep-L-4 had 10% more Cl than the STE median. Although the effluent TN values were higher than normal on and before the 02/26/09 sampling (Table 29), the effluent Cl values were within the range of the rest of the effluent samples. Using the lysimeter data, the overall median N attenuation by denitrification, adsorption or plant uptake for this site was 30%.

Site WSS-7-2

Site WSS-7-2 has a pressurized drip system at grade, covered by a mowed lawn. The drip lines are 10 in (25 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drip lines (Table 31).

Table 31. The depth from surface is given for the bottom of the drainfield(DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-7-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-1	**Shallow**	10 in (25 cm)	35 in (89 cm)	44 in (112 cm)
S-L-4	**Shallow**	10 in (25 cm)	35 in (89 cm)	44 in (112 cm)
D-L-2	**Deep**	10 in (25 cm)	79 in (201 cm)	88 in (224 cm)
D-L-3	**Deep**	10 in (25 cm)	79 in (201 cm)	88 in (224 cm)
BG-L	**Background**		69 in (198 cm)	78 in (175 cm)

Monitoring wells were not installed at this site because the top of limestone was above the water table and prevented well installation using the direct push system.

The median Cl concentration of the background lysimeter was used as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations. Cl and TN concentrations in the background lysimeter are shown in Table 32.

Table 32. The Cl and TN concentrations of the background lysimeter (BG-L) at site WSS-7-2. A background well was not installed. Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

	BG-L	
	Cl	**TN**
02/26/09	*7.9*	**0.2**
06/17/09	*2.5*	**1.6**
10/01/09	*3.1*	**0.6**
12/17/09	*3.1*	**0.2**
mean	***4.2***	**0.7**
SD	*2.5*	0.6
median	***3.1***	**0.4**

The effluent TN concentrations from the Norweco PBTS system at WSS-7-2 were variable, with a median STE TN concentration ranging from 12.0 to 71.3 mg-N/L (Figure 26). This was similar to WSS-1-2. The fluctuating TN input into the drainfield makes it difficult to discern any seasonal differences in the effectiveness of the drainfield. Calculations for TN reduction and attenuation were made using the median effluent (Eff) TN and Cl values.

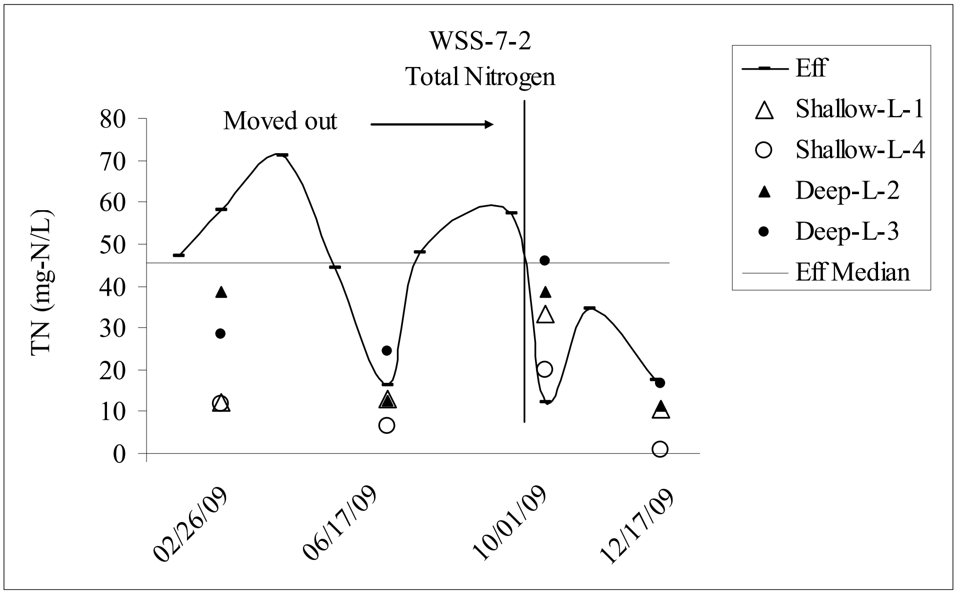


Figure 26. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-7-2. Sampling dates for effluent that included lysimeters and wells were on 02/26/09, 06/17/09, 10/01/09, and 12/17/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

At this site, the residents moved out of the house sometime between the 09/08/09 effluent sampling and the 10/02/09 sampling event. The system was not in operation on 10/02/09 and was in operation only intermittently between then and the 12/17/09 sampling event. These fluctuations drop off in effluent concentration are reflected in the data (Table 33).

Table 33. The TN in mg-N/L and the percent TN reduction (Red) including dilution are given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-2, S-L-3, S-L-5) and the deep lysimeters (D-L-1, D-L-4). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-7-2	2/26/09		6/17/09		10/01/09		12/17/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**58.0**	*-27%*	**16.3**	*64%*	**12.0**	*74%*	**17.4**	*62%*	**45.6**	*0%*
S-L-1	**12.2**	*73%*	**12.9**	*72%*	**33.1**	*27%*	**10.5**	*77%*	**12.6**	*72%*
S-L-4	**12.0**	*74%*	**6.5**	*86%*	**20.0**	*56%*	**0.9**	*98%*	**9.2**	*80%*
D-L-2	**38.7**	*15%*	**12.7**	*72%*	**38.6**	*15%*	**11.5**	*75%*	**25.7**	*44%*
D-L-3	**28.4**	*38%*	**24.5**	*46%*	**45.7**	*0%*	**16.7**	*63%*	**26.5**	*42%*

On each sampling of the lysimeters, the deep lysimeters had higher concentrations of TN than the shallow lysimeters. Cl was greatly reduced in shallow lysimeters in the December, showing effect of system not being in use since last sampling. The overall median value for TN attenuation for this system (other than by dilution), not counting the December measurements, was negative 6%. Thus, essentially, the system displayed no TN attenuation except by dilution. The TN/CL ratios and the percent TN attenuation are shown in Figure 27 and Table 34, respectively.

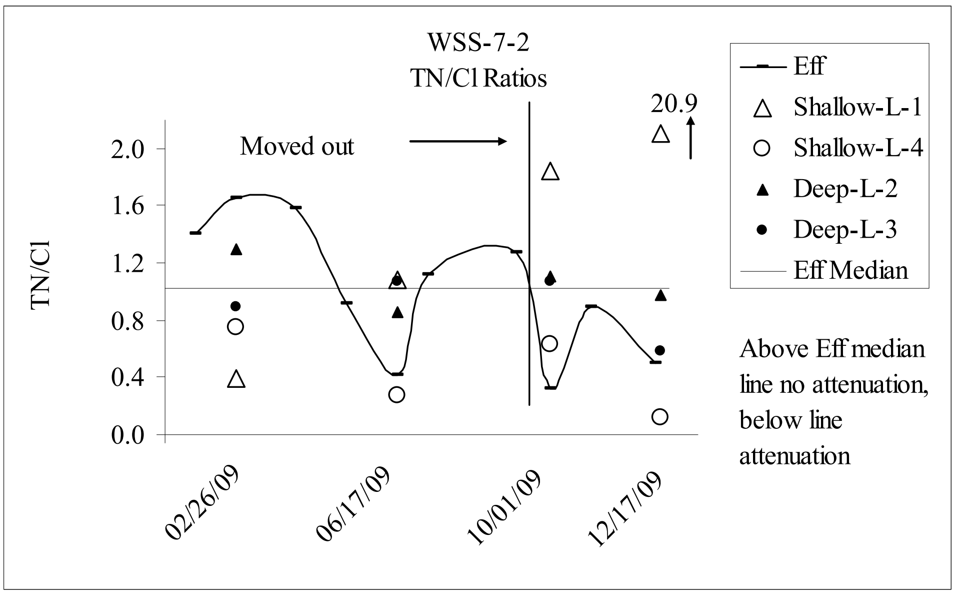


Figure 27. The TN/Cl ratios for the site WSS-7-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 34. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. <u>Since the house was unoccupied, the 12/17/09 sample values were not used in calculating the median values.</u>

WSS-7-2	2/26/09		6/17/09		10/01/09		12/17/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-1	**61%**	*21%*	**-7%**	*69%*	**-82%**	*54%*	**-1954%**	*99%*	**-7%**	*54%*
S-L-4	**26%**	*59%*	**73%**	*39%*	**38%**	*18%*	**89%**	*80%*	**38%**	*39%*
D-L-2	**-27%**	*23%*	**16%**	*62%*	**-9%**	*11%*	**5%**	*69%*	**-9%**	*23%*
D-L-3	**13%**	*18%*	**-5%**	*41%*	**-5%**	*-10%*	**43%**	*26%*	**-5%**	*18%*

One of the advantages of a pressurized drip dispersal drainfield is that the effluent is dispersed evenly though out the drainfield. Even with this even dispersion, the lysimeter data for all of the drip systems showed considerable spatial variability in both the TN concentrations and percent attenuation. There is also much variability between sample dates at the same lysimeter. It is difficult to make strong conclusions because of the intermittent operation of this system.

4.2 <u>TN Attenuation in Phase II PBTS with conventional drainfields</u>

The conventional drainfields at cooperating sites used in Phase II of this study were all Infiltrator® chamber systems. Infiltrator system drainfields are high density polyethylene arches that interlock to form a continuous drainage area which is open on the bottom. When STE is discharged from a PBTS to a conventional drainfield, it flows into a distribution box and flows down 2-4 chamber lines. The drainfields at the study sites are all relatively new. The greatest amount of the infiltration in newer drainfields occurs at the end closest to the distribution box, but as they age and the underlying soils start to become less permeable near the discharge point, more of the effluent infiltrates further down the chambers. Not knowing where the greatest amount of infiltration occurs can make it difficult to properly locate lysimeters and wells, which is much more difficult than the systems with pressurized drip dispersal systems where infiltration is uniform. It was difficult to obtain representative data beneath the conventional drainfields for this reason. At all three sites with conventional drainfields, the lysimeters had to be relocated after the first sampling round indicated that they were not sampling the main effluent plume.

Site WSS-2-2

Site WSS-2-2 has a conventional drainfield system that is at grade, covered by a mowed lawn. The bottom of the drainfield chambers is 18-19 in (46-48 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of the 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drip lines (Table 35). During the February sampling event, lysimeters S-L-1, D-L-2, and D-L-3 did not have enough water for a sample and were moved and re-numbered prior to the June sampling event. An additional shallow lysimeter (S-L-6) was also installed.

Table 35. The depth from surface is given for the bottom of the drainfield(DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-2-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-1	**Shallow**	18 in (46 cm)	42 in (107 cm)	51 in (130 cm)
S-L-4	**Shallow**	19 in (48 cm)	43 in (132 cm)	52 in (132 cm)
D-L-2	**Deep**	18 in (46 cm)	65 in (165 cm)	74 in (188 cm)
D-L-3	**Deep**	19 in (48 cm)	91 in (231 cm)	100 in (254 cm)
S-L-5	**Shallow**	19 in (48 cm)	43 in (132 cm)	52 in (132 cm)
S-L-6	**Shallow**	19 in (48 cm)	43 in (132 cm)	52 in (132 cm)
D-L-7	**Deep**	18 in (46 cm)	54 in (160 cm)	63 in (160 cm)
D-L-8	**Deep**	18 in (46 cm)	54 in (160 cm)	63 in (160 cm)
BG-L	**Background**		66 in (168 cm)	75 in (191 cm)

The background well and lysimeter for site WSS-1-2 were also used for site WSS-2-2 also, since the two sites were in close proximity. Table 20 gives the Cl and TN concentrations in the background lysimeter and well used for sites WSS-1-2 and WSS-2-2. The median Cl concentration of the background well was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations. The background lysimeter had Cl concentrations that were higher and more variable (Table 20).

The effluent TN from the FAST PBTS system at WSS-2-2 was relatively consistent compared to the other sites, ranging from 20.8 to 28.9 mg-N/L (Figure 28). Calculations for TN reduction and attenuation were made using the median effluent (Eff) TN and Cl values. This information is provided in Table 36. During the late September sampling event, the lysimeters S-L-5, S-L-6, D-L-7, and D-L-8 had TN concentrations higher than the measured effluent and median effluent.

No attenuation relative to the median effluent TN/Cl ratio was observed in the drainfield well during the four sampling events. Lysimeter samples are very similar to the effluent concentration and show little dilution. The overall TN attenuation at this site was -5%. Essentially the site showed no evidence for N-attenuation via processes other than dilution. This can be seen in Figure 29 and Table 37.

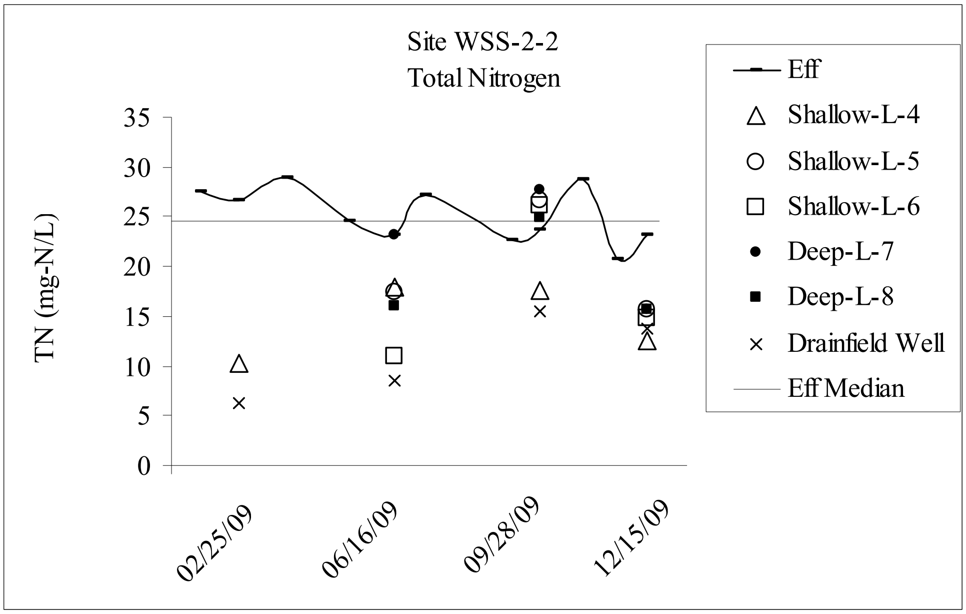


Figure 28. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-2-2. Sampling dates for effluent that included lysimeters and wells were on 02/25/09, 06/16/09, 09/28/09, and 12/15/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Table 36. The TN in mg-N/L and the percent TN reduction (Red) including dilution is given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-4, S-L-5, S-L-6) and the deep lysimeters (D-L-7, D-L-8). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-2-2	2/25/09		6/16/09		9/28/09		12/15/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**26.7**	*-9%*	**23.1**	*6%*	**23.7**	*3%*	**23.1**	*6%*	**24.5**	*0%*
S-L-4	**10.4**	*58%*	**18.0**	*27%*	**17.7**	*28%*	**12.6**	*49%*	**15.1**	*38%*
S-L-5	Not Installed		**17.5**	*29%*	**26.7**	*-9%*	**15.8**	*36%*	**17.5**	*29%*
S-L-6	Not Installed		**10.9**	*56%*	**26.1**	*-7%*	**14.8**	*40%*	**14.8**	*40%*
D-L-7	Not Installed		**23.1**	*6%*	**27.6**	*-13%*	**15.6**	*36%*	**23.1**	*6%*
D-L-8	Not Installed		**16.1**	*34%*	**24.9**	*-2%*	**15.7**	*36%*	**16.1**	*34%*
DF Well	**6.3**	*74%*	**8.6**	*65%*	**15.4**	*37%*	**13.8**	*44%*	**11.2**	*54%*

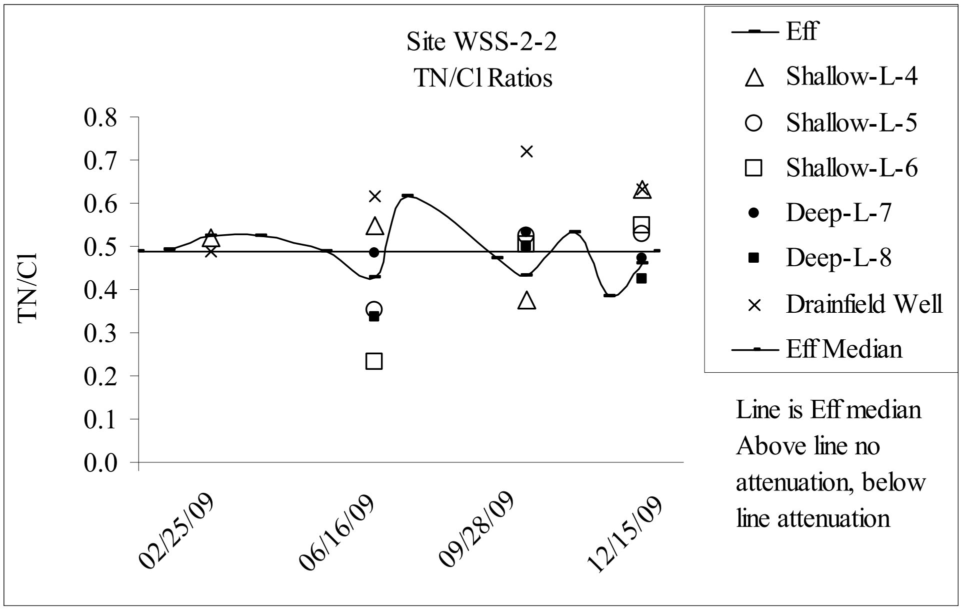


Figure 29. The TN/Cl ratios for the site WSS-2-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 37. The percent TN attenuation (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given.

WSS-2-2	2/25/09		6/16/09		9/28/09		12/15/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-4	-3%	62%	**-11%**	*39%*	**23%**	*14%*	**-31%**	*64%*	**-9%**	*51%*
S-L-5	Not Installed		**29%**	*7%*	**-7%**	*6%*	**-9%**	*45%*	**-7%**	*8%*
S-L-6	Not Installed		**53%**	*13%*	**-3%**	*4%*	**-13%**	*51%*	**-3%**	*13%*
D-L-7	Not Installed		**2%**	*11%*	**-9%**	*4%*	**2%**	*40*	**2%**	*11%*
D-L-8	Not Installed		**32%**	*11%*	**-2%**	*8%*	**13%**	*32*	**13%**	*11%*
DF Well	5%	75%	**-24%**	*74%*	**-48%**	*61%*	**-31%**	*60%*	**-27%**	*67%*

Site WSS-3-2

Site WSS-3-2 has a conventional drainfield system that is at grade and covered by a mowed lawn. The bottoms of the drainfield chambers are 29 in (74 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of the 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drainfield chambers (Table 38). The results from the February sampling event indicated that the lysimeters were not in the main septic plume. For the three lysimeters with samples, the TN concentrations were less than 2 mg-N/L and Cl was diluted by 77 to 93%. All four lysimeters were moved prior to the June sampling event in an attempt to find the portion of the drainfield receiving effluent.

Table 38. The depth from surface is given for the bottom of the drainfield(DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-3-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-2	**Shallow**	29 in (74 cm)	55 in (140 cm)	64 in (163 cm)
S-L-4	**Shallow**	29 in (74 cm)	55 in (140 cm)	64 in (163 cm)
D-L-1	**Deep**	29 in (74 cm)	91.5 in (232 cm)	100.5 in (255 cm)
D-L-3	**Deep**	29 in (74 cm)	92 in (234 cm)	101 in (257 cm)
S-L-6	**Shallow**	29 in (74 cm)	55 in (140 cm)	64 in (163 cm)
S-L-8	**Shallow**	29 in (74 cm)	55 in (140 cm)	64 in (163 cm)
D-L-5	**Deep**	29 in (74 cm)	91.5 in (232 cm)	100.5 in (255 cm)
D-L-7	**Deep**	29 in (74 cm)	92 in (234 cm)	101 in (257 cm)
BG-L	**Background**		69 in (175 cm)	78 in (198 cm)

The background well and lysimeter were located next to an empty parcel near the road of the residence. This site is in Wakulla Gardens, an area with high density (1/8 acre) lots. The drainfield well had lower TN and Cl than the background well. This indicates that the drainfield well was not sampling the septic plume. The background well TN values at this site, 1.8 ± 1.0 mg-N/L, n=4 were much higher than background at sites WSS-1-2 and site WSS-4-2. Table 39 gives the Cl and TN concentrations in the background lysimeter and well used at site WSS-3-2.

Table 39. The Cl and TN concentrations of the background well (BG Well, the background lysimeter (BG-L), and the lysimeter located off the drainfield mound (OM-L), next to the drainfield well. Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

WSS-3-2	Background Well		Background-L		Drainfield Well	
	Cl	**TN**	*Cl*	**TN**	*Cl*	TN
2/27/2009	*14*	**2.1**	*30*	**0.4**	*10*	**0.5**
6/19/2009	*18*	**0.3**	*NS*	**0.4**	*11*	**0.7**
09/29/09	*21*	**2.2**	*NS*	**1.2**	*13*	**1.3**
12/16/09	*19*	**2.6**	*11*	**0.2**	*13*	**1.6**
Mean	***18.0***	**1.8**	***20.5***	**0.5**	***11.6***	**1.1**
SD	*2.9*	1.0	*13.4*	0.5	*1.4*	0.5
Median	***18.5***	**2.1**	***20.5***	**0.4**	***11.8***	**1.0**

The median Cl concentration of the drainfield well was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations for the lysimeter samples.

The effluent TN from the Norweco PBTS system at WSS-3-2 was variable throughout the study (Figure 30). During 3 of the 11 effluent sampling events, the system was not functioning properly. Calculations for TN reduction and attenuation are made using the median effluent (Eff) TN and Cl values. Values calculated for TN reduction are shown in Table 40.

Attenuation of TN, as represented by TN/CL rations are show in Figure 31 ant Table 40. Insufficient volumes of water were in the Deep Lysimeters during the June and September sampling events. On the 09/28/09 sampling event S-L-6 had enough sample for nitrogen analysis but not for chloride. Only lysimeter S-L-6 had enough sample for analysis on 06/19/09, and no chloride samples could be collected from any of the lysimeters on 09/29/09. The drainfield well had lower concentrations of both TN and Cl than the background well, and therefore monitoring well data were not used in the TN/Cl data analysis. The median TN attenuation via denitrification, adsorption or plant uptake at this site was 32%.

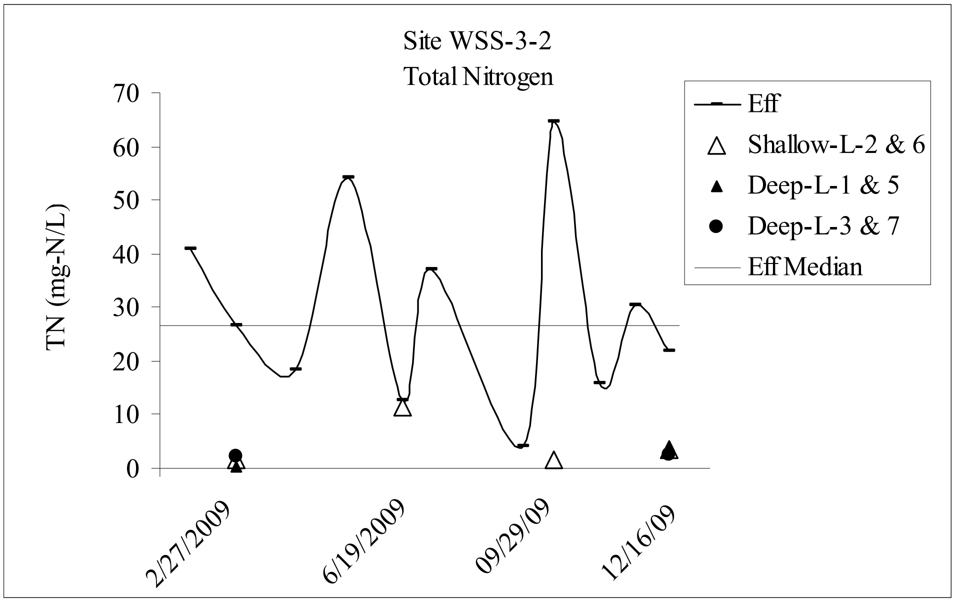


Figure 30. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-3-2. Sampling dates for effluent that included lysimeters and wells were 02/27/09, 06/196/09, 09/29/09, and 12/16/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Table 40. The TN in mg-N/L and the percent TN reduction (Red) <u>including dilution</u> is given for each of the four sampling events and the median values for the PBTS effluent (Eff) and lysimeters. The lysimeters S-L-2, D-L-1, and D-L-3 were relocated and renumbered prior to the 06/16/09 sampling as S-L-6, D-L-5, and D-L-7, respectively. The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-3-2	2/27/09		6/19/09		9/29/09		12/16/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**26.6**	*0%*	**12.7**	*52%*	**64.7**	*-143%*	**21.7**	*18%*	**26.6**	*0%*
S-L-2 or 6	**1.6**	*94%*	**11.4**	*57%*	**1.6**	*94%*	**3.6**	*87%*	**3.6**	*90%*
D-L-1 or 5	**0.4**	*98%*	**NS**		**NS**		**4.2**	*84%*	**NA**	
D-L-3 or 7	**2.2**	*92%*	**NS**		**NS**		**2.5**	*90%*	**NA**	
DF Well	**0.5**	*98%*	**0.7**	*97%*	**1.3**	*95%*	**1.6**	*94%*	**1.0**	*96%*

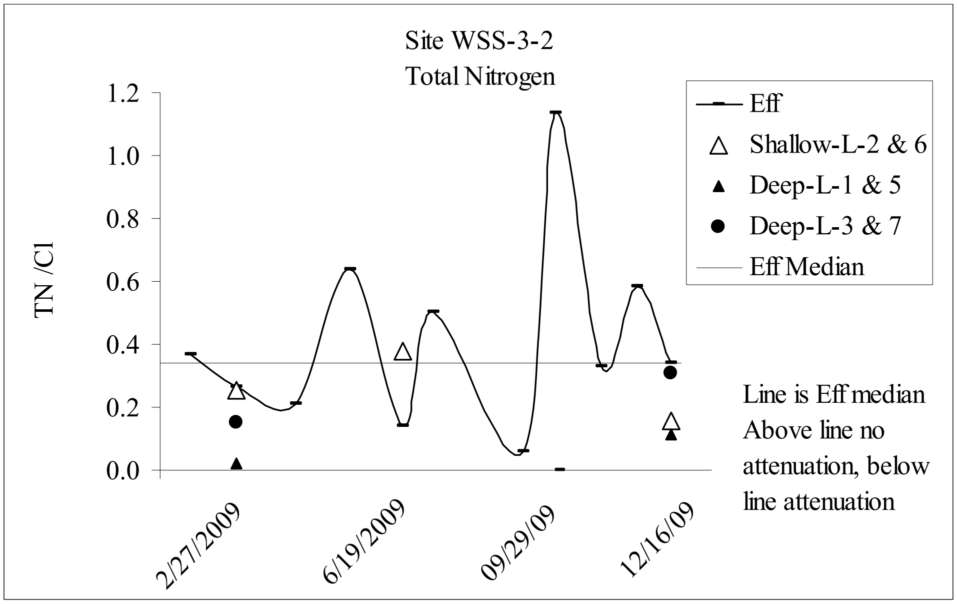


Figure 31. The TN/Cl ratios for site WSS-3-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 41. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. The median TN attenuation and Cl dilution are calculated from the medians of the TN and Cl values and are not the medians of the given TN Attenuation and Cl dilution.

WSS-3-2	2/27/2009		6/19/2009		12/16/2009		**Medians**	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN att**	*Cl dil*
Shallow-L-2 & 6	**25%**	*93%*	**-11%**	*65%*	**54%**	*73%*	**25%**	73%
Deep-L-1 & 5	**94%**	*77%*	NS		**66%**	*58%*	**80%**	68%
Deep-L-3 & 7	**55%**	*84%*	NS		**9%**	*90%*	**32%**	87%

Site WSS-5-2

Site WSS-5-2 has a mounded conventional drainfield system covered by a mowed lawn. The bottom of the drainfield chambers are 21 in (53 cm) below the soil surface in the location of the lysimeters. The shallow lysimeters were installed so the top of 9 inch (23 cm) cups were approximately 2 ft (0.6 m) below the drainfield (Table 42). During the February sampling event, lysimeters S-L-1, S-L-3, and S-L-4 had barely enough water for a sample. In an effort to find an area of the drainfield with more effluent, these three lysimeters were moved and re-numbered. Limestone prevented the installation of deeper lysimeters and each lysimeter was placed so the top of the cup was 45 in (114 cm) below the ground surface and the bottom of the cup at 54 in (137 cm).

Table 42. The depth from surface is given for the bottom of the drainfield(DF Bottom), the top of the lysimeter cup (Top of Cup) and the bottom of the lysimeter cup (Bottom of Cup)

WSS-5-2	Description	DF Bottom	Top of Cup	Bottom of Cup
S-L-1	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-2	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-3	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-4	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-5	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-6	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
S-L-7	**Shallow**	21 in (53 cm)	45 in (114 cm)	54 in (137 cm)
BG-L	**Background**		37 in (94 cm)	46 in (117 cm)

The Cl concentrations in the background well were higher than both the background lysimeter and the drainfield well (Table 43). The elevated Cl in the background well may have been the result of the homeowner washing off the salt (with bleach?) from his boats and other equipment after returning from the coast, in the area near the background well. The median Cl concentration of the background lysimeter was chosen as the $Cl_{background}$ term in both the Cl dilution and TN attenuation calculations.

Table 43. The Cl and TN concentrations of the background well (BG Well), the background lysimeter (BG-L), and the lysimeter located off the drainfield mound (OM-L), next to the drainfield well. Concentrations of Cl and TN are given in mg/L and mg-N/L, respectively. The mean, standard deviation (SD), and median of the four sampling events are given.

WSS-5-2	Background Well		Background-L		Drainfield Well	
	Cl	**TN**	*Cl*	**TN**	*Cl*	TN
2/26/2009	*20*	**0.2**	*7.6*	**0.2**	*8.4*	**3.1**
6/18/2009	*17*	**0.2**	*3.8*	**0.2**	*8.8*	**2.7**
10/01/09	*16*	**0.2**	*2.8*	**0.2**	*9.8*	**3.4**
12/17/09	*13*	**0.2**	*5.5*	**0.1**	*7.2*	**1.0**
mean	***16.5***	**0.2**	***4.9***	**0.2**	***8.5***	**2.5**
SD	*2.9*	0.0	*2.1*	0.0	*1.1*	1.0
median	***16.5***	**0.2**	***4.7***	**0.2**	***8.6***	**2.9**

Total nitrogen concentrations in the effluent, lysimeters and drainfield well are plotted in Figure 32 and the reduction in TN concentrations calculated for the various sampling points are shown in Table 43.

The TN/Cl values plotted for the monitoring points over time are presented in Figure 33. At this site TN reduction ranged from 70% to 91% but this was due to considerable dilution (Table 45). Excluding dilution, TN attenuation ranged from 8% to 76%. The median value for this site was 31%.

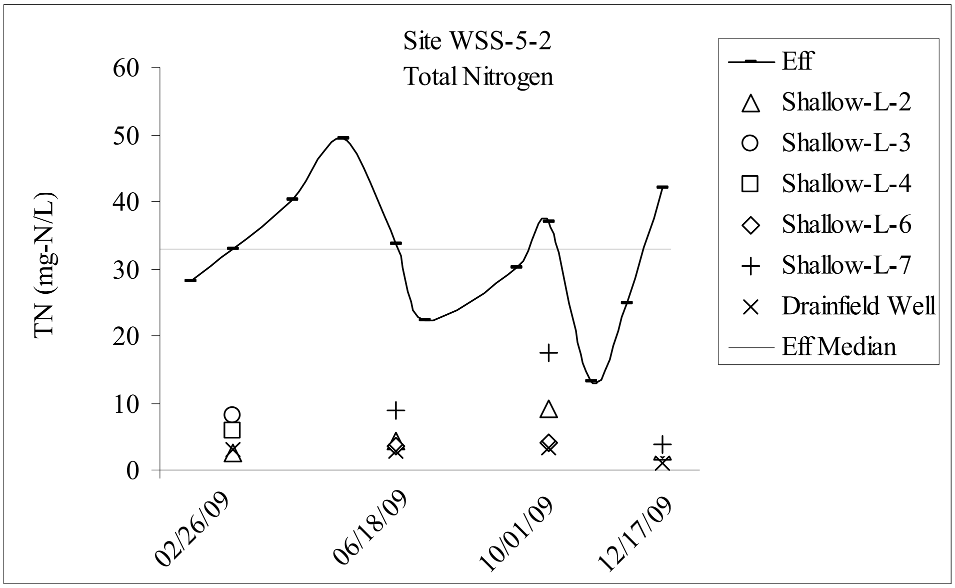


Figure 32. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-5-2. Sampling dates for effluent that included lysimeters and wells were on 02/26/09, 06/18/09, 10/01/09, and 12/17/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Table 44. The TN in mg-N/L and the percent TN reduction(Red) including dilution is given for each of the four sampling events and the median values for the PBTS effluent (Eff), the shallow lysimeters (S-L-2, S-L-3, S-L-5) and the deep lysimeters (D-L-1, D-L-4). The median TN of the effluent was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 11 effluent sampling events.

WSS-5-2	2/26/09		6/18/09		10/01/09		12/17/09		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
Eff	**33.0**	*0%*	**33.6**	*-2%*	**37.0**	*-12%*	**42.0**	*-27%*	**33.0**	*0%*
S-L-2	**2.7**	*92%*	**4.3**	*87%*	**9.2**	*72%*	**2.7**	*92%*	**3.5**	*89%*
S-L-3	**8.1**	*76%*	Removed							
S-L-4	**5.7**	*83%*	Removed							
S-L-5	Not Installed		**9.9**	*70%*	**12.8**	*61%*	**5.1**	*85%*	**9.9**	*70%*
S-L-6	Not Installed		**3.6**	*89%*	**4.0**	*88%*	**3.1**	*91%*	**3.6**	*89%*
S-L-7	Not Installed		**8.9**	*73%*	**17.5**	*47%*	**3.7**	*89%*	**8.9**	*73%*
DF Well	**3.1**	*91%*	**2.7**	*92%*	**3.4**	*90%*	**1.0**	*97%*	**2.9**	*91%*

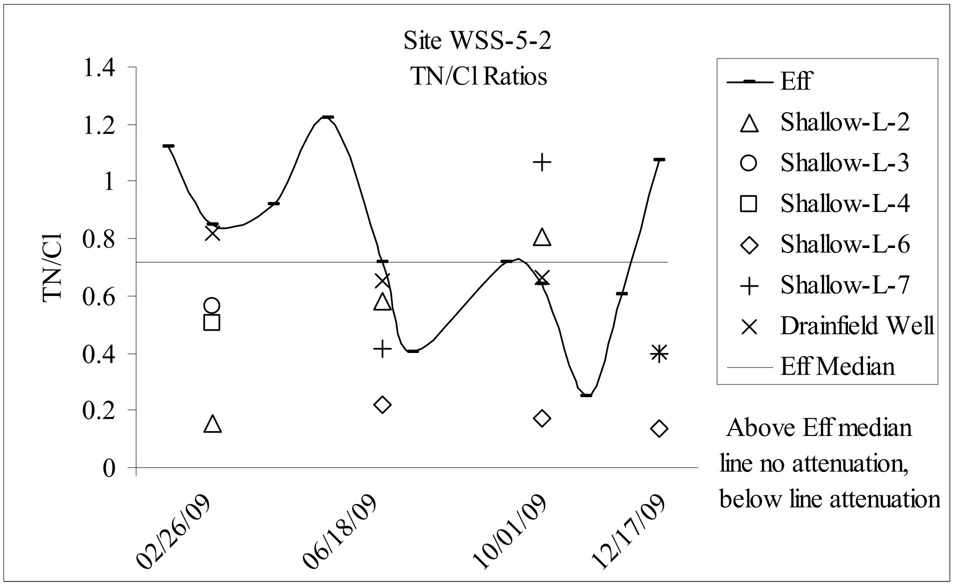


Figure 33. The TN/Cl ratios for the site WSS-5-2. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 45. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. The median TN attenuation and Cl dilution are calculated from the medians of the TN and Cl values and are not the medians of the given TN Attenuation and Cl dilution.

WSS-5-2	2/26/09		6/17/09		10/01/09		12/17/09		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
S-L-2	**79%**	*59%*	**19%**	*83%*	**-12%**	*73%*			**19%**	*73%*
S-L-3	**22%**	*66%*	Removed							
S-L-4	**30%**	*73%*	Removed							
S-L-5	Not Installed		**NS**		**-24%**	*66%*	**32%**	*75%*		
S-L-6	Not Installed		**70%**	*61%*	**76%**	*44%*	**81%**	*47%*	**76%**	*47%*
S-L-7	Not Installed		**42%**	*49%*	**-49%**	*61%*	**45%**	*78%*	**42%**	*61%*
DF Well	**-14%**	*91%*	**9%**	*90%*	**8%**	*88%*	**44%**	*94%*	**8%**	*91%*

4.3 TN Attenuation in Phase I Drainfields of Conventional Septic Systems.

The three septic systems studied in Phase I all had conventional septic tanks with at grade conventional drainfields. A full report on Phase I of this study can be found in Katz, et al, 2010. The purpose of including the Phase I data in this report is to allow comparison between the results of Phase I and Phase II studies using the same data analysis techniques.

The lysimeters in Phase 1 were of a similar design as in Phase II, using the same type of 10 inch porous cups. However in Phase I, copper tubing was used instead of PVC pipe and a different manner of attaching the lysimeter cup to the body was employed. Two short lysimeters were installed at each of the three sites so that the 10 in. lysimeter cup was at depth of 36 to 46 inches (92-118 cm) below the surface. At this depth the top of the lysimeter cup was directly beneath the bottom of the drainfield. The long lysimeters were installed so the lysimeter cup was 66 to 76 inches (168-194 cm) below surface. Although four lysimeters were installed at each site, 2 shallow and 2 deep, the two shallow lysimeters were combined into one sample and the two lysimeters were combined for one sample. This was done because of the large sample volume needed for other the parameters being measured by USGS in Phase I.

Phase I Site HK

The HK system served 4 residents and the house was constructed in the 1970s. After the first sampling on 12/17/07, the old drainfield was replaced in January 2008 due to drainfield failure. The new drainfield was in another area of the lot and Infiltrator chambers were installed. The area of the new drainfield was seeded with rye grass that was fertilized with a few handfuls of fertilizer, as reported by the homeowner. Both shallow and deep lysimeters were installed in the new drainfield, while at the old drainfield only shallow lysimeters were installed due to proximity of clay and limestone to the surface in that area. In May 2008, the area was re-seeded with summer grass and approximately 2.3 kg of 10-10-10 fertilizer was applied by the home owner. Additionally, more of the same fertilizer (less than 2 kg) was applied to the garden adjacent to drainfield. The depth of water table during the study ranged from 8.5 to 8.9 ft (2.6 to 2.7 m). The average daily water use during the study period for this site was 430 g/day (1,630 L/d), although after the drainfield was replaced conservation measures reduced the amount of water discharged to the septic system. Figure 34 is a plot of the TN concentrations in the lysimeters and drainfield wells at the HK site.

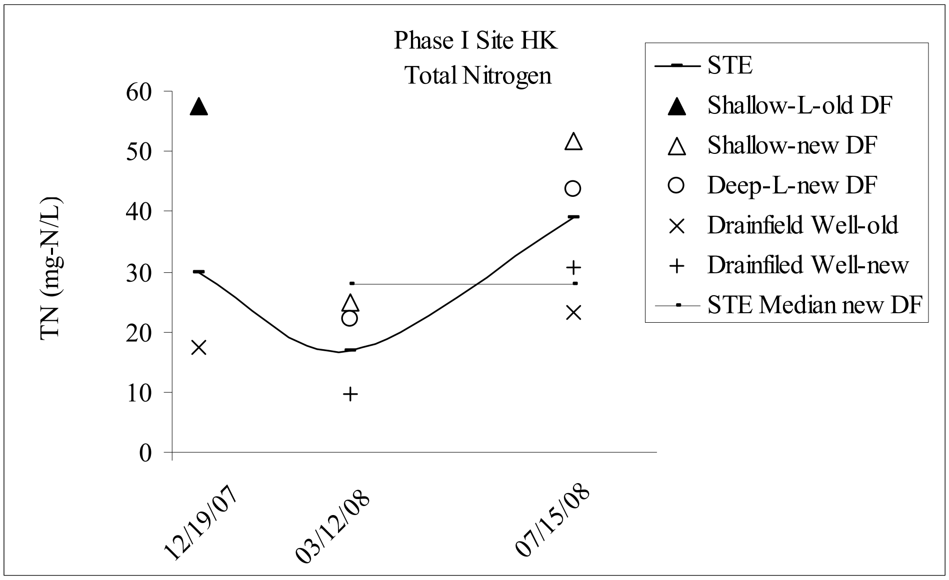


Figure 34. The TN concentrations are given for the Septic Tank Effluent (STE), lysimeters and drainfield well at the Phase I site HK. This graph includes the effect of dilution. After the 12/19/07 sampling event the drainfield at this site was replaced. Both the new and old drainfield wells were sampled on 07/15/08. TN concentrations are in mg-N/L.

The TN concentrations of STE (28.0 ± 15.6 mg-N/L) were about half what is typically found discharged from a conventional septic tank. The higher than average water use most likely diluted the effluent stream. The calculated percent reductions in TN at the various sampling points at this site are shown in Table 46.

Table 46. The TN in mg-N/L and the percent TN reduction (Red) including dilution for the STE, lysimeters and drainfield well is given for each of the three sampling events. The drainfield was replaced after the 12/19/07 sampling event. The TN reduction for 12/19/07 is calculated from the STE TN concentration on that date. The TN reduction for the 03/12/08 and 07/15/08 sampling events was calculated from the average of those two STE measurements.

HK Phase I	**12/19/07**		**03/12/08**		**07/15/08**	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*
STE	**30.0**	*0%*	**17.0**	*39%*	**39.0**	*-39%*
Shallow-L	**57.4**	*-105%*	**25.0**	*11%*	**51.6**	*-84%*
Deep-L			**22.1**	*21%*	**43.6**	*-56%*
DF Well	**17.5**	*38%*	**9.7**	*66%*	**30.6**	*-9%*

The TN concentration in the lysimeters was higher than the measured STE TN concentration on each sampling event. For the 12/19/07 data this was most likely due to the fact that the drainfield was failing in December 2007. On 03/12/08, the STE TN was exceptionally low, less than a third the typical concentration of 60 mg-N/L. Although larger than the measured STE, the lysimeters had TN concentrations of approximately half the concentrations measured on 12/19/07 and 07/15/08. The high TN concentrations measured on 07/15/08 are most likely the result of fertilizer application in May, 2008. The TN/Cl ratios for these samples are plotted in Figure 35.

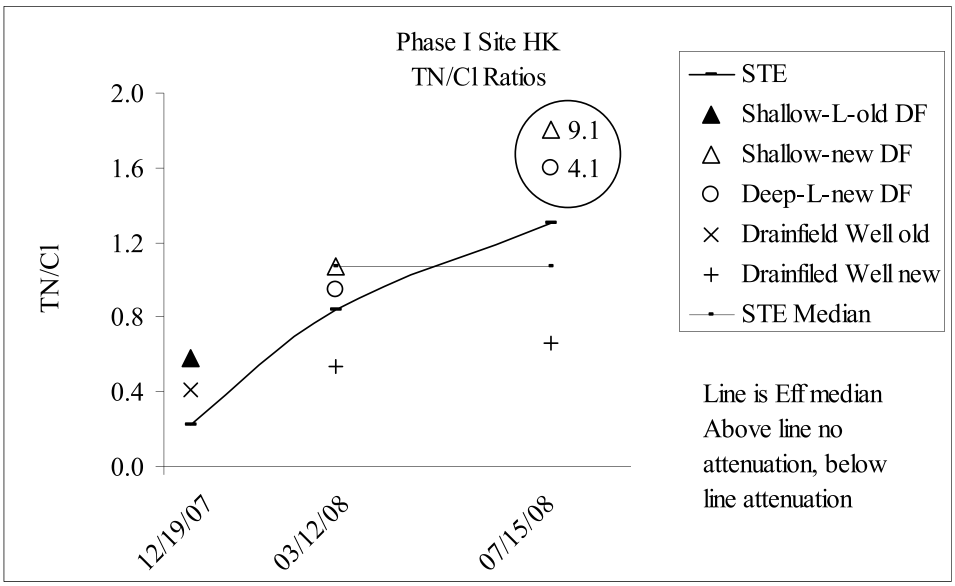


Figure 35. The TN/Cl ratios for site HK. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

The very high TN/Cl ratios in the lysimeters observed on 07/15/08 is most likely due to the addition of fertilizer two months prior. The higher ratio in the shallow lysimeter, indicating a greater increase of TN relative to Cl, supports this as the nitrogen was consumed as it moved downward in the soil. This sh shown in calculated values in Table 47. It is difficult to use the results of this site due to the fertilizer applications. TN was consistently in the lysimeters at higher concentrations than in the STE.

Table 47. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. The median TN attenuation and Cl dilution are calculated from the medians of the TN and Cl values and are not the medians of the given TN Attenuation and Cl dilution.

HK Phase I	**12/18/07**		**03/13/08**		**07/16/08**	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
Shallow-L	**-161%**	*27%*	**0%**	*7%*	**-745%**	*77%*
Deep-L			**12%**	*7%*	**-279%**	*57%*
DF Well	**-102%**	*71%*	**39%**	*41%*	**33%**	*-71%*

Phase I Site LT

Site (LT) had two to three adult residents who had lived in the house since it was built in 1987. The household utilized the original septic tank and drainfield. The current residents of the house had applied no fertilizers. Depth to groundwater ranged from 3.0-3.6 m during the study. The septic tank effluent (STE) TN from the three sampling events was very consistent, compared to the effluent of PBTS (Figure 36). Average daily water use at the LT site was 394 L/d (104 gal/d).

The percent TN reduction observed in the lysimeters and drainfield well are shown in Table 48. Both the STE TN concentrations (54.0 mg-N/L) and DF well TN concentrations (24 mg-N/L) were relatively consistent over the three sampling events. The lysimeter TN concentrations varied significantly over the three sampling events (Table 48).

The TN/Cl plot in Figure 36 shows the amount of nitrogen attenuation measured by the lysimeters and drainfield wll.

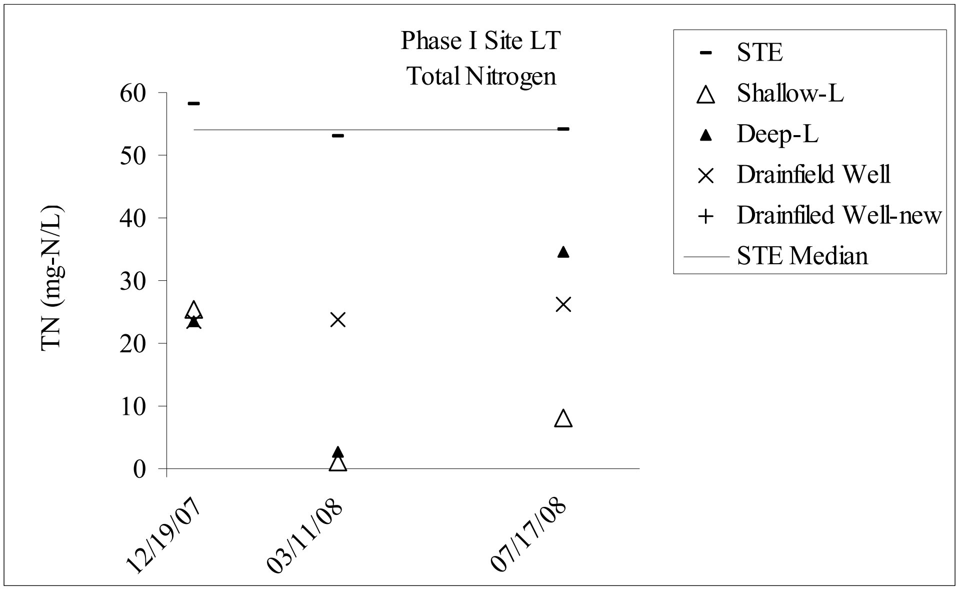


Figure 36. The TN concentrations are given for the septic tank effluent,, lysimeters and drainfield well at site LT. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Table 48. The TN in mg-N/L and the percent TN reduction (Red) including dilution is given for each of the three sampling events and the median values for the septic tank effluent (STE), the combined sample of both shallow lysimeters and combined sample of the deep lysimeters). The median TN of the STE was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 3 sampling events.

LT Phase I	**12/19/07**		**03/11/0**		**07/17/08**		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
STE	**58.0**	*-7%*	**53.0**	*2%*	**54.0**	*0%*	**54.0**	*0%*
Shallow-L	**25.5**	*53%*	**1.0**	*98%*	**8.1**	*85%*	**8.1**	*85%*
Deep-L	**23.4**	*57%*	**2.7**	*95%*	**34.6**	*36%*	**23.4**	*57%*
DF Well	**23.4**	*57%*	**23.8**	*56%*	**26.2**	*52%*	**23.8**	*56%*

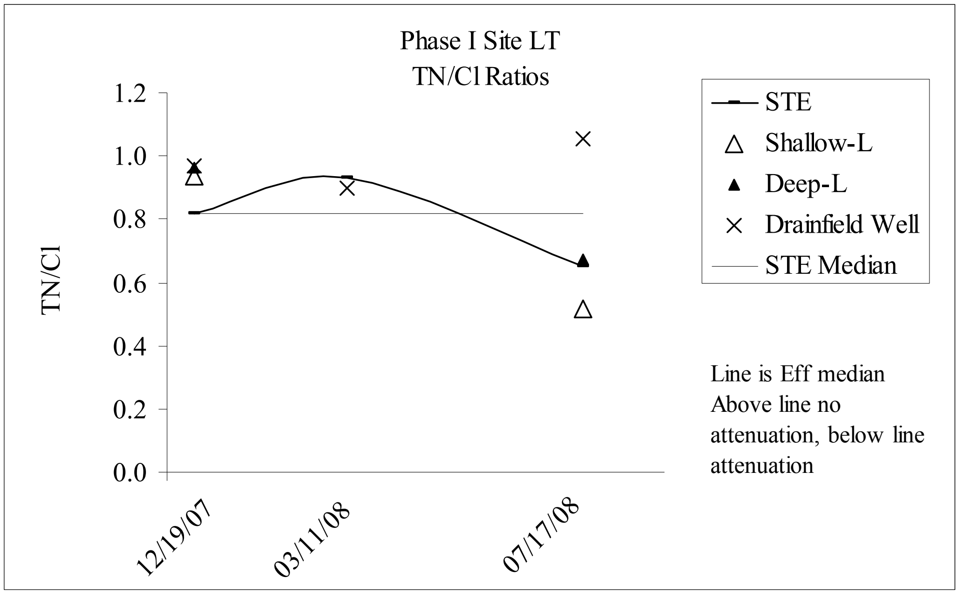


Figure 37. The TN/Cl ratio for the site LT. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

On the 03/11/08 sampling event, the background well Cl concentration was greater than Cl concentration in both the shallow and deep lysimeters, indicating the samples were 100% or more diluted (Table 49). TN attenuation other than dilution was not observed in the drainfield well samples at this site. On the 12/19/07 sampling event, no attenuation other than dilution was observed in either the shallow or deep lysimeters. However, attenuation was observed in both the shallow and deep lysimeters in July. The overall median N attenuation by denitrification/adsorption/plant uptake at this site was 0%.

Table 49. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. The median TN attenuation and Cl dilution are calculated from the medians of the TN and Cl values and are not the medians of the given TN Attenuation and Cl dilution.

LT Phase I	**12/19/07**		**03/11/0**		**07/17/08**		Medians	
	TN Atten	*Cl Dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
Shallow-L	**-14%**	*62%*	**NA**	*102%*	**36%**	*78%*	**11%**	*78%*
Deep-L	**-18%**	*66%*	**NA**	*100%*	**18%**	*27%*	**0%**	*66%*
DF Well	**-19%**	*66%*	**-10%**	*63%*	**-29%**	*65%*	**-19%**	*65%*

Phase I Site YG

The YG site had two adult residents that have lived in the household for four years, and the house was built around 2003. The original septic tank system was in use at the time of the study. The residents of the house had applied no fertilizers. Depth to the water table ranged from 4.1-4.4 m during the study. The overall median N attenuation at this site attributable to denitrification/adsorption was 66%. Figure 38 shows the TN concentrations over time in the effluent, lysimeters and drainfield well and Table 50 shows the calculated TN reduction at each of the sampling points.

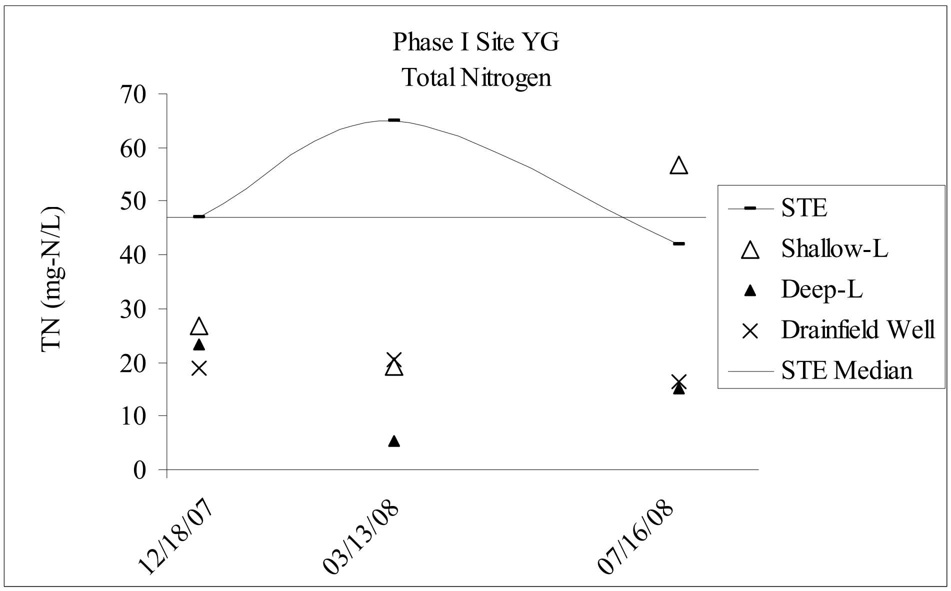


Figure 38. The TN concentrations are given for the PTBS effluent (Eff), lysimeters and drainfield well at site WSS-2-2. Sampling dates for effluent that included lysimeters and wells were 02/26/09, 06/18/09, 10/01/09, and 12/17/09. TN concentrations are in mg-N/L. The graph includes the effect of dilution.

Table 50. The TN in mg-N/L and the percent TN reduction (Red) <u>including dilution</u> is given for each of the three sampling events and the median values for the septic tank effluent (STE), the combined sample of both shallow lysimeters and combined sample of the deep lysimeters). The median TN of the STE was used for the % reduction calculations, thus the % reduction of the effluent for each sampling event indicates the variance from the median of the 3 sampling events.

YG Phase I	**12/18/07**		**03/13/08**		**07/16/08**		Medians	
	TN	*Red*	**TN**	*Red*	**TN**	*Red*	**TN**	*Red*
STE	**47.0**	*0%*	**65.0**	*-38%*	**42.0**	*11%*	**47.0**	*0%*
Shallow-L	**26.7**	*43%*	**19.4**	*59%*	**56.8**	*-21%*	**26.7**	*43%*
Deep-L	**23.3**	*50%*	**5.4**	*88%*	**15.0**	*68%*	**15.0**	*68%*
DF Well	**19.0**	*60%*	**20.6**	*56%*	**16.4**	*65%*	**19.0**	*60%*

Figure 39 shows the TN/Cl effluent concentrations in the lysimeters and drainfield well calculated from measurements taken during the three sampling periods and Table 51 shows the calculated attenuation of nitrogen that occurred at each of the points.

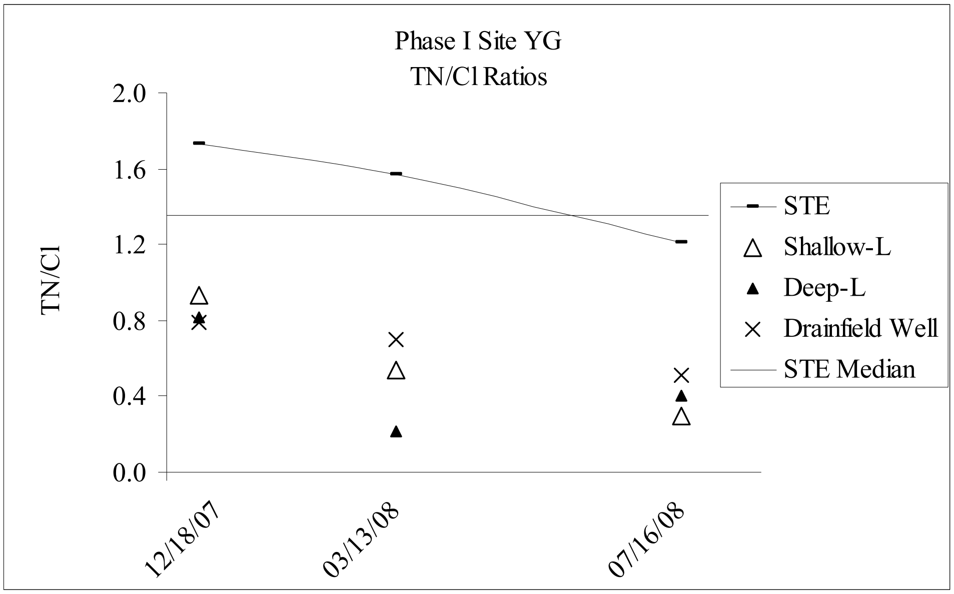


Figure 39. The TN/Cl ratio for the site YG. Samples with TN/Cl ratios smaller than the effluent ratio show attenuation of nitrogen, not including the effect of dilution. Calculations for TN reduction were made using the median effluent TN concentration. The graph is corrected for dilution.

Table 51. The percent <u>TN attenuation</u> (TN Atten) calculated from the TN/CL ratios and therefore accounts for dilution. The percent of Cl dilution (CL dil) is also given. The median TN attenuation and Cl dilution are calculated from the medians of the TN and Cl values and are not the medians of the given TN Attenuation and Cl dilution.

YG Phase I	**12/18/07**		**03/13/08**		**07/16/08**		Medians	
	TN Atten	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*	**TN Atten**	*Cl dil*
Shallow-L	**41%**	*17%*	**66%**	*-4%*	**81%**	*-457%*	**66%**	*-4%*
Deep-L	**48%**	*18%*	**86%**	*29%*	**74%**	*-8%*	**74%**	*18%*
DF Well	**50%**	*31%*	**56%**	*15%*	**67%**	*8%*	**56%**	*15%*

4.4 Dilution in drip systems versus conventional drainfield systems.

Lysimeter and drainfield well samples from PBTS sites with drip systems captured roughly 50% of the effluent, as indicated by the % dilution calculated from the Cl data. At site WSS-1-2, median dilution ranged from 25 to 46% for the lysimeters and 36% for the drainfield well (Table 22). At site WSS-4-2 (Table 26), dilution ranged from 10 to 66% for the lysimeters and was 85% for the drainfield well. At site WSS-6-2, dilution ranged from 9 to 36% for the lysimeters and was 80% for the drainfield well. At site WSS-7-2, dilution ranged from 18% to 54% for the lysimeters. The variation in dilution shows the importance in correcting TN reduction to TN attenuation based on TN/Cl ratios.

For PBTS sites with conventional drainfields, dilution was as follows: at site WSS-2-2, the lysimeters were diluted by 32-64%, the drainfield well by 60%; at site WSS-3-2, the lysimeters were diluted by 73-87%; at site WSS-5-2 the lysimeters were diluted by 47-73%, the drainfield well by 91%; at site HK the lysimeters were diluted by 47-77%; at site LT the lysimeters were diluted by 66 to 78%, the drainfield well by 65%; and at site YG the lysimeters were diluted by 0-18%, while the drainfield well was diluted by 15%. Overall, the dilution factors, as revealed by the Cl data, attest to the importance of correcting the TN data for dilution when figuring N-attenuation.

4.5 TN attenuation in Pressurized drip drainfields compared to conventional drainfields

An objective of this study was to determine if pressurized drip drainfields provided greater TN attention in comparison to conventional drainfields. Our results were not able to discern any difference between the effectiveness of the two types of installation (Table 52). Admittedly the results are subject to considerable variability, however despite the variability two of the drainfields clearly stand out in the data, Site WSS-4-2, and site YG.

Table 52. Median results for TN attenuation (excluding dilution) at the sites. Negative TN values were input as 0 values.

	Drainfield Type	Median	Min-max
WSS-1-2	Drip w/ slight mound	10%	2-32
WSS-4-2	Drip with Large Mound	78%	10-85
WSS-6-2	Drip at grade	30%	0-31
WSS-7-2	Drip at grade	0%	0-38
Median		20%	
WSS-2-2	Conventional at grade	0%	8-67
WSS-3-2	Conventional at grade	32%	25-80
WSS-5-2	Conventional large mound	31%	8-76
LT	Conventional at grade	0%	0-11
YG	Conventional at grade	66%	56-74
Median		31%	
OVERALL MEDIAN for 9 sites		30%	

Site WSS-4-2 was unique in that it was a mounded drip system, but further, the homeowner allowed the vegetation to grow more or less unchecked over the drip lines (Figure 40), as opposed to all other systems which were covered with a mowed lawn. As the drip lines were placed 8 to 12 inches (20-30 cm) below grade, our data suggest that the drip lines may be too deep to be influenced by root uptake from lawn-type vegetation, while the roots of the vegetation at site WSS-4-2 were sufficiently deep to access the drip system. Site YG did not exhibit any surface characteristics that would indicate why its performance was so efficient.

Figure 40. Vegetation growing over drip irrigation at site WSS-4-2.

4.6 Nitrate input to groundwater from septic tanks.

For the Wakulla County sites included in the CSM study, the average conventional septic tank effluent (STE) concentration was 64 ± 13 mg-N/L (Fig. ES-2). For all 35 PBTS that were sampled in this study, the average TN concentration for effluent was 29 ± 19 mg-N/L. The PBTS systems reduced N output 57 to 59% based on a raw sewage value of 70 mg-N/L. Our results indicate that the average N-attenuation in the drainfield is an additional 30%. These results indicate that for Wakulla County, a typical conventional septic tank input is 45±9 mg-N/L of wastewater to the aquifer (64* (1-0.3)). A typical PBTS system inputs 20 ± 13 mg-N/L of wastewater to the aquifer (29* (1-0.3)). Average daily water use for the 11 residences in the Phase I and Phase II study was 988±492 L/d (261.0 ± 130.0 gallons/d)(Appendix A). Thus the typical N-flux to the aquifer from a conventional septic tank is 44 ± 24 gram N per day (0.088 lbs per day). For a PBTS the value is 20 ± 16 gram N per day (0.044 lbs/day).

Summary of Findings

- The total nitrogen (TN) input value for raw sewage inputs to septic systems was 72.8 ± 39.2 mg-N/L, n=17 from five households served by PBTS. A companion study by the

- The average of monthly effluent samples from the Phase II study of 8 PBTS sites was 30 ± 11 mg-N/L. The results of the Phase II study of the 8 PBTS sites are consistent with the results of the 27 PBTS that were also sampled that was 29 ± 21 mg-N/L. For all 35 PBTS that were sampled, the average TN concentration was 29 ± 19 mg-N/L. This average concentration is a factor of three times greater than the 10 mg-N/L target effluent concentration included in Wakulla County Ordinance 2006-58 which is based on the NSF/ANSI testing standard.

- Performance Based Treatment Systems installed in Wakulla County reduce nitrogen 50-60% from input concentrations when properly maintained. Using a raw wastewater input concentration of 70 mg-N/L and the effluent results in bullet number 2 above; the 8 primary study sites yield a TN reduction of 57 ± 16%. For the 27 sites sampled only once, we calculated a TN reduction of 59 ± 30%. From direct measurements of PBTS inputs (raw sewage) and effluent on 5 sites, we calculate an average % reduction of 49.2 ± 17.8.

- Compliance, operation and maintenance issues in Wakulla County are responsible for a large percentage of systems being non-operational and performing poorly.

- Lysimeters and wells placed within pressurized drip drainfield systems and conventional drainfield systems captured roughly 50% septic tank effluent based upon Cl concentration data. Median nitrogen attenuation was 30% in these systems. Four drip systems and five conventional systems were evaluated. Our results did not allow us to discern greater effectiveness in the drip systems in comparison to the conventional systems.

- For the Wakulla County sites included in the CSM study, the average conventional septic tank effluent (STE) concentration was 64 ± 13 mg-N/L (Fig. ES-2). For all 35 PBTS that were sampled in this study, the average TN concentration was 29 ± 19 mg-N/L. Our results indicate that N-attenuation in the drainfield is 30%. These results indicate that for Wakulla County, a typical conventional septic tank inputs 45±9 mg-N/L of waste water to the aquifer. A typical PBTS system inputs 20 ± 13 mg-N/L of waste water to the aquifer. Average daily water use for the 11 residences in the Phase I and Phase II study was 988±492 L/d (Appendix A). Thus the typical N-flux to the aquifer from a conventional septic tank is 44 ± 24 gram N per day. For a PBTS, the average N flux to the aquifer would be 20 ± 16 gram N per day.

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Appendix A. FDEP Laboratory data of the Septic Tank Effluent, Lysimeters and Wells from Phase II The average daily flow and the load calculations of TN and TP in pounds per year are given. Duplicates are indicated by a "d"

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-1-2 Raw Input	01/28/09	23	5.5	70	0.42	70.4	17	211.5	45.3	10.9
WSS-1-2 Raw Input	02/25/09	24	2.7	29	0.93	29.9	3.1	185.9	16.9	1.8
WSS-1-2 Raw Input d	02/25/09	23	2.7	30	0.93	30.9	3.2	185.9	17.5	1.8
WSS-1-2 Raw Input	04/01/09	15	3	32	0.51	32.5	6.6	231.5	22.9	4.6
WSS-1-2 Raw Input	05/08/09	54	32	86	1.1	87.1	18	155.8	41.3	8.5
WSS-1-2 Trash Tank	03/31/09	25	39	54	0.005 I	54.0	7.8	231.5	38.0	5.5
WSS-1-2 Trash Tank	05/08/09	33	49	72	0.009 I	72.0	10	155.8	34.1	4.7
WSS-1-2 Trash Tank	06/16/09	40	32	36	0.017	36.0	9.8	188.5	20.7	5.6
WSS-1-2 Trash Tank d	06/16/09	39	31	35	0.023	35.0	9.5 A	188.5	20.1	5.4
WSS-1-2 Effluent	01/28/09	37	48	53	0.029	53.0	8.8	211.5	34.1	5.7
WSS-1-2 Effluent	02/25/09	40	34	40	0.24	40.2	7.9	185.9	22.8	4.5
WSS-1-2 Effluent d	02/25/09	41	34	40	0.24	40.2	8	185.9	22.8	4.5
WSS-1-2 Effluent	04/01/09	28	38	43	0.057	43.1	6.7	231.5	30.3	4.7
WSS-1-2 Effluent	05/08/09	36	38	46	0.17	46.2	8.6	155.8	21.9	4.1
WSS-1-2 Effluent	06/16/09	42	3.6	5.3	15	20.3	7.9	188.5	11.6	4.5
WSS-1-2 Effluent	07/09/09	36	0.65	2.2	8.3	10.5	7.8	617.3	19.7	14.7
WSS-1-2 Effluent	09/08/09	33	31	35	1.2	36.2	9.9	194.9	21.5	5.9
WSS-1-2 Effluent	09/28/09	39	55	58	0.12 I	58.0	7.7	194.9	34.5	4.6
WSS-1-2 Effluent	10/30/09	32	2.1	3	13	16.0	6.2	162.0	7.9	3.1
WSS-1-2 Effluent	11/23/09	30	46	53	0.063	53.1	0.72	215.8	34.8	0.5
WSS-1-2 Effluent	12/15/09	45	46	59	0.04	59.0	7.2	231.6	41.6	5.1

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-1-2-Shallow-L-1	02/25/09	25	0.22	1.7	27	28.7	3.8	185.9	16.2	2.1
WSS-1-2-Shallow-L-1	06/16/09	35	0.051	1.8	14	15.8	1.9	188.5	9.1	1.1
WSS-1-2-Shallow-L-1	09/28/09	37	0.01 U	1.2	33	34.2	1.9 A	194.9	20.3	1.1
WSS-1-2-Shallow-L-1	12/15/09	16	0.19 J	1.1	32	33.1	5.4	231.6	23.3	3.8
WSS-1-2-Shallow-L-4	02/25/09	17	0.016 I	1	15	16.0	0.057 A	185.9	9.0	0.0
WSS-1-2-Shallow-L-4	06/16/09	28	0.01 U	1.2	4.2	5.4	0.021	188.5	3.1	0.0
WSS-1-2-Shallow-L-4	09/28/09	28	0.01 U	0.86 I	26	26.0	0.011	194.9	15.9	0.0
WSS-1-2-Shallow-L-4	12/15/09	7	0.012 I	0.7	11	11.7	0.11	231.6	8.2	0.1
WSS-1-2-Deep-L-2	02/25/09	28	0.01 U	1.1	32	33.1	2.3	185.9	18.7	1.3
WSS-1-2-Deep-L-2	06/16/09	28	0.018 I	1.2	12	13.2	2.6	188.5	7.6	1.5
WSS-1-2-Deep-L-2	09/28/09	26	0.01 U	0.89 I	26	26.0	1.6	194.9	16.0	0.9
WSS-1-2-Deep-L-2	12/15/09	27	0.11	0.9 I	42	42.0	3.9	231.6	30.2	2.7
WSS-1-2-Deep-L-3	02/25/09	30	0.045	0.79 I	38	38.0	0.009 I	185.9	21.9	0.0
WSS-1-2-Deep-L-3	06/16/09	36	0.016 I	1.1	11	12.1	1.3	188.5	6.9	0.7
WSS-1-2-Deep-L-3	09/28/09	24	0.01 U	0.63	18	18.6	1.2	194.9	11.1	0.7
WSS-1-2-Deep-L-3	12/15/09	27	0.023	0.52 I	44	44.0	2	231.6	31.4	1.4

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-1-2 DF WELL	02/25/09	31	0.013 I	0.4 U	26	26.0	0.01 I	185.9	14.9	0.0
WSS-1-2 DF WELL	06/16/09	25	0.01 U	0.26 I	17	17.0	0.006 I	188.5	9.9	0.0
WSS-1-2 DF WELL d	06/16/09	25	0.01 U	0.16 I	17	17.0	0.006 I	188.5	9.8	0.0
WSS-1-2 DF WELL	09/28/09	27	0.01 U	0.24 I	11	11.0	0.008 I	194.9	6.7	0.0
WSS-1-2 DF WELL d	09/28/09	27	0.01 U	0.28 I	11	11.0	0.006 I	194.9	6.7	0.0
WSS-1-2 DF WELL	12/15/09	22	0.011 I	0.4 U	23	23.0	0.011	231.6	16.5	0.0
WSS-1-2 DF WELL d	12/15/09	22	0.01 U	0.4 U	23	23.0	0.009 I	231.6	16.5	0.0
WSS-1-2-Off Mound-L	02/25/09	6.9 A	0.05 U	0.2	0.005 I	0.2	0.031			
WSS-1-2-Off Mound-L	06/16/09	0.61	0.01 U	0.36	0.006 I	0.4	0.005 I			
WSS-1-2-Off Mound-L	09/28/09	1.8	0.01 U	0.37	0.023	0.4	0.016			
WSS-1-2-Off Mound-L	12/15/09	2.5	0.01 U	0.26	0.033	0.3	0.004 U			
WSS-1-2 BG WELL	02/25/09	2.5	0.01 U	0.081 I	0.091	0.1	0.03			
WSS-1-2 BG WELL	06/16/09	2.9	0.01 U	0.09 I	0.15	0.2	0.011			
WSS-1-2 BG WELL	09/28/09	3.3	0.01 U	0.095 I	0.17	0.2	0.007 I			
WSS-1-2 BG WELL	12/15/09	3.4 A	0.01 U	0.08 U	0.19	0.2	0.013			
WSS-1-2 BG-L	02/25/09	9.2 A	0.01 U	0.2 I	0.004 U	0.0	0.012			
WSS-1-2 BG-L	06/16/09	1.5	0.01 U	0.23	0.005 I	0.2	0.007 I			
WSS-1-2 BG-L	09/28/09	0.76	0.01 U	0.16	0.005 I	0.2	0.004 U			
WSS-1-2 BG-L	12/15/09	1.5	0.025	0.14 I	0.004 U	0.0	0.004 U			

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-1-2 Well Water	02/25/09	9.2	0.01 U	0.08 U	1.2	1.2	0.011			
WSS-1-2 Well Water	06/16/09	3.6	0.014 I	0.08 U	0.13	0.1	0.02			
WSS-1-2 Well Water	09/28/09	5.5	0.01 U	0.08 I	0.53	0.5	0.017			
WSS-1-2 Well Water	12/15/09	7	0.014 I	0.08 U	0.6	0.6	0.013			
WSS-2-2 RAW Input	01/28/09	68	13	140	0.25	140.3	14	39.1	16.7	1.7
WSS-2-2 RAW Input	02/25/09	50	6.6	78	0.25	78.3	28	63.8	15.2	5.4
WSS-2-2 RAW Input	03/31/09	50	9.2	44	0.13	44.1	4.9	80.8	10.9	1.2
WSS-2-2 RAW Input d	03/31/09	49	8.6	41	0.12	41.1	4.6	80.8	10.1	1.1
WSS-2-2 RAW Input	05/15/09	34	6.9	51	0.005 I	51.0	8.6	66.4	10.3	1.7
WSS-2-2 RAW Input	06/16/09	87	61	170	0.16	170.2	24	82.8	42.9	6.0
WSS-2-2 Trash Tank	03/31/09	52	15	39	0.69	39.7	8.1	80.8	9.8	2.0
WSS-2-2 Trash Tank	05/15/09	45	24	35	0.008 I	35.0	8.7	66.4	7.1	1.8
WSS-2-2 Trash Tank d	05/15/09	45	24	34	0.008 I	34.0	8.9	66.4	6.9	1.8
WSS-2-2 Trash Tank	06/16/09	53	13	22	0.007 I	22.0	10	82.8	5.5	2.5

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-2-2 Effluent	01/28/09	56	0.3	3.5	24	27.5	9.5	39.1	3.3	1.1
WSS-2-2 Effluent	02/25/09	51	17	23	3.7	26.7	7.3 A	63.8	5.2	1.4
WSS-2-2 Effluent	03/31/09	55	0.63 J	2.8	26	28.8	9.6	80.8	7.1	2.4
WSS-2-2 Effluent d	03/31/09	55	0.62	2.9	26	28.9	9.8	80.8	7.1	2.4
WSS-2-2 Effluent	05/15/09	50	0.053	2.5	22	24.5	8.1	66.4	4.9	1.6
WSS-2-2 Effluent	06/16/09	54	0.095	4.1	19	23.1	8.5	82.8	5.8	2.1
WSS-2-2 Effluent	07/09/09	44	0.052	3.1	24	27.1	5.4	66.7	5.5	1.1
WSS-2-2 Effluent	09/08/09	48	0.15	2.7	20	22.7	6	119.2	8.2	2.2
WSS-2-2 Effluent	09/28/09	55	2.2	4.7	19	23.7	6.9	119.2	8.6	2.5
WSS-2-2 Effluent	10/30/09	54	0.094	2.7	26	28.7	6.7	154.0	13.4	3.1
WSS-2-2 Effluent	11/23/09	54	0.33	2.8	18	20.8	0.77	131.1	8.3	0.3
WSS-2-2 Effluent	12/15/09	50	4.2	8.1	15	23.1	6.2	166.6	11.7	3.1
WSS-2-2-Shallow-L-4	02/25/09	23	0.017 I	0.75 J	9.6	9.6	0.006 I	63.8	2.0	0.0
WSS-2-2-Shallow-L-4	06/16/09	36	0.12	1	17	18.0	0.02	82.8	4.5	0.0
WSS-2-2-Shallow-L-4	09/28/09	50	0.01 U	0.66	17	17.7	0.011	119.2	6.4	0.0
WSS-2-2-Shallow-L-4	12/15/09	23	0.016 I	0.55	12	12.6	0.25	166.6	6.4	0.1
WSS-2-2-Shallow-L-5	06/16/09	53	0.12	1.5	16	17.5	4.4	82.8	4.4	1.1
WSS-2-2-Shallow-L-5	09/28/09	54	1.5	4.7	22	26.7	5.2	119.2	9.7	1.9
WSS-2-2-Shallow-L-5	12/15/09	33	0.015 I	0.75	15	15.8	6.1	166.6	8.0	3.1

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-2-2-Shallow-L-6	06/01/09	50	0.11	1.6	9.3	10.9	0.62	82.8	2.7	0.2
WSS-2-2-Shallow-L-6	09/28/09	55	0.01 U	1.1 I	25	25.0	4.5	119.2	9.5	1.6
WSS-2-2-Shallow-L-6	12/15/09	30	0.032	0.75	14	14.8	4.8 A	166.6	7.5	2.4
WSS-2-2-Deep-L-2	02/25/09	11	~	~	~	~	~	63.8	~	~
WSS-2-2-Deep-L-7	06/16/09	51	0.083 I	1.1	22	23.1	5.2 A	82.8	5.8	1.3
WSS-2-2-Deep-L-7	09/28/09	55	0.8	1.6	26	27.6	5.1	119.2	10.0	1.9
WSS-2-2-Deep-L-7	12/15/09	36	0.025	0.59	15	15.6	4.8	166.6	7.9	2.4
WSS-2-2-Deep-L-8	06/16/09	51	0.16	2.1	14	16.1	3.9	82.8	4.1	1.0
WSS-2-2-Deep-L-8	09/28/09	53	0.014 I	0.89	24	24.9	3.6	119.2	9.0	1.3
WSS-2-2-Deep-L-8	12/15/09	40	0.01 U	0.69	15	15.7	6.1	166.6	8.0	3.1
WSS-2-2 DF Well	02/25/09	16	0.01 U	0.08 U	6.2	6.2	0.014	63.8	1.2	0.0
WSS-2-2 DF Well	06/16/09	17	0.088 I	0.28	8.2	8.5	0.02	82.8	2.1	0.0
WSS-2-2 DF Well d	06/16/09	17	0.16	0.52	8.1	8.6	0.037	82.8	2.2	0.0
WSS-2-2 DF Well	09/28/09	24	0.01 U	0.45	15	15.5	0.004 U	119.2	5.6	0.0
WSS-2-2 DF Well d	09/28/09	25	0.013 I	0.4	15	15.4	0.004 U	119.2	5.6	0.0
WSS-2-2 DF Well	12/15/09	25	0.01 U	0.37 I	13	13.0	0.005 I	166.6	6.8	0.0
WSS-2-2 DF Well d	12/15/09	25	0.01 U	0.28 I	14	14.0	0.006 I	166.6	7.2	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-2-2 Well Water	02/25/09	3	0.01U	0.08 U	0.25	0.3	0.011			
WSS-2-2 Well Water d	02/25/09	3	0.01 U	0.08 U	0.25	0.3	0.01			
WSS-2-2 Well Water	06/16/09	2.6	0.01 U	0.08 U	0.26	0.3	0.008 I			
WSS-2-2 Well Water	09/28/09	2.7	0.01 U	0.1 I	0.26	0.3	0.008 I			
WSS-2-2 Well Water	12/15/09	3.3	0.01 U	0.097 I	0.21	0.2	0.007 I			
WSS-3-2 Effluent	01/28/09	110	31	40	0.71	40.7	9.7	151.0	18.7	4.5
WSS-3-2 Effluent	02/27/09	100	14	26	0.6	26.6	8.4	233.0	18.9	6.0
WSS-3-2 Effluent	04/08/09	88	0.77	14	4.5	18.5	8.2	469.5	26.4	11.7
WSS-3-2 Effluent	05/14/09	85	3.7	53	1.2	54.2	14	360.4	59.4	15.4
WSS-3-2 Effluent	06/19/09	92	1.3	12	0.24	12.2	13	480.1	17.9	19.0
WSS-3-2 Effluent d	06/19/09	92	1.2	13	0.23	13.2	13	480.1	19.3	19.0
WSS-3-2 Effluent	07/09/09	74	14	37	0.039	37.0	11	679.1	76.5	22.7
WSS-3-2 Effluent	09/08/09	68	0.76	4	0.036	4.0	13	98.9	1.2	3.9
WSS-3-2 Effluent d	09/08/09	70	0.66	3.8	0.15	4.0	13	98.9	1.2	3.9
WSS-3-2 Effluent	09/29/09	57	49	64	0.71	64.7	13	98.9	19.5	3.9
WSS-3-2 Effluent	10/30/09	48	0.49	14	1.9 J	14.0	12	147.8	7.2	5.4
WSS-3-2 Effluent	11/23/09	52	0.44	27	3.4	30.4	0.62	148.1	13.7	0.3
WSS-3-2 Effluent	12/14/09	60	5.5	29	1.1	30.1	14	138.1	12.6	5.9
WSS-3-2 Effluent d	12/14/09	60	5.8	44	1.1	45.1	17	138.1	18.9	7.1
WSS-3-2 Effluent	12/15/09	64	6.7	29	2	31.0	14	138.1	13.0	5.9
WSS-3-2 Effluent	12/16/09	66	7.3	19	2.7	21.7	13	138.1	9.1	5.5
WSS-3-2 Effluent	12/17/09	65	7.9	19	2.5	21.5	13	138.1	9.0	5.5
WSS-3-2 Effluent	12/18/09	63	7.7	20	1.4	21.4	13	138.1	9.0	5.5

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-3-2 NOR	05/14/09	87	3.5	26	4.5	30.5	9.8	360.4	33.5	10.7
WSS-3-2 NOR	06/19/09	92	0.8	13	0.19	13.2	14	480.1	19.3	20.5
WSS-3-2 NOR d	06/19/09	92	0.81	12	0.2	12.2	13	480.1	17.8	19.0
WSS-3-2 NOR	07/09/09	74	25	39	0.064	39.1	9.9	679.1	80.7	20.5
WSS-3-2-Shallow-L-2	02/27/09	18	0.01 U	0.64	0.95	1.6	0.04	233.0	1.1	0.0
WSS-3-2-Shallow-L-2	06/19/09	42	0.01 I	1.6	9.8	11.4	0.078	480.1	16.7	0.1
WSS-3-2-Shallow-L-2	09/29/09	7.5	0.01 U	0.59	1	1.6	0.045 A	98.9	0.5	0.0
WSS-3-2-Shallow-L-2	12/16/09	35	0.01 U	0.69	2.9	3.6	0.048 A	138.1	1.5	0.0
WSS-3-2-Deep-L-1	02/27/09	32	0.01 U	0.4	0.005 I	0.4	0.047	233.0	0.3	0.0
WSS-3-2-Deep-L-1	09/29/09	~	0.013 I	0.65	0.53	1.2	0.051	98.9	0.4	0.0
WSS-3-2-Deep-L-1&3	06/19/09	~	0.015 I	1.2	13	14.2	0.11	480.1	20.7	0.2
WSS-3-2-Deep-L-1	12/16/09	48	0.01 U	0.65	3.5	4.2	0.02	138.1	1.7	0.0
WSS-3-2-Deep-L-3	02/27/09	26	0.01 U	0.47	1.7	2.2	0.027	233.0	1.5	0.0
WSS-3-2-Deep-L-3	09/29/09	~	0.01 U	0.38	1.5	1.9	0.028	98.9	0.6	0.0
WSS-3-2-Deep-L-3	12/16/09	20	0.01 U	0.44	2.1	2.5	0.017	138.1	1.1	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-3-2 DF Well	02/27/09	10	0.01 U	0.08 UJ	0.47	0.5	0.13	233.0	0.4	0.1
WSS-3-2 DF Well d	02/27/09	9.9	0.01 U	0.08 U	0.45	0.5	0.42	233.0	0.4	0.3
WSS-3-2 DF Well	06/19/09	11	0.01 U	0.08 U	0.63	0.6	0.14	480.1	1.0	0.2
WSS-3-2 DF Well d	06/19/09	11	0.01 U	0.08 U	0.67	0.7	0.16	480.1	1.1	0.2
WSS-3-2 DF Well	09/29/09	12	0.022	0.21	1	1.2	0.15	98.9	0.4	0.0
WSS-3-2 DF Well d	09/29/09	13	0.044	0.44	1	1.4	0.14	98.9	0.4	0.0
WSS-3-2 DF Well	12/16/09	13	0.013 I	0.2 I	1.5	1.5	0.13	138.1	0.7	0.1
WSS-3-2 DF Well d	12/16/09	13	0.01 I	0.17 I	1.4	1.4	0.13	138.1	0.7	0.1
WSS-3-2 BG Well	02/27/09	14	0.01 U	0.18 I	1.9	1.9	0.27			
WSS-3-2 BG Well	06/19/09	18	0.01 U	0.17 I	0.1	0.1	0.17 A			
WSS-3-2 BG Well	09/29/09	21	0.01 U	0.16 I	2	2.0	0.11			
WSS-3-2 BG Well	12/16/09	19	0.01 U	0.16 I	2.4	2.4	0.12			
WSS-3-2 BG-L	02/27/09	30	0.01 U	0.4	0.004 U	0.4	0.063			
WSS-3-2 BG-L	06/19/09	~	0.01 U	0.36	0.006 I	0.4	0.089			
WSS-3-2 BG-L	09/29/09	~	0.015 I	0.4	0.08 U	0.4	0.22			
WSS-3-2 BG-L	12/16/09	11	0.01 U	0.16 I	0.008 I	0.0	0.16			
WSS-3-2 City Water	02/27/09	67	0.01 U	0.15 I	0.028	0.0	1.2			
WSS-3-2 City Water	06/19/09	58	0.01 U	0.11 I	0.01	0.0	1.2			
WSS-3-2 City Water	09/29/09	24	0.01 U	0.08 U	0.08 U	0.0	0.91			
WSS-3-2 City Water	12/16/09	35	0.01 U	0.1 I	0.013	0.0	1.1			

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-4-2 RAW Input	04/16/09	19	7.2	23	1.5	24.5	30	296.0	22.1	27.0
WSS-4-2 RAW Input	05/14/09	61	4.9	52	1.7	53.7	8.3	184.3	30.1	4.7
WSS-4-2 RAW Input	10/29/09	23	4.7	37	2.4	39.4	7.7	166.3	19.9	3.9
WSS-4-2 RAW Input d	10/29/09	23	4.8	37	2.5	39.5	7.8	166.3	20.0	3.9
WSS-4-2 RAW Input	10/30/09	38	18	95	5	100.0	7.4	166.3	50.6	3.7
WSS-4-2 Trash Tank	04/16/09	38	25	30	0.012	30.0	7.1	296.0	27.0	6.4
WSS-4-2 Trash Tank	06/18/09	50	56	59	0.01 I	59.0	7.9	89.5	16.1	2.2
WSS-4-2 Effluent	01/28/09	52	0.4	2.6	7.6	10.2	5.3	213.3	6.6	3.4
WSS-4-2 Effluent	02/27/09	48	0.34	2.5	11	13.5	5.5	187.7	7.7	3.1
WSS-4-2 Effluent	04/08/09	23	0.021	1.1	3.5	4.6	2.3	296.0	4.1	2.1
WSS-4-2 Effluent	04/16/09	24	0.072	1.2	7.7	8.9	2.7			
WSS-4-2 Effluent	05/14/09	44	0.11	1.9	24	25.9	5.8 A	184.3	14.5	3.3
WSS-4-2 Effluent	06/18/09	49	0.01 U	1.1	24	25.1	5.8	89.5	6.8	1.6
WSS-4-2 Effluent	07/09/09	56	0.053	0.82 I	24	24.0	5.5	89.8	6.8	1.5
WSS-4-2 Effluent	09/08/09	54	0.078	1.2	26	27.2	4.4	111.0	9.2	1.5
WSS-4-2 Effluent	10/02/09	54	0.084	1.2	0.12 I	1.2	4.9	166.3	0.7	2.5
WSS-4-2 Effluent d	10/02/09	56	0.082	1.2	0.12 I	1.2	4.8	166.3	0.7	2.4
WSS-4-2 Effluent	10/29/09	47 A	0.072	1.5	21	22.5	5.2	166.3	11.4	2.6
WSS-4-2 Effluent	10/30/09	46	0.1	1.3	20	21.3	5.1	166.3	10.8	2.6
WSS-4-2 Effluent	12/17/09	35	0.13	1.3	17	18.3	3.3 A	210.3	11.7	2.1
WSS-4-2 Effluent	12/18/09	35	0.14	1.4	18	19.4	3.5	210.3	12.4	2.2

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-4-2-Shallow-L-1	02/27/09	48	0.052	0.65	5.8	6.5	0.17	187.7	3.7	0.1
WSS-4-2-Shallow-L-1	06/18/09	~	0.02	0.83	5.6	6.4	0.18	89.5	1.8	0.0
WSS-4-2-Shallow-L-1	10/02/09	38	0.01 U	0.49	0.23	0.7	0.17	166.3	0.4	0.1
WSS-4-2-Shallow-L-1	12/18/09	34	0.01 U	0.58	3.2	3.8	0.12	210.3	2.4	0.1
WSS-4-2-Shallow-L-3	02/27/09	45	0.011 I	1.2	9	10.2	0.6	187.7	5.8	0.3
WSS-4-2-Shallow-L-3	06/18/09	44	0.028	0.69	4.2	4.9	0.45	89.5	1.3	0.1
WSS-4-2-Shallow-L-3	10/02/09	45	0.01 U	0.36	0.46	0.8	0.3	166.3	0.4	0.2
WSS-4-2-Shallow-L-3	12/18/09	48	0.01 U	0.39	9.8	10.2	0.18	210.3	6.5	0.1
WSS-4-2-Deep-L-2	02/27/09	50	0.01 I	0.51	0.35	0.9	0.032 A	187.7	0.5	0.0
WSS-4-2-Deep-L-2	06/18/09	28	0.01 U	0.23	0.49	0.7	0.009 I	89.5	0.2	0.0
WSS-4-2-Deep-L-2	10/02/09	9.7	0.01 U	0.27	0.089	0.4	0.014	166.3	0.2	0.0
WSS-4-2-Deep-L-2	12/18/09	29	0.01 U	0.41	7.4	7.8	0.006 I	210.3	5.0	0.0
WSS-4-2-Deep-L-4	02/27/09	46	0.014 I	0.87	8.9	9.8	0.047	187.7	5.6	0.0
WSS-4-2-Deep-L-4	06/18/09	9.7	0.01 U	0.49	0.012	0.5	0.028	89.5	0.1	0.0
WSS-4-2-Deep-L-4	10/02/09	9.1	0.01 U	0.46	0.27	0.7	0.017	166.3	0.4	0.0
WSS-4-2-Deep-L-4	12/18/09	27	0.01 U	0.29	2.1	2.4	0.004 I	210.3	1.5	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-4-2 DF Well	02/27/09	24 A	0.01 U	0.097 I	1.3	1.3	0.004 U	187.7	0.8	0.0
WSS-4-2 DF Well	06/18/09	10	0.01 U	0.08 U	0.24	0.2	0.004 U	89.5	0.1	0.0
WSS-4-2 DF Well	10/02/09	8.2	0.01 U	0.08 U	0.11	0.1	0.004 U	166.3	0.1	0.0
WSS-4-2 DF Well d	10/02/09	7.9	0.01 U	0.08 U	0.11	0.1	0.004 U	166.3	0.1	0.0
WSS-4-2 DF Well	12/18/09	7.1	0.01 U	0.08 U	0.057	0.1	0.004 U	210.3	0.1	0.0
WSS-4-2 DF Well d	12/18/09	7.1	0.01 U	0.08 U	0.049	0.0	0.004 U	210.3	0.1	0.0
WSS-4-2 BG Well	02/27/09	7	0.01 U	0.08 U	0.02	0.0	0.037 A			
WSS-4-2 BG Well	06/18/09	6.5	0.01 U	0.08 U	0.058	0.1	0.022			
WSS-4-2 BG Well d	06/18/09	6.4	0.01 U	0.08 U	0.055	0.1	0.021			
WSS-4-2 BG Well	10/02/09	16	0.01 U	0.11 I	0.051	0.1	0.048 A			
WSS-4-2 BG Well	12/18/09	17	0.01 U	0.08 U	0.048	0.0	0.013			
WSS-4-2 BG-L	06/18/09	2.7	0.01 UJ	0.08 U	0.006 I	0.0	0.004 U			
WSS-4-2 BG-L	10/02/09	0.69	0.01 U	0.08 U	0.008 I	0.0	0.004 U			
WSS-4-2 BG-L	12/18/09	1.8	0.01 U	0.084 I	0.005 I	0.0	0.004 U			
WSS-4-2 Well Water	02/27/09	7.1	0.01 U	0.1 I	0.004 U	0.0	0.068			
WSS-4-2 Well Water d	02/27/09	6.9	0.01 U	0.092 I	0.004 U	0.0	0.068			
WSS-4-2 Well Water	06/18/09	6.7 A	0.01 U	0.08 U	0.004 I	0.0	0.069			
WSS-4-2 Well Water	10/02/09	7	0.01 U	0.08 U	0.004 U	0.0	0.055			
WSS-4-2 Well Water	12/18/09	6.5 A	0.01 U	0.097 I	0.004 I	0.0	0.058			

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-5-2 Trash Tank	04/08/09	44	37	46	0.03	46.0	7.7	353.9	49.6	8.3
WSS-5-2 Trash Tank	06/18/09	48	42	49	0.011	49.0	9.9	539.0	80.4	16.2
WSS-5-2 Trash Tank d	06/18/09	48	42	48	0.01	48.0	9.8	539.0	78.8	16.1
WSS-5-2 Effluent	01/28/09	25	17	27	1	28.0	7	10.4	0.9	0.2
WSS-5-2 Effluent	02/26/09	39	26	33	0.027	33.0	5.9	10.4	1.0	0.2
WSS-5-2 Effluent	04/08/09	44	30	40	0.36	40.4	6.9	353.9	43.5	7.4
WSS-5-2 Effluent	05/13/09	41	38	51	0.74	51.7	8.4	615.8	97.0	15.7
WSS-5-2 Effluent	05/15/09	40	38	47	0.015	47.0	8.4	615.8	88.1	15.7
WSS-5-2 Effluent	06/18/09	47	27	30	3.6	33.6	8.8 A	539.0	55.1	14.4
WSS-5-2 Effluent	07/08/09	55	17	19	3.3	22.3	7.8	802.2	54.4	19.0
WSS-5-2 Effluent d	07/08/09	55	17	19	3.3	22.3	7.9	802.2	54.4	19.3
WSS-5-2 Effluent	09/08/09	42	26	30	0.13	30.1	6.5	100.3	9.2	2.0
WSS-5-2 Effluent	10/01/09	58	31	33	4	37.0	7.8	148.9	16.8	3.5
WSS-5-2 Effluent	10/30/09	53	2.1	6.4	6.8	13.2	8.3	148.9	6.0	3.8
WSS-5-2 Effluent	11/23/09	41	17	22	2.8	24.8	0.7	114.2	8.6	0.2
WSS-5-2 Effluent	12/17/09	39	28	37	2	39.0	6.3	269.8	32.0	5.2
WSS-5-2 Effluent d	12/17/09	39	30	43	1.9	44.9	6.2	269.8	36.9	5.1
WSS-5-2 NOR	05/13/09	40	41	51	0.64	51.6	8.3	615.8	96.8	15.6
WSS-5-2 NOR	06/18/09	47	29	35	5.5	40.5	10	539.0	66.4	16.4
WSS-5-2 NOR	07/08/09	56	18	19	4	23.0	8.1	802.2	56.1	19.8

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-5-2-Shallow-L-1	06/18/09	~	0.01 U	0.81	9.1	9.9	0.14	539.0	16.3	0.2
WSS-5-2-Shallow-L-1	10/01/09	19	0.01 U	0.78	12	12.8	0.089	148.9	5.8	0.0
WSS-5-2-Shallow-L-1	12/17/09	15 A	0.01 U	0.35	4.7	5.1	0.036 A	269.8	4.1	0.0
WSS-5-2-Shallow-L-2	02/26/09	22	0.01 U	0.95	1.7	2.7	0.033	10.4	0.1	0.0
WSS-5-2-Shallow-L-2	06/18/09	12	0.01 U	0.29	4	4.3	0.013 AJ	539.0	7.0	0.0
WSS-5-2-Shallow-L-2	10/01/09	16	0.01 U	0.26	8.9	9.2	0.004 U	148.9	4.2	0.0
WSS-5-2-Shallow-L-2	12/17/09	3.9	0.01 U	0.17 I	2.5	2.5	0.005 I	269.8	2.2	0.0
WSS-5-2-Shallow-L-3	02/26/09	19	0.011 I	0.85	7.2	8.1	0.42	10.4	0.3	0.0
WSS-5-2-Shallow-L-3	06/18/09	21	0.01 U	0.76	2.8	3.6	0.1	539.0	5.8	0.2
WSS-5-2-Shallow-L-3	10/01/09	28	0.01 U	0.8	3.2	4.0	0.051	148.9	1.8	0.0
WSS-5-2-Shallow-L-3	12/17/09	27	0.01 U	0.49	2.6	3.1	0.016	269.8	2.5	0.0
WSS-5-2-Shallow-L-4	02/26/09	16	0.011 I	0.83	4.9	5.7	0.07	10.4	0.2	0.0
WSS-5-2-Shallow-L-4	06/18/09	26	0.01 U	1.6	7.3	8.9	0.13	539.0	14.6	0.2
WSS-5-2-Shallow-L-4	10/01/09	21	0.01 U	1.5	16	17.5	0.061	148.9	7.9	0.0
WSS-5-2-Shallow-L-4	12/17/09	14	0.01 U	0.3	3.4	3.7	0.027 A	269.8	3.0	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-5-2 DF Well	02/26/09	8.4	0.01 U	0.08 U	3	3.0	0.004 U	10.4	0.1	0.0
WSS-5-2 DF Well	06/18/09	8.8	0.01 U	0.08 U	2.6	2.6	0.004 U	539.0	4.4	0.0
WSS-5-2 DF Well d	06/18/09	8.7	0.01 U	0.08 U	2.6	2.6	0.004 U	539.0	4.4	0.0
WSS-5-2 DF Well	10/01/09	9.8	0.01 U	0.08 U	3.3	3.3	0.004 U	148.9	1.5	0.0
WSS-5-2 DF Well d	10/01/09	9.7	0.01 U	0.08 U	3.3	3.3	0.004 U	148.9	1.5	0.0
WSS-5-2 DF Well	12/17/09	7.1	0.01 U	0.081 I	0.94	0.9	0.004 U	269.8	0.8	0.0
WSS-5-2 DF Well d	12/17/09	7.3	0.01 U	0.13 I	0.91	0.9	0.004 U	269.8	0.9	0.0
WSS-5-2 BG Well	02/26/09	20	0.01 U	0.18 I	0.004 I	0.0	0.005 I			
WSS-5-2 BG Well d	02/26/09	20	0.01 U	0.3	0.009 I	0.3	0.043			
WSS-5-2 BG Well	06/18/09	17	0.01 U	0.16 I	0.055	0.1	0.004 U			
WSS-5-2 BG Well	10/01/09	16	0.01 U	0.19 I	0.004 U	0.0	0.004 U			
WSS-5-2 BG Well	12/17/09	13	0.01 U	0.16 I	0.005 I	0.0	0.004 U			
WSS-5-2 BG-L	02/26/09	7.6	0.01 U	0.12 I	0.043	0.0	0.008 I			
WSS-5-2 BG-L	06/18/09	3.8	0.01 U	0.18 I	0.006 I	0.0	0.004 U			
WSS-5-2 BG-L	10/01/09	2.8	0.01 U	0.18 I	0.004 U	0.0	0.004 U			
WSS-5-2 BG-L	12/17/09	5.5	0.01 U	0.14 I	0.004 U	0.0	0.004 U			
WSS-5-2 Well Water	02/26/09	3.8	0.01 U	0.29 J	0.006 I	0.0	0.007 I			
WSS-5-2 Well Water	06/18/09	4	0.01 U	0.08 U	0.006 I	0.0	0.013			
WSS-5-2 Well Water	10/01/09	4.1	0.01 U	0.17 I	0.013	0.0	0.013			
WSS-5-2 Well Water	12/17/09	3.9	0.01 U	0.12 I	0.017	0.0	0.011			

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-6-2 Trash Tank	03/31/09	35	23	30	0.008 I	30.0	6	893.4	81.6	16.3
WSS-6-2 Trash Tank	06/17/09	32	4.9	30	0.004 I	30.0	6.3	357.7	18.6	7.9
WSS-6-2 Effluent	01/28/09	37	24	32	0.074	32.1	6	164.5	16.1	3.0
WSS-6-2 Effluent	02/26/09	35	25	30	0.14	30.1	6.4	224.6	20.6	4.4
WSS-6-2 Effluent	03/31/09	31	13	16	0.02	16.0	5 A	893.4	43.6	13.6
WSS-6-2 Effluent	05/14/09	37	6.5	9	1.3	10.3	4.7	841.8	26.4	12.0
WSS-6-2 Effluent	06/17/09	32 A	5.9	8.8	0.21	9.0	4.9	357.7	9.8	5.3
WSS-6-2 Effluent	07/09/09	34	14	17	0.57	17.6	5.3	1056.7	56.5	17.0
WSS-6-2 Effluent	09/08/09	28	1.9	3.7	7.5	11.2	3.9	533.9	18.2	6.3
WSS-6-2 Effluent	09/29/09	39	1.5	2.7	9.6	12.3	3.5	533.9	20.0	5.7
WSS-6-2 Effluent	10/30/09	28	0.18	0.99 J	4.3	4.3	3.5 A	240.3	3.9	2.6
WSS-6-2 Effluent	11/23/09	31	0.27	1.4	3.9	5.3	3.5	275.1	4.4	2.9
WSS-6-2 Effluent	12/14/09	23 A	0.05	0.91	8.3	9.2	2.7	239.6	6.7	2.0
WSS-6-2 Effluent	12/15/09	25	0.18	1	10	11.0	3	239.6	8.0	2.2
WSS-6-2 Effluent	12/16/09	27	1.7	3	7.1	10.1	3.2	239.6	7.4	2.3
WSS-6-2 Effluent	12/17/09	27	0.9	3.3	7	10.3	3.4	239.6	7.5	2.5
WSS-6-2 Effluent	12/18/09	45	0.27	1.3	8.3	9.6	3.4	239.6	7.0	2.5
WSS-6-2 Effluent d	12/18/09	45	0.27	2.4	8.3	10.7	3.6	239.6	7.8	2.6

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-6-2-Shallow-L-2	02/26/09	50	~	~	~	~	~	224.6	~	~
WSS-6-2-Shallow-L-2	06/17/09	34	0.015 I	0.91	0.34	1.3	0.2	357.7	1.4	0.2
WSS-6-2-Shallow-L-2	09/29/09	31	0.01 U	0.47 J	9.2	9.2	0.52	533.9	15.7	0.8
WSS-6-2-Shallow-L-2	12/16/09	22	0.01 U	0.44	4.1	4.5	0.67	239.6	3.3	0.5
WSS-6-2-Shallow-L-3	02/26/09	69	0.024	1.1	12	13.1	0.034	224.6	9.0	0.0
WSS-6-2-Shallow-L-3	06/17/09	33	0.01 U	0.85	1	1.9	0.024	357.7	2.0	0.0
WSS-6-2-Shallow-L-3	09/29/09	34	0.01 U	0.69	10	10.7	0.02	533.9	17.4	0.0
WSS-6-2-Shallow-L-3	12/16/09	23	0.01 U	0.62	5.7	6.3	0.038 A	239.6	4.6	0.0
WSS-6-2-Shallow-L-5	06/17/09	~	0.019 I	0.95	0.007 I	1.0	0.069	357.7	1.0	0.1
WSS-6-2-Shallow-L-5	09/29/09	34	0.05 U	1.1	3.2	4.3	0.049	533.9	7.0	0.1
WSS-6-2-Deep-L-1	02/26/09	31	0.01 U	2.3	9.8	12.1	0.18	224.6	8.3	0.1
WSS-6-2-Deep-L-1	09/29/09	26/24	0.014 I	0.76	10	10.8	0.06	533.9	17.5	0.1
WSS-6-2-Deep-L-1	12/16/09	22	0.01 U	0.47	5	5.5	0.06	239.6	4.0	0.0
WSS-6-2-Deep-L-4	02/26/09	40	0.015 I	1	6.9	7.9	0.14	224.6	5.4	0.1
WSS-6-2-Deep-L-4	06/17/09	29	0.01 U	0.36	2	2.4	0.024	357.7	2.6	0.0
WSS-6-2-Deep-L-4	09/29/09	29	0.01 U	0.39	9.1	9.5	0.03	533.9	15.4	0.0
WSS-6-2-Deep-L-4	12/16/09	23	0.01 U	0.25	5.2	5.5	0.022	239.6	4.0	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-6-2 DF Well	02/26/09	11	0.012 I	0.29 I	9	9.0	0.014	224.6	6.3	0.0
WSS-6-2 DF Well d	02/26/09	11	0.02 I	0.19 I	9.4	9.4	0.015	224.6	6.6	0.0
WSS-6-2 DF Well	06/17/09	11	0.01 U	0.08 U	9.8	9.8	0.004 I	357.7	10.8	0.0
WSS-6-2 DF Well d	06/17/09	11	0.01 U	0.08 U	9.8	9.8	0.016	357.7	10.8	0.0
WSS-6-2 DF Well	09/29/09	11	0.01 U	0.08 U	9.3	9.3	0.004 U	533.9	15.2	0.0
WSS-6-2 DF Well d	09/29/09	11	0.01 U	0.09 I	9.4	9.4	0.004 U	533.9	15.4	0.0
WSS-6-2 DF Well	12/16/09	9.2	0.01 U	0.17 I	8	8.0	0.015	239.6	6.0	0.0
WSS-6-2 DF Well d	12/16/09	8.9	0.01 U	0.14 I	8	8.0	0.017	239.6	5.9	0.0
WSS-6-2 BG Well	02/26/09	4	0.012 I	0.08 U	0.69	0.7	0.004 U			
WSS-6-2 BG Well	06/17/09	4.2	0.01 U	0.08 U	0.86	0.9	0.004 U			
WSS-6-2 BG Well	09/29/09	4.8	0.01 U	0.08 U	0.97	1.0	0.004 U			
WSS-6-2 BG Well	12/16/09	4.7	0.01 U	0.13 I	1.2	1.2	0.004 U			
WSS-6-2 BG-L	02/26/09	37	0.01 U	0.43	0.004 U	0.4	0.016			
WSS-6-2 BG-L	06/17/09	13	0.01 U	0.29	0.014	0.3	0.021			
WSS-6-2 BG-L	09/29/09	12	0.01 U	0.13 I	0.08 U	0.0	0.004 U			
WSS-6-2 BG-L	12/16/09	5.8	0.022	0.19 I	0.007 I	0.0	0.004 U			
WSS-6-2 City Water	02/26/09	12	0.01 UJ	0.19 I	0.38	0.4	0.024 A			
WSS-6-2 City Water	06/17/09	9.1	0.01 U	0.08	0.39	0.5	0.027 A			
WSS-6-2 City Water	09/29/09	9.4	0.01 U	0.08 U	0.37	0.4	0.018 A			
WSS-6-2 City Water	12/16/09	11	0.01 U	0.11 I	0.36	0.4	0.011			

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-7-2 RAW Input	01/28/09	55	3.1	100	0.74	100.7	12	271.6	83.3	9.9
WSS-7-2 RAW Input d	01/28/09	55	2.8	100	0.72	100.7	12	271.6	83.2	9.9
WSS-7-2 RAW Input	02/26/09	28	2.5	54	0.73	54.7	5.3	448.9	74.8	7.2
WSS-7-2 RAW Input	04/08/09	30	3.4	59	0.59	59.6	6.7	156.3	28.3	3.2
WSS-7-2 RAW Input	05/13/09	69	6.8	110	0.4	110.4	11	187.9	63.1	6.3
WSS-7-2 RAW Input	06/17/09	33	4.9	61	0.59	61.6	7.5	211.0	39.5	4.8
WSS-7-2 Trash Tank	04/08/09	45	45	65	0.088	65.1	6.7	156.3	31.0	3.2
WSS-7-2 Trash Tank	06/17/09	38	7.5	20	0.065	20.1	6.9	211.0	12.9	4.4
WSS-7-2 Effluent	01/28/09	34	33	46	0.045	46.0	6.8	271.6	38.1	5.6
WSS-7-2 Effluent d	01/28/09	33	30	48	0.14	48.1	6.5	271.6	39.8	5.4
WSS-7-2 Effluent	02/26/09	35	31	58	0.017	58.0	7	448.9	79.3	9.6
WSS-7-2 Effluent	04/08/09	45	44	71	0.26	71.3	7.7	156.3	33.9	3.7
WSS-7-2 Effluent	05/13/09	48	14	44	0.068	44.1	11	187.9	25.2	6.3
WSS-7-2 Effluent	06/17/09	39	7.3	16	0.32	16.3	7.1	211.0	10.5	4.6
WSS-7-2 Effluent	07/09/09	43	39	48	0.12	48.1	7.1	208.7	30.6	4.5
WSS-7-2 Effluent	09/08/09	45	46	57	0.21	57.2	7.7	142.5	24.8	3.3
WSS-7-2 Effluent	10/01/09	38	5.8	8.8	3.2	12.0	7.8	54.8	2.0	1.3
WSS-7-2 Effluent	10/30/09	39	35	34	0.57	34.6	7.3	54.8	5.8	1.2
WSS-7-2 Effluent	12/14/09	35	7	11	6.2	17.2	6.6	1.3	0.1	0.0
WSS-7-2 Effluent	12/15/09	35	6.7	11	6.5	17.5	6.7	1.3	0.1	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-7-2 NOR	05/13/09	47	14	36	0.18	36.2	10	187.9	20.7	5.7
WSS-7-2 NOR	06/17/09	39	7.6	17	0.051	17.1	7.3	211.0	10.9	4.7
WSS-7-2 NOR	07/09/09	44 A	41	56	0.055	56.1	8.4	208.7	35.6	5.3
WSS-7-2-Shallow-L-1	02/26/09	34	0.33	1.2	11	12.2	0.01	448.9	16.7	0.0
WSS-7-2-Shallow-L-1	06/17/09	15	0.018 I	0.93	12	12.9	0.011	211.0	8.3	0.0
WSS-7-2-Shallow-L-1	10/01/09	21	0.012 I	1.1	32	33.1	0.011	54.8	5.5	0.0
WSS-7-2-Shallow-L-1	12/17/09	3.6	0.01 U	0.86	9.6	10.5	0.014	1.3	0.0	0.0
WSS-7-2-Shallow-L-4	02/26/09	19	0.039	0.96	11	12.0	0.01	448.9	16.3	0.0
WSS-7-2-Shallow-L-4	06/17/09	27	0.015 I	1.3	5.2	6.5	0.038	211.0	4.2	0.0
WSS-7-2-Shallow-L-4	10/01/09	35	0.019 I	1	19	20.0	0.015 A	54.8	3.3	0.0
WSS-7-2-Shallow-L-4	12/17/09	11	0.015 I	0.85	0.072	0.9	0.008 I	1.3	0.0	0.0
WSS-7-2-Deep-L-2	02/26/09	33	0.062	0.69 I	38	38.0	0.005 I	448.9	52.9	0.0
WSS-7-2-Deep-L-2	06/17/09	18	0.011 I	0.67	13	13.7	0.004 U	211.0	8.8	0.0
WSS-7-2-Deep-L-2 d	06/17/09	18	0.012 I	0.73	11	11.7	0.004 U	211.0	7.5	0.0
WSS-7-2-Deep-L-2	10/01/09	38	0.01 U	0.63 I	38	38.0	0.004 U	54.8	6.4	0.0
WSS-7-2-Deep-L-2	12/17/09	15	0.01 U	0.5	11	11.5	0.004 U	1.3	0.0	0.0
WSS-7-2-Deep-L-2 d	12/17/09	15	0.01 U	0.58	11	11.6	0.004 U	1.3	0.0	0.0

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-7-2-Deep-L-3	02/26/09	35	0.068	0.43 I	28	28.0	0.004 U	448.9	38.8	0.0
WSS-7-2-Deep-L-3	06/17/09	26	0.01 U	0.47 I	24	24.0	0.004 U	211.0	15.7	0.0
WSS-7-2-Deep-L-3	10/01/09	46	0.01 U	0.7 I	45	45.0	0.007 I	54.8	7.6	0.0
WSS-7-2-Deep-L-3	12/17/09	32	0.01 U	0.67	16	16.7	0.004 U	1.3	0.1	0.0
WSS-7-2 BG-L	02/26/09	7.9	0.011 I	0.21	0.035	0.2	0.05			
WSS-7-2 BG-L	06/17/09	2.5	0.01 U	0.2	1.4	1.6	0.021			
WSS-7-2 BG-L	10/01/09	3.1	0.01 U	0.4	0.18 I	0.4	0.031			
WSS-7-2 BG-L	12/17/09	3.1	0.01 U	0.23	0.018	0.2	0.019			
WSS-7-2 Well Water	02/26/09	3.8	0.01 U	0.08 U	0.77	0.8	0.012			
WSS-7-2 Well Water d	02/26/09	3.7	0.01 U	0.08 U	0.77	0.8	0.012			
WSS-7-2 Well Water	06/17/09	4.1 A	0.01 U	0.08 U	0.48	0.5	0.011 A			
WSS-7-2 Well Water	10/01/09	3.5	0.01 U	0.14 I	0.53	0.5	0.01 I			
WSS-7-2 Well Water d	10/01/09	3.5	0.01 U	0.13 I	0.54	0.5	0.009 I			
WSS-7-2 Well Water	12/17/09	3.5	0.01 U	0.091 I	0.33	0.3	0.024			
WSS-8-2 RAW Input	01/28/09	180	4.3	70	0.18	70.2	18	320.3	68.4	17.5
WSS-8-2 Effluent	01/28/09	140	25	38	0.007 I	38.0	8.5	320.3	37.0	8.3
WSS-8-2 Effluent	02/27/09	170	19	31	0.024	31.0	6.1	233.8	22.1	4.3
WSS-8-2 Effluent	04/08/09	140	21	32	0.016	32.0	7.0 A	195.5	19.0	4.2

Appendix A (continued).

Sample	Date	Chloride (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	Total P (mg-N/L)	Avg Daily Flow (g/day)	TN (lb/yr)	TP (lb/yr)
WSS-8-2-Shallow-L-4	02/27/09	57	0.015 I	0.66	11	11.7	0.007 I	233.8	8.3	0.0
WSS-8-2 DF Well	02/27/09	30	0.01 U	0.08 I	6.4	6.4	0.14 A	233.8	4.6	0.1
WSS-8-2 BG Well	02/27/09	7	0.01 U	0.08 U	0.62	0.6	0.11	233.8		
WSS-8-2 City Water	02/27/09	54	0.01 U	0.17 I	0.089	0.1	1.2	233.8		

A - Value reported is the mean of two or more determinations
I - The reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.
J - Estimated value
U - Material was analyzed for but not detected. The reported value is the method detection limit for the sample analyzed

Appendix B. FDEP Field data for the drainfield wells, background wells, and residential water source from Phase II

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-1-2 DF WELL	02/25/09	10 min	10.50	17.45	18.05	22.19	7.71	567	8.43	96.9
WSS-1-2 DF WELL	06/16/09	10 min	10.10	16.30	17.05	22.79	7.32	503	6.79	78.9
WSS-1-2 DF WELL	09/28/09	10 min	10.70	11.90	17.05	24.58	7.62	530	4.93	59.3
WSS-1-2 DF WELL	12/15/09	10 min	8.20	18.90	17.05	22.48	7.27	581	5.54	63.9
WSS-1-2 BG WELL	02/25/09	10 min	11.90	12.85	20.90	21.49	8.53	200	7.57	85.7
WSS-1-2 BG WELL	06/16/09	10 min	11.75	19.40	20.90	23.75	8.83	211	8.72	103.1
WSS-1-2 BG WELL	09/28/09	10 min	11.40	19.70	20.90	24.11	8.97	216	4.31	51.3
WSS-1-2 BG WELL	12/15/09	10 min	8.90	20.70	20.90	22.73	8.82	225	5.38	62.4
WSS-1-2 Well Water	02/25/09	10 min	~	~	~	21.49	7.47	359	5.94	67.3
WSS-1-2 Well Water	06/16/09	10 min	~	~	~	22.71	7.55	367	4.25	49.7
WSS-1-2 Well Water	09/28/09	10 min	~	~	~	24.30	8.12	372	5.70	68.1
WSS-1-2 Well Water	12/15/09	10 min	~	~	~	21.67	7.53	374	4.33	49.6

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-2-2 DF WELL	02/25/09	10 min	11.50	17.10	17.75	20.78	7.33	427	1.44	16.1
WSS-2-2 DF WELL	06/16/09	10 min	10.85	10.85	16.85	20.97	6.79	623	1.01	11.4
WSS-2-2 DF WELL	09/28/09	10 min	10.55	11.60	16.90	23.93	7.08	776	0.59	7.1
WSS-2-2 DF WELL	12/15/09	10 min	8.40	12.40	16.90	23.23	6.93	695	1.14	13.3
WSS-2-2 Well Water	02/25/09	10 min	~	~	~	13.35	7.30	396	5.16	49.4
WSS-2-2 Well Water	06/16/09	10 min	~	~	~	23.21	7.53	375	7.18	84.1
WSS-2-2 Well Water	09/28/09	10 min	~	~	~	23.01	7.68	385	3.77	44.0
WSS-2-2 Well Water	12/15/09	10 min	~	~	~	19.73	7.43	386	4.26	46.7

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-3-2 DF WELL	02/27/09	10 min	18.60	19.10	25.30	21.56	7.71	322	2.11	24.6
WSS-3-2 DF WELL	06/19/09	10 min	18.15	22.10	25.25	21.16	7.52	324	2.12	23.8
WSS-3-2 DF WELL	09/29/09	10 min	16.35	18.30	25.25	22.42	7.51	397	1.86	21.5
WSS-3-2 DF WELL	12/16/09	10 min	15.90	18.50	25.20	22.01	7.32	414	1.76	20.2
WSS-3-2 BG WELL	02/27/09	10 min	18.45	18.50	25.50	21.26	6.93	554	1.85	20.9
WSS-3-2 BG WELL	06/19/09	10 min	17.95	18.60	25.50	21.03	6.97	539	1.66	18.7
WSS-3-2 BG WELL	09/29/09	10 min	16.20	16.40	25.45	21.94	6.97	576	1.79	20.5
WSS-3-2 BG WELL	12/16/09	10 min	15.80	15.80	25.45	22.07	6.90	572	1.74	20.1
WSS-3-2 City Water	02/27/09	10 min	~	~	~	15.62	7.54	528	8.13	82.4
WSS-3-2 City Water	06/19/09	10 min	~	~	~	26.12	7.48	490	5.56	69.1
WSS-3-2 City Water	09/29/09	10 min	~	~	~	26.05	7.58	431	6.76	83.5
WSS-3-2 City Water	12/16/09	10 min	~	~	~	18.68	7.42	441	6.18	66.3

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-4-2 DF WELL	02/27/09	10 min	5.40	5.80	20.40	19.42	5.02	115	3.53	38.9
WSS-4-2 DF WELL	06/18/09	10 min	4.95	7.10	20.30	20.28	5.09	104	2.35	25.9
WSS-4-2 DF WELL	10/02/09	10 min	4.10	7.80	19.35	21.86	5.55	102	0.48	5.4
WSS-4-2 DF WELL	12/18/09	10 min	3.40	7.10	20.35	21.30	5.04	88	0.33	3.8
WSS-4-2 BG WELL	02/27/09	10 min	6.90	18.40	19.05	19.58	5.77	55	6.03	65.8
WSS-4-2 BG WELL	06/18/09	10 min	5.90	18.00	19.05	21.55	5.90	51	6.56	74.4
WSS-4-2 BG WELL	10/02/09	10 min	4.70	18.10	19.05	22.31	6.19	75	6.23	71.7
WSS-4-2 BG WELL	12/18/09	10 min	3.80	18.20	19.05	21.43	5.56	76	7.26	82.1
WSS-4-2 Well Water	02/27/09	10 min	~	~	~	18.71	8.23	187	5.61	60.1
WSS-4-2 Well Water	06/18/09	10 min	~	~	~	23.37	8.35	185	3.78	44.4
WSS-4-2 Well Water	10/02/09	10 min	~	~	~	21.64	8.10	189	4.75	54.1
WSS-4-2 Well Water	12/18/09	10 min	~	~	~	19.46	7.97	187	7.04	76.5

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-5-2 DF WELL	02/26/09	10 min	9.00	9.05	18.95	19.78	7.09	450	4.63	50.7
WSS-5-2 DF WELL	06/18/09	10 min	7.40	7.40	18.90	20.58	7.16	446	2.41	26.9
WSS-5-2 DF WELL	10/01/09	10 min	7.10	7.20	18.90	22.90	7.11	481	2.92	34.1
WSS-5-2 DF WELL	12/17/09	10 min	4.00	4.00	18.90	20.97	6.85	447	3.42	38.4
WSS-5-2 BG WELL	02/26/09	10 min	8.40	9.35	12.65	18.71	6.71	837	0.42	4.5
WSS-5-2 BG WELL	06/18/09	10 min	6.90	6.90	12.60	20.04	6.82	735	0.32	3.5
WSS-5-2 BG WELL	10/01/09	10 min	6.50	6.60	12.60	22.59	6.79	785	0.11	1.4
WSS-5-2 BG WELL	12/17/09	10 min	3.40	3.40	12.60	21.25	6.63	795	0.42	4.8
WSS-5-2 Well Water	02/26/09	10 min	~	~	~	16.21	7.49	413	9.86	100.4
WSS-5-2 Well Water	06/18/09	10 min	~	~	~	23.87	7.36	402	1.96	23.4
WSS-5-2 Well Water	10/01/09	10 min	~	~	~	20.25	7.24	407	5.25	57.9
WSS-5-2 Well Water	12/17/09	10 min	~	~	~	19.28	7.02	398	4.04	43.8

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-6-2 DF WELL	02/26/09	10 min	9.70	9.80	19.10	20.72	4.43	137	1.69	18.9
WSS-6-2 DF WELL	06/17/09	10 min	8.60	9.30	19.05	21.46	4.65	135	1.71	19.3
WSS-6-2 DF WELL	09/29/09	10 min	7.80	9.80	19.05	23.77	4.80	140	1.62	19.2
WSS-6-2 DF WELL	12/16/09	10 min	7.80	8.30	19.05	22.99	4.73	110	2.27	26.4
WSS-6-2 BG WELL	02/26/09	10 min	9.30	10.35	19.15	21.26	4.81	35	3.16	35.6
WSS-6-2 BG WELL	06/17/09	10 min	8.35	11.80	19.10	21.06	5.07	40	2.98	33.4
WSS-6-2 BG WELL	09/29/09	10 min	7.75	10.30	19.10	23.10	5.10	42	2.98	34.9
WSS-6-2 BG WELL	12/16/09	10 min	6.50	9.50	19.15	22.95	4.90	43	2.91	33.8
WSS-6-2 City Water	02/26/09	10 min	~	~	~	14.55	7.50	307	8.74	85.8
WSS-6-2 City Water	06/17/09	10 min	~	~	~	28.18	7.43	341	5.82	74.6
WSS-6-2 City Water	09/29/09	10 min	~	~	~	26.16	7.41	299	7.16	88.5
WSS-6-2 City Water	12/16/09	10 min	~	~	~	17.64	7.33	375	6.89	72.4

Appendix B (continued).

Sample	Sample Date	Purge Time	Initial Depth to Water (ft)	Final Depth to Water (ft)	Total Well Depth (ft)	Temp (Cº)	pH	Sp Cond	DO mg/L	DO %sat
WSS-7-2 Well Water	02/26/09	10 min	~	~	~	20.47	7.08	508	8.83	98.1
WSS-7-2 Well Water	06/17/09	10 min	~	~	~	23.43	6.98	428	6.35	74.6
WSS-7-2 Well Water	10/01/09	10 min	~	~	~	20.42	7.29	449	7.64	84.8
WSS-7-2 Well Water	12/17/09	10 min	~	~	~	15.81	6.97	458	11.69	118.0
WSS-8-2 DF WELL	02/27/09	10 min	16.90	16.90	21.00	20.44	6.86	641	2.98	33.8
WSS-8-2 City Water	02/27/09	10 min	~	~	~	15.69	7.46	480	4.69	47.8
WSS-8-2 BG WELL	02/27/09	10 min	17.75	18.20	25.55	20.80	7.10	371	4.08	45.6

Appendix C. FDEP Laboratory data of the Septic Tank Effluent, Lysimeters and Wells from Phase I. The average daily flow and load calculations of Ortho-P and TN in pounds per year are given. Duplicates are indicated by a "d"

Sample	Date	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	OrthoP (mg/L)	Total P (mg/L)	Avg Daily Flow (g/day)	OrthoP (lb/yr)	TN (lb/yr)
HK Septic Tank Effluent	12/19/07	27	35	0.008	35.0	5.4		500	8.2	53.3
HK Septic Tank Effluent	03/12/08	16	18	0.14	18.1	4.3	5.1	380	5.0	21.0
HK Septic Tank Effluent d	03/12/08	15	18	0.14	18.1	4.3	4.8	380	5.0	21.0
HK Septic Tank Effluent	07/15/08	36	37	0.013	37.0	6.9	7.8	330	6.9	37.2
HK Shallow-L-1 old DF	12/19/07	0.019	0.8	62	62.8	0.93		500	1.4	95.6
HK Shallow-L-2 old DF	12/19/07	0.089	0.8	63	63.8	1.3		500	2.0	97.1
HK Shallow-L-3 old DF	12/19/07	0.11	1	87	88.0	0.9		500	1.4	134.0
HK Shallow-L-4 old DF	12/19/07	0.04	1.2	32	33.2	0.17		500	0.3	50.6
HK Shallow-L-1&2 new DF	03/12/08	0.62	1.3	24	25.3	0.24	0.3	380	0.3	29.3
HK Shallow-L-1&2 new DF d	03/12/08	0.64	1.4	24	25.4	0.24	0.25	380	0.3	29.4
HK Shallow-L-1&2 new DF	07/15/08	0.021	1.6	39	40.6	0.62	0.84	330	0.6	40.8
HK Deep-L-3&4 new DF	03/12/08	0.29	1.2	21	22.2	0.15	0.19	380	0.2	25.7
HK Deep-L-3&4 new DF d	03/12/08	0.4	1.2	22	23.2	0.15	0.2	380	0.2	26.8
HK Deep-L-3&4 new DF	07/15/08	0.024	2	49	51.0	0.46	0.97	330	0.5	51.3
HK DF Well old DF	12/19/07	6.7	5.7	11	16.7	0.042		500	0.1	25.4
HK DF Well old DF	07/15/08	3.6	3.1	20	23.1	0.49	0.54			

Appendix C (continued).

Sample	Date	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	OrthoP (mg/L)	Total P (mg/L)	Avg Daily Flow (g/day)	OrthoP (lb/yr)	TN (lb/yr)
HK DF Well new DF	03/12/08	0.89	1.1	8.1	9.2	0.091	0.14	380	0.1	10.6
HK DF Well new DF d	03/12/08	0.95	1.1	7.7	8.8	0.096	0.14	380	0.1	10.2
HK DF Well new DF	07/15/08	0.01	0.8	30	30.8	0.77	0.96	330	0.8	31.0
HK BG Well	12/19/07	0.01	0.08	0.39	0.5	0.004				
HK BG Well	03/12/08	0.01	0.08	0.56	0.6	0.004	0.02			
HK BG Well d	03/12/08	0.01	0.08	0.56	0.6	0.004	0.02			
HK BG Well	07/15/08	0.1	0.08	0.41	0.5	0.006	0.2			
HK Well Water	03/12/08	0.01	0.08	0.48	0.6	0.014	0.029			
HK Well Water	03/12/08	0.01	0.08	0.48	0.6	0.014	0.022			
HK Well Water	07/15/08	0.01	0.08	0.33	0.4	0.016	0.022			
LT Septic Tank Effluent	12/19/07	56	63	0.008	63.0	14		38	1.6	7.3
LT Septic Tank Effluent d	12/19/07	X*	62	0.007	62.0	13		38	1.5	7.2
LT Septic Tank Effluent	03/11/08	52	54	0.016	54.0	11	12	53	1.8	8.7
LT Septic Tank Effluent	07/17/08	53	55	0.013	55.0	5.9	9.3	63	1.1	10.6
LT Shallow-L-1&2	12/19/07	0.023	1.3	25	26.3	3.3		38	0.4	3.0
LT Shallow-L-1&2 d	12/19/07	0.021	1.1	24	25.1	3.4		38	0.4	2.9
LT Shallow-L-1&2	03/11/08	0.031	0.37	0.5	0.9	1.1	1.1	53	0.2	0.1
LT Shallow-L-1&2	07/17/08	0.012	1.6	6.9	8.5	2.9	3.2	63	0.6	1.6

Appendix C (continued

Sample	Date	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	OrthoP (mg/L)	Total P (mg/L)	Avg Daily Flow (g/day)	OrthoP (lb/yr)	TN (lb/yr)
LT Deep-L-3	12/19/07	0.023	0.74	35	35.7	5.6		38	0.6	4.1
LT Deep-L-4	12/19/07	0.017	1	15	16.0	1.4		38	0.2	1.9
LT Deep-L-3&4	03/11/08	0.037	0.44	2.5	2.9	3.1	3.9	53	0.5	0.5
LT Deep-L-3&4	07/17/08	0.034	1.9	30	31.9	5.2	3.9	63	1.0	6.1
LT DF Well	12/19/07	0.15	0.4	24	24.4	0.15		38	0.0	2.8
LT DF Well d	12/19/07	0.14	0.4	24	24.4	0.16		38	0.0	2.8
LT DF Well	03/11/08	0.042	0.4	25	25.4	0.16	0.17	53	0.0	4.1
LT DF Well	07/17/08	0.019	0.4	27	27.4	0.3	0.3	63	0.1	5.3
LT DF Well d	07/17/08	0.016	0.4	28	28.4	0.3	0.3	63	0.1	5.4
LT BG Well	12/19/07	0.011	1.2	1.1	2.3	0.02		38	0.0	0.3
LT BG Well	03/11/08	0.01	0.08	0.1	0.2	0.004	0.02	53	0.0	0.0
LT BG Well	07/17/08	0.01	0.08	0.098	0.2	0.004	0.033	63	0.0	0.0
LT Well Water	03/11/08	0.01	0.08	1.8	1.9	0.009	0.02	53		
LT Well Water	07/17/08	0.01	0.08	0.42	0.5	0.016	0.024	63	0.0	0.1
YG Septic Tank Effluent	12/18/07	43	48	0.005	48.0	5.8		88	1.6	12.9
YG Septic Tank Effluent d	12/18/07	42	39	0.004	39.0	5.9		88	1.6	10.5
YG Septic Tank Effluent	03/13/08	56	63	0.005	63.0	7.6	8.7	127	2.9	24.4
YG Septic Tank Effluent	07/16/08	39	37	0.006	37.0	1.9	7.4	105	0.6	11.8

Appendix C (continued).

Sample	Date	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	OrthoP (mg/L)	Total P (mg/L)	Avg Daily Flow (g/day)	OrthoP (lb/yr)	TN (lb/yr)
YG Shallow-L-1	12/18/07	0.033	0.4	27	27.4	0.007		88	0.0	7.3
YG Shallow-L-2	12/18/07	0.04	0.57	35	35.6	0.027		88	0.0	9.5
YG Shallow-L-1&2	03/13/08	0.032	0.59	20	20.6	0.024	0.041	127	0.0	8.0
YG Shallow-L-1&2	07/16/08	0.036	2.7	54	56.7	0.049	0.099	105	0.0	18.1
YG Deep-L-3	12/18/07	0.023	0.56	3.5	4.1	0.004		88	0.0	1.1
YG Deep-L-4	12/18/07	0.051	0.4	39	39.4	0.004		88	0.0	10.6
YG Deep-L-3&4	03/13/08	0.028	0.57	5.3	5.9	0.008	0.02	127	0.0	2.3
YG Deep-L-3&4	07/16/08	0.047	1.52	15	16.5	0.004	0.02	105	0.0	5.3
YG DF Well	07/16/08	0.091	0.39	16	16.4	0.018	0.75	105	0.0	5.2
YG DF Well	03/13/08	0.066	0.4	21	21.4	0.016	0.38	127	0.0	8.3
YG DF Well	12/18/07	0.065	0.4	19	19.4	0.025		88	0.0	5.2
YG BG Well	12/18/07	0.015	0.15	0.025	0.2	0.05		88		
YG BG Well	03/13/08	0.01	0.16	0.21	0.4	0.12	0.19	127		
YG BG Well	07/16/08	0.01	0.08	0.4	0.5	0.13	0.15	105		
YG BG Well d	07/16/08	0.01	0.08	0.39	0.5	0.13	0.15			

Appendix D. USGS Laboratory data of the Septic Tank Effluent, Lysimeters and Wells from Phase I. The FDEP TN value and the percent difference are given for comparison. When the FDEP measured individual lysimeters, instead of combining either both short or long lysimeters into one sample, the average of the two values was used in the % difference column. Duplicates are indicated by a "d".

Sample	Date	Cl (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)		TN FDEP (mg-N/L)	% Diff w/ FDEP
HK Septic Tank Effluent	12/19/07	136	25.7	30	<.04	30.0		35.0	15.4%
HK Septic Tank Effluent	03/12/08	20.2	13.8	17	0.2	17.2		18.1	5.3%
HK Septic Tank Effluent	07/15/08	29.9	35.1	39	<.04	39.0		37.0	5.2%
HK Shallow-L-1-4 old DF	12/19/07	103	0.077	0.81	56.6	57.4		62.0	7.6%
HK Shallow-L-1&2 new DF	03/12/08	26.7	0.618	1.7	23.3	25.0		25.4	1.4%
HK Shallow-L-1&2 new DF	07/15/08	9.08	0.056	2	49.6	51.6		40.6	23.9%
HK Deep-L-3&4 new DF d	03/12/08	26.8	0.316	1.2	20.9	22.1		23.2	4.9%
HK Deep-L-3&4 new DF	07/15/08	14.1	<.020	1.7	41.9	43.6		51.0	15.6%
HK DF Well old DF	12/19/07	42.7	6.89	7.6	9.89	17.5		16.7	4.6%
HK DF Well new DF	03/12/08	18.1	0.999	1.5	8.15	9.7		9.2	4.8%
HK DF Well new DF	03/12/08	18.1	0.805	1.2	8.02	9.2		8.8	4.7%
HK DF Well new DF	07/15/08	46.2	<.020	0.26	30.3	30.6		30.8	0.8%
HK BG Well	12/19/07	3.08	0.06	0.15	0.37	0.5		0.5	10.1%
HK BG Well	03/12/08	4.26	<.020	E.08	0.53	0.5		0.6	18.8%
HK BG Well	07/15/08	3.39	<.020	<.14	0.39	0.4		0.5	22.7%

Appendix D (continued).

Sample	Date	Cl (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)	TN FDEP (mg-N/L)	% Diff w/ FDEP
LT Septic Tank Effluent	12/19/07	40.6	51.5	58	<.04	58.0	62.5	7.5%
LT Septic Tank Effluent	03/11/08	34.5	48	53	<.04	53.0	54.0	1.9%
LT Septic Tank Effluent	07/17/08	30.9	50.7	54	E.02	54.0	55.0	1.9%
LT Shallow-L-1&2	12/19/07	30	0.037	1.5	24	25.5	25.7	0.8%
LT Shallow-L-1&2	03/11/08	1.6	E.015	0.5	0.47	1.0	0.9	10.9%
LT Shallow-L-1&2	07/17/08	18.3	<.020	1.6	6.49	8.1	8.5	4.9%
LT Deep-L-3&4	12/19/07	27	E.011	1.6	21.8	23.4	25.9	10.0%
LT Deep-L-3&4	03/11/08	2.6	0.024	0.83	1.85	2.7	2.9	9.3%
LT Deep-L-3&4	07/17/08	54.3	0.026	1.4	33.2	34.6	31.9	8.1%
LT DF Well	12/19/07	26.8	0.141	0.29	23.1	23.4	24.4	4.2%
LT DF Well	03/11/08	29.2	0.038	0.19	23.6	23.8	25.4	6.5%
LT DF Well	07/17/08	27.5	0.025	0.19	26	26.2	27.9	6.3%
LT BG Well	03/11/08	2.7	<0.02	E0.07	0.105	0.1	0.2	52.6%
LT BG Well	07/17/08	2.71	<.020	E.13	0.08	0.1	0.2	76.0%

Appendix D (continued).

Sample	Date	Cl (mg/L)	Ammonia (mg-N/L)	TKN (mg-N/L)	Nitrite + Nitrate (mg-N/L)	TN (mg-N/L)		TN FDEP (mg-N/L)	% Diff w/ FDEP
YG Septic Tank Effluent	12/18/07	27.2	39.2	47	<.04	47.0		43.5	7.7%
YG Septic Tank Effluent	03/13/08	41.4	55.6	65	<.04	65.0		63.0	3.1%
YG Septic Tank Effluent	07/16/08	34.7	37.8	42	<.04	42.0		37.0	12.6%
YG Septic Tank Effluent d	07/16/08	34.6	37.5	43.0	<0.04	43.0			13.9%
YG Shallow-L-1&2	12/18/07	31.3	0.021	0.49	26.2	26.7		31.5	16.5%
YG Shallow-L-1&2	03/13/08	38.8	0.105	0.77	18.6	19.4		20.6	6.1%
YG Shallow-L-1&2	07/16/08	196	0.131	4.9	51.9	56.8		56.7	0.2%
YG Deep-L-3&4	12/18/07	31.2	0.044	0.58	22.7	23.3		21.7	6.9%
YG Deep-L-3&4	03/13/08	27.4	E.017	0.45	4.97	5.4		5.9	8.0%
YG Deep-L-3&4	07/16/08	40	0.038	0.61	14.4	15.0		16.5	9.6%
YG DF Well	07/16/08	26.6	0.08	0.29	18.7	19.0		16.4	14.7%
YG DF Well	03/13/08	32.2	0.072	0.14	20.5	20.6		21.4	3.6%
YG DF Well	12/18/07	34.6	0.125	0.21	16.2	16.4		19.4	16.7%
YG BG Well	12/18/07	2.6	<.100	1.2	<.04	1.2		0.2	149.1%
YG BG Well	03/13/08	2.63	<.020	E.08	0.2	0.2		0.4	59.6%
YG BG Well	07/16/08	5.62	<.020	E.14	0.39	0.4		0.5	20.7%