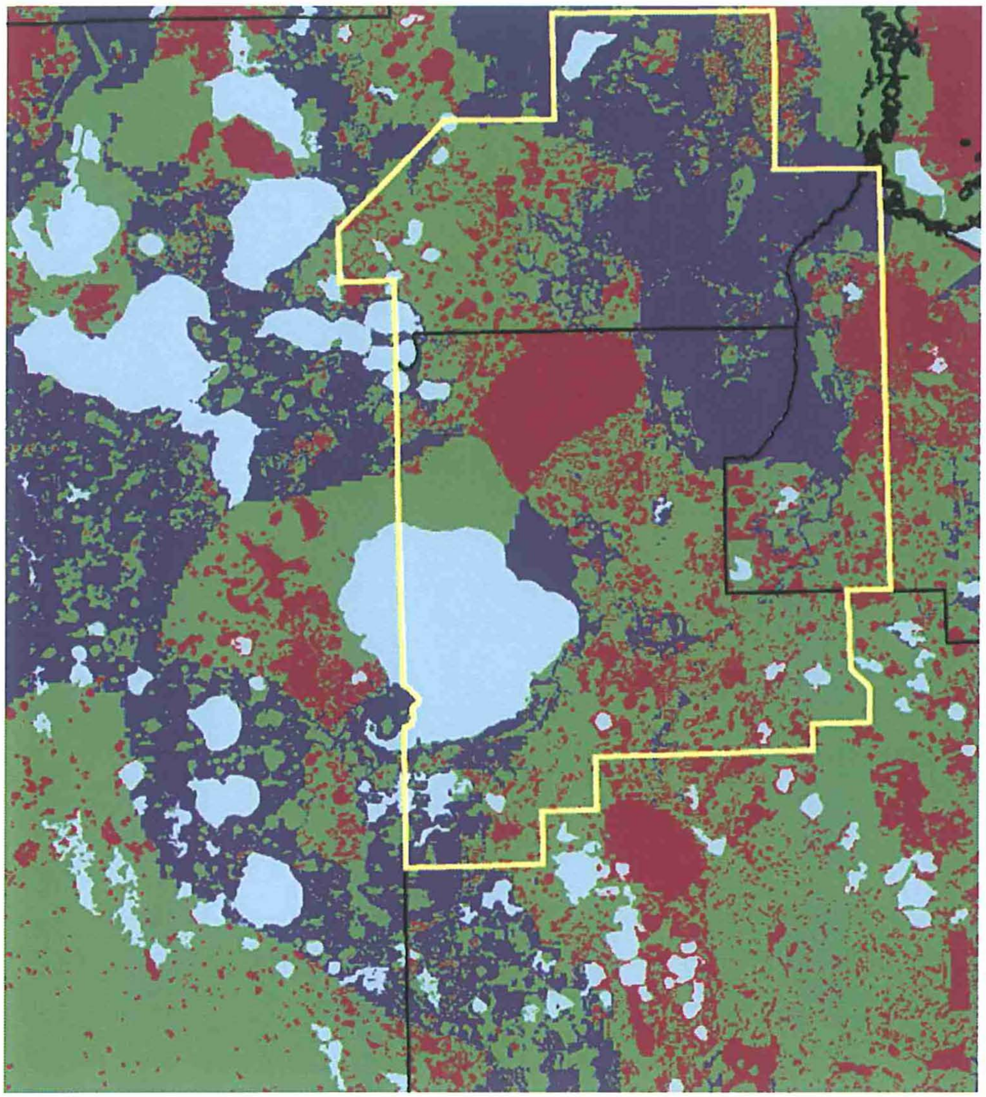
Multiple Nitrogen Loading Assessments from Onsite Waste Treatment and Disposal Systems Within the Wekiva River Basin

Wekiva Study Area, Florida



Wekiva Study Area and Wekiva Aquifer Vulnerability Zones
Source: Cichon et al, 2005

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TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

Multiple Nitrogen Loading Assessments from Onsite Waste Treatment and Disposal Systems Within the Wekiva River Basin

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By

William C. Aley IV, Mark Mechling, P.E., Gabriel S. Pastrana, P.E., Eric B. Fuller

EXECUTIVE SUMMARY

The Wekiva Parkway and Protection Act was promulgated by the Florida Legislature and subsequently signed into law in 2004. In addition to providing authority and direction to local and state governmental entities for design and construction of the Wekiva Parkway, the Act defined the boundaries of the Wekiva Study Area and directed the Florida Department of Environmental Protection (DEP), the Florida Department of Health (DOH), the St. Johns River Water Management District (SJRWMD), and the Florida Department of Agriculture and Consumer Services (DACS) to conduct studies to determine potential impacts to groundwater, springs, and surface waters in the Study Area (SB1214er, 2004).

In May of 2006, funding from Specific Appropriation 566 was provided to the Florida Department of Health to "conduct or contract for a study to further identify and quantify the nitrogen loading from onsite wastewater treatment systems (OWTS) within the Wekiva Study Area."

During January through May 2007, Ellis & Associates, Inc. (E&A) performed an assessment on three properties within the Wekiva Study Area. Criteria for selection of properties to be investigated were prepared by DOH with input from the Research Review and Advisory Committee (RRAC). Site selection criteria included: selection of one site from each of Lake, Orange, and Seminole counties; depth to water within reach of direct push drilling method; selection of sites with varying depth to groundwater; septic systems installed after 1982, but with no repairs since 1999; properties large enough to capture the nitrogen plume on-site and avoid interference from upgradient drainfields; properties using minimal fertilizer and no reclaimed water; properties with homes on public water supply with year-round residents and no excessive number of occupants; and, if compatible with other criteria, one site in each Wekiva Aquifer Vulnerability Assessment (WAVA) vulnerability class.

In general, the properties investigated met the site selection criteria. The Lake County property was not on public water; however water usage was determined by metering the system. As requested, one site in each of the three WAVA zones was investigated.

The WAVA utilized soil permeability, the thickness of the surficial and intermediate aquifers, and karst features to establish areas of relative "vulnerability" of the Floridan Aquifer System. The "Primary" WAVA zone is that defined as "more vulnerable" in the study, the "Secondary" WAVA zone is defined as "vulnerable", and the "Tertiary" WAVA zone is defined as "less vulnerable".

The tasks associated with these assessments included development of a site-specific Quality Assurance Project Plan, identifying (in conjunction with DOH) properties meeting the

established criteria for site selection, securing approval from property owners to access the candidate properties and conduct assessment activities, characterization of the onsite wastewater treatment systems, determination of soil lithology and soil analyses, delineation of (primarily) nitrate and nitrogen in the groundwater, and data interpretation and mass balance modeling.

The three sites investigated had septic systems which appeared to be in good working order at the initiation of the assessments. The drainfields at the Lake County and Orange County sites were constructed in-ground and the Seminole County Study site had a mound system.

Daily water use estimates for the three sites fell within the previously-documented expected range (EPA, 2007) with the exception of the Lake County site, which was greater than the expected range. Concentrations of nitrogen and phosphorus in the septic tank effluent fell within expected range for all three sites. Daily total nitrogen loading to the drainfield was slightly above the expected range for the Seminole and Lake County sites and within the expected range for the Orange County site.

Soil types varied by site: the Seminole County site soils were identified as similar to Myakka fine sands; the Lake County site consisted of mostly brown to gray fine sands resembling the Tavares Series near the surface, followed by alternating, non-continuous intervals of clay, clayey sands, and fine sands; the surficial soils at the Orange County site were determined to belong to the Tavares Series, followed by interfingering layers of clay loam, loamy sands, and fine sands. The mean organic content of soils was 1.29 % for the Seminole County site, 3.01% for the Lake County site, and 1.39% for the Orange County site.

The investigation methodology utilized groundwater probings, completed using direct push drill technology to delineate the horizontal and vertical extent of the plume of septic tank effluent below and downstream of the onsite wastewater treatment systems to determine how effluent induced groundwater behaves as it is transported downgradient. Initial placement of sampling points was based on apparent groundwater flow direction observed at the beginning of each investigation; however, the apparent groundwater flow direction at the Lake County and Orange County sites did not match the nitrogen plume direction. This was apparently a function of alternating, non-continuous intervals of clays and clayey sands underlying these two sites, as well as below normal rainfall during the year preceding the study. Field conductivity readings were ultimately the best indicator of contaminant plume location and were used in the field as the guiding parameter in delineation of the boundary between effluent-induced and other groundwater.

The vertical and horizontal boundaries of the nitrogen plumes were well defined by these assessments. Nitrogen concentrations of 10 mg/L were documented to a depth of approximately 10 to 15 feet below the surficial aquifer groundwater table at all three sites during the time of the investigations. Horizontal delineation of the plumes to either apparent background concentrations (Seminole) or 10-20 mg/L (Lake and Orange) were established.

The nitrogen plume encountered at the Seminole County site was characterized by both nitrate and total kjeldahl nitrogen (TKN). The highest nitrate concentrations at the site were observed directly below the drainfield. Based on nitrate concentration contour intervals of 10 mg/L, the nitrate plume's maximum dimensions measure approximately 30 feet long by 25 feet wide and approximately 8 feet thick. It is evident that substantial nitrate reduction (approximately 95%) occurs within 20 to 30 feet of the highest nitrate concentrations below the drainfield, apparently due to natural denitrification.

Once the nitrogen plume moves away from the drainfield, nitrification appears to largely discontinue. The downgradient nitrogen plume was composed mainly of TKN. The TKN plume's maximum dimensions measure approximately 120 feet long by 75 feet wide. Total nitrogen concentrations are gradually attenuated to apparent background concentrations at approximately 130 feet downgradient. It appears that this attenuation is associated with dilution from background groundwater.

The nitrogen plume encountered at the Lake County site is best defined by nitrate concentrations. The highest nitrate concentrations at the Lake County OWTS study site were observed northwest of the septic tank and drainfield. Based on a nitrate concentration contour of 10 mg/L, the dimensions of the nitrate plume measure approximately 90 feet long by 45 feet wide. The number of groundwater probings at this site was insufficient to determine the size of the plume in terms of background concentrations.

Below the drainfield at the Lake County site, there is an organic-rich layer of clayey and sandy sediments from approximately 12 to18 feet bgs. This area seems to be providing an optimal space with aerobic conditions which are supporting a high degree of nitrification above the groundwater table.

At 90 feet downgradient of the drainfield, we observed an 80% reduction in mean total nitrogen concentrations of the upper four, most concentrated, sample intervals. This reduction appears to indicate a combination of denitrification and dilution. Additionally, there is a 92% conversion of total nitrogen from TKN to nitrate in the groundwater between the drainfield and this location.

The nitrogen plume encountered during investigation of the Orange County OWTS is best defined by nitrate concentrations. Mean TKN concentrations at the Orange County site were less than 1.0 mg/L at all sample points. Based on a nitrate concentration contour of 10 mg/L, the dimensions of the nitrate plume are approximately 90 feet long, with a maximum width of 60 feet wide.

The subsurface conditions observed during the sampling event at the Orange County site appeared to be optimal for promotion of nitrification as septic tank effluent was distributed across the drainfield and leached through the underlying layers of permeable fine sands and clayey sands. Following analysis of the groundwater samples taken at this site, it appears that the septic tank effluent is being distributed fairly evenly across the drainfield and migrating in all directions once it reaches the groundwater, most likely due to the very low hydraulic gradient observed.

Comparison of mean total nitrogen concentrations in septic tank effluent to mean total nitrogen concentrations directly below the drainfield indicates a 35% reduction in total nitrogen concentration as septic tank effluent is leached through the drainfield and into groundwater, with 99.40 % of nitrogen below the drainfield occurring in the form of nitrate. Due to limited number of sampling probes, the boundary of the nitrogen plume was not delineated to 10 mg/L.

In our opinion, while the data discussed here are relevant and accurate based on the assessment period during which they were developed, seasonal variability - particularly as related to rainfall amounts - could effect the observed nitrogen concentrations over time. Only longer term studies could more accurately predict the likely attenuation associated with normal or above normal rainfall.

The "background" conditions reported here may be sufficient for comparison to plume concentrations, but would be more appropriately determined over a longer period of time, such as one year.

Mass loading calculations indicate nitrification / denitrification is taking place at the study locations (estimated at: Seminole – 32%; Lake – 52%; Orange – 23-46%) at the upper portion of the expected range of 10 – 50% reported in previous studies. The depth to groundwater and amount of unsaturated soils available for nitrification / denitrification appears to be an important component in this process based on the comparison of the results for these three locations.

It should be noted that the mass loading results reported should not be considered as "average" or "typical" since both the Seminole and Lake County sites had septic tank effluent loading from nitrogen to the drainfield at the upper end of the expected range. This was apparently based on number of residents and/or water usage. More important as a basis for comparison than the estimated loading in pounds is the apparent percentage of nitrification / denitrification, which appears to be in the upper portion of the expected range.

Nitrogen and nitrate loading to the land surface, groundwater, and surface water comes from a number of sources in addition to onsite wastewater treatment systems, such as atmospheric deposition; burning of fossil fuels; natural and chemical fertilizers used in agriculture and landscaping; municipal wastewater treatment facilities; and animal waste from commercial livestock operations. A number of other studies are recently or soon to be completed which address loading from these other sources. We recommend the results of these other studies be used in conjunction with the results of this investigation in order to establish practical means of reducing nitrogen loading to the Wekiva Study Area in a manner that addresses all nitrogen loading sources.

It should be noted that the mass loading concentrations calculated from the results of this study are representative of only three study sites in the Wekiva Study Area which may not be indicative of mass loading rates for the approximately 55,000 other OWTS sites in the study area. E&A recommends that before the mass loading rates presented in this report are used to extrapolate mass loading concentrations being applied by all OWTS in the WSA, further analysis of septic tank effluent concentrations, residential water usage, and number of residents at an appropriate number of additional sites within the Wekiva Study Area be carried out to provide better statistical certainty.

Additionally, since these studies were conducted at properties of relatively large lot size in order to allow distinguishing on-site plumes from neighboring plumes, in our opinion, a study that investigates nitrogen concentrations downgradient of more densely constructed developments (i.e., subdivisions or developments with smaller lot sizes and higher density of OWTS) is an appropriate next step to determine whether the mass loading estimates reported here are representative in terms of current and expected development in the Wekiva Study Area.

INTRODUCTION

The Wekiva Parkway and Protection Act was promulgated by the Florida Legislature and subsequently signed into law in 2004. In addition to providing authority and direction to local and state governmental entities for design and construction of the Wekiva Parkway, the Act defined the boundaries of the Wekiva Study Area and directed the Florida Department of Environmental Protection (DEP), the Florida Department of Health (DOH), the St. Johns River Water Management District (SJRWMD), and the Florida Department of Agriculture and Consumer Services (DACS) to conduct studies to determine potential impacts to groundwater, springs, and surface waters in the Study Area (SB1214er, 2004).

Of major concern was the potential impact on the Wekiva Study Area from nitrogen (N) which makes its way into surface water and groundwater from a variety of sources such as atmospheric deposition; burning of fossil fuels; natural and chemical fertilizers used in agriculture and landscaping; municipal wastewater treatment facilities; onsite wastewater treatment systems (OWTS); and animal waste from commercial livestock operations. Nitrate is of concern due to its human health effects (particularly methemoglobinemia in infants) and the increased potential for eutrophication in affected surface waters.

In May of 2006, funding from Specific Appropriation 566 was provided to the Florida Department of Health to "conduct or contract for a study to further identify and quantify the nitrogen loading from onsite wastewater treatment systems (OWTS) within the Wekiva Study Area." The objectives of the study were determined by the Department of Health staff, the Department of Health's Research Review and Advisory Committee (RRAC), which also has oversight of the study, and input from other interested parties. The purpose of the study reported here is to systematically evaluate the fate and transport of nitrogen from OWTS at representative residential properties within the Wekiva Study Area.

Typically, residential OWTS consist of a wastewater source which is collected in a septic tank, distributed over a drainfield, and allowed to percolate through a zone of unsaturated soil before entering the surficial aquifer. The septic tank provides primary treatment of the wastewater by removing the majority of solids and grease. Once the pretreated effluent leaves the septic tank, either by gravity or pumping, it is distributed over the drainfield through a series of perforated pipes underlain by a porous media, such as gravel, and allowed to percolate through an aerobic layer of unsaturated soil, where, under ideal conditions, organic and ammonia nitrogen are converted through microbial nitrification to nitrate. Ultimately, in the presence of anaerobic denitrifying bacteria and organic carbon, the nitrate may be converted to gaseous oxides of nitrogen or nitrogen gas and released into the atmosphere.

The study intended to select multiple properties across the Wekiva Study Area for investigation, including at least one site from each of the three Wekiva Aquifer Vulnerability Assessment (WAVA) zones identified by Chicon et al. (2005). Based on funding limitations, three properties were ultimately selected. This report presents the methodology and findings from the nitrogen loading assessments conducted at three sites in the Wekiva Study Area. The study included a site located in Seminole County in the Tertiary WAVA zone, a site located in Lake County in the Secondary WAVA zone, and a site located in Orange County in the Primary WAVA zone. Figure 1 illustrates the approximate locations of each study site in relation to the Wekiva Study Area and surrounding areas.

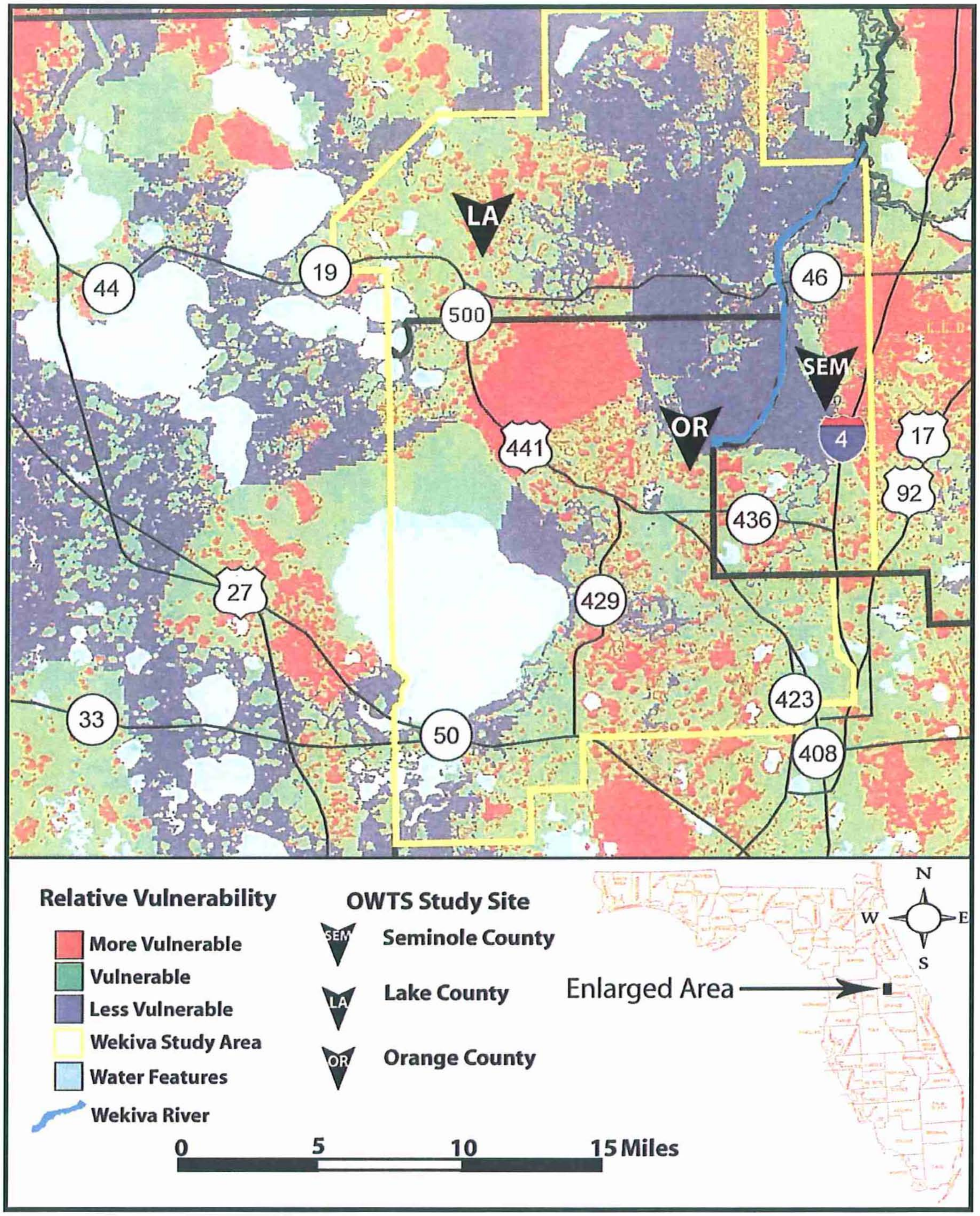

Figure 1. Regional view depicting Onsite Waste Treatment System (OWTS) study sites in relation to Wekiva Aquifer Vulnerability Zones and the Wekiva Study Area. (Adapted from Cichon, et al, 2005)

The WAVA utilized soil permeability, the thickness of the surficial and intermediate aquifers, and karst features to establish areas of relative "vulnerability" of the Floridan Aquifer System. The "Primary" WAVA zone is defined as "more vulnerable" in the study, the "Secondary" WAVA zone is defined as "vulnerable", and the "Tertiary" WAVA zone is defined as "less vulnerable".

METHODOLOGY

Site Selection

Criteria for selection of properties to be investigated were prepared by DOH with input from the Research Review and Advisory Committee (RRAC). Site selection criteria included: selection of one site from each of Lake, Orange, and Seminole counties; depth to water within reach of direct push drilling method; selection of sites with varying depth to groundwater; septic systems installed after 1982, but with no repairs since 1999; properties large enough to capture the nitrogen plume on-site and avoid interference from upgradient drainfields; properties using minimal fertilizer and no reclaimed water; properties with homes on public water supply with year-round residents and no excessive number of occupants; and, if compatible with other criteria, one site in each Wekiva Aquifer Vulnerability Assessment (WAVA) vulnerability class.

Quality Assurance Project Plan

The Quality Assurance Project Plan identified the project objectives, project organization and schedule, and described methods for field sampling methodology, laboratory analyses, database entry, QA/QC, and data reduction and reporting methodology.

The goals of the QA project plan were to ensure that:

- the measurements undertaken adequately supported the project objectives regarding data collection,
- data collected were of the highest quality that could be reasonably expected,
- the quality of the data is known,
- the data and its quality were adequately documented, and
- the data were adequately preserved and rendered in available form.

Mapping

Prior to commencement of sampling, a scaled map was produced of each site (Appendix A). Elevations of all pertinent data points were surveyed in relation to published vertical datum or an arbitrary elevation inferred from a topographic map. In addition to vertical data, horizontal (X, Y) data was recorded for all pertinent points. All vertical and horizontal data are provided in Appendix B.

System Evaluations

System evaluations in accordance with procedures outlined in 64E-6 F.A.C were performed by Green's Environmental Services, Inc, of Winter Park, Florida, at each study site. General information from the evaluations is provided in Table 1 below. Copies of the evaluation reports are provided in Appendix F. More specific information is detailed in the Site Characteristics and System Description section for each particular site.

Table 1 – General summary of OWTS investigated during Wekiva Study

Site (County)	Tank Size (gallons)	Installation Date	Condition	Drainfield Size (ft^2)	Wet Seasonal Water Table (inches bgs)	Drainfield Depth (inches bgs)	Mean DTW During Sampling Event (inches bgs)
Seminole	1,050	1988	Good*	440	8-12	13	62
Lake	1,050	1991	Good	385	> 50	36	200
Orange	1,050	1996	Good	638	≈ 40	24	256

* At the time of initial system evaluation, the tank was determined to be in good condition. After completion of the groundwater assessment, the tank was pumped out and found to have signs of stress and cracking. Note: A tightness test at the time of initial evaluation revealed no evidence of a leaking condition.

Water Use

In order to have a record of water use for the families occupying the residences involved in the study, readings were recorded daily from either a municipal water meter or a meter installed on the residential water system. Home owners were also requested to complete a questionnaire on their home water use. The average amount of water entering each septic system was calculated based on all available water use data. Average daily water use values were used to quantify the amount of water passing into the individual septic tanks daily. Water use information is presented in Appendix B, and copies of the questionnaires are provided in Appendix F.

Characterization of Septic Tank Effluent

In order to determine wastewater concentrations being applied to the drainfield, septic tank effluent (STE) was sampled at each site on three separate occasions throughout the corresponding periods of field work. The STE grab samples were collected from within the solids deflection device of each septic tank in accordance with FDEP Standard Operating Procedures, preserved in laboratory-provided containers, immediately chilled with ice, and transported to a Florida-certified laboratory for analysis. On each sampling occasion the STE samples were analyzed for CBOD5, Total Nitrogen, Total Kjeldahl Nitrogen, Phosphorous, Total Suspended Solids (TSS), and a number of field parameters.

Delineation of OWTS-effluent plumes

The investigation methodology utilized groundwater probings completed using direct push drill technology to delineate the horizontal and vertical extent of the plume of STE below and downstream of OWTS to determine how effluent induced groundwater behaves as it is transported downgradient. Electrical conductivity was used in the field as the guiding parameter in delineation of the boundary between effluent-induced and other groundwater.

Prior to establishing the probing scheme, ground water flow direction was determined by installing a network of piezometers throughout each site. All piezometers were installed by hand auger or direct push and were screened from at least two feet above the surface of the water table, as inferred by hand augering observations, and set at depths of at least two feet into the surficial water table. Well construction details for all piezometers are included in the Groundwater Elevation Table of Appendix B for each site. Decontamination methods in accordance with FDEP standard operating procedures were followed during piezometer installation to prevent cross contamination. Once groundwater elevations were verified to be at equilibrium, they were measured and subtracted from surveyed top-of-casing elevations in order to evaluate hydraulic gradient. All piezometers were removed from each site upon completion of field work. Piezometer locations are depicted on the GW flow maps provided in Appendix A. All observed groundwater elevation data and piezometer construction details are provided in Appendix B.

Following establishment of groundwater flow, multiple locations were probed and sampled in order to determine background groundwater characteristics and concentrations. Background probings were completed to depths of approximately 20 feet below the water table or until probe refusal or an impermeable zone was reached. Background borings were completed and sampled at distances away from the drainfield which were believed to be out of the range of STE influenced groundwater. Effort was made at each site to obtain samples from locations assumed to be upgradient, downgradient, and sidegradient of the drainfield.

In order to determine the depth of the plume, mounding, and concentrations at the water table directly below the drainfield, multiple locations were probed within the drainfield from the capillary fringe to depths of at least 5 feet below the contaminant plume as indicated by field conductivity readings. Groundwater samples were collected at discrete vertical intervals of two feet at all probing locations.

To delineate the horizontal and vertical extent of the STE plume and to assess attenuation down gradient of the source, multiple locations were probed and sampled downgradient of the drainfield. All figures and site maps depicting sampling locations are provided in Appendix A.

Groundwater Sampling

Groundwater was sampled with slotted-pipe probes using direct push technology and the following methodology: 1) a stainless steel, sleeve-covered slotted sampling probe was pushed to a depth where the water table was intercepted; 2) the sleeve was retracted to expose two feet of the slotted sampling device; 3) purging of the water column, and stabilization of groundwater sampling parameters was established in accordance with FDEP Standard Operating Procedure (SOP) FS 2200 using a peristaltic pump and dedicated polyethylene tubing for each sampling interval; 4) field readings of pH, temperature, electrical conductivity, dissolved oxygen, turbidity, ORP, chloride, total iron, and ferrous iron were recorded for each sampling interval and; 5) water samples were taken. In addition to the recorded field parameters, purging rate, tubing intake placement, length and location of the screened interval were also monitored and recorded.

Following acquisition of water samples at each specific depth interval, the sampling probe was removed from the ground, and the sampling device and screen were replaced by a decontaminated sampler. The sampler was then pushed to a depth two feet below the previous sampling interval and new polyethylene tubing was installed. Field methods and sampling procedures were carried out as described in steps 2, 3, 4, and 5. This procedure was repeated for each sample interval throughout the course of field work.

Field Measurements

The field parameters chloride, ferrous and total iron were measured at the time and general location that each sample was collected using a LaMotte SMART 2 Colorimeter and methods described in LaMotte, 2001. The additional field parameters turbidity, dissolved oxygen, pH, electric conductivity, temperature, and oxygen reduction potential were measured in accordance with FDEP Standard Operating Procedures for Field Activities (DEP-SOP-001/01) dated February 1, 2004, revised May 2, 2005. Calibration of field instruments was documented on form FD9000-8, and all field measurements were recorded on a modified version of form FD-9000-24. All calibration records are provided in Appendix C.

Laboratory Elemental Analysis

Groundwater samples were submitted within the applicable holding times to Environmental Conservation Laboratories, Inc. (ENCO) in Orlando, Florida, a NELAP-certified lab, for the following laboratory analyses: All samples were analyzed for Total Nitrogen (EPA Methods 350.1, 351.2, 353.1, 353.3, 354.1), approximately half of the water samples, usually including the topmost sample of every probing, were analyzed for CBOD5 (EPA Method 5210B), approximately 10 percent of samples, usually including the topmost sample of a probing, were analyzed for Total Suspended Solids (EPA Method 160.2), Total Phosphorous (EPA Method 365.4), and fecal coliform bacteria (SM 9222D). Groundwater samples were also analyzed for the ratio of nitrogen isotopes by the extraction of nitrate from groundwater via ion exchange method in order to identify any indications of human or animal wastewater vs. inorganic fertilizer as source of nitrogen.

Soil Lithology and Analyses

In order to assess the lithologic characteristics and organic content of the soils below the Wekiva study sites, USDA classification and gradation analysis were performed on soils which were sampled from a continuous soil profile completed at a location down gradient of the drainfield which was assumed to be within the effluent plume. Continuous samples of subsurface soils from the unsaturated and saturated zones were obtained by hand auger and direct push methodology. The lithology boring extended to a depth of refusal or until the plume boundary had been apparently crossed by at least five feet.

As part of the existing system evaluation, soil samples from each site were collected in order to characterize the vadose zone soil material beneath the infiltrative surface of each drainfield. For at least two vadose zone samples, USDA classification and texture confirmation by sieve analysis according to sieve analysis methods described in USDA, 2004 were carried out.

Soil organic content was measured by loss on ignition per method 5A of the Soil Survey Laboratory Methods Manual. Natural moisture content was determined in accordance to ASTM method D2216, this method determines moisture content by mass of soil where the reduction in mass by drying is due to loss of water. Classification of soil colors was determined by general visual observations. Complete soils analysis and copies of the complete system evaluations are included in Appendix E.

Quality Assurance/Quality Control of Groundwater Samples

QA/QC samples to the extent of approximately 10 percent of the number of laboratory analyzed samples were included. Approximately five percent of QA/QC samples were equipment blanks sampled in accordance with FQ1212, excluding CBOD. The other five percent of QA/QC samples were field duplicates sampled in accordance with FQ1220. Deviation of target analyte concentrations of field duplicate samples taken at the three sites was ranged from 1-9% of field sample concentrations.

RESULTS

Water Use Monitoring

Table 2 is a summary of water use monitoring for each study site. Water usage by the families studied was comparable to the ranges reported by U.S. EPA (2007) with the exception of the Lake County site, which was greater than the EPA reported range. Additional water use information is presented in Appendix B, and copies of home water use questionnaires which were completed by the home owners are provided in Appendix F.

Table 2 – Summary of water use monitoring for Wekiva Study

Site (County)	# of Residents	Type of Meter	Analysis Period (days)	Household Mean Use (gal/day)	Individual Mean Use (gal/person/day)	EPA , 2007 Mean Use (gal/person/day)	EPA, 2007 Range (gal/person/day)
Seminole	5	Municipal	20	315	63		
Lake	4	Installed indoors	8	450	112.5	68.6	26.1 – 85.2
Orange	1[1]	Municipal	9	35	35		

[1] There were two permanent residents at this location until approximately one month prior to the study

Septic Tank Effluent Analyses

Table 3 is a summary of mean concentrations found in septic tank effluent samples at each OWTS study site within the Wekiva Study Area. Complete septic tank effluent sampling results are provided in Appendix B.

Table 3. Summary of average concentrations in STE samples from Wekiva Study Area OWTS sites.

Sample Location (County)	Concentration (mg/L)								Field Measurements		
	CBOD	NO_3	NO_3/NO_2	NO_2	TKN	N Total	P Total	TSS	pH	ORP	Conductivity
SEMINOLE	98.5	0.19	0.55	0.35	73	74	8.9	49	6.69	-209	715
LAKE	100	1.7	1.79	0.06	41	43	5.5	69	6.68	-36	677
ORANGE	130	0.16	0.64	0.48	68	69	10.2	35	7.10	-239	829
EPA,2007[1]	---	<1	---	---	---	26-75	6-12	155-330	---	---	---

[1] assumed water use of 259.7 liters/person/day (68.6 gallons/person/day), Table 3-1 (EPA, 2007)
--- Not Reported

By multiplying the average quantity of effluent generated per day by the average TN concentration in the STE (Table 3), an approximate value for the amount of nitrogen loaded into the drainfield daily by each household can be estimated. Table 4 is a summary of total nitrogen loading into each Wekiva Study Area OWTS drainfield along with values from EPA (2007) for comparison.

Table 4. Summary of daily total nitrogen loading into Wekiva Study Area OWTS drainfields.

Sample Location (County)	Mean Water Use (liters/person/day)	Mean STE Total N (mg/L)	TN concentration to drainfield (g/person/day)	Household yearly load of TN (lbs/person)
SEM.	238.4	74	17.64	14.19
LAKE	425.75	43	18.31	14.73
ORANGE	132	69	9.11	7.33
EPA, 2007[1]	259.7[1]	26-75	6-17	4.82 – 13.68

[1] Table 3-1 (EPA, 2007)

(Example for Seminole County)

1192 L/day x 74 mg/L = 88208 mg/day (88.208 g/day)

88.208 g/day ÷ 5 persons = 17.6 g/day/person

These results for the three sites investigated fall within or slightly above the EPA reported range.

SEMINOLE COUNTY SITE

Site Characteristics and System Description

The Seminole County study site was located approximately 0.3 miles (1580 feet) east of the Little Wekiva River in the Tertiary WAVA zone (Figure 1). The site was in a residential community and consisted of a four bedroom, two bathroom, single family home, approximately 2,874 square feet in size, with five permanent residents. The home was situated on a parcel of land with an area of approximately one acre. The observed groundwater flow direction was to the west-southwest (Appendix A, Figure 14).

An evaluation of the OWTS was conducted in accordance with procedures outlined in 64E-6 F.A.C. by a Master Septic Tank Contractor. The evaluation of the septic system concluded that the OWTS at the Seminole County site consisted of a 1,050 gallon fiberglass septic tank and drainfield which is located to the west of the residence. The septic tank was installed in 1988, the same year that the home was built, and appeared to be in good working condition at the time of evaluation. According to the homeowners, the tank has not been pumped during at least the past three years. It was determined that there were two drainfields at the site which were situated side by side. The two drainfields, which are separated by a distance of 1-2 feet, are each approximately 440 square feet (12 feet x 37 feet). After completion of a number of field tests it appeared that the northern drainfield, which was 3-6 inches deeper than the southern drainfield, was inactive, and all STE was being distributed through the southern drainfield. The southern drainfield consisted of approximately one foot of top soil and fill overlaying an approximately one foot thick bed of gravel containing the perforated STE distribution pipes. The sediments immediately below the drainfield appeared to be non-native fill sand.

At the outset of the site assessment, the tank was tested to determine that it was water tight. The tank tested tight at that time. Subsequent to the completion of assessment activities, the tank was pumped out. Based on observations made at this latter time, the tank showed signs of stress and cracking. It is presumed that the cracks are superficial and that the sludge layer at the bottom of the tank would have prevented any possible leakage. Appendix F contains a supplemental, detailed description of the field tests performed to assess the septic tank tightness as well as the Master Septic Tank Contractor reports.

Based on the presence of mottling, the system evaluation determined that the wet seasonal water table at the site is estimated to be 8 inches to 12 inches below grade. The active drainfield was estimated to extend 13 inches below grade. It is suspected that the drainfield at this site is at least partially submerged within the water table during the wet season, although during the January/February 2007 sampling period groundwater was not encountered in the vicinity of the drainfield until at least 55 inches below grade. A copy of the system evaluation is included in Appendix F, and Table 1 summarizes the general OWTS characteristics of each study site.

Soil Characterization

Based on soil boring observations throughout the Seminole County site, lithology appeared consistent across the entire property. Soils were identified as similar to Myakka fine sands and consisted of fine sandy sediments to a depth of at least 32 feet below ground surface (bgs). The Myakka soil series is typical of broad plains on flatwoods in Florida and are common throughout Seminole County (USDA, 1990). Soil color at the site alternated between dark brown and tan. The highest organic content observed (6.9%) was in the soil sample collected below the drainfield, adjacent to P-9 at 4-5 feet bgs (Figure 2). The mean organic content was 1.29%. Although the high organic and fines content along with the dark coloration and presence of root fragments at P-9 4-5'may be indicative of a spodic layer, there was no direct indication of a well defined "bio-mat" when hand augering through the drainfield. Based on visual observation of SB-1, which was carried out approximately 30 feet down gradient of P-9, the dark colored, organic soil layer observed adjacent to P-9 appeared to be present down gradient of the drainfield although soil organic content was not measured from 4-5 feet bgs at SEM-SB-1.

A summary of soil classification results for all soils sampled at each Wekiva study site, including vadose zone soils sampled directly below the infiltrative surface of each drainfield and soils collected from continuous soil borings which were located within the nitrogen plumes is included in Appendix E. Copies of laboratory test results for the USDA classification, gradation test results, and particle size distribution reports for all soil samples analyzed are also included in Appendix E.

Instantaneous delineation of OWTS-effluent plume

Field work for the Seminole County site was conducted during January and February 2007. During the field investigation of the Seminole County site, placement of sampling points was based on field conductivity readings and the apparent groundwater flow direction, which was observed to be to the west-southwest. The investigation plan was to install a network of borings to delineate the plume of STE influenced groundwater as it percolated through the drainfield and recharged into the surficial aquifer. An explanation of the placement of soil and groundwater probings is presented in the methodology section of this report. The results of all field tests, laboratory analysis, and quality assurance analysis are provided in Appendix C and Appendix D.

In order to determine background groundwater characteristics at the Seminole County site, three points (UGB-1, SGB-1, and DGB-1) believed not to be impacted by any STE influenced groundwater were sampled at distances of at least 80 feet from the septic tank. Ten samples at discrete two feet intervals were collected from each of these three points for a total of 30 samples in this sample set. Laboratory analysis results revealed that sample point SGB-1 was likely within the on-site nitrogen plume, and sample point UGB-1 is potentially influenced by the nitrogen plume from the neighbors' drainfield which lies approximately 115 feet to the northeast. Based on the observed information, DGB-1 was assumed to be most indicative of background groundwater characteristics at the site. Table 5 is a summary of background groundwater concentrations observed in DGB-1. During field operations, groundwater with conductivity ≤200 μS/cm was assumed to be representative of background groundwater conditions.

Table 5. Summary of background groundwater quality, Seminole County OWTS site

	Conductivity (μS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Mean	202.5	1.0	0.113	6.20	1.49	1.61	0.37*
Min	164.9	0.1	0.071	4.22	0.32	0.42	-
Max	251.0	3.0	0.190	7.01	3.40	3.50	-

* Only one sample analyzed

Between six and twelve samples at discrete two feet intervals were collected from each of four boring locations (DFB-1, DFB-2, DFB-3, and DFB-4) in the drainfield for a total of 32 samples representing conditions of groundwater directly below the drainfield. All groundwater contaminant concentrations were significantly elevated directly below the drainfield. Table 6 is a summary of the average groundwater quality observed in the upper four sample intervals at each boring location directly beneath the drainfield at the Seminole County site. Only the upper four samples are included in Table 6 summary because these intervals seem to contain the most directly affected STE influenced ground water which is most representative of the conditions directly beneath the drainfield.

Table 6. Summary of average groundwater quality directly beneath the drainfield, Seminole County OWTS site

	Conductivity (μS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Mean	545.0	1.8	6.9	6.30	13.3	20.0	3.6
Min	208.0	0.1	0.1	5.6	2.0	2.4	0.3
Max	712.0	4.7	24.0	6.7	56.0	56.0	7.8

To delineate the vertical and horizontal extent of the nitrogen plume originating from the septic tank, a "fence" of eight borings (SEM-FB-1 through SEM-FB-8) was installed downgradient of the drainfield. Based on comparison of groundwater contaminant concentrations with observed background conditions, the horizontal and vertical boundaries of the nitrogen plume appear to be well defined by the fence sampling points completed during January and February 2007. Total nitrogen and NO_3-N concentrations are elevated significantly over background conditions below the drainfield, however, groundwater concentrations are at or below background concentrations in FB-7 which is 130 feet down gradient. A complete groundwater analytical summary is provided as Table B-2 in Appendix B.

Data Interpretation

The highest NO_3-N concentrations at the Seminole County site were observed directly below the drainfield. Figure 2 depicts the nitrate plume encountered during the January/February 2007 sampling event. Based on nitrate concentration contour intervals of 10 mg/L, the NO_3-N plume's maximum dimensions measure approximately 30 feet long by 25 feet wide and approximately 8 feet thick. A detailed cross section of the nitrate plume could not be presented as the plume was limited to the extent of the drainfield and an insufficient number of borings were placed in that area to define NO_3-N concentrations below 10 mg/L beyond the drainfield. It is evident that substantial NO_3-N reduction is occuring within 20 to 30 feet of the highest NO_3-N concentrations below the drainfield, likely due to denitrification.

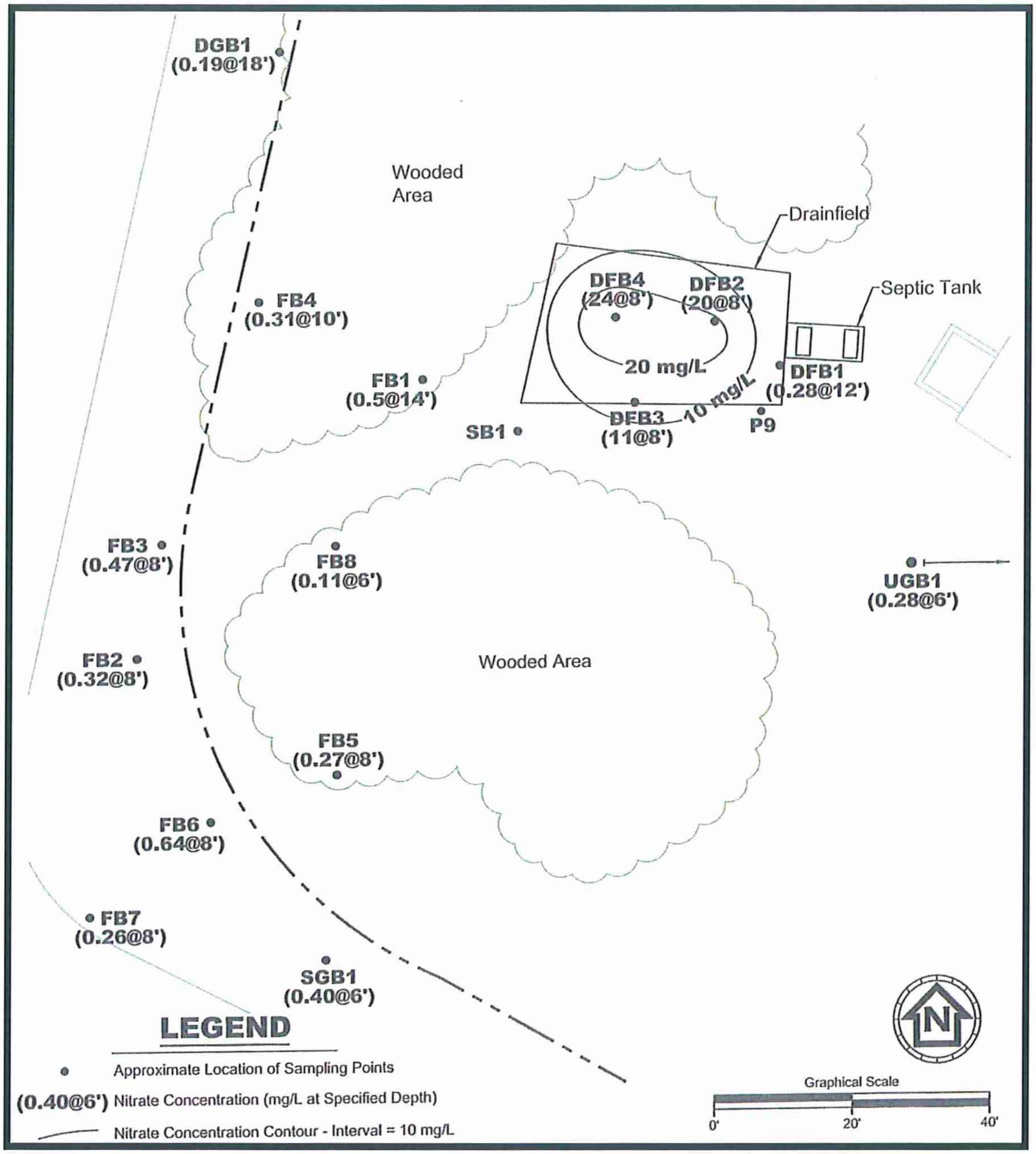

Figure 2. The nitrate plume encountered during the January/February 2007 Seminole County sampling event

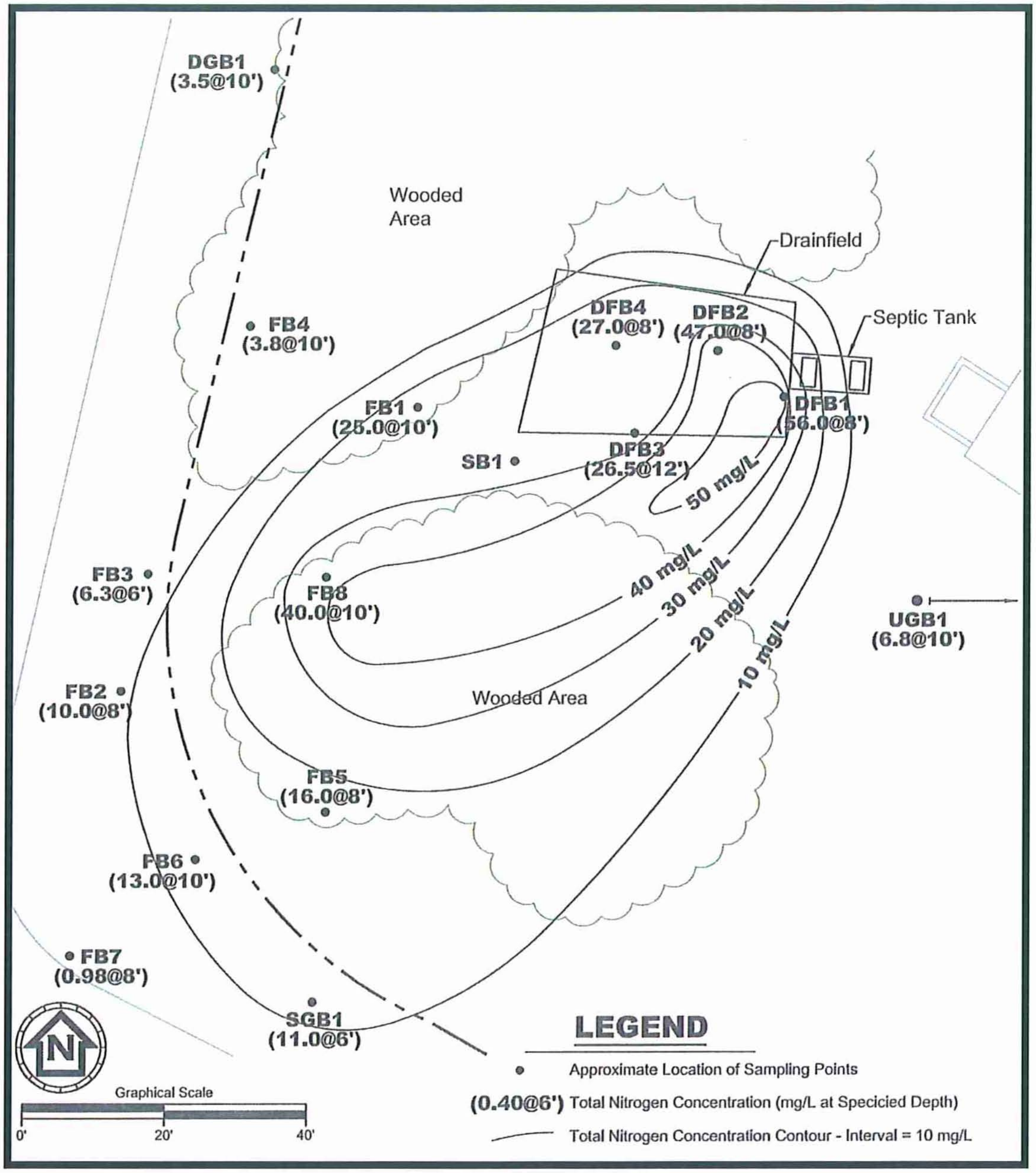

Figure 3. The total nitrogen plume encountered during the January/February 2007 Seminole County sampling event

The highest total nitrogen concentration at each sampling point was plotted to create a total nitrogen concentration map (Figure 3) depicting the aerial extent of the total nitrogen plume. The total nitrogen plume was composed mainly of total kjeldahl nitrogen (TKN). A supplemental TKN plume is included as Figure 13 in Appendix A. Figures 4 and 5 illustrate cross sections (A-A' and B-B') through the total nitrogen plume. Based on total nitrogen concentration contour intervals of 10 mg/L, the plume's maximum dimensions measure approximately 115 feet long by 75 feet wide and approximately 12 feet thick. Total nitrogen concentrations are attenuated far more gradually than NO_3-N, with approximately 70 percent reduction in concentration within 80 feet of the septic tank and 98 percent reduction in TN concentration at 130 feet. The total nitrogen reduction that is witnessed downgradient is a reduction in concentration only, not necessarily indicating reduction of mass loading.

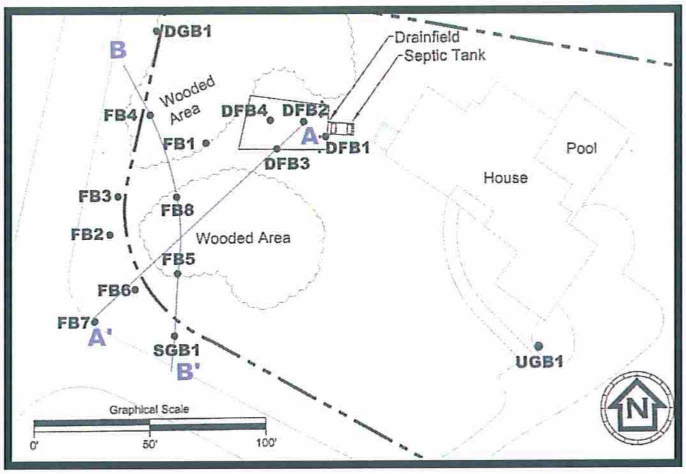

Figure 4. Locations of Seminole County cross sections A-A' and B-B'

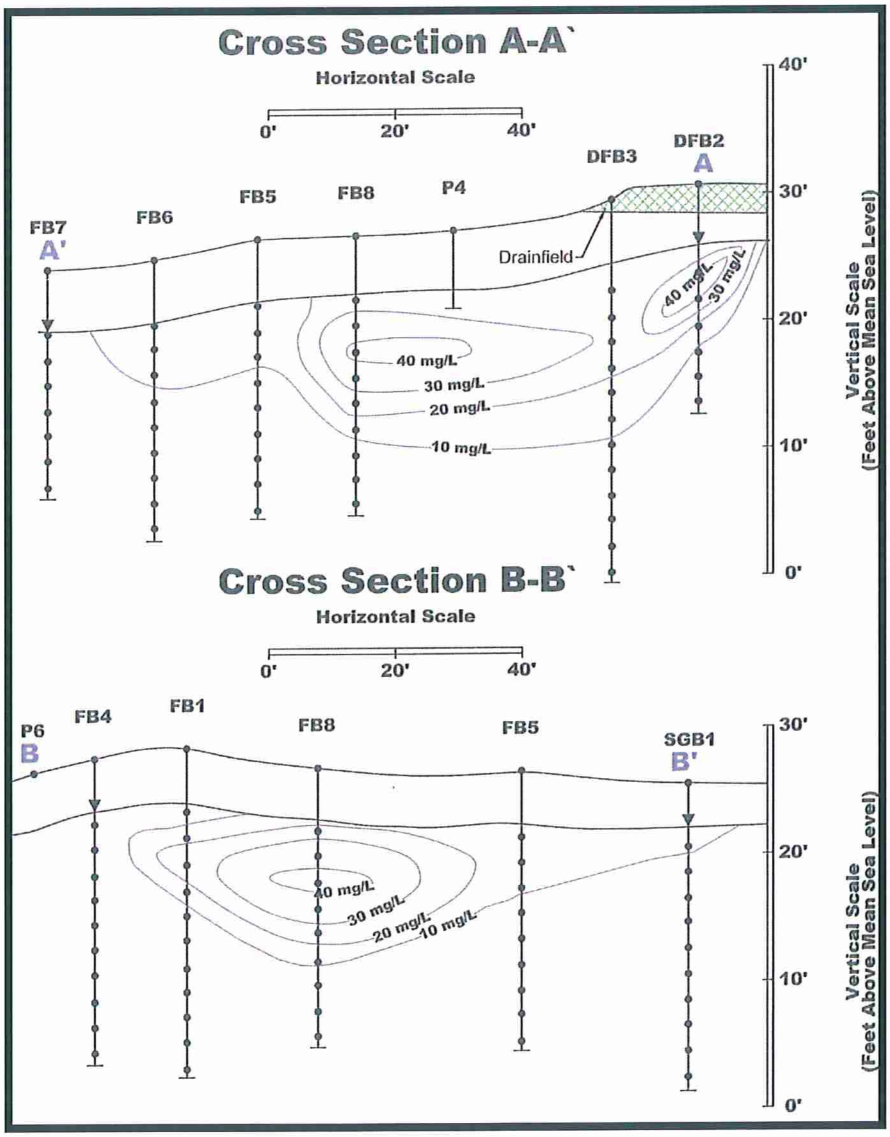

Figure 5. Cross sections A-A' and B-B' through the total nitrogen plume at the Seminole County OWTS site

Table 7. Mean total nitrogen composition in groundwater samples from the Seminole County OWTS site.

Seminole County Mean Total Nitrogen Composition					
	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (TKN) (mg/L)	(%)	Nitrate/Nitrite (as Nitrogen) (mg/L)	(%)
Effluent	74	73.33	99.09	0.55	0.74
Below Drainfield	20	13.3	66.50	6.9	34.50
Background (DGB-1)	2.75	2.65	96.36	0.082	2.98
FB-7	0.76	0.51	67.11	0.25	32.89
FB-8	34.5	34.5	100.00	0.2	0.58
FB-6	10.3	9.43	91.55	0.6	5.83

Table 7 illustrates the mean total nitrogen composition in groundwater samples taken at the Seminole County OWTS site. In the table, one column lists the percent composition (%) and one column lists the mass composition (mg/L) of each component of mean total nitrogen concentrations observed in water samples taken from: septic tank effluent, directly below the drainfield, areas considered to represent background conditions (DGB-1), downgradient of the nitrogen plume (FB-7), and within the nitrogen plume (FB-8, and FB-6).

Comparison of mean total nitrogen composition in groundwater samples collected below the drainfield to samples taken from septic tank effluent indicates that a significant amount of nitrification is occurring directly below the drainfield. Approximately 32% of the total nitrogen concentration is apparently converted to nitrate between the drainfield and the surficial water table.

At FB-8, which is 70 feet downgradient of the septic tank, approximately 100% of the mean total nitrogen concentration from the upper four, most concentrated, sample intervals was composed of TKN. Nitrate/nitrite concentrations were only slightly above background levels at FB-8 indicating that very little, if any, nitrification is occurring downgradient of the drainfield.

At FB-6, which is 115 feet downgradient of the septic tank, at the tail end of the nitrogen plume, we observed 5.83% conversion of mean total nitrogen concentrations to nitrate/nitrite. This small increase in mean nitrate/nitrite concentration could be indicative of a minor amount of nitrification occurring in the saturated zone at distances greater than 70 feet downgradient of the septic tank.

At FB-7, which is 130 feet downgradient of the septic tank, mean total nitrogen levels are reduced to apparent background concentrations. This downgradient nitrogen reduction must be attributed to dilution and/or natural nitrification/denitrification. Since nitrification appeared only to be occurring in the vicinity of the drainfield and the majority of the nitrogen plume beyond the drainfield was composed of nearly 100% TKN, natural nitrification/denitrification is most likely not the primary process responsible for nitrogen reduction at this site.

Mass Loading and Dilution

By multiplying the amount of total nitrogen loading to the drainfield from Table 4 (17.64 g/person/day) by the number of days in a year (365 days) a concentration of 6438 g/person/year

(14.19 lbs/person/year) can be calculated as the approximate yearly total nitrogen loading, per capita, observed at the Seminole County OWTS site.

Reviewing the groundwater analysis data from the previous section, it appears that dilution is the primary process affecting nitrogen removal at this site, although the nitrate plume in the vicinity of the drainfield gives an indication that nitrification/denitrification is occurring directly below the drainfield. The presence of significantly elevated (24 mg/L) nitrate concentrations directly below the drainfield and very low to background levels at all sampling points downgradient of the drainfield (Figure 2) is an indication that the majority of nitrogen being reduced below the drainfield is being fully removed by denitrification. Assuming this, and that minimal dilution has occurred at the locations immediately beneath the drainfield, a value for the percentage of nitrogen removal and mass loading by the Seminole County OWTS can be estimated.

74 mg/L (STE TN conc.) – 24 mg/L (highest NO_3 conc. below drain field) / 74 mg/L (STE TN conc.) = 68% of TN not nitrified or 32% apparent removal by nitrification/denitrification

By subtracting the maximum observed nitrate concentration from below the drainfield, which is assumed to represent the maximum amount of nitrogen reduction and removal, from the mean concentration of total nitrogen in the STE, and dividing by the mean concentration of total nitrogen in the STE, we find that there is a potential for 32% nitrogen removal by nitrification/denitrification, leaving 68% of the TN to be diluted and contributed to mass loading. This amounts to a calculated mass loading of 9.65 lbs TN/person/year at this site.

*14.19 lbs TN/person/year *0.68 = 9.65 lbs TN loading/person/year*

Review of numerous contemporary studies (Hazen and Sawyer, 2006) has estimated that a range of approximately 10-50% of total nitrogen is removed by conventional OWTS in areas with warmer climates such as Florida. In other words, 50-90% of total nitrogen leaving conventional OWTS in Florida is thought to enter the surficial aquifer, and may be transported to nearby surface water bodies. Our estimate of 68% (9.65 lbs/person/year) total nitrogen mass loading falls within this expected range.

An estimation of dilution of the nitrogen plume was made by calculating the volumetric flow rate of groundwater through soil from the effluent source through the plume, then calculating a mass balance to determine whether the calculated potential for dilution in downgradient locations can be explained.

Volumetric Flow Calculations (From Darcy's Law)

$Q = KA*\Delta h/L$, where
Q = volumetric flow
A = flow area perpendicular to L
K = hydraulic conductivity
L = flow path length
h = hydraulic head, and
Δ = the change in h over the path L

Substituting for actual and assumed values gives a calculated Q = 1228 liters/day flow into the drainfield from background groundwater.

A mass balance was then calculated as follows:

$(C_{BN})(Q_B) + (C_E)(Q_E) = C_R * (Q_B + Q_E)$, where

C_{BN} = background nitrogen concentration
Q_B = flow from background
C_E = effluent nitrogen concentration
Q_E = flow from effluent
C_R = resultant nitrogen concentration in plume

Substituting for actual values determined in laboratory analyses, and calculated and measured flow, C_R = 37.6 mg/L. This corresponds well with the concentration of nitrogen in the center of the plume throughout more than half its volume.

The volumetric flow and mass balance calculations support our hypothesis of dilution as the primary mechanism for nitrogen attenuation downgradient of the drainfield. Calculations are shown in Appendix G.

LAKE COUNTY SITE

Site Characteristics and System Description

The Lake County study site is located approximately 10.5 miles west of the Wekiva River in the Secondary WAVA zone. Situated on the site was a three bedroom, two bathroom, single family home which was built in 1991 and was approximately 2,200 square feet in size, with four permanent residents. The study site was on a parcel of land with an area of approximately 2.33 acres. Based on piezometer observations during the sampling period, the apparent groundwater flow direction at the site was to the south (Appendix A, Figure 15).

Evaluation of the OWTS concluded that the septic tank, which was located approximately 20 feet south of the west side of the house, was of concrete construction and 1,050 gallons in size. The tank was installed in 1991, the same year that the home was built, and appeared to be in good working condition at the time of evaluation. The drainfield measured approximately 385 square feet (11 feet x 35 feet) in area and consisted of approximately two feet of fine sands overlaying a one foot thick bed of gravel containing the perforated STE distribution pipes. Soils above and immediately below the gravel layer appeared to be native fine sands.

The wet seasonal water table at the site was estimated to be 50 inches below grade, and the active drainfield extended approximately 36 inches below grade. During the April 2007 sampling period, groundwater was not encountered in the vicinity of the drainfield until at least 200 inches below grade. A copy of the system evaluation is included in Appendix F.

Soil Characterization

The surficial soils of the Lake County site consisted of mostly brown to gray fine sands resembling the Tavares Series, a predominant lithology of low-lying areas on hill slopes and upland ridges of the area (USDA, 1989). Based on soil boring observations, lithology beneath the Lake County site appeared to be very heterogeneous. In general, the soils on the northwestern portion of the study area, in the vicinity of FB-7, FB-8, and FB-9, were continuous fine sands from the surface to beyond 30 feet bgs. The lithology in the vicinity of the drainfield consisted of an upper 72 inches of fine sands which were underlain by alternating, non-continuous intervals of clay, clayey sands, and fine sands. Due to the presence of a thin clayey lense, a groundwater sample was able to be collected from a perched interval at one location beneath the drainfield (LA-DFB-1) at a depth of 4-6 feet. Soils at the same depth in the vicinity of LA-DFB-2 were moist but not saturated and soils at 4-6 feet in the vicinity of LA-DFB-3 were completely dry. To the east of the drainfield, the surficial 5-6 feet of sediment was composed of Tavares Series fine sands which became so densely compacted below 6 feet that groundwater sampling by direct push was precluded everywhere beyond 20 feet east of the drainfield.

Although visual observation of continuous soil boring LA-SB-1 (Appendix E) indicated that soils below 20 feet were saturated, the lithology of dense clayey sand restricted groundwater sampling from 20 to 24 feet at some sampling points in the vicinity of the drainfield. There was no direct visual indicator of a bio-mat or a well defined spodic layer beneath the drainfield or in the vicinity of LA-SB-1. The highest organic content observed in soils sampled at the Lake County site was 10.33% by weight in a sample of wet gray clay at 14 bgs at LA-SB-1. The mean organic content in SB-1 was 3.01%.

Instantaneous delineation of OWTS-effluent plume

Field work was carried out at the Lake County OWTS site during April 2007. The investigation plan was to install a network of borings to delineate the plume of STE influenced groundwater as it percolated through the drainfield and recharged into the surficial aquifer. Sampling points were initially placed with regard to the apparent groundwater flow direction, which was observed to be toward the south based on evaluation of potentiometric head elevations in the network of piezometers installed throughout the site. The original field investigation scheme was modified when the contaminant plume was found to be directed to the north and west, apparently due to impermeable subsurface soils. Figure 6 is a site map depicting sampling points at the Lake County OWTS site. The results of all field tests, laboratory analysis, and quality assurance analysis are provided in Appendix C and Appendix D.

Table 8 is a summary of background groundwater concentrations observed at the Lake County OWTS site. Based on initial field conductivity readings and further analysis of laboratory results, sample points UGB-1, FB-1, FB-3, and FB-4 were assumed to be representative of background groundwater conditions. From these locations, 16 samples were collected which were analyzed to establish background groundwater concentrations for the Lake County study site. During field operations, groundwater with conductivity ≤200 μS/cm was assumed to be representative of background groundwater conditions.

Table 8. Summary of background groundwater quality, Lake County OWTS site

	Conductivity (μS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Mean	202.5	1.0	0.113	6.20	1.49	1.61	0.37*
Min	164.9	0.1	0.071	4.22	0.32	0.42	-
Max	251.0	3.0	0.190	7.01	3.40	3.50	-

* Only one sample analyzed

Three to five samples at discrete two feet intervals were collected from each of three boring locations (DFB-1, DFB-2, DFB-3) in the drainfield for a total of 12 samples representing conditions of groundwater directly below the drainfield. Disregarding the sample taken at 4-6 feet from sample point LA-DFB-1, all nitrogen concentrations in the groundwater directly below the drainfield were at background levels. The sample taken from 4-6 feet at LA-DFB-1 had contaminant concentrations comparable to the septic tank effluent. It appeared that most infiltration is near the septic tank outlet, and this perched groundwater interval resulted by temporary ponding of STE as it was discharged from the septic tank. Table 9 is a summary of the average groundwater quality beneath the drainfield at the Seminole County site.

Table 9. Summary of average groundwater quality beneath the drainfield, Lake County OWTS site

	Conductivity (µS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P* (mg/L)
Mean	83.0	1.47	0.28	5.86	0.59	0.91	17.9
Min	44.7	0.11	0.04	5.20	0.19	0.22	0.0
Max	110.1	3.72	0.93	6.58	2.20	2.90	49.0

* N=3

To delineate the vertical and horizontal extent of the nitrogen plume originating from the septic tank, a network of nine borings (LA-FB-1 through LA-FB-9) was installed in the vicinity of the drainfield and downgradient of the nitrogen plume. Due to the presence of numerous discontinuous clayey soil layers in the vicinity of the drainfield and very dense sandy soil layers to the east of the drainfield, either the contaminant plume did not follow the apparent groundwater flow direction or the groundwater elevations in the piezometers were non-representative of true groundwater flow. The contaminant plume was directed nearly opposite of the apparent groundwater flow direction which was indicated by groundwater elevations observed in the piezometers. Total nitrogen and NO_3-N concentrations are elevated significantly over background conditions to the north-west of the drainfield but are reduced to below10 mg/L in FB-9 which is 90 feet downgradient of the septic tank. Although the nitrogen plume boundaries appear to be fairly well approximated, the number of probings at the Lake County site was insufficient to accurately determine the full size of the nitrogen plume in terms of background concentrations. A complete groundwater analytical summary for the Lake County study site is provided as Table 2 in Appendix B.

Data Interpretation

Following analysis of the three borings completed directly below the drainfield, it appears that very little, if any, STE is reaching the groundwater below the drainfield or anywhere to the east or south of the drainfield. Instead, the nitrogen plume is migrating to the north and west. Below the drainfield at the Lake County site, there is an organic-rich layer of clayey and sandy sediments from approximately 12-18 feet bgs which are moist to wet but not saturated enough to recover groundwater samples. This area seems to be providing an optimal space with aerobic conditions which are supporting a high degree of nitrification above the groundwater table.

The highest NO_3-N concentrations at the Lake County OWTS study site were observed northwest of the septic tank and drainfield, nearly opposite of the direction of groundwater flow indicated by piezometer observations. Based on nitrate concentration contour intervals of 10 mg/L, the dimensions of the nitrate plume measure approximately 90 feet long by 45 feet wide with a total vertical thickness of approximately 14 feet however, background nitrogen concentrations were not encountered in the downgradient direction of the plume. Figure 6 depicts the nitrate plume encountered during the April 2007 sampling event at the Lake County OWTS study site.

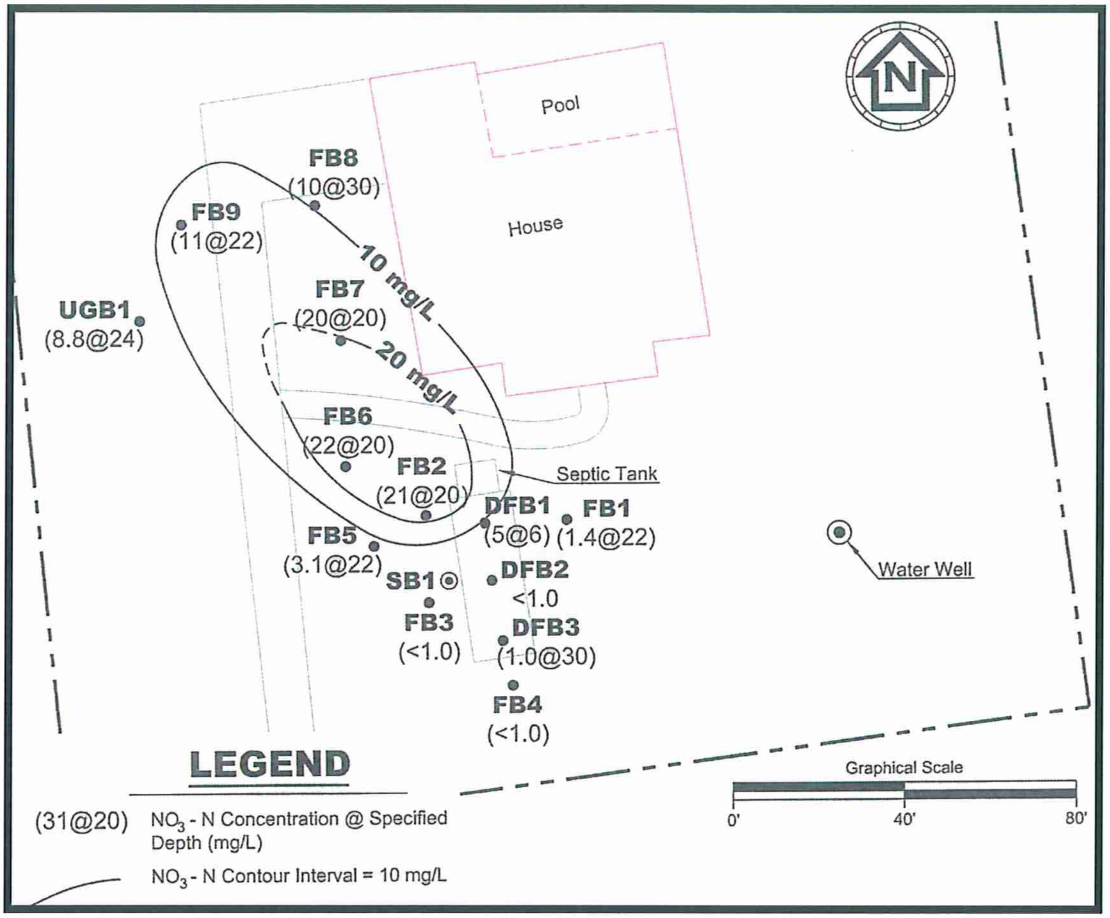

Figure 6. The nitrate (NO_3-N) plume encountered during the April 2007 Lake County sampling event

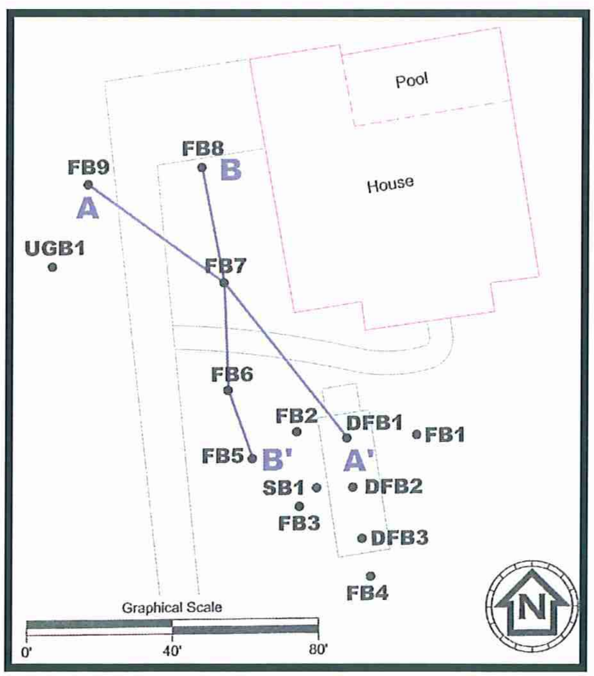

Figure 7. Locations of Lake County cross sections A-A' and B-B'

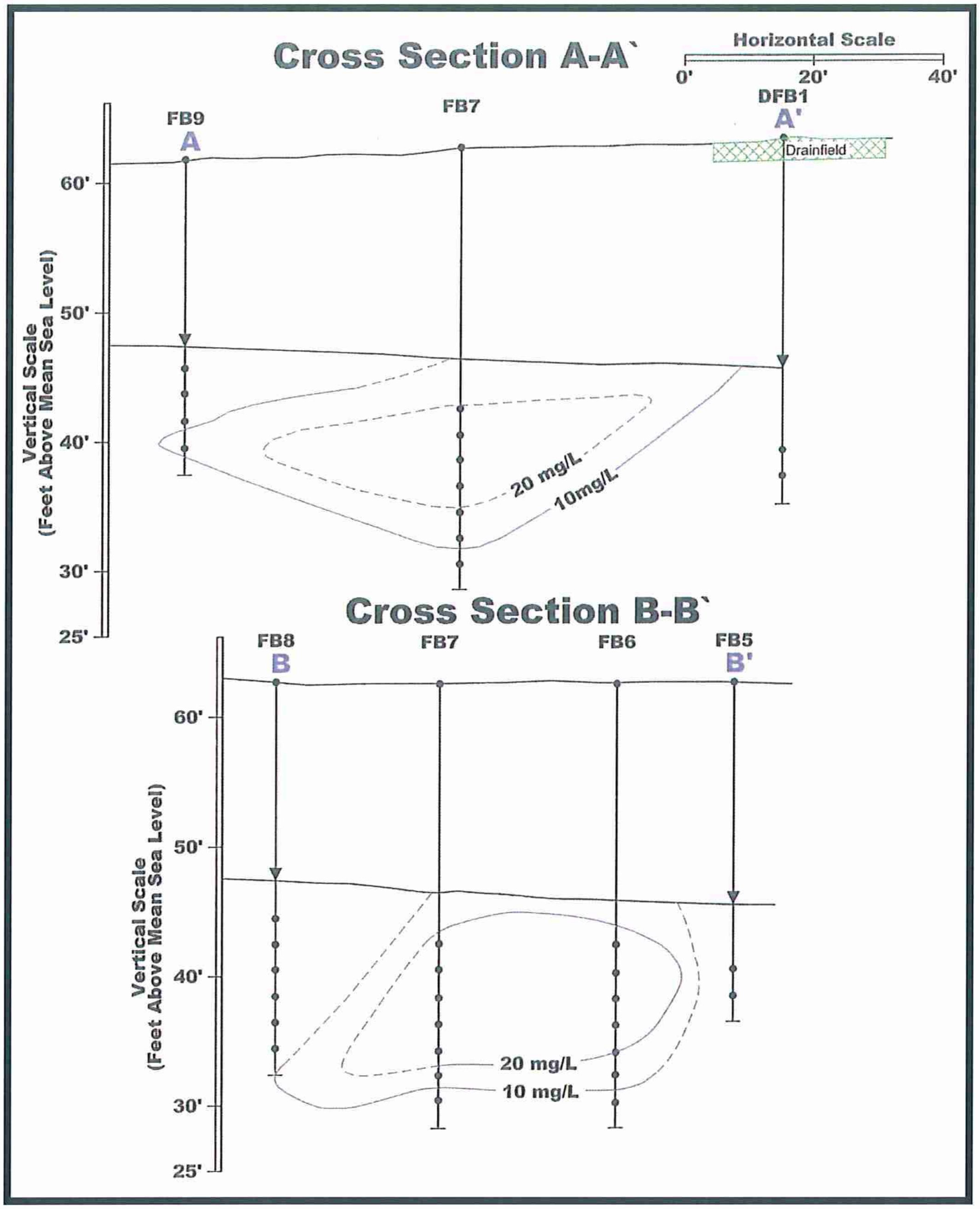

Figure 8. Cross sections A-A' and B-B' through the nitrate plume at the Lake County OWTS study site

Figures 7 and 8 illustrate cross sections (A-A' and B-B') through the nitrate plume encountered at the Lake County OWTS site during the April 2007 sampling event. Although the daily load of nitrogen into the Lake County drainfield was apparently the highest of all three sites (Table 4), the nitrogen plume observed at the Lake County study site was the least concentrated of all three plumes encountered. The highest nitrate concentration of 22 mg/L was observed at FB-6, 30 feet downgradient of the septic tank. These data appear to represent a dilution of nitrogen concentrations discharged to the septic system, i.e. the daily load is more a function of total water use which results in a lower than average total nitrogen concentration in the effluent.

Table 10. Mean total nitrogen composition in groundwater samples from the Lake County OWTS study site.

Lake County Mean Total Nitrogen Composition

	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (TKN)				Nitrate/Nitrite (as Nitrogen)	
		Organic Nitrogen		Ammonia (as Nitrogen)			
		(mg/L)	(%)	(mg/L)	(%)	(mg/L)	(%)
EFF (mean)	43	8.67	20	32.33	75	1.79	5
DFB-1 (6)	33	6.00	18	26	78	1.5	4
DFB-1(>22)	0.51	0.23	45	0.1	20	0.18	35
Background	0.56	0.15	26	0.11	20	0.31	55
FB-7	20.75	1.33	6	0.04	0.20	19.25	93
FB-9	8.875	0.565	6	0.03	0.34	8.15	92

Table 10 illustrates the mean total nitrogen composition for groundwater samples taken at the Lake County site. In the table, one column lists the percent composition (%) and one column lists the mass composition (mg/L) of each component of mean total nitrogen concentrations observed in water samples taken from: directly below the drainfield, within the nitrogen plume, from areas considered to represent background conditions, and from septic tank effluent. Table 10 shows that the sample DFB-1 (6), which was recovered from a perched water interval at 6 feet bgs below the drainfield, is similar in composition to the septic tank effluent. Groundwater samples taken from below 22 feet in DFB-1 exhibit similarities in composition to background samples, indicating very little influence from STE in the saturated zone directly below he drainfield. The difference in Ammonia and NO_3/NO_2 composition between effluent samples (EFF) and samples taken downgradient in the nitrogen plume (FB-7 and FB-8) indicates that significant nitrification is occurring between the drainfield and the surficial water table at this site.

At FB-7, which is 45 feet downgradient of the drainfield, total nitrogen in the upper four, most concentrated, sample intervals is 48% lower than TN concentrations in the STE. Additionally, there is an 88% conversion of total nitrogen from TKN to NO_3-N in the groundwater between the drainfield and FB-7 indicating that nitrification is prevalent downgradient at this site.

At FB-9, which is 90 feet downgradient of the drainfield, we observed an 80% reduction in mean total nitrogen concentrations of the upper four, most concentrated sample intervals. Groundwater taken from FB-9 had similar proportions of TKN and NO_3-N to groundwater at FB-7 indicating that very little, or no additional nitrification is likely to be occurring between FB-7 and FB-9.

Mass Loading and Dilution

By multiplying the amount of total nitrogen loading to the drainfield from Table 4 (18.31 g/person/day) by the number of days in a year (365 days) a concentration of 6683 g/person/year (14.73 lbs/person/year) can be calculated as the approximate yearly total nitrogen loading, per capita, observed at the Lake County OWTS site.

The lack of TKN downgradient of the drainfield and the presence of a nitrogen plume consisting almost exclusively of nitrate gives a good indication that a significant amount of natural nitrification is occurring below and at some distance downgradient of the drainfield at this site. Based on the decrease in total nitrogen, it is apparent that substantial denitrification is occurring as well. The highest nitrate concentration observed in the Lake County nitrogen plume was 22 mg/L at FB-6, approximately 30 feet downgradient of the septic tank (Figure 6). Nitrate concentrations similar to FB-6 were observed at FB-7, approximately 50 feet downgradient of the septic tank. Analysis of mean total nitrogen composition (Table 10) suggests that TN/NO_3 conversion occurs mostly within 50 feet of the septic tank, indicating that TN in the groundwater downgradient of FB-7 is likely contributed to mass loading into the surficial aquifer. Assuming that little to no additional nitrification/denitrification is occurring downgradient of FB-7, as suggested by the mean total nitrogen composition analysis and that the amount TN/NO_3 conversion witnessed at FB-6 represents the likely amount of denitrification and nitrogen removal that can be occurring at this site, a value for the percentage of nitrogen removal and mass loading by the Lake County OWTS can be estimated as follows.

43 mg/L (STE TN conc.) – 22 mg/L (highest NO_3 conc. below drain field) / 43 mg/L (STE TN conc.) = 48% of TN not nitrified or 52% apparent removal by nitrification/denitrification

We find that there is a potential for 52% nitrogen removal by nitrification/denitrification, leaving 48% of the TN to be diluted and contributed to mass loading at the Lake County site. This amounts to a calculated mass loading of 7.07 lbs TN/person/year at this site.

*14.73 lbs TN/person/year * .48 = 7.07 lbs TN loading/person/year*

Our estimate of 48% TN mass loading (7.07 lbs TN/person/year) falls at the lower end of the 50-90% mass loading range proposed by Hazen and Sawyer (2006).

ORANGE COUNTY SITE

Site Characteristics and System Description

The Orange County study site was located approximately 1.1 miles south and west of Wekiwa Springs State Park, the source of the Wekiva River, and was in the Primary, or more vulnerable, WAVA zone. The site consisted of a four bedroom, two and a half bathroom, single family home built in 1996, approximately 2,680 square feet in size, with a single permanent resident at the time of the study. Until one month prior to the study, two permanent residents lived in the home. The home was situated on a parcel of land with an area of approximately 0.3 acres. Although piezometer observations were inconsistent, groundwater appeared to be flowing to the south and east at the Orange County OWTS site.

An evaluation of the OWTS revealed that the septic system consisted of a baffled 1,050 gallon concrete septic tank and drainfield which is located to the east of the residence. The septic tank was installed in 1996, the same year that the home was built, and appeared to be in good working condition at the time of evaluation. According to the homeowner, the tank had never been pumped. The drainfield measured approximately 638 square feet (22 feet x 29 feet) and consisted of a network of perforated plastic STE distribution piping imbedded in a layer of gravel which was approximately one foot thick. Soils above and below the gravel layer appeared to be native fill, composed of on-site derived soils.

Based on the presence of mottling, the system evaluation determined that the wet seasonal water table at the site could be estimated at approximately 44 inches below grade, although during the February 2007 sampling period groundwater was not encountered in the vicinity of the drainfield until over 260 inches below grade. The system evaluation also noted a non-continuous layer of sandy clay in the vicinity of the drainfield. A copy of the system evaluation is included in Appendix F.

Soil Characterization

The surficial soils at the Orange County site were determined to be similar to the Tavares Series, a soil type typical of the Apopka area. The overall lithology at the site was characterized by a surficial layer of light brown fine sand to approximately 6 feet bgs followed by interfingering layers of clay loam, loamy sands, and fine sands to approximately 32 feet bgs which were underlain by fine sands to at least 40 feet bgs. From field observations, such as differences in purge rates, it appears that the clay loam and loamy sand layers are not continuous in horizontal or vertical extent. In general, the northern and western-most portions of the property could be characterized by thick deposits of very low permeability clays which prohibited continuous groundwater sampling in the case of OR-UGB-1, and also caused inconsistencies in piezometer water levels.

The highest soil organic content by weight (6.86%) was observed in a sample of brown clay from 18 feet bgs in OR-SB-1. This organic-rich clay layer extended to within one foot of the observed water table elevation at the time of sampling. The mean organic content in SB-1 was 1.39%.

Instantaneous delineation of OWTS-effluent plume

Field work was carried out at the Orange County OWTS site during February 2007. In order to delineate the plume of STE influenced groundwater, a network of borings was installed throughout the site. Sampling points were initially placed with regard to the apparent groundwater flow direction, which was observed to be toward the southeast based on evaluation of potentiometric head observed in piezometers installed throughout the site. The original field investigation scheme was modified when the contaminant plume was found to be migrating toward the northeast rather than southeast. Figure 9 depicts the locations of groundwater sampling points. The results of all field tests, laboratory analysis, and quality assurance analysis are provided in Appendix C and Appendix D.

Table 11 is a summary of background groundwater concentrations observed at the Orange County OWTS site. Due to sampling difficulties and probe refusal, background groundwater concentrations presented for the Orange County study site are based on only three samples which were recovered from sample location OR-UGB-1. Sampling location SGB-1, west of the drainfield, was originally chosen to represent side-gradient background groundwater conditions but laboratory analysis indicated that this boring location was heavily influenced by the nitrogen plume. During field operations, groundwater with conductivity ≤200 μS/cm was assumed to be representative of background groundwater conditions.

Table 11. Summary of background groundwater quality, Orange County OWTS site

	Conductivity (μS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Mean	77.3	0.52	0.58	5.42	1.06	1.85	0.41*
Min	58	0.21	0.47	5.13	0.62	1.50	---
Max	106.1	1.06	0.68	5.81	1.50	2.2	---

* Only one sample analyzed

A total of 22 groundwater samples were collected at discrete two feet intervals from each of three boring locations (DFB-1, DFB-2, and DFB-3) directly below the drainfield in Orange County. Nitrate (NO_3-N) concentrations directly below the drainfield were elevated significantly over background levels. Table 12 is a summary of average groundwater quality observed in the upper four sample intervals at each boring location within the drainfield at the Orange County study site.

Table 12. Summary of average groundwater quality beneath the drainfield, Orange County OWTS site

	Conductivity (µS/cm)	DO (mg/L)	NO_3-N (mg/L)	pH	TKN (mg/L)	Total N (mg/L)	Total P* (mg/L)
Mean	293.4	4.16	26.1	5.18	0.27	26.5	0.18
Min	127.5	1.25	0.008	4.13	0.04	0.3	0.02
Max	490	5.35	59	6.74	0.92	60	0.32

* N=3

To delineate the vertical and horizontal extent of the nitrogen plume originating from the septic tank, a "fence" of six borings (OR-FB-1 through OR-FB-6) was installed in the vicinity of the drainfield and downgradient of the nitrogen plume. Due to the very low hydraulic gradient and also partially due to the discontinuous clayey soil layers in the vicinity of the drainfield, the contaminant plume did not follow the apparent groundwater flow direction which was to the south-east according to piezometer observations. The horizontal and vertical boundaries of the nitrogen plume appear to be well defined by the fence boring sampling points completed during the February 2007 sampling event. Nitrate nitrogen (NO_3-N) concentrations were elevated significantly over background conditions in all directions from the drainfield and the most concentrated portion of the nitrogen plume was to the northeast of the drainfield. Nitrate concentrations are reduced to near 10 mg/L within 40 feet of the drainfield. However, the number of probings was insufficient to determine the size of the plume in terms of background concentrations. A complete groundwater analytical summary is provided as Table B in Appendix B.

Data interpretation

The nitrogen plume encountered during investigation of the Orange County OWTS is best defined by nitrate concentrations. Mean TKN concentrations at the Orange County site were <1.0 mg/L at all sample points. Figure 9 depicts the nitrate plume encountered during the February 2007 sampling event

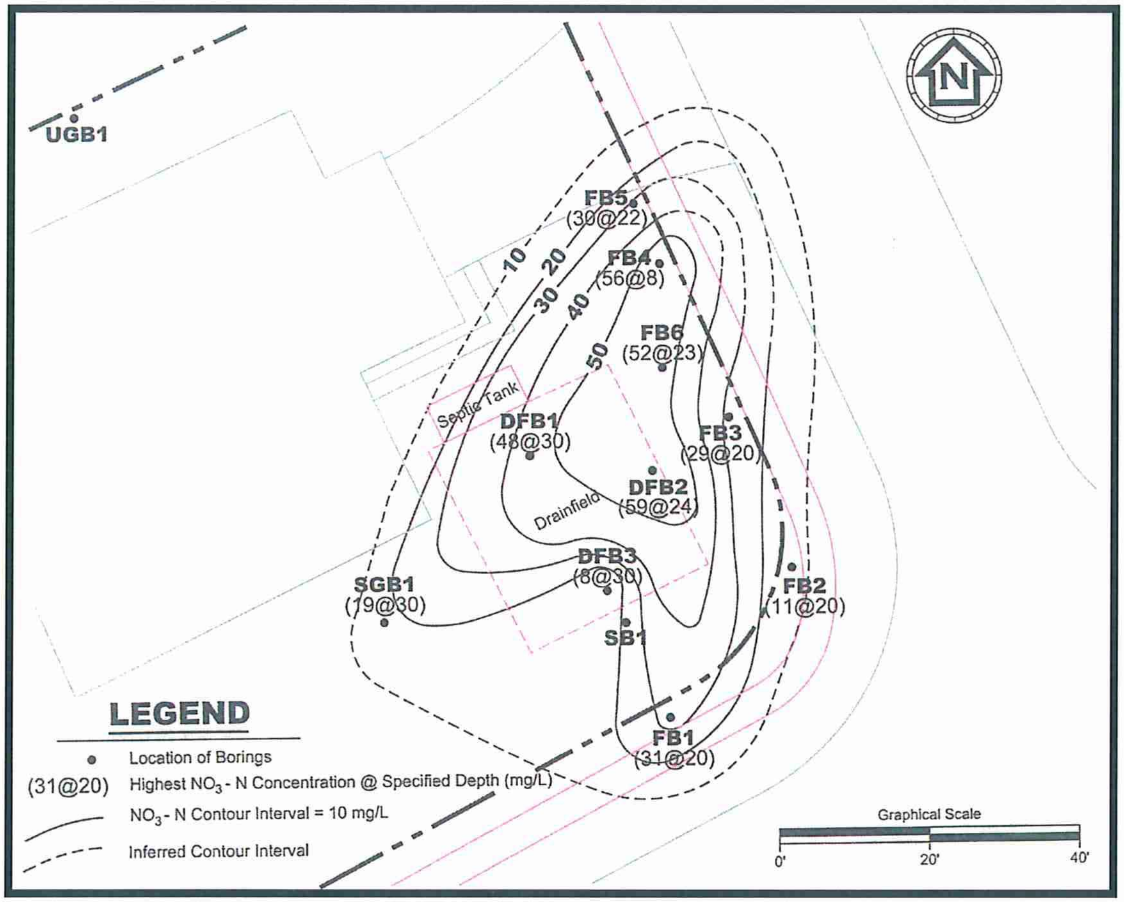

Figure 9 The nitrate plume encountered during the February 2007 Orange County OWTS sampling event

Figures 10 and 11 illustrate cross sections (A-A' and B-B') through the Orange County OWTS nitrate plume encountered during February 2007. Based on contour intervals of 10 mg/L, the nitrate plume's dimensions measure approximately 90 feet long, with a maximum width of 60 feet wide and with a well defined maximum vertical thickness of approximately 12 feet.

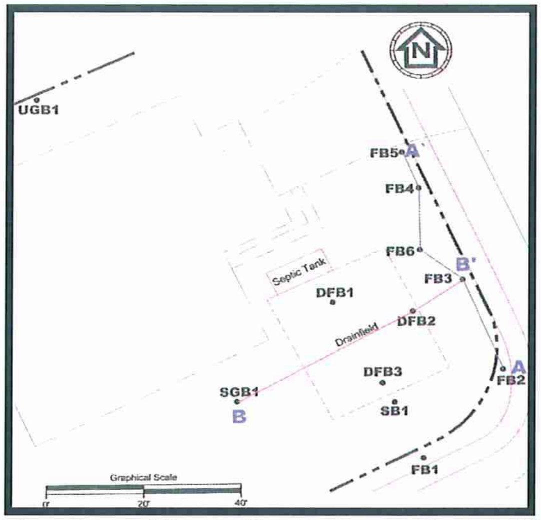

Figure 10. Locations of Orange County cross sections A-A' and B-B'

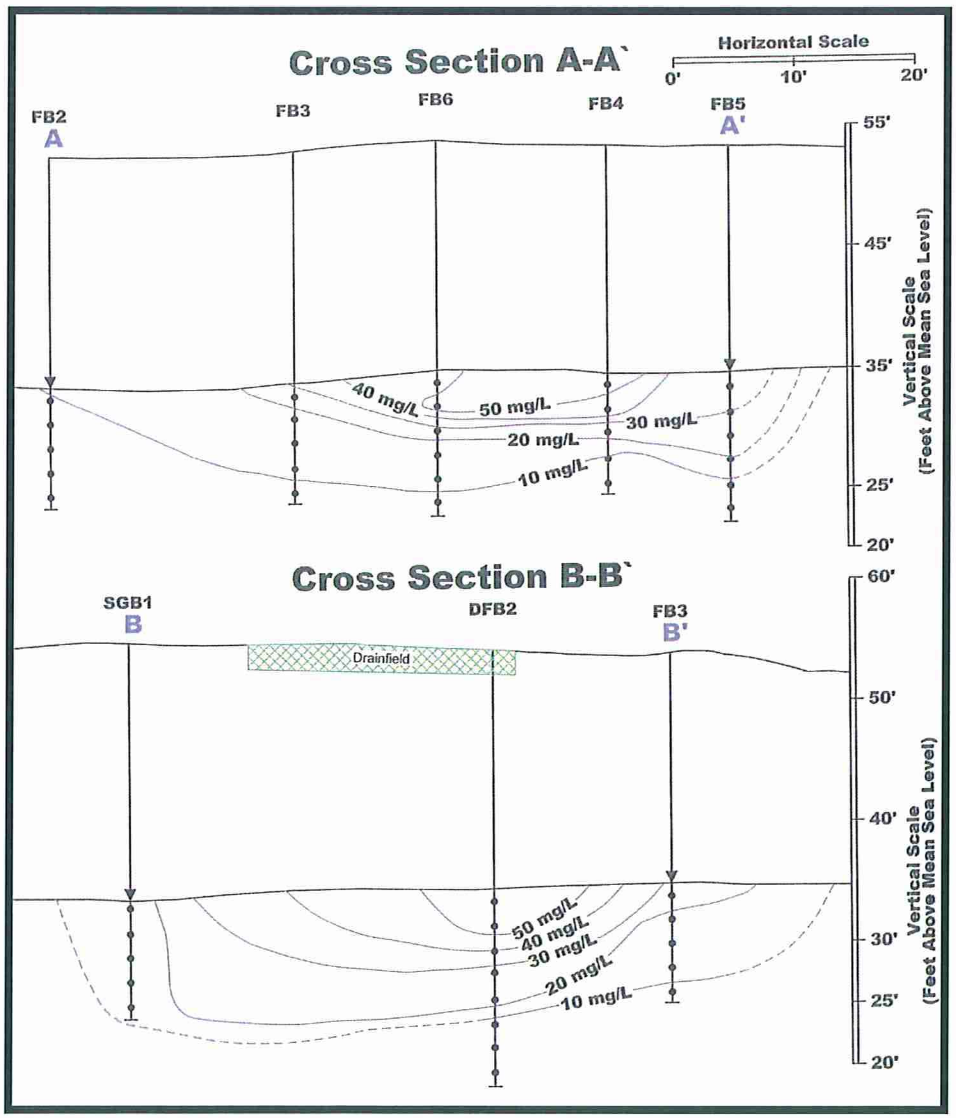

Figure 11. Cross sections A-A' and B-B' through the nitrate plume at the Orange County OWTS study site

The subsurface conditions observed during the sampling event at the Orange County site appeared to be optimal for promotion of nitrification as STE was distributed across the drainfield and leached through the underlying layers of permeable fine sands and clayey sands. Following analysis of the groundwater samples taken at this site, it appears that the STE is being distributed fairly evenly across the drainfield and migrating in all directions once it reaches the groundwater, most likely due to the very low hydraulic gradient observed. Although the most concentrated portion of the nitrate plume is observed to be migrating to the northeast, towards Wekiwa Spring, piezometer observations during field operations indicated that the primary hydraulic gradient had a south-easterly trend.

Table 13. Mean total nitrogen composition in groundwater samples at Orange County.

Orange County Mean Total Nitrogen Composition

	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)				Nitrate/Nitrite (as Nitrogen)	
		Organic Nitrogen		Ammonia (as Nitrogen)			
	(mg/L)	(mg/L)	(%)	(mg/L)	(%)	(mg/L)	(%)
EFF (mean)	69.00	10.33	14.98	58.00	84.06	0.64	0.93
Background	1.85	1.05	56.97	0.01	0.32	0.77	41.35
DFB	26.50	0.20	0.77	0.07	0.26	26.34	99.40
FB-6	39.67	0.30	0.76	0.06	0.15	39.33	99.16
FB-5	24.00	0.62	2.59	0.03	0.12	23.00	95.83

Table 13 illustrates the mean total nitrogen composition in groundwater samples taken at the Orange County site. By comparing the mean nitrogen composition of septic tank effluent samples to the mean nitrogen composition of samples from below the drainfield, it is evident that a substantial amount of nitrification is occurring between the drainfield and the water table.

Comparison of mean total nitrogen concentrations in septic tank effluent to mean total nitrogen concentrations directly below the drainfield indicates a 35% reduction in total nitrogen concentration as STE is leached through the drainfield and into groundwater, with 99.40 % of nitrogen below the drainfield occurring in the form of NO_3-N. Denitrification is most likely responsible for a large portion of the total nitrogen reduction happening below the drainfield.

At FB-6, which is approximately 20 feet downgradient, in the heart of the nitrogen plume, we observed a 150% increase in mean total nitrogen concentrations (compared to directly below the drainfield), possibly indicating that northeast is the primary direction of plume migration. The increase in total nitrogen concentrations downgradient of the septic tank can also be a function of reduced loading since the number of occupants at the residence has changed. Total nitrogen composition at FB-6 is proportionally identical to groundwater samples from below the drainfield indicating that most natural nitrification/denitrification is occurring in the vadose zone directly below the drainfield and that very little nitrification/denitrification appears to be occurring after STE enters the groundwater.

In the upper four most concentrated samples from FB-5, which is approximately 25 feet downgradient of FB-6, we observed a 60% reduction in total nitrogen concentrations and an increase in the organic nitrogen concentration which may be indicative of mixing with background water. Due to the limited number of sampling points, we were unable to define the northeastern boundary of the nitrogen plume but it appears that it is attenuated to <10 mg/L within approximately 60 feet of the drainfield. It is the opinion of E&A that most of the nitrogen attenuation observed downgradient of the drainfield is attributed to dilution and mixing and that the majority of nitrogen removal is occurring in the vadose zone below the drainfield, above the groundwater table, therefore conservative estimates for mass loading and removal of nitrogen at the Orange County OWTS site can be made by comparing TN concentrations in the STE and TN concentrations in the groundwater directly below the drainfield.

Mass Loading and Dilution

By multiplying the amount of total nitrogen loading to the drainfield from Table 4 (9.11 g/person/day) by the number of days in a year (365 days) a concentration of 3325 g/person/year (7.33 lbs/person/year) can be calculated as the approximate yearly total nitrogen loading, per capita, observed at the Orange County OWTS site.

The lack of TKN below and downgradient of the drainfield and the presence of a nitrogen plume consisting almost exclusively of nitrate gives a good indication that a significant amount of nitrification and possibly denitrification is occurring directly below the drainfield at this site. The highest nitrate concentration observed in the Orange County nitrogen plume was 59 mg/L at DFB-2, directly below the center of the drainfield and approximately 20 feet south and east of the septic tank (Figure 9). Nitrate concentrations similar to DFB-2 were observed at FB-4 and FB-6, approximately 20-30 feet downgradient of the septic tank, possibly indicating that downgradient denitrification is limited. Analysis of mean total nitrogen composition (Table 10) suggests that TN/NO_3 conversion occurs mostly directly below the drainfield, suggesting that most TN in the groundwater downgradient of the drainfield is likely contributed to mass loading into the surficial aquifer. A range of potential denitrification was calculated based on two different scenarios. First, a mean NO_3 concentration was calculated from the most concentrated samples in DFB-1 and DFB-2 to represent the case that no additional denitrification is occurring beyond the drainfield. The mean NO_3 concentration in STE influenced groundwater samples from below the drainfield is 37 mg/L. If no additional denitrification is occurring beyond the drainfield, then 54% total nitrogen dilution and mass loading can be assumed for this scenario.

Second, it was assumed that the highest NO_3 concentrations within the TN plume are representative of the maximum amount of denitrification occurring at the Orange County OWTS site and the highest NO_3 concentrations from DFB-1, DFB-2, FB-4, and FB-6, which averaged 54 mg/L, were assumed to be representative of the high range of potential dilution and mass loading possible at this site. Using the range of potential denitrification derived from both scenarios considered, a value for the range of percentage of nitrogen removal and mass loading by the Orange County OWTS can be estimated as follows.

69mg/L (STE TN conc.) – 37 mg/L (mean NO_3 conc. below drain field) / 69 mg/L (STE TN conc.) = 54% of TN not nitrified or 46% apparent removal by nitrification/denitrification

69mg/L (STE TN conc.) – 53 mg/L (mean highest NO_3 conc. in plume) / 69 mg/L (STE TN conc.) = 77% of TN not nitrified or 23% apparent removal by nitrification/denitrification

Using the above methodology, a range for potential dilution and mass loading of 54-77% of the STE load is derived. This equates to a mass loading ranging of 3.95-5.64 lbs TN/person/year for the Orange County site.

DISCUSSION / CONCLUSIONS

During January through May 2007, Ellis & Associates, Inc. (E&A) performed an assessment on three properties within the Wekiva Study Area. Criteria for selection of properties to be investigated were prepared by DOH with input from the Research Review and Advisory Committee (RRAC). Site selection criteria included: selection of one site from each of Lake, Orange, and Seminole counties; depth to water within reach of direct push drilling method; selection of sites with varying depth to groundwater; septic systems installed after 1982, but with no repairs since 1999; properties large enough to capture the nitrogen plume on-site and avoid interference from upgradient drainfields; properties using minimal fertilizer and no reclaimed water; properties with homes on public water supply with year-round residents and no excessive number of occupants; and, if compatible with other criteria, one site in each Wekiva Aquifer Vulnerability Assessment (WAVA) vulnerability class.

The properties investigated generally met the site selection criteria. The Lake County property was not on public water; however water usage was determined by metering the system. As requested, one site in each of the three WAVA zones was investigated.

The three sites investigated had septic systems which appeared to be good working order at the time of the assessments. The drainfield at the Seminole County site was a mound system and the drainfields at the Lake and Orange County sites were constructed in-ground.

Short-term groundwater elevation measurement was found to be a reliable indicator of groundwater flow direction and contaminant plume direction only at the Seminole County site. Due to alternating, non-continuous intervals of clays and clayey sands, the short-term groundwater elevation measurements at the Lake and Orange County sites were not good predictors of contaminant plume direction. This is likely influenced by the lower than normal rainfall during the past calendar year. Rainfall records from Orlando, Florida indicate less than normal rainfall in 11 of the previous 12 calendar months, and total rainfall during this period was 22% below normal (National Weather Service, May 2006 – April 2007). The observed groundwater table at the Seminole County site was below the apparent seasonal high water table elevations and the observed groundwater table at the Lake and Orange County site was substantially below the apparent seasonal high water table elevations. While *apparent* groundwater flow direction was not a good indicator of plume flow direction in two of the three cases, it should be noted that a more realistic picture of groundwater flow direction could be drawn with measurements made over a longer period of time (seasonal for a year at a minimum).

Water use for the three sites fell within the previously-documented expected range (EPA, 2007) with the exception of the Lake County site which was greater than the expected range. Concentrations of nitrogen and phosphorus in the septic tank effluent fell within the expected range for all three sites. Daily total nitrogen loading to the drainfields was slightly above the expected range for the Seminole and Lake County sites and within the expected range for the Orange County site.

Soil types varied by site: the soils at the Seminole County site were similar to Myakka fine sands; soils at the Lake County site consisted of mostly brown to gray fine sands resembling the Tavares Series near the surface, followed by alternating, non-continuous intervals of clay, clayey sands, and fine sands; the surficial soils at the Orange County site were similar to the Tavares Series, followed by interfingering layers of clay loam, loamy sands, and fine sands. The mean organic content of soils was 1.29 % for the Seminole County site, 3.01% for the Lake County site, and 1.39% for the Orange County site.

Groundwater depth and method of nitrogen / nitrate attenuation which took place appeared to differ substantially. The Seminole County site showed a shallow groundwater table (both seasonal high groundwater and observed groundwater depth) within several feet of ground surface. Nitrification and denitrification appeared to occur mainly in the immediate area of the drainfield. Denitrification of nitrates in the area of the drainfield appeared nearly complete within 20 to 30 feet downgradient of the drainfield. A TKN plume extended well downgradient of the drainfield, and appeared to be attenuated primarily by dilution from background groundwater.

In contrast, the Lake and Orange County sites had observed groundwater depths of greater than 15 to 20 feet bgs. The nitrogen plumes on these sites appeared to nitrify both in the vicinity of the drainfield and as groundwater moved downgradient of the source area. On both of these sites, based on a nitrate concentration contour of 10 mg/L, the dimensions of the nitrate plume measured approximately 90 feet long by 60 feet wide. The number of groundwater probings at the Lake and Orange County sites was insufficient to determine the size of the nitrate plume in terms of background concentrations.

In our opinion, while the data discussed here are relevant and accurate based on the assessment period during which they were developed, seasonal variability - particularly as related to rainfall amounts - could effect the observed nitrogen concentrations over time. Only longer term studies could more accurately predict the likely attenuation associated with seasonal variability.

The "background" conditions reported here may be used as a comparison to plume concentrations, but would be more appropriately determined over a longer period of time, such as one year or more.

Apparent mass loading to the shallow groundwater aquifer was estimated using Total Nitrogen analyses results. A summary of these calculations is shown in Table 14.

Table 14. Summary of apparent mass loading calculations.

	TN Load from Septic Tank to Drainfield (lbs/person/year)	Percent Apparent Nitrification / Denitrification	Mass Loading TN to shallow aquifer (lbs/person/year)
Seminole Co. Site	14.19	32%	9.65
Lake Co. Site	14.74	52%	7.07
Orange County Site	7.33	23-46%	3.95-5.64

These calculations indicate nitrification / denitrification is taking place at these locations at the upper portion of the expected range of 10 – 50% reported in previous studies. The depth to groundwater and amount of unsaturated soils available for nitrification / denitrification appears to be an important component of this process based on the comparison of the results for these three locations.

It should be noted that the mass loading results should not be considered as "average" or "typical" since both the Seminole and Lake County sites had septic tank effluent loading from nitrogen to the drainfield at the upper end of the expected range. This was apparently based on number of residents and/or water usage. More important as a basis for comparison than the estimated loading in pounds is the apparent percentage of nitrification / denitrification.

Table 15 illustrates potential mass loading scenarios based on EPA reported water usage and nitrogen loading from residential effluent, with percent apparent nitrification / denitrification identified in this study.

Table 15. Potential mass loading scenarios for the Wekiva Study Area

	TN Concentration to drainfield (mg/L)[1]	Estimated TN Load from Septic Tank to Drainfield (lb/person/year)[2]	Apparent Percent Nitrification / Denitrification (%)[3]	Estimated Mass Loading TN to Shallow Aquifer (lb/person/year)
High Effluent Load	75	15.68	23-52	7.52 – 12.07
Moderate Effluent Load	50	10.45	23-52	5.01 – 8.04
Low Effluent Load	26	5.43	23-52	2.61 – 4.15

[1] Based on EPA, 2007, Table 3-7
[2] Based on EPA, 2007, 259.7 liters/person/day, Table 3-1
[3] see Table 14

RECOMMENDATIONS

As discussed in the introduction of this report, nitrogen and nitrate loading to the land surface, groundwater, and surface water comes from a number of sources in addition to onsite wastewater treatment systems, such as atmospheric deposition; burning of fossil fuels; natural and chemical fertilizers used in agriculture and landscaping; municipal wastewater treatment facilities; and animal waste from commercial livestock operations. A number of other studies are recently or soon to be completed which address loading from these other sources. In our opinion, the results of these other studies should be used in conjunction with the results of this assessment in order to establish practical means of reducing nitrogen loading to the Wekiva Study Area in a manner that addresses all nitrogen loading sources.

It should be noted that the mass loading concentrations calculated from the results of this study are representative of only three study sites in the Wekiva Study Area which may not be indicative of mass loading rates for the approximately 55,000 other OWTS sites in the Wekiva Study Area. E&A recommends that before the mass loading rates presented in this report are used to extrapolate mass loading concentrations being applied by all OWTS in the WSA, further analysis of septic tank effluent concentrations, residential water usage, and number of residents at an appropriate number of additional sites within the Wekiva Study Area be carried out to provide better statistical certainty.

Additionally, since these studies were conducted at properties of relatively large lot size to allow distinguishing on-site plumes from neighboring plumes, in our opinion, a study that investigates nitrogen concentrations downgradient of more densely constructed developments (i.e., subdivisions or developments with smaller lot sizes and a higher density of OWTS) is an appropriate next step to determine whether the mass loading estimates reported here are representative in terms of current and expected development in the Wekiva Study Area.

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