THE COLLECTION OF FERTILIZER NUTRIENT LOADING DATA FOR USE IN THE ESTABLISHMENT OF FERTILIZER ORDINANCES BY LOCAL GOVERNMENTS IN THE IRL DRAINAGE BASIN

FINAL PROJECT REPORT
IRLNEP; SJRWMD
(Contract No. 27866)

Submitted To:
St. Johns River Water Management District

Submitted By Florida Tech Researchers:

Thomas V. Belanger, Ph.D., Principal Investigator

And

Thomas L. Price Jr., M.S., Co-Investigator

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Introduction

It is clear that the nutrient loading to the IRL must be reduced. The U.S. Environmental Protection Agency estimates the lagoon takes in 3 million pounds of nitrogen a year, 1 million more than it can absorb. The lagoon also takes in more than 400,000 pounds of phosphorus annually, twice what it can absorb and still function. One pound of fertilizer washing off a lawn can trigger the growth of 500 lbs of algae, according to the MRC (2011). Algal blooms, such as the recent brown tide bloom (2012) and the superbloom (2011), block sunlight to seagrass—the linchpin of the IRL ecosystem. When algae die, the resulting oxygen sags can trigger fish kills. If seagrasses continue to decline and suffer, the lagoon could eventually shift from a seagrass based to an algal based system---with disastrous ecological results. According to an environmental study in 2008, an acre of seagrass—the main money machine when it comes to supporting fish, crabs and other lagoon life—is worth about $4,600 a year in the recreational and commercial fishing it supports. (Waymer, 2014).

By 2028, Florida wants the nitrogen and phosphorus entering the lagoon cut in half, costing local governments from Fort Pierce to Volusia County $1.4 billion to meet the new limits (Waymer, 2014). So far, DEP TMDL nutrient loading reduction successes have been largely through expensive stormwater reduction and treatment projects by local governments. Other local plans for meeting new DEP nitrogen and phosphorus TMDL requirements include septic tank removal, street sweeping and pet waste and fertilizer input reductions through education programs and local ordinances. Several studies have pointed to the importance of fertilizers as a significant nutrient source to water bodies, but DEP only gives a few percent credit for fertilizer ordinances--one of the easiest and least expensive ways to limit nitrogen and phosphorus to the lagoon. According to the SJRWMD, fertilizer runoff/leaching is likely the main source of nutrients to the IRL, accounting for up to 70% of the lagoon wide influx of N and P. The Marine Resources Council states that homeowners routinely put down more than 10X the amount of fertilizer than agriculture does (MRC, 2011). In view of this, the cheapest and easiest way to lower nutrient loading to the IRL may be through source control by enacting strict local government residential fertilizer ordinances, if sound scientific studies indicate fertilizers are indeed to blame.

The Florida legislature has required that local governments adjacent to waters that are impaired by pollution, such as the IRL, must pass an ordinance regulating the use of fertilizers on lawns. The Florida DEP has created a model ordinance as a guideline for local governments, but this ordinance actually does very little to limit fertilizer pollution. According to the state, local government ordinances can be more restrictive than the DEP model if the changes are “science based” and take into account all relevant scientific information. Over the past several years, many local governments have enacted stronger fertilizer ordinances. These ordinances, among other things, have established restrictions such as banning or restricting P use, requiring at least 50% slow release N, and banning fertilizer application during the rainy season. Local governments say they are spreading the word about new fertilizer rules, rather than fining people. Ordinance proponents believe correct fertilizers need to be used at the correct times in the correct amounts, and strict ordinances that regulate the use of fertilizers on lawns are a cheap and logical way to achieve that goal.

The use of restrictive fertilizer ordinances by local governments is controversial. Advocates of restrictive ordinances point to the large seagrass increases in Sarasota Bay and Tampa Bay, after strict fertilizer ordinances and stormwater upgrades were enacted, as evidence that ordinances work. Sarasota County commissioners indicate their restrictive ordinance, passed in 2008, has had no negative effects and many positive ones. The commissioners said that once the wrong types of fertilizers were identified and restricted for use, stores began carrying only the correct products and the waterways benefitted. They said penalties for non-compliance in Sarasota County were not needed. In the first summer of widespread bans in Brevard County, manufacturers distributed almost two-thirds less fertilizer during peak months (Waymer, 2014; MRC, 2011). Advocates for stricter fertilizer rules point to research showing lawns can still thrive without fertilization during rainy months. Opponents, mostly associated with fertilizer, turfgrass or lawn-care interests, believe otherwise. Agencies, such as the Florida Nursery, Growers and Landscape Association, the Florida Pest Control Management Assoc. and the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) are skeptical about the need for restrictive residential fertilizer ordinances, especially rainy season fertilizer bans. They say data from environmental studies linking improved water quality with fertilizer restrictions are lacking, and that their studies show that fertilizer nitrogen is quickly taken up by the roots of mature, healthy, dense, actively growing turf grass in the summer rainy season, and no leaching occurs. They state that nutrient uptake is associated with vigorous root growth during summer months, and not fertilizing would result in more nutrients running off and leaching through the weaker grass when applied at other times of the year (Waymer, 2014). IFAS believes a properly maintained and fertilized lawn provides an effective means of nutrient uptake. In the central Florida area, IFAS recommends 2-5 lbs N per 1000 ft^2 per year, with no more than 1 lb of N being applied at any one time. They believe non-compacted soils can accumulate 1 lb of N per 1000 ft^2 without negative leaching impacts (Sartain et al., 2013; Trenholm et al., 2011).

Our study sites were characterized by less than optimally healthy residential turfgrass, a situation that we believe is more representative of the overall grass condition in the IRL drainage basin than the IFAS studies. This combined SLRIT/IRLNEP study focuses on collecting data that could be used by local governments in the IRL drainage basin to support (or not support) ordinance changes such as the restriction or ban of quick release fertilizer application or the restriction or ban of any fertilizer application in the wet season (June1—Sept. 30. The rainy season is the worst case time for fertilizer application, particularly quick release fertilizer, because of increased nutrient movement through the wet soil. Although our study was designed to compare dry season and wet season nitrogen leaching, the extremely high dry season rainfall made that goal impossible. Actually, the rainfall amounts for both the dry and wet season study periods were unusually high.

We believe fertilizer runoff may be overestimated, while fertilizer nutrient leaching is likely under-estimated. It takes very heavy rains to wash fertilizer over or through thick lawns with little topographic slope, and although some quick release and slow release fertilizer can wash off lawns via overland runoff, probably more important in Florida is that these nutrients easily leach through sandy soils into shallow groundwater, and then seep laterally into surface water. The groundwater nutrient loading avenue is often neglected in fertilizer loading studies and discussions, and is the focus of this research. This study documents the fertilizer application leaching potential to the shallow groundwater under the field conditions encountered. General IRL loading rate conclusions can be roughly based on the horizontal hydraulic gradients routinely measured at the research sites. According to Virginia Barker, Brevard County's Watershed Program Manager, Brevard County has a groundwater problem. She says it only takes a few weeks to months for groundwater in most of Brevard County to flow to the IRL. A recent study on behalf of Brevard County and 16 Brevard Cities found 60 percent or more of the nutrients entering the lagoon may be coming from groundwater, and we believe much of that is from fertilizer leaching (Waymer, 2014). According to Erickson et al. (2001) very little quantitative N leaching and runoff data from Florida turfgrass are available, although a number of investigators have demonstrated conditions favorable for N runoff and leaching from turfgrass land use (Kelling and Peterson, 1975; Petrovic, 1990; Snyder et al., 1984). Groffman et al. (2009) noted that there have been relatively few studies of nitrogen leaching from urban grasslands and Tucker et al. (2014) acknowledged the limited information available on nitrogen leaching and groundwater quality impacts from residential turfgrass fertilization. The potential for N leaching may be great on coarse textured soils (Reike and Ellis, 1974), and excessive irrigation or rainfall enhances N leaching (Snyder et al., 1984).

Project Goals and Objectives:

In view of the paucity of information on the importance of fertilizer nitrogen leaching under different field conditions, the primary objective of this study was to quantify the effects of residential fertilizer leaching on groundwater nitrogen levels in a specific Florida residential neighborhood with unique characteristics in both the dry and wet seasons (e.g. very high water table, heavy rainfall). This report presents the results of two separately funded studies that target the same research sites and are both concerned with the collection of fertilizer nutrient leaching data to add to the database and also to help support or refute the establishment of strict residential fertilizer ordinances. These two studies are funded by the St. Lucie River Issues Team (SLRIT) and the Indian River Lagoon National Estuary Program (IRLNEP) and study details are outlined in later sections of this report. Funding for the two studies was very cost effective, as the two studies merged into one larger study, allowing more nutrient sampling to occur and enabling more research trips and groundwater samples to be taken

We believe residential fertilizers are likely a major source of nitrogen to the IRL, much more important than septic tanks or many other commonly listed sources, but we are lacking conclusive cause/effect data that support this belief. Although many local governments in the IRL drainage basin, such as Martin County, have fairly restrictive ordinances, some do not. In view of that, this study is designed to provide nitrogen leaching data that may support (or not support) the formulation of more restrictive local government fertilizer ordinances in the IRL drainage basin. This study, however, was limited to a very low gradient, high water table, sandy area that is not typical of the majority of the IRL drainage basin, and therefore results are somewhat site specific. Actually, St. Lucie Village, the site of this study, passed a stronger fertilizer ordinance on 4/15/14 that, among other things, provides for a fertilizer application blackout period during the wet season and specifies the use of at least 50 percent slow release nitrogen. Since our study had already begun, special permission was granted for our wet season fertilization application beginning in July, 2014 so that the study could be completed.

Study Overview

SLRIT Study

The four residential research sites for use in the SLRIT study were located in north Ft. Pierce in St. Lucie Village (St. Lucie County), and represented residential sites that have not been fertilized for over 5 years (Figs.1 and 2). The St. Lucie Village neighborhood was characterized by coarse sandy soils, and during both the wet and dry season study periods it exhibited an extremely high water table and experienced heavy rainfall. One site (residence) served as a control (no fertilization) while the other three test sites received precise applications of granular slow release (>50% slow release N), granular quick release (<50% slow release N) and liquid quick release fertilizer (>50% soluble quick release N), with measurement times reflecting different antecedent conditions. All four sites were sampled approximately twelve times over a 24 month period (control, 2, 8, 15, 31 and 57 days after fertilizer application in the dry season; control, 1, 3, 6, 17 and 30 days after fertilizer application in the wet season). Sampling occurred over six separate days in each season. This exceeded the contract specifications, as only three sites and a total of four sampling days were originally required. Dry season sampling began February 23, 2014 and ended April 19, 2014. Wet season sampling began July 18, 2014 and concluded April 16, 2014.

Figure 1. General Location of St. Lucie Village Research Area.

Figure 2. Residential Sites in St. Lucie Village.

The four residential sites received the following fertilizer applications, as part of the SLRIT Study. Slow and quick release granular fertilizers were applied at two residential test sites by a rotary broadcast spreader with a deflector shield at a rate of 1.0 lb N/1000 $ft^{2.}$ Quick release soluble liquid fertilizer was applied at the recommended rate of 1.0 lb soluble N/1000 ft^2 at another residential test site. The fourth residential test site (373 Chamberlain) received no fertilizer during the study and served as a control. We also sampled each residential site before fertilizer application in the wet and dry seasons (control), and that served as additional control data. None of the residential test sites have any history of fertilizer application.

Residential groundwater sampling sites are shown in Figs. 3 and 4. Four separate groundwater locations were sampled at our control site (373 Chamberlain) and at least six groundwater locations were sampled at each of the three fertilized residential sites using clean M.F.E. PushPoint sediment pore water sampling rods connected to a peristaultic pump. Sampling rods were cleaned between sites by rinsing with acid, a soap solution and deionized water. At least one additional surface water grab sample was also be collected at each residential site, and groundwater samples from three locations will be collected at each residence prior to scheduled fertilizer applications. In addition, ten percent of all samples were collected in duplicate and most of the samples were collected at two depths (0.5 and 1.5 ft, below the water table) per sampling location. All samples were kept on ice and promptly delivered on the same day to DEP and EPA certified ENCO LABS in Orlando via a courier service for determination of NH_3-N, NOx-N, and TKN. Daily rainfall was measured with an installed rain gage by a homeowner (LeRoy Creswell) at 373 Chamberlin, and these data were used in data interpretation. It was important that the test sites were located in same general vicinity as the recorded rainfall so that they were subjected to similar rainfall levels. No residential lawn irrigation occurred at any test site during the study.

Figure 3. Piezometer and Surface Water Sampling Locations.

Figure 4. Groundwater Sampling Locations.

IRLNEP Additions To The SLRIT Study

IRLNEP funding was used for the following additions to the above tasks, in order to maximize the collected information in a cost effective manner. The additional IRLNEP funding allowed for four additional nutrient sampling dates at all four established test sites for the two fertilizer applications (1 dry season; 1 wet season) at approximately 30 and 45 days after fertilizer application, respectively. This sampling scenario is in addition to the eight sampling events already indicated, above. This results in a total of 12 events, as opposed to the four events originally specified in the contract. The expanded study (SLRIT/IRLNEP) gave us more information under different conditions, allowing better conclusions to me made. This entire residential fertilizer study (SLRIT, IRLNEP) represents part of a Ph.D dissertation in environmental science being completed by Tom Price (MS, Florida Tech) in which he is evaluating the importance of various nutrient sources to the IRL. Another MS student, Jared McNally, is focusing on the nutrient leaching aspects of this fertilizer study for his MS thesis.

Site and Turfgrass Fertilizer Descriptions

Three test sites and one control site (no fertilization) were selected in St. Lucie Village in north Ft. Pierce and are shown in Fig. 2. The St. Lucie Village residential sites selected for fertilizer application were 306, 320 and 351 Chamberlain, with 373 Chamberlain serving as a control (no fertilization). The St. Lucie Village test sites were had lawns grown under suboptimal conditions that were characterized by having only moderately healthy turfgrass (St. Augustine), with some dollar weed and other grasses present. The color of the St. Augustine grass was generally light to medium green and is representative of much of St. Lucie Village and the IRL drainage basin. It is not the lush, dark brown, healthy and thick turfgrass grown under optimum conditions and used by IFAS and others in their studies, but it is actually more characteristic of lawns in the IRL basin. The residential test sites were not fertilized by homeowners (other than our study applications) or irrigated at any time during the study, and the test site homeowners indicated that was generally the case every year.

Turfgrass fertilizer can be grouped in two categories, soluble liquid and granular. Soluble liquid fertilizer provides a readily available supply of nitrogen to the turf, is fast acting, allows for even coverage and is easy to apply---but usually requires numerous applications to guarantee desired results that are lasting. Granular fertilizers are produced in two different formulations. Slow release granular fertilizers are generally much better for feeding lawns that are suffering from heat stress and dry weather. One type of slow release fertilizer, polymer coated urea, provides a controlled release of nitrogen by diffusion through a polymer membrane (coating), and was used in this study. Actual release rates depend on temperature, moisture and on the thickness of the coating, but polymer coated urea usually lasts about 10-12 weeks. Quick release granular fertilizers have either no or a small amount of coating, and typically last for 2-4 weeks, depending on temperature and rainfall (or irrigation). Liquid quick release fertilizers last only 1-2 weeks (Maguire, 2009; Bonnie Plants, 2013; Lowes, 2013). The following fertilizer applications were used at the indicated sites.

306 Chamberlain Boulevard exhibited a 12,500 ft^2 lawn area that was fertilized at the rate of 1 lb N/1000ft^2. The fertilizer used was Lesco granular 24-0-11, with 5.60% of the nitrogen being ammonia nitrogen and 18.40% being urea nitrogen. 12.80% of the urea was slowly available (lasting approximately 10-12 weeks) urea because it was coated with Lesco polymer coating This resulted in a fertilizer with 54% of the nitrogen being slow release and represented our granular slow release fertilizer (> 50% slow release).

320 Chamberlain Boulevard has a 10,176 ft^2 lawn area and was fertilized at the rate of 1 lb N/1000 ft^2. The fertilizer used was Lesco granular 20-0-10, with 8.80% ammonia nitrogen and 11.20% urea nitrogen. 5.60% of the urea was slowly available because it was polymer coated, resulting in a fertilizer that was only 28% slow release, and was considered to be a granular quick release fertilizer (< 50% slow release).

351 Chamberlain Boulevard has a 7400 ft^2 lawn area and was fertilized at the rate of 1.1 lb N/1000ft^2 with a quick release soluble fertilizer (Lesco 33-0-17) mixed in water. 33% was uncoated quick release urea. Note that a calculation error was made for the dry season application (Feb, 2014) resulting in a nitrogen dose of only 0.33 lb N/1000ft^2. Also note that this lawn was subject to heavy compaction from vehicle traffic and parking, and therefore the leaching potential was greatly reduced.

Control Site: 373 Chamberlain Boulevard represented our control site (no fertilizer), which was sampled at four different locations during every sampling trip. The front yard test area was 1500 ft^2. A standard rain gage that was checked daily was located in the back yard. As an additional control, we sampled each residence (306, 320, 351 Chamberlain) 3-4 days prior to dry and wet season fertilizer applications. Although the same sites were sampled before and after fertilizer application with this sampling scenario, the sites were subjected to different rainfall and water table conditions, and therefore we believe 373 Chamberlain serves as a better control site. The sampling dates prior to fertilizer application were 2/15/14 (dry season) and 7/15/14 (wet season).

Nitrogen Soil Chemistry

Phosphorus is usually high enough in Florida soils so that it is often absent in residential fertilizers, and therefore is not a concern. Nitrogen, whether present from fertilizer inputs or from the natural soil chemistry, is removed from soils by four major processes:

Runoff and erosion
Leaching
Plant or grass uptake (roots)
Gaseous loss (ammonia volatilization or denitrification)

Runoff and erosion losses may include nitrate, urea, ammonium, and organic nitrogen, but rainfall does not generally cause significant runoff losses of fertilizer nitrogen unless very heavy rainfall occurs shortly after fertilizer application (Pruvin and Hussner, 2014). Runoff is usually low on coarse grained sandy soils, unless rainfall rates are very high. Leaching losses, the focus of this study, involves the movement of water downward through soil below the root zone. The degree of nutrient leaching depends upon the nutrient species and the situation, and can be significant under the right circumstances. Nitrogen leaching is the most important for nitrate in coarse textured sandy soils in areas where excess rainfall occurs after fertilization and where the soils have more incoming water than the soil can hold. In sandy soils, much of the nitrate formed can be lost by leaching because the sandy soils have a low water holding capacity and a high infiltration rate. If there is no runoff, and the soil is saturated before rain occurs, the bulk of the nitrate is expected to move about 10-12 inches in sandy soils for each inch of water percolating through the soil. In unsaturated sandy soils, every inch of rain percolating into the soil can move nitrate about 6 inches deeper in the soil profile (Camberato et al., 2014). Although nitrate leaching is normally the major concern, other forms of nitrogen such as urea and ammonia or ammonium can leach through soil, also.

Soil pH is considered to be a major factor regulating the nitrification process in soils and therefore the amount of nitrate present. The optimum pH for nitrification is approximately 7, but occurs between pH's of 5.5 and 10 (Camberato, 2001). Nitrate, due to its negative charge, is not held by soil particles and therefore moves easily with soil water**.** Ammonium is favored by neutral to slightly acidic pH's, and although ammonium is quite soluble, it is positively charged and attracted to negatively charged soil particles and therefore does not leach unless the soil is very porous with very little clay (Camberato, 2001). Nitrification, however, is substantially reduced in wet soils because low oxygen conditions prevent nitrification and nitrate formation from occurring. Nitrification will increase with percent soil water content to about 60% water filled pore space, after which the higher soil moisture negatively affects soil aeration and oxygen for nitrification becomes limiting. Maximum nitrification rates occur in soils when the oxygen percentage is greater than 10% (20% is the natural concentration in air). Nitrification is also affected by temperature and generally follows a bell shaped temperature response curve, with an optimum at 30-35 degrees C (Camberato, 2001).

Plant uptake refers to nitrogen absorption by roots. Although urea can be taken up by plant roots, this mode of nitrogen uptake is usually small compared to the uptake of nitrate and ammonium. Ammonia volatilization is the loss of nitrogen to the atmosphere as ammonia gas and is usually due to urea hydrolysis in soil after surface application of fertilizer. All three fertilizers used in this study have significant percentages of urea. Urea $CO(NH_2)_2$ is a white crystalline solid containing 46% nitrogen, and occurs in different percentages in various fertilizers.

Urea breakdown (hydrolysis) begins as soon as it is applied to soil. If the soil is totally dry, no reaction occurs. But with the enzyme urease, plus any small amount of soil moisture, urea normally hydrolyzes and converts to ammonia and carbon dioxide (OSU, 2014). The breakdown hydrolysis reaction usually occurs in 2 to 4 days, and happens quicker on high pH soils. Urea can be lost to the atmosphere by ammonia volatilization if it remains on the soil surface (after fertilization) for extended periods of time during warm weather. Ammonia volatilization is most likely to take place when soils are moist and warm and the source of nitrogen (urea) is on or near the soil surface (Killipack and Bucholz, 2014). Upon hydrolysis of urea the pH around the urea particle can be increased and the proportion of nitrogen in the ammonium form is often shifted toward ammonia. A few days of warm temperatures (> 30 degrees C) and high pH's would cause significant ammonia losses, as losses may be as great as 60% of the applied urea nitrogen. Rainfall or irrigation within 24 to 72 hours of application can blend urea into the soil to a depth at which ammonia volatilization losses will be minimized. Urea's high aqueous solubility reflects its ability to engage in extensive hydrogen bonding with water (Wikipedia, 2014). Fertilizer urea is considered to behave similarly to nitrate in soils because it is not strongly retained by soil colloids and appears to move freely in soil solution. Actually urea is slightly retained by weak absorption forces in the soil, and until hydrolysis occurs, urea is considered to be very soluble. Actually, urea is intermediate between nitrate and ammonium in its susceptibility to leaching. Urea is a molecule without a charge, so it can move easily with percolating water if ammonia volatilization does not occur first. If rains come within the first 12-24 hours or so of urea surface application, the leaching of urea can be significant from sandy soils.(Camberato et al., 2014; Killipack, 2014; OSU, 2014).

Lab and Field Analyses and Procedures

Ground Water Levels, Rainfall

Field water level measurements were made in the piezometers with a Herron “Little Dipper” water level measurement pressure transducer and data were used for horizontal and vertical gradient calculations. Standard differential leveling procedures were used to determine relative elevation of top of casing heights for wells and piezometers. A bench mark was constructed at each location and assigned an assumed elevation of 10.00 ft. All other elevations were measured relative to this elevation (Ghilani and Wolf, 2008). A standard rain gauge was placed in the backyard of the Creswell residence (373 Chamberlain). The gauge was attached to a 2 inch PVC pipe, three feet above the ground, and the rainfalls values were recorded daily. Piezometer and rain gage locations are shown in Fig. 3.

Specific Conductance, Temperature, pH and Dissolved Oxygen (D.O.)

Specific conductance, temperature and pH of ground water and surface was measured in the field with a Myron Ultrameter, and D.O. was measured with a YSI Model 57meter. D.O. was measured in samples collected from 2 inch piezometers, while conductivity, pH and temperature were determined at all groundwater sampling sites. Specific conductance measurements were calibrated with a potassium chloride standard at the beginning of each daily field trip. Meters used to measure pH were calibrated against two buffer solutions prior to and after each daily field use. Dissolved oxygen meters were routinely checked with air calibration and also calibrated against Winkler titrations before and after each daily field trip. All calibrations were documented in the field notebook.

Nutrient Sampling and Analysis

Florida Tech collected samples and kept them on ice or refrigerated until Environmental Conservation Laboratories, Inc., located in Orlando, could retrieve the sample via their courier service. This always occurred within three days of sample collection. Samples were analyzed for ammonia nitrogen (NH_3-N), nitrate/nitrite nitrogen (NOx) and total kjeldahl nitrogen (TKN) using standard procedures. Duplicate analyses (separate samples) were run on approximately 10% of all collected samples Method details follow:

NH_3-N

Method 350.1. Determination of ammonia nitrogen by semi-automated colorimetry. This method covers the determination of ammonia in drinking, ground, surface, and saline waters, domestic and industrial wastes. The applicable range is 0.01-2.0 mg/L NH as N. Higher concentrations can be determined by sample dilution. Approximately 60 samples per hour can be analyzed. This method is described for macro glassware; however, micro distillation equipment may also be used.

The sample is buffered at a pH of 9.5 with a borate buffer in order to decrease hydrolysis of cyanates and organic nitrogen compounds, and is distilled into a solution of boric acid. Alkaline phenol and hypochlorite react with ammonia to form indophenol blue that is proportional to the ammonia concentration. The blue color formed is intensified with sodium nitroprusside and measured colorimetrically. MDL = 0.0073 mg/L.

TKN

Method 351.2 Determination of TKN (Total Kjeldahl Nitrogen) by semi-automated colorimetry. This method covers the determination of Total Kjeldahl Nitrogen (TKN) in drinking, ground, and surface waters, domestic and industrial wastes. The procedure converts nitrogen components of biological origin such as amino acids, proteins and peptides to ammonia, but may not convert the nitrogenous compounds of some industrial wastes such as amines, nitro compounds, hydrazones, oximes, semicarbazones and some refractory tertiary amines. The applicable range is 0.1-20 mg/L TKN. The range may be extended with sample dilution. The sample is heated in the presence of sulfuric acid, H SO for two and one half hours. The residue is cooled, diluted to 25 mL and analyzed for ammonia. This digested sample may also be used for phosphorus determination. Total Kjeldahl nitrogen is the sum of free-ammonia and organic nitrogen compounds which are converted to ammonium sulfate $(NH_4)SO_4$, under the conditions of digestion described. MDL = 0.050 mg/L.

NOx-N

Official Method Name: 4500-NO3- H. Automated Hydrazine Reduction Method Current Revision: Standard Methods Online, Instrumentation; Automated Spectrophotometer Standard Methods Online - Standard Methods for the Examination of Water and Wastewater Brief Method Summary. Nitrate is reduced to nitrite with hydrazine sulfate. The nitrite (originally present) plus reduced nitrate is determined by diazotization with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride to form a highly colored azo dye that is measured colorimetrically. Nitrate and nitrite in potable and surface water and in domestic and industrial wastes can be determined over a range of 0.01 to 10 mg N/L. Applicable Concentration Range 0.01 to 10 mg-N/L. MDL = 0.016 mg/L.

Ground Water Potential

A shallow (4-5 ft) ¾ inch <u>in situ</u> piezometers was installed in the benthic sediment at a nearshore site. (Site 8, Fig. 4). The piezometer had 1 ft screened intervals with 0.010 slot screen. The <u>in situ</u> river piezometer was installed by jetting in a 1 ¼ inch temporary casing outside the piezometer pipe with a 1½ h.p. centrifugal Honda water pump connected to a 1 ¼ inch hose line. After the piezometer was allowed to settle and equilibrate for several days, the head difference between the surface water level (outside piezometer water level) and the groundwater (inside piezometer water level) was routinely measured (delta H). The vertical hydraulic gradient was obtained by dividing the delta H by the depth of the screen below the sediment surface. The well depth was 8.67 ft and the depth of the one ft screen below the sediment was three ft. The horizontal gradients were calculated by dividing the vertical difference in water level between two points (up gradient and down gradient piezometer) by the horizontal distance between the two piezometers. Two inch diameter piezometers were installed at seven different upland locations for water level measurements to be used in horizontal hydraulic gradient calculations. The horizontal distance between piezometer 1 and piezometer 7 was approximately 1000 ft, and this distance was used in the calculations (Fig. 3). When the vertical and horizontal hydraulic gradients are positive, as was the case in this study (slightly positive), the potential for groundwater seepage to the IRL exists.

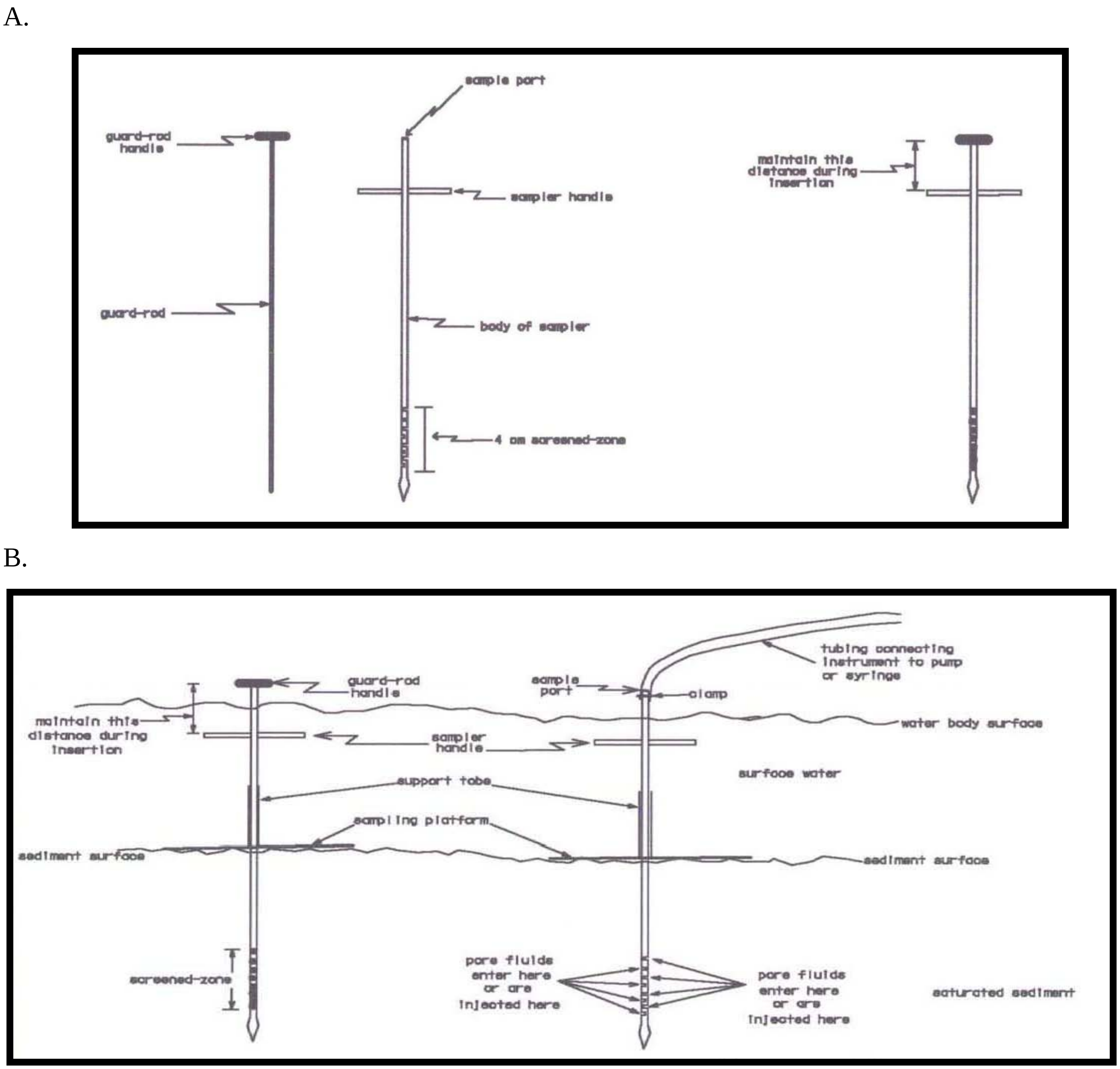


Figure 5. PushPoint Sampler Design (A) and Sampling Configuration (B).

Groundwater Sampling with PushPoint Samplers

The M.H.E PushPoint sampling tool allows us to rapidly sample ground water at various depths. The PushPoint device is a very simple, precisely machined tool consisting of a tubular body fashioned with a screened zone at one end and a sampling port at the other (Figure 5). The bore of the PushPoint body is fitted with a guard rod that gives structural support to the PushPoint and prevents plugging and deformation of the screened zone during insertion into sediments. The screened-zone consists of a series of interlaced machined slots which form a short screened-zone with approximately 20% open area. The PushPoint is made of 316 stainless steel and comes in various lengths. In this study we primarily used 36 inch length and ¼ inch diameter PushPoints. A GeoPump peristaltic pump was attached to the PushPoint sample port via Tygon tubing and water was withdrawn at a low flow sampling rate (50-200 mL/min.). The first 20-50 mL of ground water was generally turbid and this "development" water was discarded. Once non-turbid aliquots have been withdrawn, samples were usually representative and suitable for on-site and off-site analysis. To determine this, however, the purge water was checked to see if the conductivity and pH values were stable on two consecutive measurements. Most samples were taken 0.5 ft. and 1.5 ft. below the water table at each site, but in some cases only one depth could be taken due to sediment compaction. Duplicates were run on 10% of all samples and equipment blanks were collected on 5% of all samples.

Soil Sampling and Analysis

Percent soil particle size analyses were conducted on composite soil samples collected from the land surface to water table. Analyses were conducted by Florida Tech using standard sieving techniques (ASTM, 2008), and silt/clay, very fine sand, fine sand, medium sand, coarse sand and granule or larger fractions were determined. In addition, percent organic matter (O.M.) was also determined on the soil samples by combusting the sample at 550 degrees C in a muffle furnace. Procedures for determining percent organic matter are outlined in Standard Methods (APHA, 1989) and Dean (1974). Ten percent of the sediment samples were run in duplicate for precision estimates. All sediment samples were saved for possible re-analysis at a later date.

Results

Fertilizer Impact

Sediment grain analysis data are shown in Table 1, and reveal that all sites are sandy (>90% sand), with medium grain sand almost comprising 50% of the total, and coarse grained sand comprising another 16 %. Surface water and groundwater sampling site locations are shown in Fig. 3. Individual groundwater site nitrogen data are presented in Tables 2 and 3, while groundwater dry and wet season mean summary data are shown in Tables 4 through 9, respectively. Surface water nitrogen data are presented in Tables10 and 11. Water level data and vertical and horizontal hydraulic gradient data are presented in Tables 12 and 13, and collected rainfall data are shown in Tables 14 and 15. Specific conductance and pH data are presented in Tables 16 and 17. Dry and wet season nitrogen data are shown in bar graph form in Figures 6 through 9, for comparison. Duplicate nutrient analyses (separate samples) were run on 10%of the collected samples, and results are shown in Tables 18 and 19. Total rain for the weeks prior to fertilizer sampling dates was 10.2 cm (4.0 in) for the dry season and 41.9 cm (16.5 in) for the wet season. Concerning the dry season (deep and shallow) means, as shown in Table 4, there is a significant ($P < .01$) difference between the 351 NH_3-N site mean (1.04 mg/L) and the mean NH_3-N value for the 4/19/14 control mean (0.61 mg/L) or the 372 Chamberlain mean ((0.51 mg/L). We did not see a similar difference at 351 Chamberlain during the wet season, however, even though rainfall amounts were higher. The 351 Chamberlain wet season groundwater impact from the liquid quick release fertilizer application was nonexistent, as the NH_3-N and NOx-N mean concentrations were not higher than the control levels. NOx-N was not present due to anaerobic conditions, and we believe NH_3-N was flushed very quickly through the saturated soil, and not measured, or concentrations were greatly diluted due to the extremely heavy rainfall that occurred (Table 15). In the dry season, when rainfall levels were much lower, the mean NH3-N concentration was significantly ($P<.01$) greater than mean control concentrations. Other dry season (deep and shallow) means were higher than control means for NH_3-N at 306 and 320 A-C, although the difference was not statistically significant and the measured values were low. In the wet season, except for sites 320 D-J, nitrogen levels were generally low and there was no statistically significant difference ($P<.05$) between NH_3-N or NOx-N control means and test site data means. Although rainfall levels in both the dry and wet seasons are considered high, much higher rainfall levels in the wet season did not correlate with higher NH_3-N or NOx-N groundwater levels, and the very high rainfall in the wet season could have resulted in unusually high groundwater flushing rates and/or dilution, reducing the measured impact.

Table 1. Grain Size Analysis by Percent for Soil Samples Taken at Study Site Piezometer Locations

Site ID	Screen Size (mm)						
	2	1	0.5	0.25	0.125	0.0625	pan
	Pebbles (%)	Very Coarse Sand (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Very Fine Sand (%)	Silt (%)
306A	0.24	1.86	31.05	52.93	12.61	0.98	0.34
306B	0.03	0.65	19.34	51.25	26.06	0.84	1.83
320A	0.41	2.91	16.48	43.54	30.02	6.00	0.66
320B	0.21	2.89	6.48	40.87	32.75	6.74	10.06
320C	0.54	0.93	27.85	49.20	18.71	2.16	0.60
320D	0.02	2.10	12.36	48.72	28.95	6.58	1.27
320E	0.26	0.89	21.84	53.72	21.63	1.30	0.37
351A	0.16	0.41	9.02	59.61	26.36	2.12	2.32
351B	1.17	6.69	19.58	37.42	20.68	4.96	9.49
351C	0.05	0.99	12.44	50.65	25.78	2.45	7.64
373A	0.09	0.33	10.63	52.92	33.39	2.27	0.38
373B	0.36	0.54	8.12	47.79	38.28	2.20	2.71
Mean	0.29	1.76	16.26	49.05	26.27	3.22	3.14
SD	0.30	1.72	7.53	5.81	6.80	2.12	3.54

Table 2. Dry Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site								Site							
306AD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	306AS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	2.20	1.80	2.20	2.20	2.30	3.60	2.38	TN (mg/L)	2.30	0.78	2.90	1.80	3.20	0.70	1.95
NH3 (mg/L)	1.30	0.94	1.40	0.79	1.00	1.90	1.22	NH3 (mg/L)	0.60	0.05	1.30	1.00	1.20	0.10	0.71
TKN (mg/L)	2.20	1.80	2.20	2.20	2.30	3.60	2.38	TKN (mg/L)	2.30	0.78	2.90	1.80	3.20	0.70	1.95
NOx (mg/L)	0.016	0.016	0.016	0.017	0.016	0.018	0.017	NOx (mg/L)	0.018	0.016	0.018	0.016	0.016	0.016	0.017
306BD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	306BS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.20	1.40	1.70	1.60	1.80	2.00	1.62	TN (mg/L)	1.10	1.50	1.80	1.70	1.50	3.90	1.92
NH3 (mg/L)	0.13	0.21	0.32	0.25	0.32	0.42	0.28	NH3 (mg/L)	0.04	0.10	0.23	0.27	0.22	1.10	0.33
TKN (mg/L)	1.20	1.40	1.70	1.60	1.80	2.00	1.62	TKN (mg/L)	1.10	1.50	1.80	1.70	1.50	3.90	1.92
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016	NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
306CD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	306CS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	0.97	0.97	1.10	1.50	1.00	1.30	1.14	TN (mg/L)	1.10	1.00	2.00	2.60	1.30	1.20	1.53
NH3 (mg/L)	0.04	0.05	0.17	0.31	0.10	0.23	0.15	NH3 (mg/L)	0.04	0.10	0.32	0.62	0.11	0.01	0.20
TKN (mg/L)	0.96	0.97	1.10	1.50	1.00	1.30	1.14	TKN (mg/L)	1.10	1.00	1.90	2.60	1.30	1.20	1.52
NOx (mg/L)	0.017	0.016	0.016	0.016	0.016	0.016	0.016	NOx (mg/L)	0.016	0.016	0.078	0.016	0.016	0.016	0.026
306DD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	306DS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.10	1.10	1.10	1.10	0.94	1.00	1.06	TN (mg/L)	0.71	0.69	0.71	0.84	0.86	3.80	1.27
NH3 (mg/L)	0.49	0.44	0.52	0.57	0.42	0.63	0.51	NH3 (mg/L)	0.11	0.07	0.13	0.19	0.24	0.01	0.12
TKN (mg/L)	1.10	1.10	1.10	1.10	0.94	1.00	1.06	TKN (mg/L)	0.71	0.69	0.71	0.84	0.86	1.10	0.82
NOx (mg/L)	0.016	0.016	0.020	0.016	0.016	0.016	0.017	NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	2.7*	0.016
306ED	2/19	2/23	3/1	3/8	3/24	4/19	Mean	306ES	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)		0.62	0.76	0.81	0.70	0.66	0.71	TN (mg/L)		1.40	1.00	0.93	0.81	1.60	1.15
NH3 (mg/L)		0.20	0.34	0.33	0.30	0.28	0.29	NH3 (mg/L)		0.10	0.14	0.16	0.18	0.01	0.12
TKN (mg/L)		0.62	0.74	0.81	0.70	0.66	0.71	TKN (mg/L)		1.40	1.00	0.93	0.81	1.50	1.13
NOx (mg/L)		0.016	0.018	0.016	0.016	0.016	0.016	NOx (mg/L)		0.016	0.017	0.016	0.016	0.070	0.027
*Outlier															

Table 2 (cont.). Dry Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site															
320AD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320AS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	0.60	0.82	0.60	0.74	0.72	1.10	0.76	TN (mg/L)	1.70	1.60	2.20	2.40	2.80	1.70	2.07
NH3 (mg/L)	0.11	0.23	0.12	0.17	0.13	0.53	0.22	NH3 (mg/L)	0.23	0.01	0.51	0.76	1.00	0.08	0.43
TKN (mg/L)	0.58	0.82	0.57	0.72	0.69	1.10	0.75	TKN (mg/L)	1.70	1.60	2.20	2.40	2.80	1.70	2.07
NOx (mg/L)	0.020	0.016	0.027	0.020	0.030	0.019	0.022	NOx (mg/L)	0.016	0.016	0.016	0.019	0.016	0.016	0.017
320BD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320BS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	2.80	3.10	2.90	3.00	2.70	3.00	2.92	TN (mg/L)	2.60	1.90	3.30	3.10	4.00	3.50	3.07
NH3 (mg/L)	0.93	0.94	1.10	1.00	0.87	1.30	1.02	NH3 (mg/L)	0.61	0.17	0.36	0.81	1.30	0.01	0.54
TKN (mg/L)	2.80	3.10	2.80	3.00	2.60	3.00	2.88	TKN (mg/L)	2.60	1.90	3.30	3.10	4.00	3.00	2.98
NOx (mg/L)	0.036	0.018	0.054	0.044	0.056	0.016	0.037	NOx (mg/L)	0.016	0.016	0.016	0.018	0.016	0.450	0.089
320CD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320CS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	2.80	3.40	4.00	3.00	2.70	3.10	3.17	TN (mg/L)	2.60	3.00	2.80	4.10		3.20	3.14
NH3 (mg/L)	0.89	1.20	1.80	1.00	0.93	1.10	1.15	NH3 (mg/L)	0.42	0.22	0.63	1.40		0.02	0.54
TKN (mg/L)	2.80	3.40	4.00	2.90	2.70	3.10	3.15	TKN (mg/L)	2.60	3.00	2.70	4.10		2.90	3.06
NOx (mg/L)	0.016	0.016	0.016	0.018	0.016	0.017	0.017	NOx (mg/L)	0.016	0.016	0.019	0.018		0.280	0.070
320C2D	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320C2S	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)			4.20	3.50	2.90	3.20	3.45	TN (mg/L)			4.20	3.60	4.60	2.10	3.63
NH3 (mg/L)			1.90	1.40	1.10	1.30	1.43	NH3 (mg/L)			1.50	0.99	1.80	0.03	1.08
TKN (mg/L)			4.20	3.50	2.90	3.20	3.45	TKN (mg/L)			4.20	3.60	4.60	2.00	3.60
NOx (mg/L)			0.018	0.018	0.060	0.016	0.03	NOx (mg/L)			0.016	0.023	0.016	0.047	0.026
320DD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320DS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	2.00	2.00	2.40	2.20	2.00	2.00	2.10	TN (mg/L)	4.30	3.80	3.50	3.50	3.40	4.20	3.78
NH3 (mg/L)	0.65	0.81	0.94	0.90	0.86	1.00	0.86	NH3 (mg/L)	1.60	1.50	1.30	1.40	1.20	1.70	1.45
TKN (mg/L)	1.90	1.90	2.20	2.20	1.90	2.00	2.02	TKN (mg/L)	4.30	3.80	3.40	3.50	3.40	4.20	3.77
NOx (mg/L)	0.120	0.093	0.180	0.024	0.110	0.080	0.101	NOx (mg/L)	0.016	0.038	0.094	0.021	0.044	0.016	0.038
320ED	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320ES	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)		8.00	6.80	3.20	6.00	5.10	5.82	TN (mg/L)		22.00	30.00	60.00		11.00	30.75
NH3 (mg/L)		5.60	5.20	1.20	3.40	5.40	4.16	NH3 (mg/L)		16.00	26.00	44.00		4.30	22.58
TKN (mg/L)		8.00	6.70	3.20	6.00	5.10	5.80	TKN (mg/L)		20.00	30.00	60.00		10.00	30.00
NOx (mg/L)		0.016	0.022	0.019	0.024	0.016	0.019	NOx (mg/L)		1.300	0.520	0.110		0.680	0.653
320FD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320FS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)			3.40	3.00	3.40	4.60	3.60	TN (mg/L)							
NH3 (mg/L)			0.05	0.46	1.00	1.60	0.78	NH3 (mg/L)							
TKN (mg/L)			3.40	3.00	3.40	4.60	3.60	TKN (mg/L)							
NOx (mg/L)			0.019	0.021	0.016	0.016	0.018	NOx (mg/L)							

Table 2 (cont.). Dry Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site															
320GD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320GS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)				5.80	6.00	6.20	6.00	TN (mg/L)						5.50	
NH3 (mg/L)				3.70	3.30	4.30	3.77	NH3 (mg/L)						1.80	
TKN (mg/L)				5.70	5.90	6.20	5.93	TKN (mg/L)						5.50	
NOx (mg/L)				0.020	0.016	0.017	0.018	NOx (mg/L)						0.080	
320HD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320HS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)				3.60	5.40	3.70	4.23	TN (mg/L)						12.00	
NH3 (mg/L)				1.90	3.40	2.40	2.57	NH3 (mg/L)						7.80	
TKN (mg/L)				3.60	5.40	3.70	4.23	TKN (mg/L)						12.00	
NOx (mg/L)				0.058	0.053	0.080	0.064	NOx (mg/L)						0.074	
320ID	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320IS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)				7.60	9.00	7.70	8.10	TN (mg/L)						37.00	
NH3 (mg/L)				4.90	6.00	4.60	5.17	NH3 (mg/L)						11.00	
TKN (mg/L)				7.50	8.90	7.70	8.03	TKN (mg/L)						15.00	
NOx (mg/L)				0.08	0.06	0.08	0.075	NOx (mg/L)						22.00	
320JD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	320JS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)						3.40		TN (mg/L)						33.00	
NH3 (mg/L)						2.20		NH3 (mg/L)						29.00	
TKN (mg/L)						3.40		TKN (mg/L)						33.00	
NOx (mg/L)						0.080		NOx (mg/L)						0.016	
*Outlier															

Table 2 (cont.). Dry Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site															
351AD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351AS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.50	1.80	2.80	2.40	3.40	2.60	2.42	TN (mg/L)	2.90	2.50	2.60	2.50	2.10	2.60	2.53
NH3 (mg/L)	0.15	0.38	0.97	0.39	0.17	0.70	0.46	NH3 (mg/L)	0.01	0.01	0.0073	0.04	0.01	0.04	0.02
TKN (mg/L)	1.50	1.80	2.80	2.40	3.40	2.60	2.42	TKN (mg/L)	2.90	2.50	2.60	2.50	2.10	2.60	2.53
NOx (mg/L)	0.016	0.016	0.020	0.017	0.016	0.016	0.017	NOx (mg/L)	0.016	0.016	0.016	0.019	0.016	0.016	0.017
351BD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351BS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	3.50	3.00	3.40	3.90	2.60	4.60	3.50	TN (mg/L)	2.60	2.90	2.50	2.50		3.10	2.72
NH3 (mg/L)	0.49	0.47	0.59	0.69	0.57	0.68	0.58	NH3 (mg/L)	0.01	0.03	0.03	0.03		0.07	0.03
TKN (mg/L)	3.40	3.00	3.40	3.80	2.60	4.60	3.47	TKN (mg/L)	2.60	2.90	2.40	2.50		3.10	2.70
NOx (mg/L)	0.034	0.016	0.037	0.060	0.019	0.080	0.041	NOx (mg/L)	0.016	0.016	0.018	0.018		0.016	0.017
351B2D	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351B2S	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)				2.50	1.90	2.40	2.27	TN (mg/L)				2.50	1.70	3.90	2.70
NH3 (mg/L)				0.39	0.28	0.17	0.28	NH3 (mg/L)				0.02	0.04	0.01	0.02
TKN (mg/L)				2.40	1.80	2.40	2.20	TKN (mg/L)				2.50	1.70	4.00	2.73
NOx (mg/L)				0.120	0.100	0.080	0.100	NOx (mg/L)				0.018	0.016	0.021	0.018
351CD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351CS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)		4.80	4.30			7.60	5.57	TN (mg/L)	2.80	1.60	1.50	3.70	5.70	2.70	3.00
NH3 (mg/L)		1.90	2.50			4.90	3.10	NH3 (mg/L)	0.79	0.13	0.35	1.60	1.80	0.01	0.78
TKN (mg/L)		4.80	4.30			7.60	5.57	TKN (mg/L)	2.80	1.60	1.50	3.70	5.70	2.60	2.98
NOx (mg/L)		0.016	0.020			0.016	0.017	NOx (mg/L)	0.016	0.016	0.016	0.018	0.016	0.140	0.037
351DD	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351DS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	3.60	3.20	3.00	3.60		3.70	3.42	TN (mg/L)	2.70	4.60	3.90		9.40	3.80	4.88
NH3 (mg/L)	1.70	1.50	1.40	1.50		1.90	1.60	NH3 (mg/L)	1.10	2.50	1.80		6.60	1.80	2.76
TKN (mg/L)	3.60	3.20	3.00	3.50		3.70	3.40	TKN (mg/L)	2.70	4.60	3.90		9.40	3.80	4.88
NOx (mg/L)	0.020	0.016	0.020	0.017		0.016	0.018	NOx (mg/L)	0.016	0.016	0.019		0.016	0.016	0.017
351ED	2/19	2/23	3/1	3/8	3/24	4/19	Mean	351ES	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)		3.40	4.40			6.50	4.77	TN (mg/L)		3.40		4.30	5.00	3.10	3.95
NH3 (mg/L)		0.75	1.70			3.00	1.82	NH3 (mg/L)		0.38		1.70	1.30	0.61	1.00
TKN (mg/L)		3.40	4.40			6.50	4.77	TKN (mg/L)		3.40		4.30	5.00	3.10	3.95
NOx (mg/L)		0.016	0.017			0.016	0.016	NOx (mg/L)		0.016		0.018	0.016	0.016	0.017
*Outlier															

Table 2 (cont.). Dry Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site																
373AD	2/19	2/23	3/1	3/8	3/24	4/19	Mean		373AS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.10	1.20	1.30	1.30	1.00	1.00	1.15		TN (mg/L)	1.40	2.00	3.60	2.60	1.30	2.20	2.18
NH3 (mg/L)	0.35	0.28	0.42	0.42	0.41	0.50	0.40		NH3 (mg/L)	0.09	0.12	0.01	0.18	0.34	0.10	0.14
TKN (mg/L)	1.00	1.20	1.20	1.20	0.94	1.00	1.09		TKN (mg/L)	1.40	2.00	3.60	2.50	1.20	2.20	2.15
NOx (mg/L)	0.060	0.042	0.085	0.089	0.062	0.080	0.070		NOx (mg/L)	0.018	0.016	0.027	0.055	0.054	0.016	0.031
373BD	2/19	2/23	3/1	3/8	3/24	4/19	Mean		373BS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.60	1.60	1.70	2.60	0.74	2.30	1.76		TN (mg/L)	6.10	6.60	4.20	5.20	1.10	3.70	4.48
NH3 (mg/L)	0.69	0.70	0.75	0.74	0.22	1.10	0.70		NH3 (mg/L)	2.80	3.60	1.90	1.90	0.21	1.30	1.95
TKN (mg/L)	1.50	1.60	1.60	2.50	0.74	2.30	1.71		TKN (mg/L)	6.10	6.60	4.10	5.10	1.10	3.70	4.45
NOx (mg/L)	0.088	0.067	0.140	0.120	0.016	0.080	0.085		NOx (mg/L)	0.016	0.016	0.042	0.092	0.016	0.017	0.033
373CD	2/19	2/23	3/1	3/8	3/24	4/19	Mean		373CS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.10	2.10	1.90	2.40	0.89	0.89	1.55		TN (mg/L)	3.10	3.40	3.30	3.30	4.00	1.80	3.15
NH3 (mg/L)	0.06	0.01	0.03	0.29	0.10	0.20	0.11		NH3 (mg/L)	0.06	0.14	0.14	0.03	0.0073	0.01	0.07
TKN (mg/L)	0.95	2.10	1.70	2.20	0.89	0.80	1.44		TKN (mg/L)	3.10	3.40	3.30	3.30	4.00	1.50	3.10
NOx (mg/L)	0.110	0.016	0.120	0.180	0.016	0.096	0.090		NOx (mg/L)	0.016	0.016	0.022	0.026	0.016	0.250	0.058
373DD	2/19	2/23	3/1	3/8	3/24	4/19	Mean		373DS	2/19	2/23	3/1	3/8	3/24	4/19	Mean
TN (mg/L)	1.50	0.89	1.50	2.30	1.20	1.50	1.48		TN (mg/L)	2.00	1.50	1.60	2.60	2.10	1.10	1.82
NH3 (mg/L)	0.27	0.11	0.25	0.29	0.49	0.46	0.31		NH3 (mg/L)	0.22	0.13	0.17	0.21	1.10	0.10	0.32
TKN (mg/L)	1.40	0.88	1.40	2.20	1.10	1.50	1.41		TKN (mg/L)	2.00	1.50	1.60	2.60	2.00	1.10	1.80
NOx (mg/L)	0.042	0.018	0.050	0.065	0.070	0.080	0.054		NOx (mg/L)	0.016	0.016	0.019	0.021	0.073	0.016	0.027
*Outlier																

Table 3. Wet Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site									Site							
306AD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		306AS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	3.70	4.40	4.20	4.60			4.23		TN (mg/L)	4.30	4.60	12.00	3.50			6.10
NH3 (mg/L)	2.40	2.90	2.80	2.80	1.80	3.10	2.63		NH3 (mg/L)	2.30	2.80	1.00	1.50	0.02	0.10	1.29
TKN (mg/L)	3.70	4.40	4.20	4.60			4.23		TKN (mg/L)	4.30	4.60	12.00	3.50			6.10
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.047	0.021
306BD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		306BS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.80	1.90	12.00	2.00			4.43		TN (mg/L)	1.40	2.60	5.80	2.80			3.15
NH3 (mg/L)	0.50	0.54	0.46	0.53	0.49	0.66	0.53		NH3 (mg/L)	0.38	0.84	0.66	0.58	0.32	0.84	0.60
TKN (mg/L)	1.80	1.90	12.00	2.00			4.43		TKN (mg/L)	1.40	2.60	5.80	2.80			3.15
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
306CD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		306CS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.30	1.60	1.70	1.50			1.53		TN (mg/L)	1.80	2.10	2.80	2.60			2.33
NH3 (mg/L)	0.32	0.40	0.38	0.34	0.39	0.54	0.40		NH3 (mg/L)	0.57	0.83	0.74	0.98	0.55	1.00	0.78
TKN (mg/L)	1.30	1.60	1.70	1.50			1.53		TKN (mg/L)	1.80	2.10	2.80	2.60			2.33
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
306DD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		306DS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	0.64	0.67	5.90	0.68			1.97		TN (mg/L)	0.36	0.82	5.20	3.00			2.35
NH3 (mg/L)	0.31	0.22	0.19	0.30	0.28	0.30	0.27		NH3 (mg/L)	0.06	0.02	0.01	0.04	0.08	0.01	0.04
TKN (mg/L)	0.64	0.67	5.90	0.68			1.97		TKN (mg/L)	0.36	0.63	5.10	1.10			1.80
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.200	0.100	2*	0.52*	59*	0.105
306ED	7/15	7/18	7/20	7/23	8/2	8/16	Mean		306ES	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	0.79	0.74	1.90	0.78			1.05		TN (mg/L)	0.56	1.20	3.70	21.00			6.62
NH3 (mg/L)	0.44	0.35	0.36	0.30	0.34	0.22	0.34		NH3 (mg/L)	0.17	0.04	0.01	0.02	0.02	0.01	0.04
TKN (mg/L)	0.79	0.74	1.90	0.78			1.05		TKN (mg/L)	0.56	0.80	1.20	1.80			1.09
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.37*	2.5*	20*	10*	24*	0.016
*Outlier																

Table 3 (cont.). Wet Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site									Site							
320AD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320AS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	0.92	1.20	1.10	1.10			1.08		TN (mg/L)	1.80	2.90	3.50	2.70			2.73
NH3 (mg/L)	0.37	0.45	0.48	0.49	0.46	0.30	0.43		NH3 (mg/L)	0.79	0.79	1.60	0.20	0.44	0.04	0.64
TKN (mg/L)	0.92	1.20	1.10	1.10			1.08		TKN (mg/L)	1.80	2.90	3.50	2.70			2.73
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
320BD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320BS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	2.30	3.50	3.30	3.90			3.25		TN (mg/L)	3.20	1.80	2.00	1.40			2.10
NH3 (mg/L)	1.10	1.40	1.50	1.70	1.40	1.30	1.40		NH3 (mg/L)	1.40	0.01	0.15	0.06	0.15	0.18	0.32
TKN (mg/L)	2.30	3.50	3.30	3.90			3.25		TKN (mg/L)	3.20	1.70	1.90	1.40			2.05
NOx (mg/L)	0.030	0.026	0.016	0.016	0.016	0.016	0.020		NOx (mg/L)	0.016	0.130	0.031	0.016	0.016	0.016	0.038
320CD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320CS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	2.10	2.90	2.50	2.90			2.60		TN (mg/L)	3.80	3.70	3.90	3.00			3.60
NH3 (mg/L)	1.00	1.20	1.10	1.40	1.40	1.20	1.22		NH3 (mg/L)	2.50	0.91	1.60	0.22	0.45	0.32	1.00
TKN (mg/L)	2.10	2.90	2.50	2.90			2.60		TKN (mg/L)	3.80	3.70	3.90	3.00			3.60
NOx (mg/L)	0.029	0.016	0.016	0.016	0.016	0.016	0.018		NOx (mg/L)	0.016	0.016	0.016	0.016	0.021	0.028	0.019
320C2D	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320C2S	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	2.10	2.90	2.30	2.90			2.55		TN (mg/L)	3.80	2.20	2.00	2.70			2.68
NH3 (mg/L)	1.10	1.10	1.00	1.30			1.13		NH3 (mg/L)	1.80	0.12	0.22	0.15			0.57
TKN (mg/L)	2.00	2.80	2.30	2.90			2.50		TKN (mg/L)	3.80	2.20	2.00	2.70			2.68
NOx (mg/L)	0.070	0.038	0.018	0.016			0.036		NOx (mg/L)	0.016	0.016	0.016	0.063			0.028
320DD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320DS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.60	2.30	1.90	2.30			2.03		TN (mg/L)	2.50	4.70	3.70	5.80			4.18
NH3 (mg/L)	0.69	0.91	0.76	1.10	0.86	0.66	0.83		NH3 (mg/L)	1.30	2.30	1.70	2.90	2.40	1.70	2.05
TKN (mg/L)	1.50	2.30	1.90	2.30			2.00		TKN (mg/L)	2.40	4.70	3.70	5.80			4.15
NOx (mg/L)	0.039	0.026	0.016	0.016	0.016	0.046	0.027		NOx (mg/L)	0.024	0.016	0.016	0.016	0.016	0.016	0.017
320ED	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320ES	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.00	7.60	1.60	2.90			3.28		TN (mg/L)		1.90		2.40			2.15
NH3 (mg/L)	0.14	4.40	0.34	1.80	3.80	9.00	3.25		NH3 (mg/L)		0.01		0.01	0.01	0.01	0.01
TKN (mg/L)	1.00	7.60	1.60	2.90			3.28		TKN (mg/L)		1.90		2.40			2.15
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)		0.016		0.048	0.300	0.250	0.154
320FD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320FS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	8.50	6.40	7.40	5.00			6.83		TN (mg/L)		2.80	2.50	7.30			4.20
NH3 (mg/L)	7.00	3.60	4.50	2.80	1.60	0.47	3.33		NH3 (mg/L)		0.33	0.01	1.70			0.68
TKN (mg/L)	8.50	6.40	7.40	5.00			6.83		TKN (mg/L)		2.80	2.20	7.30			4.10
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)		0.016	0.290	0.016			0.107

Table 3 (cont.). Wet Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

320GD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320GS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	5.10	7.80	5.40	7.00			6.33		TN (mg/L)		6.40		7.30			6.85
NH3 (mg/L)	4.50	5.50	3.60	4.40	4.90	4.50	4.57		NH3 (mg/L)		2.90		4.30			3.60
TKN (mg/L)	5.10	7.80	5.40	7.00			6.33		TKN (mg/L)		6.40		7.30			6.85
NOx (mg/L)	0.019	0.016	0.016	0.016	0.016	0.016	0.017		NOx (mg/L)		0.016		0.016			0.016
320HD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320HS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	7.70	9.60	8.80	8.20			8.58		TN (mg/L)	10.00	12.00		14.00			12.00
NH3 (mg/L)	6.00	8.00	6.40	5.20			6.40		NH3 (mg/L)	9.40	9.40		9.50			9.43
TKN (mg/L)	7.60	9.60	8.70	8.20			8.53		TKN (mg/L)	10.00	12.00		14.00			12.00
NOx (mg/L)	0.072	0.028	0.076	0.016			0.048		NOx (mg/L)	0.022	0.016		0.016			0.018
320ID	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320IS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	7.20	19.00	11.00	13.00			12.55		TN (mg/L)	1.50	34.00	11.00	14.00			15.13
NH3 (mg/L)	5.80	16.00	8.70	9.70			10.05		NH3 (mg/L)	0.53	26.00	3.20	8.00			9.43
TKN (mg/L)	7.20	19.00	11.00	13.00			12.55		TKN (mg/L)	1.40	34.00	6.10	13.00			13.63
NOx (mg/L)	0.045	0.031	0.048	0.025			0.037		NOx (mg/L)	0.023	0.016	5.100	0.720			1.465
320JD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		320JS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	8.20	3.10	6.60	4.50			5.60		TN (mg/L)	5.60	22.00	5.50	21.00			13.53
NH3 (mg/L)	7.20	1.60	5.40	2.90			4.28		NH3 (mg/L)	4.40	16.00	3.60	14.00			9.50
TKN (mg/L)	8.20	3.00	6.60	4.40			5.55		TKN (mg/L)	5.50	22.00	5.50	21.00			13.50
NOx (mg/L)	0.033	0.019	0.052	0.016			0.030		NOx (mg/L)	0.016	0.020	0.016	0.016			0.017
*Outlier																

Table 3 (cont.). Wet Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site									Site							
351AD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351AS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.60	3.30	1.90	2.10			2.23		TN (mg/L)	1.30	1.90	1.90	4.00			2.28
NH3 (mg/L)	0.47	1.20	0.43	0.26	0.05	0.08	0.42		NH3 (mg/L)	0.02	0.07	0.18	0.18	0.05	0.06	0.09
TKN (mg/L)	1.60	3.30	1.90	2.10			2.23		TKN (mg/L)	1.30	1.90	1.90	4.00			2.28
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
351BD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351BS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.80	2.10	2.30	1.90			2.03		TN (mg/L)	1.40	2.40	2.20	4.10			2.53
NH3 (mg/L)	0.24	0.14	0.19	0.13	0.11	0.13	0.16		NH3 (mg/L)	0.01	0.04	0.01	0.07	0.02	0.05	0.03
TKN (mg/L)	1.80	2.10	2.30	1.90			2.03		TKN (mg/L)	1.40	2.40	2.20	4.10			2.53
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016
351B2D	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351B2S	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.20	1.40	2.00	1.90			1.63		TN (mg/L)	1.40	3.00	2.40	5.80			3.15
NH3 (mg/L)	0.30	0.08	0.15	0.15			0.17		NH3 (mg/L)	0.08	0.03	0.01	0.11			0.06
TKN (mg/L)	1.10	1.40	2.00	1.90			1.60		TKN (mg/L)	1.40	3.00	2.40	5.80			3.15
NOx (mg/L)	0.035	0.016	0.016	0.016			0.021		NOx (mg/L)	0.016	0.016	0.016	0.016			0.016
351CD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351CS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	6.10	5.20	6.70	4.60			5.65		TN (mg/L)		1.80	1.50	4.00			2.43
NH3 (mg/L)	3.90	3.50	3.20	2.20	2.30	0.49	2.60		NH3 (mg/L)		0.04	0.01	0.22	0.02	0.18	0.09
TKN (mg/L)	6.10	5.20	6.70	4.60			5.65		TKN (mg/L)		1.80	1.50	4.00			2.43
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)		0.016	0.016	0.016	0.019	0.016	0.017
351DD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351DS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	4.20	1.90	9.20	2.30			4.40		TN (mg/L)	3.60	2.00		3.40			3.00
NH3 (mg/L)	2.20	0.64	7.20	0.62	2.50	1.90	2.51		NH3 (mg/L)	1.90	0.30		0.55	1.90	2.60	1.45
TKN (mg/L)	4.20	1.90	9.20	2.30			4.40		TKN (mg/L)	3.60	2.00		3.40			3.00
NOx (mg/L)	0.016	0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)	0.016	0.016		0.016	0.016	0.016	0.016
351ED	7/15	7/18	7/20	7/23	8/2	8/16	Mean		351ES	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)		3.80	3.40	3.60			3.60		TN (mg/L)		2.20	3.30	3.00			2.83
NH3 (mg/L)		1.10	0.87	0.58	1.60	0.67	0.96		NH3 (mg/L)		0.12	0.35	0.06	0.46	0.12	0.22
TKN (mg/L)		3.80	3.40	3.60			3.60		TKN (mg/L)		2.20	3.30	3.00			2.83
NOx (mg/L)		0.016	0.016	0.016	0.016	0.016	0.016		NOx (mg/L)		0.016	0.016	0.016	0.016	0.016	0.016
*Outlier																

Table 3 (cont.). Wet Season Groundwater Nitrogen Concentrations (fertilizer application 2/21/14)

Site									Site							
373AD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		373AS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.20	1.20	1.00	1.40			1.20		TN (mg/L)	1.10	1.80	0.98	1.90			1.45
NH3 (mg/L)	0.50	0.48	0.38	0.61	0.44	0.30	0.45		NH3 (mg/L)	0.17	0.02	0.17	0.10	0.08	0.02	0.09
TKN (mg/L)	1.10	1.20	0.95	1.40			1.16		TKN (mg/L)	1.10	1.80	0.94	1.90			1.44
NOx (mg/L)	0.051	0.050	0.073	0.016	0.095	0.025	0.052		NOx (mg/L)	0.016	0.016	0.036	0.016	0.016	0.016	0.019
373BD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		373BS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.40	4.60	2.00	1.70			2.43		TN (mg/L)	3.90	3.60	6.30	2.70			4.13
NH3 (mg/L)	0.78	2.70	0.98	0.85	2.60	0.94	1.48		NH3 (mg/L)	1.60	0.28	3.40	0.17	1.30	5.40	2.03
TKN (mg/L)	1.30	4.00	1.90	1.70			2.23		TKN (mg/L)	3.80	3.60	6.30	2.70			4.10
NOx (mg/L)	0.056	0.064	0.110	0.016	0.016	0.016	0.046		NOx (mg/L)	0.020	0.016	0.016	0.016	0.016	0.016	0.017
373CD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		373CS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	0.97	2.60	0.91	1.10			1.40		TN (mg/L)	1.40	3.30	2.20	4.40			2.83
NH3 (mg/L)	0.34	0.01	0.29	0.29	0.25	0.16	0.22		NH3 (mg/L)	0.12	0.01	0.01	0.10	0.10	0.21	0.09
TKN (mg/L)	0.90	2.60	0.85	1.10			1.36		TKN (mg/L)	1.40	2.90	2.20	3.80			2.58
NOx (mg/L)	0.066	0.023	0.053	0.016	0.016	0.016	0.032		NOx (mg/L)	0.016	0.380	0.026	0.610	0.016	0.016	0.177
373DD	7/15	7/18	7/20	7/23	8/2	8/16	Mean		373DS	7/15	7/18	7/20	7/23	8/2	8/16	Mean
TN (mg/L)	1.10	3.70	1.10	1.20			1.78		TN (mg/L)	1.40	3.30	1.20	2.40			2.08
NH3 (mg/L)	0.46	0.26	0.45	0.53	0.45	0.43	0.43		NH3 (mg/L)	0.38	0.06	0.21	0.10	0.17	0.16	0.18
TKN (mg/L)	1.00	3.70	1.00	1.20			1.73		TKN (mg/L)	1.20	3.30	1.20	2.40			2.03
NOx (mg/L)	0.063	0.023	0.072	0.016	0.016	0.016	0.034		NOx (mg/L)	0.018	0.016	0.016	0.016	0.016	0.016	0.016
*Outlier																

Table 4. Dry Season Deep and Shallow Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.34	2.18	3.15	2.80	2.24
23-Feb-14	1.13	2.30	8.95	3.12	2.41
1-Mar-14	1.53	3.03	9.22	3.16	2.39
8-Mar-14	1.51	2.93	11.11	3.10	2.79
24-Mar-14	1.44	2.92	5.03	3.98	1.60
19-Apr-14	1.98	2.61	10.42	3.88	1.81
All dates*	1.52	2.76	8.95	3.45	2.20
Ammonia					
	306	320 A-C	320 D-J	351	373
19-Feb-14	0.34	0.53	1.13	0.61	0.57
23-Feb-14	0.23	0.46	5.98	0.81	0.64
1-Mar-14	0.49	0.99	6.70	1.17	0.46
8-Mar-14	0.45	0.94	7.31	0.71	0.51
24-Mar-14	0.41	1.02	2.74	1.35	0.49
19-Apr-14	0.47	0.55	5.93	1.16	0.47
All dates*	0.41	0.79	5.73	1.04	0.51
TKN					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.33	2.18	3.10	2.79	2.18
23-Feb-14	1.13	2.30	8.43	3.12	2.41
1-Mar-14	1.52	3.00	9.14	3.14	2.31
8-Mar-14	1.51	2.92	11.09	3.07	2.70
24-Mar-14	1.44	2.90	4.99	3.96	1.55
19-Apr-14	1.70	2.50	8.65	3.88	1.76
All dates*	1.46	2.72	8.46	3.44	2.15
NOx					
	306**	320 A-C	320 D-J	351	373
19-Feb-14	0.016	0.020	0.068	0.019	0.046
23-Feb-14	0.016	0.016	0.362	0.016	0.026
1-Mar-14	0.023	0.023	0.167	0.020	0.063
8-Mar-14	0.016	0.022	0.045	0.034	0.081
24-Mar-14	0.016	0.030	0.046	0.027	0.054
19-Apr-14	0.022	0.108	1.787	0.037	0.079
All dates*	0.019	0.040	0.481	0.027	0.061

*All dates post fertilization

**Outliers removed

Table 5. Dry Season Deep Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.37	2.07	2.00	2.87	1.33
23-Feb-14	1.18	2.44	5.00	3.24	1.45
1-Mar-14	1.37	2.93	4.20	3.58	1.60
8-Mar-14	1.44	2.56	4.23	3.10	2.15
24-Mar-14	1.35	2.26	5.30	2.63	1.27
19-Apr-14	1.71	2.60	4.67	4.57	1.42
All dates*	1.41	2.56	4.68	3.42	1.58
Ammonia					
	306	320 A-C	320 D-J	351	373
19-Feb-14	0.49	0.64	0.65	0.78	0.34
23-Feb-14	0.37	0.79	3.21	1.00	0.27
1-Mar-14	0.55	1.23	2.06	1.43	0.36
8-Mar-14	0.45	0.89	2.18	0.74	0.44
24-Mar-14	0.43	0.76	2.99	0.34	0.50
19-Apr-14	0.69	1.06	3.07	1.89	0.57
All dates*	0.50	0.95	2.70	1.08	0.43
TKN					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.37	2.06	1.90	2.83	1.21
23-Feb-14	1.18	2.44	4.95	3.24	1.45
1-Mar-14	1.37	2.89	4.10	3.58	1.48
8-Mar-14	1.44	2.53	4.20	3.03	2.03
24-Mar-14	1.35	2.22	5.25	2.60	1.21
19-Apr-14	1.71	2.60	4.67	4.57	1.40
All dates*	1.41	2.54	4.63	3.40	1.51
NOx					
	306	320 A-C**	320 D-J	351	373
19-Feb-14	0.016	0.024	0.120	0.023	0.075
23-Feb-14	0.016	0.017	0.055	0.016	0.036
1-Mar-14	0.017	0.029	0.074	0.023	0.099
8-Mar-14	0.016	0.025	0.038	0.054	0.114
24-Mar-14	0.016	0.041	0.047	0.045	0.057
19-Apr-14	0.016	0.017	0.053	0.037	0.084
All dates*	0.016	0.026	0.053	0.035	0.078

*All date post fertilization

**Outliers removed

Table 6. Dry Season Shallow Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.30	2.30	4.30	2.75	3.15
23-Feb-14	1.07	2.17	12.90	3.00	3.38
1-Mar-14	1.68	3.13	16.75	2.63	3.18
8-Mar-14	1.57	3.30	31.75	3.10	3.43
24-Mar-14	1.53	3.80	3.40	4.78	1.94
19-Apr-14	2.24	2.63	21.30	3.20	2.20
All dates*	1.62	3.00	17.22	3.34	2.82
Ammonia					
	306	320 A-C	320 D-J	351	373
19-Feb-14	0.20	0.42	1.60	0.48	0.79
23-Feb-14	0.08	0.13	8.75	0.61	1.00
1-Mar-14	0.42	0.75	13.65	0.73	0.74
8-Mar-14	0.45	0.99	22.70	0.68	0.58
24-Mar-14	0.39	1.37	1.20	1.95	0.47
19-Apr-14	0.24	0.03	11.50	0.42	0.38
All dates*	0.32	0.65	11.56	0.88	0.63
TKN					
	306	320 A-C	320 D-J	351	373
19-Feb-14	1.30	2.30	4.30	2.75	3.15
23-Feb-14	1.07	2.17	11.90	3.00	3.38
1-Mar-14	1.66	3.10	16.70	2.60	3.15
8-Mar-14	1.57	3.30	31.75	3.10	3.38
24-Mar-14	1.53	3.80	3.40	4.78	1.88
19-Apr-14	1.68	2.40	15.55	3.20	2.13
All dates*	1.50	2.95	15.86	3.34	2.78
NOx					
	306	320 A-C	320 D-J	351	373
19-Feb-14	0.017	0.016	0.016	0.016	0.017
23-Feb-14	0.016	0.016	0.669	0.016	0.016
1-Mar-14	0.029	0.017	0.307	0.017	0.028
8-Mar-14	0.016	0.020	0.066	0.018	0.049
24-Mar-14	0.016	0.016	0.044	0.016	0.052
19-Apr-14	0.564	0.198	5.678	0.038	0.075
All dates*	0.128	0.053	1.353	0.021	0.044

*All date post fertilization

**Outliers removed

Table 7. Wet Season Deep and Shallow Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.67	2.50	5.35	2.51	1.56
18-Jul-14	2.06	2.64	9.97	2.58	3.01
20-Jul-14	5.52	2.58	5.95	3.35	1.96
23-Jul-14	4.25	2.58	8.19	3.39	2.10
3-Aug-14					
16-Aug-14					
All dates*	3.94	2.60	8.04	3.11	2.36
Ammonia					
	306	320 A-C	320 D-J	351	373
15-Jul-14	0.74	1.26	4.27	1.01	0.54
18-Jul-14	0.89	0.75	6.92	0.60	0.48
20-Jul-14	0.66	0.96	3.47	1.14	0.74
23-Jul-14	0.74	0.69	4.88	0.43	0.34
3-Aug-14	0.43	0.72	2.26	0.90	0.67
16-Aug-14	0.68	0.56	2.72	0.63	0.95
All dates*	0.68	0.73	4.05	0.74	0.64
TKN					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.67	2.49	5.31	2.50	1.48
18-Jul-14	2.00	2.61	9.96	2.58	2.89
20-Jul-14	5.26	2.56	5.46	3.35	1.92
23-Jul-14	2.14	2.58	8.11	3.39	2.03
3-Aug-14					
16-Aug-14					
All dates*	3.13	2.58	7.85	3.11	2.28
NOx					
	306**	320 A-C	320D-J	351	373
15-Jul-14	0.016	0.026	0.030	0.018	0.038
18-Jul-14	0.036	0.034	0.019	0.016	0.074
20-Jul-14	0.025	0.018	0.515	0.016	0.050
23-Jul-14	0.016	0.022	0.069	0.016	0.090
3-Aug-14	0.016	0.017	0.040	0.016	0.026
16-Aug-14	0.020	0.018	0.039	0.016	0.017
All dates*	0.023	0.022	0.136	0.016	0.051

*All dates post fertilization

**Outliers removed

Table 8. Wet Season Deep Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.65	1.86	5.61	2.98	1.17
18-Jul-14	1.86	2.63	7.97	2.95	3.03
20-Jul-14	5.14	2.30	6.10	4.25	1.25
23-Jul-14	1.91	2.70	6.13	2.73	1.35
3-Aug-14					
16-Aug-14					
All dates*	2.97	2.54	6.73	3.31	1.88
Ammonia					
48	306	320 A-C	320 D-J	351	373
15-Jul-14	0.79	0.89	4.48	1.42	0.52
18-Jul-14	0.88	1.04	5.72	1.11	0.86
20-Jul-14	0.84	1.02	4.24	2.01	0.53
23-Jul-14	0.85	1.22	3.99	0.66	0.57
3-Aug-14	0.66	1.09	2.79	1.31	0.94
16-Aug-14	0.96	0.93	3.66	0.65	0.46
All dates*	0.84	1.06	4.08	1.15	0.67
TKN					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.65	1.83	5.59	2.96	1.08
18-Jul-14	1.86	2.60	7.96	2.95	2.88
20-Jul-14	5.14	2.30	6.09	4.25	1.18
23-Jul-14	1.91	2.70	6.11	2.73	1.35
3-Aug-14					
16-Aug-14					
All dates*	2.97	2.53	6.72	3.31	1.80
NOx					
	306**	320 A-C	320 D-J	351	373
15-Jul-14	0.016	0.036	0.034	0.020	0.059
18-Jul-14	0.016	0.024	0.022	0.016	0.040
20-Jul-14	0.016	0.017	0.034	0.016	0.077
23-Jul-14	0.016	0.016	0.017	0.016	0.016
3-Aug-14	0.016	0.016	0.016	0.016	0.036
16-Aug-14	0.016	0.016	0.024	0.016	0.018
All dates*	0.016	0.018	0.023	0.016	0.037

*All date post fertilization

**Outliers removed

Table 9. Wet Season Deep Summary Data

Total Nitrogen					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.68	3.15	4.90	1.93	1.95
18-Jul-14	2.26	2.65	11.97	2.22	3.00
20-Jul-14	5.90	2.85	5.68	2.26	2.67
23-Jul-14	6.58	2.45	10.26	4.05	2.85
3-Aug-14					
16-Aug-14					
All dates*	4.91	2.65	9.30	2.84	2.84
Ammonia					
	306	320 A-C	320 D-J	351	373
15-Jul-14	0.70	1.62	3.91	0.50	0.57
18-Jul-14	0.90	0.46	8.13	0.10	0.09
20-Jul-14	0.48	0.89	2.13	0.11	0.95
23-Jul-14	0.62	0.16	5.77	0.20	0.12
3-Aug-14	0.20	0.35	1.20	0.49	0.41
16-Aug-14	0.39	0.18	0.85	0.60	1.45
All dates*	0.52	0.41	3.62	0.30	0.60
TKN					
	306	320 A-C	320 D-J	351	373
15-Jul-14	1.68	3.15	4.83	1.93	1.88
18-Jul-14	2.15	2.63	11.97	2.22	2.90
20-Jul-14	5.38	2.83	4.38	2.26	2.66
23-Jul-14	2.36	2.45	10.11	4.05	2.70
3-Aug-14					
16-Aug-14					
All dates*	3.30	2.63	8.82	2.84	2.75
NOX					
	306	320 A-C	320 D-J	351	373
15-Jul-14	0.016	0.016	0.021	0.016	0.018
18-Jul-14	0.124	0.045	0.017	0.016	0.107
20-Jul-14	0.530	0.020	1.356	0.016	0.024
23-Jul-14	4.410	0.028	0.121	0.016	0.165
3-Aug-14	2.114	0.018	0.158	0.017	0.016
16-Aug-14	16.616	0.020	0.133	0.016	0.016
All dates*	4.758	0.026	0.357	0.016	0.065

*All date post fertilization

**Outilers removed

Table 10. Surface Water Nitrogen Concentrations, Dry Season Sampling

SW	2/19/2014	2/23/2014	3/1/2014	3/8/2014	3/24/2014	4/19/2014	Mean	SD
TN (mg/L)	0.38	0.75	0.71	0.45	0.33	0.98	0.64	0.25
NH3 (mg/L)	0.01	0.01	0.01	0.01	0.010I	0.01	0.01	0.00
TKN (mg/L)	0.38	0.75	0.71	0.45	0.31	0.98	0.64	0.26
NOx (mg/L)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00
320 SW1	2/19/2014	2/23/2014	3/1/2014	3/8/2014	3/24/2014	4/19/2014	Mean	SD
TN (mg/L)				2.30	1.80	2.60	2.23	0.40
NH3 (mg/L)				1.20	0.24	0.84	0.76	0.48
TKN (mg/L)				2.30	1.80	2.00	2.03	0.25
NOx (mg/L)				0.02	0.02	0.59	0.21	0.33
320 SW2	2/19/2014	2/23/2014	3/1/2014	3/8/2014	3/24/2014	4/19/2014	Mean	SD
TN (mg/L)						3.20	3.20	
NH3 (mg/L)						0.86	0.86	
TKN (mg/L)						3.10	3.10	
NOx (mg/L)						0.12	0.12	

Table 11. Surface Water Nitrogen Concentrations, Wet Season Sampling

SW	7/15/2014	7/18/2014	7/20/2014	7/23/2014	8/3/2014	8/16/2014	Mean	SD
TN (mg/L)	0.92	2.20	0.54	0.92			1.22	0.71
NH3 (mg/L)	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01
TKN (mg/L)	0.90	2.20	0.54	0.92			1.22	0.71
NOx (mg/L)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.00
320 SW1	7/15/2014	7/18/2014	7/20/2014	7/23/2014	8/3/2014	8/16/2014	Mean	SD
TN (mg/L)	4.20	2.40	1.70	2.90			2.33	0.49
NH3 (mg/L)	2.70	1.00	0.54	0.77	0.57	0.35	0.65	0.22
TKN (mg/L)	4.20	2.40	1.70	2.90			2.33	0.49
NOx (mg/L)	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.00
320 SW2	7/15/2014	7/18/2014	7/20/2014	7/23/2014	8/3/2014	8/16/2014	Mean	SD
TN (mg/L)	3.80	11.00	2.90	4.20			6.03	3.55
NH3 (mg/L)	0.24	0.91	0.58	1.80	0.72	0.27	0.86	0.52
TKN (mg/L)	3.50	11.00	2.80	4.20			6.00	3.58
NOx (mg/L)	0.30	0.04	0.05	0.02	0.02	0.02	0.03	0.01

Table 12. Dry Season Relative Water Levels, Hydraulic Gradients and Dissolved Oxygen

2/6/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.23	*	0.003	*
2	10.34	*		
3	10.22	*		
4	9.8	*		
5	9.36	*		
6	9.15	*		
7	8.07	*		

2/19/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.17	*	0.003	0.06
2	10.25	*		
3	10.11	*		
4	9.56	*		
5	9.08	*		
6	8.93	*		
7	8.03	*		

2/23/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.23	*	0.003	0.07
2	10.3	*		
3	10.12	*		
4	9.78	*		
5	9.26	*		
6	9.02	*		
7	7.95	*		

3/1/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.97	*	0.003	0.23
2	9.86	*		
3	10.21	*		
4	9.42	*		
5	8.81	*		
6	8.67	*		
7	7.69	*		

*Missing Data

3/8/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.81	*	0.003	0.05
2	9.87	*		
3	9.9	*		
4	9.1	*		
5	8.5	*		
6	8.38	*		
7	7.5	*		

3/23/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.22	*	0.003	0.07
2	10.3	*		
3	10.12	*		
4	9.78	*		
5	9.26	*		
6	9.02	*		
7	7.95	*		

3/24/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.46	*	0.003	0.12
2	9.64	*		
3	9.69	*		
4	8.88	*		
5	8.24	*		
6	8.04	*		
7	7.76	*		

4/19/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.35	0.14	0.004	0.07
2	10.9	0.04		
3	10.63	0.03		
4	9.97	0.01		
5	9.76	0.01		
6	9.36	*		
7	7.76	*		

Table 12. Dry Season Relative Water Levels, Hydraulic Gradients and Dissolved Oxygen

7/15/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.04	*	0.003	0.09
2	9.13	*		
3	9.54	*		
4	8.96	*		
5	8.37	*		
6	8.21	*		
7	7.05	*		

7/18/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.73	*	0.003	*
2	10.1	*		
3	10.08	*		
4	9.8	*		
5	9.39	*		
6	9.05	*		
7	7.81	*		

7/20/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.7	*	0.003	0.25
2	10.09	*		
3	9.22	*		
4	9.7	*		
5	9.22	*		
6	8.95	*		
7	7.82	*		

*Missing Data

7/23/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	10.7	0.27	0.003	0.25
2	10.51	0.13		
3	10.41	0.11		
4	10.05	0.1		
5	9.66	0.14		
6	9.31	*		
7	8.07	*		

8/3/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.19	0.15	0.003	0.36
2	11.02	0.15		
3	10.2	0.13		
4	9.96	0.1		
5	9.61	0.19		
6	9.22	*		
7	8.23	*		

8/16/2014				
Pz ID	Rel.Depth (ft)	DO (mg/L)	H_h	H_v
1	11.73	0.27	0.003	0.15
2	10.8	0.31		
3	10.57	0.09		
4	10.08	0.11		
5	9.8	0.12		
6	9.39	*		
7	8.81	*		

Table 14. Dry Season Precipitation

Date	Precipitation (cm)	Date	Precipitation (cm)	Date	Precipitation (cm)
15-Dec	0	26-Jan	0.2	11-Mar	0
16-Dec	0	27-Jan	0	12-Mar	0.2
17-Dec	0.6	28-Jan	0	13-Mar	0
18-Dec	0	29-Jan	0	14-Mar	0
19-Dec	0	30-Jan	2	15-Mar	0
20-Dec	0	31-Jan	2	16-Mar	0.2
21-Dec	0	1-Feb	0	17-Mar	0
22-Dec	0	2-Feb	0	18-Mar	1.2
23-Dec	0	3-Feb	0	19-Mar	0
24-Dec	0	4-Feb	0.8	20-Mar	0
25-Dec	0	5-Feb	0	21-Mar	0
26-Dec	0	6-Feb	0	22-Mar	0
27-Dec	0	7-Feb	0	23-Mar	0
28-Dec	0	8-Feb	0.1	24-Mar	1.0
29-Dec	0.4	9-Feb	0	25-Mar	1.2
30-Dec	0	10-Feb	0.2	26-Mar	0
31-Dec	0	11-Feb	0	27-Mar	0.03
1-Jan	0.2	12-Feb	0	28-Mar	0
2-Jan	0	13-Feb	7	29-Mar	2.11
3-Jan	0	14-Feb	0.2	30-Mar	0
4-Jan	0.8	15-Feb	0	31-Mar	0
5-Jan	0	16-Feb	0	1-Apr	0
6-Jan	0	17-Feb	0	2-Apr	0
7-Jan	0	18-Feb	0	3-Apr	0
8-Jan	0	19-Feb	0	4-Apr	0
9-Jan	>12.5	20-Feb	0	5-Apr	0
10-Jan	0	21-Feb	0.8	6-Apr	0
11-Jan	0	22-Feb	0	7-Apr	0
12-Jan	0	23-Feb	0.4	8-Apr	0.51
13-Jan	0	24-Feb	0	9-Apr	0
14-Jan	0	25-Feb	0.2	10-Apr	0
15-Jan	0	26-Feb	0	11-Apr	0.25
16-Jan	0	27-Feb	0	12-Apr	0
17-Jan	0	28-Feb	0.2	13-Apr	0
18-Jan	0.2	3-Mar	0.4	14-Apr	0
19-Jan	0	4-Mar	0	15-Apr	0.41
20-Jan	0	5-Mar	0	16-Apr	0
21-Jan	0	6-Mar	0	17-Apr	0.03
22-Jan	0	7-Mar	0.2	18-Apr	3.02
23-Jan	0.4	8-Mar	0	19-Apr	1.96
24-Jan	0	9-Mar	0		
25-Jan	0	10-Mar	0		

Note: Data for 3/24/15-4/19/15 from Ntl. Weather Service, Ft. Pierce Airport

Table 15 Wet Season Precipitation

Date	Precipitation (cm)		Date	Precipitation (cm)
1-Jun	1		13-Jul	0.4
2-Jun	2		14-Jul	0
3-Jun	0		15-Jul	1.4
4-Jun	0		16-Jul	3.5
5-Jun	0		17-Jul	0.4
6-Jun	0		18-Jul	0.2
7-Jun	0		19-Jul	1
8-Jun	1.6		20-Jul	0
9-Jun	0		21-Jul	0.4
10-Jun	0		22-Jul	0
11-Jun	0		23-Jul	2.8
12-Jun	3.8		24-Jul	0
13-Jun	2.6		25-Jul	0.2
14-Jun	0.6		26-Jul	1.6
15-Jun	3.6		27-Jul	0.2
16-Jun	0		28-Jul	0
17-Jun	0		29-Jul	0.2
18-Jun	0.6		30-Jul	0
19-Jun	0.4		31-Jul	7.6
20-Jun	0.4		1-Aug	1.8
21-Jun	1.8		2-Aug	0.4
22-Jun	0		3-Aug	0.2
23-Jun	0		4-Aug	1.2
24-Jun	0		5-Aug	0.6
25-Jun	0		6-Aug	0.6
26-Jun	0.2		7-Aug	2.2
27-Jun	0		8-Aug	0.8
28-Jun	0		9-Aug	0.4
29-Jun	0		10-Aug	0
30-Jun	2.2		11-Aug	0.4
1-Jul	0		12-Aug	1.4
2-Jul	1.2		13-Aug	1.2
3-Jul	0		14-Aug	0
4-Jul	0		15-Aug	1.6
5-Jul	0.4		16-Aug	5.2
6-Jul	0.4			
7-Jul	0.2			
8-Jul	0.4			
9-Jul	0.6			
10-Jul	0.2			
11-Jul	0.4			
12-Jul	0			

Table 16. Dry Season Specific Conductance and pH

2/19/2014								
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
306	AD	447	6.88		320	AD	423	6.62
306	AS	793	6.74		320	AS	915	6.42
306	BD	625	6.63		320	BD	824	6.68
306	BS	556	6.55		320	BS	1097	6.68
306	CD	595	6.67		320	CD	717	6.96
306	CS	596	6.72		320	CS	454	7.08
306	DD	353	6.53		320	DD	560	6.37
306	DS	510	6.84		320	DS	593	6.43
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
351	AD	1143	6.39		373	AD	598	6.24
351	AS	1654	6.72		373	AS	628	6.00
351	BD	1743	6.55		373	BD	787	6.27
351	BS	1917	6.61		373	BS	854	6.12
351	CD	*	*		373	CD	801	6.27
351	CS	938	7.02		373	CS	653	6.35
351	DD	688	6.51		373	DD	719	6.11
351	DS	775	6.45		373	DS	848	6.25

*Missing Data

Table 16 (cont.). Dry Season Specific Conductance and pH

2/23/2014								
Site	**Location**	**Specific Conductance (µS/m)**	**pH**		**Site**	**Location**	**Specific Conductance (µS/m)**	**pH**
306	AD	325	5.61		**320**	AD	458	5.94
306	AS	755	6.08		**320**	AS	826	6.2
306	BD	575	5.92		**320**	BD	922	6.65
306	BS	569	5.94		**320**	BS	982	7.03
306	CD	600	6.09		**320**	CD	709	6.88
306	CS	603	6.06		**320**	CS	327	7.15
306	DD	369	6.19		**320**	DD	554	6.19
306	DS	494	6.32		**320**	DS	613	6.12
306	ED	368	6.29		**320**	ED	333	6.39
306	ES	320	6.28		**320**	ES	3771	6.48
306	ESD	*	*		**320**	ESD	3273	6.56
Site	**Location**	**Specific Conductance (µS/m)**	**pH**		**Site**	**Location**	**Specific Conductance (µS/m)**	**pH**
351	AD	1033	7.85		**373**	AD	587	6.04
351	AS	1640	8.35		**373**	AS	954	6.15
351	BD	1823	8.35		**373**	BD	744	6.55
351	BS	1809	8.53		**373**	BS	878	6.56
351	CD	870	7.59		**373**	CD	517	6.09
351	CS	1064	7.66		**373**	CS	560	6.37
351	DD	687	6.57		**373**	DD	775	5.88
351	DS	863	6.99		**373**	DS	697	5.91
351	ED	1161	7.75		**373**	DSD	*	*
351	ES	1338	8.16					

*Missing Data

Table 16 (cont.). Dry Season Specific Conductance and pH

3/1/2014								
Site	**Location**	**Specific Conductance (µS/m)**	**pH**		**Site**	**Location**	**Specific Conductance (µS/m)**	**pH**
306	AD	406	6.27		**320**	AD	437	6.58
306	AS	579	6.29		**320**	AS	805	6.56
306	BD	658	6.51		**320**	BD	810	6.72
306	BS	647	6.51		**320**	BS	1163	6.98
306	CD	617	6.80		**320**	CD	731	6.98
306	CS	631	6.73		**320**	CS	542	7.26
306	DD	377	6.70		**320**	C2D	771	6.86
306	DS	540	6.79		**320**	C2S	660	7.93
306	ED	371	7.02		**320**	DD	589	6.54
306	ES	362	6.81		**320**	DS	693	6.61
					320	ED	2828	6.55
					320	ES	5460	6.70
					320	FD	1298	7.25
Site	**Location**	**Specific Conductance (µS/m)**	**pH**		**Site**	**Location**	**Specific Conductance (µS/m)**	**pH**
351	AD	1189	6.50		**373**	AD	605	6.32
351	AS	1714	6.68		**373**	AS	625	6.13
351	BD	1758	6.54		**373**	BD	629	6.42
351	BS	2007	6.62		**373**	BS	718	6.33
351	CD	918	6.81		**373**	CD	557	6.40
351	CS	1018	7.09		**373**	CS	629	6.56
351	DD	675	6.74		**373**	DD	710	6.27
351	DS	726	6.33		**373**	DS	899	6.29
351	ED	1017	6.42					
351	ES	*	*					

*Missing Data

Table 16 (cont.). Dry Season Specific Conductance and pH

3/8/2014							
Site	Location	Specific Conductance (µS/m)	pH	Site	Location	Specific Conductance (µS/m)	pH
306	AD	629	6.16	**320**	AD	392	6.40
306	AS	623	6.19	**320**	AS	465	6.33
306	BD	629	6.50	**320**	BD	836	6.48
306	BS	628	6.41	**320**	BS	1060	6.69
306	CD	548	6.59	**320**	CD	776	6.80
306	CS	594	6.68	**320**	CS	679	6.84
306	DD	326	6.69	**320**	C2D	745	6.84
306	DS	487	6.73	**320**	C2S	583	7.08
306	ED	342	6.66	**320**	DD	535	6.51
306	ES	399	6.73	**320**	DS	658	6.51
				320	ED	852	6.48
				320	ES	4709	6.82
				320	FD	900	7.01
				320	FS	*	*
				320	GD	486	6.49
				320	GS	*	*
				320	HD	405	6.76
				320	HS	*	*
				320	ID	1235	6.77
				320	IS	*	*
				320	SW1	440	7.14
Site	Location	Specific Conductance (µS/m)	pH	Site	Location	Specific Conductance (µS/m)	pH
351	AD	1149	6.57	**373**	AD	529	6.36
351	AS	1154	6.57	**373**	AS	515	6.12
351	BD	1484	6.41	**373**	BD	597	6.36
351	BS	1139	6.53	**373**	BS	656	6.08
351	B2D	1436	6.30	**373**	CD	616	6.23
351	B2S	1745	6.61	**373**	CS	547	6.21
351	CD	957	6.79	**373**	DD	621	6.22
351	CS	*	*	**373**	DS	683	6.25
351	DD	545	6.38				
351	DS	*	*				
351	ED	864	6.53				
351	ES	*	*				

*Missing Data

Table 16 (cont.). Dry Season Specific Conductance and pH

3/24/2014

Site	Location	Specific Conductance (µS/m)	pH	Site	Location	Specific Conductance (µS/m)	pH
306	AD	342	6.41	**320**	AD	434	6.58
306	AS	481	6.29	**320**	AS	509	6.34
306	BD	682	6.40	**320**	BD	825	6.43
306	BS	670	6.47	**320**	BS	1006	6.60
306	CD	653	6.61	**320**	CD	820	6.81
306	CS	654	6.65	**320**	CS	8	*
306	DD	380	6.63	**320**	C2D	785	6.70
306	DS	466	6.51	**320**	C2S	863	6.66
306	ED	419	6.68	**320**	DD	456	6.57
306	ES	459	6.69	**320**	DS	645	6.46
				320	ED	914	6.59
				320	ES	*	*
				320	FD	2616	6.63
				320	FS	*	*
				320	GD	594	6.45
				320	GS	*	*
				320	HD	812	6.61
				320	HS	*	*
				320	ID	1326	6.90
				320	IS	*	*
				320	SW1	386	6.79

Site	Location	Specific Conductance (µS/m)	pH	Site	Location	Specific Conductance (µS/m)	pH
351	AD	1082	6.39	**373**	AD	678	6.51
351	AS	1593	6.53	**373**	AS	654	6.15
351	BD	1740	6.48	**373**	BD	775	6.24
351	BS	*	*	**373**	BS	788	6.22
351	B2D	1175	6.25	**373**	CD	744	6.22
351	B2S	1538	6.40	**373**	CS	750	6.29
351	CD	1571	6.72	**373**	DD	835	6.38
351	CS	*	*	**373**	DS	962	6.10
351	DD	1119	6.83	**373**	ED	1890	6.35
351	DS	*	*	**373**	ES	1168	6.42
351	ED	1049	6.80				
351	ES	*	*				

*Missing Data

Table 16 (cont.). Dry Season Specific Conductance and pH

4/19/2014								
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
306	AD	560	6.40		**320**	AD	464	6.46
306	AS	448	6.44		**320**	AS	894	6.40
306	BD	681	6.56		**320**	BD	850	6.49
306	BS	799	6.48		**320**	BS	666	6.65
306	CD	645	6.63		**320**	CD	842	6.78
306	CS	842	6.64		**320**	CS	414	6.78
306	DD	364	6.87		**320**	C2D	842	6.50
306	DS	510	6.78		**320**	C2S	637	6.67
306	ED	428	6.80		**320**	DD	421	6.71
306	ES	410	6.81		**320**	DS	625	6.56
					320	ED	286	6.64
					320	ES	4997	6.60
					320	FD	1414	6.83
					320	FS	*	*
					320	GD	630	6.99
					320	GS	930	6.67
					320	HD	536	6.97
					320	HS	4943	6.53
					320	ID	1437	7.04
					320	IS	5535	6.61
					320	JD	391	7.72
					320	JS	6627	6.47
					320	SW1		
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
351	AD	1126	6.75		**373**	AD	679	6.62
351	AS	1733	6.59		**373**	AS	992	6.38
351	BD	1629	6.75		**373**	BD	892	6.33
351	BS	1076	6.75		**373**	BS	839	6.33
351	B2D	1282	6.59		**373**	CD	854	6.37
351	B2S	2336	6.50		**373**	CS	802	6.40
351	CD	1660	6.87		**373**	DD	706	6.39
351	CS	2373	6.68		**373**	DS	842	6.27
351	DD	693	7.20					
351	DS	778	6.55					
351	ED	1175	6.50					
351	ES	1194	6.46					

*Missing Data

Table 17. Wet Season Specific Conductance and pH

7/15/2014								
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
306	AD	*	*		**320**	AD	468	6.41
306	AS	*	*		**320**	AS	502	6.44
306	BD	727	6.74		**320**	BD	771	6.26
306	BS	663	6.38		**320**	BS	873	6.37
306	CD	639	6.32		**320**	CD	744	6.53
306	CS	613	6.44		**320**	CS	893	6.47
306	DD	352	6.56		**320**	C2D	810	6.45
306	DS	408	6.48		**320**	C2S	837	6.47
306	ED	316	6.55		**320**	DD	463	6.54
306	ES	317	6.60		**320**	DS	509	6.44
					320	ED	757	6.10
					320	ES	*	*
					320	FD	2492	6.49
					320	FS	*	*
					320	GD	842	6.57
					320	GS	*	*
					320	HD	1841	6.72
					320	HS	5249	6.70
					320	ID	3322	6.82
					320	IS	5894	6.66
					320	JD	928	6.67
					320	JS	1213	6.51
					320	SW1	1000	6.93
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
351	AD	1156	6.46		**373**	AD	736	6.26
351	AS	1555	6.41		**373**	AS	666	5.78
351	BD	1513	6.38		**373**	BD	803	6.26
351	BS	1522	6.38		**373**	BS	1121	6.14
351	B2D	1133	6.28		**373**	CD	882	6.01
351	B2S	1796	6.41		**373**	CS	925	*
351	CD	1392	6.55		**373**	DD	733	5.99
351	CS	*	*		**373**	DS	770	5.90
351	DD	750	6.59					
351	DS	768	6.50					
351	ED	*	*					
351	ES	*	*					

*Missing Data

Table 17 (cont.). Wet Season Specific Conductance and pH

7/18/2014								
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
306	AD	358	6.11		**320**	AD	514	6.19
306	AS	517	5.78		**320**	AS	960	6.08
306	BD	723	5.91		**320**	BD	804	6.22
306	BS	730	5.95		**320**	BS	697	6.37
306	CD	619	6.07		**320**	CD	938	6.44
306	CS	661	6.10		**320**	CS	997	6.46
306	DD	368	6.32		**320**	C2D	804	6.32
306	DS	487	6.32		**320**	C2S	916	6.40
306	ED	323	6.35		**320**	DD	512	6.38
306	ES	374	6.36		**320**	DS	590	6.17
					320	ED	2680	6.22
					320	ES	4259	6.37
					320	FD	1531	6.47
					320	FS	1130	6.57
					320	GD	849	6.44
					320	GS	1046	6.36
					320	HD	3037	6.61
					320	HS	6223	6.67
					320	ID	3238	6.69
					320	IS	5385	6.82
					320	JD	313	6.28
					320	JS	2811	6.14
					320	SW1	577	6.22
Site	Location	Specific Conductance (µS/m)	pH		Site	Location	Specific Conductance (µS/m)	pH
351	AD	1038	5.97		**373**	AD	727	5.73
351	AS	*	*		**373**	AS	1254	5.83
351	BD	1437	6.15		**373**	BD	1074	5.65
351	BS	1280	6.29		**373**	BS	1107	5.71
351	B2D	1411	6.19		**373**	CD	941	5.98
351	B2S	2245	6.08		**373**	CS	918	5.82
351	CD	1137	6.21		**373**	DD	765	5.91
351	CS	1729	6.33		**373**	DS	1332	5.91
351	DD	783	6.30					
351	DS	880	5.95					
351	ED	1173	5.81					
351	ES	1185	5.81					

*Missing Data

Table 17 (cont.). Wet Season Specific Conductance and pH

7/20/2014								
Site	Location	Specific Conductance (μS/m)	pH		Site	Location	Specific Conductance (μS/m)	pH
306	AD	481	6.44		**320**	AD	546	6.03
306	AS	536	5.75		**320**	AS	1068	6.11
306	BD	736	5.88		**320**	BD	792	6.26
306	BS	727	5.93		**320**	BS	783	6.31
306	CD	622	6.10		**320**	CD	823	6.32
306	CS	683	6.11		**320**	CS	1015	6.34
306	DD	368	6.20		**320**	C2D	801	6.27
306	DS	475	6.15		**320**	C2S	986	6.32
306	ED	318	6.24		**320**	DD	486	6.33
306	ES	402	6.23		**320**	DS	570	6.11
					320	ED	6394	6.24
					320	ES	*	*
					320	FD	1877	6.39
					320	FS	3283	6.43
					320	GD	769	6.11
					320	GS	*	*
					320	HD	2937	6.54
					320	HS	*	*
					320	ID	4108	6.38
					320	IS	5152	6.45
					320	JD	770	6.12
					320	JS	1140	6.05
					320	SW1	482	6.36
Site	Location	Specific Conductance (μS/m)	pH		Site	Location	Specific Conductance (μS/m)	pH
351	AD	1175	6.15		**373**	AD	732	5.99
351	AS	1580	6.15		**373**	AS	669	5.61
351	BD	1400	6.22		**373**	BD	936	5.51
351	BS	1672	6.21		**373**	BS	1123	5.38
351	B2D	1287	6.10		**373**	CD	874	5.50
351	B2S	2512	6.02		**373**	CS	1039	5.51
351	CD	977	6.19		**373**	DD	731	5.48
351	CS	1625	6.46		**373**	DS	780	5.41
351	DD	1106	6.43					
351	DS	*	*					
351	ED	1216	6.03					
351	ES	1548	6.08					

*Missing Data

Table 17 (cont.). Wet Season Specific Conductance and pH

7/23/2014							
Site	Location	Specific Conductance (μS/m)	pH	Site	Location	Specific Conductance (μS/m)	pH
306	AD	375	5.85	**320**	AD	4731	6.19
306	AS	533	0.77	**320**	AS	1135	6.17
306	BD	710	6.12	**320**	BD	828	6.32
306	BS	708	6.14	**320**	BS	692	6.47
306	CD	614	6.22	**320**	CD	742	6.43
306	CS	657	6.20	**320**	CS	920	6.51
306	DD	366	6.27	**320**	C2D	792	6.41
306	DS	566	6.32	**320**	C2S	862	6.39
306	ED	308	6.47	**320**	DD	468	6.45
306	ES	505	6.39	**320**	DS	572	6.13
				320	ED	3466	6.26
				320	ES	6485	6.43
				320	FD	2014	6.50
				320	FS	7745	6.53
				320	GD	739	6.42
				320	GS	846	6.23
				320	HD	1203	6.65
				320	HS	5581	6.50
				320	ID	2667	6.59
				320	IS	4831	6.63
				320	JD	426	6.23
				320	JS	2647	6.24
				320	JSD	*	*
				320	SW1	539	6.48
				320	SW2	866	5.48
Site	Location	Specific Conductance (μS/m)	pH	Site	Location	Specific Conductance (μS/m)	pH
351	AD	1208	6.20	**373**	AD	729	6.52
351	AS	1519	6.51	**373**	AS	1311	6.25
351	BD	1239	6.50	**373**	BD	844	5.98
351	BS	1973	6.48	**373**	BS	578	6.07
351	B2D	1589	6.34	**373**	CD	854	6.21
351	B2S	2553	6.56	**373**	CS	649	6.09
351	CD	898	6.67	**373**	DD	737	6.13
351	CS	1370	6.69	**373**	DS	1150	6.18
351	DD	832	6.49				
351	DS	958	6.25				
351	ED	1180	6.22				
351	ES	1628	6.33				

Table 17 (cont.). Wet Season Specific Conductance and pH

8/3/2014							
Site	Location	Specific Conductance (μS/m)	pH	Site	Location	Specific Conductance (μS/m)	pH
306	AD	463	5.91	**320**	AD	493	5.58
306	AS	515	5.81	**320**	AS	891	5.65
306	BD	686	6.05	**320**	BD	773	5.68
306	BS	612	5.99	**320**	BS	579	5.84
306	CD	599	5.90	**320**	CD	938	5.83
306	CS	624	5.86	**320**	CS	658	6.19
306	DD	365	5.81	**320**	DD	501	5.87
306	DS	517	5.76	**320**	DS	588	5.64
306	ED	308	5.80	**320**	ED	2584	5.85
306	ES	436	5.79	**320**	ES	5076	5.99
				320	FD	1882	6.07
				320	FS	*	*
				320	GD	793	5.86
				320	GS	*	*
				320	SW1	558	5.92
				320	SW2	960	5.92
Site	Location	Specific Conductance (μS/m)	pH	Site	Location	Specific Conductance (μS/m)	pH
351	AD	1073	5.71	**373**	AD	727	5.70
351	AS	2662	5.82	**373**	AS	1633	5.66
351	BD	1331	5.84	**373**	BD	1031	5.40
351	BS	1436	6.04	**373**	BS	1011	5.25
351	CD	912	6.03	**373**	CD	866	5.48
351	CS	1488	6.03	**373**	CS	671	5.48
351	DD	740	5.95	**373**	DD	750	5.48
351	DS	794	5.47	**373**	DS	1206	5.43
351	ED	1206	5.53				
351	ES	1263	5.60				

*Missing Data

Table 17 (cont.). Wet Season Specific Conductance and pH

8/16/2014								
Site	Location	Specific Conductance (μS/m)	pH		Site	Location	Specific Conductance (μS/m)	pH
306	AD	417	5.72		**320**	AD	473	6.40
306	AS	769	5.74		**320**	AS	1399	6.45
306	BD	718	6.52		**320**	BD	790	6.67
306	BS	796	6.42		**320**	BS	571	6.72
306	CD	612	6.42		**320**	CD	887	6.73
306	CS	752	6.42		**320**	CS	544	6.78
306	DD	372	6.55		**320**	DD	522	6.47
306	DS	858	6.57		**320**	DS	650	6.35
306	ED	316	6.68		**320**	ED	2559	6.58
306	ES	460	6.56		**320**	ES	3281	6.67
					320	FD	1757	6.81
					320	FS	*	*
					320	GD	815	6.70
					320	GS	*	*
					320	SW1	547	6.67
					320	SW2	526	6.05
Site	Location	Specific Conductance (μS/m)	pH		Site	Location	Specific Conductance (μS/m)	pH
351	AD	1322	6.54		**373**	AD	700	6.52
351	AS	1647	6.57		**373**	AS	1375	6.56
351	BD	1431	6.68		**373**	BD	858	6.21
351	BS	1433	6.64		**373**	BS	907	5.89
351	CD	961	6.70		**373**	CD	908	6.36
351	CS	1695	6.80		**373**	CS	672	6.27
351	DD	747	6.88		**373**	DD	737	6.51
351	DS	800	6.40		**373**	DS	1280	6.40
351	ED	1165	6.29					
351	ES	1356	6.50					

*Missing Data

Table 18. Dry Season Nitrogen Field Duplicate Data

2/19/2014																
Sample ID	**320 AS**	**320 ASD**	**% Diff.**						**351 DS**	**351 DSD**	**% Diff.**		**373 DS**	**373 DSD**	**% Diff.**	**Mean**
TN (mg/L)	1.70	2.00	17.65						2.70	2.40	11.11		2.00	1.80	10.00	12.92
NH3 (mg/L)	0.23	0.19	17.39						1.10	1.10	0.00		0.22	0.21	4.55	7.31
TKN (mg/L)	1.70	2.00	17.65						2.70	2.40	11.11		2.00	1.80	10.00	12.92
NOx (mg/L)	0.016	0.016	0.000						0.016	0.016	0.000		0.016	0.016	0.000	0.00
2/23/2014																
Sample ID	**306 ES**	**306 ESD**	**% Diff.**		**320 ES**	**320 ESD**	**% Diff.**		**351 ES**	**351 ESD**	**% Diff.**		**373 DS**	**373 DSD**	**% Diff.**	**Mean**
TN (mg/L)	1.40	1.70	21.43		22.00	16.00	27.27		3.40	4.00	17.65		1.50	1.60	6.67	18.25
NH3 (mg/L)	0.098	0.110	12.245		16.00	9.00	43.75		0.38	0.32	15.79		0.13	0.11	15.38	21.79
TKN (mg/L)	1.40	1.70	21.43		20.00	14.00	30.00		3.40	4.00	17.65		1.50	1.60	6.67	18.94
NOx (mg/L)	0.016	0.016	0.000		1.300	2.200	69.231		0.016	0.016	0.000		0.016	0.016	0.000	17.31
3/1/2014																
Sample ID	**306 ES**	**306 ESD**	**% Diff.**		**320 ES**	**320 ESD**	**% Diff.**		**351 ED**	**351 EDD**	**% Diff.**		**373 DS**	**373 DSD**	**% Diff.**	**Mean**
TN (mg/L)	1.00	1.00	0.00		30.00	30.00	0.00		4.40	5.40	22.73		1.60	1.60	0.00	5.68
NH3 (mg/L)	0.14	0.14	0.00		26.00	27.00	3.85		1.70	2.50	47.06		0.17	0.17	0.00	12.73
TKN (mg/L)	1.00	1.00	0.00		30.00	29.00	3.33		4.40	5.40	22.73		1.60	1.60	0.00	6.52
NOx (mg/L)	0.017	0.016	5.882		0.520	0.460	11.538		0.017	0.019	11.765		0.019	0.016	15.789	11.24
3/8/2014																
Sample ID	**306 ES**	**306 ESD**	**% Diff.**						**351 CS**	**351 CSD**	**% Diff.**		**373 DS**	**373 DSD**	**% Diff.**	**Mean**
TN (mg/L)	0.93	0.77	17.20						3.70	3.50	5.41		2.60	1.50	42.31	21.64
NH3 (mg/L)	0.16	0.15	6.25						1.60	1.50	6.25		0.21	0.19	9.52	7.34
TKN (mg/L)	0.93	0.77	17.20						3.70	3.50	5.41		2.60	1.50	42.31	21.64
NOx (mg/L)	0.016	0.016	0.000						0.018	0.016	11.111		0.021	0.020	4.762	5.29
3/24/2014																
Sample ID	**306ES**	**306ESD**	**% Diff.**		**320ID**	**320IDD**	**% Diff.**		**351ES**	**351ESD**	**% Diff.**		**373DS**	**373DSD**	**% Diff.**	**Mean**
TN (mg/L)	0.81	1.20	48.15		9.00	8.40	6.67		5.00	4.70	6.00		2.10	1.90	9.52	17.58
NH3 (mg/L)	0.18	0.19	5.56		6.00	5.80	3.33		1.30	1.80	38.46		1.10	0.90	18.18	16.38
TKN (mg/L)	0.81	1.20	48.15		8.90	8.30	6.74		5.00	4.70	6.00		2.00	1.90	5.00	16.47
NOx (mg/L)	0.016	0.016	0.000		0.06	0.05	10.00		0.016	0.016	0.000		0.073	0.016	78.082	22.02
4/19/2014																
Sample ID					**320 C2S**	**320 C2SD**	**% Diff.**		**351 ES**	**351 ESD**	**% Diff.**		**373 DS**	**373 DSD**	**% Diff.**	**Mean**
TN (mg/L)					2.10	2.00	4.76		3.10	2.70	12.90		1.10	0.98	10.91	9.52
NH3 (mg/L)					0.032	0.044	37.500		0.61	0.65	6.56		0.100	0.099	1.000	15.02
TKN (mg/L)					2.00	1.90	5.00		3.10	2.70	12.90		1.10	0.98	10.91	9.60
NOx (mg/L)					0.047	0.05	6.383		0.016	0.016	0.000		0.016	0.016	0.000	2.13
															Mean	12.93

Table 19. Wet Season Nitrogen Field Duplicate Data

Sample ID	306 ED	306 EDD	% Diff.		320 ED	320 EDD	% Diff.		351 DS	351 DSD	% Diff.		373 DS	373 DSD	% Diff.					Mean
TN (mg/L)	0.79	0.73	7.59		1.00	1.20	20.00		3.60	3.80	5.56		1.40	1.10	21.43					13.64
NH3 (mg/L)	0.44	0.45	2.27		0.14	0.33	135.71		1.90	1.90	0.00		0.38	0.35	7.89					36.47
TKN (mg/L)	0.79	0.73	7.59		1.00	1.20	20.00		3.60	3.80	5.56		1.20	1.10	8.33					10.37
NOx (mg/L)	0.016	0.016	0.000		0.016	0.016	0.000		0.016	0.016	0.000		0.018	0.017	5.556					1.39
7/18/2014																				
Sample ID	306 ES	306 ESD	% Diff.		320 ES	320 ESD	% Diff.		351 ES	351 ESD	% Diff.		373 DS	373 DSD	% Diff.					
TN (mg/L)	1.20	1.20	0		1.90	1.90	0		2.20	2.10	4.55		3.30	2.00	39.39					10.98
NH3 (mg/L)	0.037	0.043	16.216		0.0073	0.0073	0		0.12	0.22	83.33		0.060	0.062	3.333					25.72
TKN (mg/L)	0.80	0.78	2.50		1.90	1.90	0.00		2.20	2.10	4.55		3.30	2.00	39.39					11.61
NOx (mg/L)	0.37	0.45	21.62		0.016	0.016	0		0.016	0.016	0		0.016	0.016	0					5.41
7/20/2014																				
Sample ID	306 ES	306 ESD	% Diff.		320 ED	320 EDD	% Diff.		351 ES	351 ESD	% Diff.		373 DS	373 DSD	% Diff.					
TN (mg/L)	3.70	5.70	54.05		1.60	1.60	0.00		3.30	3.00	9.09		1.20	1.10	8.33					17.87
NH3 (mg/L)	0.0073	0.0073	0		0.34	0.36	5.88		0.35	0.35	0.00		0.21	0.27	28.57					8.61
TKN (mg/L)	1.20	1.60	33.33		1.60	1.60	0.00		3.30	3.00	9.09		1.20	1.10	8.33					12.69
NOx (mg/L)	2.50	4.10	64.00		0.016	0.016	0		0.016	0.016	0		0.016	0.016	0					16.00
7/23/2014																				
Sample ID	306 ES	306 ESD	% Diff.		320 ES	320 ESD	% Diff.		351 ES	351 ESD	% Diff.		373 DS	373 DSD	% Diff.		320 JS	320 JSD	% Diff.	
TN (mg/L)	21.00	20.00	4.76		2.40	1.90	20.83		3.00	2.60	13.33		2.40	2.60	8.33		21.00	20.00	4.76	10.40
NH3 (mg/L)	0.016	0.023	43.750		0.010	0.016	60.000		0.064	0.063	1.563		0.100	0.097	3.000		14.00	15.00	7.14	23.09
TKN (mg/L)	1.80	2.40	33.33		2.40	1.80	25.00		3.00	2.60	13.33		2.40	2.60	8.33		21.00	20.00	4.76	16.95
NOx (mg/L)	20.00	18.00	10.00		0.048	0.045	6.250		0.016	0.016	0.000		0.016	0.016	0.000		0.016	0.016	0	3.25
8/3/2014																				
Sample ID	306 ES	306 ESD	% Diff.		320 ES	320 ESD	% Diff.		351 ES	351 ESD	% Diff.		373 DS	373 DSD	% Diff.					
NH3 (mg/L)	0.015	0.011	26.667		0.007	0.007	0.000		0.46	0.48	4.35		0.17	0.16	5.88					9.224
NOx (mg/L)	10.00	9.50	5.00		0.30	0.32	6.67		0.016	0.016	0.000		0.016	0.016	0.000					2.917
8/16/2014																				
Sample ID	306 ES	306 ESD	% Diff.		320 ES	320 ESD			351 ES	351 ESD	% Diff.		373 DS	373 DSD	% Diff.					
NH3 (mg/L)	0.0078	0.0074	5.1282		0.0073	0.0073	0.0000		0.12	0.12	0		0.16	0.19	18.75					5.970
NOx (mg/L)	24.00	25.00	4.17		0.25	0.28	12.00		0.016	0.016	0		0.016	0.016	0					4.042
																			Mean	12.33

Nitrate is the predominate form of NOx-N in aerated groundwater, but because oxygen was lacking in the groundwater at our test sites (Tables 12 and 13), nitrification was inhibited and significant nitrate was not produced. Also, although the water logged soils and anaerobic conditions at the sites favored denitrification, the lack of nitrate prevented the gaseous loss of nitrogen via denitrification from occurring. Urea rapidly hydrolyzes to ammonia/ammonium, especially at temperatures greater than 50 degrees F. At slightly acid pH's, as was the case in this study, if urea is left on a moist soil surface for even short periods of time, significant quantities of N can be lost by ammonia volatilization, after hydrolysis (Phelps, 2009). The rate of surface volatilization depends on moisture level, temperature and surface pH of the soil. If the soil surface is moist, the water evaporates into the air. Ammonia released from the urea is picked up in the water vapor and lost. On dry soil surfaces (which we did not have), less urea-N is lost. Temperatures greater than 50 degree F and pH's greater than 6.0 significantly increase the rate of urea conversion to ammonia gases, and these conditions existed in this study (Ohio State University, 2014). We believe some ammonia volatilization occurred after urea hydrolysis at our test sites because the soils were sandy, moist and warm with acidic pH's---conditions favorable for volatilization. However, because of the extremely wet nature of the soils due to the high water table and frequent rainfall, volatilization was probably less important at these sites than urea leaching. If the urea fertilizer does not remain on the surface and is watered into the soil by rain in the first 2-3 days after application, as generally was the case in this study, volatilization will be minimal to non-existent. To stop ammonia volatilization from urea the urea must be tied up by the soil. To get urea in direct contact with the soil it must rain enough to wash the urea from the residue and move it below the surface. If the residue is light, 0.25 to 0.50 inches of rain is enough to dissolve the urea and wash it into the soil. If the residue is heavy, 0.50 inches of rain or greater is required to work it into the soil (Camberato, 2001).

Since the pH's of the groundwater at the test sites were generally slightly acidic (6.5-7.0), the ammonia was in the form of ammonium, which can be readily taken up by grass. Ammonium usually leaches very little because it has a positive charge and is held by the negative sites on clay in the soil. In sands, however, where there is very little clay, ammonium forms of nitrogen can leach readily. Urea is a non-ionic compound and is highly soluble and when it is placed onto wet soil or in solution it will leach rapidly through the soil, especially if excess rain occurs and the soil coarse to medium sand, as was the case at our sites. One inch of water will effectively wet the top 10 inches of a typical Florida sand profile **(**OSU, 2014). Although some ammonium uptake by grass most likely occurred, we believe this was minor as the turfgrass at all sites was not healthy and did not exhibit a strong root structure, and leaching occurred faster that grass uptake could occur. Because of the heavy rain following fertilizer applications, we believe significant urea nitrogen was quickly lost or diluted and therefore was not picked up in our routine sampling and analyses.

At our study sites, we did not see a significant spike in ammonia nitrogen levels shortly after fertilizer application in either the dry or wet sampling periods. The dry season was unusually wet, resulting in water table elevations just below ground surface. We sampled two days after fertilizer application in the dry season, but may have missed significant urea leaching to the groundwater with the extremely high water table conditions that existed, and heavy rainfall that occurred (Table 14). We measured 1.2 inches of rain in the dry season within two days after fertilizer application (0.8 inches fell on the same day the fertilizer was applied). In the wet season, although we sampled one day after fertilizer application to try and capture any urea leachate spike occurring shortly after fertilizer application , heavy rainfall and high water table conditions may have washed urea (or ammonium) too rapidly through the soil and/or caused significant dilution in the sampled groundwater. Rain data show 1.6 inches fell within two days after fertilizer application, in the wet season, and 4.9 inches fell within two days prior to fertilizer application (3.5 inches one day prior to application (Table 15). Because little urea would be left on the soil due to the heavy rainfall and high water table conditions occurring before and after fertilization in both the dry (2/19/14—4/19/14) and wet seasons (7/15/14—8/16/14) sampling, significant ammonia volatilization would not be expected to occur.

We established two different sampling scenarios to serve as controls. 373 Chamberlain Boulevard represented our separate control site (no fertilizer), which was sampled at four different locations during every sampling trip. The front yard test area was 1500 ft^2. As an additional control, we sampled each residence (306, 320, and 351 Chamberlain) 3-4 days prior to dry and wet season fertilizer applications. Although the same exact sites were sampled before and after fertilizer application with this sampling scenario, the sites were subjected to different rainfall and water table conditions, and these differences may have affected some pre and post fertilizer comparisons. The control sampling dates prior to fertilizer application were 2/15/14 (dry season) and 7/15/14 (wet season.

The surface water was sampled at three locations (Fig. 3): one location was located in the IRL (SW) and two locations in a drainage ditch that discharges to the IRL. One of the ditch sampling sites was adjacent to the eastern boundary of the 320 Chamberlain backyard (320 SW2). The other ditch site (320 SW2) was located further east approximately 200 ft from the IRL shoreline. The ditch sampling began on 3/8/14 for 320 SW1 and on 4/19/14 for 320 SW2. Tables 10 and 11 present surface water nitrogen data for the dry and wet season sampling periods, respectively. SW NOx-N was low for the dry and wet seasons, averaging 0.02 mg/L at both sites. NOx-N was much higher at the ditch sites, averaging 0.21 mg/L in the dry season at 320 SW1. NOx-N at the ditch sites in the wet season were low and averaged 0.03 mg/L (Table 11), suggesting dilution from the extreme rainfall that occurred during that period. Although NH_3-N was low in the IRL (<0.02 mg/L), it was much higher in the ditch in the dry and wet seasons (mean = 0.65 mg/L). The high NOx-N in the ditch (dry season) and the elevated NH_3-N in the ditch (dry and wet season) appears to be primarily influenced by septic tank leachate, but the low nitrogen levels at site SW, in the IRL, indicate the elevated nutrient concentrations in the ditch were not impacting IRL levels at the sampling times.

Septic Tank Impact

It became evident after reviewing several initial sets of groundwater nitrogen data from the fertilizer sampling sites, that a septic tank and drainfield existed in the backyard of 306 Chamberlain, and it was influencing nitrogen concentrations. At later dates we established additional sampling sites in the backyard to determine the tank and drainfield plume location and found that the groundwater at sites 320 D-J was usually impacted by septic tank leachate, exhibiting elevated concentrations of NH_3-N, NOx and specific conductance levels (Tables 2 and 3;16 and 17). Because groundwater sampling sites were being constantly added, the initial 4/19/14 mean control data could not be compared with the test site mean. NOx-N concentrations were generally not elevated at any site due to near anoxic to anoxic conditions, prohibiting nitrification from occurring (Tables 2 and 3). The septic tank at 306 Chamberlain represented an old system located in close proximity to a drainage canal and, in this case, represented a pathway to the IRL. Groundwater sampling occurred at the septic tank impacted sites (D-J), as well as occasionally at the receiving ditch, and results were compared with unimpacted site data (Figs.6 through 9). In Tables 4 through 9 and Figs. 6 through 9, 320 A-C represents the unimpacted front yard sites, 320 D-J are the backyard sites that are impacted, to one degree or another. All sites were within 25 feet of the drainfield. Since nitrification is not occurring due to anoxic conditions measured in nearby 2 in piezometers, NH_3-N is the key nitrogen species. Tables 4 (Dry Season Summary, Deep and Shallow GW Data Combined) and 7 (Wet Season Summary, Deep and Shallow GW Data Combined) indicate there is a large difference between unimpacted sites (320 A-C) and impacted septic tank sites (320 D-J). Although all sites were fertilized in the dry and wet seasons, the septic tank influence at sites 320 D-J greatly overshadowed any fertilizer impact.

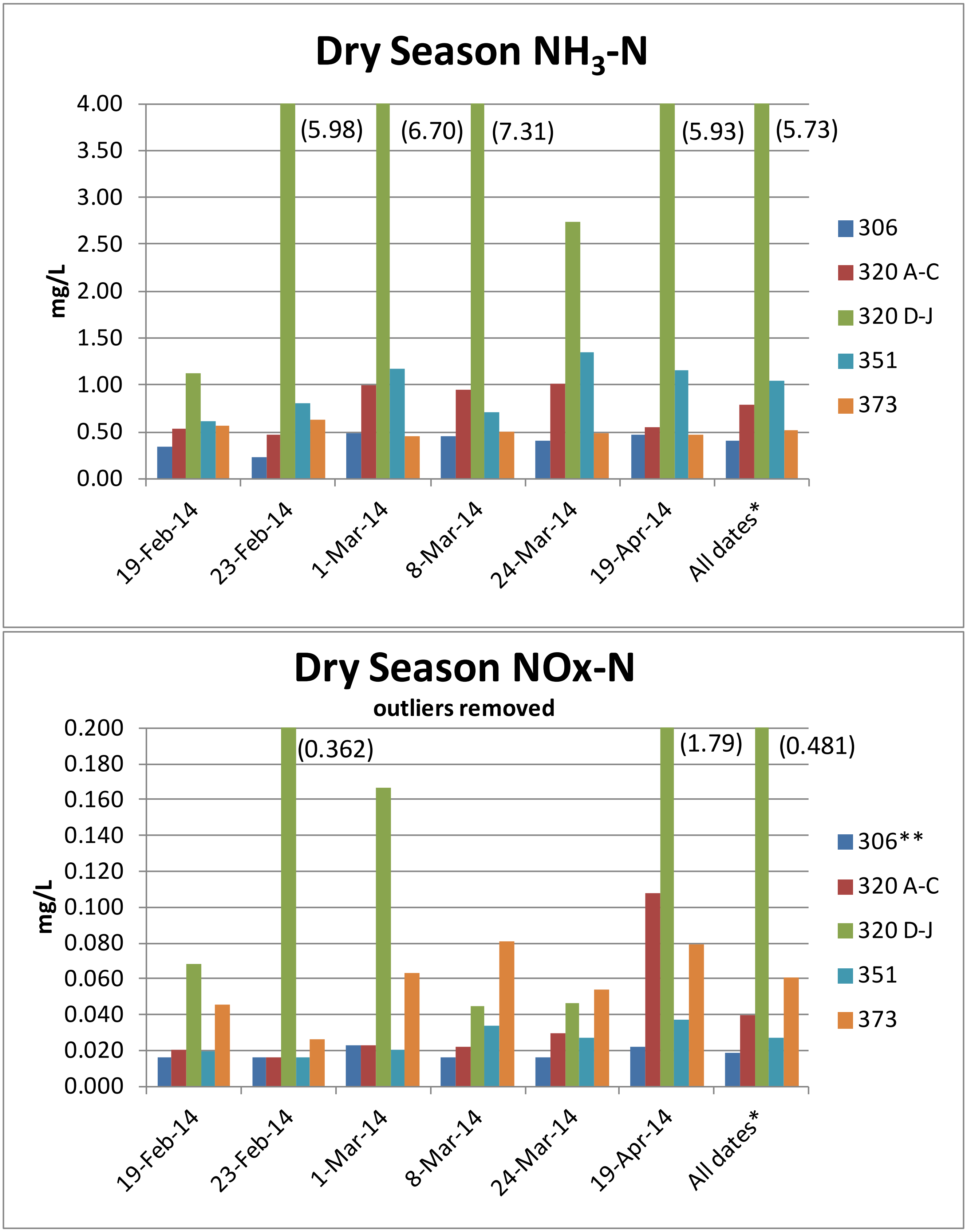


Figure 6. Dry Season Inorganic Nitrogen Concentration Data.

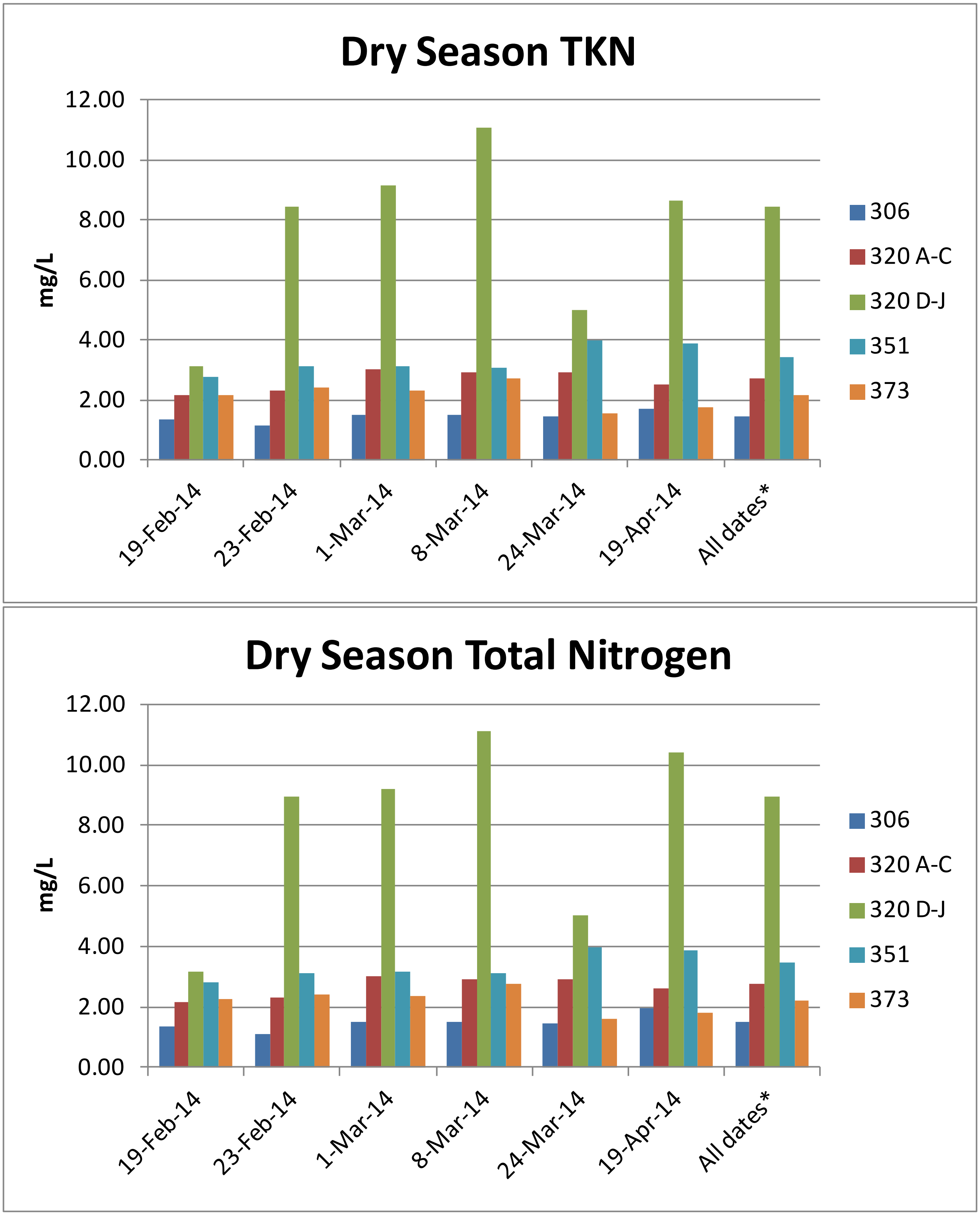
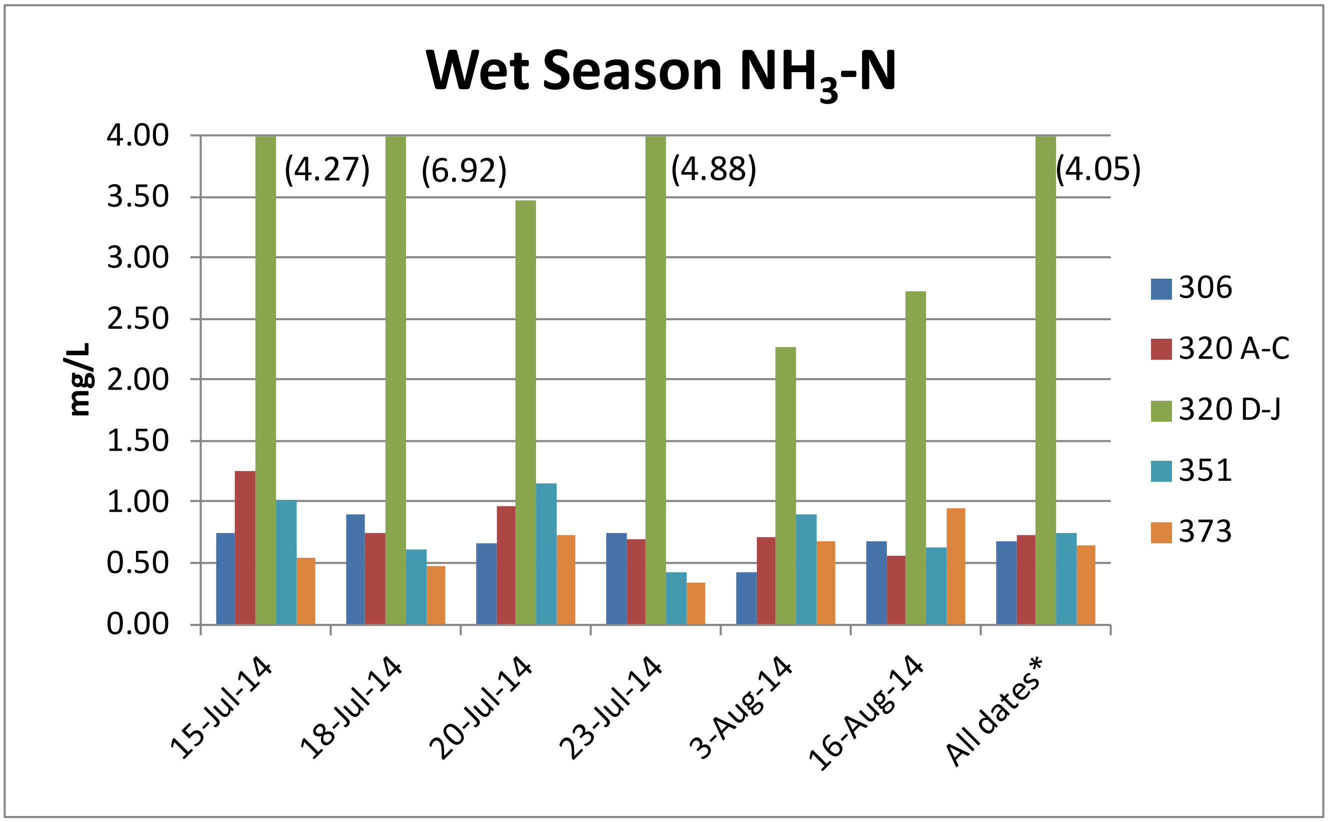


Figure 7. Dry Season TKN and TN Concentration Data.



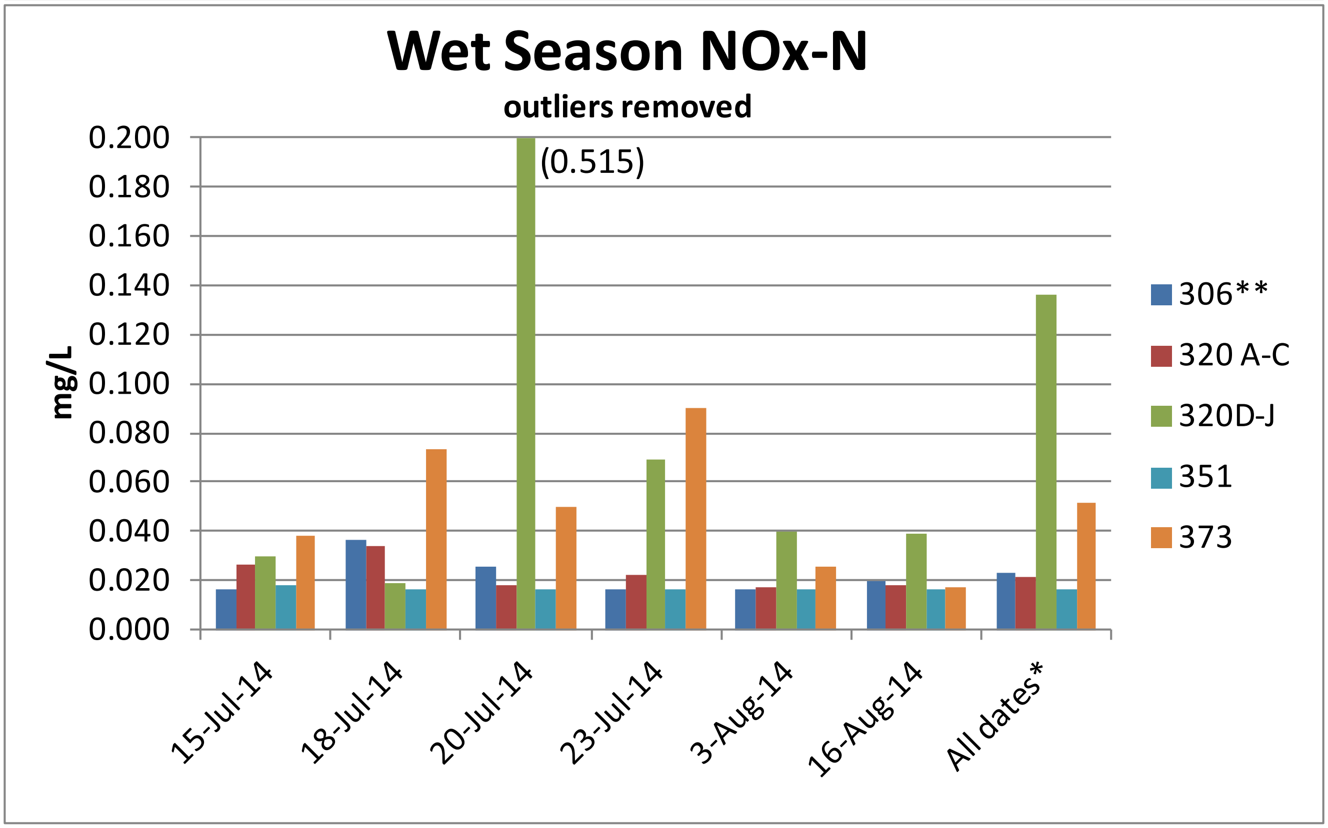
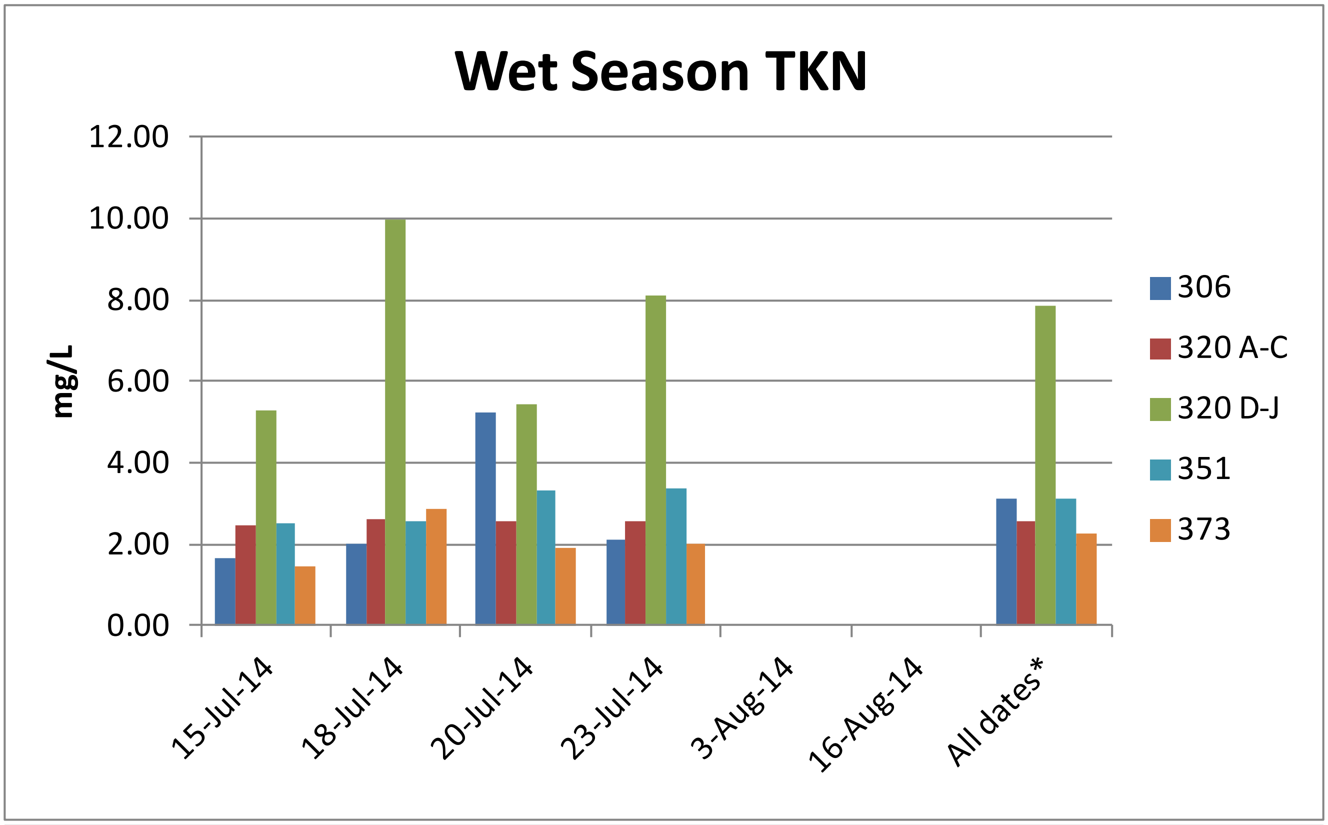


Figure 8. Wet Season Inorganic Nitrogen Concentration Data.



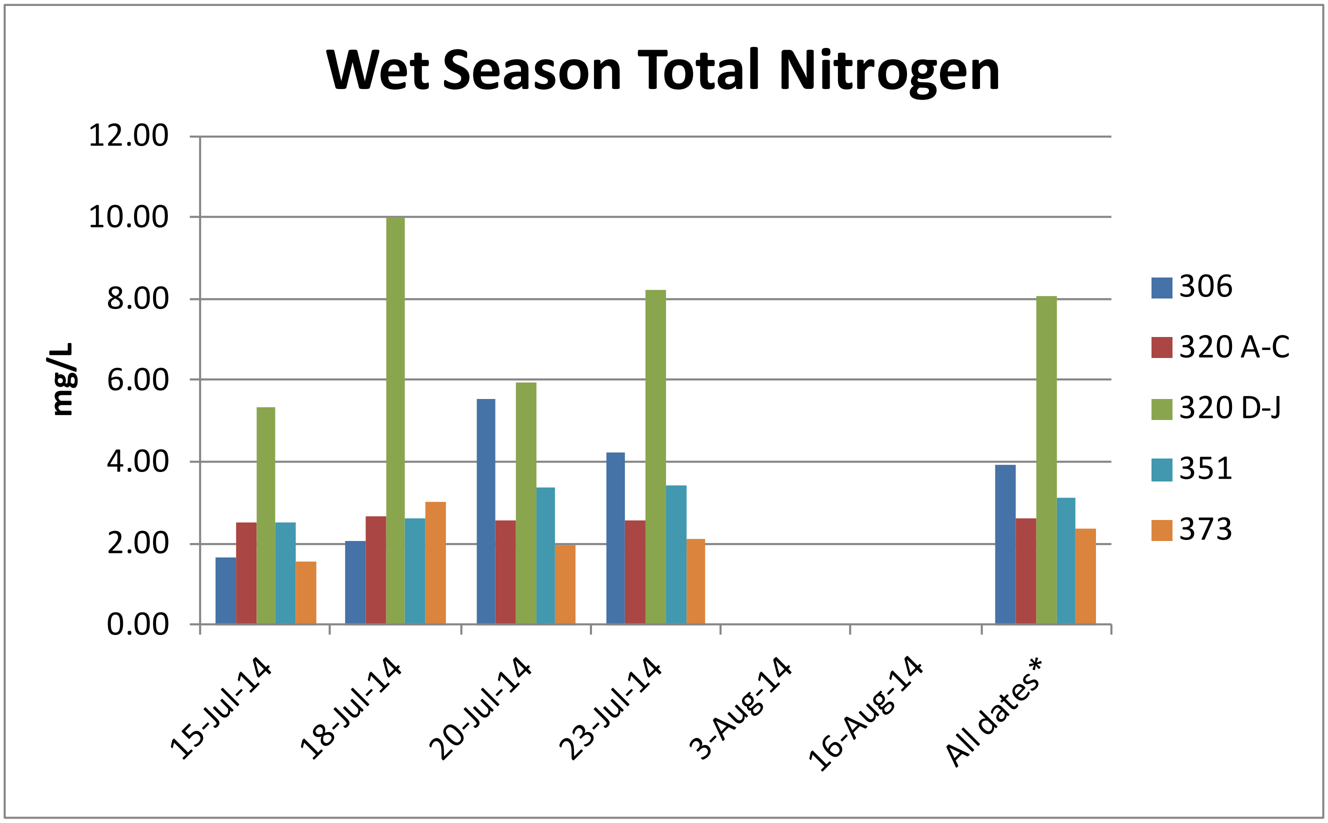


Figure 9. Wet Season TKN and TN Concentration Data.

The mean dry season concentrations for NH_3-N were 5.73 mg/L (320 D-J) vs 0.79 mg/L (320 A-C) or 0.51 mg/L for the 373 Chamberlain control mean (Fig. 8;Table 4) The wet season 320 D-J deep and shallow NH_3-N mean (4.05 mg/L) was significantly higher than the 373 Chamberlain mean (0.64 mg/L; $P < .01$) again showing the septic tank leachate influence (Fig. 8;Table 7). NOx-N was generally low because of anaerobic conditions that prevented nitrification from occurring. The mean NOx-N values were elevated at OSTDS impacted (320 D-J) vs unimpacted (320 A-C) sites due to higher NOx levels on just two dates. Dry season NOx levels on 2/23/14 (0.362 mg/) and 4/19/14 (1.79 mg/L) were high, resulting in a deep and shallow mean of 0.481 mg/L vs a mean of 0.040 mg/L for the unimpacted front yard sites and 0.061 mg/L for the 372 Chamberlain control (Fig. 6). For the wet season, the7/20/14 shallow/deep NOx mean was high (0.515 mg/L; Fig. 8), resulting in an overall NOx wet season mean of 0.136 mg/L. Although dissolved oxygen levels were near anoxic at nearby piezometer locations (Table 13), measurement sites near the septic tank drainfield must have had sufficient groundwater oxygen present to allow nitrification to occur. The unimpacted septic front yard mean (320 A-C) NOx level was significantly lower (0.022 mg/L; Table 7). Many of the impacted groundwater sites exhibited high specific conductance levels, as well, further indicating septic tank influence. The receiving surface water ditch (SW1) , located 20 ft from the end of the drainfield, was occasionally sampled, and averaged 0.21 mg/L NOx in the dry season, but only 0.02 mg/L in the wet season. Tables 4 and 7 present deep and shallow groundwater nitrogen data, averaged together, while Tables 5, 6, 8 and 9 present separate deep and shallow nitrogen concentrations for dry and wet season samples. It is apparent that the 306 Chamberlain septic tank, as represented by the 320 D-J data, is having a major nitrogen loading impact on the groundwater and adjacent surface water ditch, although the groundwater entry point to the ditch is small. Other homes in the neighborhood should be investigated to determine is this is a common problem in the area, and therefore represents a negative impact on the IRL.

The overall importance of septic tanks or on-site treatment and disposal systems (OSTDS) to the nutrient and bacterial contamination of the IRL has been an unresolved question for many years .Since septic tanks are sometimes cited s the major source of nutrient loading to the IRL, our septic tank study findings from other studies are briefly presented here. In view of the high numbers of OSTDS and the poor site conditions often existing in the IRL watershed, four Florida Tech studies were funded over a six year period by three different agencies to directly determine the importance of OSTDS contamination to the IRL and its tributaries. Another three year Lower St. Johns River (LSJR) study funded by the FDEP was completed in July, 2011 and provided information relevant to the IRL studies, as well. Eight specific residential OSTDS sites were investigated in combined FY 05 and 06 SFWMD Issues Team studies on the St. Lucie Estuary, while three residential sites were investigated in Ft. Pierce in a FY 09 NEP study. Also, three additional sites were included in a three year NPS study completed in 2010 on OSTDS impacts on Mosquito Lagoon. In the more recently completed FDEP study on the LSJR, a total of fourteen residential sites located within five general neighborhoods were seasonally sampled in 2009 and 2010. These studies involved sampling a combined 28 OSTDS residential sites and required the seasonal collection of groundwater and surface water quality and hydrologic data. In each study, groundwater samples were collected at each residential site with piezometers and PushPoint samplers at transect locations adjacent to and down-gradient from each septic tank drainfield to the edge of adjacent surface water bodies. The FDEP 2011 study, as well as another study by Belanger and Price (2008), also used stable nitrogen isotope ratios to help determine the nitrogen sources (OSTDS, fertilizer, wildlife etc.) to the LSJR and St. Lucie Estuary, respectively, but results were not conclusive and did not clearly indicate the primary source of nitrogen to the surface water.

We believe our direct approach yields more definitive conclusions than modeling and other indirect methods, such as nitrogen isotopes ratios, often used by others. When the direct measurement data from the above completed studies are combined, plume migration distances can be approximated under the various environmental and OSTDS conditions. Our site-specific data indicate nutrient travel distances are generally in the 1-3 ft/yr range and that bacteria are usually removed within short distances (5-10 ft) of OSTDS drainfields, as the soil is generally an effective bacterial filter. Our data indicate that residence age, depth to water table, sediment type and horizontal hydraulic gradient are very important site factors in determining nutrient plume migration distance. With the collected data from the above site specific studies, we feel we have a reasonable database (28 residences) that was obtained under a wide range of hydrogeologic scenarios, allowing us to make reasonable conclusions concerning OSTDS impacts.

Collective direct measurement data from all our OSTDS studies, (Belanger, Heck and Andrews, 1997; Belanger and Price, 2006; Belanger and Price, 2007; Belanger, 2009; Belanger, Heck and Price, 2011; Zarillo et al., 2010), indicate that while OSTDS can contribute nutrients to water bodies such as the IRL and its tributaries under certain site condition scenarios, properly functioning (not failing) OSTDS are not the "smoking gun" many have predicted and do not appear to a significant a source of nutrients and fecal coliform bacteria as many have thought. Nearly all our sites were on the mainland side of the IRL, however, and the barrier island may be a different story. The barrier island exhibits significant subsurface tidal flushing and may be pumping higher levels of septic tank nutrients to the IRL through the coarse-grained sandy soils. This should be investigated.

According to our previous study observations and collected data, the septic tanks monitored in those studies were generally properly sited and functioning adequately. We believe the overwhelming majority of septic tanks in the IRL drainage basin are functioning properly, but failing systems and improperly sited septic tanks need to be identified and corrected, as they can impact the lagoon. Conditions that prevent or interfere with proper septic system function include unsuitable soils, high water tables, steep slopes and under design or improper use. Many of these conditions occasionally occur in areas around the IRL or its tributaries and therefore make these residential lots unsuitable for septic systems.

Soil plays a key role in a septic system. Tightly bound and poorly drained soil types (clays) are not effective filters. At the other extreme, gravel or coarse sand is also a poor filter because the wastewater drains through it so rapidly that little treatment takes place. Treatment is also prevented when the soil is too wet. Septic systems depend on good contact between the wastewater and relatively dry soil particles so that the soil can adsorb nutrients as the wastewater passes through the system. Saturated soils cannot adsorb nutrients well. Soils that drain very slowly may be chronically saturated and the system, therefore, may be inoperative much of the time. In a poorly drained soil, the wastewater is also likely to surface and run directly to the receiving water body. High groundwater tables can also prevent treatment by periodically flooding the drain system. Frequently a septic problem can be traced to improper use and subsequent malfunction. These problems commonly arise from under design, that is, too small a tank or an inadequate drainfield. Other problems are caused by serving more people than the system was designed for, using improper washing products, following a poor septic tank maintenance schedule (e.g. pumping out), and putting excessive solids in the system (e.g. garbage disposal).

As discussed previously, one improperly sited septic tank case was discovered in this fertilizer study---a situation where the septic tank drainfield was located in saturated soil and the drainfield was within 15 ft of a surface water ditch that empties into the IRL. Although we believe the occurrence of such situations are minor and not the norm, if many such situations exist the negative impact on the IRL would be significant. Therefore, we believe improperly sited or functioning septic systems should be identified.

Summary and Conclusions

This study did not provide conclusive evidence supporting the establishment of strict residential fertililizer ordinances. Although we believe the overall residential nitrogen fertilizer leachate impact on groundwater and surface water bodies, such as the IRL, is significant, we were not able to prove it in this study because of the uniqueness of the study site and the high rainfall conditions encountered. A combination of several factors probably contributed to the study results which, except for liquid quick release fertilizer in the dry season, generally indicated minimal fertilizer leachate impact on groundwater. At our research sites groundwater levels were extremely high and the water was anoxic, preventing nitrification, and therefore NOx-N, from occurring. The lower than expected NH_3-N levels are more difficult to explain. Since ammonia could not be converted to nitrate, ammonia/ammonium levels would be expected to be high. The form largely depends on the pH. Urea hydrolysis begins as soon as it is applied to soil. With any small amount of soil moisture, urea normally hydrolyzes to ammonia and carbon dioxide and can be lost to the atmosphere. If urea remains on the soil surface for extended periods of time, ammonia volatilization will occur and a large percentage of the original fertilizer nitrogen can be lost. When soils are moist, such as our site was, volatilization will occur but can be reduced when heavy rainfalls occur which can blend urea into the soil to a depth where ammonia volatilization losses may be minimal. We believe ammonia volatilization represented a significant nitrogen loss, but was somewhat limited when heavy rains came within 12-24 hours after urea application, mixing urea into the soil. Therefore, it appears a major amount of ammonia may have been lost due to both urea hydrolysis and ammonia volatilization, and some nitrogen may also have been lost due to direct ammonia/ammonium and urea leaching that occurred quickly through the saturated soil. Ammonium is favored by slightly acidic groundwater and is quite soluble. Since our research sites exhibited acidic groundwater pH's with porous sandy soils and very little clay or organic matter, ammonium was likely present and it could readily leach through the soil. Also, because urea is soluble, leaching of urea itself can be very significant and occur through sandy soils before hydrolysis, as well. This likely occurred at 351 Chamberlain during the wet season. Although we observed a significant ($P<.01$) difference in NH_3-N in the dry season between the mean control and fertilizer site data (Fig. 6), the liquid quick release fertilizer could have quickly lost urea and NH_3-N (after hydrolysis) in the wet season due to rapid flushing through the saturated sandy soil. Also, the extremely high rainfall and water table conditions may have significantly diluted leachate concentrations, resulting in no noticeable impact.

The lower than expected dry and wet season ammonia/ammonium levels at the fertilized residential research sites, as shown in Figures 6 and 8, are due to several contributing factors. Ammonia volatilization most likely represented a significant loss of nitrogen in the moist soils, but when heavy rains occasionally occurred just after fertilization, ammonia volatilization was prevented due to soil mixing and ammonia/ammonium leaching became more of a factor and may not have been captured by our sampling scheme (depth and frequency). With the above said, however, we believe ammonia volatilization is one reason that NH_3-N was so low at the test sites and the fertilizer nitrogen impact appeared minimal. Thus, in locations where saturated and anaerobic soil conditions prevail, nitrate will not be present and ammonia volatilization may reduce nitrogen loads from groundwater leaching to surface water bodies such as the IRL. This is especially true where the water table slope (horizontal hydraulic gradient) is low, and stagnant, low flow groundwater conditions persist. These conditions would also reduce surface runoff during heavy rainfall events, as less surface nitrogen would exist. The barrier island may act differently, however, as it exhibits significant subsurface tidal flushing and may be pumping higher levels of fertilizer nutrients to the IRL through the coarse-grained sandy soils that exist there, especially if aerobic conditions prevail and nitrification is occurring. This should be further investigated.

The key factor in this study causing the fertilizer groundwater data to indicate minimal to non-existent leachate impact was that the soils in the St. Lucie Village neighborhood were saturated and anaerobic, preventing the formation of nitrate. Nitrification will increase with percent soil water content to about 60% water filled pore space, after which the higher soil moisture negatively affects soil aeration and oxygen for nitrification becomes limiting. Our study area exhibited nearly 100% saturation, most of the time, with groundwater levels usually at or within inches of the ground surface, and often with the water table at the ground surface (wet season). Nitrate, due to its negative charge, is not held by soil particles and therefore moves easily with soil water**,** and is generally the nitrogen form of most concern. Therefore, nitrogen leaching to groundwater is much more important when soils are not saturated and dissolved oxygen is present. Nitrogen loading via groundwater leachate becomes much more important when aerobic water table conditions exist. With nitrate absent and ammonia then becoming the major nitrogen form, ammonia volatilization likely became much more important. In addition, dilution from the extreme rainfall that occurred during the study probably greatly reduced ammonia concentrations, indicating minimal impact from fertilizer leaching. Liquid soluble quick release fertilizer proved to have a significant NH_3-N leachate impact on groundwater when lower rainfall and water table levels existed (dry season at 351 Chamberlain) , but not when extreme rainfall and very high water table levels persisted, as was the case in the wet season (Figs 6 and 8).

Literature Cited

Alyamani, M.S. and Z. Sen. 1993. Determination of hydraulic conductivity from complete grain size analysis curves. Ground Water 32,4: 551-555.

American Public Health Association. 1989. Standard Methods for the Examination of Water and Wastewater. 17th Edition.

.

American Society of Testing Materials. 2008. D4822-88. Standard Guide for the Selection of Methods of Particle Size analysis for Fluvial Sediments.

Belanger, T.V., H.H. Heck and M.S. Andrews. 1997. Groundwater Flow characteristics of the Mosquito Lagoon, Fl. Final Report Submitted to the Water Resources Division, National Park Service. Project Number: CANA-N-027.000.

Belanger, T.V. and T.L. Price Jr. 2006. OSDS Impacts on the St. Lucie River and Indian River Lagoon (Year I). Final Report to the St. Lucie River Issues Team. (SFWMD. Contract OT05095). 62p.

Belanger, T.V, and T.L. Price Jr. 2007, OSDS Impacts on the St. Lucie River Estuary and Indian River Lagoon (Year II). Final Report to the St. Lucie River Issues Team. (SFWMD Contract OT060154). 30 p.

Belanger, T.V. and T.L. Price Jr. 2008, Using Stable Nitrogen Isotope Ratios To Determine Nitrogen Sources To the St. Lucie River Estuary. Final Report to the St. Lucie River Issues Team. (SFWMD Contract 4600000497). 59 p

.

Belanger, T.V. 2009. The Importance of OSTDS Contaminant Loading to the IRL. Contract #: 25141. Final Report to the National Estuary Program. 61 pp.

Belanger, T.V., H.H.Heck, and T.L.Price,Jr. 2011. Preliminary Evaluation of Septic Tank Influences on Nutrient Loading to the Lower St. Johns River Basin and its Tributaries. Final Report Submitted to FDEP. FDEP Contract WM 952. 87 p.

Zarillo, G.H., T. Belanger, K. Zarillo, J. Rosario-Llantin and D. McGinnis. 2010. The Development of a Hydrologic Model of Mosquito Lagoon in Canaveral National Seashore. National Park Service Contract No. N5180070017. Ft. Collins, Co.

Bonnie Plants, 2013. bonnieplants.com/library/a-rundown-of-fertilizer-forms-and-types/

Bower, H. 1988. The Bower and Rice slug test---an update. Ground Water, 27:304-309

Camberato, J., B. Jones and R. L. Nielson. 2014. Nitrogen Loss in Wet and Wetter Fields. Purdue Univ. Dept. of Agronomy. Corny News Network.

Camberato, J. Nitrogen in Soil and Fertilizer. 2001. SC Turfgrass Foundation News, Jan-March. Vol. 8, Number 1, pp. 6-10.

Dean, W. 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. J. Sedimentary Petrology, 44(1): 242-248.

J. E. Erickson, J. L. Cisar, J. C. Volin, and G. H. Snyder, Nov.-Dec. 2001. Comparing Nitrogen Runoff and Leaching between Newly Established St. Augustinegrass Turf and an Alternative Residential Landscape. Crop Science, Vol. 41. PP. 1889-1895.

Ghilani, C. D. and P. R. Wolf. 2008. Leveling Field Procedures and Calculations. In: Elementary Surveying, 12th Edition. Prentice Hall.

Groffman, P.M., C.O. Williams, R.V. Pouyat, L.E. Band, and I.D. Yesilonis. 2009. Nitrate leaching and nitrous oxide flux in urban forests and grasslands. J. Environ. Qual. 38: 1848-1860.

Kelling, K. A., and A. E. Peterson. 1975. Urban lawn infiltration rates and fertilizer runoff losses under simulated rainfall. Soil Science Society Am. Proc. 39:348-352.

Killpack, S. and D. Bucholz, 2014. Nitrogen in the Environment: Ammonia Volatilization. Univ. of Mo. Extension. http://extension.missouri.edu/p/WQ257.

Killpack, S. and D. Bucholz, 2014. Nitrogen in the Environment: Leaching. Univ. of Mo. Extension. http://extension.missouri.edu/p/WQ262.

Lowes, 2013. Fertilizer Buying Guide. http:www.lowes.com/cd_Fertilizer + Buying + Guide_543192373

Maguire, M. and M. Alley. 2009. Fertilizer Types and Calculating Application Rates. Virginia Cooperative Extension.Publication 424-035.

Marine Resources Council. Fall, 2010. Brevard and St. Lucie CountiesConsider Reducing Fertilizer Pollution. The Marker. News of the IRL. Vol. 25, No. 3.

Ohio State Univ. Extension, 2014. Agronomy Facts. Selecting Forms of Nitrogen Fertilizer. AGF 201-95. ohioline.osu.edu/agf-fact/0205.html.

Petrovic, A.M. 1990. The fate of nitrogenous fertilizers applied to turfgrass. J. Environ. Qual. 19:1-14.

Phelps, G.G. 2009. Chemistry of groundwater in the Silver Springs Bason, Florida. USGS Scientific Investigations Report 2004-5144. USGS. Reston, Va.

Pruvin, t. and L. Hussner. 2014. What Happens to Nitrogen in Soils. Texas A and M. Agrilife Extension. E-59, 6-01.

Reike, P. E., and B. G. Ellis. 1974. Effects of nitrogen fertilization on nitrate movement under turfgrass. P. 120-130. In: E. C. Roberts (ed). Proc. 2nd In. Turfgrass Res. Conf. Blacksburg, Va.

Sartain, J. L. Trenholm, E. Gilman, T. Obreza and G. Toor. 2013. Frequently Asked Questions About Landscape Fertilization for Florid- Friendly Landscape Ordinances. Univ. of Fl IFAS Extension publication # EN41115. http://edis.ifas.edu/wq143.

Snyder, G. H., B. J. Augustin, and J. M. Davidson. 1984. Moisture sensor-controlled irrigation for reducing N leaching in Bermudagrass turf. Agro. J. 76:964-969.

Trenholm, L. J. Unruh and J. Sartain. 2012. Nitrate Leaching and Turf Quality in Established Floratam and St. Augustinegrass. Journal of Env. Quality.Technical Report doi:10.2134,jeq2011.0183.

Tucker, W.A. and M.G. Diblin, R.A. Mattson, R.W. Hicks, and Y. Yang. 2014. Nitrate in shallow groundwater associated with residential land use in central florida. J. Environ. Qual. 43: 639-646.

Waymer, J. 2014. Costly and Creative Clean-Up Ideas For the IRL, Florida Today. 8/5/2014.

Waymer, J. 2014. Just What Caused This Mess? Florida Today. 3/4/2014.

Waymer, J. 2014. Did the Summer Fertilizer Ban Work? Florida Today. 10/5/14.

Wikipedia, 2014. http://en.Wikipedia.org/wiks/urea

Zarillo, G.H., T. Belanger, K. Zarillo, J. Rosario-Llantin and D. McGinnis. 2010. The Development of a Hydrologic Model of Mosquito Lagoon in Canaveral National Seashore. National Park Service Contract No. N5180070017. Ft. Collins, Co.