Revised Estimates of Nitrogen Inputs and Nitrogen Loads in the Wekiva Study Area

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Executive Summary

This report presents estimates of relative contributions of nitrogen to groundwater in the Wekiva Study Area. It is a follow-up to the report submitted by the Florida Department of Health in June of 2007 to the Governor. A goal of that study was to determine if OSTDS were a "significant source of nitrogen to the underlying groundwater relative to other sources".
The methodology and terminology of this report follows closely the previous Wekiva nitrogen assessments (MACTEC, 2007; Young, 2007). In particular, input is the amount of nitrogen that is released to or near the surface of the environment, while load is the amount of nitrogen that enters the ground or surface water. Figure 0-1 illustrates this distinction.

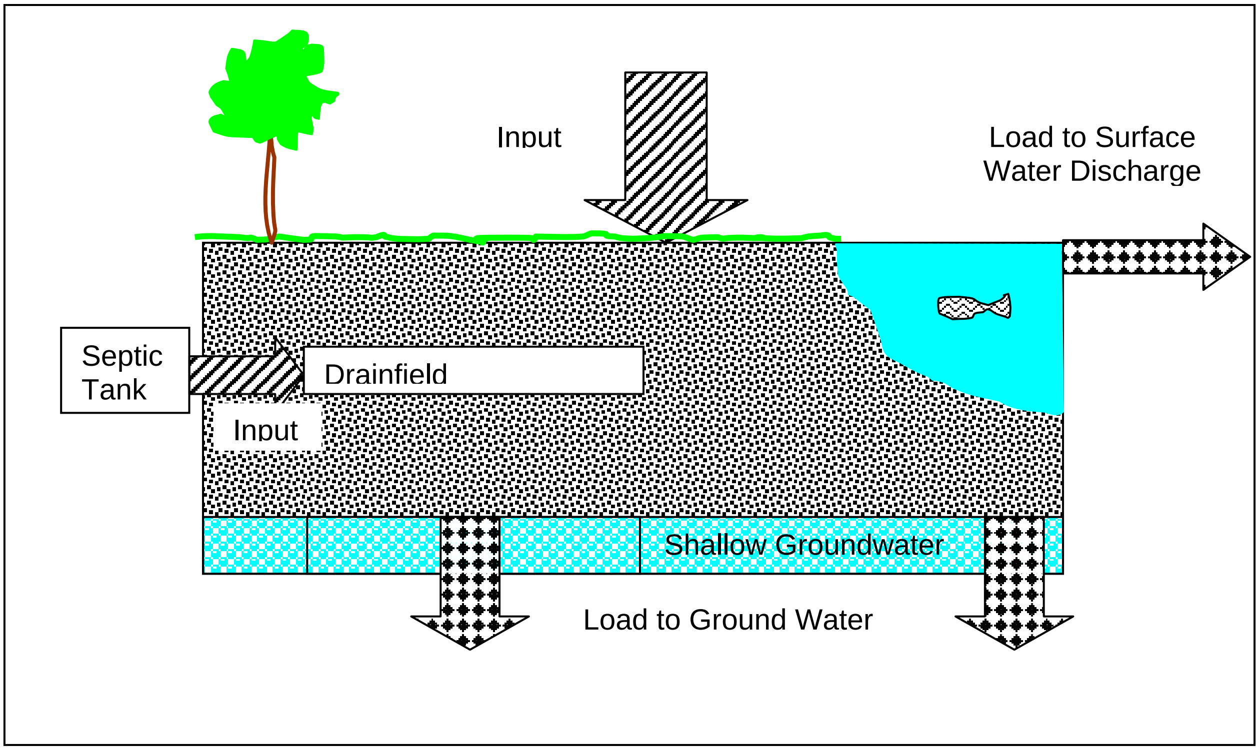

Figure 0-1. Conceptual sketch of distinction between inputs and loads.

Two issues raised in the 2007 report are addressed in this revised input estimate: First, the field work during the Department's study indicated a larger nitrogen contribution for an OSTDS than considered in the assessment (29 lbs/yr instead of 20 lbs/yr). Second, the estimated amount of fertilizer used in the Wekiva Study Area was twice the amount one would estimate based on pro-rating by area the total fertilizer sales registered by the Department of Agriculture and Consumer Services in Lake, Orange and Seminole Counties.

Inputs were determined by estimating atmospheric deposition, fertilizer use, livestock waste, and wastewater effluent discharged into the Wekiva Study Area. The revised relative contributions to nitrogen inputs to the Wekiva Study Area are shown in figure 0-2. The total input was estimated at 6,500 tons/yr or 5,900 metric tons (MT)/yr. Inputs are grouped together by land use category, except for wastewater and atmospheric deposition, which was uniform throughout the area. The figure illustrates that many sources, covered by a variety of jurisdictions, contribute to the nitrogen problem. The contribution by wastewater treatment facilities (WWTF) accounts already for nitrogen reduction accomplished there. Without restrictive nitrogen treatment standards for these facilities, the inputs could be about 1,800 MT/yr higher.

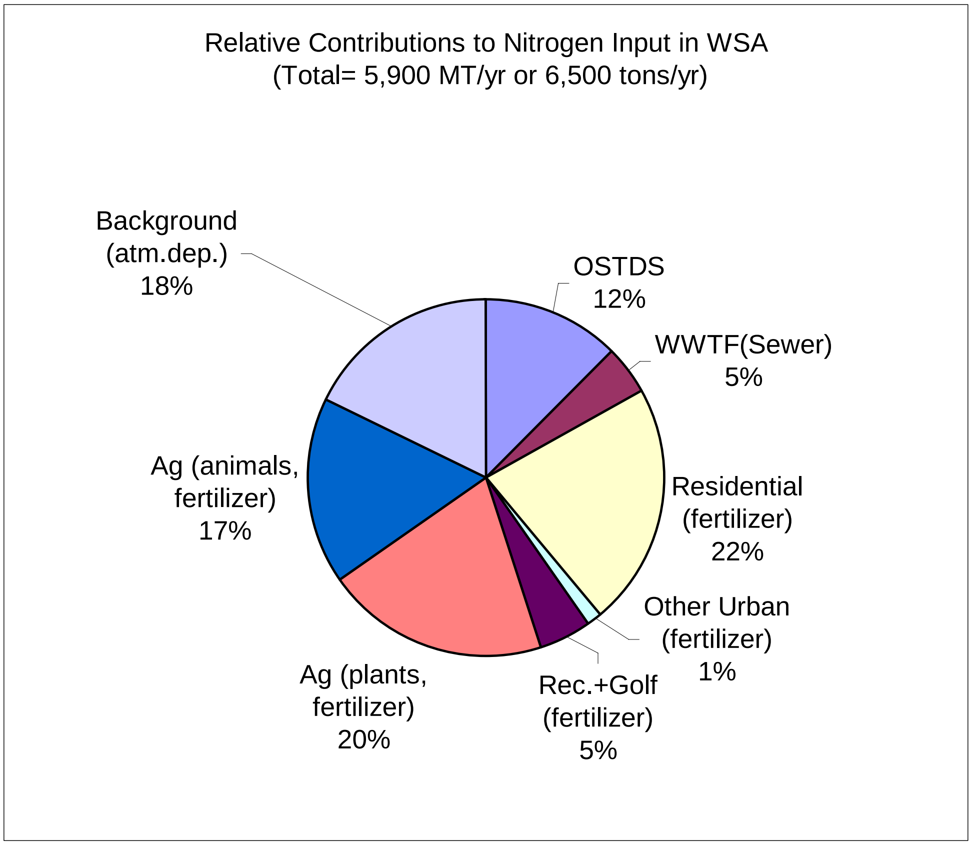

Figure 0-2. Relative contributions to nitrogen input by land use, wastewater and background.

Loads were generally determined by multiplying concentrations with flow rates. For land use classifications the concentrations were shallow groundwater concentrations and the flow was the groundwater recharge rate, which was with one exception obtained from the Groundwater flow model of the St. Johns River Water Management District. The exception was the agricultural tree crops land use classification, for which best management practices irrigation resulted in a much larger flow and therefore loading rate. Loads for each land use were adjusted for a hypothetical background load determined by multiplying a background concentration of 0.2 mg/L total nitrogen with the groundwater recharge rate.
Wastewater loads were determined by considering the concentration reduction observed under the discharge areas relative to concentrations and flows that determined the input. The concentration reduction (40%) for OSTDS was based on the results of the 2007 Wekiva Study field work.

Figure 0-3 presents the estimate for relative contributions to groundwater loading in the Wekiva Study Area. The shift in relative contributions is a result of the apparent treatment effectiveness of soil. For low nitrogen and water application rates, such as for atmospheric deposition, soil removed about 95% of the nitrogen, while for high nitrogen and water application rates, such as for rapid infiltration basins, OSTDS and tree crops, soil removed half or less of the nitrogen. This indicated that the amount of irrigation is an important loading factor that should be addressed in future studies.

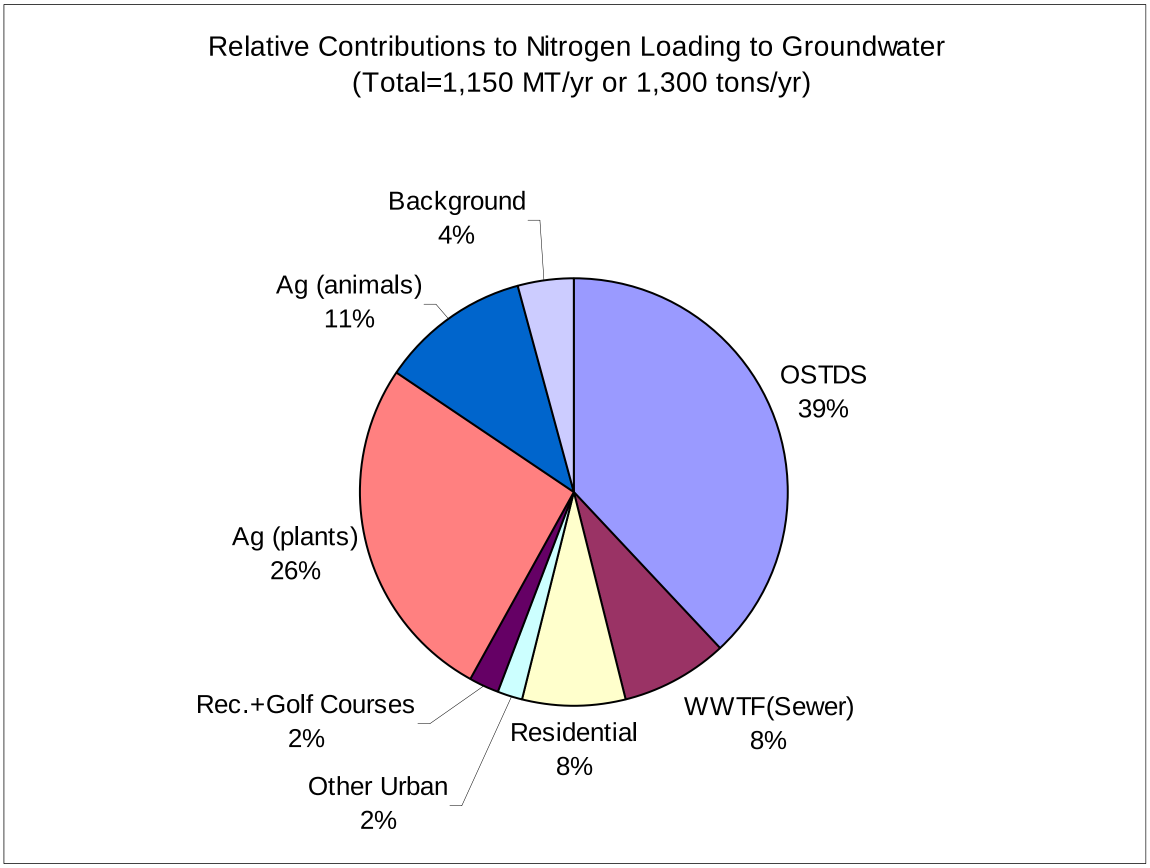

Figure 0-3. Relative contributions to total nitrogen loads to groundwater.

In addition, an estimated 600 tons/yr or 550 MT/yr of nitrogen were discharged via stormwater runoff. Overall, these two estimates indicated that about 70% of the nitrogen input to the Wekiva Study Area is not transferred to ground or surface water.

In order to reduce nitrogen loads to groundwater and surface water in the Wekiva Study Area, better management practices for sources are needed and future population growth must be addressed. This includes OSTDS, for which the Department has proposed nitrogen reduction strategies both for existing and new systems.

1 Introduction

The objective of this report is to present revised estimates of relative contributions of total nitrogen to waters in the Wekiva Study Area. The 2007 Wekiva Study by the Florida Department of Health assessed nitrogen contributions by onsite sewage treatment and disposal systems (OSTDS) to the Wekiva Study Area. The assessment focused on total nitrogen. A goal of the study was to determine if OSTDS were a “significant source of nitrogen to the underlying groundwater relative to other sources”. This included an assessment of the relative contribution of nitrogen inputs by onsite systems compared to other sources (Young, 2007). As the summary report (Briggs et al., 2007) pointed out, two pieces of information were not considered in that assessment: First, the field work during the Department’s study indicated a larger nitrogen contribution for a typical OSTDS than considered in the assessment; Second, the estimated amount of fertilizer used in the Wekiva Study Area, which comprises only parts of Lake, Orange and Seminole Counties, appeared unlikely high relative to the total fertilizer sales registered by the Department of Agriculture and Consumer Services in these three counties.

The methodology and terminology of this report follows closely the previous Wekiva nitrogen assessments (MACTEC, 2007; Young, 2007). In particular, input is the amount of nitrogen that is released to or near the surface of the environment, while load is the amount of nitrogen that enters the ground or surface water. Either inputs or loads quantify the variety of sources of nitrogen to the underlying groundwater. For most sources, the difference between inputs and loads reflects largely treatment processes in the soil. Because of this, loads characterize the impact on groundwater better than inputs. Figure 1-1 illustrates this distinction.

The Wekiva Study Area encompasses 305,000 acres in Lake, Orange and Seminole Counties in central Florida. While boundaries are not hydrological they encompass most of the springsheds and surface watersheds that contribute water to the Wekiva River before it merges with the St. Johns River. Figure 1- 2 shows the location of the Wekiva Study Area in relation to surface drainage basins and springs recharge areas.

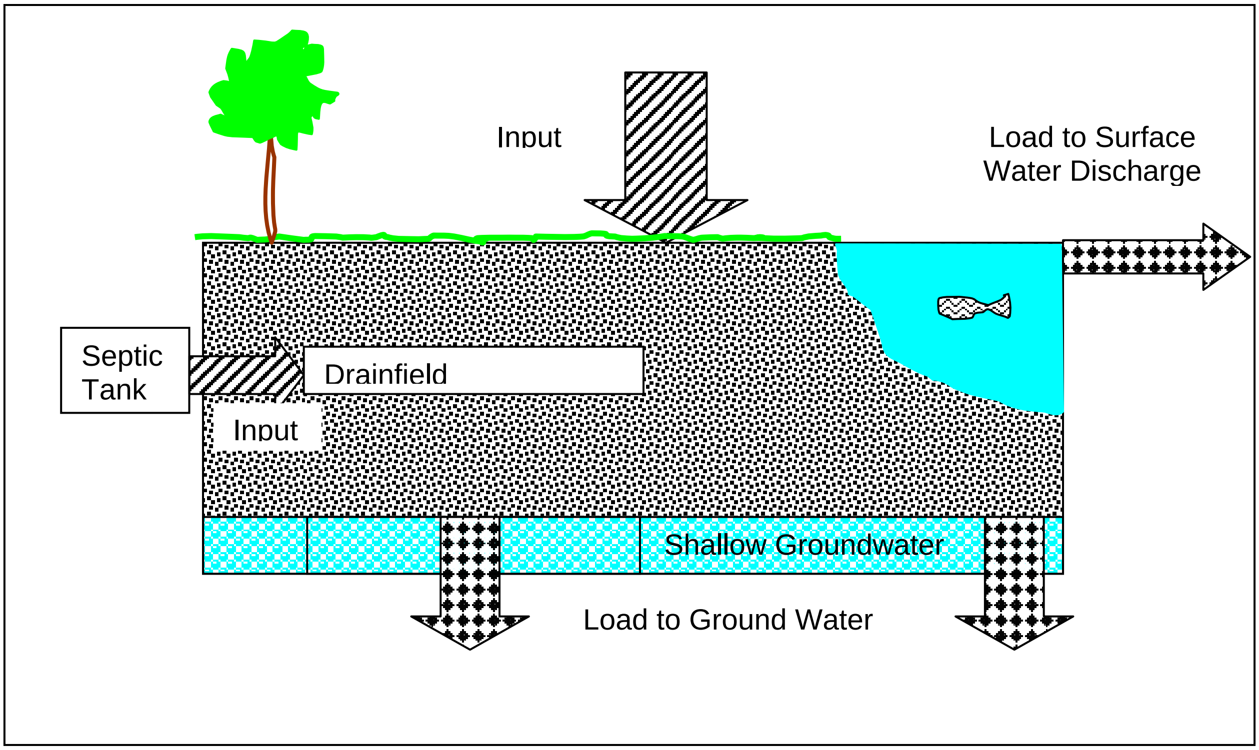

Figure 1-1. Conceptual sketch of distinction between inputs and loads.

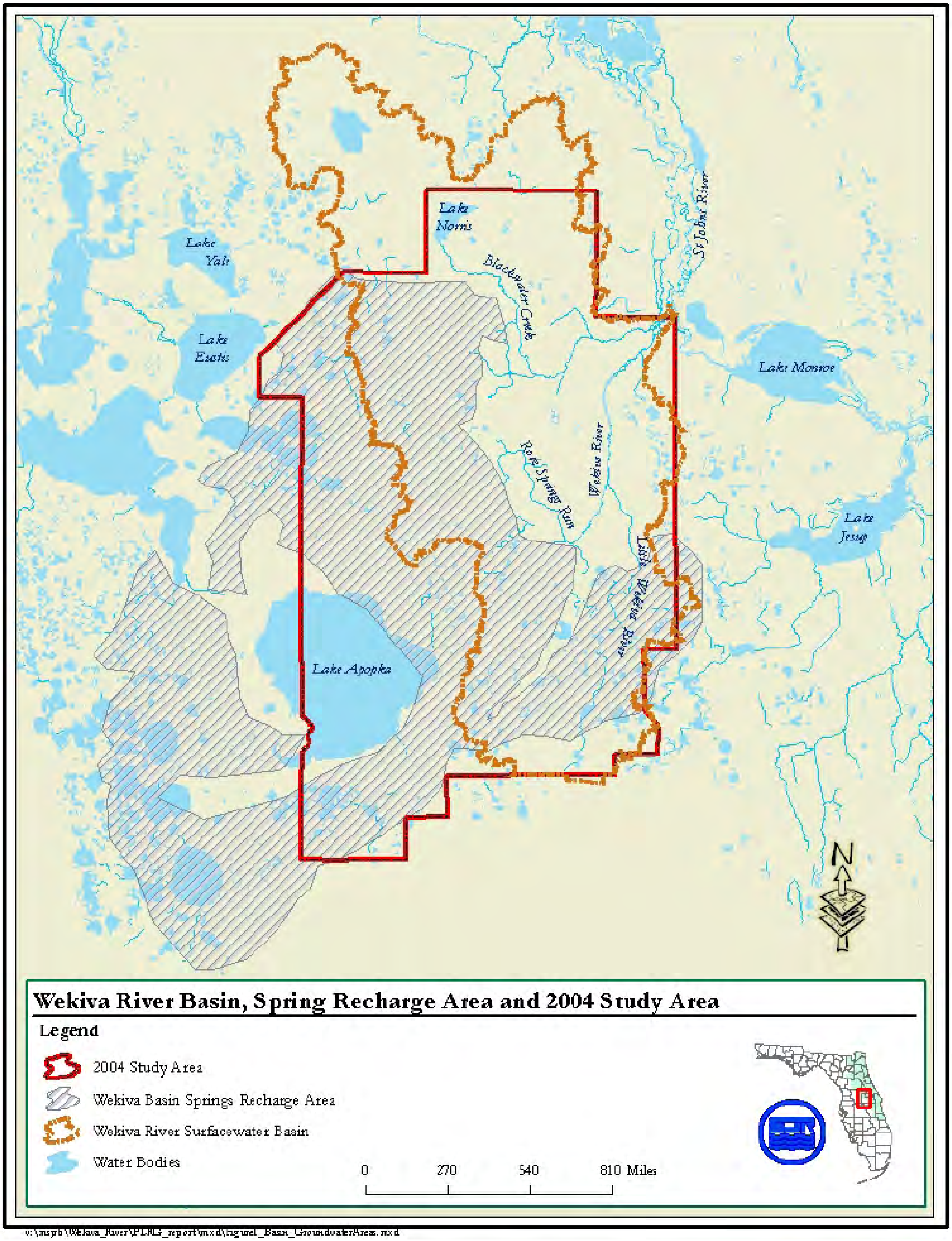

Figure 1-2. Location of Wekiva Study Area relative to springs recharge area and surface drainage basins (from Mattson et al., 2006).

2 Input Assumptions

2.1 Input by OSTDS

The input per system for a typical onsite sewage treatment and disposal system serving 2.6 people, the average household size, was taken as 29 lbs/year. This was based on the mid-range per-capita nitrogen release from the septic tanks observed in the DOH Wekiva Study field work. Such an input was consistent with other recent literature surveys of nitrogen discharged by septic systems. Data supporting this revision were discussed in the task 4 report of the Department's 2007 Wekiva Study (Roeder, 2007). For 55,417 OSDTS in the Wekiva Study Area at the end of 2005 this results in an estimated input of 730 MT/yr or 804 tons/year.

An estimate of how nitrogen inputs by OSTDS have developed over time was obtained by combining census data on house ages in the Wekiva Study Area with onsite permit information and is shown in figure 2- 1. The number of onsite systems estimated for 2005 were prorated by the age of the structures in the WSA given in census files, under the assumption that 91% of all systems were present by the end of 1998.

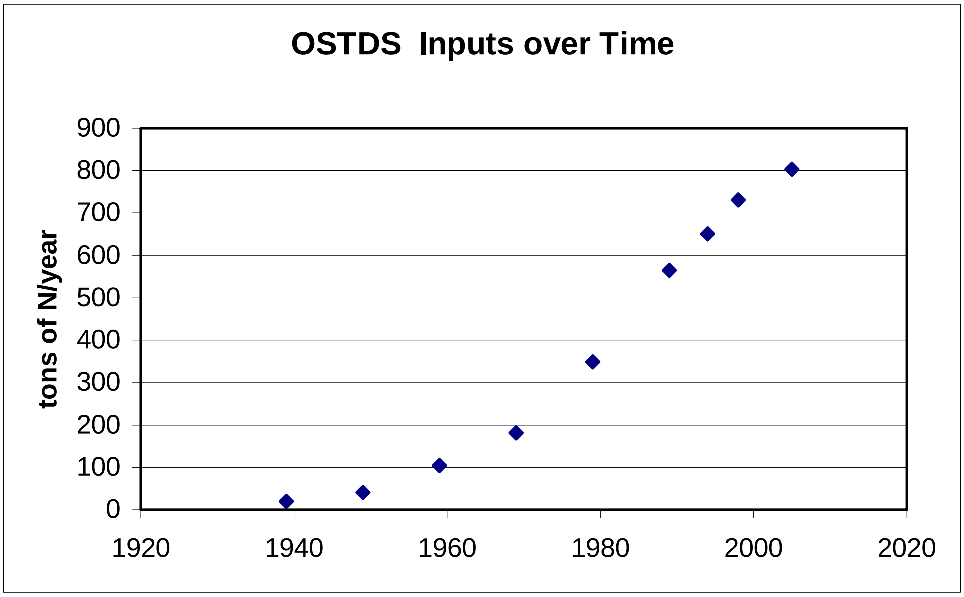

Figure 2-1. Estimated nitrogen inputs from OSTDS in the Wekiva Study Area.

2.2 Input by Sewer (Centralized Wastewater Treatment Facilities):

The estimates for inputs by centralized wastewater treatment facilities are: 28.8 MT/yr that are discharged to surface water; 72.6 MT/yr discharged to groundwater, and 164.7 MT/yr reused, for a total of 266 MT/yr or 293 tons/year. During the previous Wekiva Study Area assessment (Young, 2007), discharge flows and concentrations of wastewater treatment facilities in the Wekiva Study Area were reviewed. Information was available for approximately 80% of permitted capacity. The estimate prorated inputs based on permitted capacity for treatment systems with missing information. It also assumed that 10% of discharge by the Conserv II facility, a large regional facility for the distribution of treated sewage, occurs in the Wekiva Study Area.

A consistency check is achieved by comparison between this estimate and a coarse estimate of treated sewage generated. The number of households on not on onsite systems (157,000) multiplied by an annual input of 29 lbs/household and an average treatment effectiveness of 87% would result in about the same input. The average total nitrogen discharge concentration for wastewater treatment facilities with data was 6.1 mg/L. The sewer input calculation did not consider losses due to exfiltration or import or export of nitrogen from or to areas outside of the WSA.

A similar estimate allowed an assessment of how large nitrogen inputs from wastewater would be if not for centralized wastewater treatment facilities. Without this treatment 2,100 MT/yr of nitrogen instead of 266 MT/yr would be discharged from sewers in addition to the nitrogen from onsite systems.

2.3 Input by Atmospheric Deposition:

The estimated nitrogen input to WSA from atmospheric deposition was 1,050 MT/year or 1,150 tons/yr. Compared to the MACTEC (2007) report, the estimate of nitrogen input from atmospheric deposition was changed in two ways: Data from a station in the Orlando area were used to estimate wet deposition of nitrate and ammonia rather than only nitrate. Nickerson and Madsen (2005) provided trend functions for wet ammonia and nitrate deposition recorded in Orlando from 1978 to 1997. Ammonia did not show a linear increase over time, with 1.02 meq/m^2 month or 1.7 kg/ha.yr as the constant value. Nitrate showed a positive trend for the monthly wet deposition: $q= 1.33+0.044*(year-1978)\ meq/m^2 month$, which results in a yearly wet deposition of 4.2 kg/ha yr for the end of 2004. The estimated wet total nitrogen deposition is then 5.94 kg/ha year. Dry deposition was assumed to be 30% of the total deposition, the average of the 15% recorded by the CASTNET Indian River Lagoon monitor and the 44% reported by Poor, et al. (2001) for Tampa Bay, or 2.55 kg/ha year. This fraction is similar to 37% dry deposition cited by Dixon (1994) for the Gainesville area in a review of nitrogen deposition. Figure 2-2 shows the regressions of wet deposition with seasonal variability and the estimated total deposition over the period 1978-2004.

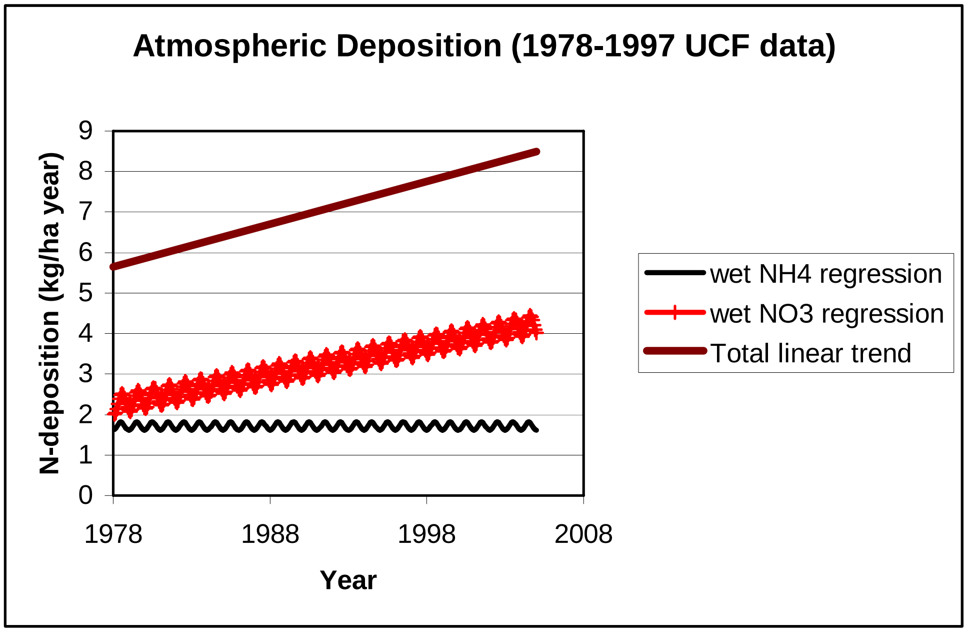

Figure 2-2. Estimated development of yearly wet and total nitrogen deposition based on 20-year observations at University of Central Florida. Regressions reported by Nickerson and Madsen (2005)

Thus, the total nitrogen from atmospheric deposition was estimated to be 8.5 kg/ha year. This value was higher but within the error bounds reported by Poor et al. (2001) for the Tampa Bay, and somewhat higher than the value of 7.6 kg/ha yr given as an estimate for urban bulk loading by Dixon (1994). It is somewhat lower than the 11.4 kg/ha yr obtained by Heyl (1992) for Sarasota Bay.

The input from atmospheric deposition was calculated by multiplying the deposition rate by the area for each land use/land cover classification. .

2.4 Inputs by Fertilizers

2.4.1 Fertilizer Sales

The nitrogen fertilizer sale estimates for the WSA are 1,470 tons/year (1,300 MT/yr) for farm use and 1,980 tons/year (1,800 MT/yr) for non-farm use, for a total of 3,450 tons/year (3,100 MT/yr). This estimate was developed from fertilizer sales data, published by the Department of Agriculture and Consumer Services (http://www.flaes.org/). These data included nitrogen sold and a split between farm and non-farm use of fertilizer for each of the three Wekiva counties for the time period 1998-2007. Non-farm total N sales increased steadily over this period by about 520 tons/year. The average non-farm fraction over the ten-year period was 47%. This is illustrated in Figure 2-3.

In order to estimate how much fertilizer was used in the Wekiva Study Area the following approach was used:
Farm fertilizer nitrogen, estimated as the county farm-use fraction of fertilizer multiplied by county nitrogen sales, was prorated by the county's total area in the Wekiva Study Area. Non-farm fertilizer nitrogen, estimated as the county non-farm use fraction of fertilizer multiplied by county nitrogen sales, was prorated by the county's population in the Wekiva Study Area. Because population is relatively concentrated in the Wekiva Study Area, this approach leads to somewhat higher fertilizer use estimates than an approach that only considers total area as suggested by Anderson (2006). The consistency of the tons/person of non-farm fertilizer sales between the three counties supports the assumption that non-farm uses, such as residential fertilization, are more dependent on the number of people than on the area. Table 1 shows the resulting fertilizer sales for the Wekiva Study Area.

A further consistency check was possible by comparing the census estimate for the population increase in the three counties between 2000 and 2006 (U.S. Census Bureau, 2007) with the increase in non-farm fertilizer use. The population increased by about 44,800 person per year between 2000 and 2006. Multiplying the number of people by the estimate for per capita non-farm nitrogen use of 0.0117 tons/capita year resulted in an estimated increase of 520 tons/year in non-farm use, which matched the observed increase in non-farm nitrogen sales.

The resulting nitrogen fertilizer use estimates for the WSA were 1,470 tons/year (1,300 MT/yr) for farm use and 1,980 tons/year (1,800 MT/yr) for non-farm use, for a total of 3,450 tons/year (3,100 MT/yr). This was noticeably higher than prorating a gross average area sales rate to the Wekiva Study Area, (2,700 tons/year), or even a county area-weighted average (3,000 tons/year) for the Wekiva Study Area. Still, a comparison with the estimates for fertilizer inputs based on application rates as given in the previous assessment suggests that the application rates based approach results in estimates higher by a factor of close to two (6,300 tons/ year for WSA). This discrepancy occurred similarly in the MACTEC study area where simple area-prorating of fertilizer sales lead to an estimated 3,700 tons/year sold and the application rate-based estimate resulted in an estimate of 8,400 tons/year nitrogen applied.

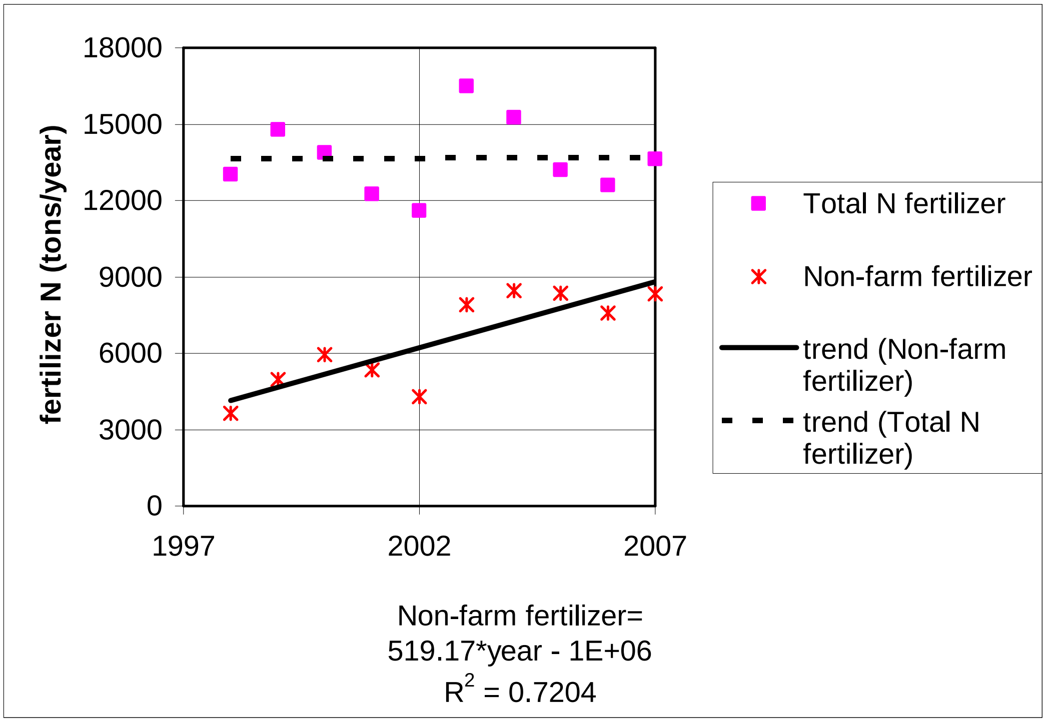

Figure 2-3. Farm and non-farm sales of total nitrogen fertilizer in the three counties, showing an increase by 520 tons/year for non-farm fertilizer between 1998 and 2007.

Table 1. Estimates of fertilizer use in the Wekiva Study Area, based on 1998-2007 average fertilizer sales, areas and 2000 populations.

Area	County Area from GIS (acres)	Area in WSA (acres)	Fraction of County in WSA	County Farm Fertilizer (tons/year)	WSA Farm Fertilizer (tons/year)	tons/ acre year
Lake	743,040	101,395	0.14	2,262	309	0.0030
Orange	645,120	163,731	0.25	3,712	942	0.0058
Seminole	221,440	39,655	0.18	1,214	217	0.0055
Total	1,609,600	304,780		7,188	1,468	0.0048
Population	County Population 2000 from census	Population in WSA 2000	Fraction of County in WSA	County Non-Farm Fertilizer (tons/year)	WSA Non-Farm Fertilizer (tons/year)	tons/ person year
Lake	210,528	98,644	0.47	1,204	564	0.0122
Orange	896,344	259,774	0.29	3,424	992	0.0132
Seminole	365,196	127,054	0.35	1,221	425	0.0096
Total	1472068	485,472		5,849	1,981	0.0117

2.4.2 Effective Fertilizer Application Rates

To determine fertilizer inputs by land use, application rates can be multiplied by the fertilized area. In order to address the lower overall fertilizer numbers a modification in the approach was necessary. The previous model assumed that a fertilizer application rate derived from literature values applied to all area of a land use not classified as impervious (covered by hard surfaces). As no new literature was identified that would shed more light on application rates, the question was rephrased to assess if the fraction of a land use classification to which the application rate applies could be less than previously assumed.

The split between farm and non-farm use does not strictly align with land uses. In particular, “nurseries” is given as an example for fertilizer classified as non-farm use, even though the land use is agricultural (http://www.flaes.org/). DACS-staff provided guidance on the fertilizer category likely applied to the various land uses (William Cox, written communication). Fertilizer classified as farm and as non-farm use may be used in nurseries, tree nurseries, ornamentals, and floriculture. Because nurseries could use a sizable proportion of non-farm fertilizer sales, this issue introduces some uncertainty about the relative contribution of agriculture and non-agriculture fertilizer inputs. The Department of Agriculture and Consumer Services (DACS) is developing improved methods of capturing information to provide more insight into fertilizer use by user group in the future. For the purposes of this revised estimate, fertilizer use on these land use classifications were split evenly between farm and non-farm use.

The fraction of the area fertilized depended on two factors, how much area was impervious and how much of the pervious area was actually fertilized.

The first factor concerned perviousness as an indicator of usable area for plants that might need fertilizer. The stormwater model WMM, which was applied by CDM (2005) in the Wekiva area, utilizes directly connected impervious area (DCIA), the fraction of the land surface area that is directly connected to the storm water drainage system. The total impervious area can be larger by a factor of about 2 (Rouge River National Wet Weather Demonstration Project, 1998, p.18). Lee and Heaney (2002) reported both DCIA and total impervious areas from four sites in south Florida, which also showed larger impervious fractions than directly connected impervious area. Values for impervious fractions for residential land uses were based on Lee and Heaney’s values. For other land uses the maximum of the DCIA-value given in the CDM (2005) stormwater report and the impervious fraction given in the MACTEC (2007) report were utilized.

The second factor indicated how much of the remaining pervious area was fertilized. The previous assessments (MACTEC, 2007; Young, 2007) assumed that all pervious areas in non-agricultural land uses would be fertilized at the rate for turf grass. This approach was followed here for golf-courses. For other land uses it was assumed that only a fraction of the remaining area was fertilized. For example, tree groups may be fertilized less and canopy cover in Broward county has been estimated between 11 and 45 % (Morrow et al. 2001).

The fraction of fertilized pervious area was adjusted separately for agriculatural and non-agricultural land use classifications in 5% increments until the farm and non-farm fertilizer use estimates were within 4% of the sales estimate. This resulted in an estimate that 60% of non-agricultural pervious area and 85% of agricultural pervious land area could be fertilized at the assumed application rates. Pervious fraction multiplied by turf grass fertilization fraction yields an overall estimate of what fraction of each non-agricultural land use could be covered by turf grass. While the fertilizer application rate was based on turf grass, it should be noted that other landscaping and ornamental plants were included in this use and not captured separately.

As a consistency check, these residential fertilizer estimates were compared to more direct estimates of the lawn area.

Hodges et al (1994, p.79) estimated 1.1 acre of lawn per single family household in Florida. If one applied this estimate to the 120,000 detached single unit structures present in the Wekiva Study Area in 2000 according to census data, 132,000 acres would be covered by lawn. This is about twice the total land use area for low and medium density residential land uses combined. Obviously, the average lawn must be smaller in the Wekiva Study Area. The MACTEC impervious assumption estimates resulted in an average lawn size of 0.4 acres per detached structure. The pervious area and fertilized fraction estimates given for this revision resulted in an average fertilized area for low and medium density residential areas of about 0.17 acre. This is similar to a national average lawn size of 0.2 estimated by Vinlove and Torla (1995). Such an average could be comprised of smaller lawns in medium density residential land uses (2-5 units/acre) and larger lawns in low density residential land uses. Phelps (2004) cited results of an evaluation of aerial photographs in Marion County by Jones et al (1996) that indicated that 34% of high density residential land use area was covered by turf, 66% of medium density, and 17% of low density. These ratios would result an average lawn size of 0.28 acre for low and medium density residential land uses, about half way between the MACTEC and this revised estimate. If the fertilized area is indeed larger then estimated here, then the application rate would have to be smaller for fertilizer use to remain within the fertilizer sales statistics.

2.4.3 Estimated Fertilizer Nitrogen Input

After the revisions discussed above, the total estimated fertilizer input was 3,200 MT/year or 3,500 tons/year. This was close to the 3,130 MT/yr or 3,450 tons/year estimated as the prorated county nitrogen sales data. Figure 2-4 shows the distribution of fertilizer by land use. For this graphic, low, medium and high density land uses were aggregated into a residential land use category.

The estimate suggested that around 2002 agricultural fertilizer use was the largest source of nitrogen fertilizer applied in the Wekiva Study Area, followed by residential fertilizer. The fertilizer sales over the ten-year period indicated a marked increase in the non-farm fraction while sales overall remained constant. This indicated that increasing urbanization is decreasing agricultural fertilizer inputs but does not decrease fertilizer inputs overall.

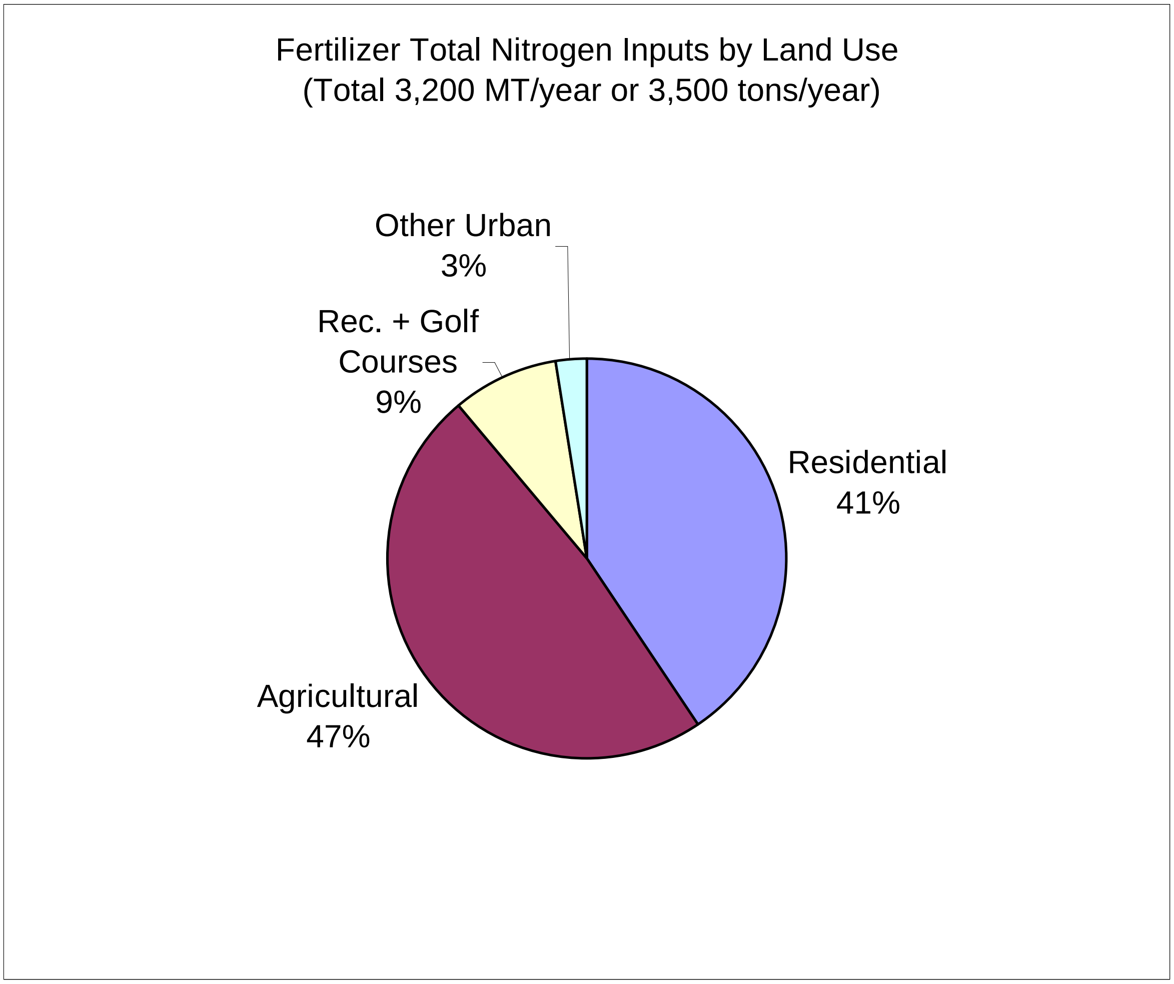

Figure 2-4. Distribution of estimated fertilizer nitrogen input between land uses.

2.5 Animal Waste:

The input assumptions of the previous assessments (MACTEC, 2007; Young, 2007) remained the same. The resulting estimate for the animal waste contribution to the Wekiva Study Area was 650 MT/yr or 720 tons/year nitrogen. This estimate only considered livestock but not wildlife or pet contributions, for which no literature sources were found.

3 Relative Contributions to Inputs

3.1 Inputs without consideration of centralized wastewater treatment

A first approach to input assessment was an estimate of nitrogen that enters the land surface before consideration of the effectiveness of centralized wastewater treatment facilities. This includes fertilizer sales, all wastewater before treatment, atmospheric deposition, and live stock waste. The contributions of these inputs are shown in figure 3-1 and table 2. Fertilizer is the largest input, followed by human wastewater.

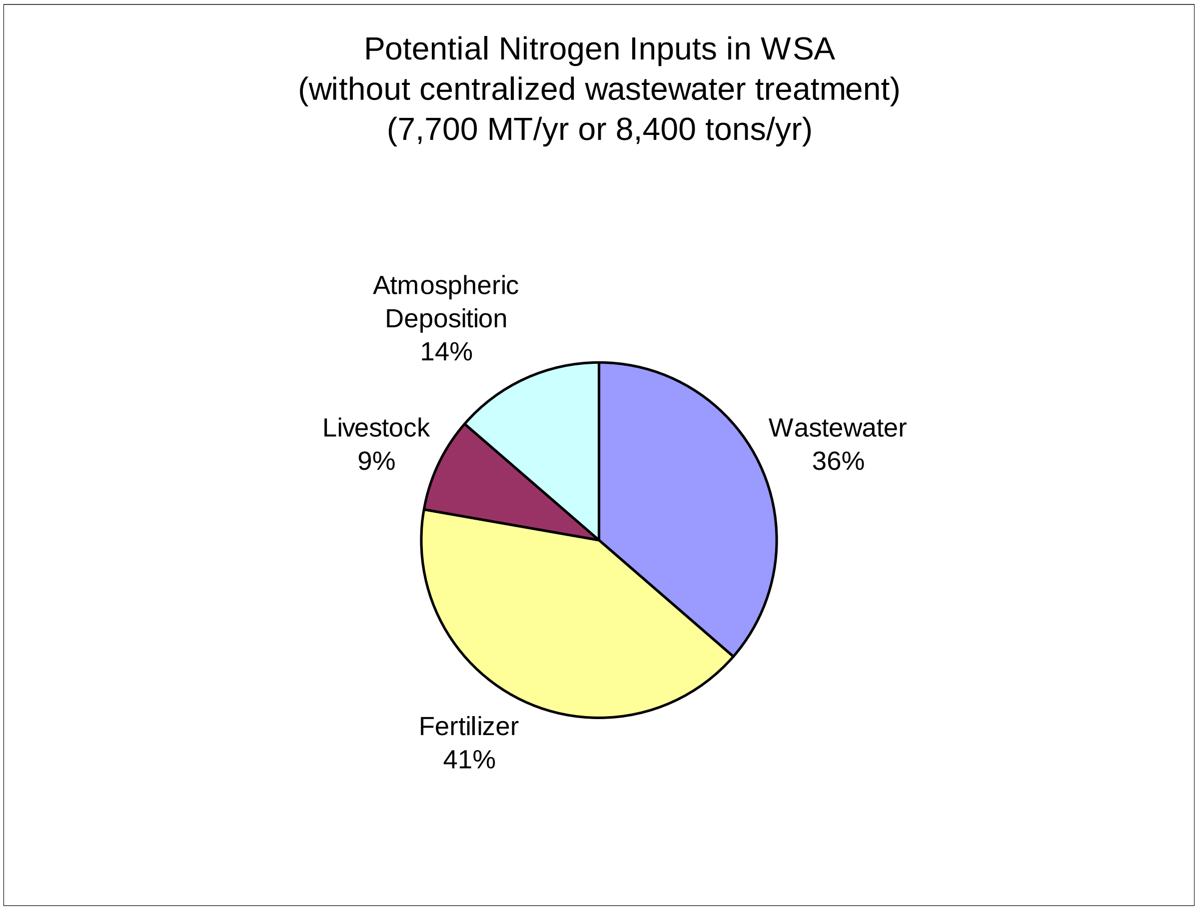

Figure 3-1. Relative contributions to overall nitrogen inputs in the Wekiva Study Area, without consideration of centralized wastewater treatment effectiveness.

Table 2. Nitrogen inputs in the WSA without consideration of centralized wastewater treatment.

	Input (MT/yr)	Input (tons/yr)
Wastewater	2,797	3,080
Fertilizer	3,171	3,492
Livestock	653	719
Atmospheric Deposition	1,048	1,154
Sum	7,669	8,446

3.2 Inputs including wastewater treatment facilities

Upon consideration that centralized wastewater treatment facilities control already part of the potentially available nitrogen, the picture shifted. The difference between figure 3-1 and 3-2 represents the effectiveness of centralized wastewater treatment, which effect a reduction of over 25% of nitrogen input between these estimates.

The estimated input of 5,900 MT/yr nitrogen was about 27% less than the 8,100 MT/yr estimated during task 3 of the DOH Wekiva Study (Young, 2007). The reduction was largely due to the consideration of fertilizer sales in estimating this input, which resulted in a 45% reduction of this input. OSTDS input increased by 45% with the inclusion of results from the 2007 DOH Wekiva Study. Of the inputs, OSTDS, atmospheric deposition, and non-farm fertilizer use had increasing tendencies. Fertilizer sales overall appeared to remain at a constant level. For livestock and sewer no historic data were researched.

Figures 3-2 and 3-3 and tables 3 and 4 present the estimated inputs released to the waters and soils of the Wekiva Study Area. The difference between the two presentations is in the role of land use. Looking ahead to the loading estimate, all inputs on a land use (except wastewater and a natural background) will result in a common loading to water. To make inputs and loads comparable and to provide somewhat more detail for management discussions it was considered helpful to aggregate by land use. The following categories were used: residential (low, medium, high), background (atmospheric deposition and inputs from extensively managed land uses, such as open range, upland forest), other urban (commercial, institutional, transport, utilities, extractive), recreational and golf, plant agriculture (all crops), animal agriculture (all pasture, horse farms, aquaculture, feeding operations).

4 Nitrogen Loading

As the MACTEC report (2007) outlined, three pathways are distinguished in this assessment of loadings. The loading mass rates are estimated as the product of flow and concentration. Stormwater runoff and recharge, or percolation of a part of rainfall to groundwater, are the two pathways that transport diffuse sources as a function of land use. For these diffuse loads, estimated concentrations, which vary by land use, and estimated flows, which vary by land use or location, were multiplied with each other. For more identifiable sources, in particular wastewater, the mass rate of loading was estimated as a fraction of the input, which was equivalent to calculating the discharge flow times a commonly observed reduction in concentration.

Anderson (2007), in commenting on the MACTEC-report suggested that “the relative contributions of each nitrogen source should be based on estimated inputs until such time that field data is available to more accurately calculate loadings from each source in a consistent fashion”. The consistency concern related apparently chiefly to the estimation of flow rates as illustrated by his example in which local groundwater concentrations under a drainfield were multiplied by a diffuse recharge rate, thereby ignoring the available information on local wastewater flow out of a drainfield. A drawback of a loading contribution estimate based solely on input information is that it assumes that soil is equally effective in removing inputs from various sources and along various transport pathways. Such a simplifying assumption disregards much information regarding both concentration and flow.

The following presents a loading estimate based on current information. As additional information becomes available, such as results of additional inquiries in residential fertilizer fate and transport, this estimate can be updated. The loading estimate may also point towards areas where additional information can be most useful.

Table 3. Nitrogen inputs in the Wekiva Study Area by source

Source	Input (MT/yr)	Input (tons/yr)
OSTDS	730	804
WWTF(sewer)	266	293
Fertilizer	3,171	3,492
Livestock	653	719
Atmospheric Deposition	1,048	1,154
Sum	5,868	6,462

Table 4. Nitrogen inputs in the Wekiva Study Area by land use, wastewater, and background

Land Use	Input (MT/yr)	Input (tons/yr)
OSTDS	730	804
WWTF(Sewer)	266	293
Residential (fertilizer)	1,290	1,421
Other Urban (fertilizer)	82	90
Rec.+Golf (fertilizer)	274	302
Ag (plants, fertilizer)	1,194	1,315
Ag (animals, fertilizer)	984	1,083
Background (atm.dep.)	1,048	1,154
Sum	5,868	6,462

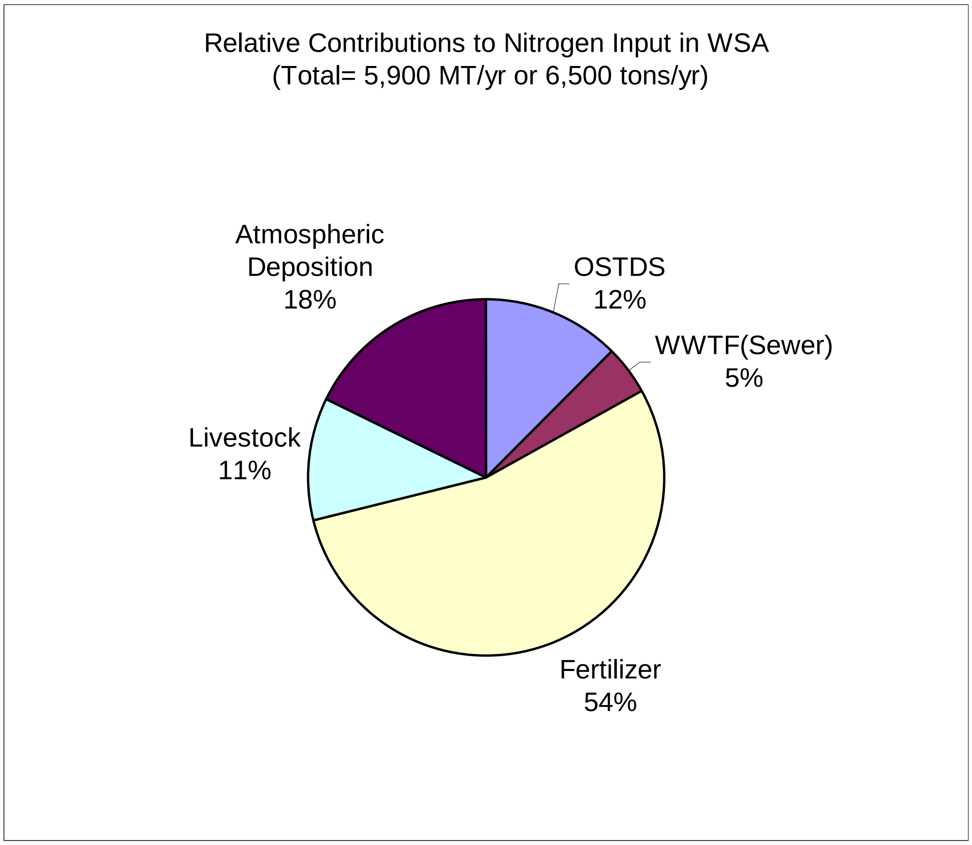

Figure 4-1. Estimated relative contributions to nitrogen input in the Wekiva Study Area.

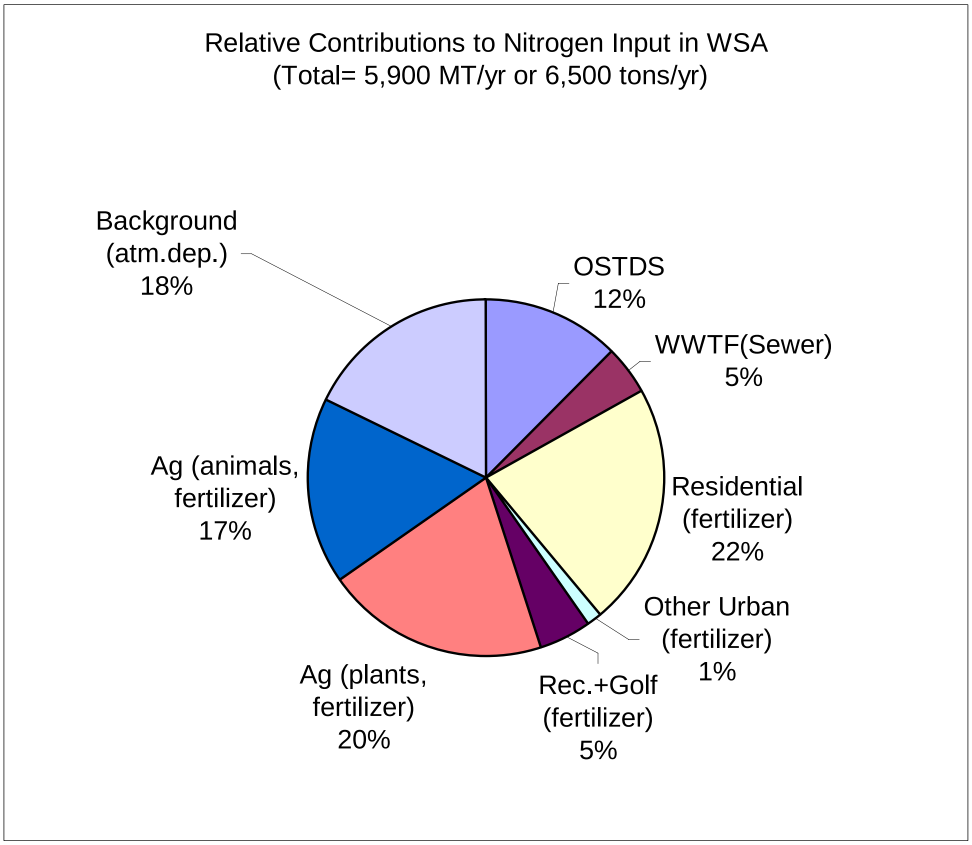

Figure 4-2. Relative contributions to nitrogen input by land use, wastewater and background.

4.1 Water budget for the Wekiva Study Area

The first step in the loading assessment was an estimate of the water flows involved in transport of nitrogen. This was accomplished by an approximate water budget for the Wekiva Study Area. To allow comparisons between areas and account for the fact that the WSA has political and not hydrological boundaries, the amount of water was conveniently expressed as the annual depth of water on top of the area. CDM (2005) gave an average precipitation of approximately 50.3 in/yr. Average groundwater recharge values by land use were obtained by Dr. Young in the course of task 3 of the 2007 Wekiva Study from an overlay of land use and recharge values for the regional groundwater flow model of the St Johns River Water Management District. The area-weighted average recharge was 7.6 in/year. This value was consistent with results by Wanielista et al (2005), who estimated an average spring discharge of at least 7 in/yr in the 450 square miles of springshed.

Estimates for non-spring discharge by rainfall and stormwater runoff or possibly diffuse groundwater discharge were obtained by looking at the gaging station of the Wekiva River at SR 46, where the Wekiva River leaves the Wekiva Study Area, River Basin and MACTEC's area of analysis. Wanielista et al. (2005) estimated that at least 58% of the flow at this point stems from spring discharge. This left about 42% of the discharge that could be attributed to rainfall and stormwater runoff, which was 8.7 in/year. The value was very similar to 9.1 in/yr found by Wanielista et al. (2005) for part of the Little Wekiva River watershed within the Wekiva Study Area.

The Wekiva Study Area extends further west than the surface watershed of the Wekiva River, into an area where recharge is more important than runoff. Mattson et al. (2006) estimated the fraction of springs discharge in the Wekiva River flow higher. Both facts suggested that 8.7 in/year is an upper bound of surface water discharge that is not stemming from springs.
The remainder of the water, 50.3-7.62-8.74 = 33.9 in/yr, was an estimate for the amount of water returned to the air as evapotranspiration. These values for spring discharge and evapotranspiration were similar to those obtained for water balances for springs on the west coast of Florida (Knochenmus and Yobbi, 2001). In that area no surface water discharge was present, and instead a similarly large diffuse groundwater flow provided outflow from the area.

Water supply was excluded from this gross water balance. For the purposes of this assessment the assumption was that human water use is supplied by water from the Wekiva Study Area and returned to the Wekiva Study area in a closed loop. Thus, this closed loop had on the scale of the Wekiva Study Area no net effect on the water balance and only the effect of flushing nitrogen into the groundwater.

For domestic use resulting in wastewater the amount of water could be quantified. The number of people living in the Wekiva Study Area (485,500 in 2000) multiplied by a daily per capita use of 68.6 gallons resulted in a yearly water use estimate of 12.2 billion gallons, or about 1.5 in/year over the Wekiva Study Area.

Water use for agricultural irrigation was only estimated for tree crops (discussed below). The irrigation for this land use was estimated to recycle 0.7 in/year water over the entire Wekiva Study Area. If other land uses also experienced much irrigation the amount of water recycling through the Wekiva Study Area would become more important relative to the amount of water that flows simply from recharge areas to the springs and river. This effect was not assessed here in any more detail, but could be included in further studies.

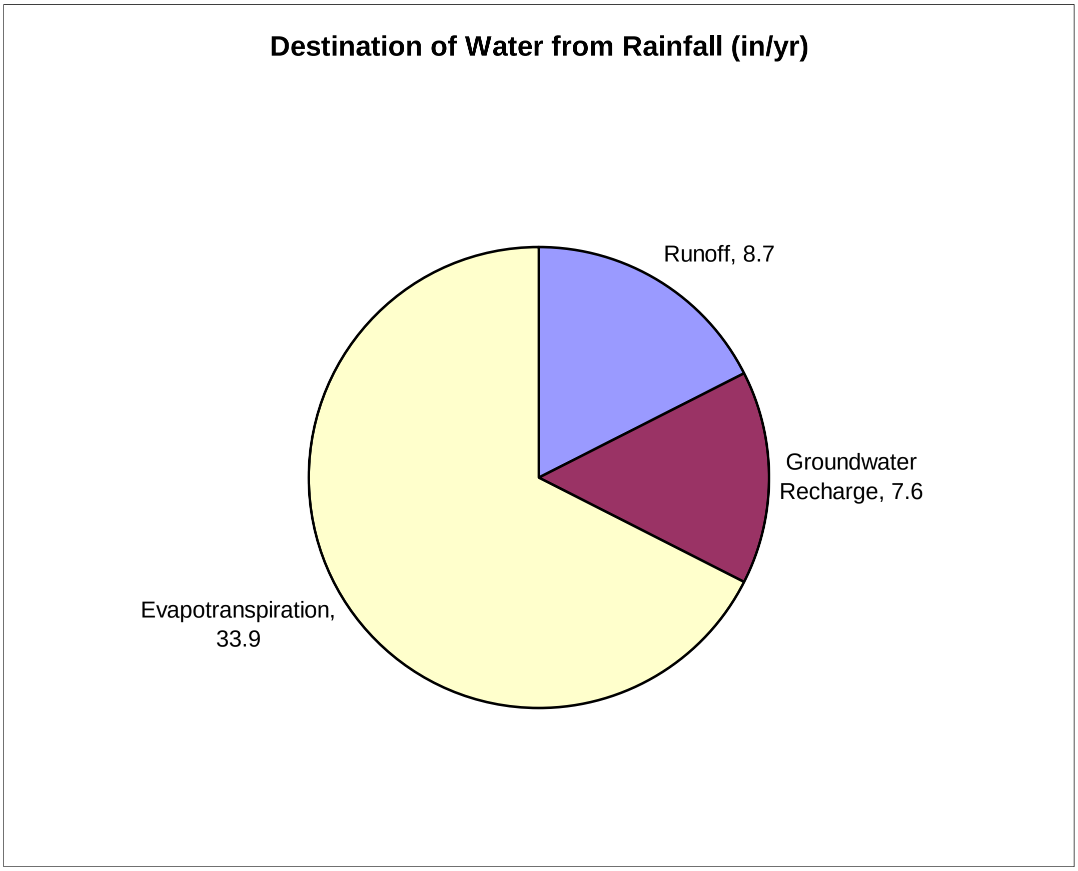

Figure 4-3. Water budget for the Wekiva Study Area based on the Wekiva River gaging station at SR46. For comparison, wastewater generation amounted to approximately 1.5 in/year and was assumed to not cause a net change in the water balance.

4.2 Load to Groundwater

4.2.1 Load from OSTDS

The average removal observed at the three sites of the field work was 40%, leading to a load estimate per system of 17.4 lbs N/year. The field work performed during the Department's Wekiva Study in 3007 included two systems in Tavares soil with low water table and passage through clay zones. For these the estimated removal was between 25% and 50%. This was higher than the 10% estimated by Otis (2007) in a separate task of the study, possibly due to the presence of clay. In the third site, in Myakka soil, the estimated removal was a third, this was lower than the 50% for discharge as TKN or >90% for discharge in nitrate form estimated by Otis (2007).

The average estimated removal fraction based on field work was noticeably higher than estimated in a draft report for task 3 of the Wekiva Study as the weighted average of soil denitrification potential. As Otis (2007) pointed out, nitrogen removal can be very site specific and depends on several factors. The 40% removal estimate is within the range of 10-50% given in Anderson and Otis (2000), but higher than the 30% removal estimated in the MACTEC (2007) report. In this report, 40% removal was assumed, which resulted in an OSTDS loading estimate of 438 MT/year or 482 tons/year.

Drainfields that don't maintain the modern requirements for separation from the water table are likely to experience less nitrogen removal. A coarse estimate based on soil types and system ages suggested that between 5 and 10% of systems may be in such a situation, which would increase the load from OSTDS by about 3%.

4.2.2 Load from wastewater treatment facilities

Loading from wastewater treatment facilities to groundwater varied by discharge mechanism. For groundwater discharge via rapid infiltration systems and similar technologies, 40% removal was assumed. This removal fraction was within the range given by EPA for rapid infiltration systems (EPA, 2003, 2006), and the same removal effectiveness as assumed for OSTDS. It was only somewhat lower than the 50% suggested by FDEP's former reuse coordinator David York in his comments included in MACTEC report. For reuse applications, a similar removal fraction as given by EPA (2002) for slow rate land treatment was assumed (70%). This resulted in a groundwater load of 93 MT/yr or 102 tons/yr of nitrogen from wastewater treatment facilities. This load did not include exfiltration from wastewater transport networks.

4.2.3 Load from diffuse sources

The mass loading rate brought about by water recharging the ground water was determined by estimation of flow and concentration. Concentrations were adjusted for background concentrations to capture the increase in loading due to land uses.

The estimation method considered that the input was applied over large areas with little or no water, and subsequently only the percolating fraction of water facilitated transport. This was the case for transport of fertilizer input and livestock input and atmospheric deposition towards groundwater. To account for such more diffuse sources, MACTEC suggested the approach to utilize shallow groundwater concentrations, as an indicator of the nitrogen that has arrived in the water and multiply them with the recharge rate, which represents the flow of water that had the apparent concentrations. The variation in the amount of water available to transport nitrogen to the groundwater meant that the mass loading was spatially variable.

The shallow groundwater concentrations in the MACTEC report were applied here, with three exceptions:

First, background concentrations were assumed to be 0.2 mg/L total nitrogen, rather than 0.1 mg/L nitrate-nitrogen. This value was consistent with the concentrations observed in the unimpacted Alexander and Juniper Springs (Wetland Solutions, Inc, 2004; Mattson et al., 2006), and observations in wells in forests that appeared unimpacted by fertilization and human disturbances (Phelps, 2004, Toth and Fortich, 2002). Generally, such samples have a high fraction of TKN and a low fraction of nitrate. 0.2 mg/L nitrate-nitrogen has also been used as a cut-off value to distinguish background groundwater values from impacted groundwater (O'Reilly et al., 2007)

Second, for low density residential land uses field work during the 2007 Wekiva Study indicated that total nitrogen concentration under low density residential land uses are usually lower than 3 mg/L given by MACTEC (2007). That value was based on lysimeter studies. During the 2007 field work, background samples in shallow ground water unimpacted by drainfields averaged between 0.5 and 2 mg/L at the three sites. The mid-range of 1.3 mg/L or slightly less than half the previous estimate was the number used in the following for residential and urban land uses. This concentration was applied to all fertilized land uses that previously were assigned a 3 mg/L concentration in recharge water. This number is similar to nitrate-nitrogen well concentrations observed in shallow wells under residential land uses in the Silver Springs Basin by Phelps (2004). Nitrate-nitrogen dominated nitrogen species in that study.

Third, for tree crops among the agricultural land uses, data became available from a BMP verification study (Citrus Research and Education Center, 2007). The total nitrogen concentrations in shallow groundwater varied around 10 mg/L, somewhat lower than the 15 mg/L given by MACTEC (2007). The yearly fertilizer input for the years 2004-2006 for the 8 sites for which the yearly sums are given averaged around the 227 kg/ha yr given in the MACTEC report. The water balances for these 8 sites showed average yearly evapotranspiration of 43.8 in, rainfall of 47.2 in, irrigation of 41.8 in, and drainage to the water table of 45.8 in. Irrigation resulted in a recharge rate of 46 in/yr instead of 11 in/yr estimated from the groundwater recharge model. The resulting estimate for groundwater loading was 112 kg/ha yr, or half of the fertilizer input. These monitoring data pointed to the importance of irrigation for the mobilization of nutrient, which the MACTEC (2007) discussed in the context of turf grass. The estimated nitrogen transfer to groundwater was larger by a factor of two than what was observed in lysimeters during leaching events over the same time frame. These lysimeters measured an average load of 42 kg/ha yr, or only 20% of the input. Both the relative magnitude of evapotranspiration and recharge, and the groundwater concentrations around 10 mg/L are in agreement with earlier modeling predictions by Harrison et al. (1999) for BMP practices. For consistency, the product of recharge rate and shallow groundwater concentration was used in the following.

The question arose if the areas of land uses should be adjusted to account for impervious surfaces and non-fertilized areas. This adjustment appeared unnecessary for the following reason: the recharge rates were obtained by a regional groundwater model that did not distinguish between pervious and impervious surfaces for the recharge rate and therefore the average recharge rate accounted for variations in the local recharge between pervious and impervious surfaces. The non-fertilized areas accounted for the yearly nitrogen fertilizer application rates, while the shallow groundwater concentrations were not finely resolved enough to distinguish between fertilized and not-fertilized areas. Fertilized area was only considered in the agricultural tree crops land use, for which the recharge rate was not determined from the groundwater flow model but from measurements within the citrus grove. Therefore the load from this land use was estimated by multiplying the groundwater concentration times the recharge due to irrigation times the estimated effective fertilized area fraction of 0.85.

The results indicated that 620 MT/yr or 680 tons/year of nitrogen enters the groundwater as part of the diffuse recharge to ground water. Agriculture is the largest source, in turn dominated by tree crops. Tree crops, as a result of the consideration of irrigation, contributed slightly more than half of the agricultural nitrogen on a sixth of the agricultural area. The difference between the estimate using the assumptions of the MACTEC (2007) report and the BMP-based estimate was about 100 MT/yr for the agricultural tree crop land use. If other crops or urban landscapes are irrigated to a similar extent, the estimate of 620 MT/yr would need to be increased.

A comparison of inputs and loads provided an estimate of the apparent nitrogen losses occurring between the surface and the shallow groundwater. Background groundwater concentrations indicated about 95% removal relative to atmospheric deposition. Other land uses saw on average about a 85% apparent loss. The heavily irrigated tree crops show a 50% reduction of fertilizer input, similar to the estimated removals for onsite systems and rapid infiltration wastewater disposal facilities.

4.2.4 Total load to groundwater

The approximate overall nitrogen load to groundwater was estimated as 1,150 MT/yr or 1,300 tons/yr nitrogen by adding onsite systems and land applications of wastewater to the diffuse loads discussed in the previous section. This groundwater load was effective on water that can eventually discharge from springs. Table 5 shows the contribution of groundwater loadings by sources.

The average concentration from this load was 4 mg/L, determined by dividing the load of 1,150 MT/yr by 7.6 in/yr recharge over 305,000 acres of area. This was by a factor of about two higher than the total nitrogen concentrations estimated for Wekiva (2.1 mg/L) and Rock Springs (1.6 mg/L) from the sum of nitrate and organic nitrogen (Wetland Solutions, Inc., 2004 table 2-7). The loading assumptions appear unlikely be too high by this factor of two. A plausible explanation is that some nitrogen removal occurs during transport from shallow groundwater to the springs. The extent of this removal is likely to depend on aquifer vulnerability and travel time between shallow groundwater and springs. If these factors are correlated with land use, relative contributions could shift, for example, the more common occurrence of OSTDS in more vulnerable areas could increase their contributions to loads relative to background contributions from less vulnerable areas. Such shifts are expected to be limited. A future more detailed study, such as a ground water quality model that incorporates conduit flow could quantify the impact of such attenuation factors.

Table 5. Estimated nitrogen loads to groundwater by source

Loading Ground Water	Load (MT/yr	Load (tons/yr)
OSTDS	438	482
WWTF(Sewer)	93	102
Residential	88	97
Other Urban	22	24
Rec.+Golf Courses	28	31
Ag (plants)	303	334
Ag (animals)	130	143
Background	47	52
Sum	1,150	1,266

4.2.5 Relative contributions to nitrogen loading to groundwater

Figure 4-2 presents the estimated relative contributions of nitrogen loading to groundwater. Among the sources of nitrogen considered, OSTDS is prominent with about 40%. Its share of wastewater loads has increased relative to inputs because of the higher apparent nitrogen removal rate of slow rate applications and the diversion to surface discharge of some treated wastewater. OSTDS contribution relative to fertilizer has increased because fertilizer loads are more reduced relative to inputs, except in heavily irrigated situations. Still, fertilizer contributions to the load overall are similar to OSTDS. Background load contributions have much decreased relative to inputs, reflecting the low concentrations found in unimpacted springs.

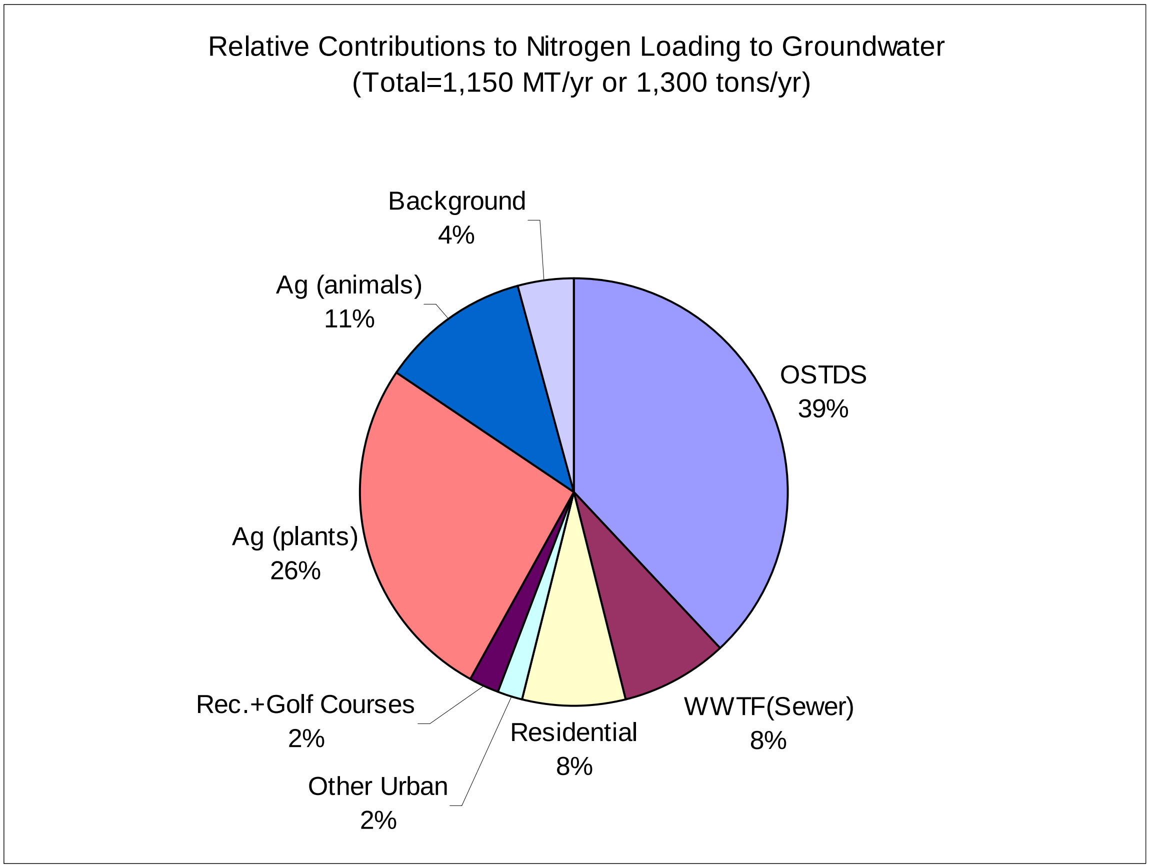

Figure 4-4. Relative contributions to total nitrogen load to groundwater.

4.3 Non-spring surface water discharge loading

The second transport mechanism of nitrogen from the land surface to water is storm water or runoff as surface water. The MACTEC report utilized event mean concentrations only for nitrate-nitrogen, not for total nitrogen, and did not provide loading rates for all land uses. Therefore, this revised estimate utilized values for event mean concentrations and directly connected impervious area fractions provided in the Wekiva Stormwater Model (CDM, 2005).

4.3.1 Rainfall-runoff coefficients

The coefficients suggested by CDM (2005) for predicting runoff assume that 20% of rainfall runs off as surface runoff even for pervious surfaces. This is higher than the conceptual model presented by Wanielista et al. (2005), and the assessment by Gao (2007) for the Wekiva River. Such an estimate would result in an average runoff of 19 in/year, which is more than twice than what the water balance for the Wekiva River indicates as an upper limit for surface water discharge and what gaging stations in the area suggests for river flow as analyzed by Wanielista et al. (2005). A lower effective value for runoff coefficients for watershed-scale models was also observed by Hendrickson and Hart (2007) in the lower St Johns River.

Various runoff coefficients could be chosen to meet the constraint that the overall runoff estimate can not exceed 9 in/yr in accordance with the water balance. A secondary constraint used here was that the pervious runoff coefficient should be at least five times smaller than the impervious runoff coefficient to agree with the relative importance assigned to the two by CDM (2005). Loading estimates overall were not very sensitive to changes in the parameters, given that the total runoff was fixed and event mean concentrations vary only within a factor of two except for agricultural feeding operations. A runoff coefficient of 0.06 for pervious surfaces results in a runoff of about 3.3 in/year. This value is close to those obtained for USGS gaging stations in high recharge areas in the Clermont area and thus appeared consistent for runoff from areas with much groundwater recharge and little impervious area (Wanielista et al., 2005). To meet the overall runoff limit, a 0.54 runoff coefficient for impervious surfaces was chosen.

4.3.2 Nitrogen concentrations

Event mean concentrations for total nitrogen by land use were also taken from the CDM (2005) report. Some information was available on treatment effectiveness with regard to downstream water bodies (CDM, 2005; Harper, 2007). Hendrickson and Hart (2007) cautioned that they found on larger scales event mean concentrations for nitrogen that were only 2/3 of other literature values. Little information was available on the treatment effectiveness with regard to groundwater recharge from retention facilities. On the scale of the Wekiva Study Area no explicit treatment effectiveness by stormwater management measures was considered in this report. Some effectiveness is implied by the lower runoff coefficient for impervious surfaces used here (0.54), which is about a third lower than proposed by CDM (2005).

Surface water contamination by onsite systems was not considered separately, but assumed to be addressed by the event mean concentrations for residential land uses. Stormwater loading models such as the one used here provide options to increase loads due to large numbers of systems that fail and discharge to the land surface instead of to ground water. Generally, this contribution is minor (Rouge River National Wet Weather Demonstration Project, 1998). Gao (2007) provides an estimate of 206 for the number of onsite system that are located within 200 m of river segments in the Wekiva River Basin. Yearly repair rates for the three counties having part of the Wekiva Study Area are on the order of 1.5% to 2% (Roeder, 2007). Both numbers suggest that a surface water contribution rate of 10% of onsite systems as suggested by Rouge River National Wet Weather Demonstration Project (1998) is much too high for consistent discharge to surface water in the whole Wekiva Study Area. Furthermore, the 10% estimate is based in part on the number of systems for which the drainfield is below the ground water table, which for the purposes of this report should be part of groundwater loading. There may be localized areas of higher failure rates or higher numbers of systems that don’t meet modern construction standards where higher contribution rates could be justified in a more detailed assessment.

4.3.3 Rainfall-runoff or stormwater loading, including background load

Loads were estimated as the product of runoff, area and event mean concentration. Background contributions were estimated as those stemming from undeveloped land (DCIA fraction =0.005) with the event mean concentration for undeveloped land. The loading contribution from each land use was determined as the difference between background load and the load estimated for that land use with updated DCIA and event mean concentration. The fraction of load stemming from background concentrations varied between half for an impervious to pervious runoff coefficient ratio of four to somewhat more than a third for a ratio of 15. An intermediate estimate with a 0.06 runoff coefficient for pervious surfaces and a 0.54 runoff coefficient for impervious surfaces resulted in an estimate of 520 MT/yr or 570 tons/yr, of which background contributions were 42%.

4.3.4 Total surface water discharge load

To obtain the overall estimated surface water loading, surface water discharges by wastewater treatment facilities had to be added. These consisted of 29 MT/yr or 32 tons/yr. No additional in-stream reduction was considered. Although Gao (2007) and Wetland Solutions, Inc (2005) provided evidence that removal of nitrogen, in particular nitrate, occurs within the water body, the objective of this report was to provide a loading estimate to surface water rather than a river water quality model.

Table 7 provides the estimated nitrogen loading contributions from different land uses and wastewater. The overall load estimate was 550 MT/yr or 600 tons/yr. Division of this load by the 8.7 in/yr estimated runoff resulted in an average concentration of 2 mg/L. This appeared to be within a factor of two compared to the measured concentrations around 1 mg/L in the Wekiva River and Little Wekiva River (Wetland Solutions, Inc., 2004). Mattson et al., (2006) provide TN concentrations of 1.25 at the Wekiva River at SR 46 and 1.68 mg/L in the Rock Spring Run. They also discuss an apparent reduction in nitrogen concentrations with distance downstream from the springs. In addition to in-stream removal processes, such a reduction could be caused by dilution of more contaminated spring water with cleaner wetland and lake surface water discharge.

Figure 4-3 illustrates the nitrogen loading to surface water due to rainfall runoff or stormwater, and direct sewer discharge. Residential land uses represented a third of the stormwater nitrogen load, and a sixth of the stormwater nitrogen load came from the “other urban” category. Overall, about half of estimated surface water loading was associated with residential and urban land uses. Even without an increase in impervious surfaces and event mean concentrations due to urbanization, about 40% of the load would remain. More than half of this background load was provided by the flow out of wetlands and lakes. Agriculture, recreation and golf contributed only minor amounts to the estimated stormwater load, because very little runoff is attributed to them. About half of the estimated agricultural surface water load was from animal feeding operations.

Table 6. Estimated nitrogen loads to surface water other than springs discharge

Loading Surface Water Discharge	MT/yr	Tons/yr
OSTDS	0	0
WWTF(Sewer)	29	32
Residential	192	212
Other Urban	87	96
Rec.+Golf	4	5
Ag (plants)	5	6
Ag (animals)	14	15
Background	217	239
Sum	549	604

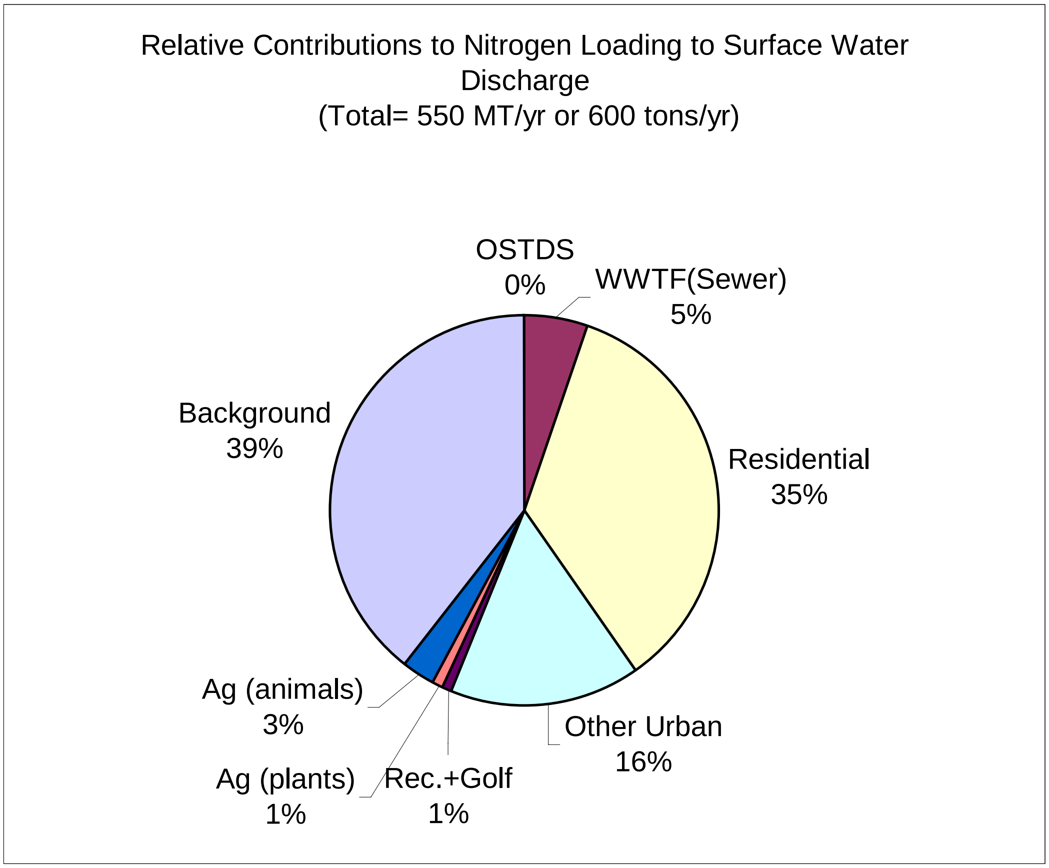

Figure 4-5. Relative contributions to total nitrogen load to surface water discharge.

4.4 Total Load to Waters in the Wekiva Study Area

Addition of the loads via different pathways and from different sources and land uses resulted in a load estimate to waters of the Wekiva Study Area shown in table 9 and figure 4-4. This aggregation is most appropriate for nitrogen loads to the Wekiva River at SR46, where both surface and ground water contribute to the nitrogen load. By averaging surface water and groundwater load contributions, which had very different patterns, the aggregated pie chart provides fewer insights into transport mechanisms and possible management approaches. Overall, these two estimates indicated that about 70% of the nitrogen input to the Wekiva Study Area is not transferred to water but removed before entering groundwater or a river.

OSTDS were a prominent contributor with 26% of the estimated load, all of which as load to ground water. OSTDS increased contribution to load relative to centralized wastewater treatment facilities was due to the higher removal effectiveness assumed for reuse slow-rate applications. OSTDS contributions are expected to increase with continued population growth unless this source is addressed.

Agricultural land uses together provided a contribution of 25% of the total nitrogen load, most of that as ground water load. This contribution is expected to decrease over time as agriculture is replaced by residential and urban land uses.

Table 7. Estimated total load of nitrogen to waters of the Wekiva Study Area

Loading to Water	Load (MT/yr)	Load (tons/yr)
OSTDS	438	482
WWTF(Sewer)	122	134
Residential (fertilizer)	281	309
Other Urban (fertilizer)	109	120
Rec.+Golf Courses	32	35
Ag (plants)	309	340
Ag (animals)	144	159
Background	265	291
Sum	1,698	1,871

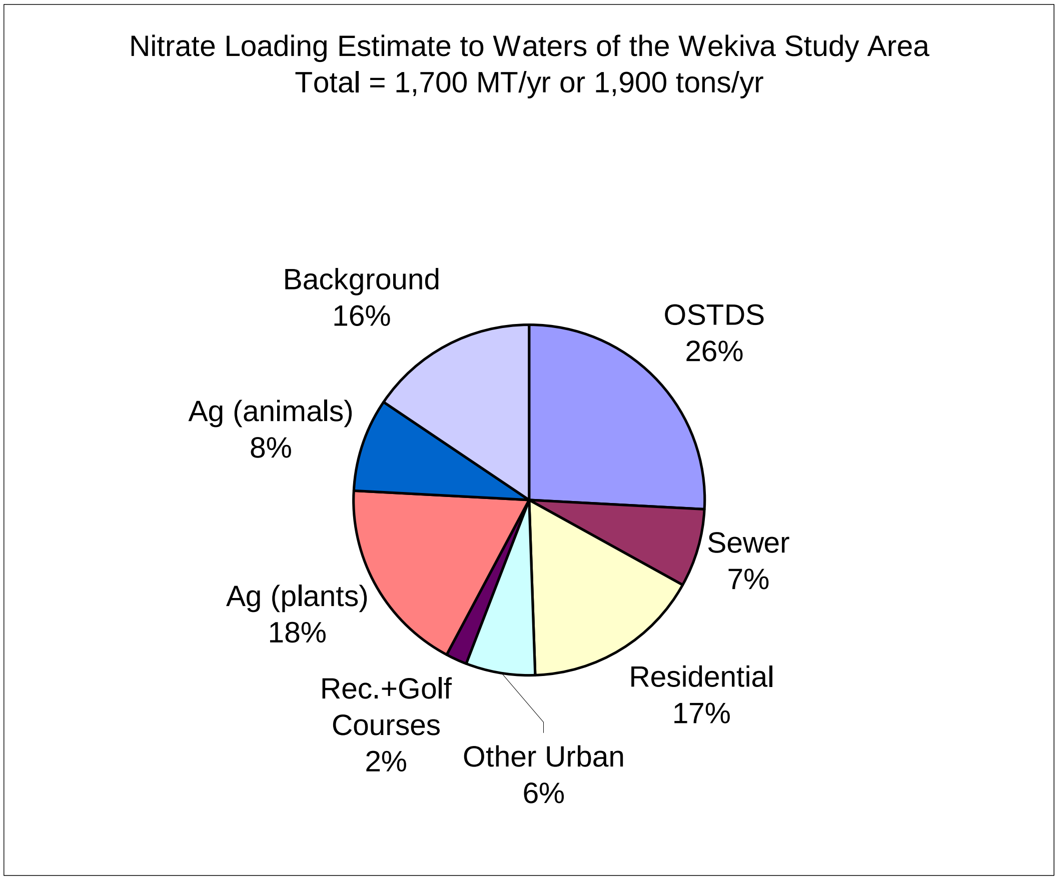

Figure 4-6. Relative contributions to total nitrogen load to all waters in the Wekiva Study Area

Residential and urban land uses together contributed a similar 23%. About three quarters of this contribution occurred in the form of stormwater. Non-farm fertilizer use was the largest considered input for these land uses. This contribution is expected to increase with new development and the increased fraction of non-farm fertilizer sold.

Background contributions were estimated at 16%. This contribution was determined by runoff from a hypothetically undeveloped Wekiva Study Area and recharge as if shallow groundwater concentrations were unimpacted. This contribution is unlikely to change unless increased atmospheric deposition eventually affects it.

Sewer contributions were estimated at 7%. They are expected to decrease in the short term as the Wekiva-specific rules promulgated by FDEP come into effect. In the long run, increases in population may lead again to an increase.

4.5 Equitable and Cost-Effective Solutions

In order to achieve the nitrogen pollution reductions goals for the springs and river (35% to 85%), all controllable sources must be reduced to a large extent. One way to approximate an equitable distribution of reductions would be to ensure that the costs paid per pound of nitrogen removed or the fees paid per pound of nitrogen discharged are similar across sources. This was the motivation for the proposal of a nitrogen discharge fee in the Department's 2007 Wekiva Study report. Such a fee could fund cost effective nitrogen reduction measures in the Wekiva Study Area.

In the absence of such a fee, a comparison of past measures between sources provides suggestions of where additional contributions to nitrogen reduction could come from. Among the sources discussed, centralized wastewater treatment facilities have achieved the most quantifiable reductions in nitrogen inputs and loads. In response to concerns in the Wekiva Study Area, FDEP has adopted new rules that will require further upgrades in treatment. Data in FDEP's 2004 report suggest that the cost is at least $5 per pound of nitrogen removed for an upgrade of existing wastewater treatment facilities. Nitrogen reduction by providing sewer for additional people appears to be one to two orders of magnitudes more expensive.

The effectiveness of fertilizer best management practices is more difficult to assess without in-depth study. The decrease in farm uses of nitrogen is at least partly due to the replacement of farms by residences and other development, without a net reduction in fertilizer sales over the last ten years. A new residential turf rule that will be implemented in 2008 and 2009 aims to change lawn fertilizer compositions and application rates and is expected to result in reductions of primarily phosphorus but also nitrogen inputs by perhaps a quarter.

Onsite sewage treatment and disposal systems in the Wekiva Study Area have so far not contributed to nitrogen reduction practices. The costs of changing design and construction standards appear to be roughly similar to the costs for centralized wastewater treatment facilities. The Department has proposed modifications to onsite sewage rules in the Wekiva Study Area to reduce the nitrogen load of existing and system and decrease the growth in onsite nitrogen loading due to a growing population.

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6 Appendix 1

Summary of Inputs by Land Use/Land Cover Classification

Land Use/Land Cover		Area		Input atm dep.	impervious fraction			net fertil.d fraction	Fertilizer rate	Input fertilizer	Animal waste rate	Input animal waste	Input w/o atm. dep.	Input Total
LU code	Decription	(acre)	(ha)	(kg/yr)	MACTEC, (2007) (-)	DCIA CDM, (2005) (-)	this report (-)	(-)	(kg/ ha year)	(kg/yr)	(kg/ ha year)	(kg/yr)	(kg/yr)	(kg/yr)
1100	Low density Residential	22,645	9,168	77,928	0.147	0.3	0.4	0.36	148	488,472	0	0	488,472	566,400
1200	Medium density Residential	44,361	17,960	152,660	0.278	0.37	0.55	0.27	148	717,681	0	0	717,681	870,341
1300	High density Residential	7,792	3,155	26,815	0.67	0.71	0.7	0.18	148	84,043	0	0	84,043	110,858
1400+ 1480	Commercial and airports	8,470	3,429	29,149	0.9425	0.85	0.94	0.036	200	24,691		0	24,691	53,839
1500	Industrial	2,714	1,099	9,340		0.85	0.85		0	0	0	0	0	9,340
1600	Extractive	634	257	2,183		0.85	0.85		0	0	0	0	0	2,183
1700	Institutional	3,311	1,341	11,396	0.91	0.65	0.91	0.054	200	14,479		0	14,479	25,875
8100	Transportation	3,492	1,414	12,017	0.85	0.01	0.85	0.09	200	25,447	0	0	25,447	37,464
8300	Utilities	2,327	942	8,007	0.85	0.85	0.85	0.09	200	16,957	0	0	16,957	24,964
1800	Recreational, Marinas and fish camps, swimming beaches	1,839	744	6,327	0.015	0.005	0.02	0.588	200	87,534		0	87,534	93,861
1820	Golf Courses	3,174	1,285	10,923	0	0.17	0.17	0.83	175	186,652	0	0	186,652	197,574
2100	Agriculture-Field Crops	59	24	204	0	0.01	0.15	0.8415	150	3,031	0	0	3,031	3,235
2140	Agriculture-Row Crops	693	280	2,384	0	0.01	0.15	0.8415	630	148,664	0	0	148,664	151,047
2150	Agriculture-Field Crops	2,569	1,040	8,839	0	0.01	0.15	0.8415	150	131,266		0	131,266	140,106
2200	Agriculture-Tree Crops	6,016	2,436	20,703	0	0.01	0.15	0.8415	227	465,266	0	0	465,266	485,969
2400	Agriculture-Nurseries	129	52	443	0	0.01	0.15	0.8415	227	9,963		0	9,963	10,407

2410	Agriculture-Tree Nurseries	83	34	285	0	0.01	0.15	0.8415	227	6,411		0	6,411	6,696
2420	Agriculture-Soc Farms	120	49	414	0	0.01	0.15	0.8415	200	8,198	0	0	8,198	8,612
2430	Agriculture-Ornamentals	5,353	2,167	18,422	0	0.01	0.15	0.8415	227	413,994	0	0	413,994	432,416
2450	Agriculture-Floriculture	21	9	72	0	0.01	0.15	0.8415	200	1,434	0	0	1,434	1,507
2500	Agriculture-Specialty Farms	87	35	298		0.01	0.15	0.8415	200	5,901		0	5,901	6,199
2110	Agriculture-Improved Pasture	13,268	5,372	45,658	0	0.01	0.15	0.8415	63	284,769	41	220,233	505,002	550,660
2120	Agriculture-Unimproved Pasture	4,226	1,711	14,541		0.01	0.15		0	0	41	70,141	70,141	84,682
2130	Agriculture-Woodland pasture	3,280	1,328	11,287	0	0.01	0.15		0	0	41	54,441	54,441	65,728
2300	Agriculture-Feeding Operations	162	66	558		0.01	0.15		0	0	4,150	272,287	272,287	272,845
2510	Agriculture-Horse Farms	2,151	871	7,403	0	0.01	0.15	0.8415	63	46,170	41	35,707	81,876	89,279
2540	Agriculture-Aquaculture	15	6	52		0.01	0.15		0	0	0	0	0	52
1900	open land	2,841	1,150	9,778		0.005	0.15		0	0	0	0	0	9,778
2600	Other open lands rural	266	108	914		0.005	0		0	0	0	0	0	914
3000	Upland nonforested	17,096	6,921	58,831		0.005	0		0	0	0	0	0	58,831
4000	Upland forest	45,169	18,287	155,441		0.005	0		0	0	0	0	0	155,441
5000	Water Body	38,688	15,663	133,136		0.275	0.28		0	0	0	0	0	133,136
6000	Wetlands	52,103	21,094	179,303		0.275	0.28		0	0	0	0	0	179,303
7000	Barren Land	9,428	3,817	32,443		0.005	0		0	0		0	0	32,443
	Totals	304,582	123,313	1,048,157						3,171,023		652,809	3,823,832	4,871,989
	Totals (MT/yr)			1,048						3,171		653	3,824	4,872
	Totals (tons/yr)			1,154						3,492		719	4,211	5,366

7 Appendix 2

Summary of Groundwater Loads by Land Use/Land Cover

Land Use/Land Cover		Area	Input	Input	GW concentration		GW recharge		GW load		Apparent removal	
			atm. dep.	w/o atm. dep.	Background TN	Impacted TN	recharge	recharge	Background	Additional	Background	additional
LU Code	Descriptive	(ha)	(kg/yr)	(kg/yr)	(mg/L)	(mg/L)	(mm/yr)	(in/yr)	(kg/yr)	(kg/yr)	(-)	(-)
1100	Low Density Residential	9,168	77,928	488,472	0.2	1.3	287	11.3	5,254	28,896	0.93	0.94
1200	Medium Density Residential	17,960	152,660	717,681	0.2	1.3	254	10.0	9,126	50,196	0.94	0.93
1300	High Density Residential	3,155	26,815	84,043	0.2	1.3	267	10.5	1,684	9,263	0.94	0.89
1400+ 1480	Commercial and airports	3,429	29,149	24,691	0.2	1.3	285	11.2	1,952	10,735	0.93	0.57
1500	Industrial	1,099	9,340	0	0.2	0.2	316	12.4	694	0	0.93	n/a
1600	Extractive	257	2,183	0	0.2	0.2	404	15.9	208	0	0.90	n/a
1700	Institutional	1,341	11,396	14,479	0.2	1.3	297	11.7	797	4,383	0.93	0.70
8100	Transportation	1,414	12,017	25,447	0.2	1.3	259	10.2	731	4,021	0.94	0.84
8300	Utilities	942	8,007	16,957	0.2	1.3	259	10.2	487	2,679	0.94	0.84
1800	Recreational, Marinas and fish camps, swimming beaches	744	6,327	87,534	0.2	1.3	228	9.0	339	1,863	0.95	0.98
1820	Golf Courses	1,285	10,923	186,652	0.2	8	259	10.2	666	25,986	0.94	0.86
2100	Agriculture-Field Crops	24	204	3,031	0.2	6	274	10.8	13	382	0.94	0.87
2140	Agriculture-Row Crops	280	2,384	148,664	0.2	23	135	5.3	75	8,605	0.97	0.94
2150	Agriculture-Field Crops	1,040	8,839	131,266	0.2	4	271	10.7	563	10,693	0.94	0.92
2200	Agriculture-Tree Crops	2,436	20,703	465,266	0.2	10	287	**46***	1,006	237,060	0.95	0.49
2400	Agriculture-Nurseries	52	443	9,963	0.2	6	392	15.5	41	1,187	0.91	0.88
2410	Agriculture-Tree Nurseries	34	285	6,411	0.2	6	355	14.0	24	691	0.92	0.89
2420	Agriculture-Sod Farms	49	414	8,198	0.2	4	80	3.2	8	148	0.98	0.98
2430	Agriculture-Ornamentals	2,167	18,422	413,994	0.2	6	347	13.6	1,502	43,566	0.92	0.89
2450	Agriculture-Floriculture	9	72	1,434	0.2	6	221	8.7	4	109	0.95	0.92
2500	Agriculture-Specialty Farms	35	298	5,901	0.2	6	469	18.5	33	954	0.89	0.84
2300	Agriculture-Feeding Operations	66	45,658	505,002	0.2	18	257	10.1	34	77,278	0.94	0.85
2110	Agriculture-Improved Pasture	5,372	14,541	70,141	0.2	5.5	271	10.7	2,916	17,890	0.95	0.74
2120	Agriculture-Unimproved Pasture	1,711	11,287	54,441	0.2	5.5	197	7.8	675	20,006	0.93	0.63
2130	Agriculture-woodland pasture	1,328	558	272,287	0.2	5.5	284	11.2	755	3,003	0.94	0.99
2510	Agriculture-Horse Farms	871	7,403	81,876	0.2	5.5	257	10.1	447	11,857	0.94	0.86
2540	Agriculture-Aquaculture	6	52	0	0.2	6	469	18.5	6	168	0.89	n/a
1900	open land	1,150	9,778	0	0.2	0.2	206	8.1	475	0	0.95	n/a
2600	Other open lands rural	108	914	0	0.2	0.2	216	8.5	46	0	0.95	n/a
3000	Upland nonforested	6,921	58,831	0	0.2	0.2	192	7.6	2,655	0	0.95	n/a
4000	Upland forest	18,287	155,441	0	0.2	0.2	206	8.1	7,522	0	0.95	n/a
5000	Water Body	15,663	133,136	0	0.2	0.2	121	4.8	3,781	0	0.97	n/a
6000	Wetlands	21,094	179,303	0	0.2	0.2	54	2.1	2,278	0	0.99	n/a
7000	Barren Land	3,817	32,443	0	0.2	0.2	72	2.8	551	0	0.98	n/a
	Totals	123,313	1,048,157	3,823,832	0.2		194	7.6	47,348	571,617	0.95	0.85

* based on irrigation

8 Appendix 3

Summary of Stormwater and Total Loads by Land Use/Land Cover

Land Use/Land Cover			Stormwater runoff					Background				
		Area	DCIA	EMC	Run-off	Load rate	Storm load	Run-off	Storm load	excess storm load	Total Background	Total Excess Load
LU Code	Descriptive	(ha)	(-)	(mg/L)	(in/yr)	(kg/ ha yr)	(kg/yr)	(in/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)
1100	Low Density Residential	9168	0.3	2.29	10.3	6.0	54,742	3.1	9,140	45,602	14,394	74,498
1200	Medium Density Residential	17960	0.37	2.36	12.0	7.2	128,720	3.1	17,905	110,814	27,032	161,010
1300	High Density Residential	3155	0.71	2.42	20.2	12.4	39,110	3.1	3,145	35,965	4,829	45,228
1400+ 1480	Commercial and airports	3429	0.85	2.01	23.5	12.0	41,231	3.1	3,419	37,812	5,371	48,547
1500	Industrial	1099	0.85	1.79	23.5	10.7	11,766	3.1	1,096	10,670	1,790	10,670
1600	Extractive	257	0.85	1.79	23.5	10.7	2,750	3.1	256	2,494	464	2,494
1700	Institutional	1341	0.65	2.29	18.7	10.9	14,598	3.1	1,337	13,261	2,134	17,644
8100	Transportation	1414	0.85	1.79	23.5	10.7	15,137	3.1	1,409	13,728	2,141	17,749
8300	Utilities	942	0.85	1.79	23.5	10.7	10,087	3.1	939	9,148	1,426	11,827
1800	Recreational, Marinas and fish camps, swimming beaches	744	0.005	1.25	3.1	1.0	742	3.1	742	0	1,081	1,863
1820	Golf Courses	1285	0.17	2.32	7.1	4.2	5,396	3.1	1,281	4,115	1,947	30,101
2100	Agriculture-Field Crops	24	0.01	2.48	3.3	2.1	49	3.1	24	25	37	407
2140	Agriculture-Row Crops	280	0.01	2.68	3.3	2.2	622	3.1	280	343	355	8,948
2150	Agriculture-Field Crops	1040	0.01	2.52	3.3	2.1	2,171	3.1	1,037	1,134	1,600	11,827
2200	Agriculture-Tree Crops	2436	0.01	2.05	3.3	1.7	4,136	3.1	2,428	1,707	3,434	238,767
2400	Agriculture-Nurseries	52	0.01	2.3	3.3	1.9	99	3.1	52	47	93	1,235
2410	Agriculture-Tree Nurseries	34	0.01	2.3	3.3	1.9	64	3.1	33	30	57	721
2420	Agriculture-Sod Farms	49	0.01	2.3	3.3	1.9	93	3.1	49	44	56	192
2430	Agriculture-Ornamentals	2167	0.01	2.3	3.3	1.9	4,129	3.1	2,161	1,968	3,663	45,533
2450	Agriculture-Floriculture	9	0.01	2.3	3.3	1.9	16	3.1	8	8	12	117
2500	Agriculture-Specialty Farms	35	0.01	2.34	3.3	1.9	68	3.1	35	33	68	987
2300	Agriculture-Feeding Operations	66	0.01	78.23	3.3	64.8	4,251	3.1	65	4,186	99	7,189
2110	Agriculture-Improved Pasture	5372	0.01	2.48	3.3	2.1	11,033	3.1	5,355	5,678	8,271	82,956
2120	Agriculture-Unimproved Pasture	1711	0.01	2.48	3.3	2.1	3,514	3.1	1,706	1,808	2,381	19,698
2130	Agriculture-woodland pasture	1328	0.01	2.48	3.3	2.1	2,727	3.1	1,324	1,404	2,079	21,410
2510	Agriculture-Horse Farms	871	0.01	2.34	3.3	1.9	1,688	3.1	868	820	1,316	12,676
2540	Agriculture-Aquaculture	6	0.01	2.34	3.3	1.9	12	3.1	6	6	12	174
1900	open land	1150	0.005	1.25	3.1	1.0	1,147	3.1	1,147	0	1,621	0
2600	Other open lands rural	108	0.005	1.25	3.1	1.0	107	3.1	107	0	154	0
3000	Upland nonforested	6921	0.005	1.25	3.1	1.0	6,900	3.1	6,900	0	9,555	0
4000	Upland forest	18287	0.005	1.25	3.1	1.0	18,232	3.1	18,232	0	25,753	0
5000	Water Body	15663	0.275	1.25	9.7	3.1	48,047	9.7	48,047	0	51,828	0
6000	Wetlands	21094	0.275	1.6	9.7	3.9	82,827	9.7	82,827	0	85,105	0
7000	Barren Land	3817	0.005	1.25	3.1	1.0	3,805	3.1	3,805	0	4,356	0
	Totals	123313					520,016		217,165	302,850	264,514	874,468

9 Appendix 4

Wastewater Inputs and Loads

Category	Units	#	Input/ unit (lbs/yr)	Input (MT/ year)	Input (tons/ year)	Assumed removal (-)	Load (tons/ year	Load (MT/ year)
OSTDS	Systems	55,417	29	730	804	0.4	482	438
WWTF (sewer)	GW discharge			72.6	80	0.4	48	44
	Surface Water discharge			28.8	32	0	32	29
	Reuse discharge			164.7	181	0.7	54	49
	Sum WWTF (sewer)			266	293		134	122