# Aquifer Footprint Analysis

Prepared for

**The Nature Conservancy**

November 11th, 2017

Prepared by

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## List of Acronyms and Abbreviations

AFA – Aquifer Footprint Analysis

AWT – Advance Waste Treatment

BMAP – Basin Management Action Plan

CLC – Cooperative Land Cover

CoA – Census of Agriculture

CUP – Consumptive Use Permit

FAS – Floridan Aquifer System

FDACS – Florida Department of Agriculture and Consumer Services

FDEP – Florida Department of Environmental Protection

FDOH – Florida Department of Health

FLWMI – Florida Water Management Inventory

FSAID – Florida Statewide Agricultural Irrigation Demand

FSI – Florida Springs Institute

FWC – Florida Fish and Wildlife Conservation Commission

GIS – Geographic Information System

GPD – Gallons per Day

Lbs-N/Ac/yr – Pounds of Nitrogen per Year

MGD – Millions of Gallons per Day

NADP – National Atmospheric Deposition Program

NNC – Numeric Nutrient Criteria

NSILT – Nitrogen Source Inventory and Loading Tool

NWFWMD – Northwest Florida Water Management District

OSTDS – Onsite Sewage Treatment and Disposal System

RIB – Rapid Infiltration Basin

SJRWMD – St. Johns River Water Management District

SRWMD – Suwannee River Water Management District

SWFWMD – Southwest Florida Water Management District

TGY – Thousands of Gallons per Year

USGS – United States Geological Survey

WMD – Water Management District

## 1. Introduction

The Floridan Aquifer supplies fresh water for natural and human systems throughout the Florida's Springs Region (Figure 1), including all or portions of 38 counties, four water management districts (WMDs), and about 15 million acres. Intensive land development practices have resulted in documented impacts to the aquifer and springs across the region, during the last century. Aquifer levels in Florida's Springs Region are declining due to increasing groundwater pumping, thereby reducing spring flows (Harrington et al. 2010; Knight and Clarke 2014). A growing proportion of the land surface in North Florida is receiving excessive nitrogen loads from fertilizer and wastewater disposal. Through leaching, a significant fraction of this applied nitrogen is reaching the Floridan Aquifer and springs (FSI 2000; Knight 2015). The karst landscape forming the Floridan Aquifer makes it more vulnerable to contamination. The aquifer is recharged by rainwater draining through the carbonate rocks, as well as through surface features such as sinkholes and karst windows, giving substances like nitrogen a more direct path to the aquifer (Florida Geological Survey, 2005). Figure 2 provides an overview of a karst system.

Figure 1 – The Florida Springs Region

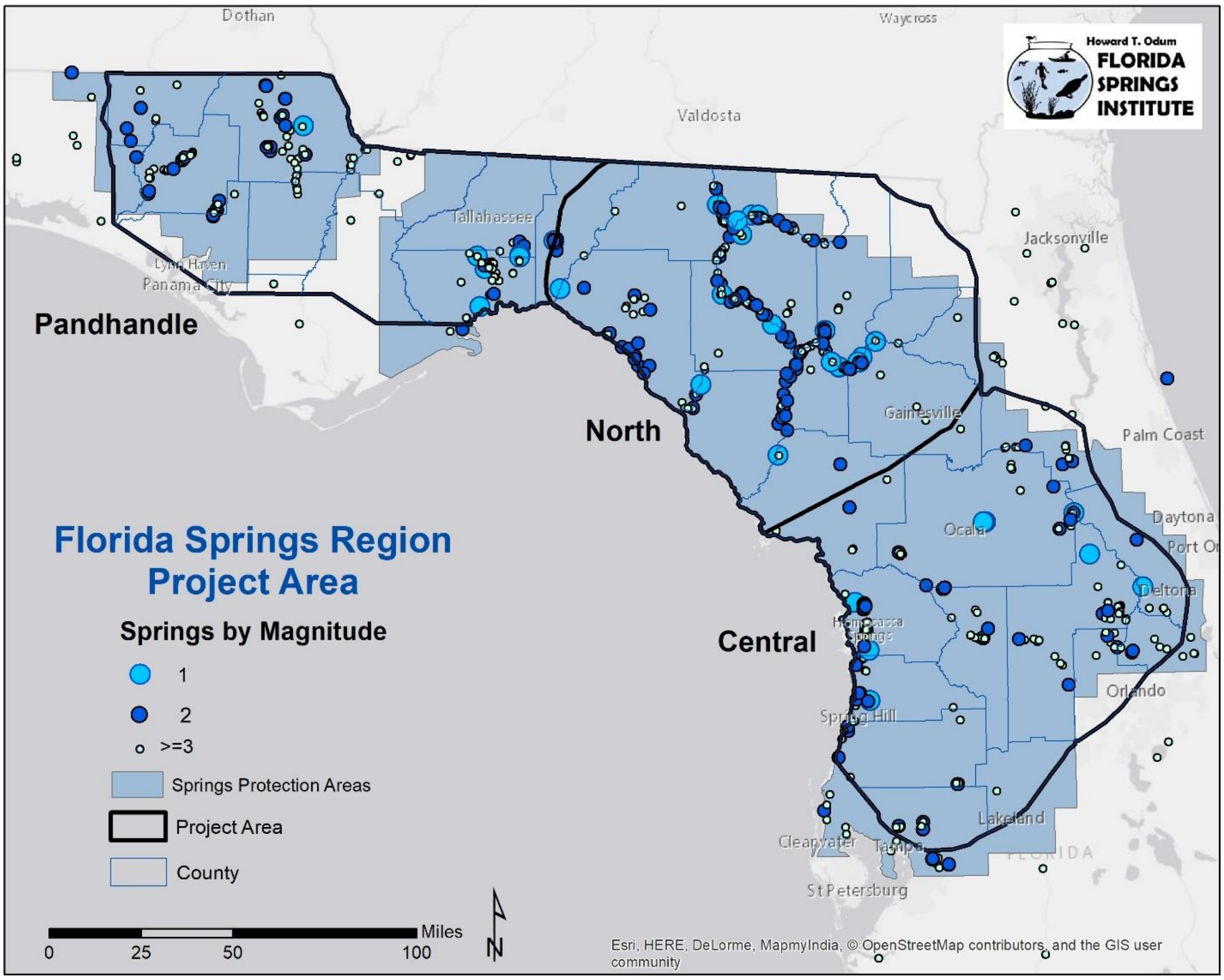
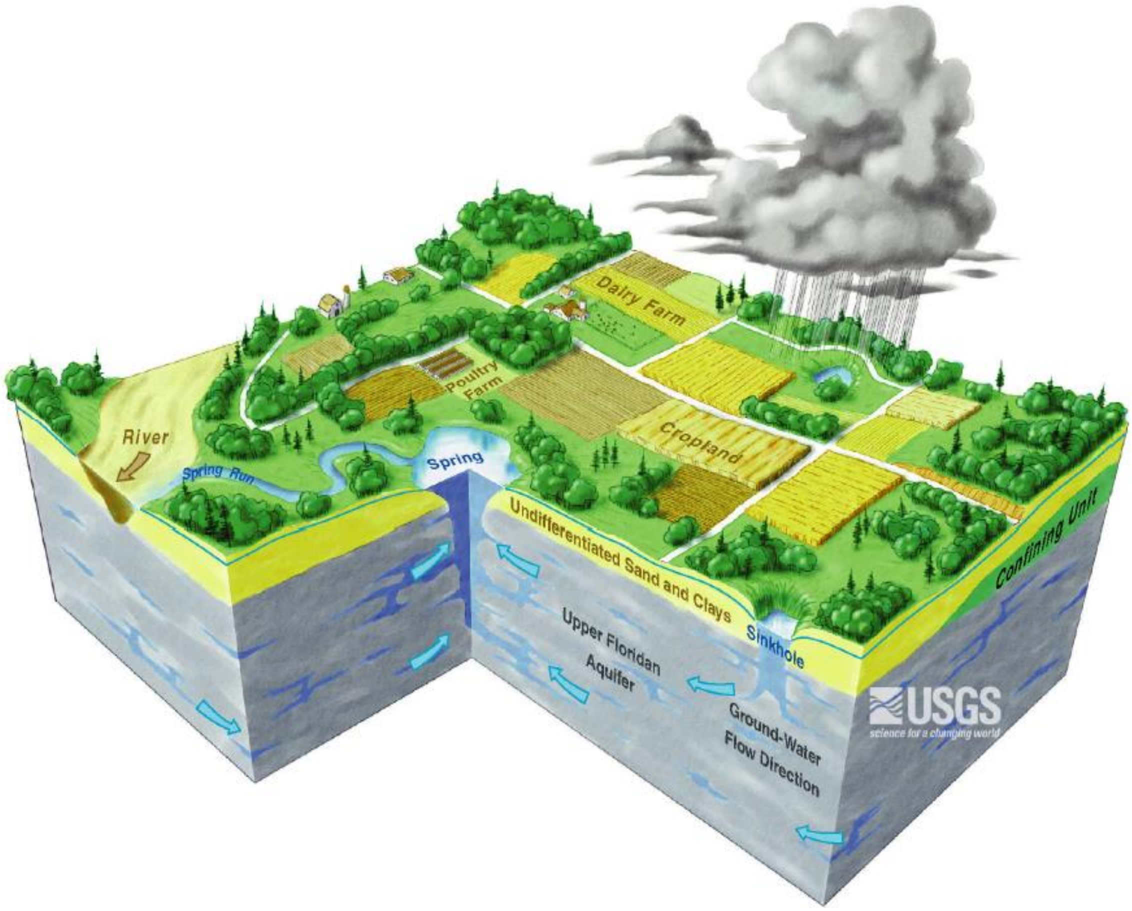


Figure 2 – An overview of a karst system (Berndt et al., 2014)




While many human activities contribute to reduced flows and elevated nitrate-nitrogen levels at our springs, the magnitudes of individual contributions vary widely. Site-specific aquifer vulnerability and the intensity of land use activities regulate the degree of aquifer contamination by nitrogen. On the other hand, groundwater extraction through wells contributes to regional lowering of aquifer levels and spring flow declines.

Utilizing available data, the Florida Springs Institute (FSI) has developed a Geographic Information System (GIS) analysis of aquifer impacts (water quantity and quality) by land parcel for the North Florida Springs Region. This analysis relies on existing GIS data, including aquifer recharge, land use/land cover, property ownership records, consumptive use permits, and published nitrogen attenuation rates, to assess the “Aquifer Footprint” of land owners in the North Florida Springs Region. This “Aquifer Footprint Analysis” (AFA) has been prepared to quantify the Aquifer Footprint associated with private and governmental land holdings to serve as a tool for the identification of parcels and areas with a high potential impact on the aquifer.

## 1.1 Project Objectives

The Howard T. Odum Florida Springs Institute has conducted an 'Aquifer Footprint Analysis' for the Florida Springs Region. The project objectives were to (1) estimate nitrogen loading to the aquifer from fertilizers and wastewater; (2) to estimate groundwater withdrawals from the aquifer; (3) to create an overall 'Aquifer Footprint' based on analysis results; (4) to perform a hotspot analysis; (5) to develop a geodatabase containing the analysis and results, including Aquifer Footprint estimates and parcel ownership data for all analyzed parcels; and (6) to develop tables and maps summarizing analysis results.

The Aquifer Footprint Analysis (AFA) is the first quantitative and comprehensive spatial analysis and geodatabase for groundwater use and nitrogen application rates by parcel for water and fertilizer users throughout the Florida Springs Region. Input parameters used in the AFA analysis include:

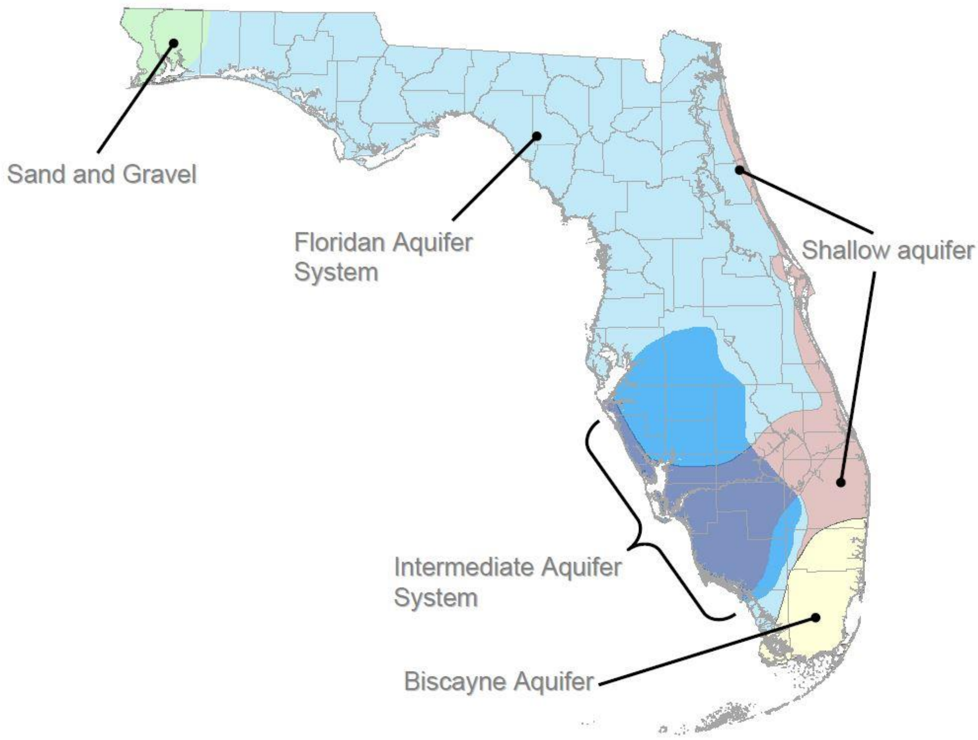
- Estimated and reported public/private groundwater use
- Estimated and reported commercial/industrial groundwater use
- Estimated domestic self-supply groundwater use
- Estimated agricultural irrigation groundwater use
- Estimated wastewater nitrogen loading to the Floridan Aquifer
- Estimated fertilizer nitrogen loading to the Floridan Aquifer by land use
- Estimated atmospheric nitrogen deposition

The analysis was performed using ArcGIS ArcMap 10.5. The project's final deliverable includes a geodatabase of the AFA and result summary tables organized by county, region, and for ten selected springsheds.

## 1.2 Project Area

Of Florida's aquifers, the Floridan Aquifer is the largest and most important, supplying drinking water for millions of Florida's residents and visitors (Florida Geological Survey, 2005). An overview of Florida's aquifers is shown in Figure 3. With an overall extent of 260,000 km$^2$, the Floridan Aquifer extends beyond Florida into neighboring states (Williams, 2016). The project area is the portion of the aquifer in the Florida Springs Region, shown in Figure 1.

Figure 3 – An overview of Florida's aquifer systems (Florida Geological Survey, 2005)



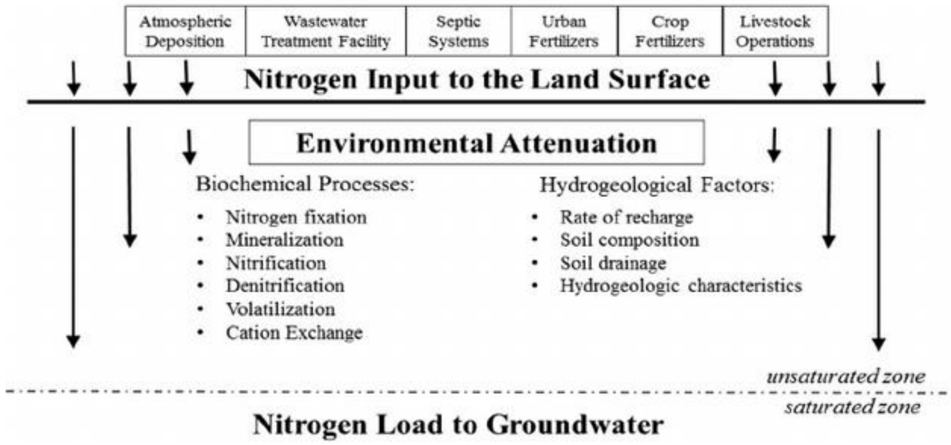

Florida has over 1,000 artesian springs stretching from Central Florida through the Panhandle, shown in Figure 1. The AFA's project area follows the basic extent of the Florida Springs Protection Areas which were developed by the Florida Geological Survey also shown in Figure 1. The project area's boundaries begin at the Florida and Alabama border north of Panama City, extend down through Central Florida, with its farthest extent reaching to north Tampa. It comprises 38 counties, roughly 15 million acres, and four water management districts—Northwest Florida, Suwannee River, St. Johns River, and Southwest Florida. For analysis purposes the project area was also broken into three distinct regions—Panhandle, North, and Central, shown in Figure 1.

## 2. Review of Literature

### 2.1 Nitrogen-Related Studies

The most comprehensive source for nitrogen load estimate data in Florida is the Nitrogen Source Inventory and Loading Tool (NSILT), a spreadsheet-based tool developed by the Florida Department of Environmental Protection (FDEP) (Eller & Katz, 2017). The tool identifies sources of nitrogen at the land surface and quantifies their estimated load to the aquifer. NSILT uses property appraiser land use data, data on fertilizer use, atmospheric deposition estimates, information on agricultural and livestock waste management practices, and waste disposal data to develop nitrogen load estimates (Eller & Katz, 2017). To estimate the load to the aquifer from the inputs at the land surface, NSILT includes aquifer recharge data and subsurface nitrogen attenuation rates for each land use type (Eller & Katz, 2017). NSILT has been applied to at least ten Basin Management Action Plan (BMAP) areas in the Florida Springs Region, providing nitrogen loading estimates for urban and agricultural fertilization, septic systems, wastewater treatment facilities, atmospheric deposition, and livestock operations (Figure 4). NSILT was an integral reference for this project's nitrogen estimation process.

Figure 4 – An overview of the NSILT methodology structure (Eller & Katz, 2017)




Another source for nitrogen estimation data is the FDEP's Florida Springs Initiative Monitoring Report (Harrington, et al 2010). The report summarizes water quality and spring discharge data for the first five years of the project from 2001 to 2006 with a focus on nitrate levels and potential sources (Harrington, et al 2010). A precursor to NSILT, this report gave a general overview of nitrogen inputs and relevant land uses for ten springsheds throughout the Florida Springs Region.

Other nitrogen related studies have been done in Florida on a local scale, including a report prepared by AMEC (known previously as MACTEC) (2010) for Alachua County estimating sources of nitrate in the springs of the Santa Fe River basin. This study differs from the previously mentioned studies in that nitrogen estimates were created using reported concentration data from published groundwater studies for relevant land use types (MACTEC, 2010). Katz et al.'s (2009) study of the Ichetucknee Springs Basin is a combination of both methods, with groundwater sample concentrations and estimates based on land use type being used in a GIS analysis. Another study with a similar methodology was done by the United States Geological Survey (USGS) (Katz et al, 1999) in the Suwannee River Basin.

The USGS developed nitrogen estimations at the county level for the Conterminous US for the years 1982-2001 which uses similar inputs as NSILT including land use data, Census of Agriculture figures, U.S. Census Bureau data, and atmospheric deposition estimates (Ruddy, et al 2006). The report and database provide a county-level baseline for nitrogen estimates going back over 30 years and is an important source for historical estimates. Karst vulnerability and risk assessments done outside of the U.S. also offer insight into nitrogen monitoring and estimation strategies (Zwhalen, 2004; Zhang, 2015; Rebolledo et al, 2016)

## 2.2 Groundwater Use-Related Studies

The most comprehensive source for water use estimates in Florida are the USGS statewide water use reports published every five years. The most recent published report for 2010 provides residential, commercial, agricultural, industrial, and power generation water use estimates (Marella, 2014). The estimates are developed using data gathered under USGS guidelines from sources such as consumptive use permits, metered data, data from WMDs, and irrigated crop estimates (Marella, 2014). Totals derived from mostly metered data include public supply and commercial-industrial-mining self-supplied, whereas domestic self-supplied and agricultural self-supplied are mostly estimated (Marella, 2014).

Other studies have estimated water use at a smaller scale, including the reports prepared by WMDs. An example is the Southwest Florida WMD annual report (2015), which analyzes the same categories as the USGS report. It is updated annually so it is a great source for more current estimates within their WMD. Other studies have a more specific focus, such as Morales, et al.'s (2011) study on commercial, industrial, and institutional water use estimation. This study provides a detailed breakdown for these types of properties.

## 3. Assumptions and Rationale

### 3.1 Analysis Structure

The core layers of the analysis are parcels and land use. Due to the size of the project area, covering just over 15 million acres, the number of parcels exceeds one million with many parcels an acre or less in size. After considering the features of parcels at various sizes, it was decided that only parcels 5 acres and larger would be analyzed at the parcel level.

#### 3.1.1 City Limits

Within city limits, residential parcels are usually less than 5 acres. If treated the same way as parcels over 5 acres, the resulting processing time would be prohibitive for anticipated project updates.  Also, since these parcels would generally be very similar, little new information would be gained by the additional processing. Two options were considered for handling the <5 acres parcels within city limits.

For the first option, cities are essentially treated as a single polygon. Available data includes the number of sewer and septic systems, per capita water use and city population, so an estimate of nitrogen loading and water use can be estimated for the city. For the second option, only parcels within city limits and >5 acres would be processed. These parcels would be treated the same way as those outside of city limits. Other parcels would be excluded (treated as blanks).

The first option was chosen because it provides a more complete overall picture of the area within the city limits. This would be better for summing totals across a larger area. Within city limits, parcels over 5 acres are likely to be variable in terms of their designation and use, so rough estimates on a parcel basis would probably not be much more informative than an overall estimate. Cities will have their own rules and policies, so strategies and approaches for water policy would likely have to be city specific in any case. Parcel data within cities is available, so further, finer scale analysis can be done in the future if required.

#### 3.1.2 Parcels Less Than 5 Acres, Outside City Limits

Concentrated residential areas made up of parcels less than five acres outside of city limits are generally suburban areas or housing developments with intense water use and nitrogen input from sewage or septic tanks and lawn fertilization. To include these areas in the analysis, which will allow for a more accurate estimate of aquifer impact, a generalized methodology was developed using land use data, rather than parcel data. It is described in Section 4.4.1.

### 3.1.3 Parcels 5 Acres or Larger, Outside City Limits

Parcels greater than or equal to 5 acres make up much of the study area, accounting for 86 percent of the project area, and were analyzed at the parcel level. The hotspot analysis was performed on this layer at the end of the analysis.

### 3.1.4 Land Use

The primary source for land use data in the NSILT studies is Property Appraiser land use codes. Because these codes generalize a parcel to only one land use type, it was decided that land use data would be joined to the parcel to more accurately reflect the nitrogen load of the parcels. Parcel land use codes are used in other parts of the analysis to assign a general category to the parcel.

## 3.2 Nitrogen Estimation

### 3.2.1 Wastewater

The NSILT study, on which much of this project's nitrogen estimation methodology was based, developed separate estimates for on-site treatment and disposal systems (OSTDS [buried septic tank/drainfield systems]) and wastewater treatment facilities. The AFA analyzed septic tanks using the same methodology as NSILT, which utilized the recent Florida Department of Health (FDOH) FLWMI (Florida Water Management Inventory) geodatabase. The FLWMI project is a relatively recent undertaking for the FDOH. For this reason, some parcels are identified as unknown. To include all relevant parcels, an assumption was made that if a parcel is outside city limits and is categorized as having an unknown wastewater system, it is assigned as a septic system. If within city limits and unknown, it is assumed that the parcel is on the city's sewer system.

Wastewater treatment facilities posed a unique challenge due to the spatial nature of this project. The people contributing to the nitrogen load from an OSTDS are generally in the same location as the OSTDS, whereas the people contributing to the nitrogen load from wastewater treatment facilities are spread throughout a large area. Since the goal of the AFA is to assign an ' aquifer footprint' that will estimate the impact of individuals—be that individual people or properties—it was decided that our methodology would apply a general waste estimate to residential areas known to be or thought to be using sewer systems.

Raw domestic wastewater resulting from a variety of household incomes in the U.S. typically has a total nitrogen concentration between 30 and 50 mg/L, with an assumed average of 40 mg/L (Metcalf & Eddy, 1991) Municipal wastewaters consist of a blend of various fractions of domestic sewage and commercial wastewaters and are also assumed to have an average total nitrogen concentration of 40 mg/L (Metcalf & Eddy, 1991)

Domestic wastewater is typically treated by one of two general methods throughout Florida: OSTDS or conventional wastewater treatment facilities that remove wastewater solids and dissolved pollutants to varying degrees (Metcalf & Eddy, 1991). The Federal Clean Water Act requires that all conventional domestic and municipal wastewater treatment systems in Florida's Springs Region achieve a minimum of Secondary Treatment, generally defined as a solids reduction greater than 80% and a reduction in the concentration of biodegradable dissolved pollutants greater than 80%. Secondary treatment generally reduces the concentration of total nitrogen dissolved in the wastewater within a range from 15 to 30 mg/L, assumed to average 20 mg/L for this analysis. In Florida, due to limited assimilative capacity for pollutants in surface waters, Advanced Secondary Treatment is prevalent throughout North Florida and converts most of the dissolved total nitrogen in the wastewater from the ammonia form to nitrate nitrogen, and reduces the average total nitrogen concentration to about 5 to 15 mg/L, assumed to average 10 mg/L or less (Metcalf & Eddy, 1991).

Advanced Wastewater Treatment (AWT) is required for many of the largest municipal systems in the Springs Region and is intended to further reduce the concentrations of dissolved nutrients, specifically total nitrogen and total phosphorus, to less than 3 and 1 mg/L, respectively (Metcalf & Eddy, 1991). Conventional wastewater systems discharge treated effluents to land-based systems such as rapid infiltration basins (RIBs), sprayfields, wetlands, or land-based reuse sites. These disposal methods provide additional nitrogen attenuation but have highly variable effectiveness for reduction of total nitrogen concentrations (Metcalf & Eddy, 1991). An overall average of 4 mg/L of total nitrogen was used for the AFA analysis for human wastewaters treated in conventional treatment/disposal systems. This is roughly equivalent to 1 lbs-N/yr per capita.

### 3.2.2 Fertilizer Application Rates

Detailed NSILT spreadsheets and reports from various BMAPs were obtained from the FDEP. These spreadsheets and reports were used to create a fertilizer application rate summary table which can be found in Appendix A. Since the NSILT project began, the methodology has changed slightly and sometimes varies depending on the BMAP. If variations were observed, then the most recent application rate was used in the creation of the summary table. If there were land uses in the project area that were not present in any of the NSILT studies, best professional judgement was used in assigning a rate. This applied mainly to natural areas that were assigned 0 lbs-N/ac/yr for human nitrogen loads and only received an estimate for atmospheric deposition.

Unless listed as ‘tree crops’ in land use data, coniferous plantations are not included in the NSILT analysis. According to staff at FDEP, this is because they are fertilized infrequently, only twice during the stand growth, and the NSILT analysis is for a fixed period (1-4 years). The fertilizer application rate for tree crops was listed as 80 lbs-N/ac/yr in the NSILT spreadsheets. Based on the infrequent fertilization practices of pine plantations, an estimate of 19 lbs-N/ac/yr was used, taken from the 2000 Jokela & Long study, which is an average of fertilization over 8 to 10 years This figure was also used by Katz et al. (2009) in their study on the Ichetucknee Springs Basin.

### 3.2.3 Animal Waste

The NSILT livestock methodology involves totaling relevant land use acreage and using the Census of Agriculture populations to calculate a percentage of animals in each BMAP area (Eller, et al., 2017). Cattle and horses are calculated separately, which was also done in this analysis. NSILT, however, includes poultry, hogs, turkeys, and others in a miscellaneous livestock category. There are no specific land uses associated with most of these categories—only cattle, poultry, and horses had separate categories in the FDEPs Statewide Landuse layer, so it was used instead of the project's main land use layer, the Cooperative Land Cover (CLC) layer, and joined to the parcels. Of the three categories, poultry population estimates and land use had the most discrepancies. The existence of concentrated poultry operations with numbers exceeding one million chickens seemed to distort the numbers. Due to the spatial nature of this project, it was decided that a per acre estimate would be used. Graham and Clark's (2013) review of BMPs indicates an average TN leaching concentration of 10 mg/L for poultry operations. Dr. Knight divided this number by 0.1 mg/L as the estimated background level in the aquifer to identify an estimate of 100 lbs-N/ac/yr for poultry operations.

### 3.3 Aquifer Recharge

Aquifer recharge areas indicate how freely water can enter the aquifer from the land surface. The recharge map used by NSILT does not cover the AFA project area so a combination of three recharge maps were used in the analysis. Two recharge maps are more detailed and have coverage for the St. Johns WMD and the Suwannee River WMD. The third is a 1988 USGS recharge map. For more information on these recharge maps, see the Data Sources table in Appendix B. It is used in all areas not covered by the WMD maps. It is also used for all the city limit polygons because the city limit estimates were made using general population figures, not spatial data. Therefore, only one recharge factor was applied to each city limit. The detailed WMD maps would only be useful for city limits if the cities were analyzed in detail.

### 3.4 Atmospheric Deposition

Atmospheric deposition, the process that brings nitrogen back to the land surface from the atmosphere, comprises wet and dry deposition. The National Atmospheric Deposition Program (NADP) combines this into one total deposition map. The map had to be converted from an ArcGIS Coverage file into a raster, creating uneven edges. Because of this, areas of the coast were not assigned a deposition value. To fill in these missing values, a county average was calculated and applied. The acreage of each parcel was multiplied by the corresponding atmospheric deposition value.

### 3.5 Groundwater Use Estimation

The main data source for groundwater use estimation is consumptive use permit (CUP) records from relevant water management districts. Records of actual water use vary by WMD and by permit, so the average daily withdrawal allocation for each permit was used to estimate groundwater use. Estimates for public supply use are made using data from the 2010 USGS water use report, so all public supply records were excluded from the CUPs.

St. Johns River WMD (SJRWMD) and Southwest Florida WMD (SWFWMD) provided their CUP data in a point shapefile. Their data included a source of withdrawal, which allowed non-groundwater sources to be excluded. The SWFWMD and SJRWMD data contained multiple well points, but overall when the points were summed they equaled the total allocation for that permit, so the 'sum' statistic was used to calculate the estimate. The extent of the area and the parcels using the groundwater for each permit is unknown, so the groundwater use estimate is only applied to the parcel that contains the well, leading to possible overestimates for that parcel and underestimates for any other parcels using groundwater from that permit.

Northwest Florida WMD (NWFWMD) and Suwannee River WMD (SRWMD) provided their CUP data in a polygon shapefile, which shows the extent of the permit which makes estimates more accurate. However, these polygon files do not include the source of the withdrawals. The permits for the 10 highest CUPs for both WMDs were pulled and the estimate was adjusted based on the allocated groundwater withdrawal. This includes power facilities in both WMDs, whose large allocation was mainly made up of surface water. Other large industrial operations were corrected, including PCS Phosphate, whose total allocation was 407.92 million gallons per day (MGD) but only 64.16 MGD was groundwater. All outliers were examined and corrected, but it was not possible to correct each record by hand due to the scope of the project. This means that other parcels in these WMDs are potentially overestimated from the inclusion of non-groundwater use.

### 3.6 Springshed Selection

Ten springsheds were selected for detailed reporting to represent a wide array of springshed conditions. The primary factors considered in the selection process were existing land cover and projected development. Land uses are directly correlated to nutrient inputs and water use, and therefore are an important factor in assessing springsheds. Evaluating projected land use helps determine which springsheds are facing the highest development threat and help inform the future impact of land use conversion, prioritize areas to implement land and water quantity protections, and will inform the types of restoration approaches best suited to protect the lands essential to the springs. Existing land uses in selected springsheds varied from primarily agriculture, to primarily urban, to primarily natural land, to a mixture of land cover classifications. Additionally, some springsheds had a high potential for development and more intense land practices in the future, while others had low development potential, indicating that the land use practices would remain constant.

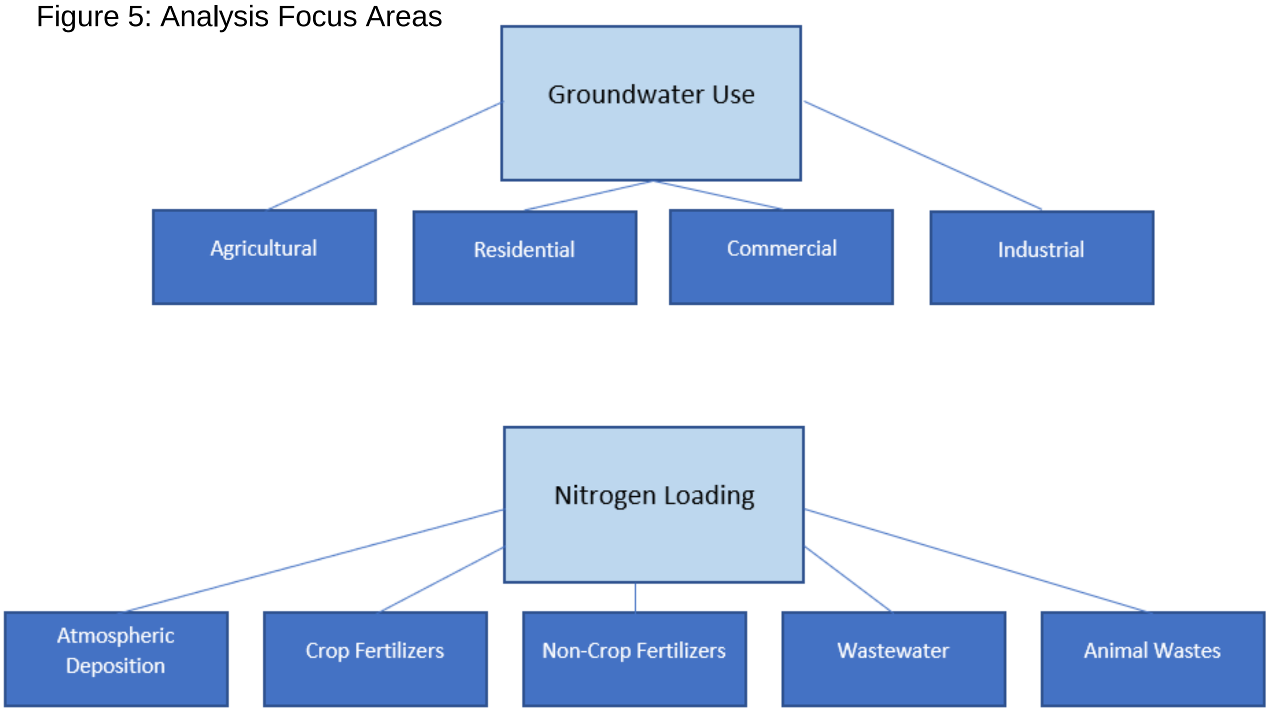
# 4. Methodology

## 4.1 Data Sources

### 4.1.1 Nitrogen Load Estimation - Sources

The Aquifer Footprint Analysis is broken into two focus areas—nitrogen load estimation and groundwater use estimation, with each comprising different estimate methodologies for various parcel categories (See Figure 5 for an overview of the Analysis Focus Areas).

Figure 5: Analysis Focus Areas




Statewide parcel data from the Florida Department of Revenue were used to create the framework for the analysis. The Florida Fish and Wildlife Conservation Commission's (FWC) Cooperative Land Cover (CLC) was used to represent land use in the nitrogen load estimation process unless otherwise noted. FDEP's NSILT project was another integral source for this process. NSILT's overall methods and calculations were followed as closely as possible and will be clearly noted when they differ. City limit polygons were obtained from the 2010 U.S. Census.

Septic and sewer system estimates were calculated using data from the FDOH FLWMI database. Animal waste inputs were estimated using Census of Agriculture data for horses and cattle, as per the NSILT methodology. A per acre estimate was developed for poultry using data from a report on BMP effectives (Graham and Clark, 2013), the rationale for this is discussed in more detail in Section 3.2.3. This is the one instance where CLC was not used for land use, due to its insufficient detail for livestock categories. Instead, the FDEP's Statewide Land Use layer was used, which had separate categories for cattle, horses, and poultry. Data from the NADP combines wet and dry deposition to estimate total deposition. These estimates were used for all parcels, regardless of land use type, to estimate atmospheric deposition.

Once NSILT's attenuation factors have been applied, the final step in nitrogen load to groundwater estimation is to adjust the estimates based on recharge level. Detailed recharge maps from St. Johns WMD and Suwannee River WMD were used as well as a more general USGS map when no other coverage was available. This is discussed in greater detail in Section 3.3.

#### 4.1.2 Groundwater Use Estimation - Sources

The components of water use estimation include estimates of water use for irrigated agricultural land, from the Florida Department of Agriculture and Consumer Service's (FDACS) Florida Statewide Agricultural Irrigation Demand (FSAID) geodatabase, as well as CUP data from WMDs, and general water use estimates from the United States Geological Survey's 2010 water use research (Marella, 2014).

### 4.2 Nitrogen Load Estimation

Using nitrogen application estimates from the NSILT project, a table was created that links fertilizer application amounts in lbs-N/ac/yr to CLC land use codes (See Appendix A for the full table). Once this information was added to the CLC land use layer, CLC land use types were identified within each parcel. The input was calculated and then summed to create an overall Fertilization Input Rate.

#### 4.2.1 Crop Fertilizers

NSILT uses two types of crop fertilizer estimation methodologies—one based on fertilizer sales totals and the other on fertilizer application rates based on agricultural best management practices (Eller & Katz, 2017). To make estimates more tailored to crop types, the second method was used in this analysis. Based on application rates assigned to each CLC land use (LU) code, the following equation was used to calculate the total input of lbs-N/ac/yr:

*Estimated Crop Fertilization Input = Fertilizer application rate (lbs-N/ac/yr) * LU acres*

#### 4.2.2 Non-Crop Fertilizers

NSILT includes two types of residential fertilizer application methods. One method is for self-fertilization and the other is for fertilization by a lawn service. Due to the spatial nature of the AFA, and to simplify calculations, the self-fertilization method was used. Residential fertilization practices vary greatly and studies have found these practices to be linked with socio-economic characteristics of the area (Eller & Katz, 2017). To address this, some of the NSILT projects applied a probability factor to their calculations. The factors are shown in Table 1.

Table 1: NSILT Probability Factor (Eller et al., 2017)

| Probability Factor | Probability of Fertilization | Property Value |
|---|---|---|
| 0.90 | 90% | Greater than $150,000 |
| 0.75 | 75% | Between $150,000 and $50,000 |
| 0.10 | 10% | Less than $50,000 |

This factor was applied to residential fertilizer estimate calculations, which in addition to the fertilizer application rate, also factor in the amount of land assumed being fertilized (50 %) as well as the number of applications per year (3), shown below:

*Estimated Residential Fertilization Input =*

*45.56 lbs-N/ac/application * 3 applications * 0.50 of land * LU acres * Probability Factor*

Fertilization for commercial, recreational, and industrial parcels was estimated using NSILT's equation for lawn service fertilization. It is similar to the self-fertilization equation, but uses lower application rates and fewer applications under the assumption that lawn service companies follow best management practices and also that there is less permeable area to be fertilized (35%) (Eller, et al. 2017).

*Estimated Commercial/Industrial/Recreational Fertilization Input =*

*21.78 lbs-N/ac/application * 2 applications * 0.35 of land * LU acres*

Golf course fertilization rates are generally much higher than other recreational areas. For this reason, NSILT used a separate application rate (Eller, et al. 2017).

*Estimated Golf Course Fertilization Input = 141.1 lbs-N/ac/yr * LU acres*

### 4.2.3 Wastewater

Data from the FDOH's FLWMI was used in the estimation of nitrogen from wastewater in NSILTs study and was also used in the AFA analysis. The FLWMI geodatabase contains parcel data with wastewater system information. This information was joined to the analysis parcels using the parcel LINK number. To aid in the analysis, a category was assigned to each parcel based on the property appraiser land use codes see Appendix C for full table. The FLWMI project is still in the early phases so some parcels are listed as having unknown wastewater systems. To address this any parcel that is identified as unknown but is a non-vacant residential parcel is assigned as having a septic system since all parcels over 5 acres are outside of city limits.

For residential OSTDS parcels, the average household size for each county (See Appendix D) determined by the U.S. Census (2010), is multiplied by 9.012 lbs-N/yr, the U.S. Environmental Protection Agency's (2002) estimate for pounds of nitrogen produced per year per person. For each residential sewer parcel, the average county household size is multiplied by 1 lbs-N/yr, which is discussed in more detail in Section 3.2.1.

For commercial OSTDS parcels, 9.012 lbs-N/yr is multiplied by 19.48, the average number of employees per company in Florida as determined by the U.S. Census (2010). For commercial sewer parcels, 1 lbs-N/yr is multiplied by 19.48.

### 4.2.4 Animal Waste

Large livestock populations in Florida make animal waste a significant source of nitrogen to the land surface. Census of Agriculture (COA) population data was used to estimate cattle and horse nitrogen input. Due to the more detailed livestock categories in FDEP Statewide LU, it was used for this portion of the analysis. Livestock related land uses were selected and joined to the complete parcel layer—including parcels of all acres—so that the total acreage for each land use in each county could be totaled. A total for each land use was then calculated for the portion of the county within the project area to create a percentage. As in NSILT's methodology, if only 10% of a county's livestock land use area is in the project area, then only 10% of the population is used in the calculation.

For cattle, the 'Total Cattle and Calves' category was used from the CoA. The land uses 'Cattle Feeding Operations', 'Feeding Operations', and 'Improved Pasture' were used. These categories differ from NSILT, because NSILT used property appraiser land use data where as FDEP Statewide LU was used in this project. Because 'Improved Pasture' is a large category encompassing many fields, it was only identified as related to cattle if it was also located within a parcel whose parcel land use code was 'Grazing Land'. The county cattle population within the project area was divided by the related land use acres within each county to create a per acre county average. This average was multiplied by the acreage of the parcel to create an estimated cattle population. NSILT uses the estimate of 0.337 lbs-N/day for cattle (Eller et al., 2017). It also had an estimate for dairy cows, but because there wasn't any accurate dairy-specific land use, and many counties didn't have the number of dairy cows listed in CoA to avoid farm identification, only cattle were included. The following equation was used to estimate cattle input:

*Estimated Cattle Waste Input = Estimated Cattle Population * 0.337 * 365*

The same methodology was used to estimate the nitrogen load from horses. The FDEP land use categories used were 'Horse Farms' and 'Specialty Farms' which were primarily identified as horse farms through inspection of the data. An estimated horse population was calculated by multiplying the per acre county average by the related land use acres within the county. This was multiplied by the figure used in NSILT, 0.273 lbs-N/day, shown below:

*Estimated Horse Waste Input = Estimated Horse Population * 0.273 * 365*

Due to large discrepancies noted in the land use data and the CoA population figures for poultry, a generalized estimate was developed. This is discussed more in Section 3.2.3. The category 'Poultry Feeding Operations' was used to identify relevant land uses. An estimate of 100 lbs-N/ac estimate was used to estimate the input from poultry waste, as shown below:

*Estimated Poultry Waste Input = 100 lbs-N/ac * LU acres*

### 4.2.5 Atmospheric Deposition

The total nitrogen (wet and dry) atmospheric deposition map from the NADP was used to assign atmospheric deposition amounts to the project area. The map is available as an ArcGIS Coverage file (.e00) and was converted first to a raster and then to a polygon. The map was overlaid on the parcels and a value was assigned to each. The deposition values are kg-N/ha, and were converted into lbs-N/ha. The acreage of each parcel was multiplied by the corresponding atmospheric deposition value.

### 4.2.6 Attenuation and Recharge

Once all inputs to the land surface have been estimated, subsurface attenuation processes were accounted for. NSILT's recommended attenuation factor was applied by land use type to account for subsurface processes (Table 2). The NSILT reports listed various ranges for attenuation. Based on a review of all attenuation ranges used, the summary figures in Table 2 were chosen. The equation is shown below:

*Attenuated Input = Estimated Nitrogen Input * (1 - Attenuation Factor)*

Table 2 – Attenuation Summary by land use type (Eller et al, 2017)

| **Category** | **Attenuation Summary** |
|---|---|
| Attenuation | 0.90 |
| WWTF - Sewers | 0.40 |
| Septic Systems | 0.40 |
| Urban Fertilizer | 0.80 |
| Farm Fertilizer | 0.70 |
| Livestock-Cattle | 0.90 |
| Horse Farms | 0.90 |

After the estimates were adjusted for attenuation, the parcel's recharge rate was identified by overlaying the merged recharge map, using the recharge factors shown in Table 3.

Table 3 – Recharge Factors by recharge level (Eller et al., 2017)

| **Recharge Level** | **Recharge Factor** |
|---|---|
| High Recharge | 0.90 |
| Medium Recharge | 0.50 |
| Low Recharge | 0.10 |

The final nitrogen estimate was calculated with the following equation:

*Final Nitrogen Load to the Aquifer= Attenuated Input * Recharge Factor*

Attenuation and recharge were also applied to estimates for areas of parcels less than 5 acres and for city limits, which are discussed in more detail in Sections 4.3 and 4.4. An overview of the nitrogen estimation methodology is presented in Appendix E.

## 4.3 Groundwater Use Estimation

### 4.3.1 Crop

Although CUP data were obtained from WMDs that included agricultural permits, it was decided that crop groundwater use estimates would be taken, if available, from FDACS FSAID ILG (Irrigated Lands Geodatabase). This database has detailed data of mapped irrigated crop acreage and average estimated irrigation. These estimates were joined to the corresponding parcel. If an irrigated area extended into multiple parcels, the percentage of acres in each parcel was calculated and that corresponding percentage of the water use was applied to that parcel.

### 4.3.2 Residential/Commercial/Industrial

Consumptive use permits locations and withdrawal allocations were obtained from the SJRWMD, SRWMD, NWFWMD, and the SWFWMD. Since reported usage is variable and is not done for many types of permits, the allocation was used to represent the gross usage. Permits for SJRWMD and SWFWMD had multiple attributes listed for many permits. Any time there was any activity such as renewal or change of ownership, the permit and its allocation were listed. The original methodology involved adding the allocation of all permits in a parcel, however this led to exaggerated use estimates. For this reason, the mean from all listed permits was used. If multiple permits really exist on a property, this method will underestimate the allocation. However, the amount of groundwater being pumped can be less than the allocation, which balances the effects of using a mean. Northwest Florida WMD and St. Johns WMD provided a polygon shapefile showing the extent of the permits. If the permit extent comprised multiple parcels, the parcels were totaled, and portions of the water use were attributed to each parcel.

Once all CUPs were joined to the parcels, public-supply parcels were addressed. Since detailed public-supply residential water use data was not available for the project area, gallons per day (GPD) per capita estimates from the most recent USGS Florida water use report were used (Marella, 2014). For this reason, all CUPs with the use type 'Public Supply' were given an allocation of zero so public supply wasn't included twice. Each parcel was assigned a category based on its parcel land use code which allowed vacant residential parcels to be excluded from the analysis. Every residential parcel was multiplied by the county average household size and the number of residential units, which was then multiplied by the county per capita groundwater use estimate. Including the number of residential units in the equation ensured multi-family parcels were represented.

*Estimated Residential Groundwater Use =*

*County Average Household Size * Number of Residential Units * County Per Capita Estimate*

Overall county estimates were also made for commercial and industrial sectors in the 2010 USGS report (Marella, 2014). To address commercial and industrial parcels that did not have a CUP, parcels were assigned a category (See Appendix 3) and all commercial and industrial parcels were calculated for each county using the full parcel layer that included all parcels to get an accurate count. The average use estimate per county was divided by the number of parcels to give a per parcel county groundwater use estimate. This estimate was applied to commercial and industrial parcels respectively if there was no associated CUP. An overview of groundwater estimation methodology is given in Appendix E.

## 4.4 Parcels Less Than 5 Acres

### 4.4.1 Nitrogen Estimation – Non-Crop Fertilizers

Fertilizer use in residential parcels less than 5 acres was estimated using a generalized version of the residential methodology in Section 4.2.2. Based on the CLC land use codes, residential land uses were selected. Since land use data was being used instead of parcel data, property value information was not available, so a probability factor was not used. The following equation estimates fertilizer use for residential parcels less than 5 acres:

*Estimated Residential Fertilization Input (Parcels < 5 acres) =*

*45.56 lbs-N/ac/application * 3 applications * 0.50 of land * LU acres*

### 4.4.2 Nitrogen Estimation – Wastewater

FLWMI data and the CLC layer were used to estimate nitrogen loading from wastewater in residential areas made up of parcels less than 5 acres. Residential land uses are broken into three categories in the Cooperative Land Cover (CLC) layer:

- Low Density Residential: 1 dwelling unit per acre
- Medium Density Residential: 2-5 dwelling units per acre
- High Density Residential: >5 dwelling units per acre

For the analysis, 1 dwelling/ac was used for low density, 3 dwellings/ac for medium density, and 5 dwellings/ac for high density. The number of people in each residential land use area were estimated by multiplying the number of estimated units per acre by the number of acres. The FLWMI was overlapped with the residential areas to get a general estimate of the type of wastewater system. The estimated population for septic land use areas were multiplied by 9.012 lbs-N/yr and the sewer land use areas were multiplied by 1 lbs-N/yr.

### 4.4.3 Nitrogen Estimation – Atmospheric Deposition

The NADP Total Nitrogen map was overlaid with the land use layer and all land uses for parcels less than 5 acres were given an atmospheric deposition value and multiplied by the land use acres.

### 4.4.4 Groundwater Use Estimation – Residential

Since land use data is used instead of parcels in the less than 5-acre areas, the methodology for estimating these residential populations discussed in Section 4.2.3a was used to estimate groundwater use. Once the estimated population for each residential area was calculated it was multiplied by the USGS per capita county estimate for public supply use

## 4.5 City Limits

### 4.5.1 Nitrogen Estimation – Wastewater

City limit polygons and FLWMI data were used to estimate nitrogen loading from wastewater in city limits. The number of OSTDS in each city was multiplied by the average county household size to obtain the OSTDS population. This population was then subtracted from the total city population as shown in U.S. Census data (2010). If the resulting number was negative, this was an indication of a small city with no sewer system, like Archer, Florida. In that case, the sewer population was changed to zero. Finally, the OSTDS population was multiplied by 9.012 lbs-N/yr and the sewer population was multiplied by 1 lbs-N/yr.

### 4.5.2 Nitrogen Estimation – Atmospheric Deposition

The NADP total nitrogen map was overlaid with the city limits and the areas of different deposition values were identified and the acreage was calculated. The deposition value was multiplied by the acres and the amount was summed for each city.

### 4.5.3 Groundwater Use Estimation – Non-Crop

City limit polygons, obtained from the U.S. Census, contained detailed socio-economic data. The population figures for each city limit were multiplied by the USGS per capita county public supply use estimate. This created an overall residential estimate based on the population, and did not include consumptive use permits, with the rationale that water use on public-supply and domestic self-supply is at a similar level.

### 4.5.4 Groundwater Use Estimation – Crop

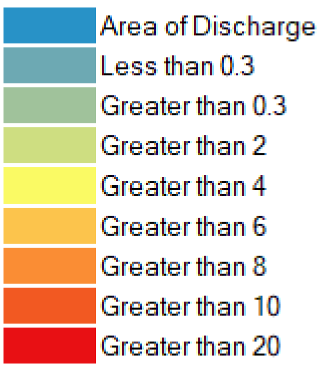
Rural areas can have city limits that extend well beyond the built-up area, for example High Springs and Newberry. To address the agricultural groundwater use in these areas, irrigation estimates from the FSAID database were joined to the city limits. If an irrigated area extended beyond the city limit, the percentage of acres in each irrigated area was calculated and that corresponding percentage of the water use was applied to that city.

## 4.6 Overall Aquifer Footprints

### 4.6.1 Nitrogen Classification

All nitrogen load estimates were divided by the parcel acreage for normalization. Based on a review of the distribution of final values, a classification scale was developed. Natural nitrogen loads are derived from precipitation and average less than 0.3 lbs-N/ac/yr to the groundwater in the springs region (Knight 2015). Nitrogen loads between 0.3 and 2 lbs-N/ac/yr to the aquifer generally result in spring nitrate concentrations less than the state numeric water quality standard of 0.35 mg/L. Nitrogen loads higher than 2 lbs-N/ac/yr have been determined to disrupt the natural balance of springs aquatic communities. From 2 lbs-N/ac/yr the scale was continued in increments of 2 until 10 lbs-N/ac/yr. The highest break value was set as 20 lbs-N/ac/yr because even though there are values much higher than this, 20 lbs-N/ac/yr will have a significant effect on the groundwater in the aquifer. The scale breakdown is shown in Figure 6.

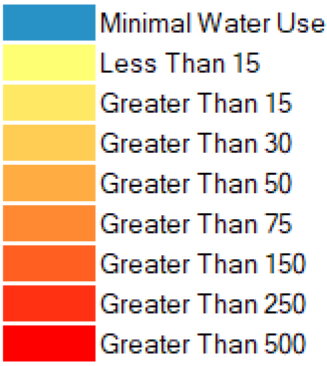
Figure 6 – Estimated Nitrogen Load (lbs-N/ac/yr to the aquifer) Scale Breakdown




### 4.6.2 Groundwater Use Classification

All groundwater use estimates were also divided by the parcel acreage for normalization and converted from gallons per day to thousand gallons per year (TGY). The average residential public supply per capita estimate is 85 gal/day (Marella, 2014) so this number was multiplied by the average household size for Florida, 2.48. This estimation for water use per household was then multiplied by 365 for an annual average and then divided by 1000 to convert into thousands of gallons. This was then divided by 5 acres, the smallest acreage for parcels in the analysis, to get a groundwater use estimate for an average public supply household – 15 TGY/acre. This was set as the lowest break value above zero (no known water use), with 500 TGY/acre as the highest break value. The scale is shown in Figure 7.

Figure 7 – Estimated Groundwater Use (TGY/ac) Scale Breakdown




### 4.6.3 Aquifer Footprint Summary

Increased nitrogen levels and reduced groundwater flow both contribute to the observed degradation of Florida's aquifer and springs. While there is currently no integrated model that estimates the synergistic effects of each stress (reduced flows and increased nitrate nitrogen concentrations) on the ecological health of springs, there is a growing database on the effects of individual contributions to impairment (FDEP 2000, WSI 2009, Knight 2015).

For the Floridan Aquifer Footprint Analysis Project, FSI has combined the scales of increasing nitrogen loading and increasing groundwater consumptive use into a single semi-quantitative scale from Low to High Aquifer Footprint. The nitrogen and groundwater scales both had nine classes, so each class was assigned a value from 0 to 8, as shown in Table 4. Once assigned to each parcel, the nitrogen and groundwater use values were added, creating a list of values ranging from 0 to 16. These values were broken down into nine classes with values from 0 to 8 to create the final 'Aquifer Footprint' (Table 5).

Table 4 – Overall Footprint Classification Scale Breakdown

| Overall Scale | Groundwater (thousands of gallons/ac/year) | Nitrogen (lbs-N/ac/year) |
|---|---|---|
| 0 | 0 | 0 |
| 1 | <15 | >0.5 |
| 2 | >= 15 | >=0.5 |
| 3 | >=30 | >=2 |
| 4 | >=60 | >=4 |
| 5 | >=90 | >=6 |
| 6 | >=150 | >=8 |
| 7 | >=250 | >=10 |
| 8 | >=500 | >=20 |

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Table 5 – Final Footprint Scale

| Overall Scale Sum (GW + N) | Final Footprint |
|---|---|
| 0 | 0 |
| 1 – 2 | 1 |
| 3 – 4 | 2 |
| 5 – 6 | 3 |
| 7 – 8 | 4 |
| 9 – 10 | 5 |
| 11 – 12 | 6 |
| 13 – 14 | 7 |
| 15 – 16 | 8 |

The Low end of the Aquifer Footprint scale indicates that a parcel has a low land use intensity, resulting in groundwater nitrate concentrations less than the State of Florida springs Numeric Nutrient Criterion (NNC) for nitrate nitrogen of 0.35 mg/L and a groundwater use per capita of less than 50 gallons per day. The middle of this range, or Medium Aquifer Footprint indicates a blended condition of elevated groundwater nitrate and significant groundwater extraction on a per capita basis, of about 500 gallons per day. Since this is a combined scale, a parcel or individual might get a Medium Aquifer Footprint ranking due to an extremely high nitrogen loading or an extremely high groundwater use, without exerting both impacts simultaneously. The high end of the Aquifer Footprint scale indicates the likelihood of very contaminated groundwater with nitrate nitrogen (above the human health standard of 10 mg/L) and a very high area-based or per capita groundwater extraction and resulting aquifer and springs flow depletion.

### 4.7 Hotspot Analysis

Upon completion of the analysis, the results were visualized using a diverging color scheme of blue to red. Visualization of analysis results is a subjective process, with the type of symbolization, class size, color scheme and other factors chosen by the map's creator. A hotspot analysis provides more objective results by looking for statistically significant patterns in the data. The ArcGIS Optimized Hotspot Analysis Tool statistically analyzes the results using the Getis-Ord Gi* and the False Discovery Rate correction method. The result is the identification of areas of statistically significant spatial clusters, meaning it's not just high impact parcels that are identified, but parcels whose neighboring parcels are identified as having a similar pattern.

## 5. Results

### 5.1 Nitrogen Load Estimates

The Nitrogen Load Estimation results map is shown in Figure 8, with a summary tabulated by county and region in Appendices 1 and 2. The Nitrogen Estimation results for the ten selected springsheds are presented in Figure 9. Detailed maps for the 10 select springsheds are in Appendix 8. The overall picture of nitrogen loading to the Floridan Aquifer System (FAS) is consistent with previous groundwater mapping work conducted by FSI (Figure 10). Loads of nitrogen to the aquifer are highest in those regions where aquifer confinement is lowest which in turn correspond to the more developable lands through the center of North Florida. The most intense nitrogen loading areas are typically associated with areas of intensive agriculture and urban development. The total estimated nitrogen loading to the FAS in the 37 county Springs Region is more than 44,000,000 lbs/yr. An estimated 78% of this load is on land parcels greater than 5 acres. Counties with the highest estimated nitrogen loads to the FAS are Marion, Jackson, Suwannee, Alachua, Lake, and Levy. The highest county-wide per acre nitrogen loading rates are in Suwannee and Jackson counties. Of the 10 selected springsheds, Madison Blue has by far the largest estimated nitrogen load to the aquifer, at roughly 11 million pounds of nitrogen per year. Lafayette Blue, Rainbow, and Silver are the next highest. On a lbs-N/ac/yr basis, Madison Blue is the highest, followed by Jackson Blue, Lafayette Blue, Rainbow, and Silver. For more details on springshed results, see Appendix 3.

Figure 8 – AFA Results: Estimated Nitrogen Load to the Aquifer (lbs-N/ac/yr)

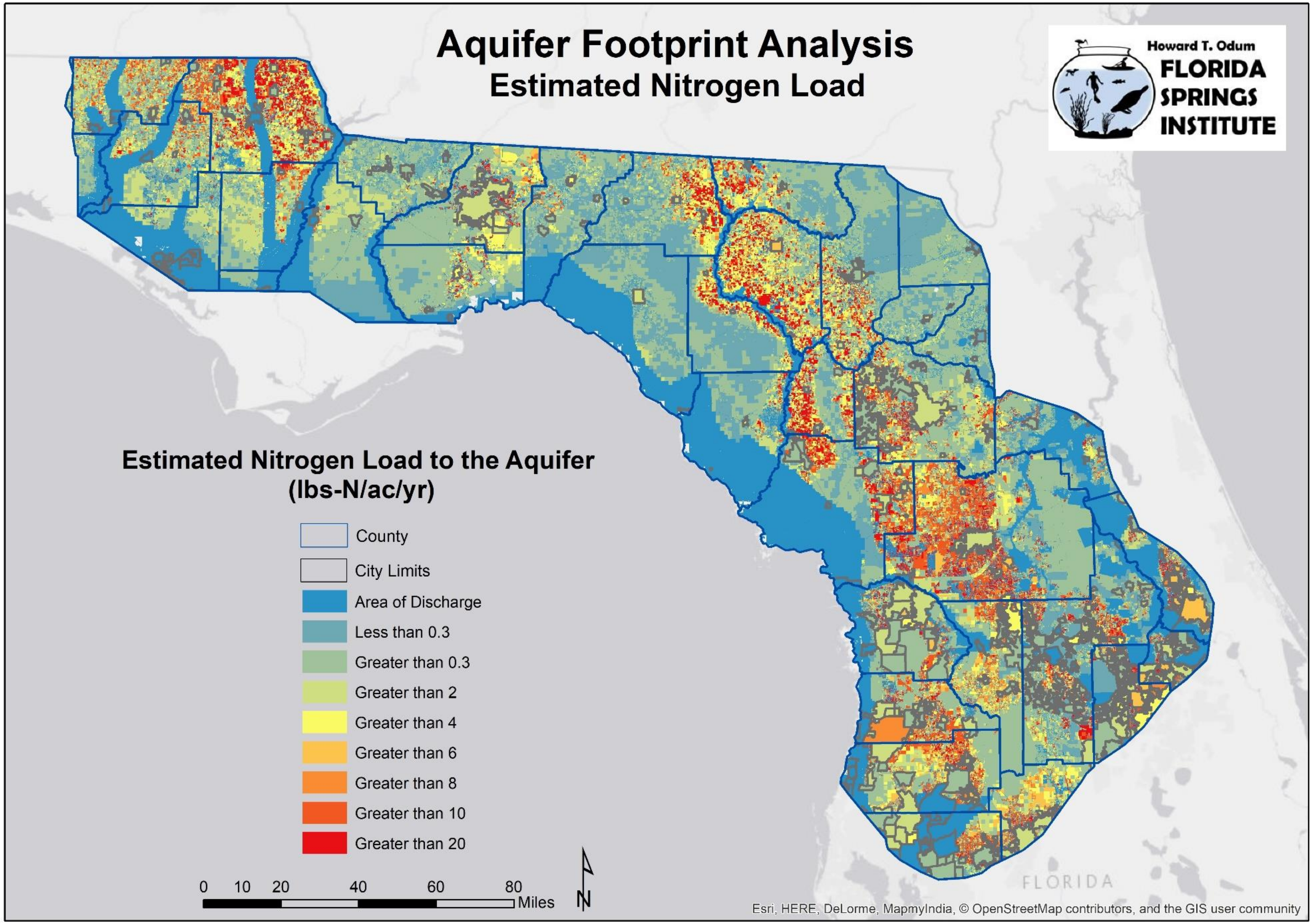


Figure 9 – AFA Results: Estimated Nitrogen Load to the Aquifer (lbs-N/ac/yr) – Select Springsheds

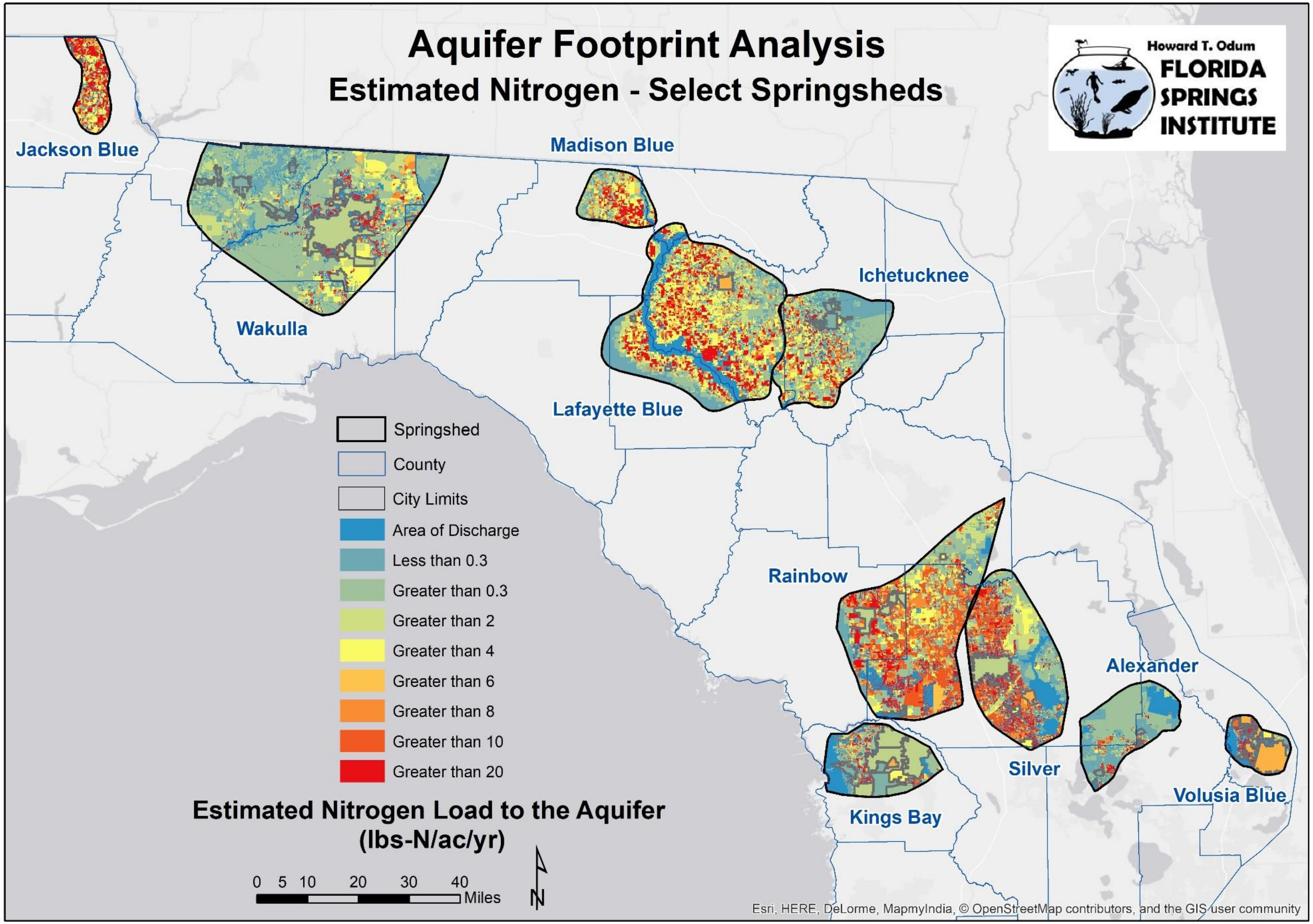
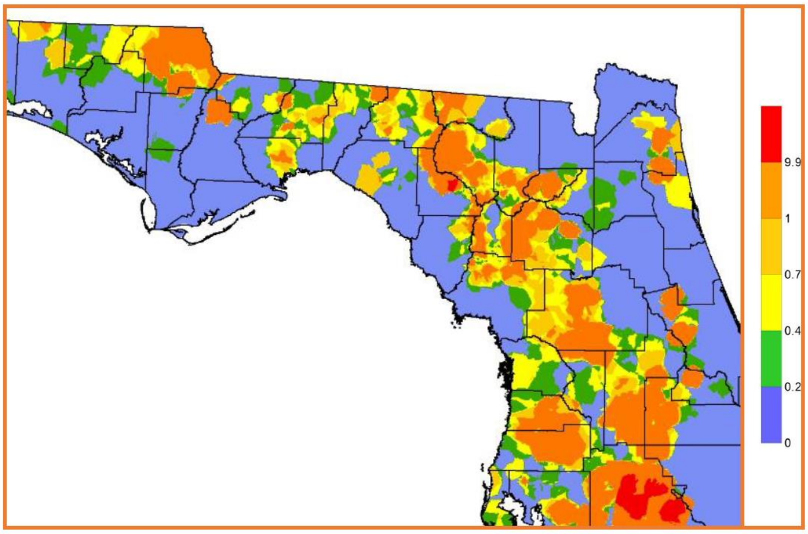


Figure 10 – Nitrate Concentration Results From a Previous FSI Study (Knight, 2015)

Florida Groundwater Nitrate Concentrations 2000-04 (mg N/L)




Nitrogen loading of about 1 to 2 lbs N/ac/yr results in groundwater nitrate concentrations from 0.35 to 1 mg/L (Knight, 2015). Figures 8 through 10 indicate that under areas of intensive nitrogen loading, the aquifer is likely to be contaminated by nitrate concentrations that are above levels that are harmful to springs biota, and at even higher loads may be harmful to humans. All areas in Figures 8 and 9 that have nitrogen loading rates between 0.5 to 4 lbs N/ac/yr (green through yellow) are associated with areas of the Floridan Aquifer with resulting groundwater nitrate concentrations between 0.35 and 2 mg/L, a concentration range associated with springs impairment.  Loading rates in the range from 4 to 10 lbs N/ac/yr (the orange shades) may be associated with groundwater concentrations between 2 and 10 mg/L. This is a range that is very harmful to springs. The highest nitrogen loading rate, above 20 lbs N/ac/yr, is likely to be associated with groundwater nitrate concentrations above the human health standard of 10 mg/L (Graham and Clark (2013).

## 5.2 Groundwater Use Estimates

The Groundwater Use Estimation results map is presented in Figure 11, while Figure 12 contains the results for springshed analysis. The results summary is tabulated by county in Appendix 4, along with results maps for selected springsheds in Appendix 8. The overall picture of groundwater extraction from the Floridan Aquifer System is most intense in highly developed agricultural and urban areas. In the Springs Region studied for this report the major groundwater extractions are concentrated in the following counties; Hamilton, Hillsborough, Lake, Orange, and Suwannee. The total estimated groundwater extraction from the FAS in the 37 counties in the project area is about 953 million gallons per day. An estimated 62% of this groundwater extraction is on land parcels greater than 5 acres. Based on estimates from the Florida Springs Institute (Knight 2015; Knight and Clarke 2014) the safe yield from the FAS based on the need to protect springs ecological function is less than 24 thousand gallons per year per acre (TGY/ac).16 of the 37 counties are at levels higher than 24 TGY/ac. Of the selected springsheds, Lafayette Blue, Wakulla, Rainbow, and Silver had the highest estimated groundwater withdrawals. More detailed results are available for springsheds in Appendix 6.

Figure 11 - AFA Results: Estimated Groundwater Use

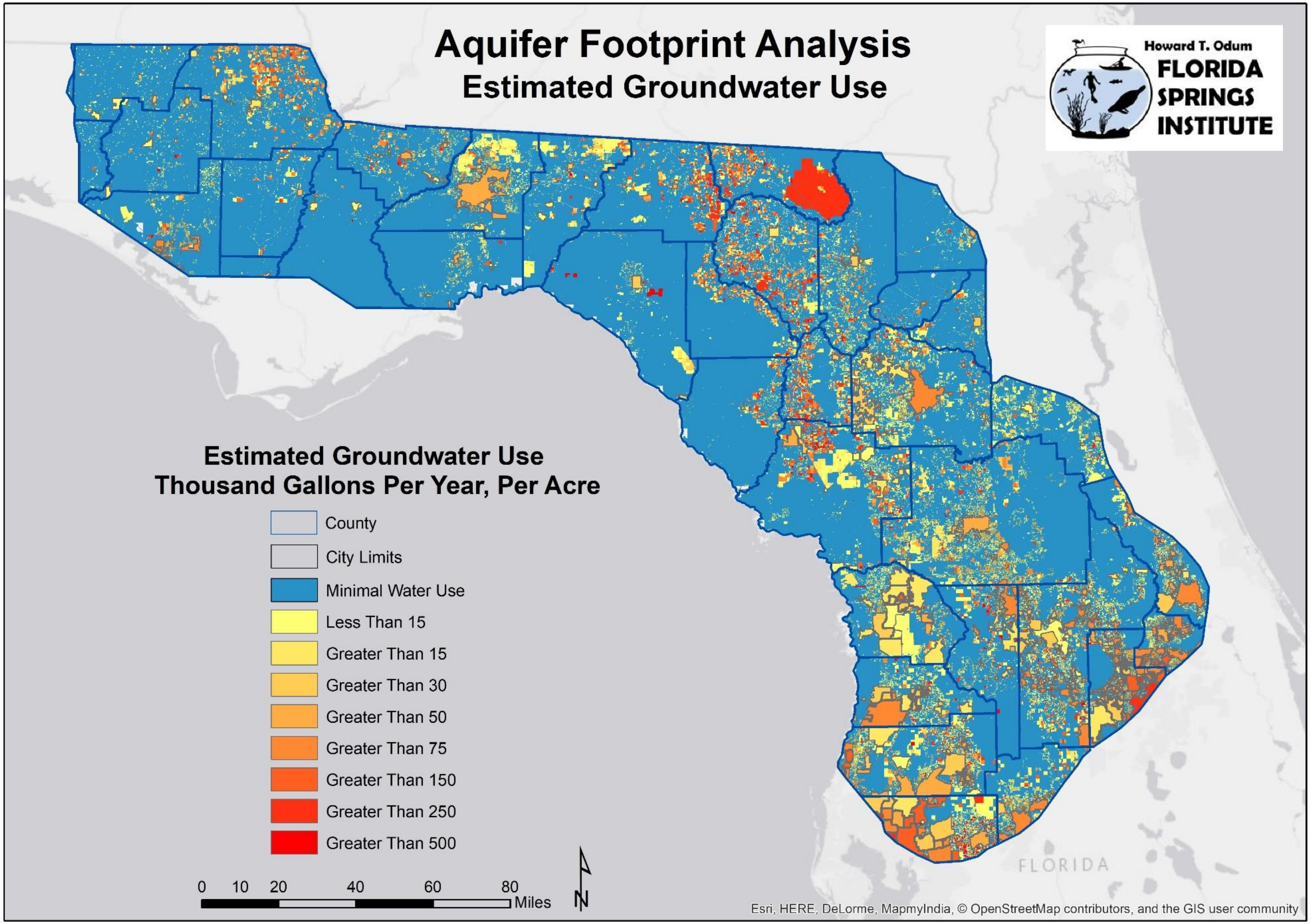
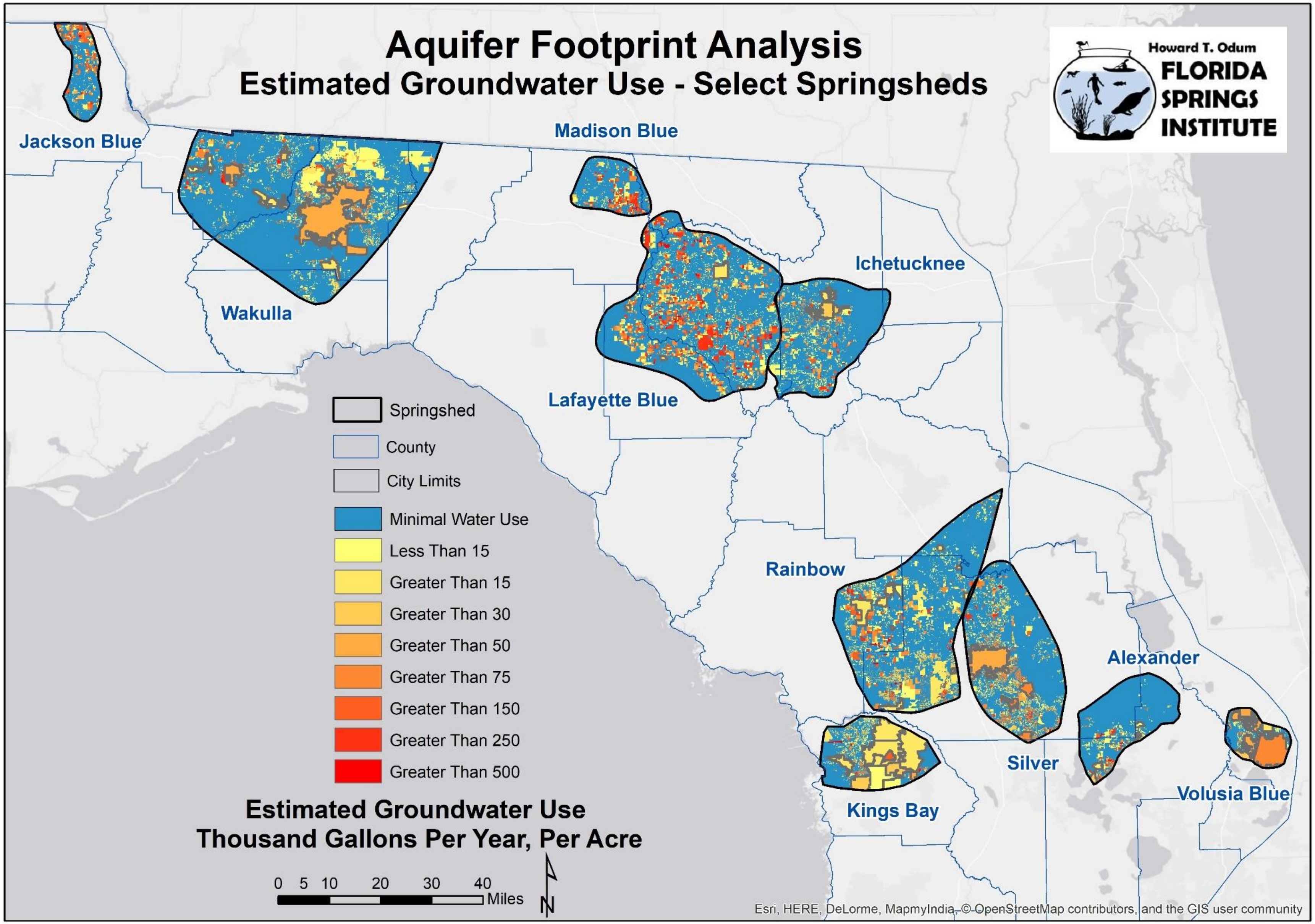


Figure 12 - AFA Results: Estimated Groundwater Use - Springsheds



### 5.3 Overall Aquifer Footprint

Figure 13 provides the results maps of the combined Aquifer Footprint for both estimated nitrogen loading and estimated groundwater extractions. All evaluated land parcels 5 acres and greater, land use areas for parcels less than 5 acres, and city limits are ranked from Low to High aquifer footprint, ranging from 0 to 8. Figure 14 shows the Aquifer Footprint results map for the springsheds. Nine of the ten focus springsheds are colourful, indicating existing conditions that are harmful to their springs ecosystems. Except for Alexander Springs, the other nine springs have all been determined to be impaired by excessive nitrogen loading. Total Maximum Daily Loads and Basin Management Action Plans are either in place or in preparation to alleviate these unacceptable impairments. This AFA will allow thoughtful prioritization for focusing on the most cost-effective land conservation practices. These spring systems are also already protected by regulatory Minimum Flows and Levels (MFLs) or will be by July 2018. This AFA indicates that most of these springs are already being impacted by excessive groundwater extractions that exceed a safe yield. A detailed summary table for the overall footprint is in Appendix 7.

Figure 13 - AFA Results: Overall Footprint

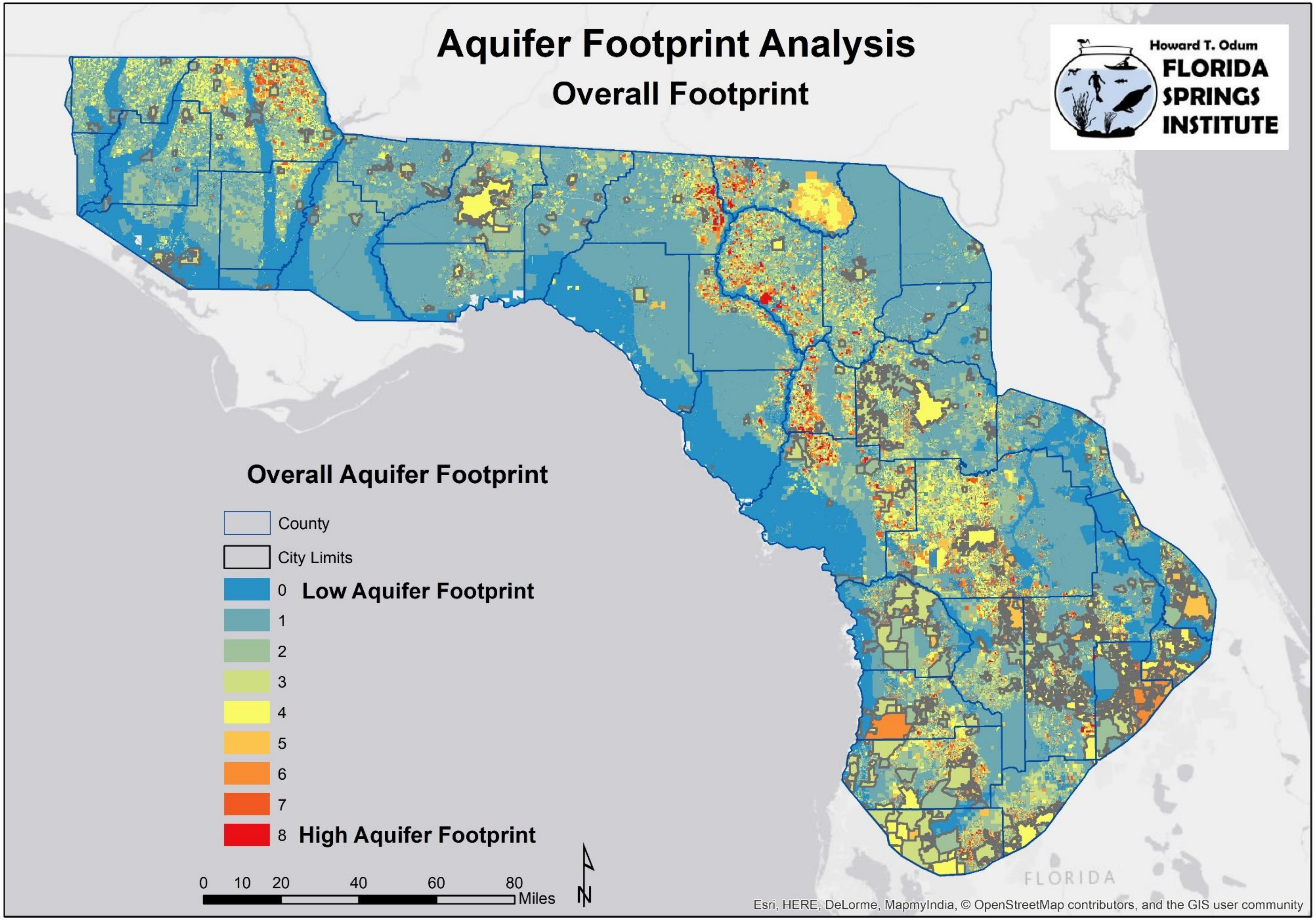
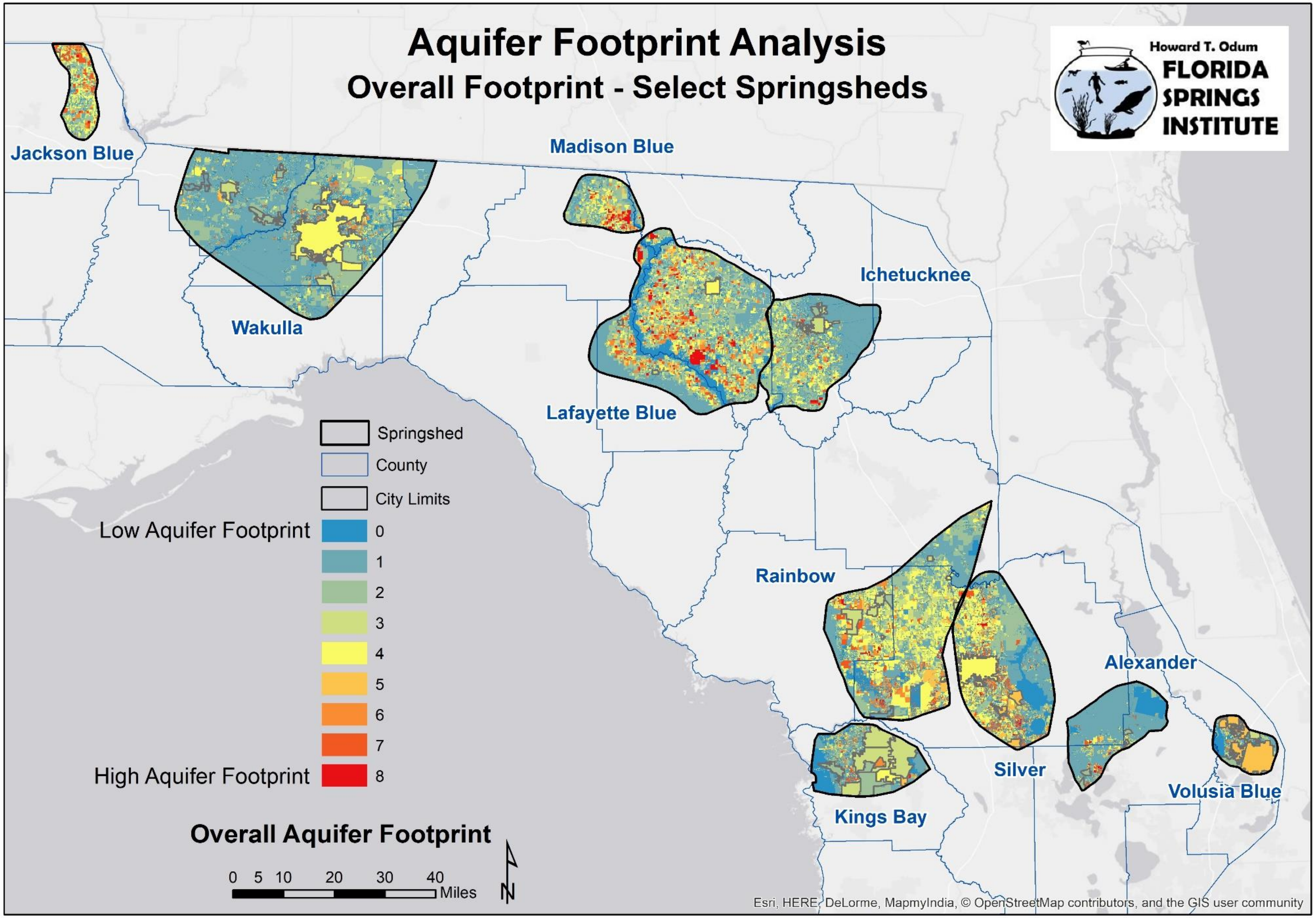


Figure 14 - AFA Results: Overall Footprint - Springsheds



## 5.4 Hotspot Analysis

The Optimized Hotspot Analysis, an ArcMap tool, identified clusters of statistically significant parcels with high estimated nitrogen loads to the aquifer. The ‘Lbs-N/acre/yr’ field was used in the analysis. The results map is presented in Figure 15. Of the 10 springsheds selected by TNC, Jackson Blue, Madison Blue, Rainbow, Lafayette blue, and Silver had the most intense hotspots, indicating these areas as having the highest estimated levels of nitrogen loading. The cold spots, or areas of low estimated nitrogen loading, are mostly in areas of aquifer discharge. Only parcels 5 acres and larger were analyzed, so gaps are present for areas of parcels less than 5 acres and for city limits. This should be considered when examining springsheds like Volusia Blue and Kings Bay, that do not have a large number of hotspots, but cities make up a larger portion of the springshed.

The results map for the Optimized Hotspot Analysis for estimated groundwater use is shown in Figure 16. The ‘TGY/ac/yr’ field was used in the analysis. Very few hotspots were identified in the analysis. Lafayette Blue and Jackson Blue had the most hotspots of the 10 selected springsheds. One possible explanation for the lack of statistically significant hot and cold spots in the groundwater analysis is the methods used to assign groundwater use to each parcel. For WMDs with only point data, the groundwater use was attributed to only the parcel containing the points, leaving the neighboring parcels with no groundwater use estimate. These results indicate a need for more detailed analysis for future work at local level.

The Overall Footprint Optimized Hotspot Analysis results map is presented in Figure 17. The ‘Final Footprint’ field (a value from 0 to 8) was used in the analysis. Of the 10 springsheds selected by TNC, Jackson Blue, Madison Blue, Lafayette Blue, Rainbow, and Silver had the most hotspots. Wakulla had the least hotspots and the most cold spots.

Figure 15 - AFA Results: Nitrogen Hotspot Analysis

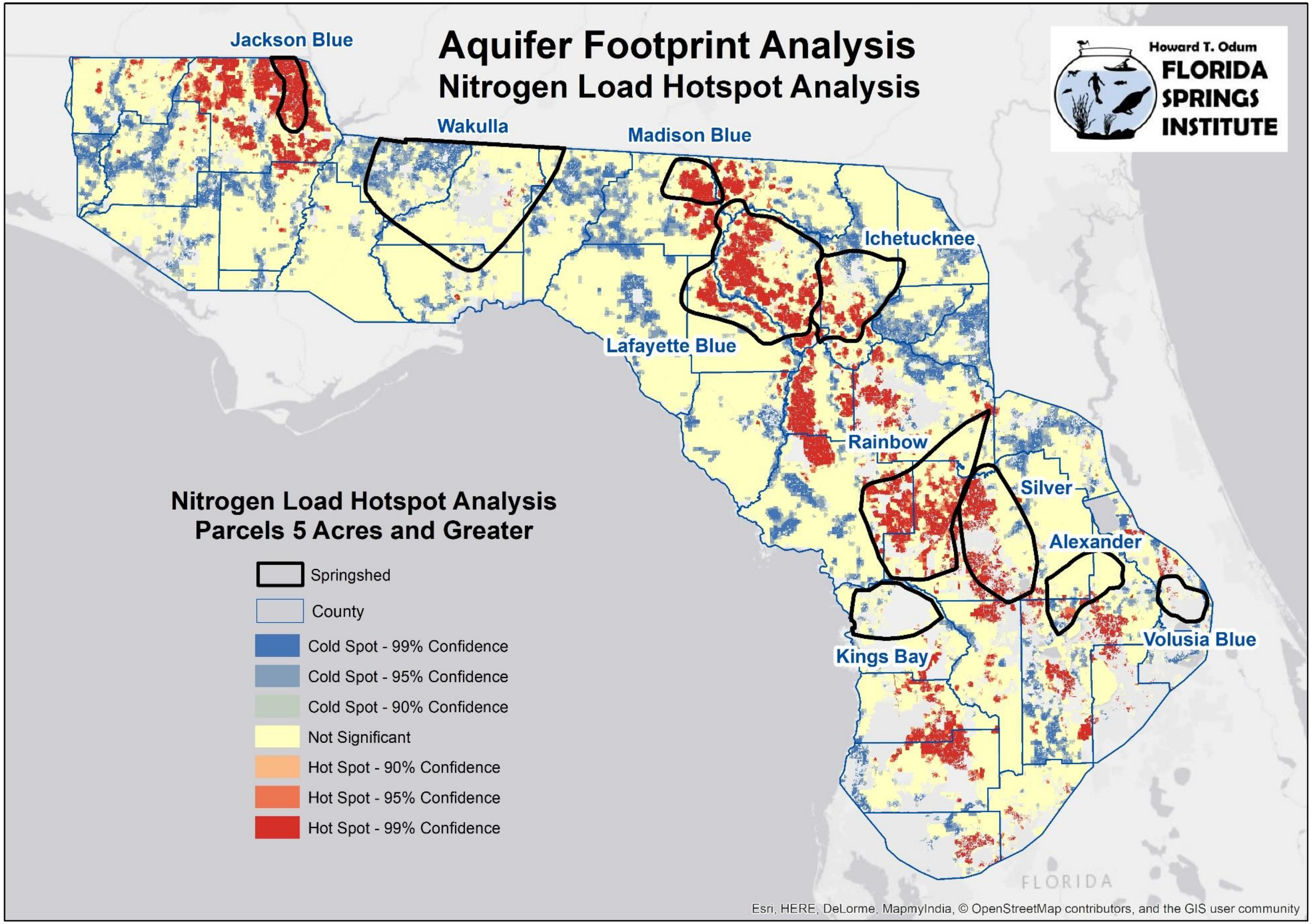


Figure 16 - AFA Results: Groundwater Use Hotspot Analysis

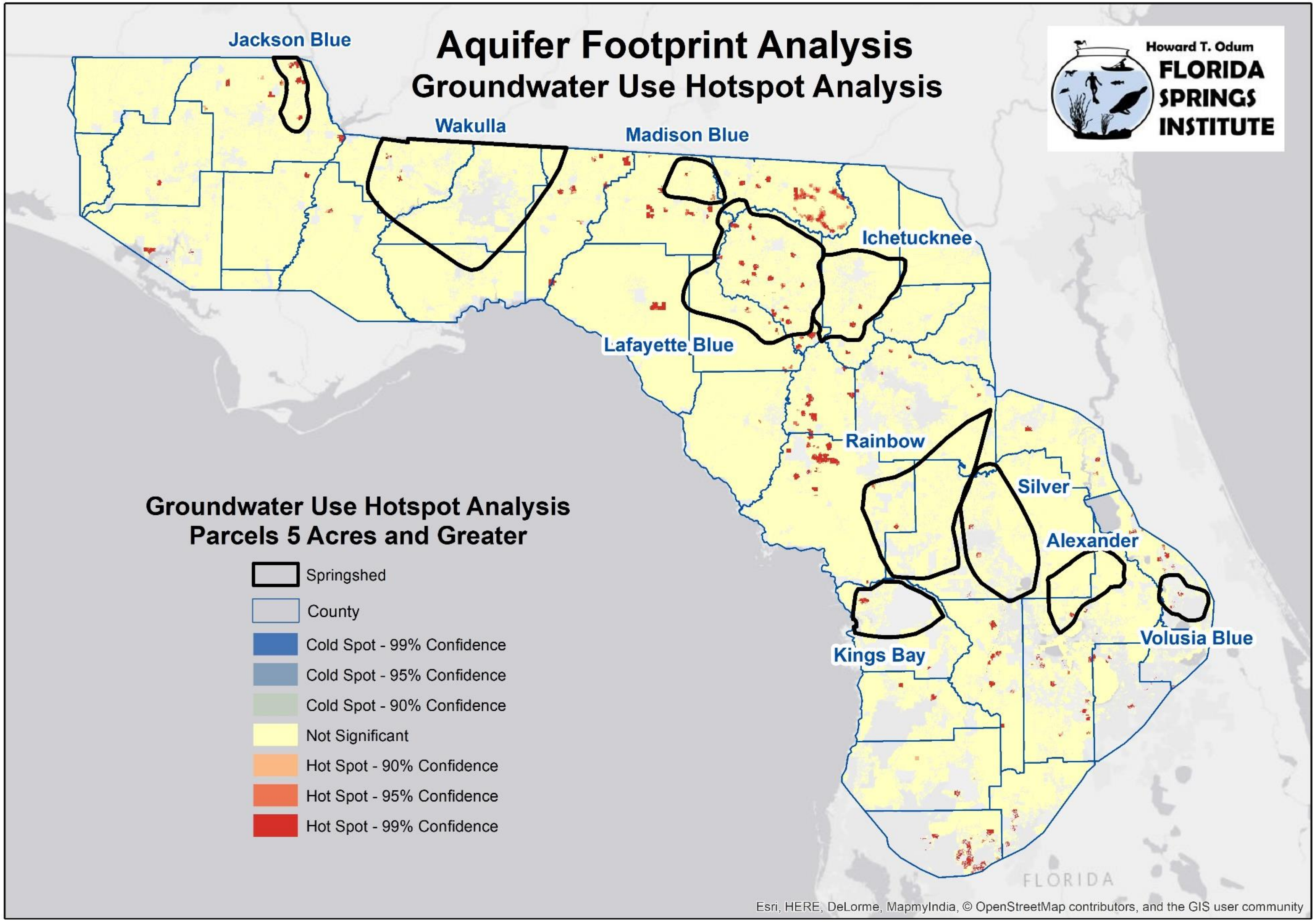
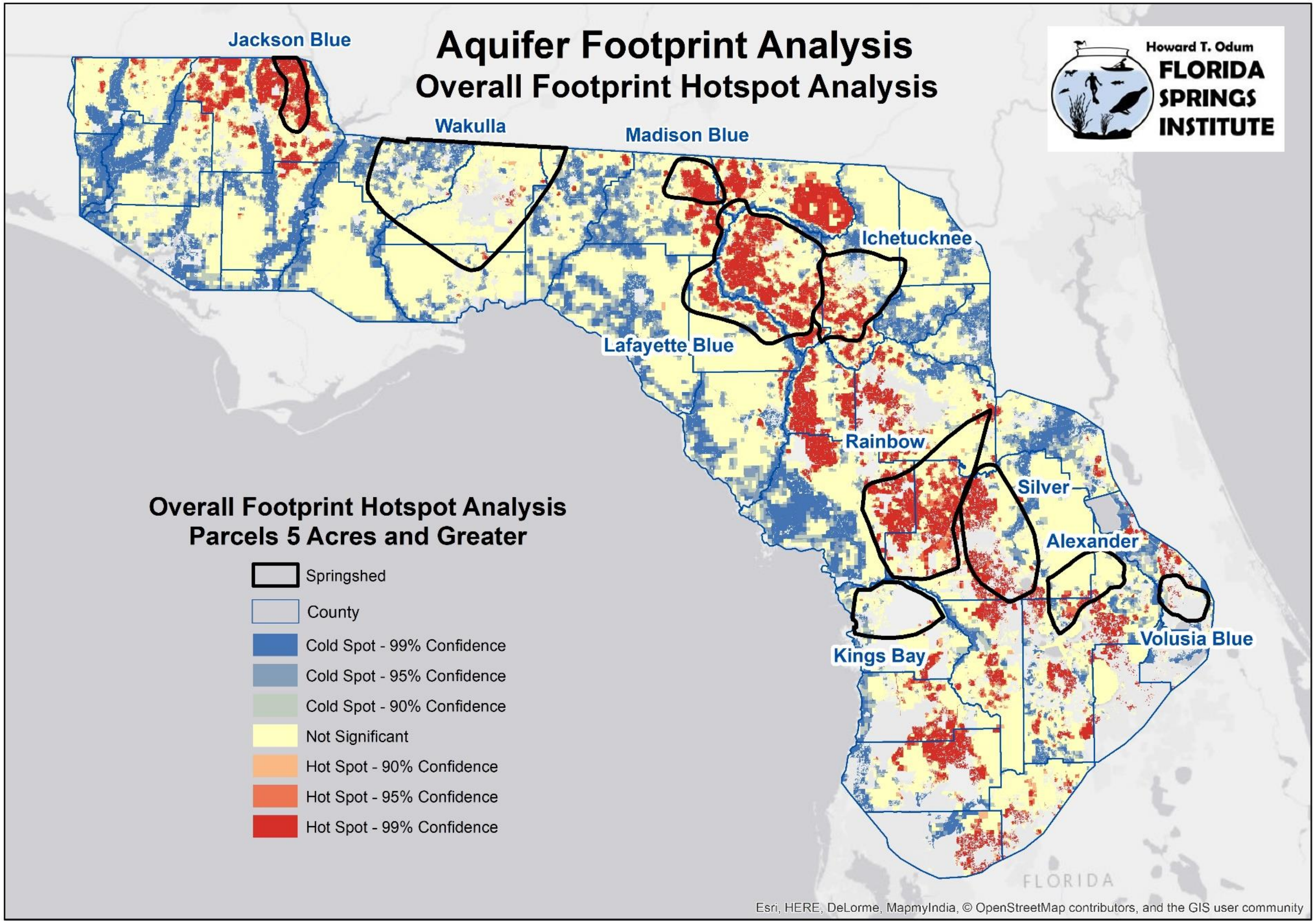


Figure 17 - AFA Results: Overall Footprint Hotspot Analysis



### 5.5 Limitations

The core structural components of the analysis are parcels and land use data. The analysis is performed under the assumption that these layers are representative of current use, however parcel details, ownership, and land use can change at any time. If there is a question about a specific parcel, the parcel ID can be used to obtain the most current data available from the Florida Department of Revenue. The CLC land use file was compiled by the FWC based on data created by Florida's Water Management districts at different times, therefore land cover and land uses may have changed, meaning the actual 'footprint' would differ from this study's estimates.

The nitrogen application rates obtained from FDEP's NSILT research are the best available estimations. The CLC land use data does not provide specific crop data, however, it is available in the FDACS' FSAID geodatabase. Since NSILT only has application rates for a small portion of the listed crops, the data were not used. This means that the results of the Aquifer Footprint Analysis provide general estimates for agriculture. Fertilizer application rates can vary significantly, so this generalization can be a limitation for agricultural parcel estimates. Urban fertilizer application also varies greatly. Estimated application rates from the NSILT research are used, but variation in fertilization practices generalize the 'aquifer footprint' estimates.

The livestock category posed a challenge in the estimation process. There are many animal feeding operations located in the project area and these operations may significantly alter the per parcel estimate using the NSILT methodology, since it is originally a spreadsheet-based methodology, not a spatial one. Data for specific operations is difficult to obtain but other avenues should continue to be researched, including the possibility of using wastewater treatment data for larger operations. If examining a specific springshed, localized data could be obtained to make this category more accurate.

Recharge rates are an important part of the nitrogen estimation process which is affected in the AFA by the fact that three different maps are being used. If a more detailed statewide recharge map becomes available in the future, it could be used to update the AFA. If a smaller area is being examined, such as a county or springshed, a detailed recharge map could be used for the parcels within city limits since city limits were analyzed with a more generalized map and only given one factor. Gainesville is an example of a city with great variation in recharge and would benefit from a more detailed analysis.

Water use estimates rely on data from the USGS' 2010 water use research because water withdrawals are not consistently reported for CUPs. Based on these USGS estimates, an assumption is made that residential per capita use is the same for public-supply and self-supply. The USGS performs their study every five years, however the 2015 water use data are not yet available. The seven-year old generalized data are noted as a limitation and all efforts will be made to obtain more specific and more current data if possible in the project timeframe.

It is important to note that all groundwater use estimates in the AFA are gross groundwater use estimates, not net estimates which include return back to the aquifer. Estimating net groundwater use is the ideal, however larger scale estimations like the USGS reports (Marella, 2014) and the FSAID database only estimate gross use.

Commercial and industrial parcels not associated with a CUP were estimated using county estimate totals from the USGS water use report (Marella, 2014). It should be noted that these categories have the least specific estimates of all groundwater use categories.

The variations among CUPs from different WMDs are discussed in Section 3.5. SRWMD and NWFWMD do not distinguish between the sources of water withdrawal leading to overestimates. All of the counties that have estimated groundwater use figures that are higher than USGS estimates are from SRWMD and NWFWMD. The other estimates are lower than USGS estimates. This is most likely due to the generalization of estimates in city limits and areas of parcels less than 5 acres. In these two categories, only a general residential estimate is calculated. All commercial and industrial groundwater use is not included in these two estimates. These inconsistencies indicate a need for a more detailed analysis once areas of interest or springsheds of interest have been identified.

Due to the project's limitations, the AFA results are most suitable for high level planning and analysis and should not be used for planning or decisions at the municipal or parcel level. Localized and site-specific data would be needed to assess an area of interest at a more detailed resolution.

## 6. Conclusion

The Aquifer Footprint Analysis used open-source data from national, state, and local governments to estimate nitrogen loading to and groundwater use from the aquifer, to create an overall 'Aquifer Footprint' for parcels over five acres, land use areas of parcels less than five acres, and city limits. The accompanying geodatabase provides a baseline for future studies. The Aquifer Footprint Analysis is a powerful tool for prioritizing efforts to protect the quality and quantity of the Floridan Aquifer system and the springs and human economy it supports. Refinements and updates are anticipated to continue to improve its usefulness in the future.

## References

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## Appendix A – NSILT Fertilizer Application Rates and Associated CLC Codes

| CLC Land Use Code | CLC Land Use Code Description | Nitrogen Application Rate (lbs-N/ac/yr) |
|---|---|---|
| 1110 | Upland Hardwood Forest | 0 |
| 1111 | Dry Upland Hardwood Forest | 0 |
| 1112 | Mixed Hardwoods | 0 |
| 1120 | Mesic Hammock | 0 |
| 1122 | Prairie Mesic Hammock | 0 |
| 1123 | Live Oak | 0 |
| 1124 | Pine - Mesic Oak | 0 |
| 1125 | Cabbage Palm | 0 |
| 1140 | Slope Forest | 0 |
| 1150 | Xeric Hammock | 0 |
| 1210 | Scrub | 0 |
| 1211 | Oak Scrub | 0 |
| 1213 | Sand Pine Scrub | 0 |
| 1214 | Coastal Scrub | 0 |
| 1220 | Upland Mixed Woodland | 0 |
| 1230 | Upland Coniferous | 0 |
| 1231 | Upland Pine | 0 |
| 1240 | Sandhill | 0 |
| 1300 | Pine Flatwoods and Dry Prairie | 0 |
| 1310 | Dry Flatwoods | 0 |
| 1311 | Mesic Flatwoods | 0 |
| 1312 | Scrubby Flatwoods | 0 |
| 1340 | Palmetto Prairie | 0 |
| 1400 | Mixed Hardwood-Coniferous | 0 |
| 1410 | Successional Hardwood Forest | 0 |
| 1500 | Shrub and Brushland | 0 |
| 1600 | Coastal Uplands | 0 |
| 1610 | Beach Dune | 0 |
| 1620 | Coastal Berm | 0 |
| 1630 | Coastal Grassland | 0 |
| 1650 | Maritime Hammock | 0 |
| 1660 | Shell Mound | 0 |
| 1670 | Sand Beach (Dry) | 0 |
| 1710 | Sinkhole | 0 |
| 1720 | Upland Glade | 0 |
| 1730 | Limestone Outcrop | 0 |
| 1800 | Cultural - Terrestrial | 21.78 |
| 1810 | Mowed Grass | 0 |
| 1811 | Vegetative Berm | 0 |
| 1812 | Highway Rights of Way | 0 |
| 1821 | Low Intensity Urban | 45.56 |

| CLC Land Use Code | CLC Land Use Code Description | Nitrogen Application Rate (lbs-N/ac/yr) |
|---|---|---|
| 1822 | High Intensity Urban | 45.56 |
| 1831 | Rural Open | 0 |
| 1832 | Rural Structures | 45.56 |
| 1840 | Transportation | 0 |
| 1841 | Roads | 0 |
| 1842 | Rails | 0 |
| 1850 | Communication | 0 |
| 1860 | Utilities | 0 |
| 1870 | Extractive | 0 |
| 1871 | Strip Mines | 0 |
| 1872 | Sand & Gravel Pits | 0 |
| 1873 | Rock Quarries | 0 |
| 1875 | Reclaimed Lands | 0 |
| 1877 | Spoil Area | 0 |
| 1880 | Bare Soil/Clear Cut | 0 |
| 2100 | Freshwater Non-Forested Wetlands | 0 |
| 2110 | Prairies and Bogs | 0 |
| 2111 | Wet Prairie | 0 |
| 2112 | Mixed Scrub-Shrub Wetland | 0 |
| 2114 | Seepage Slope | 0 |
| 2120 | Marshes | 0 |
| 2121 | Isolated Freshwater Marsh | 0 |
| 2122 | Coastal Interdunal Swale | 0 |
| 2123 | Floodplain Marsh | 0 |
| 2140 | Floating/Emergent Aquatic Vegetation | 0 |
| 2141 | Slough | 0 |
| 2210 | Cypress/Tupelo(incl Cy/Tu mixed) | 0 |
| 2211 | Cypress | 0 |
| 2212 | Tupelo | 0 |
| 2213 | Isolated Freshwater Swamp | 0 |
| 2214 | Strand Swamp | 0 |
| 2215 | Floodplain Swamp | 0 |
| 2220 | Other Coniferous Wetlands | 0 |
| 2221 | Wet Flatwoods | 0 |
| 2222 | Pond Pine | 0 |
| 2230 | Other Hardwood Wetlands | 0 |
| 2231 | Baygall | 0 |
| 2232 | Hydric Hammock | 0 |
| 2233 | Mixed Wetland Hardwoods | 0 |
| 2234 | Titi Swamp | 0 |
| 2240 | Other Wetland Forested Mixed | 0 |
| 2241 | Cypress/Hardwood Swamps | 0 |
| 2242 | Cypress/Pine/Cabbage Palm | 0 |
| 2300 | Non-vegetated Wetland | 0 |
| 2400 | Cultural - Palustrine | 0 |

| CLC Land Use Code | CLC Land Use Code Description | Nitrogen Application Rate (lbs-N/ac/yr) |
|---|---|---|
| 2410 | Impounded Marsh | 0 |
| 2430 | Grazed Wetlands | 0 |
| 2440 | Clearcut Wetland | 0 |
| 2450 | Wet Coniferous Plantation | 0 |
| 3000 | Lacustrine | 0 |
| 3100 | Natural Lakes and Ponds | 0 |
| 3111 | Clastic Upland Lake | 0 |
| 3113 | Flatwoods/Prairie/Marsh Lake | 0 |
| 3114 | River Floodplain Lake/Swamp Lake | 0 |
| 3115 | Sinkhole Lake | 0 |
| 3116 | Coastal Rockland Lake | 0 |
| 3117 | Sandhill Lake | 0 |
| 3118 | Major Springs | 0 |
| 3200 | Cultural - Lacustrine | 0 |
| 3210 | Artificial/Farm Pond | 0 |
| 3211 | Aquacultural Ponds | 0 |
| 3220 | Artificial Impoundment/Reservoir | 0 |
| 3230 | Quarry Pond | 0 |
| 3240 | Sewage Treatment Pond | 0 |
| 3250 | Stormwater Treatment Areas | 0 |
| 3260 | Industrial Cooling Pond | 0 |
| 4000 | Riverine | 0 |
| 4100 | Natural Rivers and Streams | 0 |
| 4110 | Alluvial Stream | 0 |
| 4120 | Blackwater Stream | 0 |
| 4130 | Spring-run Stream | 0 |
| 4140 | Seepage Stream | 0 |
| 4160 | Tidally-influenced Stream | 0 |
| 4170 | Riverine Sandbar | 0 |
| 4200 | Cultural - Riverine | 0 |
| 4210 | Canal | 0 |
| 4220 | Ditch/Artificial Intermittent Stream | 0 |
| 5000 | Estuarine | 0 |
| 5210 | Exposed Limestone | 0 |
| 5212 | Non-vegetated | 0 |
| 5220 | Tidal Flat | 0 |
| 5230 | Oyster Bar | 0 |
| 5240 | Salt Marsh | 0 |
| 5250 | Mangrove Swamp | 0 |
| 6000 | Marine | 0 |
| 7000 | Exotic Plants | 0 |
| 7300 | Brazilian Pepper | 0 |
| 9100 | Unconsolidated Substrate | 0 |
| 18211 | Urban Open Land | 0 |
| 18212 | Residential, Low Density | 45.56 |

| CLC Land Use Code | CLC Land Use Code Description | Nitrogen Application Rate (lbs-N/ac/yr) |
|---|---|---|
| 18213 | Grass | 45.56 |
| 18214 | Trees | 0 |
| 18221 | Residential, Med. Density - 2-5 Dwelling Units/AC | 45.56 |
| 18222 | Residential, High Density > 5 Dwelling Units/AC | 45.56 |
| 18223 | Commercial and Services | 21.78 |
| 18224 | Industrial | 21.78 |
| 18225 | Institutional | 21.78 |
| 18311 | Rural Open Forested | 0 |
| 18312 | Rural Open Pine | 0 |
| 18331 | Cropland/Pasture | 122 |
| 18332 | Orchards/Groves | 150 |
| 18333 | Tree Plantations | 80 |
| 18334 | Vineyard and Nurseries | 90 |
| 18335 | Other Agriculture | 122 |
| 21111 | Wiregrass Savanna | 0 |
| 21112 | Cutthroat Seep | 0 |
| 21121 | Shrub Bog | 0 |
| 21211 | Depression Marsh | 0 |
| 21212 | Basin Marsh | 0 |
| 21231 | Freshwater Tidal Marsh | 0 |
| 22131 | Dome Swamp | 0 |
| 22132 | Basin Swamp | 0 |
| 22211 | Hydric Pine Flatwoods | 0 |
| 22311 | Bay Swamp | 0 |
| 22312 | South Florida Bayhead | 0 |
| 22321 | Coastal Hydric Hammock | 0 |
| 22323 | Cabbage Palm Hammock | 0 |
| 22331 | Bottomland Forest | 0 |
| 22332 | Alluvial Forest | 0 |
| 182111 | Urban Open Forested | 0 |
| 182112 | Urban Open Pine | 0 |
| 182131 | Parks and Zoos | 21.78 |
| 182132 | Golf courses | 141.1 |
| 182133 | Ballfields | 21.78 |
| 182134 | Cemeteries | 21.78 |
| 182135 | Community rec. facilities | 21.78 |
| 183111 | Oak - Cabbage Palm Forests | 0 |
| 183311 | Row Crops | 151 |
| 183312 | Field Crops | 150 |
| 183313 | Improved Pasture | 30 |
| 183314 | Unimproved/Woodland Pasture | 0 |
| 183315 | Other Open Lands - Rural | 122 |
| 183321 | Citrus | 150 |

| CLC Land Use Code | CLC Land Use Code Description | Nitrogen Application Rate (lbs-N/ac/yr) |
|---|---|---|
| 183322 | Fruit Orchards | 150 |
| 183323 | Pecan | 90 |
| 183324 | Fallow Orchards | 0 |
| 183331 | Hardwood Plantations | 80 |
| 183332 | Coniferous Plantations | 19 |
| 183341 | Tree Nurseries | 90 |
| 183342 | Sod Farms | 130 |
| 183343 | Ornamentals | 105 |
| 183344 | Vineyards | 90 |
| 183345 | Floriculture | 90 |
| 183351 | Feeding Operations | 0 |
| 183352 | Specialty Farms | 30 |
| 221312 | Gum Pond | 0 |
| 222112 | Cabbage Palm Flatwoods | 0 |
| 1833151 | Fallow Cropland | 0 |

## Appendix B – Data Summary

| Purpose | Data | File Type | Extent | Version | Source | For further information: |
|---|---|---|---|---|---|---|
| Land Use | Cooperative Land Cover | Vector/ Raster | Florida | 3.2 | FWC and FNAI | http://myfwc.com/research/gis/applications/articles/Cooperative-Land-Cover |
| | Statewide Land Use and Land Cover | Vector | Florida | 2004-2016 | FDEP (various WMDs) | http://geodata.dep.state.fl.us/datasets/2f0e5f9a180a412fbd77dc5628f28de3_3 |
| Administrative | Florida County and population | Vector | Florida | 2015 | US Census/TIGER | https://www.census.gov/geo/maps-data/data/tiger-data.html (County and Census Tract) |
| | Parcels by County with Tax Information | Vector | Florida | 2015 | FGDL | http://www.fgdl.org/metadataexplorer/full_metadata.jsp?docId=%7BBF1746D0-6DA2-4A9F-9803-72D30CA22D90%7D&loggedIn=false |
| Nitrogen Loading | Atmospheric Deposition | Raster | Florida | 2015 | NADP | http://nadp.sws.uiuc.edu/committees/tdep/tdepmaps/ |
| | NSILT | Excel | Various BMAPs | Varies | FDEP | http://fdep.maps.arcgis.com/apps/MapJournal/index.html?appid=e71ecaa35bdd4caaba7a0c411691dfa7 |
| | 1988 USGS Recharge Map | Shapefile | Florida | 1988 | USGS | http://www.fgdl.org/metadata/fgdc_html/rcharg_dec03.fgdc.htm (See Cross reference/Citation info) |

| | | | | | | |
|---|---|---|---|---|---|---|
| | WMD Recharge Map | Shapefile | WMD | Varies | SJRWMD, SRWMD | http://data-floridaswater.opendata.arcgis.com/datasets/e740bfd1d37f46fea0e39529f18bd91c_0 (SJRWMD) http://www.srwmd.state.fl.us/index.aspx?NID=319 (SRWMD) |
| | City Limit Boundaries | .gdb | Florida | 2010 | US Census | https://www.census.gov/geo/maps-data/data/tiger-data.html (Places, County Subdivisions, and Related Areas) |
| Groundwater Use | Consumptive Use Permits | Vector | WMD | Varies | FL WMDs | Requested directly from each WMD |
| | FSAID Geodatabase | .gdb | Florida | 2017 | FDACS | http://www.freshfromflorida.com/Business-Services/Water/Agricultural-Water-Supply-Planning |
| | Water withdrawals, use, and trends in Florida 2010 | Excel | Florida | 2010 | USGS | https://fl.water.usgs.gov/infodata/wateruse/datatables2010.html |
| | FL Water Management Inventory | Vector | Florida | 2016 | FLDOH FWMI | http://www.floridahealth.gov/environmental-health/onsite-sewage/research/FLWMI/ |

## Appendix C – Categories Assigned from Parcel Land Use Codes

| Use Code | Definition | Category Assignment |
|---|---|---|
| **Residential** | | |
| 000 | Vacant Residential | Other |
| 001 | Single Family | Residential |
| 002 | Mobile Homes | Residential |
| 003 | Multi-family - 10 units or more | Residential |
| 004 | Condominiums | Residential |
| 005 | Cooperatives | Residential |
| 006 | Retirement Homes not eligible for exemption | Residential |
| 007 | Miscellaneous Residential (migrant camps, boarding homes, etc.) | Residential |
| 008 | Multi-family - fewer than 10 units | Residential |
| 009 | Residential Common Elements/Areas | Other |
| **Commercial** | | |
| 010 | Vacant Commercial | Other |
| 011 | Stores, one story | Commercial |
| 012 | Mixed use - store and office or store and residential combination | Commercial |
| 013 | Department Stores | Commercial |
| 014 | Supermarkets | Commercial |
| 015 | Regional Shopping Centers | Commercial |
| 016 | Community Shopping Centers | Commercial |
| 017 | Office buildings, non-professional service buildings, one story | Commercial |
| 018 | Office buildings, non-professional service buildings, multi-story | Commercial |
| 019 | Professional service buildings | Commercial |
| 020 | Airports (private or commercial), bus terminals, marine terminals, piers, marinas | Commercial |
| 021 | Restaurants, cafeterias | Commercial |
| 022 | Drive-in Restaurants | Commercial |
| 023 | Financial institutions (banks, saving and loan companies, mortgage companies, credit services) | Commercial |
| 024 | Insurance company offices | Commercial |

| Use Code | Definition | Category Assignment |
|---|---|---|
| 025 | Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats | Commercial |
| 026 | Service stations | Commercial |
| 027 | Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment, mobile home sales, motorcycles, construction vehicle sales | Commercial |
| 028 | Parking lots (commercial or patron), mobile home parks | Other |
| 029 | Wholesale outlets, produce houses, manufacturing outlets | Commercial |
| 030 | Florists, greenhouses | Commercial |
| 031 | Drive-in theaters, open stadiums | Commercial |
| 032 | Enclosed theaters, enclosed auditoriums | Commercial |
| 033 | Nightclubs, cocktail lounges, bars | Commercial |
| 034 | Bowling alleys, skating rinks, pool halls, enclosed arenas | Commercial |
| 035 | Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned) | Commercial |
| 036 | Camps | Commercial |
| 037 | Race tracks (horse, auto, or dog) | Commercial |
| 038 | Golf courses, driving ranges | Commercial |
| 039 | Hotels, motels | Commercial |
| **Industrial** | | |
| 040 | Vacant Industrial | Other |
| 041 | Light manufacturing, small equipment manufacturing plants, small machine shops, instrument manufacturing, printing plants | Industrial |
| 042 | Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants | Industrial |
| 043 | Lumber yards, sawmills, planing mills | Industrial |
| 044 | Packing plants, fruit and vegetable packing plants, meat packing plants | Industrial |
| 045 | Canneries, fruit and vegetable, bottlers and brewers, distilleries, wineries | Industrial |
| 046 | Other food processing, candy factories, bakeries, potato chip factories | Industrial |
| 047 | Mineral processing, phosphate processing, cement plants, refineries, clay plants, rock and gravel plants | Industrial |

| Use Code | Definition | Category Assignment |
|---|---|---|
| 048 | Warehousing, distribution terminals, trucking terminals, van and storage warehousing | Industrial |
| 049 | Open storage, new and used building supplies, junk yards, auto wrecking, fuel storage, equipment and material storage | Industrial |
| **Agricultural** | | |
| 050 | Improved agricultural | Other |
| 051 | Cropland soil capability Class I | Other |
| 052 | Cropland soil capability Class II | Other |
| 053 | Cropland soil capability Class III | Other |
| 054 | Timberland - site index 90 and above | Other |
| 055 | Timberland - site index 80 to 89 | Other |
| 056 | Timberland - site index 70 to 79 | Other |
| 057 | Timberland - site index 60 to 69 | Other |
| 058 | Timberland - site index 50 to 59 | Other |
| 059 | Timberland not classified by site index to Pines | Other |
| 060 | Grazing land soil capability Class I | Other |
| 061 | Grazing land soil capability Class II | Other |
| 062 | Grazing land soil capability Class III | Other |
| 063 | Grazing land soil capability Class IV | Other |
| 064 | Grazing land soil capability Class V | Other |
| 065 | Grazing land soil capability Class VI | Other |
| 066 | Orchard Groves, citrus, etc. | Other |
| 067 | Poultry, bees, tropical fish, rabbits, etc. | Other |
| 068 | Dairies, feed lots | Other |
| 069 | Ornamentals, miscellaneous agricultural | Other |
| **Institutional** | | |
| 070 | Vacant Institutional, with or without extra features | Other |
| 071 | Churches | Commercial |
| 072 | Private schools and colleges | Commercial |
| 073 | Privately owned hospitals | Commercial |
| 074 | Homes for the aged | Commercial |

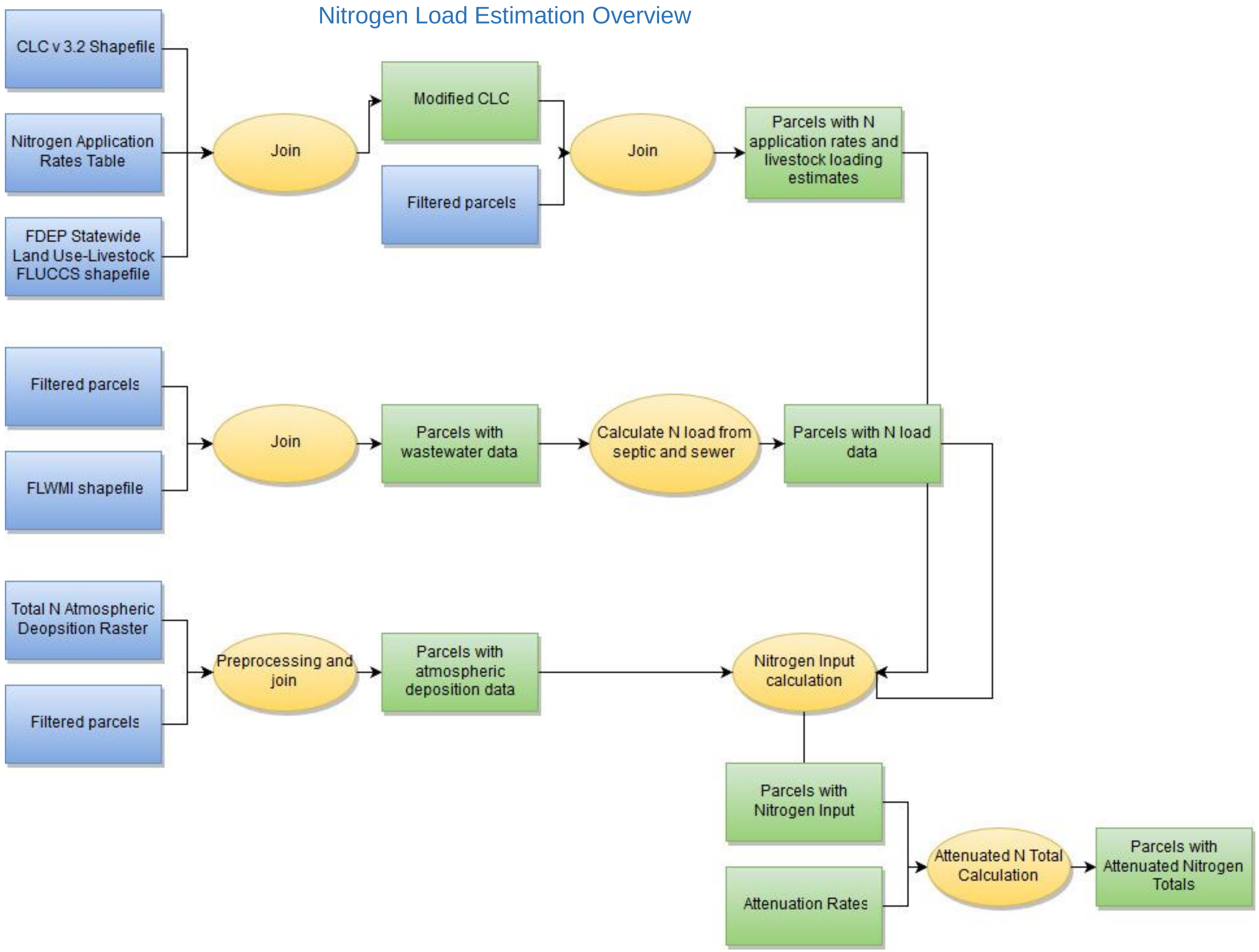
| Use Code | Definition | Category Assignment |
|---|---|---|
| 075 | Orphanages, other non-profit or charitable services | Commercial |
| 076 | Mortuaries, cemeteries, crematoriums | Commercial |
| 077 | Clubs, lodges, union halls | Commercial |
| 078 | Sanatoriums, convalescent and rest homes | Commercial |
| 079 | Cultural organizations, facilities | Commercial |
| **Governmental** | | |
| 080 | Vacant Governmental | Other |
| 081 | Military | Commercial |
| 082 | Forest, parks, recreational areas | Other |
| 083 | Public county schools - including all property of Board of Public Instruction | Commercial |
| 084 | Colleges (non-private) | Commercial |
| 085 | Hospitals (non-private) | Commercial |
| 086 | Counties (other than public schools, colleges, hospitals) including non-municipal government | Commercial |
| 087 | State, other than military, forests, parks, recreational areas, colleges, hospitals | Other |
| 088 | Federal, other than military, forests, parks, recreational areas, hospitals, colleges | Other |
| 089 | Municipal, other than parks, recreational areas, colleges, hospitals | Commercial |
| **Miscellaneous** | | |
| 090 | Leasehold interests (government-owned property leased by a non-governmental lessee) | Other |
| 091 | Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication | Other |
| 092 | Mining lands, petroleum lands, or gas lands | Other |
| 093 | Subsurface rights | Other |
| 094 | Right-of-way, streets, roads, irrigation channel, ditch, etc. | Other |
| 095 | Rivers and lakes, submerged lands | Other |
| 096 | Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps | Other |
| 097 | Outdoor recreational or parkland, or high-water recharge subject to classified use assessment | Other |
| **Centrally Assessed** | | |

| Use Code | Definition | Category Assignment |
|---|---|---|
| 098 | Centrally assessed | Other |
| **Non-Agricultural Acreage** | | |
| 099 | Acreage not zoned agricultural with or without extra features | Other |

## Appendix D – Average Household Size (U.S. Census 2010)

| County Name | Average Household Size |
|---|---|
| ALACHUA | 2.32 |
| BAKER | 2.82 |
| BAY | 2.41 |
| BRADFORD | 2.53 |
| CALHOUN | 2.52 |
| CITRUS | 2.2 |
| CLAY | 2.76 |
| COLUMBIA | 2.52 |
| DIXIE | 2.37 |
| FRANKLIN | 2.29 |
| GADSDEN | 2.61 |
| GILCHRIST | 2.58 |
| GULT | 2.33 |
| HAMILTON | 2.54 |
| HERNANDO | 2.38 |
| HILLSBOROUGH | 2.55 |
| HOLMES | 2.47 |
| JACKSON | 2.4 |
| JEFFERSON | 2.38 |
| LAFAYETTE | 2.63 |
| LAKE | 2.42 |
| LEON | 2.35 |
| LEVY | 2.45 |
| LIBERTY | 2.57 |
| MADISON | 2.48 |
| MARION | 2.35 |
| ORANGE | 2.64 |
| PASCO | 2.42 |
| POLK | 2.59 |
| PUTNAM | 2.48 |
| SEMINOLE | 2.55 |
| SUMTER | 2.04 |
| SUWANNEE | 2.52 |
| TAYLOR | 2.44 |
| UNION | 2.66 |
| VOLUSIA | 2.31 |
| WAKULLA | 2.61 |
| WALTON | 2.38 |
| WASHINGTON | 2.5 |

## Appendix E – Methodology Overview



Groundwater Use Estimation Overview

## Footprint Calculation Overview