BLUE WATER AUDIT – YEAR 1 METHODS SUMMARY

1. Project Overview

The primary objectives of Year 1 of the Blue Water Audit (BWA) project were to (1) estimate nitrogen loading to the FAS in the Florida Springs Region; (2) to estimate groundwater withdrawals from the FAS in the Florida Springs Region; (3) to create an overall 'Aquifer Footprint' based on analysis results; and (4) to develop an educational website and interactive map.

The Blue Water Audit (BWA) analysis is broken into 3 spatial analysis units:

- **Unit 1**: individual parcels that are 5 acres and larger (outside of city limits)
- **Unit 2:** generalized land use where parcel size is less than 5 acres (outside of city limits)
- **Unit 3:** cities (all parcels within city limits are analysed as single entities)

The BWA has two focus areas – **nitrogen loading and groundwater withdrawals** – that are made up of different source categories. Existing data were gathered and analyzed for each category. Data from the agencies listed in Table 1 were used in the analysis. See Appendix 1 for a complete list of data sources used in Year 1 of the BWA Analysis.

Blue Water Audit - Year 1 Analysis *Data Sources & Abbreviations*	
Florida Department of Environmental Protection (FDEP)	St. Johns River Water Management District (SJRWMD)
Florida Department of Health (FDOH)	Southwest Florida Water Management District (SWFWMD)
Florida Department of Revenue (FDOR)	South Florida Water Management District (SFWMD)
Florida Department of Agriculture and Consumer Services (FDACS)	U.S. Geological Survey (USGS)
Northwest Florida Water Management District (NWFWMD)	U.S. Census
Suwannee River Water Management District (SRWMD)	National Atmospheric Deposition Program (NADP)

Table 1 – BWA Year 1 analysis data sources and abbreviations

2. Unit 1 – Nitrogen Load Estimation – Overview and Sources

The most comprehensive source for nitrogen load estimation 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, quantifies their estimated load attenuation during groundwater recharge, and resulting mass load to the aquifer. NSILT uses property appraiser land use data, estimated fertilizer use by land cover, 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 twenty four 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. NSILT was an integral reference for the BWA's nitrogen estimation process.

The nitrogen load estimation portion of the BWA analysis also starts with estimated nitrogen loads based on natural and human-modified land uses. As with NSILT, the BWA analysis next estimates nitrogen attenuation processes and aquifer recharge to estimate the overall nitrogen load to the groundwater. The BWA analysis does not attempt to address the subsequent movement and possible depuration of nitrogen once it has entered the Floridan Aquifer.

The framework of the BWA analysis is made up of statewide parcel data from the Florida Department of Revenue (FDOR). Land use is another integral component of the analysis. The Florida Department of Environmental Protection's (FDEP) Statewide Land Use and Land Cover (LULC) data were used to identify general land use. The LULC layer is made up of land use data collected from various agencies around the state. The Florida Department of Agriculture and Consumer Services' (FDACS) Florida Statewide Agricultural Irrigation Demand (FSAID) Geodatabase was used to identify agricultural land use. The LULC layer and the FSAID layer were merged to create the final land use layer used in the BWA. Categories for nitrogen load estimation in the BWA analysis include atmospheric deposition, crop fertilizers, non-crop fertilizers, human-derived wastewater sources, and livestock waste disposal practices (Figure 1).

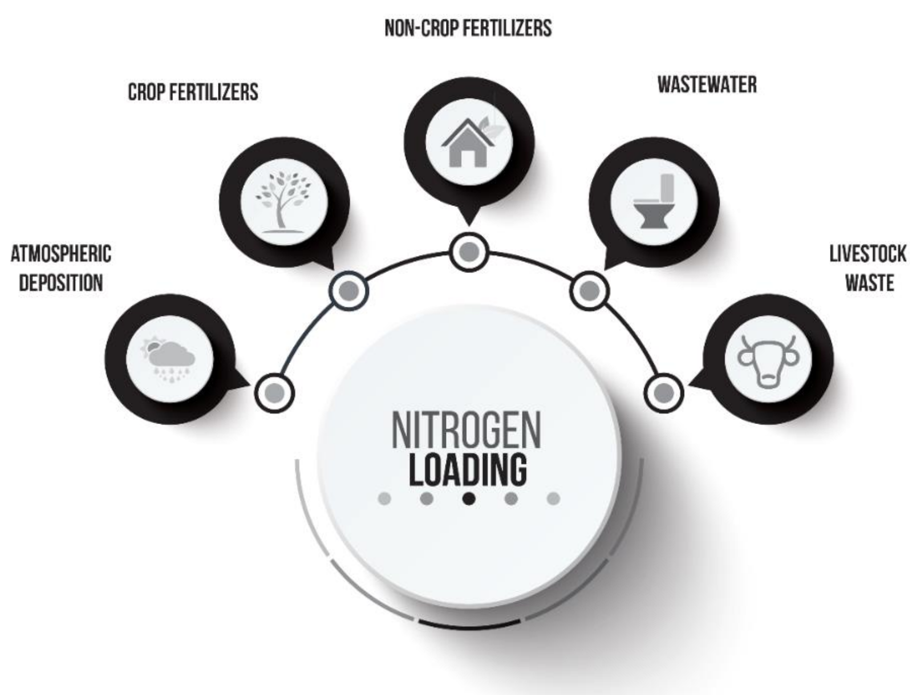

Figure 1 – Blue Water Audit nitrogen source categories

Atmospheric nitrogen deposition was estimated using data from the National Atmospheric Deposition Program (NADP), which combines wet and dry deposition to estimate total nitrogen deposition. The merged land use layer and NSILT fertilizer application rates were used to estimate the nitrogen load from crop and non-crop fertilization. Wastewater inputs were estimated using septic and sewer system data from the Florida Department of Health (FDOH) Florida Water Management Inventory (FLWMI) database. Livestock waste inputs were estimated using Census of Agriculture data. A per-acre nitrogen load estimate was developed for poultry using data from a report on Best Management Practice (BMP) effectiveness (Graham and Clark, 2013).

Once the load to the land surface had been estimated, NSILT's attenuation factors were applied. The final step in estimating the nitrogen load to groundwater was to account for the effects of recharge rates on vertical nitrogen transport to the Floridan Aquifer. Detailed aquifer recharge maps from St. Johns and Suwannee River Water Management Districts (WMDs) were used as well as a more general United States Geological Survey (USGS) map when no other coverage was available.

2.1 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. Atmospheric nitrogen deposition consists of a variable combination of inorganic and organic nitrogen fractions. For the BWA unattenuated portion of the total nitrogen in atmospheric deposition was assumed to be convertible to nitrate in the unsaturated zone above the aquifer. The atmospheric deposition values are reported as kg-N/ha and were converted into lbs-N/ac. The total atmospheric deposition values were identified, and the acreage of each parcel was multiplied by the corresponding atmospheric deposition value.

2.2 Fertilizers

To estimate crop and non-crop fertilizers, a table was created containing all land use codes from the FDEP and FSAID layers. NSILT fertilizer application estimates in lbs-N/ac/yr were linked to the relevant land use types. The table was joined to the merged land use layer and land use types were identified within each parcel. The nitrogen input was calculated based on the extent of relevant land use types and then summed to create an overall Fertilization Input Rate for each parcel.

2.2.1 Crop Fertilizers

NSILT uses two types of crop fertilizer estimation methodologies. One is based on fertilizer sales totals for the state. The other estimates fertilizer application rates based on agricultural best management practices (Eller & Katz, 2017). The BWA analysis used the application rate method to make estimates more tailored to crop types. The following equation was used to calculate the total input of lbs-N/ac/yr to the land surface:

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

2.2.2 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 commercial lawn service. Due to the spatial nature of the BWA, and to simplify calculations, only 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 2.

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

Table 2 – NSILT probability factor (Eller et al., 2017)

The NSILT probability factor was applied to BWA residential fertilizer estimate calculations, which also factor in the amount of land assumed to be fertilized (50 percent of the parcel) as well as the number of applications per year (3), as 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 and recreational parcels was estimated using NSILT's equation for lawn service fertilization. It is like the self-fertilization equation but uses lower application rates and fewer applications under the assumption that lawn service companies follow best management practices and that there is less permeable area to be fertilized (35 percent of the parcel).

Estimated Commercial/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 (Eller & Katz, 2017). For this reason, NSILT used a separate application rate. This higher golf course fertilization estimate was used in the BWA analysis.

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

2.3 Wastewater

Data from the FDOH's FLWMI were used in the estimation of nitrogen from wastewater in NSILTs study and were also used in the BWA analysis. The FLWMI geodatabase contains parcel data with associated wastewater system information. According to the FDOH, data were gathered from various stakeholders across the state but not all providers submitted data, which left some areas unidentified. To address this issue in the BWA analysis, if a parcel was listed as unknown, it was assigned as sewer if it was a non-vacant residential parcel within city limits and assigned as septic if it was a non-vacant residential parcel outside city limits. The wastewater information was joined to the analysis parcels and a category was assigned to each parcel based on the property appraiser land use codes.

For residential OSTDS parcels, the average household size for each county determined by the 2010 U.S. Census is multiplied by 9.012 lbs-N/yr, the U.S. Environmental Protection Agency's estimate for pounds of nitrogen produced per year per person. For each residential parcel connected to a central sewer, the average county household size is multiplied by 1 lbs-N/yr, which is discussed in more detail in Section 8.1.1. This lower per capita rate is based on the assumption that about 90% of the nitrogen in domestic sewage is removed during primary, secondary, and advanced wastewater treatment.

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 2010 U.S. Census. For commercial parcels connected to central sewers, 1 lbs-N/yr is multiplied by 19.48.

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.

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 LULC and FSAID 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). The following equation was used to estimate cattle waste nitrogen loads to the land surface:

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

The same methodology was used to estimate the nitrogen load from horses. The 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 8.1.3. The category 'Poultry Feeding Operations' was used to identify relevant land uses. An estimate of 100 lbs-N/ac was used to estimate the input from poultry waste, as shown below:

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

2.5 Attenuation and Recharge

Once all inputs to the land surface had been estimated, subsurface attenuation processes were accounted for. The NSILT reports listed various ranges for attenuation. Based on a review of all attenuation ranges used, the summary figures in Table 3 were chosen. The equation is shown below:

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

Category	Attenuation Summary
Atmospheric Deposition	0.90
WWTF - Sewers	0.60
Septic Systems	0.50
Urban Fertilizer	0.80
Farm Fertilizer	0.70
Livestock-Cattle	0.90
Horse Farms	0.90

Table 3 – Attenuation summary by land use type

After the estimates were adjusted for attenuation, the parcel's recharge factor was identified by overlaying the merged recharge map, using the recharge factors shown in Table 4.

Recharge Level	Recharge Factor
High Recharge	0.90
Medium Recharge	0.50
Low Recharge	0.10

Table 4 – Recharge factors by recharge level (Eller et al., 2017)

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 and 5.

3. Unit 1 – Groundwater Withdrawal Estimation – Overview and Sources

The components of groundwater withdrawal estimation include estimates of water use for irrigated agricultural land from the FDACS FSAID Irrigated Lands Geodatabase (ILG), reported water withdrawal records from water management districts (WMDs), modified CUP data from WMDs, and general groundwater withdrawal estimates from the USGS 2010 water use report (Marella, 2014).

3.1 Agricultural Groundwater Withdrawals

The FDACS FSAID ILG is the primary source for estimated agricultural groundwater withdrawals. 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 water use was applied to that parcel.

3.2 Reported Groundwater Withdrawals

In some portions of the Florida Springs Region, owners of larger wells are required to routinely report their groundwater withdrawals to water management districts. The records of reported groundwater withdrawals vary greatly by district. Not all wells report their withdrawals and districts began obtaining these reported data at different times. Reported groundwater withdrawal records were obtained from Suwannee River WMD, St. Johns WMD, Southwest Florida WMD, and South Florida WMD. An average of all reported groundwater withdrawals within the years of 2008-2018 was taken. These averages were joined to the parcel or parcels related to the well permit.

3.3 Consumptive Use Permits

CUP withdrawal allocations were obtained from all five Florida WMDs and matched to well locations and parcels. If there was no FSAID estimate or reported withdrawal data for a parcel, then the CUP allocation amounts were used. Generally, the allocation amount for a permit is higher than the actual water withdrawals. To address this, permits were compared that had both reported withdrawal data and a CUP allocation. Based on this comparison, it was found that on average up to 56 percent of the allocation was withdrawn. Therefore, only 56 percent of each CUP allocation was used in the BWA analysis. To make household level residential groundwater withdrawal estimates, the BWA analysis uses general estimates developed in the

2010 USGS water use report (Marella, 2014). Public supply CUPs were not included in the BWA analysis to ensure they were not counted twice.

3.4 General Estimates

To estimate residential ground water withdrawals, non-vacant residential parcels were 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 from the 2010 USGS report. Including the number of residential units in the equation ensured multi-family/unit buildings 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 reported groundwater withdrawals or a CUP, parcels were assigned a category based on parcel use type and all commercial and industrial parcels were totaled for each county using the full parcel layer that included all parcels (regardless of acreage) to get an accurate count. The average use estimate per county was divided by the number of parcels in that category 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 or reported groundwater withdrawals.

4. Unit 2 – Parcels Less Than 5 Acres

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 2.2.2. A probability factor was not used for Unit 2 calculations because general land use data was used instead of parcel data, so there is no information about property value. The following equation estimates fertilizer use for areas of residential land use:

Estimated Residential Fertilization Input (Unit 2 – Areas of parcels < 5 acres) =

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

4.2 Nitrogen Estimation – Wastewater

FLWMI data and the merged land use 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 categories based on density. 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 areas served by central sewers were multiplied by 1 lbs-N/yr.

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 Groundwater Withdrawal Estimation – Residential

Since land use data were used instead of parcels for Unit 2 of the BWA analysis, the population of these areas was estimated based on the density of the residential land use type as discussed in Section 4.2. Once the number of units per acre were determined, that number was multiplied by the county average household size and then multiplied by the USGS per capita county estimate for public supply water use.

Estimated Residential Groundwater Use (Unit 2 – Areas of parcels < 5 acres) =

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

5. Unit 3 - City Limits

5.1 Nitrogen Estimation – Wastewater

FLWMI data were used to estimate nitrogen loading from wastewater in city limits. The number of OSTDS within each city limit 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.

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.

5.3 Groundwater Withdrawal Estimation – Non-Crop

City limit polygons, obtained from the U.S. Census, contain 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.

5.4 Groundwater Withdrawal 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 the corresponding percentage of water use was applied to that city.

6 Generalization for Online Display

The BWA analysis results form a detailed, comprehensive geodatabase with nitrogen load estimates and groundwater withdrawal estimates for parcels five acres and larger, areas of parcels less than five acres, and city limits. Due to the size of the project area and the complexity of the data, the results have been generalized for online display so that the overall pattern of impact is retained but specific parcel boundaries are mostly obscured, as shown in Figure The results were generalized by converting the detailed polygon to a raster. The generalization also improves the interactive map's performance.

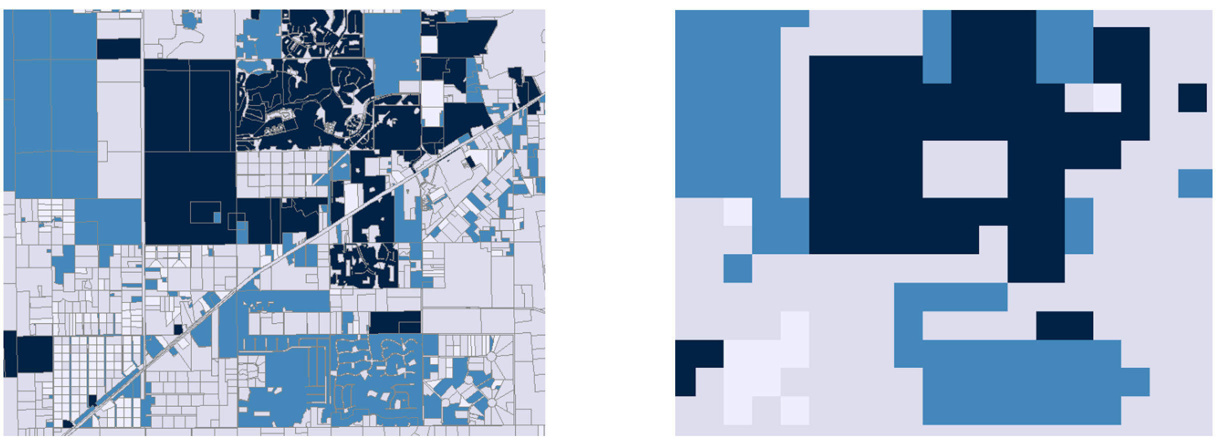

Figure 2 – BWA Result generalization example

7 Overall Aquifer Footprints

7.1 Nitrogen Classification – Floridan Aquifer Nitrogen Footprint

All nitrogen load estimates were divided by parcel area for normalization. Based on a literature review of nitrogen loads, attenuation rates, and resulting groundwater nitrate concentrations, a BWA nitrogen footprint classification scale was developed for reporting results. Five categories as shown in Figure 3 were identified based on the assessed likelihood of harm to springs and public health as follows:

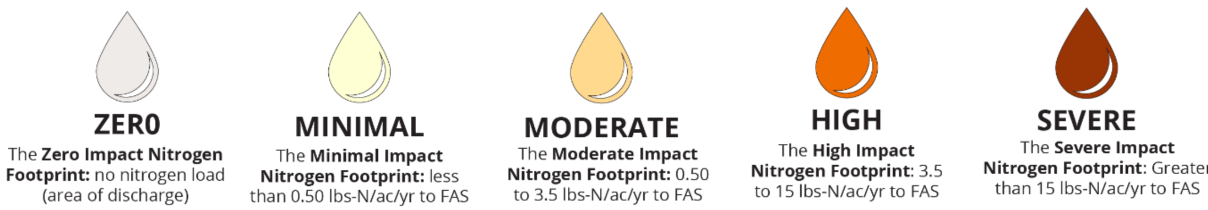

Figure 3 – BWA Nitrogen Footprint categories

Zero Impact is reserved for areas of the Floridan Aquifer where groundwater discharges to the land surface. These areas occur along the coastal margins where much of the land surface is topographically lower than the average piezometric surface of the aquifer. It is assumed there is no net transport of nitrogen to the underlying groundwater in these mapped areas of negative recharge.

Minimal Impact is reserved for areas of the Floridan Aquifer where nitrogen loads to the land surface are estimated to maintain groundwater nitrate concentrations less than or equal to 0.35 mg/L. Naturally-occurring groundwater nitrate concentrations throughout the Springs Region are generally less than 0.1 mg/L. The maximum Numeric Nutrient Criterion (NNC) for nitrate at springs is 0.35 mg/L. For the purposes of the BWA the nitrogen load to the aquifer that results in a nitrate concentration below 0.35 mg/L is about 0.50 lbs/ac/yr. Based on estimated average assimilation rates this is equivalent to a total nitrogen load to the land surface of about 3.0 lbs/ac/yr.

Moderate Impact denotes the BWA nitrogen footprint in areas where groundwater nitrate concentrations are in the range from 0.35 to 2.5 mg/L. FDEP has determined that these concentrations contribute to springs impairment and excessive algal growth. The 2.5 mg/L nitrate concentration in groundwater drinking supplies is below the human health standard of 10 mg/L but has been linked through epidemiological studies with a three to five-fold increase in the incidence of various cancers and birth defects. Groundwater nitrogen loading rates estimated to result in this range of nitrate concentrations vary from 0.5 to 3.5 lbs/ac/yr. The corresponding surface nitrogen loading rates in Florida's Springs Region range from 3 to 25 lbs/ac/yr.

High Impact denotes the BWA nitrogen footprint in areas where groundwater nitrate concentrations are in the range from 2.5 to 10 mg/L. These concentrations are considered by FDEP to be very harmful to springs and other surface waters receiving groundwater inputs and are also likely harmful to public health. Nitrogen loading to the groundwater in the range of 3.5 to 15 lbs/ac/yr are estimated to result in these harmful nitrate concentrations. It is estimated that surface nitrogen loads in the range of 25 to 100 lbs/ac/yr result in this high level of groundwater nitrate pollution.

Severe Impact denotes the BWA nitrogen footprint that results in a groundwater nitrate concentration greater than 10 mg/L, the human health drinking water standard in Florida. This nitrate concentration is associated with the occurrence of acute toxicity to infants and elderly people resulting in "blue baby syndrome" or methemoglobinemia. The estimated nitrogen load to the aquifer that will exceed this standard is about 15 lb/ac/yr, resulting from a nitrogen load to the land surface greater than 100 lbs/ac/yr.

7.2 Groundwater Withdrawal Classification – Floridan Aquifer Groundwater Withdrawal Footprint

All groundwater use estimates were also divided by the parcel acreage for normalization and converted from gallons per day to thousand gallons per year per acre (TGY/ac). Groundwater provides close to 100% of human water uses in Florida's springs region. Groundwater use footprints are based on a target maximum threshold for average springs flow reductions of 5%. Multiple minimum flow evaluations for major springs by Florida's water management districts have determined the threshold for "significant harm" to be in the range of 3 to 15%. An average spring flow reduction of 5% is considered by the Florida Springs Institute as generally protective of springs health, while allowing some human consumption of groundwater.

A water balance for the Floridan Aquifer found that the historic Florida spring flow averaged about 10.5 billion gallons per day (Knight and Clarke, 2016). Based on an allowable reduction of 5% and a Florida Springs Region area of about 27 million acres, this is equivalent to an average footprint of about 7.1 TGY/ac. The average residential public supply per capita estimate is about 85 gal/day (Marella, 2014). When multiplied by the average household size (2.48 persons) and normalized over a 5 acre property for one year, this "average" residential use is equivalent to about 15 TGY or 3 TGY/ac. It must be pointed out that all groundwater extracted from the aquifer is not actually consumed. Anywhere from zero to 80% of the water pumped from the aquifer for human uses may be returned. Based on this consideration a minimal impact (less than 5% reduction in average spring flows) is assumed for an extraction rate of 10 TGY/ac. Four groundwater footprint categories, as shown in Figure 4, were identified as follows:

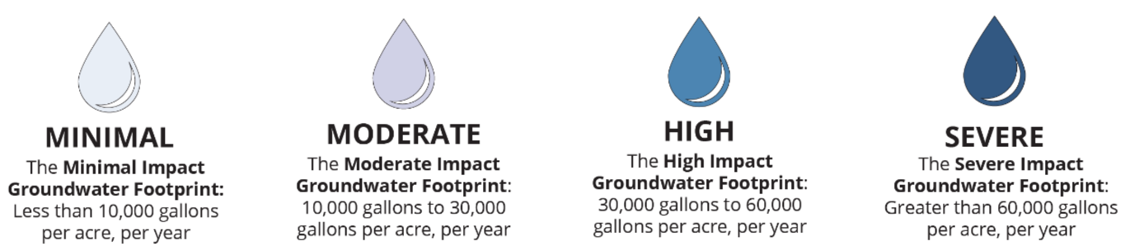

Figure 4 – BWA Groundwater Footprint categories

Minimal Impact is based on an estimated groundwater withdrawal of 10 TGY/ac. This groundwater use rate is assumed to result in average spring flow reductions of less than 5%.

Moderate Impact is based on keeping average spring flow reductions less than 15%. The estimated range of groundwater extractions that will comply with that goal are estimated between 10 and 30 TGY/ac.

High Impact denotes a BWA groundwater footprint that results in an estimated average spring flow reduction in the range of 15 to 30%. An estimated groundwater extraction in the range of 30 to 60 TGY/ac will result in this level of significant harm.

Severe Impact denotes the groundwater footprint that greatly exceeds significant harm to Florida's springs, rivers, and estuaries. Any groundwater extraction greater than 60 TGY/ac is considered severe and contributing to lasting springs impairment.

8. Assumptions and Rationale

8.1 Nitrogen Load Estimation

8.1.1 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 BWA analyzed septic tanks using the same methodology as NSILT, which utilized the recent Florida Department of Health (FDOH) FLWMI (Florida Water Management Inventory) geodatabase.

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 generally spread throughout a large area. Since the goal of the BWA is to assign an 'aquifer footprint' that will estimate the impact of individuals—be that individual people or properties—it was decided that the BWA 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), spray fields, 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 BWA analysis for human wastewaters treated in conventional treatment/disposal systems. This is roughly equivalent to 1 lbs-N/yr per capita.

8.1.2 Fertilizer Application Rates

Detailed NSILT spreadsheets and reports from various BMAPs were obtained from FDEP. These spreadsheets and reports were used to create a fertilizer application rate 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.

8.1.3 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 LULC layer. 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 appeared 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. Based on the estimates reported above for nitrogen loading an estimate of 100 lbs-N/ac/yr for poultry operations is assumed to result in approximately 10 mg/L in the Floridan Aquifer System

8.1.4 Aquifer Recharge

Estimates of aquifer recharge indicate how freely water can enter the aquifer from the land surface. The recharge map used by NSILT does not cover the entire BWA 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 1. The 1988 USGS recharge map 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.

8.1.5 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.

8.2 Groundwater Withdrawal Estimation

CUP and reported water withdrawal data from WMDs generally had the water source listed. If there was no water source listed, then some estimates included surface water. To address this, the permit for the top 10 or 20 highest estimates was pulled and reviewed individually. The estimate was corrected to reflect only the groundwater withdrawal amounts. An example of this is the PCS phosphate mine in SRWMD, whose allocation is 407 MGD but of that only 64 MGD is groundwater. It was not possible to check every permit because of the number of permits, so some smaller estimates may include sources other than groundwater. It will be a priority during Year 2 of the BWA to get the most accurate source data from the WMDs.

9. 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. The FDEP land use layer was compiled by FDEP 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.

NSILTs application rate estimates for crops were used for agricultural land use identified in the FSAID geodatabase. These estimates were applied with the knowledge that fertilizer application amounts vary greatly from crop to crop and farm to farm. The current 2017 version of FSAID was used to represent agricultural lands as accurately as possible but due to the transitional nature of agriculture the BWA estimates should be viewed as generalized estimates of the overall agricultural land use. 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. This is especially true for city limits, which are treated as a single entity using population data. This means that no fertilizer estimates have been made for cities which generally have high non-crop fertilizer use. This is a limitation that will be addressed in Year 2 of the BWA analysis.

To create an 'aquifer footprint' for all parcels, all wastewater estimates were applied to each specific parcel. This is mostly accurate for parcels with OSTDS, but the spatial representation of input from parcels with sewer is not accurate as the wastewater is eventually released as effluent from a wastewater treatment facility or applied elsewhere in the case of spray fields. This methodology will continue to be refined during future iterations of the BWA analysis.

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 will 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 estimate more accurate.

Recharge rates are an important part of the nitrogen estimation process which is affected in the BWA by the fact that three different maps of varying detail are being used. City limits were analyzed with a more generalized map and only given one recharge factor since they are treated as a single entity. 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. 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 was not yet available. The seven-year old generalized data are noted as a limitation and updated data will be used in the Year 2 BWA analysis.

It is important to note that all groundwater withdrawal estimates in the BWA are gross groundwater withdrawal 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 generalization of BWA results for online display, as discussed in Section 6, retains the overall pattern of Aquifer Footprint estimates but does not show the detail of individual parcel boundaries. This can lead to areas being assigned a higher or lower footprint estimate, based on the footprints of parcels around it.

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