DRAFT
Technical Support Document
2023 Nitrogen Source Inventory Loading Tools for Springs Basin Management Action Plans

Division of Environmental Assessment and Restoration
Watershed Planning & Coordination
Florida Department of Environmental Protection

April 2025

2600 Blair Stone Rd.
Tallahassee, FL 32399
Floridadep.gov

Acknowledgments

This document describes the data sources and values that were used by the Florida Department of Environmental Protection (DEP) in the 2023 Nitrogen Source Inventory Loading Tools (NSILTs) updates for the following basin management action plans (BMAPs):

- Chassahowitzka/Homosassa Springs Groups
- Crystal River/Kings Bay
- DeLeon Spring
- Gemini Springs
- Jackson Blue Spring and Merritts Mill Pond Basin
- Lower and Middle Suwannee River Basin
- Rainbow Springs Group and Rainbow Springs Run/Silver Springs, Silver Springs Group, and Upper Silver River
- Santa Fe River Basin
- Upper Wakulla River and Wakulla Spring
- Volusia Blue Spring
- Wacissa River and Wacissa Spring Group
- Weeki Wachee/Aripeka Spring
- Wekiwa and Rock Springs

For additional information on NSILTs and springs water quality restoration efforts, please contact:

Florida Department of Environmental Protection/ Water Quality Restoration Program
2600 Blair Stone Road, Mail Station 3565
Tallahassee, FL 32399-2400
Email: BMAPProgram@FloridaDEP.gov

Table of Contents

List of Figures

List of Tables

Introduction

The Florida Department of Environmental Protection (DEP) developed a Nitrogen Source Inventory and Loading Tool (NSILT) to provide information on the major sources of nitrogen in the springs basin management action plan (BMAP) areas (Eller and Katz 2017). These major sources are as follows: Atmospheric deposition; wastewater treatment facilities (WWTFs); urban fertilizers; onsite sewage treatment and disposal systems (OSTDS, also known as "septic systems"); biosolids; livestock waste; and agricultural fertilizers. The approach applies to the groundwater contributing area (or springshed) for the impaired springs and the surface waters they augment. Over time, the nitrogen sources in the spring BMAP areas have changed and the DEP methodology for estimating nitrogen loads has improved. These improvements are a result of additional information as well as new tools that provide better estimates of nitrogen loads.

This technical support information identifies the data sources and methodology used for the 2023 NSILT estimates. This report documents the assumptions used by DEP when applying the NSILT approach to the adopted springs BMAPs as of January 2025. The NSILT is an Arc geographic information system (ArcGIS) and spreadsheet-based tool that provides spatial estimates of the relative current contributions from major nitrogen sources. The NSILT approach involves estimating the nitrogen load to the land surface for various source categories, then applying a source-specific biochemical attenuation factor and a location-specific recharge factor to determine the impact to groundwater quality in the Upper Floridan aquifer (UFA). The estimated load to groundwater determines the scope of reduction strategies needed for BMAP implementation for each source category. Multiple public meetings were held to share the NSILT methodology and results as well as to solicit comments. Between January 2023 to January 2025, location-specific adjustments were made based on feedback from stakeholders. Additional NSILT data and resources are available upon request.

Figure 1 shows the BMAPs that have updated NSILTs described by this document, which includes the following springsheds:

- Chassahowitzka Spring Group
- Homosassa Springs Group
- Crystal River/Kings Bay
- DeLeon Spring
- Gemini Springs
- Jackson Blue Spring
- Rainbow Springs Group
- Santa Fe: Devil's Ear, Hornsby, and Ichetucknee Springs, and Outside Springsheds
- Silver Springs Group
- Suwannee: Madison Blue, Middle Suwannee, Fanning/Manatee Springs, and Outside Springsheds
- Volusia Blue Spring
- Wacissa Spring Group
- Wakulla Spring
- Weeki Wachee/Aripeka Spring
- Wekiwa/Rock Springs

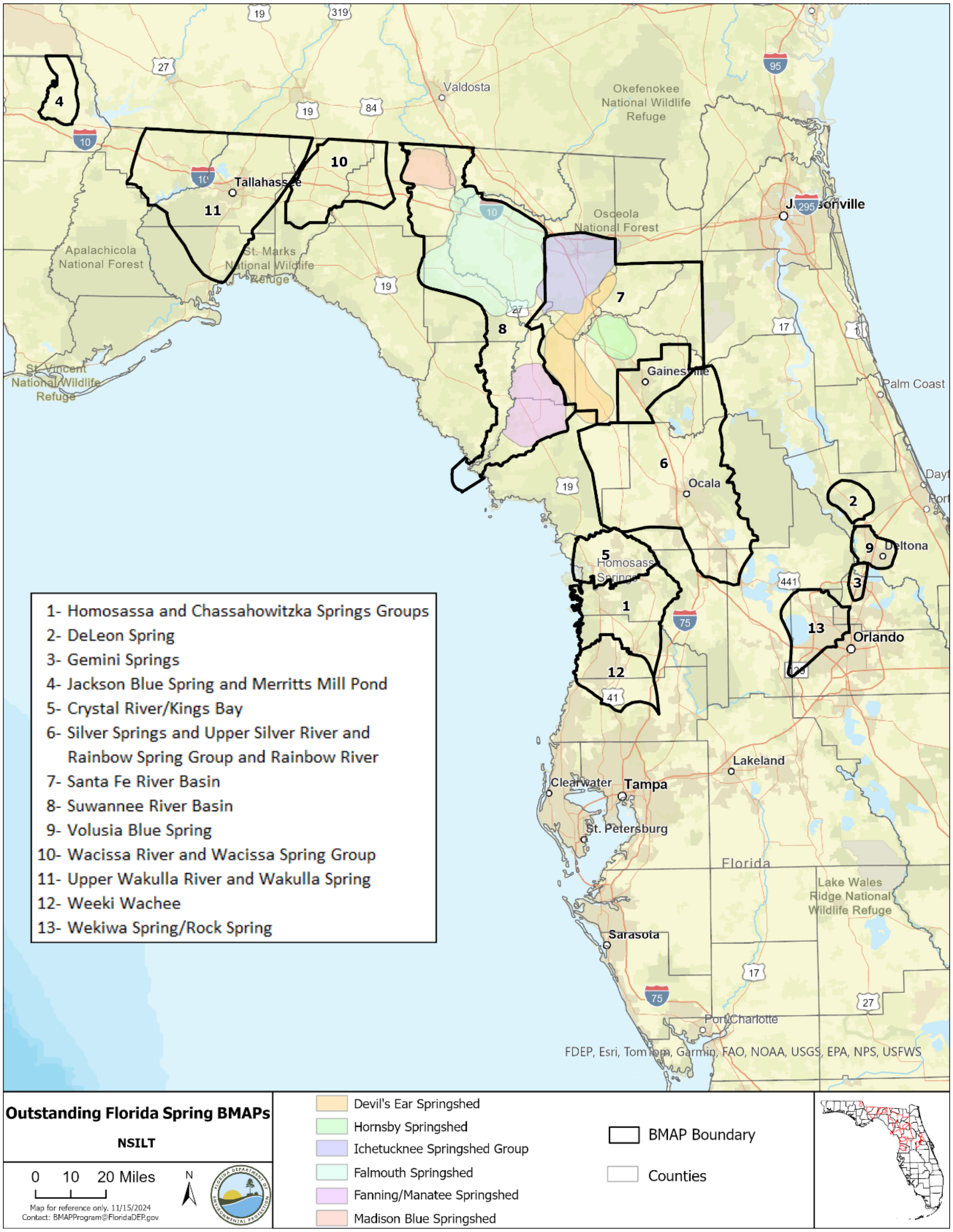

Figure 1. Map of the spring BMAPs and springsheds with updated NSILTs

Background

Florida springs provide sites of recreational and cultural value as well as sources of potable water and afford a way to assess regional groundwater quality. Springs integrate groundwater vertically, spatially, and temporally from the UFA--the highly transmissive limestone aquifer that is the source of water flowing from the springs (Bush and Johnston 1988; Katz 1992, 2004; Davis 1996). Rainfall that infiltrates into the subsurface and recharges the aquifer system contains nitrogen and other dissolved chemicals of concern originating from anthropogenic activities at or near the land surface. Groundwater with elevated nitrate concentrations flows toward the spring. Elevated nitrate concentrations in Florida's springs contribute to water quality degradation in their receiving surface waters. Therefore, the NSILT results are used in the development and implementation of the BMAPs for impaired spring systems, by focusing nitrogen source reduction efforts on the sources in order to achieve the greatest improvement in water quality. A link to the Water Quality Restoration Program website and the BMAP documents is located in **Appendix A**.

The NSILT does not account for legacy loads of nitrogen that may already be present in the aquifer and continue to adversely impact groundwater quality. Several spring basin studies have reported increasing nitrate-N concentrations in groundwater and springs over time. Nitrogen that entered groundwater from past anthropogenic practices may slowly exit the groundwater flow system via springs, given that the average groundwater residence times in large spring basins in Florida is on the order of decades (Katz et al. 1999, Katz 2004, Phelps 2004, Happell et al. 2006, Toth and Katz 2006, and Knowles et al. 2010).

Estimating Nitrogen Inputs to the Land Surface

Springshed Boundary Adjustments

The NSILT analysis was run on the springshed boundaries which were consistent with the BMAP boundary or the springshed plus outside springshed areas (i.e., the Lower and Middle Suwannee BMAP and the Santa Fe BMAP) that were included in the BMAP boundary because there are adjacent areas that feed the groundwater system that augments the adjacent tributaries and rivers. Springshed boundaries were previously defined in the first iteration of the NSILTs, published between 2015 and 2018. Where appropriate, the springshed boundaries remained consistent with the previous NSILT evaluation. Some springshed boundaries were adjusted to meet the requirements of priority focus area (PFA) boundaries as defined in the 2016 Springs and Aquifer Protection Act. Requirements of the act dictated that priority focus areas should follow easily identifiable landmarks or political boundaries. To address this requirement, the boundaries for DeLeon, Volusia Blue, Wekiwa, Jackson Blue, Wacissa, and Weeki Wachee springsheds were adjusted.

In their original NSILTs, the Weeki Wachee springshed overlapped the southern part of the Chassahowitzka and the Homosassa springsheds, respectively. In the updated NSILTs, the overlapping area was removed from the Chassahowitzka and Homosassa areas and accounted for in the Weeki Wachee contributing area. Comparably to the prior NSILT versions, the NSILT methodology was run separately on the Homosassa and Chassahowitzka springsheds.

Another boundary change made in the 2023 NSILTs is that the Aripeka and Weeki Wachee springsheds were analyzed as one, instead of separating the two springsheds. Rainbow and Silver springsheds were also analyzed as one area.

It is important to note that the Wekiva River surface water contributing area is a separate BMAP area from the Wekiwa Springs area. For the Wekiwa and Rock Springs NSILT, only the springshed area is evaluated; the surface watershed for the Wekiva River is excluded from the NSILT. Management actions in the Wekiva River BMAP are attributed to benefiting the surface watershed of the river, but projects are needed in the springshed area to benefit the springs.

In the Santa Fe BMAP area, there are three separate springshed areas that are analyzed separately; the Santa Fe springsheds are the following:

- Devil’s Ear Complex;
- Ichetucknee; and
- Hornsby springsheds.

In the Suwannee BMAP area, there are also three separate springshed areas that are analyzed separately; the Suwannee springsheds are as follows:

- Fanning/Manatee;
- Falmouth/Troy/Lafayette/Peacock; and
- Madison Blue springsheds.

In Santa Fe and Suwannee springsheds, the areas outside the springsheds but within the BMAP boundary are considered contributing to the rivers. These areas were evaluated in a separate NSILT analysis. The total maximum daily loads (TMDLs) for the Suwannee and Santa Fe BMAPs include numeric nutrient criteria for river water quality. Due to this requirement, a nutrient loading evaluation was performed separately to better characterize impact on outside the springshed areas and surface water quality. The NSILT was applied to support nitrogen source identification and to estimate the nutrient reductions that are needed in these areas to ensure that water quality in both rivers meets the TMDL targets.

Boundary Data

For the 2023 updates, a springshed GIS layer was created for the NSILT analysis, which also includes the county boundaries and the recharge areas. These boundaries were used for all the county-level and recharge-based calculations. The springsheds boundaries used are the same as the BMAP boundary expect for Suwannee and Santa Fe which each are broken up into three springsheds plus the outside areas, respectively. This GIS boundary layer is available upon request.

Atmospheric Deposition

Estimates of nitrogen loading from atmospheric deposition are derived from the U.S. National Atmospheric Deposition Program (NADP) Total Deposition (TDEP) Science Committee's hybrid model. The TDEP model evaluates wet and dry deposition monitoring network data and calculates an estimated total nitrogen deposition load (Schwede and Lear 2014). TDEP data are provided as an annual total and presented in a four-kilometer by four-kilometer grid raster file. Data from the 2019 and 2020 datasets were averaged to estimate nitrogen loading (see link to the NADP TDEP in **Appendix A**). Data were then spatially evaluated to determine the loading in areas of each groundwater recharge category within each BMAP or springshed. Recharge and biochemical attenuation factors (see **Table 11**) were then applied to the estimated loading to land surface to estimate loading to groundwater.

WWTFs

The average annual input of nitrogen to the land surface for WWTFs was estimated for each effluent land application site for all facilities disposing of effluent in the BMAP area. The average annual input was estimated using the mean total nitrogen (TN) concentration in milligrams per liter (mg/L) and mean discharge volume in million gallons per day (MGD) for each WWTF. The data were sourced from the DEP Wastewater Facility Regulation (WAFR) database for effluent discharged from January 2019 through December 2021.

WWTFs were considered to contribute to loading to a BMAP if the effluent was disposed of within the BMAP, regardless of whether the facility itself was within the BMAP. Some WWTFs were not required to monitor and report TN effluent concentrations, and, therefore, did not have TN data available in the WAFR database. Some of these facilities that did not report TN concentrations reported nitrate-N (NO_3-N) concentrations. For those facilities, an estimated TN concentration was calculated assuming that nitrate-N would compose 38.5% of the TN concentration (Helgeson and McNeal 2009). In cases where no TN data or nitrate-N data were collected at a facility during the data period or the data quality was questionable, an effluent value based on a review of similar-sized facilities within springs BMAP areas was used to estimate the TN concentration. The facilities were classified as "small," "medium," or "large" based on their average daily flow. The estimated TN concentrations for facilities with insufficient WAFR data for a direct estimate are summarized in **Table 1**.

Table 1. Average TN concentration by facility size for WWTFs with insufficient data

Facility Size	Flow (MGD)	Estimated Average TN Effluent Concentration (mg/L)
Large	> 0.1	4.34
Medium	0.1 – 0.02	7.22
Small	< 0.02	11.76

Facilities report nitrogen concentration data and flow data at different intervals depending on their specific permit requirements. When available, the reported monthly average data were used to calculate flow and concentration. If monthly average data were not available, summary data was prioritized in the following order: weekly average, quarterly average, annual average, 3-month rolling average, and maximum. When multiple flow and/or nitrogen monitoring sites existed for a facility, the effluent information that best reflected the effluent quality at the disposal site was used for evaluation.

All applicable wastewater effluent reuse and disposal practices were considered: direct surface water discharges; rapid infiltration basins (RIBs); sprayfields; public access reuse (e.g., golf course and residential reuse); absorption fields; and wetland disposal. Direct surface water discharges were considered surface water sources and excluded as loads to groundwater. For all other reuse and disposal types, an appropriate biochemical attenuation factor was applied, dependent on the practice (**Table 11**). Effluent disposal locations were spatially evaluated to determine the recharge category of the deposition site, and the appropriate recharge factor was applied to determine the loading to groundwater.

OSTDS

OSTDS loading was calculated by estimating the number of septic systems within a BMAP and multiplying the number of OSTDS by the expected loading per system. The Florida Department of Health (DOH) Florida Water Management Inventory (FLWMI) data were used to estimate the number of OSTDS within each BMAP (see link to the FLWMI in **Appendix A.**

FLWMI data identifies a wastewater source for every parcel in the state in one of eight categories: "Known Septic," "Likely Septic," "Somewhat Likely Septic," "Known Sewer," "Likely Sewer," "Somewhat Likely Sewer," "Unknown," and "Undetermined." Parcels identified as "Known Septic," "Likely Septic," and "Somewhat Likely Septic" in the FLWMI database were considered to use septic systems for wastewater treatment. There was assumed to be one septic system per parcel. FLWMI data were spatially evaluated to determine the appropriate recharge category for each OSTDS location. FLWMI data are provided by county. For this analysis, all FLWMI data used were updated between 2021 and 2023. **Table 2** shows the year of OSTDS data that were used from the FLWMI for the estimated number of septic systems by county.

Table 2. Year the FWRI data were updated by county

County	Update Year
Citrus, Hernando, Orange, Pasco, and Sumter	2023
Alachua, Columbia, Dixie, Gilchrist, Hamilton, Lafayette, Lake, Levy, Madison, Marion, Putnam, Seminole, Suwannee, Taylor, Union, and Volusia	2022
Gadsden, Jackson, Jefferson, Leon, and Wakulla	2021

Loading per septic system was estimated by determining the persons per household and multiplying this by a per capita loading rate. The 2020 U.S. Census data were used to estimate the number of persons per household, by county, as shown in **Table 3.** A per capita contribution of 10 pounds of nitrogen per year (lbs-N/yr) was estimated based on the Florida Onsite Sewage Nitrogen Reduction Strategies Study Final Report (Armstrong 2015), which was an update to the prior NSILT estimates of 9.012 lbs-N/yr.

Loading to the land surface was calculated by multiplying the number of OSTDS by the loading rate. OSTDS locations were spatially evaluated as the centroid of the parcel, and the appropriate recharge factor was determined. A biochemical attenuation factor (**Table 11**) and a recharge factor were then applied to estimate loading to groundwater.

Table 3. 2020 U.S. Census persons per household by county

County	Persons Per Household Based On the 2020 U.S. Census
Alachua	2.48
Baker	2.91
Citrus	2.25
Columbia	2.62
Dixie	2.5
Gadsden	2.43
Gilchrist	2.53
Hamilton	2.6
Hernando	2.46
Jackson	2.27
Jefferson	2.21
Lafayette	2.8
Lake	2.56
Leon	2.38
Levy	2.39
Madison	2.38
Marion	2.4
Orange	2.87
Pasco	2.54
Putnam	2.43

County	Persons Per Household Based On the 2020 U.S. Census
Seminole	2.6
Sumter	2.04
Suwannee	2.82
Taylor	2.51
Union	2.36
Volusia	2.43
Wakulla	2.59

Farm Fertilizer

Farm fertilizer loading to land surface estimates were calculated by determining the agricultural area used for specific crops within a BMAP, multiplied by an estimated crop specific fertilizer application rate. The Florida Department of Agriculture and Consumer Services (DACS) Florida Statewide Irrigation Agricultural Demand 9 (FSAID 9) geodatabase was used to estimate the total area used to produce each crop type (**Appendix A**). Fertilization rates for each specific crop category are based on an annual average per acre and are based on estimates previously used in the NSILT with some updates based on feedback received from DACS, Florida water management districts (WMDs), and the University of Florida-Institute of Food and Agricultural Sciences (UF-IFAS).

When a parcel was identified as rotating crops (changes in crop type from year to year), the application rate was estimated as an average of the annual application rates for the individual crops. When crops are grown as double or triple crops (more than one crop grown on a parcel in a single year), the fertilizer application rate was estimated by summing the application rate for each crop type. Some adjustments to application rates for crops grown in a multi-crop system were made based on feedback from DACS. Hay was assumed to be fertilized at 80 pounds of nitrogen per acre (lbs-N/ac) per cutting with an average of 2.5 cuttings per year. Crop-specific fertilizer application rates were consistent across all BMAP areas except for the following adjustments as described in the sections below.

Blueberries

Blueberries fertilizer application rate was reduced to 75 lbs-N/ac per year in the Wakulla BMAP area, based on stakeholder feedback and consistent with the previous NSILT.

Soybeans

Based on stakeholder feedback, soybeans are grown as a commodity crop in the Suwannee and Santa Fe BMAPs and are expected to have an annual application rate of 20 lbs-N/ac per year for these BMAPs. In other BMAPs, soybeans are used most commonly as a cover crop and have no expectation for fertilization.

Sorghum

Based on DACS feedback, sorghum is not grown for grain in the Suwannee and Santa Fe BMAPs and have a lower application rate of 50 lbs-N/ac per year as opposed to an estimated rate of 150 lbs-N/ac per year in other BMAPs.

Field Crops

Based on feedback from the DACS and SJRWMD, producers in the St. Johns River Region tend to grow more nutrient-intensive field crops and recommended an application rate of 90 lbs-N/ac per year for the field crop commodity in the region. **Table 4** describes the fertilizer application rates used in this NSILT update. Note that when more than one crop type is listed in the table, the category is a double or triple crop type.

Table 4. FSAID crop categories fertilizer application rates in lbs-N/ac

Crop	Default Fertilizer Application Rates (lbs-N/ac)	Wakulla Application Rates (lbs-N/ac)	Suwannee & Santa Fe Application Rates (lbs-N/ac)	DeLeon, Gemini, Volusia Bule, Wekiwa, and Silver Springs Application Rates (lbs-N/ac)
Asparagus Fern	90	90	90	90
Aspidistra	90	90	90	90
Beans	100	100	100	100
Berries	100	100	100	100
Blackberries	100	100	100	100
Blueberries	100	75	100	100
Cabbage	175	175	175	175
Cabbage_Kale	175	175	175	175
Cabbage_Onions_Vegetables	175	175	175	175
Carrots	300	300	300	300
Carrots_Corn	300	300	300	300
Carrots_Rye	340	340	340	340
Citrus	140	140	140	140
Container Nursery	150	150	150	150
Coontie Fern	90	90	90	90
Corn	240	240	240	240
Corn	180	180	180	180
Corn_Cotton	175	175	175	175
Corn_Cucumbers	270	270	270	270
Corn_Oats	280	280	280	280
Corn_Peanuts	130	130	130	130
Corn_Rye	280	280	280	280
Corn_Soybeans	120	120	130	120
Cotton	110	110	110	110
Cotton_Peanuts	65	65	65	65

Crop	Default Fertilizer Application Rates (lbs-N/ac)	Wakulla Application Rates (lbs-N/ac)	Suwannee & Santa Fe Application Rates (lbs-N/ac)	DeLeon, Gemini, Volusia Bule, Wekiwa, and Silver Springs Application Rates (lbs-N/ac)
Cropland_Pastureland	50	50	50	50
Cucumbers	150	150	150	150
Cucumbers Fall_Melons	150	150	150	150
Dry Beans_Tomatoes Spring	200	200	200	200
Fern	90	90	90	90
Field Corn	240	240	240	240
Field Corn_Hay	210	210	210	210
Field Crops	60	60	60	90
Field Nursery	90	90	90	90
Grass_Pasture	80	80	80	80
Fruit_Nuts	100	100	100	100
Grains	70	70	70	70
Grapes	90	90	90	90
GreenBeans	100	100	100	100
Hay	180	180	180	180
Hay_Improved Pastures	180	180	180	180
Hay_Melons	180	180	180	180
Hay_Oats	220	220	220	220
HorseFarms	50	50	50	50
Improved Pastures	50	50	50	50
Leatherleaf	90	90	90	90
Liriope	90	90	90	90
Melons	150	150	150	150
Millet	50	50	50	50
Millet_Rye	90	90	90	90
Mixed Crops	60	60	60	60
Nurseries and Vineyards	90	90	90	90
Nursery	90	90	90	90
Oats	70	70	70	70
Oats_Peanuts	60	60	60	60
Onions_Vegetables	150	150	150	150
Ornamentals	90	90	90	90
Other Groves	90	90	90	90
Other Hay_NonAlfalfa	180	180	180	180
Pasture	50	50	50	50
Pasture_Peanuts	50	50	50	50
Pasture_Rye	90	90	90	90

Crop	Default Fertilizer Application Rates (lbs-N/ac)	Wakulla Application Rates (lbs-N/ac)	Suwannee & Santa Fe Application Rates (lbs-N/ac)	DeLeon, Gemini, Volusia Bule, Wekiwa, and Silver Springs Application Rates (lbs-N/ac)
Peaches	60	60	60	60
Peanuts	20	20	20	20
Peanuts_Cotton	65	65	65	65
Peanuts_Rye	60	60	60	60
Peanuts_Wheat	60	60	60	60
Peas	60	60	60	60
Pecans	100	100	100	100
Pittosporum	90	90	90	90
Potatoes	300	300	300	300
Row Crops	60	60	60	60
Rye	70	70	70	70
Small Grains	70	70	70	70
Small Veg	150	150	150	150
Small Veg Fall_Small Veg Spring	150	150	150	150
Small Veg Spring	150	150	150	150
Snap Beans	100	100	100	100
Sod	200	200	200	200
Sorghum	150	150	50	150
Soybeans	0	0	20	0
Specialty Farms	30	30	30	30
Spring Onion_Vegetables	150	150	150	150
Squash	150	150	150	150
Squash_Vegetables	300	300	300	300
Strawberries	150	150	150	150
Sweet Corn	300	300	300	300
Sweet Corn_Zucchini	450	450	450	450
Sweet Potatoes	60	60	60	60
Timber Nursery	50	50	50	50
Tobacco	80	80	80	80
Tobacco_Rye	120	120	120	120
Tomatoes	200	200	200	200
Tomatoes Fall	200	200	200	200
Tomatoes Fall_Tomatoes Spring	400	400	400	400
Tomatoes Spring	200	200	200	200
Tree Nurseries	90	90	90	90
Vegetables	150	150	150	150
Watermelon	150	150	150	150

Crop	Default Fertilizer Application Rates (lbs-N/ac)	Wakulla Application Rates (lbs-N/ac)	Suwannee & Santa Fe Application Rates (lbs-N/ac)	DeLeon, Gemini, Volusia Bule, Wekiwa, and Silver Springs Application Rates (lbs-N/ac)
Wheat	80	80	80	80
Wildlife Strip Crops	30	30	30	30
Winter Wheat	40	40	40	40
Zucchini	150	150	150	150

Crop production areas were spatially evaluated to determine the appropriate acreage for each recharge category. Recharge and attenuation factors (**Table 11**) were applied to estimate the loading to groundwater.

Nurseries

Loading to land surface from nurseries was calculated in a similar way to general farm fertilizer. However, due to greater plant spacing and lower fertilizer leaching rates related due to containerization, adjustments were made to the application rates. It was estimated that only 80% of the acreage identified as nurseries is fertilized. Further, the fertilization leaching amount was reduced by 70% due to the applied fertilizer remaining in the container compared to typical, ground-planted agricultural operations. This container adjustment was not applied to fern crops in Volusia County based on feedback from SJRWMD that these operations are typically ground-planted and not container-based. The nursery crop categories are listed in **Table 5**. Recharge and attenuation factors (**Table 11**) were applied to estimate the loading to groundwater.

Pasture Lands

Loading to land surface from pasture lands was calculated in a similar way to farm fertilizer. However, based on information from DACS, pasture locations are rotated, and it is only anticipated that 20% of pasture areas will be fertilized in a given year. The acreage of pasture lands identified in FSAID was reduced to 20% of the total, then multiplied by the expected application rate to determine the loading from land surface for pastures. The farm fertilizer biochemical attenuation factors were also used for pasture lands (**Table 11**). Where the rotation adjustment was applied for crop categories that were categorized as pasture lands are identified in **Table 5**.

Table 5. FSAID nursery and pasture crop categories

* Denotes nursery crop categories adjusted for container practices outside Volusia County.

Nursery Crop Categories	Pasture Crop Categories
Asparagus Fern*	**Grass Pasture**
Aspidistra*	**Horse Farms**
Container Nursery	**Improved Pastures**
Coontie Fern*	**Pasture**

Nursery Crop Categories	Pasture Crop Categories
Fern*	
Field Nursery	
Leatherleaf*	
Nurseries and Vineyards	
Nursery	
Ornamentals	
Pittosporum*	
Timber Nursery	
Tree Nurseries	

Livestock Waste, Except Dairies

Twelve types of livestock waste were considered in NSILT loading estimates. However, dairy cows were evaluated differently than the other 11 livestock types (see **Dairies** section below). Cattle farms are included in the NSILT as non-dairy livestock operations. Livestock waste loading to land surface was calculated by estimating the population of each livestock type in each BMAP area and multiplying the estimated count by a livestock type specific waste factor. The livestock waste factors used were recommended by DACS and are consistent with the 2018 NSILT. Livestock categories and waste factors are summarized in **Table 6** below. To estimate livestock populations, the 2017 U.S. Department of Agriculture (USDA) Census of Agriculture data were used (see link in **Appendix A** to the 2017 Census of Agriculture site). The 2017 census data provided estimated animal head count totals, by county, for each livestock type. For cattle, an average of the 2020 and 2021 USDA Survey of Agriculture (see link in **Appendix A** tot he USDA National Agricultural Statistics Service) estimates for cattle were used to determine head county by county. For basins with identified dairies, the estimated cows included in the dairy calculations were removed from the head count for the county in which the dairy was located. To estimate calf numbers, it was estimated that 35% of the cattle were calves.

USDA head counts for the whole county were adjusted based on the proportion of livestock land in the county that was also within the BMAP or springshed, as reported in FSAID 9. The headcounts were also evaluated by recharge category in each BMAP or springshed compared to the livestock land of that recharge category in the county as a whole.

Further adjustments included the consideration that broiler chickens and cow/calves are not anticipated to provide loading for the entire year because they are not *in situ* for an entire 12 months. Broiler chickens are anticipated to be on an eight-week rotation, and cow/calves are estimated to be on a six-month rotation. Annual loading was reduced accordingly to account for these rotations.

Once a livestock waste loading to the land surface was calculated based on the estimated headcount in the springshed by recharge area, waste load based on the type of animal, and rotation considerations, a biochemical attenuation factor (**Table 11**) and a recharge factor were then applied to estimate loading to groundwater.

Table 6. Livestock waste factors by livestock type

Livestock Type	Waste Factor Per Animal (lbs-N/day)
Beef Cattle	0.337
Other Cattle	0.31
Calves	0.068
Donkeys	0.1
Horses	0.273
Chicken, Broilers	0.002
Chicken, Layers	0.003
Goats	0.035
Hogs	0.19
Sheep	0.198
Turkeys	0.006

Dairies

In the 2023 NSILTs, dairies were divided into concentrated animal feeding operations (CAFOs) where waste is managed under an industrial wastewater permit issued by DEP, and non-CAFO dairies, where a facility's presumption of compliance is through the Best Management Practice (BMP) Program administered by DACS. The evaluation for each type are described below.

CAFOs

CAFO dairies operate under an industrial permit from DEP that requires annual reporting of operations and a nutrient management plan that oversees the waste handling processes for dairy waste. For CAFO dairies, loading to land surface estimates were made by multiplying the number of animals at the operation based on the average of 2019 and 2020 annual reported herd counts as required by the permit, by a per animal waste factor calculated in the nutrient management plan, then reduced by waste load based on their waste handling processes as identified in the nutrient management plan. Nutrient management plans are site specific and vary from operation to operation. Attenuation (**Table 11**) and recharge factors were applied to the estimated loading to land surface to estimate loading to groundwater.

Non-CAFO Dairies

Non-CAFO dairies are governed by the adopted DACS Dairy BMP Manual and the applicable BMPs. Non-CAFO dairies in BMAP areas have a statutory obligation to enroll in the DACS

BMP Program or conduct water quality monitoring that is approved by the state. Dairies enrolled in the BMP Program by DACS are subject to DACS Implementation Verification procedures. Non-CAFO dairy information was provided by DACS, including information on herd size, waste handling practices, and animal confinement.

If a dairy herd was identified as grazed in pasture, it was estimated that they would be confined for 15% of the time to account for time in the milking parlors. A waste factor of 0.36 lbs-N/day for dairy cows and 0.15 lbs-N/day for non-milking cows was estimated. Annual loading was estimated by multiplying the number of cows by the daily waste factor, multiplied by 365 days per year, multiplied by application loss coefficients based on waste handling practices. Generally, a 50% application loss factor was applied for waste generated in pasture. For waste generated and collected in confinement, nitrogen loss percentages for specific waste handling practices are identified in **Table 7**.

Table 7. Nitrogen loss percentages for non-CAFO manure handling practices

Manure Handling Practices	Nitrogen Loss %
Scraped Solids	25%
Applied Solids	20%
Concrete Waste Storage Ponds	60%
Sprayfield	30%
Direct Deposition	60%
Sand Separator	5%
Screen Separator	7%
Static "Vat" Separator Solids	85%
Static "Vat" Separator Effluent	15%
Screw Press Solids	80%
Screw Press Effluent	20%
Earthen Lagoon	30%

Horse Farms/Cattle Farms

For the Rainbow Springs and Silver Springs BMAP where there are more such operations than other BMAPs, horse farms and cattle farms were evaluated as separate loading categories. For horse farms and cattle farms, loading from farm fertilizer crops that are associated with these operations were estimated, as well as loading from the livestock categories for the relevant livestock types.

In Silver Springs, of the total pasture lands and hay crop area, it was estimated that 20% of pasture lands and hay acreages were horse farms. Additionally, 100% of acres identified as horse farm area was associated with horse farm operations for the NSILT. In Rainbow Springs, it was estimated that of the total pasture lands and hay crop area in the springshed, 40% of pasture lands and hay acres were horse farms. Also, 100% of horse farmlands identified in the FSAID land use data were associated with horse farms. The remaining pasture lands and hay crop acreages in each springshed, respectively, were attributed to cattle farms.

For livestock waste estimates, 100% of horse livestock waste was attributed to horse farms, and 100% of beef cattle, “other” cattle, and calves were associated with cattle farms in both springsheds. Loading for farm fertilizer and livestock waste categories associated with horse farms and cattle farms were calculated as described above in the livestock waste section, including the spatial evaluation to determine recharge areas. The loading for these categories was removed from the general farm fertilizer and livestock waste categories to avoid double-counting loads. A horse farm- and cattle farm-specific attenuation factor (**Table 11**) was applied to the surface loading to determine the loading to groundwater.

UTF

Since the development of the original NSILT, the methodology used for estimating nitrogen inputs from urban fertilizer has significantly improved. Fertilizers applied to turfgrass typically found in urban areas (including residential lawns, commercial properties, and public green spaces) are referred to as urban turfgrass fertilizers. The UTF load to land surface was estimated separately for single family residential parcels and other UTF as described below. For all UTF loads, a recharge factor was applied based on location, as well as a biochemical attenuation factor (**Table 11**) was applied to land surface loading estimates to determine loading to groundwater.

Single Family Residential Fertilizer Loading

Single family residential UTF loading was estimated using a number of steps. The first step determined the area of single family residential parcels and an impervious area coefficient was applied to remove pervious area from the evaluation. Next, a maximum amount of fertilized area per parcel was set to evaluate likeliness to fertilize, and finally estimating fertilization amount for the area expected to receive fertilization. The section below goes into these steps in more detail.

Determining Parcels

To determine the area of single family residential parcels, the Florida Department of Revenue CADASTRAL database and land use code DOR001 was used. It was estimated that 27.8% of all single family residential parcels are impervious (Tilley, 2006). For BMAPs with predominantly rural areas, it was estimated that a maximum of 0.5 acres of land per parcel would be fertilized because the parcels tend to be larger and less landscaped, while for predominantly urban BMAPs, it was estimated that a maximum of one acre of land per parcel would be fertilized.

Determining Likeliness to Fertilize

Prior to applying the fertilizer application rates to the pervious land area, the probability that a homeowner will fertilize the lawn needed to be considered. Based on socioeconomic studies, property values can be used as an indicator of probability of fertilization by homeowners in residential areas (Kinzig et al. 2005, Law et al. 2004, Zhou et al. 2008, Cook et al. 2012). Three tiers of property values were considered in each BMAP, where it was estimated that there was a 10%, 75%, and 90% likeliness to fertilize for the low, medium, and high property value categories, respectively. Property value ranges were BMAP specific and were based on property value estimates used in the previous NSILT analysis. There was an estimated increase of 79% since the prior NSILT based on State of Florida average home price evaluations (**Appendix A**).

Fertilization Rates by BMAP

The estimated urban turfgrass self-fertilization amounts were regional and based on survey data. The Florida panhandle region fertilization rate assumptions were updated from the previous NSILT evaluation. These revised NSILT used fertilization values determined by a recent City of Tallahassee survey and were applied in the Jackson Blue, Wakulla, and Wacissa estimates (Skybase7 2023). Fertilization rates for other BMAP areas were consistent with the previous NSILT evaluations (Martin 2008, Suoto 2009). Local ordinances were reviewed for seasonal fertilizer bans; where seasonal bans were in effect, fertilizer application was adjusted proportionately to the period of the year that fertilization was not allowed.

Table 8. Single family residential UTF information

Springshed	Max Fert. Acres	Low Value Break	High Value Break	Average Self Fertilizer Application	Lawn Service Application Rate	% Service	% Self	% None	Average Fert. Rate (lbs-N/ac/year)
Chassahowitzka Spring Group	1	89,500	268,500	96.30	131	32.0%	68.0%	0.0%	107.30
DeLeon Spring	1	89,500	268,500	98.27	131	33.0%	51.0%	16.0%	93.24
Devil's Ear Spring	0.5	136,040	257,402	93.03	108.9	32.0%	68.0%	0.0%	98.11
Falmouth Spring	0.5	89,500	223,750	93.03	108.9	32.0%	68.0%	0.0%	98.11
Fanning Springs and Manatee Spring	0.5	98,450	259,550	93.03	108.9	32.0%	68.0%	0.0%	98.11
Gemini Springs	1	89,500	268,500	98.27	131	33.0%	51.0%	16.0%	93.24
Homosassa Spring Group	1	89,500	268,500	96.30	131	32.0%	68.0%	0.0%	107.30
Hornsby Spring	0.5	141,410	304,300	93.03	108.9	32.0%	68.0%	0.0%	98.11
Ichetucknee Spring Group	0.5	108,653	239,860	93.03	108.9	32.0%	68.0%	0.0%	98.11
Jackson Blue Spring	0.5	89,500	268,500	56.91	108.9	19.0%	16.0%	65.0%	29.80
Kings Bay	1	89,500	268,500	96.30	131	32.0%	68.0%	0.0%	107.30
Madison Blue Spring	0.5	89,500	223,750	93.03	108.9	32.0%	68.0%	0.0%	98.11
Rainbow Spring Group	1	107,400	259,550	114.28	131	33.0%	51.0%	16.0%	101.41

Springshed	Max Fert. Acres	Low Value Break	High Value Break	Average Self Fertilizer Application	Lawn Service Application Rate	% Service	% Self	% None	Average Fert. Rate (lbs-N/ac/year)
Silver Springs	1	89,500	268,500	114.28	131	33.0%	51.0%	16.0%	101.41
Volusia Blue Spring	1	89,500	161100	85.14	131	34.4%	49.6%	16.0%	87.18
Wacissa Spring Group	0.5	85,920	214,800	56.91	108.9	19.0%	16.0%	65.0%	29.80
Wakulla Spring	0.5	89,500	268,500	56.91	108.9	19.0%	16.0%	65.0%	29.80
Weeki Wachee Spring Group	1	89,500	268,500	96.30	131	32.0%	68.0%	0.0%	107.30
Wekiwa Spring	1	89,500	268,500	98.27	131	33.0%	51.0%	16.0%	93.24

Due to different methodologies used in the previous NSILTs, some BMAPs captured the percentage of the population expected to apply zero fertilizer in the average self-application rate, while others separately defined a specific percentage of parcels that do not apply fertilizer that were not included in the self-application rate. The variability in the application rate calculations resulted in some BMAPs being described with 0% of the population applying no fertilizer, when the portion of the population with zero fertilizer application is already incorporated in the average self-application rate.

Other UTF

UTF loading to land surface from non-residential sources was estimated by determining the area of land use types likely to apply fertilizer, applying an impervious area coefficient to remove impervious area from the evaluation, estimating the pervious area likely to receive fertilizer, and estimating the fertilizer application rate for fertilized areas (**Table 9**). Water management district land cover data was used to determine the land area likely to receive fertilizer (**Appendix A**). Fifteen land cover categories were considered likely to receive fertilization, and an estimated impervious area was applied to each land cover category (Tilley 2006). The area of these land cover categories were evaluated against the areas already assessed as single family residential, and any area that overlapped with single family residential areas was removed from evaluation as area that could receive fertilizer as "other UTF."

Table 9. Other UTF land use categories and estimated impervious area

WMD Land Cover Code	Percent Impervious	Percent of Pervious Area Receiving Fertilizer
1220: Medium Density, Mobile Home Units	32.6%	17.7%
1230: Medium Density, Mixed Units (Fixed and Mobile Home Units)	32.6%	15.4%
1320: High Density, Mobile Home Units	44.4%	20.7%
1330: Multiple Dwelling Units, Low Rise	44.4%	27.8%
1340: High Density, Multiple Dwelling Units, High Rise (Four Stories or More)	44.4%	32.8%
1400: Commercial and Services	72.2%	31.3%
1411: Shopping Centers	72.2%	31.3%
1480: Cemeteries	8.3%	42.2%
1700: Institutional	34.4%	43.3%
1720: Religious	39.9%	37.7%
1740: Medical and Health Care	72.2%	33.8%
1750: Governmental	35.4%	41.0%
1850: Parks and Zoos	12.5%	44.9%
1860: Community Recreational Facilities	12.5%	59.8%

Not all pervious area for these land cover codes will be fertilized. To estimate the area of pervious area that will be fertilized, land cover tree canopy coverage data provided by the City of Tallahassee was used to estimate the percentage of pervious area that would receive fertilization as summarized in **Table 9**. It was assumed that all area expected to receive fertilization would be managed by landscaping professionals that would apply fertilizer consistent with the *Green Industries Best Management Practices (BMP) Manual* (GI-BMP) guidelines (DEP 2010) (see link in **Appendix A**). An evaluation for the GI-BMP was performed to estimate the application rate by region for the north and central regions and is summarized in **Table 10** below.

Table 10. Green Industries BMP regional fertilizer application rates

Region	Annual Fertilizer Application Rate
North	2.5 lbs-N/1,000 square feet
Central	3.0 lbs-N/1,000 square feet

Sports Turfgrass Fertilizer

Golf Courses

Golf course loading to the land surface was estimated by evaluating the active golf courses in each BMAP area, estimating the total acreage of each golf course, and determining the fertilizer application rate based on prior NSILT course-specific survey responses or using an estimated regional fertilizer application rate. The estimated regional rate was derived from a survey of regional golf course practices published by Hort Technology (Shaddox et al. 2023) and amounted to an estimated application rate of 2.2 lbs-N/1,000 square feet for the whole of the golf course property. Golf courses no longer in operation were excluded as current loading sources.

Additionally, the management of each golf course was identified as a local government, special district, or private entity for possible consideration in the allocation process.

Other (Non-Golf) Sports Turfgrass Fertilizer

Sports turfgrass loading estimates were consistent with the previous NSILT evaluations. Sports turfgrass area was determined by reviewing areas with the property appraisers land use categories that may include sports turfgrass and performing an aerial review to determine the total acreage used as sports turfgrass. It was assumed that these lands are fertilized at rates and frequencies applied by lawn service companies following the GI-BMP recommendations (DEP 2010). Fertilizer application rates are consistent with the previous NSILT evaluations.

Biosolids

Biosolids loading to the land surface was estimated by determining what biosolid application sites were within BMAP boundaries and reviewing annual reports to determine the application quantity. Annual reports from 2018 to 2022 were evaluated. Data were provided in tons of material applied. It was estimated that biosolids had an approximate nitrogen concentration of five percent. The location of biosolids application sites was spatially evaluated to determine the appropriate recharge categories for the area, and attenuation and recharge factors were applied to estimate loading to groundwater. The biosolid application process and leaching is estimated based on site-specific data. Loading estimates will be refined in future updates to protect the aquifer under vulnerable karstic features. DEP will continue to evaluate data and update loads and allocations as appropriate.

Estimating Loading to Floridan Aquifer

Biochemical Attenuation

A source-specific specific biochemical attenuation factor (BAF) was applied to each loading source to account for near-surface biochemical process that result in a reduction of nitrogen available to leach to groundwater. Processes such as denitrification, volatilization, immobilization, and cation exchange all contribute to the reduction of leachable nitrogen. These processes occur to varying degrees depending on the application method, the form of nitrogen, soil properties, and other factors. BAFs used in this evaluation, listed in **Table 11**, represent the estimated percentage of the nitrogen attenuated or removed by subsurface processes.

Table 11. 2023 NSILT biochemical attenuation factors

*Includes sports turfgrass fertilizer and golf courses.

Nitrogen Source Category	BAF	Literature References
Atmospheric Deposition	90%	Katz et al. 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs-Reuse	75%	Jordan et al. 1997; Candela et al. 2007; Rahil and Antonopoulos 2007
WWTFs-RIBs and Absorption Fields	25%	Merritt and Toth 2006; Sumner and Bradner 1996

Nitrogen Source Category	BAF	Literature References
WWTFs-Sprayfield	60%	Katz et al. 2009; Lombardo Associates 2011; Howard T. Odum Florida Springs Institute 2011
WWTFs-Wetland Treatment	85%	Thompson and Milbrandt, 2016; Liu et al. 2024
Urban Fertilizer*	70%	Goolsby et al. 1999; Erikson et al. 2001; Barton and Colmer 2006; Katz et al. 2009
OSTDS	30%	Armstrong, J.H. 2015
Livestock Waste (Non-Dairy)	90%	Dubeux et al. 2007; Silveira et al. 2007; Burns et al. 2009; Dubeux et al. 2009; Obour et al. 2010; Sigua 2010; Sigua et al. 2010; Silveira et al. 2011; Woodard et al. 2011; White-Leech et al. 2013a; White-Leech et al. 2013b
Farm Fertilizer	80%	McNeal et al. 1995; Wang and Alva 1996; Paramasivam and Alva 1997; Newton et al. 1999; Hochmuth 2000a; Hochmuth 2000b; Simonne et al. 2006; He et al. 2011; Liu et al. 2013
Farm Fertilizer – Irrigated	65%	McNeal et al. 1995; Wang and Alva 1996; Paramasivam and Alva 1997; Newton et al. 1999; Hochmuth 2000a; Hochmuth 2000b; Simonne et al. 2006; He et al. 2011; Liu et al. 2013
Livestock Waste - Dairy (non-CAFO)	50%	Woodard et al. 2002; Landig et al. 2010
Livestock Waste - Dairy (CAFO)	85%	Cabrera et al. 2006
Cattle Farms (Silver and Rainbow Only)	90%	Dubeux et al. 2007; Silveira et al. 2007; Burns et al. 2009; Dubeux et al. 2009; Obour et al. 2010; Sigua 2010; Sigua et al. 2010; Silveira et al. 2011; Woodard et al. 2011; White-Leech et al. 2013a; White-Leech et al. 2013b
Horse Farms (Silver and Rainbow Only)	90%	Dubeux et al. 2007; Silveira et al. 2007; Burns et al. 2009; Dubeux et al. 2009; Obour et al. 2010; Sigua 2010; Sigua et al. 2010; Silveira et al. 2011; Woodard et al. 2011; White-Leech et al. 2013a; White-Leech et al. 2013b
Biosolids	50%	Division of Water Resource Management Staff Feedback

Generally, biochemical attenuation factors are consistent with the prior NSILT evaluation, with a few exceptions. OSTDS attenuation for all BMAPs was revised based on Florida-specific data provided by the DEP Onsite Sewage Program (Armstrong 2015). Attenuation factors for the springsheds in the Suwannee BMAP were updated to be consistent with other BMAPs. The Jackson Blue NSILT was the only evaluation to evaluate farm fertilizer loading with separate irrigated and non-irrigated attenuation factors, respectively, consistent with the previous NSILT evaluation.

Recharge

Nitrogen that is not attenuated during biochemical attenuation processes can leach to groundwater and impact water quality at the spring vent. Subsurface processes dictate the impact of the leached nitrogen on water quality at the spring vents. To evaluate the relative impact of leached nitrogen, a recharge factor was applied to the attenuated load based on the hydrologic conditions of the location of the loading. Four recharge categories were considered: high, medium, low, and discharge. Leaching to groundwater is a function of the properties of the soil and unsaturated (vadose) zone, drainage, wetness, depth to water table, and hydraulic conductivity. In areas where water can readily recharge through the vadose zone into underlying formations that have high hydraulic conductivity, it is anticipated that the majority of nitrogen will impact water quality at the spring vent and would be considered a high recharge area. In areas where water cannot readily recharge the Floridan aquifer due to characteristics of overlying soils, the presence of a surficial aquifer, or other properties that would otherwise retard the movement of leached water to the Floridan aquifer, a low recharge factor was applied, reducing the expected impact on water quality at the spring vent. In areas where water is expected to discharge from the Floridan aquifer, such as in wetland areas, it is not anticipated that nitrogen deposited in these areas will impact at spring vents and the loading was not included in the NSILT evaluation.

For all BMAPs, in areas that were considered to have recharge, it was estimated that 90% of the attenuated load would impact water quality at the spring vent. In areas that were considered to have low recharge, it was estimated that only 10% of the attenuated nitrogen would impact water quality at spring vents. At all BMAPs except for Wakulla Spring and Jackson Blue Spring, in areas considered to have medium recharge it is estimated that 50% of the attenuated load will impact the spring vent water quality. In Wakulla, the recharge evaluation was based on confinement of the Floridan aquifer, and it was estimated that in semiconfined areas only 40% of the attenuated load would impact the spring vent. In the Jackson Blue springshed, recharge was primarily based on soils. While there is some variation in soils in this springshed, it was determined that it would be unlikely that 50% of the attenuated load would be reduced due to areas with slightly different soils and it was considered that 60% of the load would impact the spring vent.

All recharge factors are consistent with the previous NSILT evaluation, additional information on BMAP specific recharge can be found in the technical support documents in the appendices of the previous BMAP documents.

References

Armstrong, J.H. 2015. Florida Onsite Sewage Nitrogen Reduction Strategies Study Final Report.

Barton, L., and T.D. Colmer. 2006. Irrigation and fertilizer strategies for minimizing nitrogen leaching from turfgrass. *Agricultural Water Management* 80: 160–175.

Burns, J.C., M.G. Wagger, and D.S. Fisher. 2009. Animal and pasture productivity of "Coastal" and "Tifton 44" Bermudagrass at three nitrogen rates and associated soil nitrogen status. *Agronomy Journal* 101 (1): 32–40.

Bush, P.W., and R.H. Johnston. 1988. Ground-water hydraulics, regional flow, and ground-water development of the Floridan aquifer system in Florida and parts of Georgia, South Carolina, and Alabama. *U.S. Geological Survey Professional Paper* 1403-C.

Cabrera, V.E., A. de Vries, and P.E. Hildebrand. 2006. Prediction of nitrogen excretion in dairy farms located in North Florida: A comparison of three models. *Journal of Dairy Science* 85:1830–1841.

Candela, L., S. Fabregat, A. Josa, J. Suriol, N. Vigues, and J. Mas. 2007. Assessment of soil and groundwater impacts by treated urban wastewater reuse: A case study: Application in a golf course (Girona, Spain). *Science of the Total Environment* 374: 26–35.

Cook, E.M., S.J. Hall, and K.L. Larson. 2012. Residential landscapes as social-ecological systems: A synthesis of multi-scalar interactions between people and their home environment. *Urban Ecosyst* 15: 19–52.

Davis, J.H. 1996. Hydrogeologic investigation and simulation of ground-water flow in the UFA of north-central Florida and southwestern Georgia and delineation of contributing areas for selected city of Tallahassee, Florida, water-supply wells. *U.S. Geological Survey Water-Resources Investigations Report* 95-4296.

Dubeux, J.C.B., Jr., L.E. Sollenberger, B.W. Mathews, J.M. Scholberg, and H.Q. Santos. 2007. Nutrient cycling in warm-climate grasslands. *Crop Science* 47: 915–928.

Dubeux, J.C.B., Jr., L.E. Sollenberger, L.A. Gaston, J.M.B. Vendramini, S.M. Interrante, and R.L. Stewart, Jr. 2009. Animal behavior and soil nutrient redistribution in continuously stocked Pensacola bahiagrass pastures managed at different intensities. *Crop Science* 49: 1503–1510.

Eller, Kirstin T., and Brian G. Katz. 2017. "Nitrogen Source Inventory and Loading Tool: An integrated approach toward restoration of water-quality impaired karst springs." *Journal of Environmental Management.*

Erikson, J.E., J.L. Cisar, J.C. Volin, and G.H. Snyder. 2001. Comparing nitrogen runoff and leaching between newly established St. Augustine turf and an alternative residential landscape. *Crop Science* 41: 1889–1895.

Florida Department of Environmental Protection. 2010. Florida friendly best management practices for protection of water resources by the green industries. Tallahassee, FL.

Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, and B.T. Aulenbach et al. 1999. Flux and sources of nutrients in the Mississippi–Atchafalaya River Basin. *National Oceanic and Atmospheric Administration Coastal Ocean Program* No. 17.

Happell, J.D., S. Opsahl, Z. Top, and J.P. Chanton. 2006. Apparent CFC and 3H/3He age differences in water from Floridan aquifer springs. *Journal of Hydrology* 319:410–426.

He, J., M.D. Dukes, G.J. Hochmuth, J.W. Jones, and W.D. Graham. 2011. Evaluation of sweet corn yield and nitrogen leaching with CERES-maize considering input parameter uncertainties. *Transaction of the American Society of Agricultural and Biological Engineers* 54(4):1257–1268.

Helgeson, T. and McNeal, M. 2009. A Reconnaissance-Level Quantitative Comparison of Reclaimed Water, Surface Water, and Groundwater. *WateReuse Foundation*.

Hochmuth, G.J., and Hanlon, E.A. 2000a. IFAS standardized fertilization recommendations for vegetable crops. *Circular 1152. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.*

———. 2000b. A summary of N, P, and K research with tomato in Florida. *Document SL355. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.*

Howard T. Odom Florida Springs Institute. 2011. Wakulla Spring–An adaptive management strategy. *Prepared for the Wakulla Springs Working Group. Gainesville, FL.*

Jordan, M.J., H.J. Nadelhoffer, and B. Fry. 1997. Nitrogen cycling in forest and grass ecosystems irrigated with 15N-enriched wastewater. *Ecological Applications* 7 (3): 864–881.

Katz, B.G. 1992. Hydrochemistry of the upper Floridan aquifer, Florida. *U.S. Geological Survey Water-Resources Investigations Report* 91-4196.

Katz, B.G. 2004. Sources of nitrate contamination and age of water in large karstic springs of Florida. *Environmental Geology* 46: 689–706.

Katz, B.G, H.D. Hornsby, J.F. Boklke, and M.F. Mokray. 1999. Sources and chronology of nitrate contamination in spring waters, Suwannee River Basin, Florida. *U.S. Geological Survey Water-Resources Investigations Report* 99-4252.

Katz, B.G., A.A. Sepulveda, and R.J. Verdi. 2009. Estimating nitrogen loading to ground water and assessing vulnerability to nitrate contamination in a large karstic springs basin, Florida. *Journal of the American Water Resources Association* 45: 3.

Kinzig, A.P., P. Warren, C. Martin, D. Hope and M. Katti. 2005. The effects of human socioeconomic status and cultural characteristics on urban patterns of biodiversity. *Ecology and Society* 10 (1).

Knowles, L., Jr., B.G. Katz, and D.J. Toth. 2010. Using multiple chemical indicators to characterize and determine the age of groundwater from selected vents of the Silver Springs Group, Central Florida, USA. *Hydrogeology Journal* 18:1825–1838.

Landig, F., O. Fenton, P. Bons, D. Hennessy, K. Richards, and P. Blum. 2010. Estimation of nitrate discharge in a fractured limestone aquifer below a dairy farm in Ireland. In: *Groundwater management in a rapidly changing world, Proceedings from the 7th International Groundwater Quality Conference* (Zurich, Switzerland).

Law, N.L, L.E. Band, and J.M. Grove. 2004. Nitrogen input from residential lawn care practices in suburban watersheds in Baltimore County, MD. *Journal of Environmental Planning and Management* 47 (5): 737–755.

Liu, G.D., E.H., Simonne, and G.J. Hochmuth. 2013. Soil and fertilizer management for vegetable production in Florida. *Document HS711. Gainesville, FL: University of Florida Institute of Food and Agricultural Sciences.*

Liu, T., D. Li, Y. Tian, J. Zhou, Y. Qiu, D. Li, G. Liu, Y. Feng. 2024. Enhancing nitrogen removal in constructed wetlands: The role of influent substrate concentrations in integrated vertical-flow systems. *Environmental Science and Ecotechnology* 21 (2024) 100411.

Lombardo Associates. 2011. Onsite sewage treatment and disposal and management options. *Newton, MA.*

Martin, T. 2008. Lawn care behavior, Crystal River/Weeki Wachee Spring and Rainbow River survey. *Final report prepared for the Southwest Florida Water Management District.*

McNeal, B.L, C.D. Stanley, W.D. Graham, P.R. Gilreath, D. Downey, and J.F. Creighton. 1995. Nutrient loss trends for vegetable and citrus fields in west-central Florida: 1. Nitrate. *Journal of Environmental Quality* 24(1): 95–100.

Merritt, M., and D.J. Toth. 2006. Estimates of upper Floridan aquifer recharge augmentation based on hydraulic and water-quality data (1986–2002) from the Water Conserv II RIB systems, Orange County, Florida. *St. Johns River Water Management Special Publication SJ2006-SP3. Palatka, FL.*

Newton G.L., G.J. Gascho, G. Vellidis, R.N. Gates, and R.K. Hubbard et al. 1999. Nutrient balance for triple-crop forage production systems fertilized with dairy manure or commercial fertilizer. *Water Resource Conference. Athens, GA: University of Georgia.*

Obour, A.K., M.L. Silveira, J.M.B. Vendramini, M.B. Adjei, and L.E. Sollenberger. 2010. Evaluating cattle manure application strategies on phosphorus and nitrogen losses from a Florida spodosol. *Agronomy Journal* 102(5): 1511–1520.

Paramasivam, S., and A.K. Alva. 1997. Leaching of nitrogen forms from controlled-release nitrogen fertilizers. *Communications in Soil Science and Plant Analysis* 28(17&18): 1663–1674.

Phelps, G.G. 2004. Chemistry of ground water in the Silver Springs Basin, Florida, with emphasis on nitrate. *U.S. Geological Survey Scientific Investigations Report* 2004-5144.

Rahil, M.H., and V.Z. Antonopoulos. 2007. Simulating soil water flow and nitrogen dynamics in a sunflower field irrigated with reclaimed wastewater. *Agricultural Water Management* 92: 142–150.

Schwede, D.B., and G.G. Lear. 2014. A novel hybrid approach for estimating total deposition in the United States. *Atmospheric Environment* 92: 207–220.

Sigua, G.C. 2010. Sustainable cow-calf operations and water quality: A review. *Agron. Sustain. Dev.* 30: 631–648.

Sigua, G.C., R.K. Hubbard, S.W. Coleman, and M. Williams. 2010. Nitrogen in soils, plants, surface water and shallow groundwater in a bahiagrass pasture of southern Florida, USA. *Nutrient Cycling in Agroecosystems* 86: 175–187.

Silveira, M.L., V.A. Haby, and A.T. Leonard. 2007. Response of coastal bermudagrass yield and nutrient uptake efficiency to nitrogen sources. *Agronomy Journal* 99: 707–714.

Silveira, M.L., A.K. Obour, J. Arthington, and L.E. Sollenberger. 2011. The cow-calf industry and water quality in south Florida: A review. *Nutrient Cycling in Agroecosystems* 89: 439–452.

Simonne, E., M. Dukes, G. Hochmuth, B. Hochmuth, D. Studstill, and A. Gazula, 2006. Monitoring nitrate concentration in shallow wells below a vegetable field. *Proc. Fla. State Hort. Soc.* 119: 226–230.

Shaddox, T.W., J. B. Unruh, M. E. Johnson, C. D. Brown, and G. Stacey. 2023. Nutrient Use and Management Practices on United States Golf Courses. *HortTechnology* 33(1): 79-97.

Skybase7. 2023. 2023 TAPP Residential Turf Grass Fertilizer Survey. *Report of Findings prepared for the City of Tallahassee.*

Souto, L., M. Collins, D. Barr, G. Milch, J. Reed, and M.D. Ritner. 2009. Wekiva residential fertilizer practices. Contract# G0078. University of Central Florida for the Florida Department of Environmental Protection

Sumner, D.M., and L.A. Bradner. 1996. Hydraulic characteristics and nutrient transport and transformation beneath a rapid infiltration basin, Reedy Creek Improvement District, Orange County, Florida.

Thompson, M., Milbrandt, E. 2016. Nutrient Loading from Sanibel's Surficial Aquifer. *Sanibel-Captiva Conservation Foundation Marine Laboratory.*

Tilley, J.S., and E.T. Slonecker, 2006, Quantifying the Components of Impervious Surfaces: U.S. Geological Survey Open-File Report 2006-1008.

Toth, D.J., and B.G. Katz. 2006. Mixing of shallow and deep groundwater as indicated by the chemistry and age of karstic springs. Hydrogeology Journal 14: 1060-1080.

Wang, F.L., and A.K. Alva. 1996. Leaching of nitrogen from slow-release urea sources in sandy soils. *Soil Science Society of America Journal* 60: 1454–1458.

White-Leech, R., K. Liu, L.E. Sollenberger, K.R. Woodard, and S.M. Interrante. 2013a. Excreta deposition on grassland patches. I. Forage harvested, nutritive value, and nitrogen recovery. *Crop Science* 53: 688–695.

———. 2013b. Excreta deposition on grassland patches. II. Spatial pattern and duration of forage responses. *Crop Science* 53: 696–703.

Woodard, K.R., French, E.C., Sweat, L.A., Graetz, D.A., Sollenberger, L.E., Macoon, B., Portier, K.M.,Wade, B.L., Rymph, S.J., Prine, G.M., VanHorn, H.H. 2002. Plant and Environment Interactions: Nitrogen Removal and Nitrate Leaching for Forage Systems Receiving Dairy Effluent. *Journal of Environmental Quality* 31: 1980-1992.

Woodard, K.R., and L.E. Sollenberger. 2011. Broiler litter vs. ammonium nitrate as nitrogen source for bermudagrass hay production: Yield, nutritive value, and nitrate leaching. *Crop Science* 51: 1342–1352.

Zhou, W., A. Troy, and M. Grove. 2008. Modeling residential lawn fertilization practices: Integrating high resolution remote sensing with socioeconomic data. Environmental Management 41: 742–752.

Technical Support Document - Appendix A

Important Links

The links below were correct at the time of document preparation. Over time, the locations may change, and the links may no longer be accurate. None of these linked materials are adopted into this BMAP.

- Atmospheric Deposition Program (NADP) Total Deposition (TDEP) data: https://catalog.data.gov/dataset/nadp-total-deposition-data
- DEP Springs BMAP documents: https://floridadep.gov/dear/water-quality-restoration/content/florida-springs-basin-management-action-plans
- Florida Friendly Best Management Practices for Protection of Water Resources by Green Industries, GI-BMP Manual: https://ffl.ifas.ufl.edu/ffl-and-you/gi-bmp-program/gi-bmp-manual/
- Florida Statewide Agricultral Irrigation Demand Geodatabase, Version 9: https://www.DACS.gov/Agriculture-Industry/Water/Agricultural-Water-Supply-Planning
- Florida Water Management Inventory with locations of known and estimated septic systems: https://ww10.doh.state.fl.us/pub/bos/Inventory/FloridaWaterManagementInventory/
- Home value price resources:
  - www.roofstock.com
  - www.neighborhoodscout.com
  - www.visualcapitalist.com
- Previous NSILT technical supporting documents: publicfiles.dep.state.fl.us - /DEAR/NSILT/
- Statewide Land Use Land Cover: https://geodata.dep.state.fl.us/datasets/FDEP::statewide-land-use-land-cover/about
- U.S Census Data, 2020: https://www.census.gov/programs-surveys/decennial-census/decade/2020/2020-census-results.html
- USDA Census of Agriculture, 2017: https://www.nass.usda.gov/Publications/AgCensus/2017/index.php

- USDA Survey of Agriculture: https://quickstats.nass.usda.gov/
- Water Quality Restoration Program, DEP: https://floridadep.gov/dear/water-quality-restoration