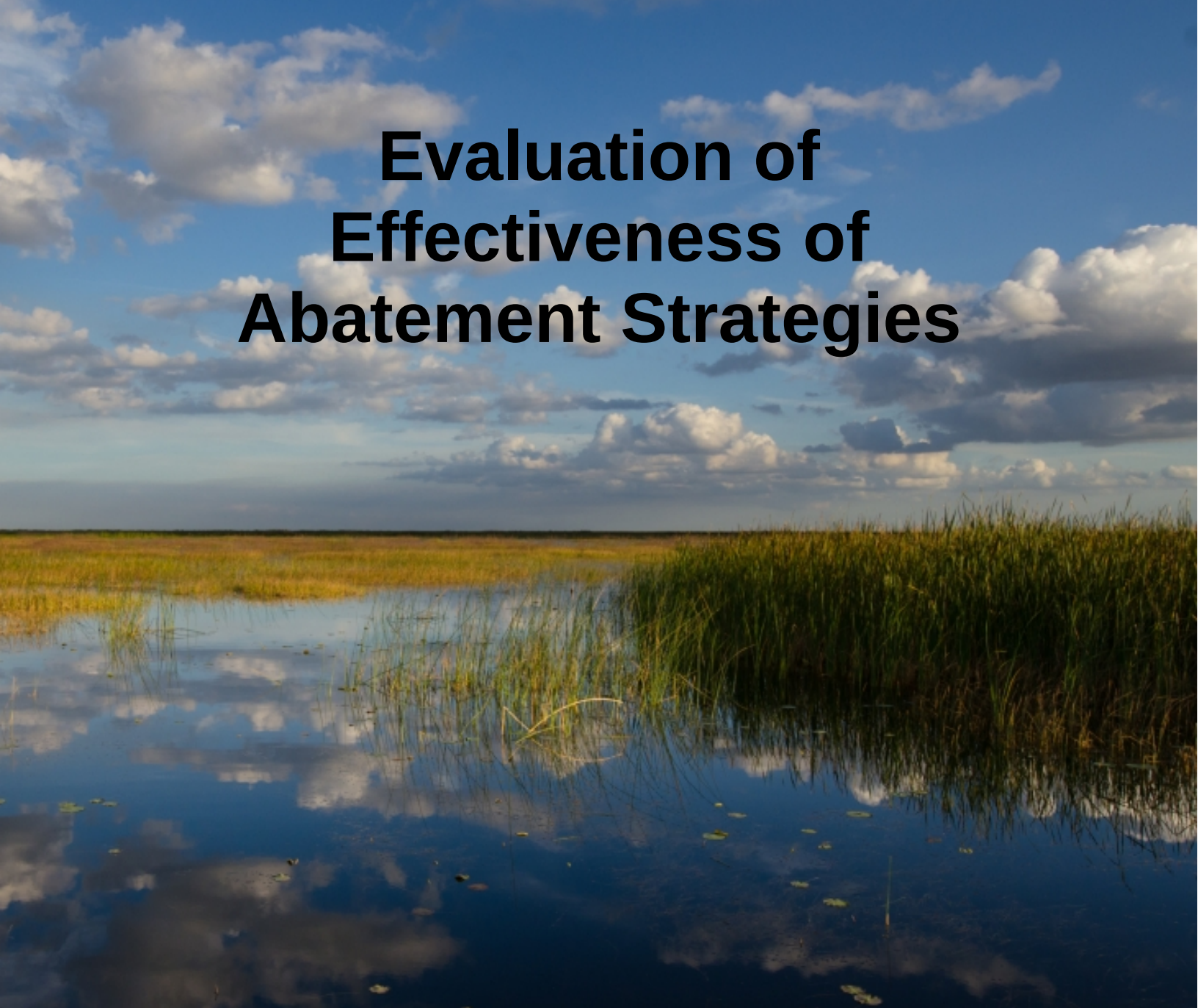




Evaluation of Effectiveness of Abatement Strategies

*Compared Against Pre-Drainage and Existing
Conditions in the Lake Okeechobee Watershed*

Deliverable 2.1: Pre-Drainage Characterization Report

OCTOBER 1, 2018

Soil and Water Engineering Technology, Inc.



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List of Abbreviations

BLASRoute	Basin Land Area to Stream Routing
BMAP	Basin Management Action Plan
BMP	Best Management Practice
BUCShell	Basin Unique Cell Shell (command line shell program)
CERP	Comprehensive Everglades Restoration Plan
COMPNAME	Component Name (in NRCS soil maps)
DEM	Digital Elevation Model
EAA	Everglades Agricultural Area
EAAMod	Everglades Agricultural Area Model
ESW	East Sub-Watershed (of the LOW)
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FEC	Fisheating Creek
FIPS	Federal Information Processing Standard
FLUCCS	Florida Land Use, Cover (and Forms) Classification System
GIS	Geographic Information System
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems
HARN	High Accuracy Reference Network
HSPF	Hydrological Simulation Program - FORTRAN
HUC	Hydrologic Unit Code
LOW	Lake Okeechobee Watershed
LOWPP	Lake Okeechobee Watershed Protection Plan
MUKEY	Mapunit Key (in NRCS soil maps)
MUNAME	Mapunit Name (in NRCS soil maps)
N	Nitrogen
NAD	North American Datum
NSRSM	Natural System Regional Simulation Model
NRCS	Natural Resources Conservation Service
Ortho-P	Ortho-phosphate
P	Phosphorus

PDL D	Pre-drainage Landscape Database
SFWMD	South Florida Water Management District
SRP	Soluble Reactive Phosphorus
SSW	South Sub-Watershed (of the LOW)
SWET	Soil and Water Engineering Technology, Inc.
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
USLE	Universal Soil Loss Equation
WAM	Watershed Assessment Model
WSW	West Sub-Watershed (of the LOW)
WY	Water Year

Executive Summary

The Watershed Assessment Model (WAM) was used to develop estimates of water and nutrient loadings to Lake Okeechobee under pre-drainage conditions, i.e., conditions that existed prior to agricultural and urban development. This project provides a reference point for an ultimate mitigation target for the Lake Okeechobee Watershed (LOW) (**Figure 1**) and is part of a larger effort to determine the effectiveness of future abatement strategies.

The LOW consists of nine sub-watersheds with six located north of Lake Okeechobee and three located immediately east, south, and west of the lake. Agricultural and urban development has resulted in extensive alteration of land cover and hydrography throughout the LOW. To simulate these changes, a variety of sources including descriptions of the area from the 1800s and aerial photography from the mid-1900s were consulted, and existing land use, hydrography, and soils datasets were modified based on these sources. All non-native land uses were converted to the best available estimates of native land cover, manmade hydrologic features were removed, and sloughs and streams added to reflect estimated natural conditions. The original natural topography has been altered in many places, particularly in the southern part of the watershed where extensive subsidence has occurred due to drainage and soil oxidation. A topographic dataset reflecting pre-drainage conditions that was developed for the Natural System Regional Simulation Model (NSRSM) was obtained from the South Florida Water Management District (SFWMD) to use in the model setup.

Literature was reviewed to develop estimates of nutrient concentrations in runoff and recharge to groundwater from native land covers that have not been impacted by human development. These estimates were developed for each type of native land use, and the literature data were also used to determine appropriate nutrient attenuation coefficients for overland and in-stream flow.

Simulations of the pristine conditions in all nine sub-watersheds were run with WAM over calendar years 1994-2013 and the overall discharge volume of water, nutrient loads and flow-weighted concentrations to Lake Okeechobee were calculated. The estimates from the WAM simulations are that on average, over the period from water year (WY) 1995 – WY 2013 about 1.8 million acre-feet of water were discharged into Lake Okeechobee each year, carrying nutrient loads into the lake of almost 2,400 metric tons (mt) of total nitrogen (TN) and about 80 mt of total phosphorus (TP) each year. Flow-weighted concentrations of TN and TP in water entering the lake were 1.05 mg/L and 0.036 mg/L, respectively.

In comparison, a measured annual average value of approximately 2.3 million acre-feet of water were discharged into Lake Okeechobee over the time frame from WY 1995-WY 2013

1 Introduction

The Watershed Assessment Model (WAM) was used to evaluate the impact of alternative land uses, implementation of best management practices (BMPs), and nutrient load reduction projects for the Lake Okeechobee Watershed (LOW) (Bottcher et al. 2012; SWET 2017a, 2017b). In addition to these applications, WAM can simulate pre-drainage conditions to provide base targets for abatement programs, such as the Lake Okeechobee Watershed Protection Plan (LOWPP) and the Lake Okeechobee Basin Management Action Plan (BMAP), and in the federal planning process for the Comprehensive Everglades Restoration Plan (CERP). The term “pre-drainage” (used interchangeably with “pre-development”) conditions are defined as environmental conditions that existed in the sub-watersheds prior to the timeframe from roughly 1850 to 1900. It is meant to reflect conditions before the replacement of native vegetation and hydrography due to agriculture and urbanization.

WAM is a process-based model that can be used to perform hydrological and water quality analyses to:

- Simulate flows and nutrient loads for existing and pre-drainage land uses, soils, and land management practices.
- Analyze the hydrological and water quality impacts on streams and lakes for management scenarios, such as land use changes, implementation of BMPs, or the addition of regional reservoirs and stormwater treatment areas.
- View and analyze the simulated flow and concentrations for every stream reach in the sub-watershed using the ArcMap™ platform.
- Prioritize geographical areas where BMP efforts are to be focused.
- Provide quantitative comparisons of flows and nutrient loads between pre-drainage (i.e., prior to development), existing, and future conditions.

The South Florida Water Management District (SFWMD), the Florida Department of Environmental Protection (FDEP), and the Florida Department of Agriculture and Consumer Services (FDACS), hereinafter collectively referred to as the Coordinating Agencies, have identified WAM as the best tool for performing such analyses in the LOW.

For this deliverable, Soil and Water Engineering Technology, Inc. (SWET) used WAM to evaluate pre-drainage conditions in the LOW. Later deliverables will use WAM to determine the effectiveness of future abatement strategies for reducing nutrient loads to Lake Okeechobee and the impact of those strategies on the drainage system in the LOW (**Figure 1**) and ultimately Lake Okeechobee. The simulation of pre-drainage conditions was defined as a need in the adopted Lake Okeechobee BMAP (FDEP 2014) since it will provide a reference point for an ultimate mitigation target for the watershed.

The LOW consists of nine sub-watersheds. Six of these are north and upstream of Lake Okeechobee, while the remaining three are located immediately east, south, and west of the lake and are generally downstream of the lake but in certain cases may discharge to the lake. In what follows, the three southern-most sub-watersheds will be referred to as the East sub-watershed (ESW), South sub-watershed (SSW), and West sub-watershed (WSW). A calibrated WAM simulation was developed to estimate water flows and nutrient loads across all the nine sub-watersheds in the LOW (SWET 2017a, 2017b), including the hydrologically connected southern part of the Everglades Agricultural Area (EAA)

that does not lie within the Lake Okeechobee BMAP area. The simulation period of record (POR) was from 1975 through the end of 2013. The simulations for the northern six sub-watersheds were built upon earlier work (Bottcher et al. 2012), while the simulations of the three southern sub-watersheds were a new application. These simulations will serve as the reference estimates for existing conditions for the current project.

1.1 Objectives and Goals

The primary objective of this project is to assess the effectiveness of the most promising hydrological and nutrient abatement programs and associated BMPs/technologies for meeting LOWPP/BMAP targets across the entire LOW. The effectiveness will be assessed on a relative basis by comparing simulation results against the current state of the watershed. In this context, the estimated results from the pre-drainage simulation can serve as a bound for what may possibly be achieved. As mentioned in the preceding section the calibrated WAM application to the LOW (SWET 2017a, 2017b), which was shown to adequately model the situations concerned, will serve as the current conditions basis for this assessment. It is subsequently referred to as the “existing conditions scenario.” The goal of the **current** deliverable is to use WAM to simulate all nine sub-watersheds for the pre-drainage scenario (Tasks 2.1 and 2.1). These tasks are detailed below.

1.1.1 Tasks and Deliverables

The list of tasks and deliverables for this project as given in the scope of work are listed below, with the due dates indicated. The following section discusses the approach for the current tasks, 2.1 and 2.2.

Task 1: Work Plan (Completed)

- Deliverable 1.1: Draft Work Plan.
- Deliverable 1.2: Final Work Plan.

Task 2: Pre-Drainage Characterization (This Report)

- **Deliverable 2.1: Pre-drainage Characterization Report including GIS datasets (see Table 1) (9/10/2018)**
- Deliverable 2.2: Final Pre-drainage Characterization Report including GIS datasets (see **Table 1**) (10/1/2018)

Task 3: Abatement Scenarios (Future Report)

- Deliverable 3.1: Draft Abatement Scenarios Report including Cost-Benefit Analysis Results and a Draft Power Point Presentation (12/31/2018)
- Deliverable 3.2: Final Abatement Scenarios Report (1/22/2019)

Task 4: Comprehensive Report and Final Stakeholders Presentation

- Deliverable 4.1: Draft Comprehensive Report (2/25/2019)
- Deliverable 4.2: Final Comprehensive Report and a PowerPoint Presentation (4/8/2019)

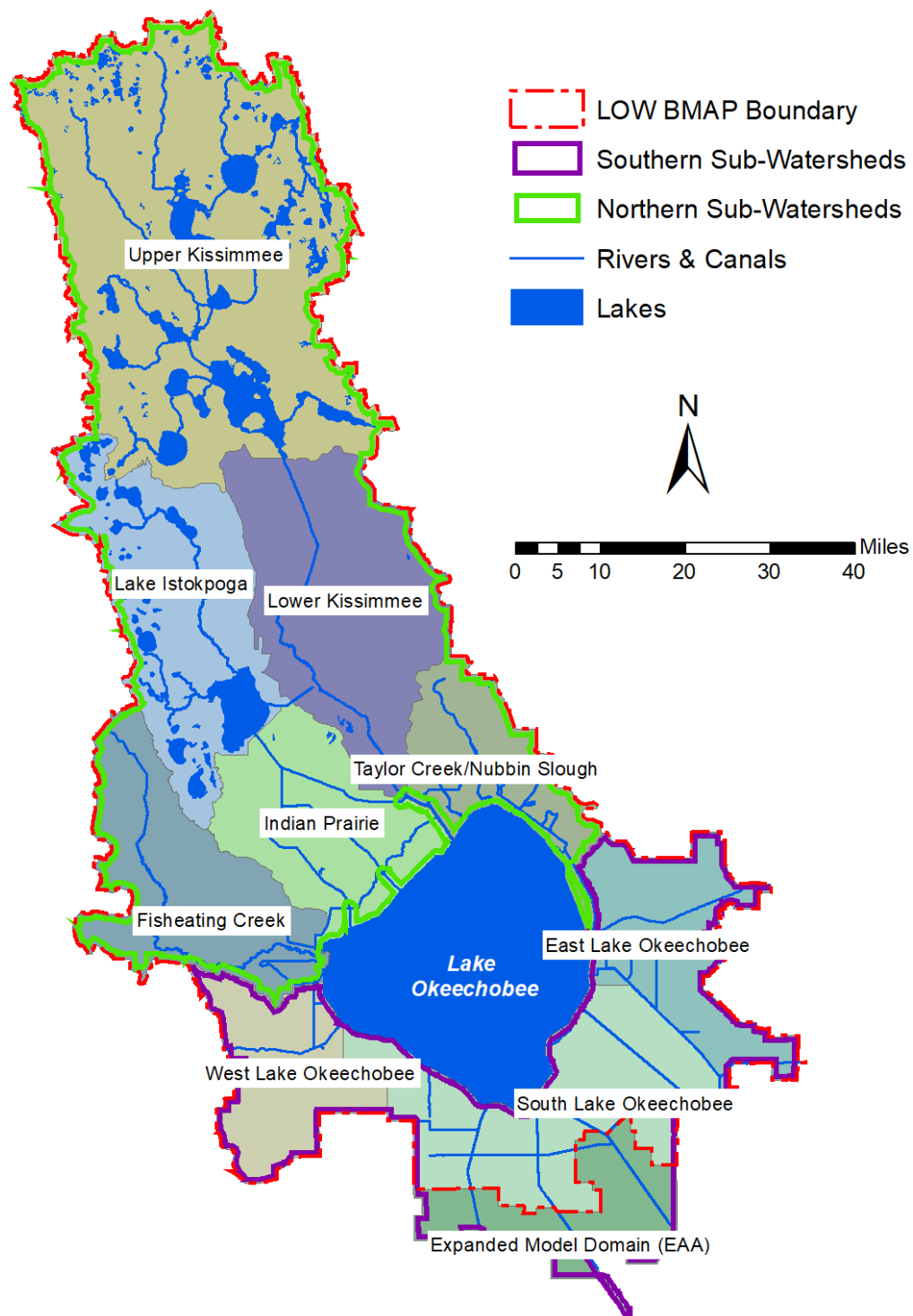


Figure 1. The Lake Okeechobee Watershed depicting current major hydrologic features and the nine sub-watersheds (six northern, three southern) simulated for this project.

1.2 A Brief Description of WAM

WAM simulates water and nutrient loading from a wide variety of land covers and land use practices while incorporating geographic and geologic features. WAM has been successfully used to simulate many different scenarios representing a wide range of conditions across Florida. WAM uses a geographic information system (GIS) grid-based representation to simulate the physical characteristics of the watershed. One of the first steps in the simulation process is the determination of the specific combination of land use/land cover, soil, wastewater service area, and rainfall for each cell in the watershed. These four datasets are overlain to identify the unique combinations of these inputs. These unique cell combinations characterize the specific conditions that occur on each cell within the watershed.

Estimates of runoff, percolation, and nutrient loads are generated at the source cell level as a daily time series. Depending on the unique cell combination, one of three sub-models is used to simulate hydrologic and chemical processes within the cell. The sub-model Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) (Knisel, 1993) is used on well drained soils with deep water tables. On poorly drained soils with high water tables, the Everglades Agricultural Model (EAAMod) (Bottcher et al., 1998; SWET, 2008) is used. For wetlands and open water, the Special Case sub-model (SWET, 2008) is used, which determines water and nutrient loads using a water balance based on the rainfall, potential ET, plant ET coefficient, percolation rate, and water storage depth. Typically, the source cells are specified to be one hectare (ha) in size. These estimates are then routed via overland and subsurface flow to the stream network and are in turn routed through the network to the basin or sub-watershed outlet. Water flow and nutrient concentrations are typically output on a daily basis, although the internal time step used by the routing algorithm does not exceed 10 minutes (an adaptive time stepping algorithm is used). Nutrients simulated by WAM include soluble and particulate ammonia (NH₃) and organic nitrogen, nitrate (NO₃), as well as soluble and particulate phosphorus. See **Section 5 (Appendix A)** for a more detailed discussion of WAM.

1.2.1 Required Datasets

To develop a WAM simulation for a specific area the following spatial datasets are required:

- Basin and sub-basin boundaries
- Topography
- Hydrologic network
- Land use/cover
- Soils
- Rain gage locations
- Hydraulic structures
- Utility (wastewater) service area
- Location of water and nutrient point sources (or sinks)
- Irrigation source specification

These datasets were used for the calibrated WAM application to the LOW (SWET 2017a, 2017b). In addition to these spatial datasets, a time series of recorded rainfall values at each rain station, daily temperatures, and other climate data are required to run WAM.

1.3 Pre-Drainage Characterization

The task to evaluate water and nutrient loading under pre-drainage conditions is the subject of this report. This includes discussion of the preparation of inputs for WAM using pre-drainage datasets for the nine sub-watersheds, and the subsequent application of WAM to estimate water flow and nutrient loads under pre-drainage conditions. As discussed above, the simulation of pre-drainage conditions was defined as a need in the adopted Lake Okeechobee BMAP. The primary use of the pre-drainage simulation results will be to serve as one end point representing an idealized set of water and nutrient loadings (although unlikely to be achieved in practice) with the other end point being established current conditions. With these two end points it is possible to evaluate where specific abatement strategies implemented as part of future tasks fall on the spectrum between these points and determine how closely a particular scenario can approach these ideal loading conditions.

1.3.1 Previous Work

A number of studies on pre-drainage/pre-development conditions have been conducted in the LOW that are directly related to the work for this study. Zahina et al. (2007) created a geospatial database of pre-drainage vegetation within the SFWMD boundary to provide a comprehensive data source for pre-drainage ecological conditions of the region. McVoy et al. (2011) developed characterizations of the pre-drainage vegetation, soils, regional topography, and hydrology of the Everglades. This work focused on the area south of the lake, with some limited data for the East and West sub-watersheds.

A study to assess pre-drainage conditions in the Fisheating Creek (FEC) sub-watershed (HDR 2011) produced an estimated land cover dataset based on soils data that was used in a WAM simulation for pre-drainage conditions in the sub-watershed. A later project titled “Lake Okeechobee Watershed Pre-Drainage Characterization Study” (HDR 2015) developed pre-drainage vegetative cover and hydrography datasets for a majority of the area in the five northern sub-watersheds (excluding FEC) for use with a WAM simulation. No simulations using WAM were conducted for that study, but the feature class datasets were directly usable in the WAM setup for this study.

The areas that had pre-drainage datasets completed for the 2011 (FEC) and 2015 (the rest of the northern LOW) reports lie within the purple and green boundaries, respectively, shown in **Figure 2**. Pre-drainage land cover and hydrology datasets for use in WAM had not been developed for most of the three remaining sub-watersheds, indicated by the red boundary. Note that a portion of the East Lake Okeechobee sub-watershed had pre-drainage data, while some small areas around the periphery of the northern sub-watersheds do not, due to minor changes in the delineation of the boundary. Any area without existing land cover and/or hydrography datasets usable in WAM had the appropriate datasets developed as part of this task.

A summary of the spatial datasets required by WAM, broken down by task, is shown in **Table 1**. Each spatial dataset is listed with associated columns indicating if it was altered from the existing datasets for the task, and the source of the dataset. For example, the watershed/sub-watershed boundaries were not altered, and conform to the 2017 WAM simulation setup.

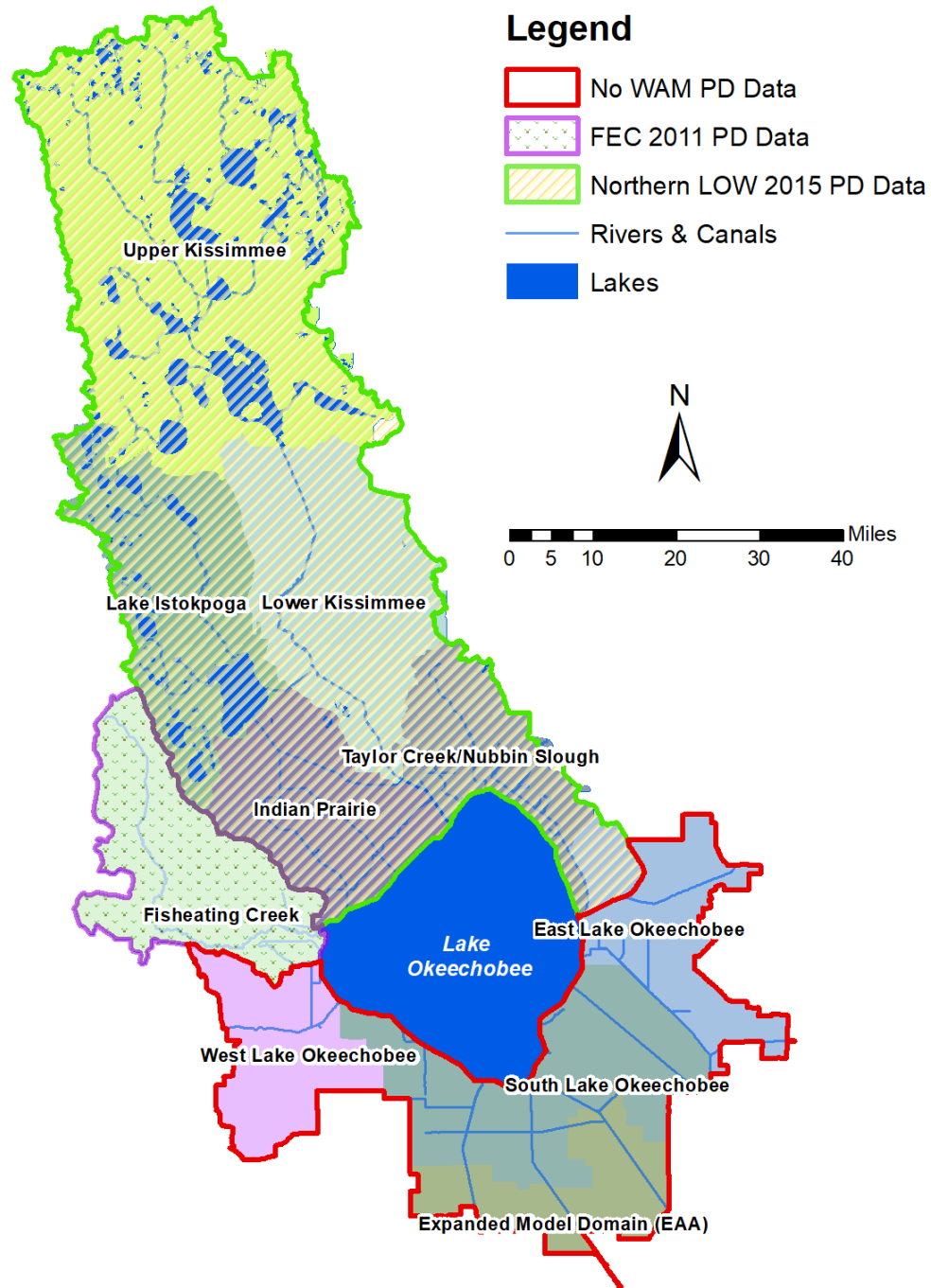


Figure 2. The areas with completed pre-drainage (i.e., PD) land cover and hydrology datasets (FEC, northern LOW) are enclosed by the purple and green boundaries, respectively. The red boundary encloses the area where pre-drainage land cover and hydrology datasets were created. For clarity, some small areas lacking pre-drainage data around the northern sub-watersheds are not highlighted.

The map projection used for all datasets was North American Datum (NAD) 1983 High Accuracy Reference Network (HARN) Florida State Plane East (Federal Information Processing Standard [FIPS] 0901), with feet as the linear unit. Of the datasets listed, it was critical to obtain the topographic dataset from the SFWMD (used for NSRSM simulations) since SWET had only limited spatial information about subsidence south of Lake Okeechobee.

Table 1. List of spatial datasets required by WAM, and source of information for updates. Rows highlighted in blue are datasets requiring significant modification, those in gray are used unchanged, and those in yellow have all anthropomorphic features removed.

Pre-Drainage Scenario (Task 2 Due 9/10/2018)		
<i>Dataset</i>	<i>Altered</i>	<i>Source</i>
Land use/cover	Yes	Have for northern sub-watersheds, developed from SFWMD
Hydrologic network	Yes	Taken from prior work for the northern sub-watersheds, developed for the East, South, and West Lake Okeechobee sub-watersheds
Soils	Yes	Required modifications where native soil type not present in Natural Resources Conservation Service (NRCS) soils data
Topography	Yes	Obtained from SFWMD (NSRSM)
Watershed and sub-watershed boundaries	No	Used model domain and sub-watershed boundaries from 2017 WAM simulations
Rain gage locations	No	Reused from 2017 WAM simulations
Hydraulic structures	Yes	Removed structures
Utility zones	Yes	Current zones were removed; no utility zones present in the datasets
Point sources/sinks	Yes	Current sources/sinks were removed; no sources/sinks present in the resulting datasets
Irrigation sources	Yes	Current sources will be removed; no sources present in the datasets

Of the spatial datasets listed in **Table 1**, the land use/cover, hydrography network, soils, and topography (datasets shown in light blue) required significant modification to develop the inputs for most or all of the model domains. All non-native land uses were converted to the best available estimates of native land cover. The current hydrography of the region has been significantly altered through canals being dug for flood control and agricultural irrigation, so manmade hydrologic features were removed from the dataset and sloughs and streams added to reflect estimated natural conditions. The soils dataset required less modification although some soils have been so extensively altered that the original soil type was no longer obvious. These were removed from the dataset and replaced by the nearest adjacent soil type(s). The original natural topography has also been altered in many places, particularly in the southern part of the watershed where extensive subsidence has occurred due to drainage and subsequent oxidation and consequently the current topography is several feet below the pre-drainage land surface. Details of how the land cover, hydrography, soils, and topography datasets were modified are discussed in **Section 2** below.

The datasets for hydraulic structures, point source locations, utility service areas, and irrigation specifications (shown in light yellow in **Table 1**) represent manmade features, and were only altered by removing features to represent natural conditions. The utility service area and irrigation sources datasets need to be present for WAM to run but were modified so that no service areas or irrigation sources are present.

Because there are no available daily rainfall or other climatology records from the pre-drainage time frame, the model was run using the same recent rainfall and climatology data that were used in prior WAM modeling efforts. The period of record (POR) is from 1991-2013, with the first three years used as a spin-up period for the WAM land source models run via BUCShell. The full model was run over the 20-year period from January 1, 1994 through the end of 2013. Annual average results are calculated over WY 1995 – WY 2013 (19 years). This model period was chosen to be long enough to cover both wet and dry periods as well as covering the 11-year calibration/verification period used in the 2017 modeling efforts (2003-2013) (SWET 2017a, 2017b) while avoiding excessive simulation run times.

2 WAM Model Setup

2.1 Modification of Spatial Datasets

2.1.1 *Modification of Soils Dataset*

The soils dataset is discussed first since it was subsequently used as the foundation of the pre-drainage land use/cover feature class. The soils dataset was originally created for the 2017 modeling effort by downloading feature classes from NRCS on a county-by-county basis and merging them into a single dataset. To ensure that the most recent dataset was used for the current project, the soils data were re-downloaded from the NRCS website. This was done by Hydrologic Unit Code (HUC) using the online NRCS Map Viewer application. Each HUC feature class was dissolved on a set of fields including Mapunit Key (MUKEY) and Mapunit Name (MUNAME) and then clipped to the LOW boundary. The features were merged and dissolved again to remove multiple overlapping polygons. A lookup table was created by exporting the table of features to Excel and the MUKEY and MUNAME fields were copied to a new worksheet. Rows with duplicate MUKEYs were deleted (note that MUKEY entries are unique across the U.S.) To facilitate the development of the pre-drainage land use/cover dataset (see steps 1 and 2 in the itemized list in **Section 2.1.2**, below) a field (“NRCS_FLUCCS”) was added in the soils feature class to hold the Florida Land Use Land Cover Classification System (FLUCCS) code for the associated soil type taken from the 2015 work. Entries in the newly created feature class that did not have FLUCCS entries were assigned a FLUCCS value of -99. These missing entries were then manually filled in by finding a related soil type, e.g., matching “Adamsville fine sand, 0 to 2 percent slopes” to “Adamsville sand, 0 to 2 percent slopes” and using the FLUCCS code for that soil, or by finding an entry for native vegetation in the NRCS soil series description.

After FLUCCS codes were assigned to all native soil types, the feature class was edited to change non-native soil types (e.g., “Arents,” “Pits,” “Urban Land,” etc.) to the nearest native type. Some types that have combined native/non-native MUNAMEs (e.g., “Myakka-Urban land complex”) were changed to the dominant native type (e.g., “Myakka”). Obvious anthropomorphic features such as canals or retention ponds were edited by clipping out the feature and merging it with the native type. Many of these

consisted of canals constructed between the lakes in the Upper Kissimmee sub-watershed or the numerous canals in the Indian Prairie, East, and South sub-watersheds. There were also several reservoirs and retention ponds mapped as water in the soils dataset that were edited to reflect the surrounding soil types.

Figure 3 shows one example of how the soils feature class was edited in the South sub-watershed. The current conditions are shown in the left pane and the estimated pre-drainage in the right. The polygons were edited in ArcMap by cutting and merging the water and Udorthents soils types representing the L-21, L-24, L-25, and L-26 canals to reflect the surrounding Pahokee and Terra Ceia soils. This type of editing was required in many places throughout the LOW, although the overall percentage of map area that had to be altered was less than 1% or 2%.

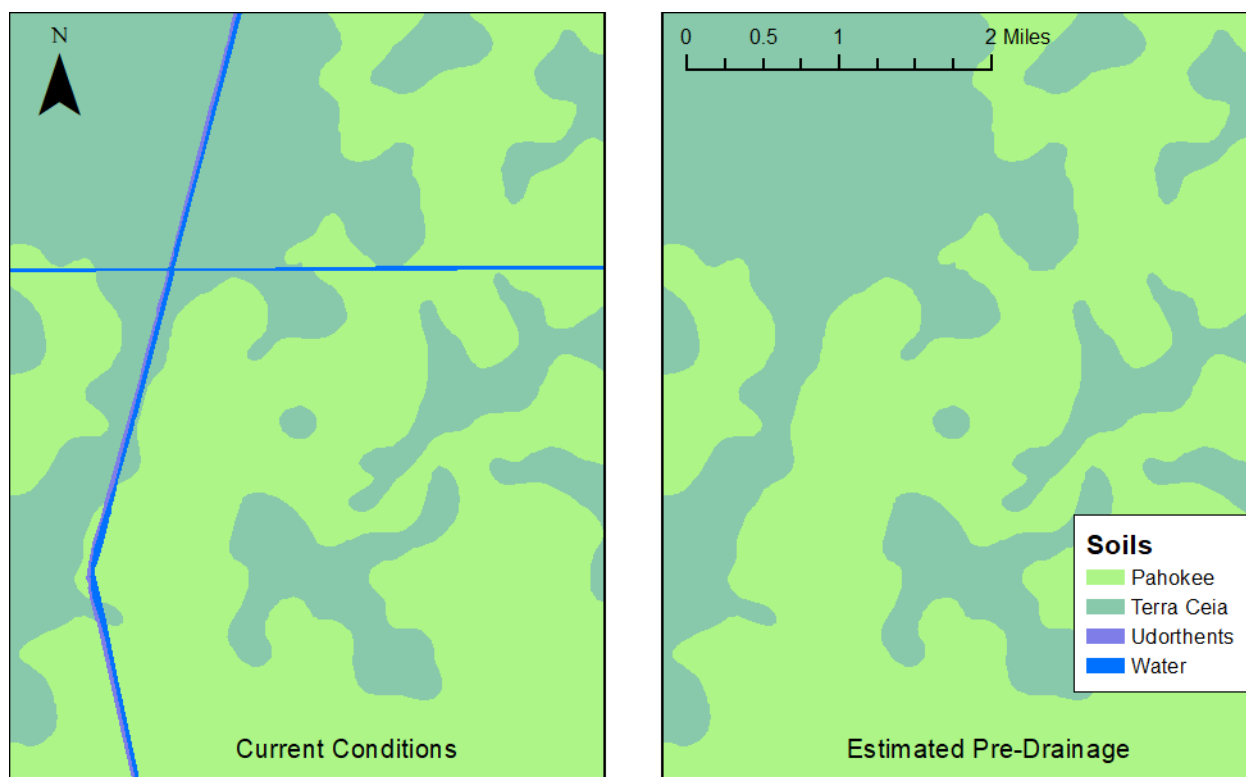


Figure 3. Comparison of soils feature class for current conditions (left) and pre-drainage (right) for a portion of the South sub-watershed.

The Florida Power & Light reservoir in the East sub-watershed was edited by examining the NRCS soil survey for Martin County (NRCS, 1981) which had aerial imagery of the county prior to construction of the reservoir. However, the soils map included in the report had the boundary of the reservoir delimited with no soils information provided within the reservoir. The imagery was loaded into ArcMap and the soils feature class was modified based on comparison of the imagery and the soil types surrounding the reservoir.

The final modified soils feature class used in the pre-drainage simulations is shown in **Figures 4 and 5**. The soils dataset was then clipped to each model domain and used as the WAM soils feature class as well as forming the basis for determining the pre-drainage land cover, discussed next.

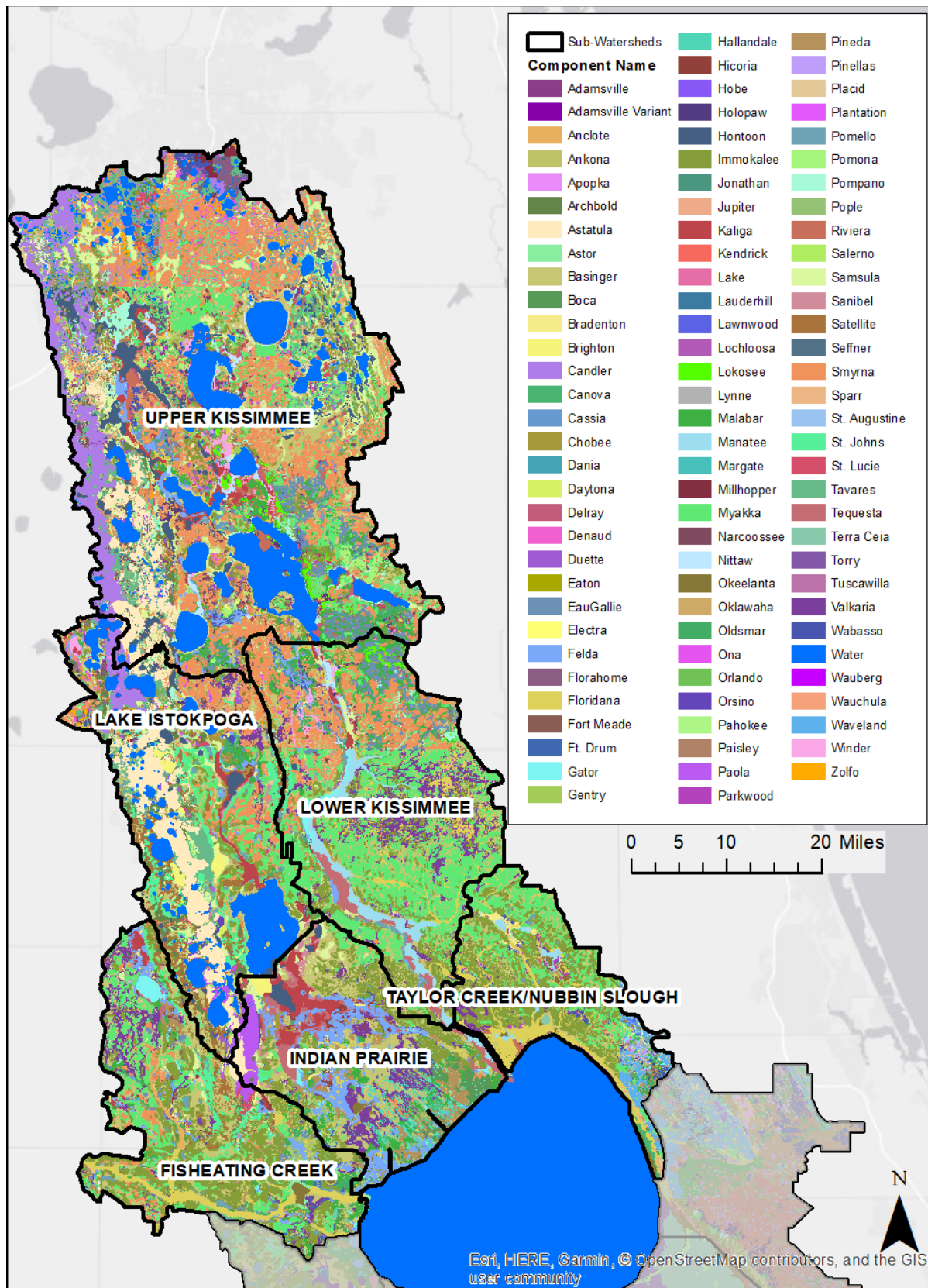


Figure 4. Soils used for the pre-drainage simulations in the six northern sub-watersheds.

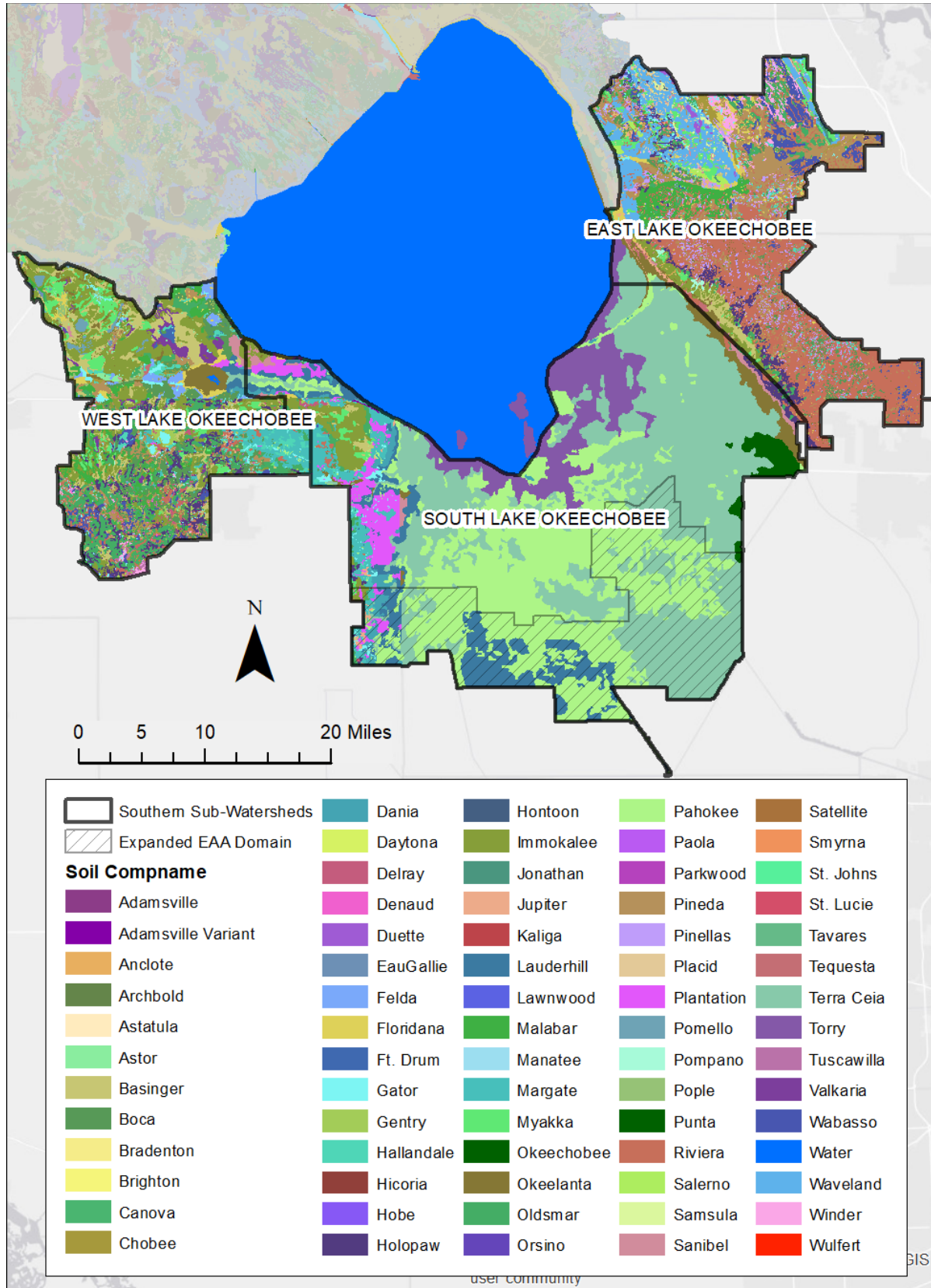


Figure 5. Soils used for the pre-drainage simulations in the three southern sub-watersheds.

2.1.2 Creation of Pre-drainage Land Cover

WAM requires a land use dataset to spatially assign land use and land cover properties in combination with soil properties and rainfall zones. The land cover of over 1,458,000 acres of the study area has been extensively altered due to anthropogenic activities. Excluding lakes, this accounts for approximately two-thirds of the watershed. To develop an appropriate land use/cover dataset to simulate pre-drainage conditions, it was necessary to estimate the native land cover based on available information. The 2011 study to assess pre-drainage conditions in the FEC sub-watershed (HDR 2011) produced an estimated land cover dataset based on soils data and used descriptions of soils series (maintained by the NRCS) that also include native vegetation. Those descriptions were converted to codes using FLUCCS codes. Starting in 2012 this approach was extended by SWET to assess pre-drainage conditions throughout the remaining five northern sub-watersheds of the LOW. The methodology describing this approach was compiled into the HDR (2015) study. The 2015 study also contains an extensive literature review pertaining to the development of the pre-drainage land cover for the northern basin (a summary of that literature review is provided in **Section 6 (Appendix B)**).

Zahina et al. (2007) produced a pre-drainage landscape database (PDL) for the LOW sub-watersheds. They started with the creation of a geospatial database of pre-development vegetation within the boundaries of the SFWMD, which includes the LOW. A vegetation classification scheme was developed to define major natural community types that would also meet anticipated data requirements of hydrological models and restoration projects. The project area was divided into sub-regions having unique or similar vegetation patterns and a map of historic vegetation was created for each sub-region based on available pre-development vegetation map sources. Vegetation communities and descriptions in the map were converted to the vegetation community classes. Not all the SFWMD jurisdictional area was mapped using this approach, but where PDL data were available, they were factored into the 2015 assessment. For the current task, data from the PDL were used to guide the setup of the pre-drainage soil and land cover layer in WAM. The spatial coverage of the PDL includes the three sub-watersheds not covered by the 2015 work (**Figure 6**). Lastly, McVoy et al. (2011) produced a detailed study that examines many aspects of the pre-drainage state of the Everglades, from Lake Okeechobee south to Florida Bay. Much of the data used to examine pre-drainage vegetation relied on the work of Zahina et al. (2007), but it contained significant information pertaining to vegetation in the southern sub-watershed and data from that report are incorporated here.

The pre-drainage land use/cover dataset created for the current project is based on the modified soils dataset discussed above in **Section 2.1.1** (steps 1 and 2 below) but also drew on the data sources outlined above for additional details. The detailed methodology used to produce the native land cover for the nine sub-watersheds is presented below.

1. Research and assign native FLUCCS codes to NRCS soil series as part of developing the soils dataset. Develop a NRCS-FLUCCS lookup table from this.
2. Create base native land use/cover coverage by joining the NRCS-FLUCCS lookup table (**Table 23**) to NRCS coverage using MUNAME field.
3. Assign FLUCCS codes to any vegetation codes used in the PDL coverage (Zahina et al. 2007) that were not previously assigned as part of the 2015 work (**Table 24**).
4. Perform a spatial union of the modified soils dataset with the PDL feature class to obtain a feature class with both NRCS-based FLUCCS codes and PDL-based codes.

-
5. Replace all NRCS-based FLUCCS codes for water (5100) with PDL-based codes if the PDL code was not also water, and if it was available. This served to change any remaining anthropogenic water features to native land covers.
 6. Replace all non-native soils that remained in the modified soils feature class with PDL-based FLUCCS codes where available. This included "Arents," "Pits," "Quartzipsamments," "Udifuvents," and "Udorthents."
 7. Replace NRCS-based FLUCCS codes that correspond to anthropogenic features underlain with native soils with PDL-based codes. This corresponded to much of the Lower Kissimmee River floodplain.
 8. Examine and remove any remaining anthropogenically created water or other features such as levees.

The overall approach was to first determine if a FLUCCS code could be assigned to the features in the modified soil feature class based on NRCS information, otherwise the PDL-based FLUCCS codes were used based on the spatial location of the feature within the PDL dataset. This approach gave a greater amount of detail in the estimated land cover assigned, in contrast with simply using the PDL feature class where available. Use of the PDL data exclusively in the areas it covered led to a very pronounced change in estimated land cover types across the transition where the PDL data did not exist, such as the upper part of the LOW.

The pre-drainage feature class was then carefully examined, and a number of features were manually edited with several anthropogenic features identified and revised. For example, around the southern perimeter of Lake Okeechobee, any polygon that has PDL-based FLUCCS of 5100 (water) had the FLUCCS code set to 5100, irrespective of the NRCS-based value. The area of Lake Hicpochee to the southwest of Lake Okeechobee shown by Zahina et al. (2007) was also changed to 5100 based on PDL data. Several small features where no code could be determined were merged with an adjacent polygon. Around the southern end of Lake Okeechobee, "Urban Land" (NRCS-based FLUCCS 4110) had the FLUCCS code changed to 6173 ("Misc. Wetland Hardwoods," note that 6173a is "Pond Apple"). Other land covers that had NRCS-based codes of 6110 ("Bay Swamps") with soil types of either "Udorthents, 2 to 35 percent slopes" or "Arents-Urban land complex, organic substratum" were changed to use the FLUCCS code 6172 ("Mixed wetland hardwoods"). Some small linear features extending into the sawgrass plain south of Lake Okeechobee that had NRCS-based codes of either 6110 or 6173 were changed to 6411 ("Freshwater marshes - sawgrass"). Some small features on the southeast side of Lake Okeechobee were reclassified to FLUCCS codes of 6173 if they were water or otherwise incorrect. Lastly, some small features in the sawgrass plain (6411) that were on "Urban" land were changed to 6411.

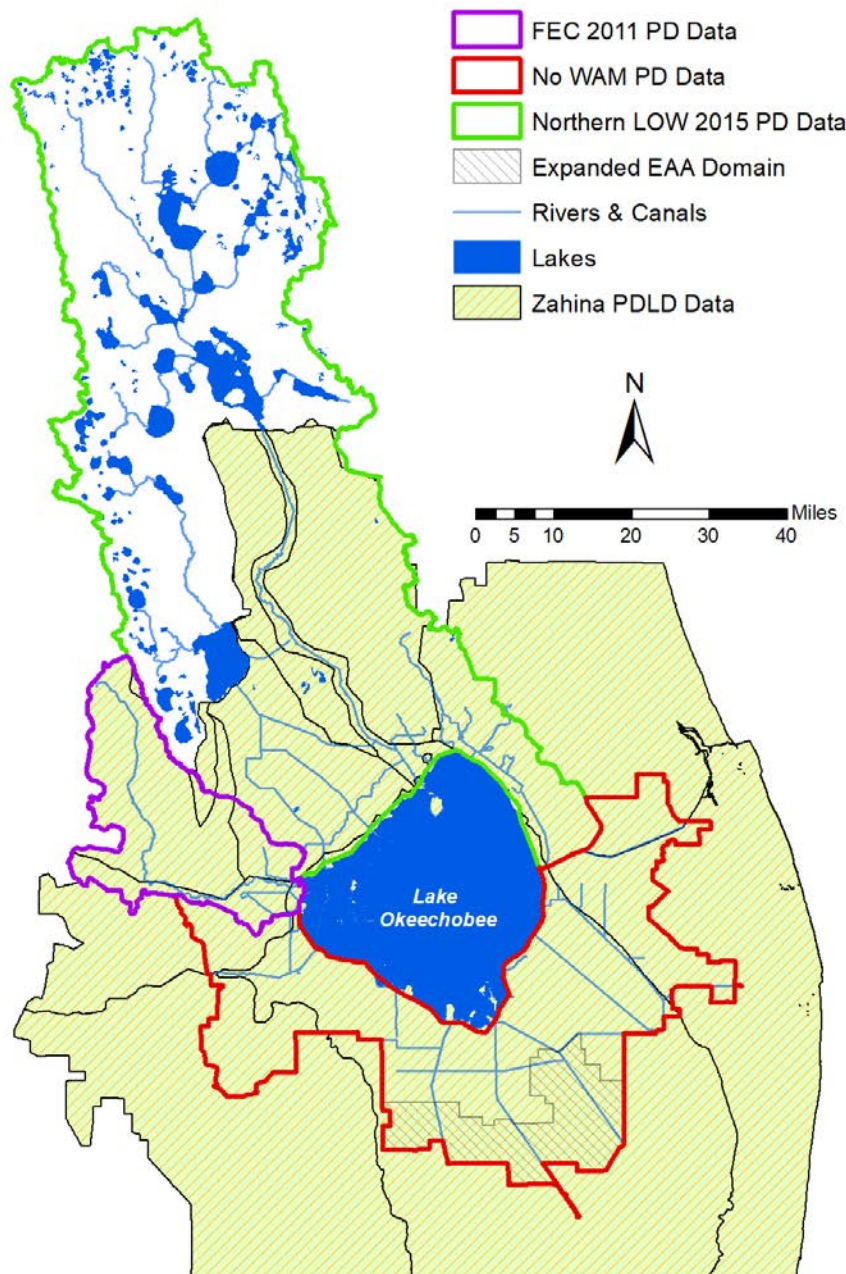


Figure 6. The hatching pattern indicates the area covered by PDL data created by Zahina et al. (2007). The red line denotes the boundary of the sub-watersheds that require the creation of a land cover dataset.

Soil descriptions and the lookup table created to assign FLUCCS codes to soil mapunit can be found from **Appendix B, Section 6**, which were originally developed for the 2011 and 2015 pre-drainage studies and have been modified using the steps outlined above. These include native land cover descriptions of the NRCS soil series and the PDL vegetation codes, respectively, for all the sub-watersheds. The soil series in Appendix B is represented by the column name COMPNAME (Component Name), which may contain several actual soil types. Both tables include the FLUCCS codes that were assigned based on the

vegetation descriptions and a “best match” obtained from the “Florida Land Use, Cover and Forms Classification System” handbook (Florida Department of Transportation 1999).

The lookup table between the NRCS MUNAME and the best estimated FLUCCS code for that soil unit is also included in Appendix B. This table was joined in ArcMap to the modified soils feature class and the FLUCCS code was copied to a new field. The resulting feature class was saved as a new feature class that became the basis for the pre-drainage land use/cover feature class (Step 2, above). This lookup table includes a spatial compilation of the NRCS and PDL D FLUCCS code assignments in the northern sub-watersheds where both datasets overlapped. The PDL D information was spatially distributed using the NRCS soils polygons. However, there is not a one-to-one relationship of vegetation codes to soil types. For comparison purposes, the majority vegetation code was determined for each soil type (MUNAME).

Application of the methodology for determining pre-drainage land cover resulted in the acreages shown in **Table 2**. The first four land uses shown in the table are run either under GLEAMS or EAAMod, depending on the soil type. GLEAMS is used to simulate water and nutrient loading on well-drained soils such as Astatula and Paola series, while EAAMod is used for source cells underlain with soils that are relatively poorly drained such as Immokalee and Myakka series. The remaining six are run under the Special Case land source model. The estimated land cover acreages for the six northern sub-watersheds can be compared with Table 2 in the 2017 recalibration report (SWET 2017a). Note that the FEC sub-watershed is 547 acres larger than in the 2017 report, due to a change of the sub-watershed boundary. The updated total reflects this.

Table 2. Pre-drainage land cover acreages for the nine sub-watersheds.

WAM Land Cover	UK	LK	LI	IP	FEC	TC/NS	East SW	West SW	South SW
Pine Palmetto Flatwoods	421,914 (41%)	244,546 (57%)	142,640 (36%)	72,538 (26%)	156,296 (49%)	106,446 (54%)	41,585 (17%)	95,655 (47%)	14,929 (3%)
Hardwoods	63,852 (6%)	231 (0%)	10,309 (3%)	7,107 (3%)	7,635 (2%)	2,320 (1%)		1,235 (1%)	
Hardwoods/Conifer mixed	98,901 (10%)	4,165 (1%)	67,374 (17%)	2,510 (1%)	1,301 (0%)	16,733 (8%)	43,464 (18%)	13,925 (7%)	1,256 (0%)
Barren Land (shorelines)	25 (0%)		1,028 (0%)						
Open Water	129,716 (13%)	3,876 (1%)	55,803 (14%)	427 (0%)	37 (0%)	2,743 (1%)	575 (0%)	6,941 (3%)	13,875 (3%)
Bay Swamps	14 (0%)		3 (0%)		2 (0%)	11 (0%)			30 (0%)
Mixed Wetland Hardwoods	94,893 (9%)	90,935 (21%)	59,052 (15%)	113,147 (41%)	85,187 (27%)	27,548 (14%)	32,786 (14%)	28,247 (14%)	1,371 (0%)
Cypress	2,705 (0%)	373 (0%)	33 (0%)			2 (0%)	2,536 (1%)	684 (0%)	46 (0%)
Wetland Forested Mixed	61,510 (6%)	2,636 (1%)	17,682 (4%)	6,677 (2%)	2,590 (1%)	2,804 (1%)	79,192 (33%)	3,422 (2%)	40,639 (8%)
Freshwater Marshes	154,896 (15%)	82,412 (19%)	40,234 (10%)	74,004 (27%)	64,996 (20%)	39,113 (20%)	38,876 (16%)	53,986 (26%)	468,308 (87%)
Total	1,028,426	429,174	394,158	276,410	318,044	197,720	239,014	204,095	540,454

An example of the application of the methodology for determining pre-drainage land cover to a part of the Upper Kissimmee sub-watershed is shown in **Figure 7**. This figure is a portion of the sub-watershed immediately south-east of Kissimmee with the left pane showing the current conditions land use and the right pane showing the pre-drainage land use/cover after following the steps listed above to create the estimated land cover. In the left pane, the Florida Turnpike is the gray line running diagonally from the upper left to the lower right. Lakes Tohopekaliga and Gentry are labeled. The urban (symbolized by various red and gray shades) and agricultural land uses (greens) were modified based on the underlying soil types. Note that the PDL did not extend to this part of the LOW. The features that typically required hand editing are the narrow canals between lakes (two of which are indicated with red arrows) and the removal of myriad small water features associated with urban and agricultural land uses, e.g., retention ponds. Many of these can be seen in the areas labeled “Medium Density Residential” (bright red) east of the turnpike. Removal of the canal features from the dataset required using ArcMap editor tools to cut the water (and associated spoil pile features) and assign the FLUCCS code based on the closest adjacent feature. Small water features were also assigned the FLUCCS code of the nearest adjacent feature as well. In any areas where roads were underlain by soils categorized as non-native were treated the same. At the completion of the editing a geoprocessing dissolve operation was run on the feature class to merge features that had the same FLUCCS attribute. This substantially reduced the number of features to make working with the feature class in ArcMap more efficient.

The land cover distributions for the six northern and three southern sub-watersheds are shown in **Figures 8 and 9**, respectively. Note that the area designated as “custard apple” on the southern shore of Lake Okeechobee is included under the “wetland forested mixed” land use category for modeling purposes.

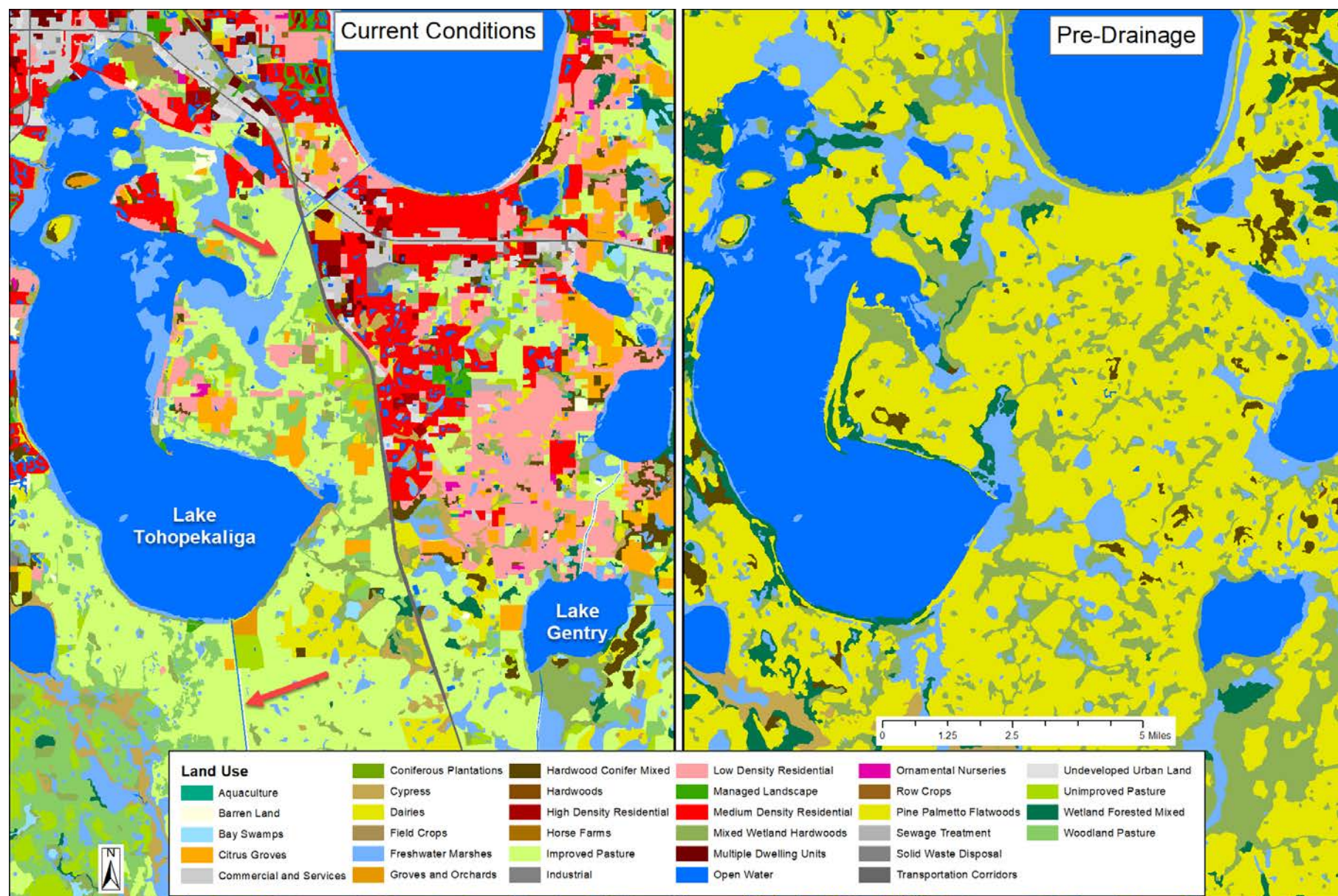


Figure 7. Comparison between Upper Kissimmee current conditions (left) and the modified pre-drainage land use (right).

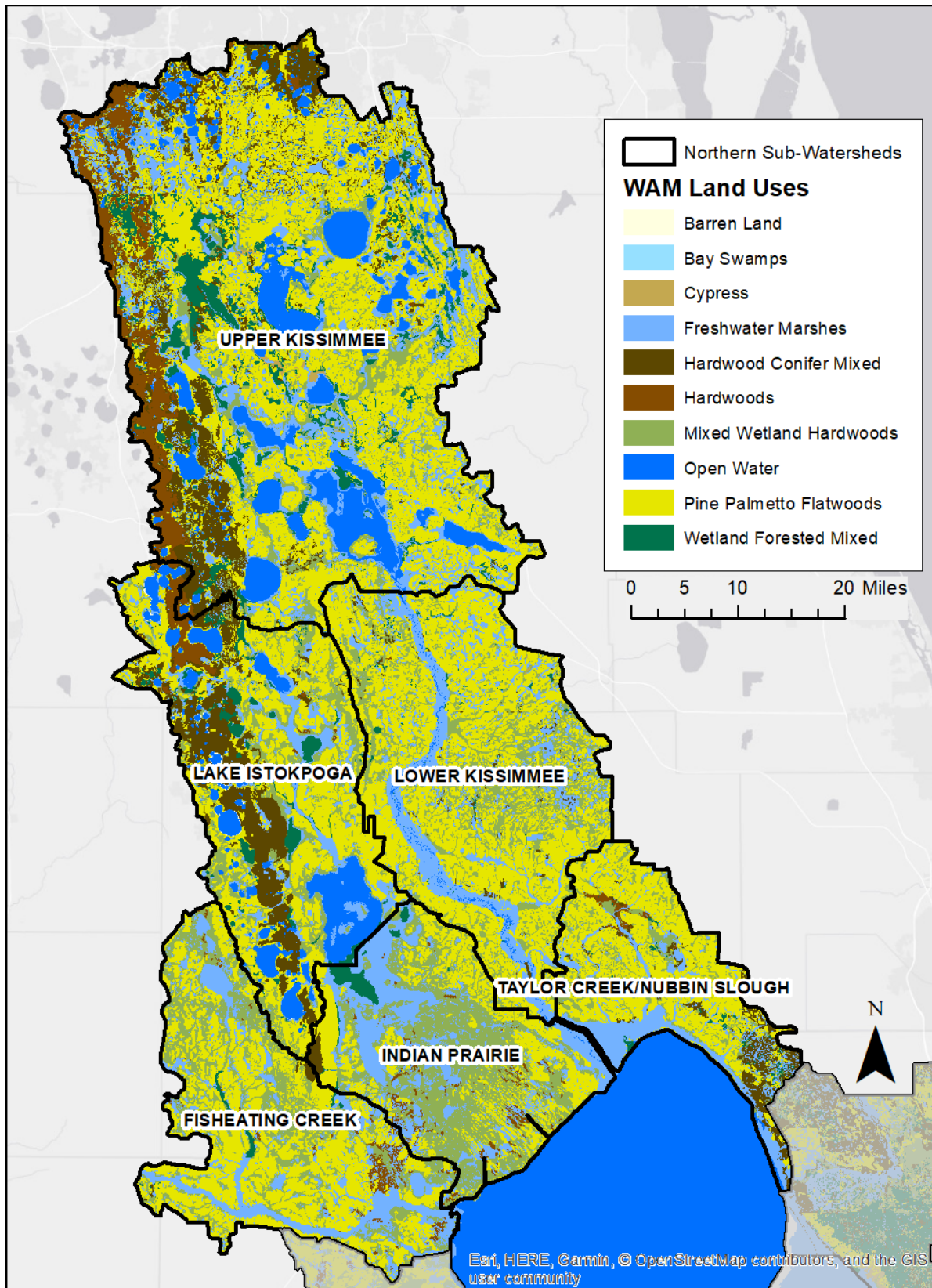


Figure 8. Estimated pre-drainage land cover in the six northern sub-watersheds.

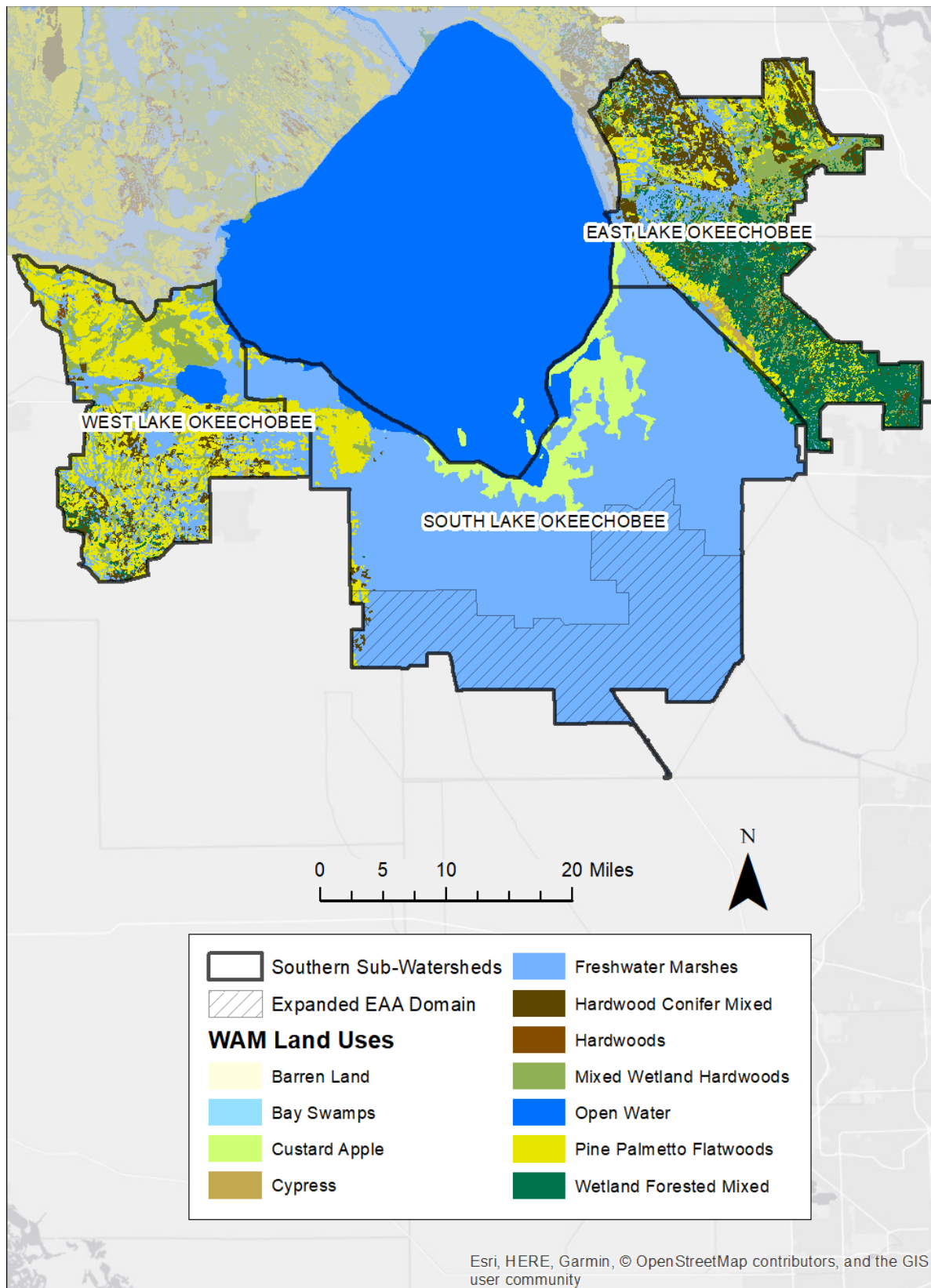


Figure 9. Estimated pre-drainage land cover in the three southern sub-watersheds.

2.1.3 Pre-drainage Hydrologic Reach Delineation

Development of a hydrologic reach network was begun during the 2015 study (HDR 2015) to represent historical, pre-anthropogenic flow conditions within the northern sub-watersheds in the LOW. The primary resources for delineating pre-drainage reaches for that work were high resolution aerial imagery from the 1940s, topography, soils dataset, and information from the literature review conducted for that study. The methodology used is described in detail in the 2015 report (HDR 2015). However, the reach network developed during the 2015 work required extensive editing to incorporate it in WAM.

The majority of reaches in the sub-watersheds were categorized as either sloughs or streams. For the most part, the designation “stream” was assigned to those reaches that could be identified as having a well-defined continuous channel in early imagery, while the “slough” designation was assigned to drainages most other places. While the distinction between these types within WAM is largely arbitrary, attenuation coefficients are assigned based on the reach type, and streams typically have lower attenuation rate coefficients (the parameter “ a ”) but not necessarily different background coefficients (“ C_b ”). Note that attenuation coefficients can vary between different scenarios, and a new reach subtype can be created with different sets of attenuation coefficients if needed. The reach types also vary in the initial value of the Manning’s roughness coefficient assigned to each reach, as well as the general shape of the cross-sectional profile. In all cases the initial cross-sectional profile assigned to a reach is a function of the upstream drainage area. Both the roughness coefficient and the profile can be altered on a reach-by-reach basis. For the pre-drainage hydrology, the profiles assigned to sloughs are flatter and wider than streams, unless manually altered afterwards. In some cases where a channel was not apparent in the imagery, individual slough segments were assigned very broad profiles up to several hundred meters wide.

Other reach types present in the pre-drainage scenarios are those used to represent lakes and shorelines. Lake reaches are used where a large water feature in the land cover clearly lies within the reach network. The lake reaches are parametrized to ensure that the length and width of the reach matches the area represented by the lake. Shoreline reaches are added around lake features and are used as an accounting mechanism to determine the water and nutrient loading to the lake from the surrounding land. Shoreline reaches do not attenuate nutrients and have the evaporation coefficients set to zero. Lake and shoreline reaches are only used in the Lake Istokpoga and Upper Kissimmee sub-watersheds.

In each sub-watershed, additional work editing the network was required to ensure that all reaches were connected to an outflow point, and that reaches did not overlap; instead, each reach segment had to attach to other segments at an end point. Bottom elevations had to be established and verified, and cross-sectional profiles had to be created. The top of bank elevations were calculated by determining the average elevation within a 100-meter buffer along each reach using the topographic dataset (see **Section 2.1.4** below). Bottom elevations were determined subtracting the depth of the estimated profile from the top of bank elevations; these were verified by checking against the topographic dataset and neighboring reaches to ensure consistent values. Most of these steps could be done in ArcMap using the tools developed for setting up WAM scenarios, but additional manual editing was also required.

None of the earlier work by SWET included the development of pre-drainage hydrology in the East, South, or West sub-watersheds. In the East and West sub-watersheds, the steps outlined above were replicated to develop reasonable reach networks. In contrast, the pre-drainage South sub-watershed was a broad drainage area that had little to no discrete drainage features (e.g., streams). The works of McVoy et al.

(2011) and Said and Brown (2013) were very useful in developing the reach network for the three southern sub-watersheds.

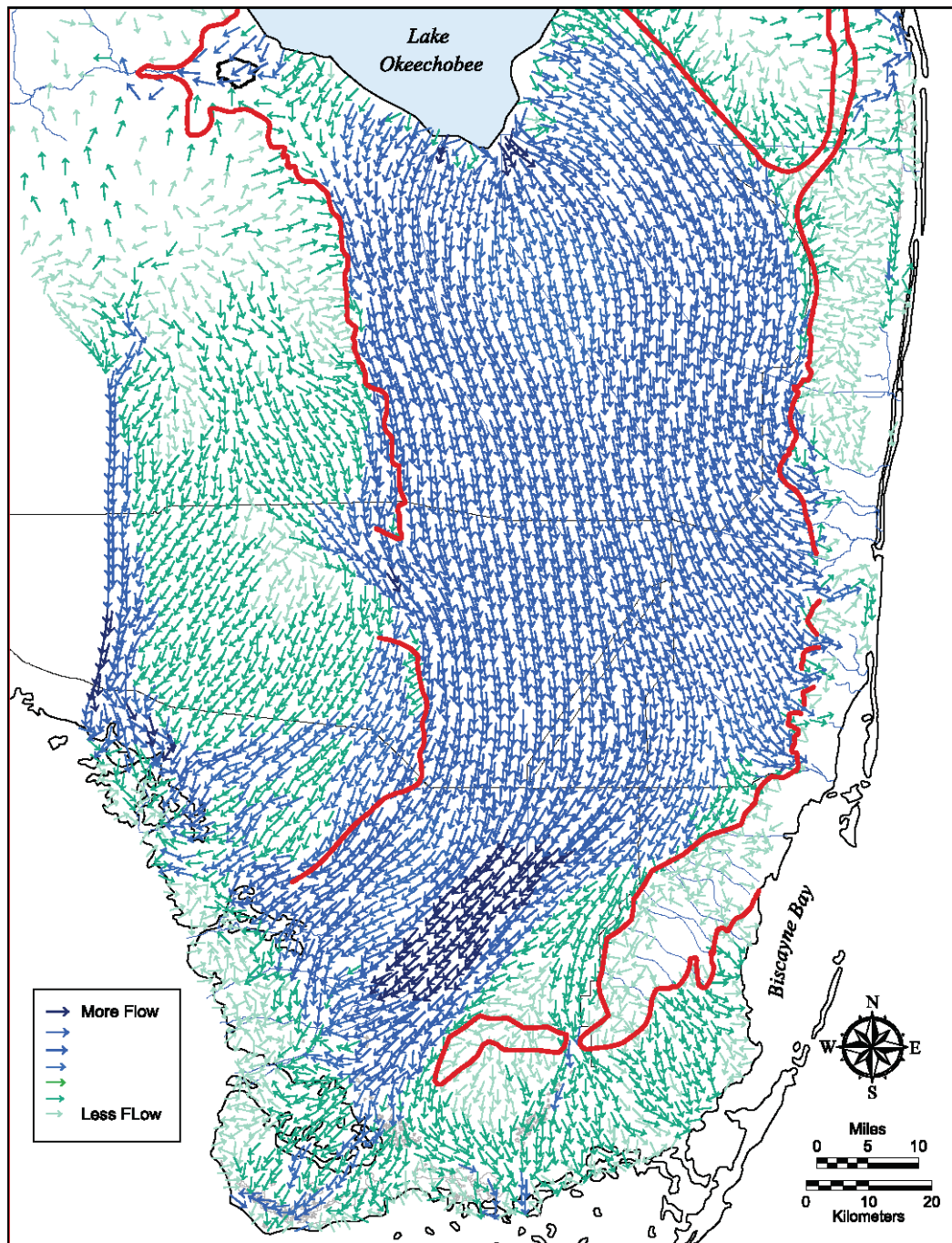


Figure 10. Hydrology of the Everglades: Pre-drainage surface water flows, ca. 1850s. Arrow size and color reflects flow magnitude. Selected post-drainage levees and roads shown for orientation. Red lines mark the pre-drainage boundary of the Everglades. Source: NSRSM v3.3 (Said and Brown 2010). From McVoy et al. 2011 (Plate 3a).

Plate 3a in McVoy et al. (2011) (**Figure 10**; see also Figure 95 in Said and Brown 2013) presents simulated long-term average of monthly flow vectors for dry and wet seasons. These show the widespread parallel shallow flow across the sawgrass plains immediately south of Lake Okeechobee,

which corresponds to the current South sub-watershed. Additionally, the vector directions were used to guide the placement of sloughs in the three sub-watersheds. Said and Brown (2013) also include a number of figures that show the pre-drainage Caloosahatchee River and some of its tributaries which assisted in the placement of these reaches. Additionally, Said and Brown (2013) include (their Figure 19) the military map of Ives from 1856 which also shows some small tributaries of the Caloosahatchee River. McVoy et al. (2011) describe the drainage south from Lake Okeechobee and west to the Okeechobee Marsh in great detail. A composite map of the Okeechobee Marsh west of Lake Okeechobee also assisted in developing the reach network in the West sub-watershed.

The reaches in the West sub-watershed WAM setup were added as sloughs, with Lake Hicpochee simulated as a lake reach. The reaches forming the eastern end of the Caloosahatchee River drainage are modeled as very wide channels, with little variation in the elevations of the segments from Lake Okeechobee westward until about the middle of the model domain.

The reaches in the East sub-watershed were also added as very broad sloughs. Except for a few areas along the eastern boundary, these drain either back into Lake Okeechobee or into the eastern edge of the sawgrass plain, i.e., into the South sub-watershed.

The South sub-watershed is simulated as a set of very wide, shallow sloughs to mimic the wide swath of drainage across the sawgrass plains. Note that the southern boundary of the sub-watershed is considerably north of where the ridge-and-slough landscape characteristic of the Everglades begin.

The pre-drainage reach networks used in the WAM simulations are shown for the northern and southern sub-watersheds in **Figures 11** and **12**, respectively. In Section 3, the drainage network for each sub-watershed is shown with reach numbers indicated. The numbering system for reaches is generated during the construction of the stream network using the WAM toolbar with the reaches numbered consecutively from each outfall point up through the drainage network. Numbering can be altered by the user if desired.

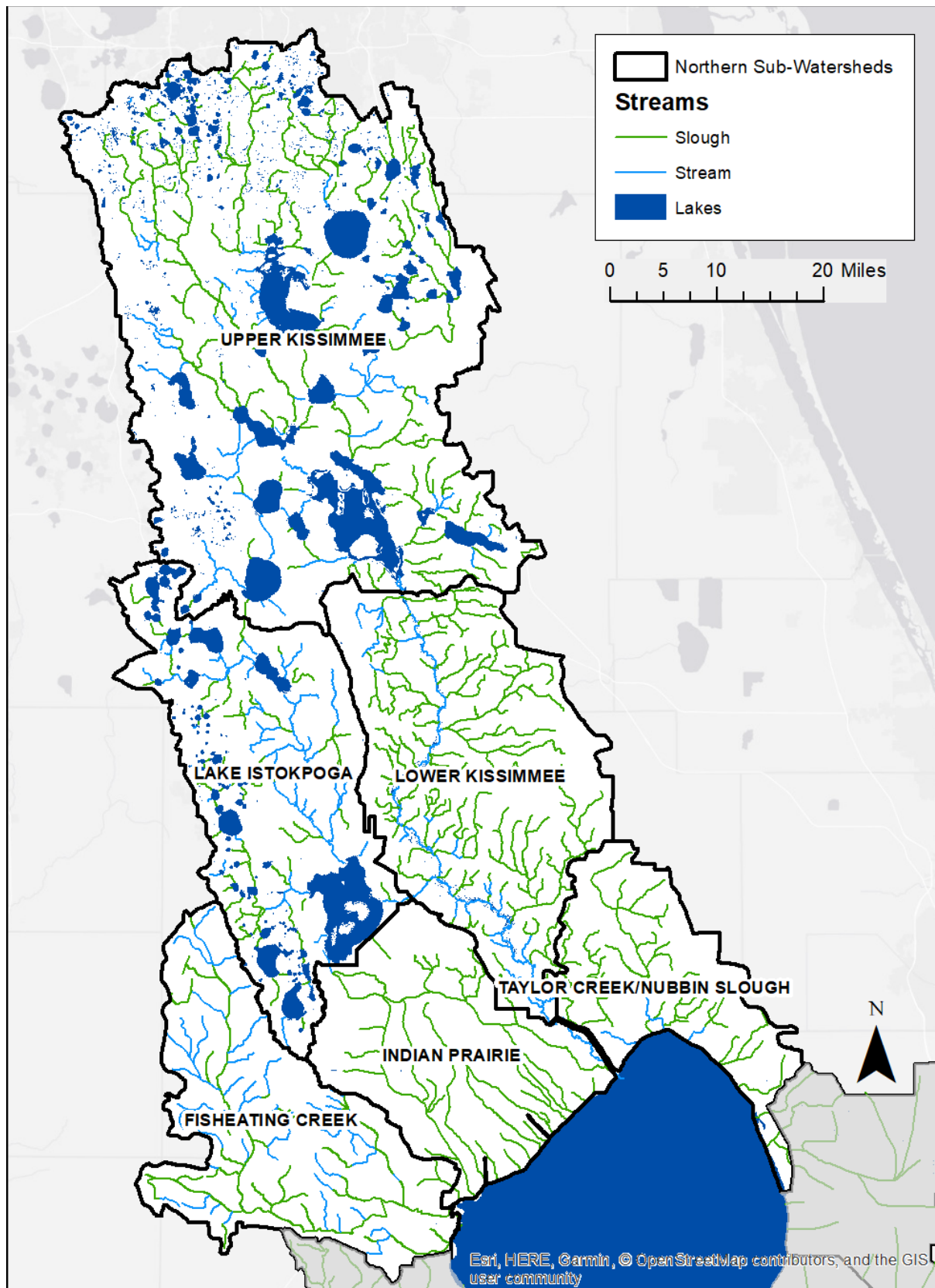


Figure 11. Pre-drainage reach network in the northern sub-watersheds.

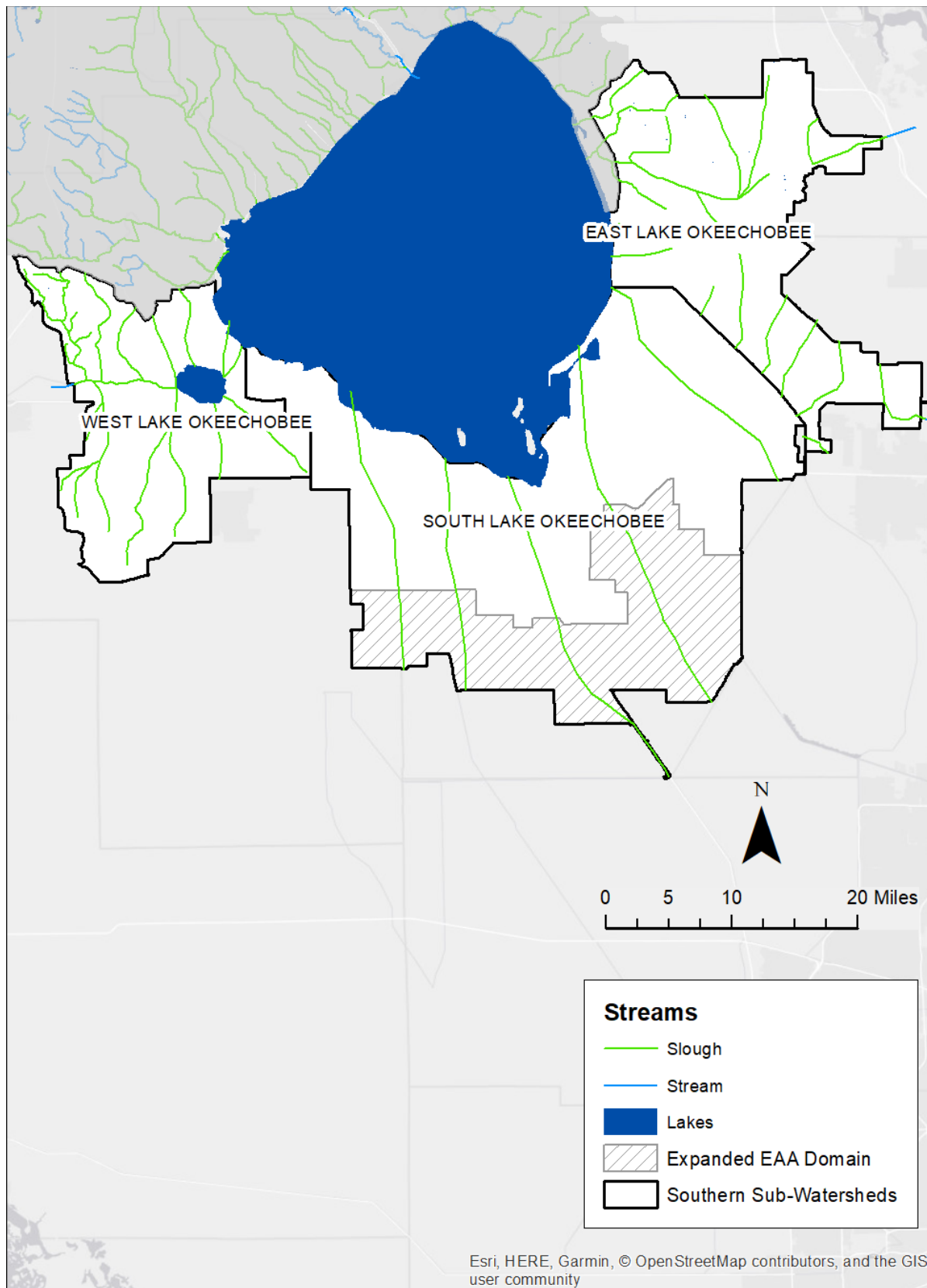


Figure 12. Pre-drainage reach network in the southern sub-watersheds.

2.1.4 *Modification of Topography*

The changes to the LOW from agriculture and urbanization have significantly changed the topography of the area. One major alteration to the topography has been subsidence within the EAA, which results in surface elevations several feet below pre-drainage conditions. Said and Brown (2013) present raster maps of topographic elevations used by the NSRSM (their Figure 13). The topographic dataset used in that study was obtained from the SFWMD and used in this current modeling effort. Because it did not cover the northern portions of the LOW, data from the existing topographic dataset were used to fill in elevation values for those areas not covered by the NSRSM raster (**Figure 13**). The existing topographic dataset used for the 2017 WAM simulations was provided by the SFWMD (2014). The primary use of the topographic data set in WAM is to determine overland flow directions, which are calculated on a one-hectare grid size, which is considerably coarser than the grid size of the provided datasets (which have 100 × 100-foot cells). During the WAM setup, the raster is resampled and then aggregated up to a one-hectare cell size. Consequently, the elevation used for each cell in the WAM simulations is an average of over 10 cells, which serves to smooth out any anthropogenic features that cannot otherwise be edited out.

2.1.5 *Estimates of Nitrogen and Phosphorus Concentrations in Runoff from Pristine Land Cover*

Studies pertaining to nitrogen (N) and phosphorus (P) concentrations in Florida under pristine conditions are somewhat limited. There are two general categories of data that were useful for the current study: 1) nutrient concentrations in runoff from various types of land cover and vegetation, and 2) concentrations in receiving waterbodies i.e., lakes and streams. When simulating pre-drainage conditions using WAM, data from the first category are used to set bounds of nutrient concentrations generated at the source cell level by the BUCShell sub-model, but before overland and in-stream attenuation occurs in the WAM sub-model BLASRoute. See **Appendix A (Section 5.1)** for a detailed description of this process. Data from the second category are used to guide the estimation of overland and in-stream attenuation parameters.

2.1.5.1 *Nutrient Concentrations in Source Cell Runoff*

Studies estimating nutrient concentrations in runoff at the source cell level typically give data for very general land cover and vegetation types, e.g., “wetlands,” “woods,” etc. For the 2011 and 2015 studies, N and P concentrations and associated nutrient loads were developed for more specific pristine land cover and vegetative types, such as upland forest and wetlands. To accomplish this, SWET staff met with wetland experts (Mark Brown, University of Florida and Bob Knight, Florida Springs Institute) to develop nutrient concentration estimates for all native vegetative conditions based on their professional judgement. These estimates represent mean concentrations because there was no way to fully represent the temporal variability that can exist seasonally and during different flow events. The final calibrated pre-development N and P concentrations and loads for FEC were reviewed by environmental stakeholders, including Paul Grey (Audubon Society) and Hilary Swain (Archbold Biological Station), who agreed the predicted values were reasonable, but possibly a little high, based on their knowledges of native systems in South Florida.

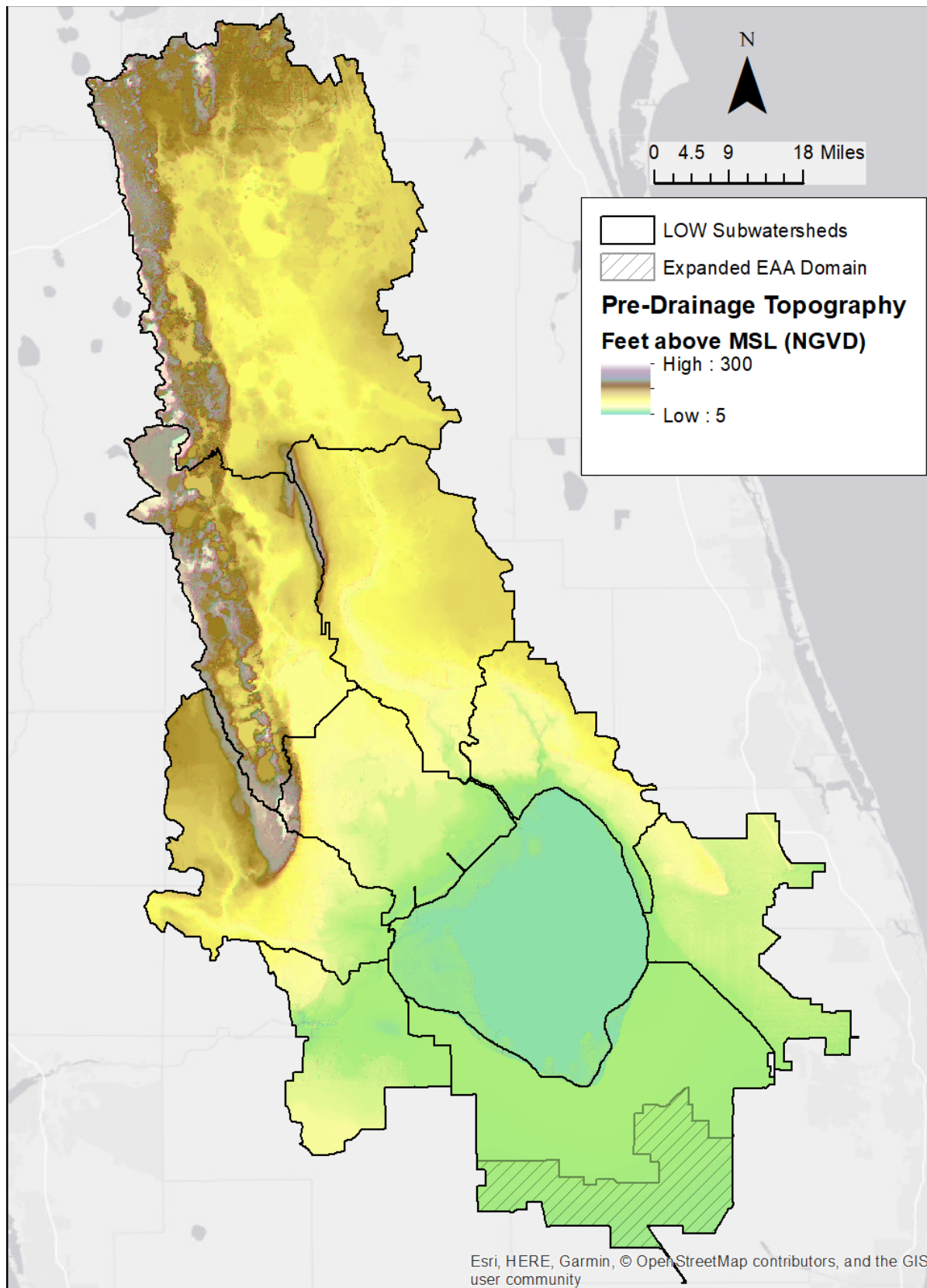


Figure 13. Pre-drainage Topography used in the WAM simulations.

Reiss et al. (2009) summarized a database of environmental parameters for isolated wetlands in Florida. This included a comprehensive literature review of the hydrology and nutrient chemistry of wetlands in Florida. Specific attention was given to a literature review of measured N and P concentrations in wetlands, both in the water column and in the soils. Most relevant to this modeling effort, Reiss et al. classified the data collected as from “non-impacted wetlands,” which have had minimal impact from human disturbance, or from wetlands that had been impacted by human activity, e.g., wetlands that have been completely surrounded by urban and/or agricultural land uses. The literature review included data from throughout Florida, with about 50% pertaining to south and central Florida.

Reiss et al. (2009) grouped wetlands into four broad types by two categories, vegetation and hydrogeomorphology. The two vegetation types are forested and emergent, with forested wetlands characterized by woody species that are at least 20 feet (6 meters) tall or taller (FLUCCS codes 610, 620, and 630). Emergent wetlands (marshes) are comprised of rooted herbaceous aquatic vegetation (FLUCCS codes 641). The hydrogeomorphic categories used by Reiss et al. are divided into depressional and basin wetlands. Depressional wetlands often occur in relatively small watersheds and are dependent on precipitation. Basin wetlands were characterized in the study as larger wetland systems often with a seasonal or semi-permanent surface hydrologic connection to other wetlands or aquatic bodies.

Tables 3 and 4 (Tables 2, 3, and 6 in Reiss et al. 2009) show ranges of N and P concentrations for the four categories listed above. The forms of nitrogen listed are nitrate (NO_3), ammonia (NH_3), total Kjeldahl nitrogen (TKN), and TN. The forms of P listed are orthophosphate (Ortho-P), soluble reactive P (SRP), Organic P and TP. The columns headed by “#” indicate the number of entries used to calculate the maximum and minimum values, i.e., there were 79 measurements found for nitrate concentrations in depressional forested wetlands. **Table 5** gives the quartiles of concentrations for three of the categories, disregarding “basin forested” because of the lack of data points. Most of the cited measurements originated from the two types of depressional wetlands (although very few report TN), with relatively few from basin wetlands. In many cases the minimum values tend to be close to the detection limit, particularly for nitrate. Note that these include concentration data taken from across Florida since the data were not categorized by location.

Overall, these data suggest that the middle range (i.e., 50%) of TN concentrations is between 1.1 and 2.0 mg/L, with slightly higher values in depressional emergent environments relative to depressional forested environments. Reasonable maximum and minimum values (excluding outliers) are from about 3.2 mg/L down to 0.5 mg/L. The middle range of TP concentrations is between 0.016 mg/L and 0.08 mg/L, with reasonable maximum and minimum values from 0.14 mg/L down to about 0.006 mg/L.

Table 3. Nitrogen concentrations for non-impacted wetlands (after Reiss et al. 2009).

Land Cover		NO_3 (mg N/L)	#	NH_3 (mg N/L)	#	TKN (mg N/L)	#	TN (mg N/L)	#
Depressional forested	<i>Min</i>	0.002	79	0.002	66	0.002	82	1.6	2
	<i>Max</i>	1.9		1.7		5.6		1.67	
Basin forested	<i>Min</i>	0.004	3	0.01	3	0.62	3	0.94	1
	<i>Max</i>	0.09		0.095		0.98			

Depressional emergent	<i>Min</i>	0.002	49	0.005	29	0.41	49	N.A.	0
	<i>Max</i>	0.047		2.6		6			
Basin emergent	<i>Min</i>	0.007	9	0.06	9	0.92	4	N.A.	0
	<i>Max</i>	0.117		1.2		1.77			

Table 4. Phosphorus concentrations for non-impacted wetlands (after Reiss et al. 2009).

Land Cover		Ortho-P (mg P/L)	#	SRP (mg P/L)	#	Organic P (mg P/L)	#	TP (mg P/L)	#
Depressional forested	<i>Min</i>	0.0008	7	Non-detect	1	0.02	2	0.002	82
	<i>Max</i>	0.48				0.12		0.64	
Basin forested	<i>Min</i>	0.003	2	N.A.	0	0.01	1	0.009	3
	<i>Max</i>	0.006						0.01	
Depressional emergent	<i>Min</i>	N.A.	0	N.A.	0	N.A.	0	0.0069	49
	<i>Max</i>							0.12	
Basin emergent	<i>Min</i>	0.002	8	N.A.	0	N.A.	0	0.007	5
	<i>Max</i>	0.035						0.08	

Table 5. Quartiles of nutrient concentrations from non-impacted wetlands.

	Depressional Forested	Depressional Emergent	Basin Emergent
Nitrate-N (mg N/L)			
25th Percentile	0.002	0.002	0.011
Median	0.005	0.006	0.024
75th Percentile	0.02	0.01	0.038
Ammonia -N (mg N/L)			
25th Percentile	0.018	0.016	0.111
Median	0.024	0.02	0.16
75th Percentile	0.05	0.033	0.23
TKN (mg N/L)			
25th Percentile	1.085	1.123	0.96
Median	1.45	1.694	1.1
75th Percentile	2	2.2	1.608
TP (mg P/L)			
25th Percentile	0.027	0.016	0.009
Median	0.044	0.026	0.012

	Depressional Forested	Depressional Emergent	Basin Emergent
75th Percentile	0.085	0.041	0.047

Several other literature sources were examined as well and are summarized in **Table 6**. Frink (1991) reviewed estimates of nutrient exports from a variety of land use categories in the northeast United States and compared those estimates to calculated nutrient exports to 33 lakes in Connecticut. Overall, Frink (1991) found a wide range of loads from woodlands across the northeast, with TN loads ranging from about 0.2 to 10 lbs/ac/y and TP loads ranging from 0.01 to 0.8 lbs/ac/y. With typical runoff of about 7 in/y these would result in concentrations of TN from 0.1 to 6.3 mg/L and TP from 0.006 to 0.5 mg/L. Note that these estimates do not distinguish between pristine and impacted land uses.

Donigian (2002) presented results from the application of the HSPF model in the state of Connecticut to determine nutrient loadings to Long Island Sound (the Connecticut Watershed Model, or CTWM). The loadings were broken down by land use, with “Forest” and “Wetland” being the two natural land uses studied (in addition to non-native urban and agricultural). As with Frink (1991), Donigian (2002) did not distinguish between pristine and impacted natural land uses. Donigian (2002) used Frink’s export coefficients in calculating nutrient loads. Calculated TN loads ranged between 1.4 and 3.5 lbs/ac/y for wetlands and 1.4 and 4.3 lbs/ac/y for forests, with wetlands and forests producing 5 and 10 in/y runoff, respectively. The corresponding concentrations range from 1.2 to 3.1 mg/L for wetlands and 0.62 to 1.9 mg/L for forests. Calculated TP loads were between 0.02 and 0.05 lbs/ac/y for wetlands, corresponding to concentrations of 0.018-0.044 mg/L, and 0.03 and 0.08 lbs/ac/y for forests, corresponding to 0.013 and 0.035 mg/L TP concentrations.

Gray (2002) gives values of nutrient loading and concentrations from pristine wetlands in the LOW of 0.63-2.7 lbs/ac/y (corresponding to 0.4-1.7 mg/L) for TN and 0.01-0.1 lbs/ac/y (0.005-0.066 mg/L) TP.

Table 6. Summary of nutrient loads and concentrations for various land covers.

Land Cover		Flow	TP		TN	
		in/y	Load lbs/ac/y	Conc mg/L	Load lbs/ac/y	Conc mg/L
Frink (1991)						
Woods	<i>Min</i>	7	0.01	0.006	0.2	0.1
	<i>Max</i>	7	0.8	0.5	10	6.3
Donigian (2002)						
Wetlands	<i>Min</i>	5	0.02	0.018	1.4	1.2
	<i>Max</i>	5	0.05	0.044	3.5	3.1
Forests	<i>Min</i>	10	0.03	0.013	1.4	0.62
	<i>Max</i>	10	0.08	0.035	4.3	1.90
Gray (2002)						

Land Cover		Flow	TP		TN	
Pristine Wetlands	Min	7	0.01	0.005	0.63	0.4
	Max	7	0.10	0.066	2.70	1.7

Nutrient Speciation

Data for the speciation of TN and TP, i.e., concentrations of ammonia, nitrate/nitrite, soluble organic N, and particulate N for TN, and soluble/dissolved and particulate P for phosphorus are very limited for pristine conditions. As shown in **Tables 3 and 4** Reiss et al. (2009) found the speciation of TN and TP was highly variable and the way these data were presented does not lend itself to establishing average percentages of the N and P species. Kadlec and Knight (1996) indicated that for two Florida wetlands the speciation of TN was nitrate-N ~7%, ammonia-N ~10%, and TKN ~75%, and for TP dissolved P ~55% and particulate 45%. Unfortunately, these data were based on only a few samples and lacked information on soluble organic forms of N and P.

Therefore, it was felt that a more reasonable approach for defining the relative speciation of the nutrients would be to look at representative data within the Okeechobee watershed that has speciation data. It was found that a few reference sites suggested by FDEP that are located in fairly pristine wetlands along the Kissimmee River did have N and P speciation data collected back in the 1970s and 1980s. It was decided to use these sites along with Fisheating Creek (FEC), which is one of the lesser developed sub-watersheds, to develop reasonable estimates of the N and P species for native conditions. **Figures 14 and 15** show the total dissolved P and ortho-P for site W-IN-EX, which is a structure on the west side of the Boney Marsh just west of the S65-B structure (now removed) on the C-38 canal. Other sites reviewed, including E-IN in Boney Marsh about ten miles north of the old S65-B structure and E02 in Lake Kissimmee, showed similar speciation for N and P, with the exception of ammonia N in Lake Kissimmee which was slightly lower, about 1.7% of TN versus about 3% to 4% for the wetlands. The N speciation histograms for the reference sites look very similar to the FEC N histograms (**Figures 16 – 18**) below and are not shown.

The FEC TN concentrations are closer to observed native levels than other sub-watersheds; therefore, using FEC for speciation of TN was also assumed appropriate. However, the FEC TP concentrations are higher than reported native TP levels, which means their speciation data may not be representative and therefore the reference wetland sites were considered to be more appropriate for TP speciation. The SFWMD data for FEC did provide a significant amount of nitrate-nitrite N, ammonia N, TKN, and ortho-P concentrations along with the TN and TP concentrations as shown in **Figures 16 – 19**. Unfortunately, there were only a limited number of samples that had dissolved TKN, which allows particulate TKN to be estimated. However, the reference sites did have substantially more dissolved TKN data. The limited FEC data indicated that about 85% of the TKN is in the dissolved form, which is close to the W-IN-EX and E-IN reference sites that were at 84% and 81% of TKN, respectively.

Because WAM simulates dissolved (soluble P) and TP, dissolved P is the critical parameter for comparison to the WAM results. Analysis of the mean concentrations of dissolved P and TP for the reference sites W-IN-EX and E-IN, and FEC indicates that the percentages of dissolved P in TP are 56%, 67%, and 63%, respectively. If ortho-P is of interest, then the WAM predicted dissolved P can be further speciated into soluble ortho-P and soluble organic P. Analyzing the reference sites, it was found that ortho-P concentrations at sites W-IN-EX and E-IN were 31% and 24% of TP, respectively. It was interesting to

observe that FEC had an ortho-P percentage of TP of 63%, which likely implies that the anthropogenic activities causing the TP concentration increases are primarily only influencing ortho-P concentrations. It is possible that the soluble organic P, which is the difference between dissolved P and ortho-P, is being generated by natural background processes that are not influenced significantly by anthropogenic activities, such as fertilization.

Based on the above analyses of existing data, the following native condition TN and TP speciation targets are:

- Nitrate-nitrite N $\cong$ 3% of TN
- Ammonia N $\cong$ 4% of TN
- Dissolved TKN $\cong$ 83% of TN
- Particulate TKN $\cong$ 14% of TN
- Dissolved P $\cong$ 63% of TP
- Ortho-P $\cong$ 28% of TP

Since WAM simulates total dissolved P, not ortho-P, it will be up to the user to understand that if ortho-P concentrations are desired, then it can be estimated reasonably by multiplying the above estimated ortho-P percentage times TP.

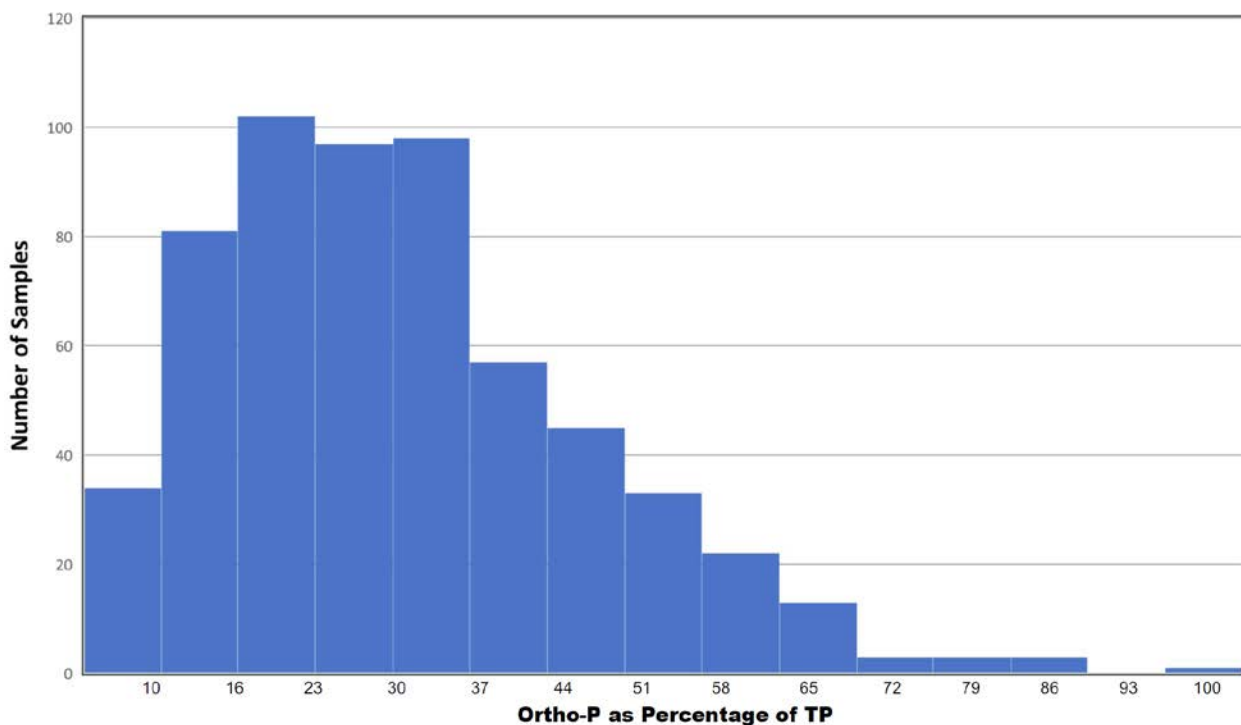


Figure 14. Distribution of percentages of Ortho-P in measured TP from W-IN-EX

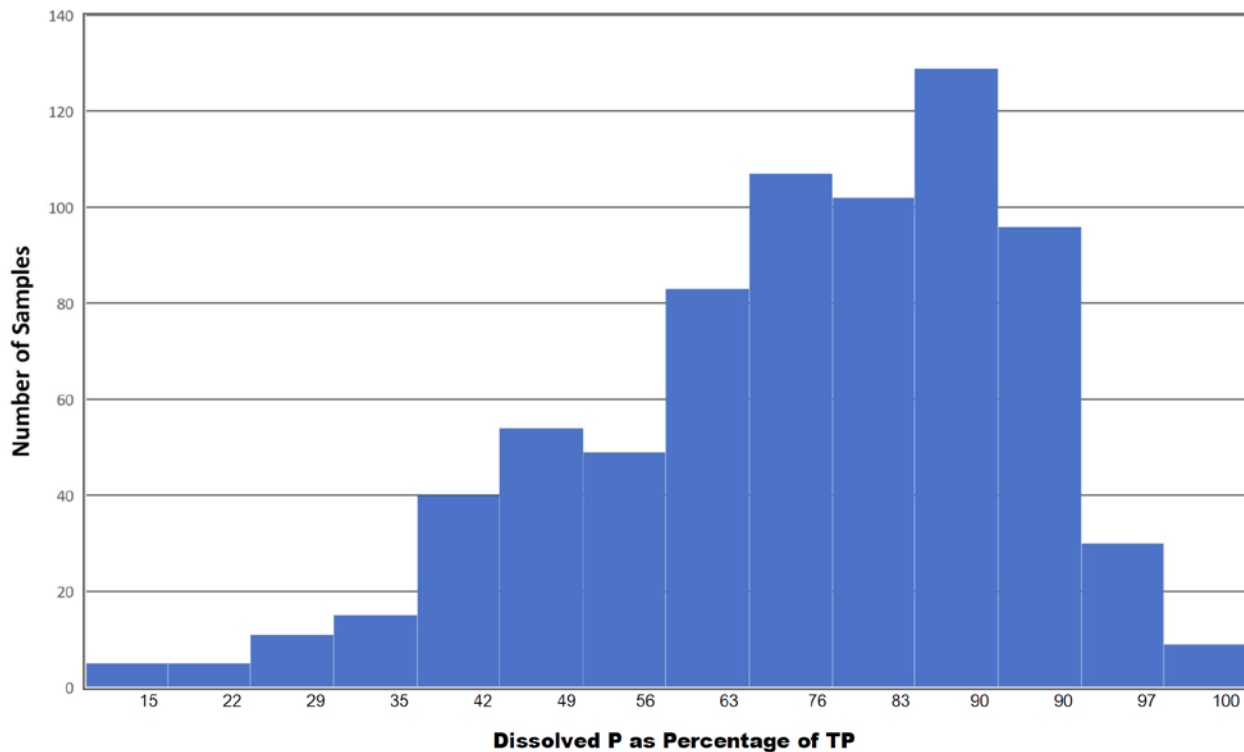


Figure 15. Distribution of percentages of Dissolved P in measured TP from W-IN-EX.

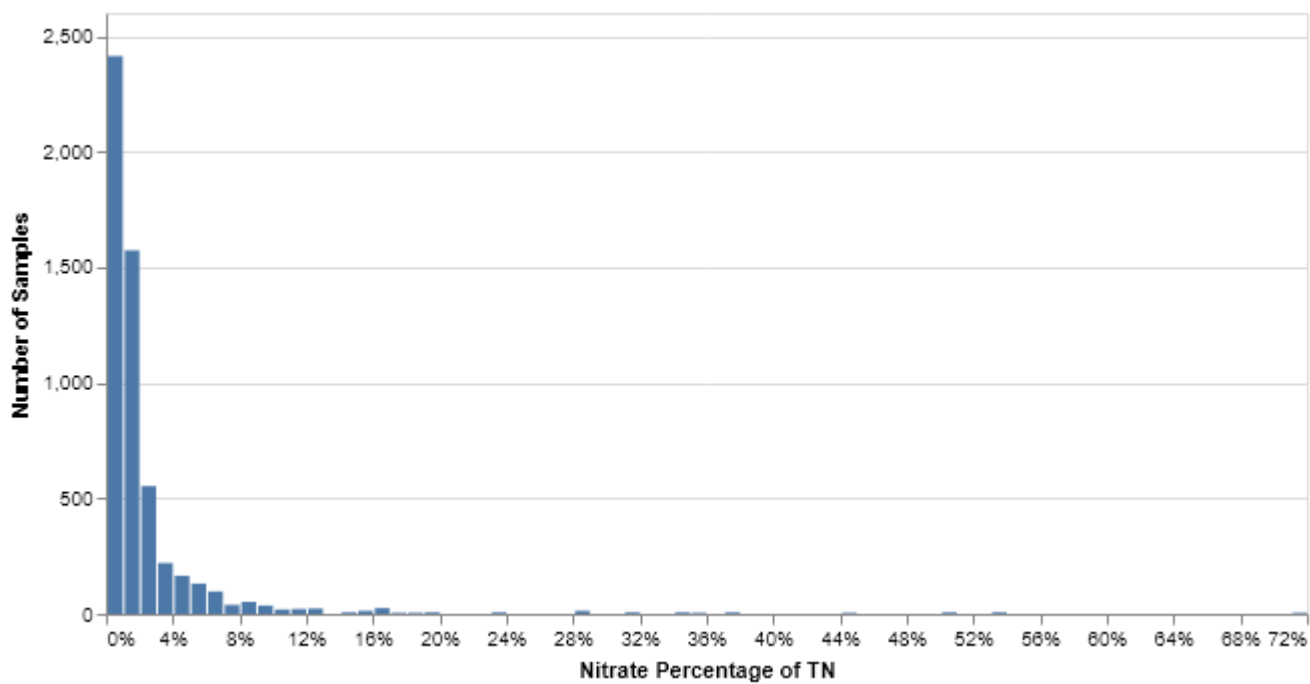


Figure 16. Distribution of percentages of nitrate in measured TN from FEC.

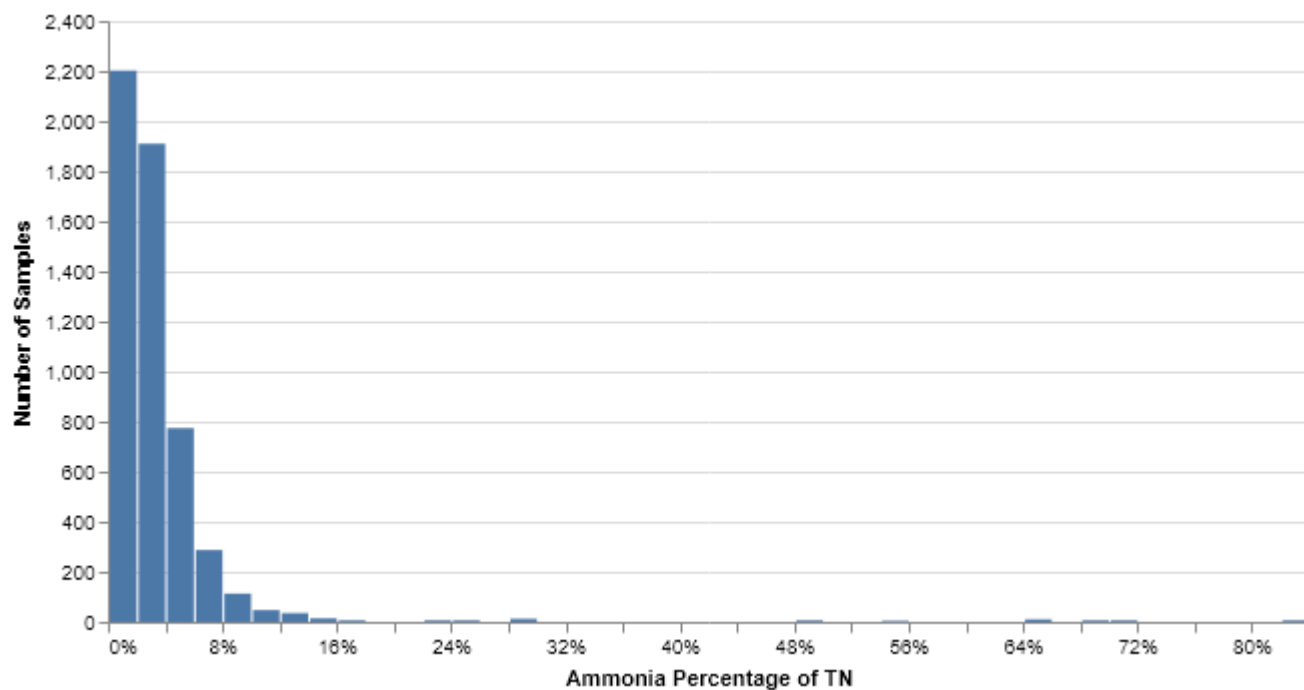


Figure 17. Distribution of percentages of ammonia in measured TN from FEC.

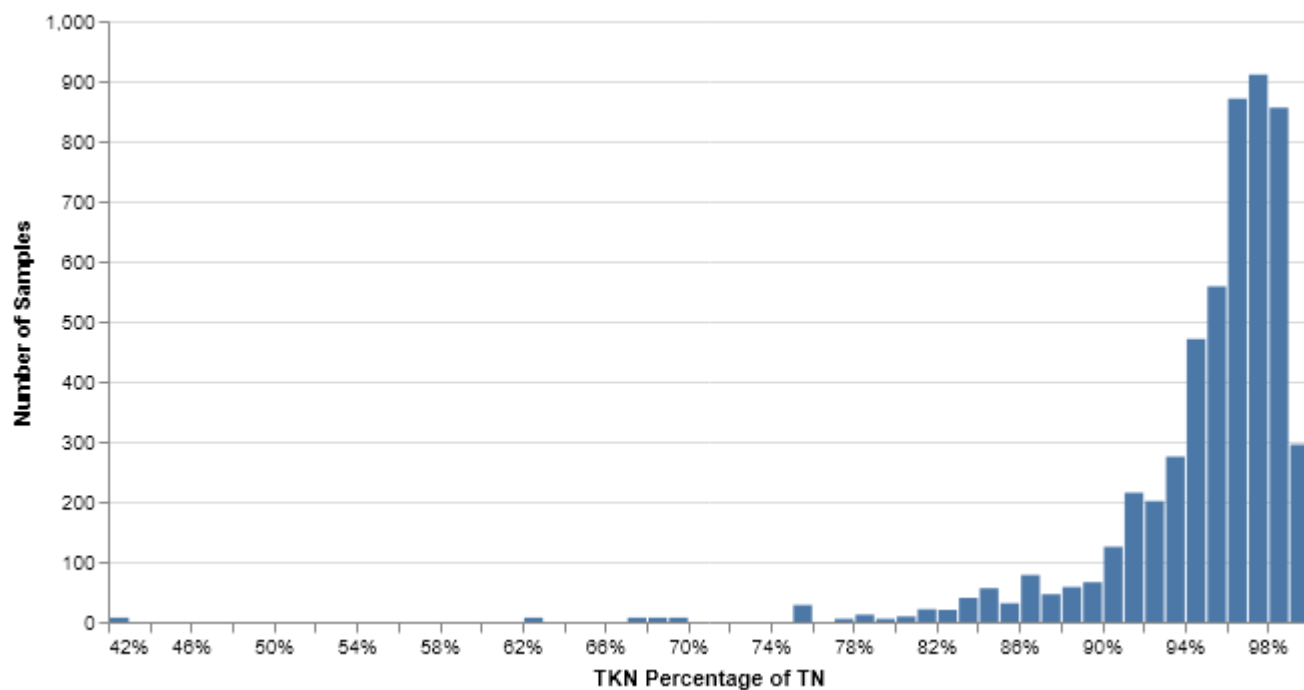


Figure 18. Distribution of percentages of TKN in measured TN from FEC.

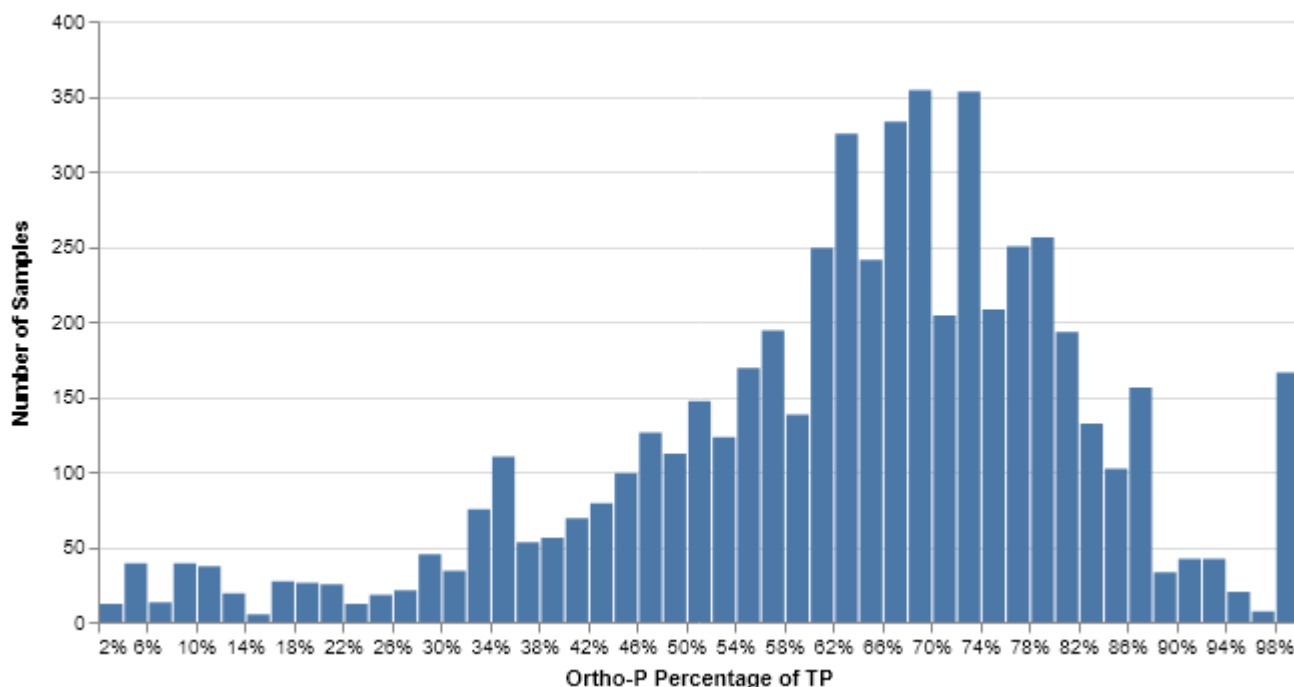


Figure 19. Distribution of percentages of ortho-P in measured TP from FEC.

2.1.5.2 Waterbody Nutrient Concentrations

Estimates of nutrient concentrations in lakes and streams under pristine conditions are important for determining attenuation coefficients for the pre-drainage WAM simulations.

2.1.5.2.1 In-Stream

Smith et al. (2003) summarize estimated natural background concentrations of nutrients throughout the United States. For the Southern Coastal Plain (which extends well beyond Florida but includes all the northern sub-watersheds as well as the East and West sub-watersheds) they report ranges for TN of 0.4-0.9 mg/L and 0.02-0.04 mg/L for TP.

Hand (2004) summarizes concentrations of N and P for a variety of environments throughout Florida, including values for the 10th through 90th percentiles. These include data from both impacted and non-impacted sources. The median in-stream concentration of TN is 1.05 mg/L (range from 0.31-2.28 mg/L from the 10th to the 90th percentile). The median TP concentration in streams is 0.08 mg/L (range from 0.01-0.49 mg/L), in blackwater streams (i.e., streams with high tannin content) the median TP value is 0.11 mg/L (range from 0.02-0.38 mg/L).

Jones (2005) documented TN and TP concentrations of 1.12 – 1.33 mg/L and 0.034 – 0.071 mg/L, respectively, in the channelized Kissimmee, remnant river run, and C-38 stations in Pools A and C. These concentrations were measured over a three-year period prior to the initiation of phase I construction in 1999. Jones (2005) also cites measured concentrations of TP (Odum 1953) in the Kissimmee River of 0.06, 0.002, and 0.012 mg/L, although a footnote indicates that the lower values may have been below detection limits at the time. Mean discharge-weighted concentration of TP in the Kissimmee River over

the time period from 1974-1995 range from a low of 0.043 mg/L at S-65 (the outflow structure from Lake Kissimmee) to a high of 0.105 mg/L at S-65 E (Jones 2005).

In developing the TMDL report for Lake Kissimmee (Kang and Gilbert 2013) used the HSPF model to evaluate TN and TP concentrations under what they termed the “natural land use background condition.” This was accomplished by reassigning land uses representing current conditions to a mixture of forest and wetland during HSPF model simulations. They estimated that the TN and TP concentrations in Lake Kissimmee should have had long-term averages of 1.09 and 0.032 mg/L, respectively.

2.1.5.2.2 In-Lake

Hand (2004) indicates that the median in-stream concentration of TN is 0.75 mg/L in lakes (range from 0.33-1.8 mg/L), while the median concentration of TP in lakes is 0.03 mg/L (range from 0.01-0.15 mg/L).

Paleolimnological studies have used diatom assemblages in sediment cores to estimate pre-development P concentrations in several Florida lakes (Brenner et al 1993; Whitmore and Brenner 2002; Whitmore 2003; Riedinger-Whitmore et al. 2005). Two of the lakes studied for these reports are within the LOW: Lake Francis (Brenner et al. 1993) and Lake Persimmon (Riedinger-Whitmore et al. 2005), which are immediately west of Lake Istokpoga. Most of the other lakes studied are near Winter Haven and Lakeland, immediately west of the LOW.

Brenner et al. (1993) report that Lake Francis was historically eutrophic with TP levels between 0.05 and 0.07 mg/L inferred from diatom assemblages in the lower parts of sediment cores. Although Riedinger-Whitmore et al. (2005) studied Lake Persimmon, they did not infer any historic TP concentrations. The other lakes studied in the reports include Bonny, Conine, Haines, Lulu, May, and Parker, which are in Polk County. Historic (pre-development) inferred TP concentrations are in the range of 0.024-0.044 mg/L.

2.1.6 WAM Nutrient Settings

2.1.6.1 Source Cell Nutrient Concentrations

Using these data points as guidance, the mean, minimum, and maximum concentrations for nutrients leaving source cells with the land cover categories used in WAM are presented in **Tables 7–9**. The values shown in **Table 7** are used to set runoff concentrations in the wetland land uses that are run under the Special Case sub-model in BUCShell, i.e., WAM Land Use IDs 9, 10, 12, 14, 15, and 16. The remaining land uses, “Pine Palmetto Flatwoods” (ID 5), “Hardwoods” (ID 6), and “Hardwood Conifer Mixed” (ID 7) are run either under GLEAMS (for cells on well drained soils) or EAAMod (for cells on high water table soils). For these remaining land uses, the values in **Tables 7–9** are used as a target for long-term averages and general upper and lower bounds of concentrations leaving source cells. The values for the wetland land uses are also used to set background nutrient concentration coefficients for attenuation processes if constituents pass through wetlands during the overland routing process.

Table 7. Mean N and P concentrations for WAM land uses.

Land Use	WAM LUID	NO ₃ -N (mg/l)	Ammonia-N (mg/l)	TN (mg/l)	Dissolved P (mg/l)	TP (mg/l)
Bay Swamps	10	0.08	0.140	1.6	0.018	0.03
Cypress	14	0.08	0.140	1.6	0.024	0.04

Freshwater Marshes	16	0.055	0.096	1.1	0.022	0.035
Hardwood Conifer Mixed	7	0.05	0.100	1.45	0.042	0.055
Hardwoods	6	0.05	0.100	1.5	0.03	0.04
Mixed Wetland Hardwoods	12	0.055	0.096	1.1	0.031	0.05
Open Water	9	0.19	0.010	0.9	0.016	0.02
Pine Palmetto Flatwoods	5	0.05	0.100	1.4	0.035	0.045
Wetland Forested Mixed	15	0.055	0.096	1.1	0.03	0.05

Table 8. Maximum N and P concentrations for WAM land uses.

Land Use	WAM LUID	NO3-N (mg/l)	Ammonia-N (mg/l)	TN (mg/l)	Dissolved P (mg/l)	TP (mg/l)
Bay Swamps	10	0.16	0.28	3.2	0.054	0.09
Cypress	14	0.16	0.28	3.2	0.072	0.12
Freshwater Marshes	16	0.11	0.1925	2.2	0.066	0.105
Hardwood Conifer Mixed	7	0.1	0.2	2.9	0.126	0.165
Hardwoods	6	0.1	0.2	3	0.09	0.12
Mixed Wetland Hardwoods	12	0.11	0.1925	2.2	0.093	0.15
Open Water	9	0.19	0.010	0.9	0.016	0.02
Pine Palmetto Flatwoods	5	0.1	0.2	2.8	0.105	0.135
Wetland Forested Mixed'	15	0.11	0.1925	2.2	0.09	0.15

Table 9. Minimum N and P concentrations for WAM land uses.

Land Use	WAM LUID	NO3-N (mg/l)	Ammonia-N (mg/l)	TN (mg/l)	Dissolved P (mg/l)	TP (mg/l)
Bay Swamps	10	0.04	0.07	0.8	0.0036	0.006
Cypress	14	0.04	0.07	0.8	0.0048	0.008
Freshwater Marshes	16	0.0275	0.048125	0.55	0.0044	0.007
Hardwood Conifer Mixed	7	0.025	0.05	0.725	0.0084	0.011
Hardwoods	6	0.025	0.05	0.75	0.006	0.008
Mixed Wetland Hardwoods	12	0.0275	0.048125	0.55	0.0062	0.01
Open Water	9	0.19	0.010	0.9	0.016	0.02
Pine Palmetto Flatwoods	5	0.025	0.05	0.7	0.007	0.009
Wetland Forested Mixed	15	0.0275	0.048125	0.55	0.006	0.01

2.1.6.2 Rainfall Nutrient Concentrations

Nitrogen concentrations in rainfall are set to 0.2 mg/L (assigned to the nitrate fraction) and 0.007 mg/L assigned to dissolved phosphorus. These are the same values used for the current conditions simulations (SWET 2017a, 2017b).

3 Results

Results from the pre-drainage WAM simulations are presented here. **Table 10** shows **annual average** (calculated by water year) runoff, percolation, TN, and TP loadings from source cells broken down by land cover in each of the sub-watersheds. Nutrient loadings are given in metric tons (mt), while runoff and percolation are given as acre-feet (ac-ft). If a sub-watershed does not have a particular land cover within its domain, the cell entry is left blank, for example, only Upper Kissimmee and Lake Istokpoga have the land cover “Barren Land.” The source cell loadings are what leave the source cell before overland and in-stream routing is simulated and do not reflect any attenuation processes.

Table 11 shows **annual average** water volumes and nutrient loads leaving each sub-watershed. This is the primary product of this study, as it gives the estimates of water volume and nutrient loads and average concentrations discharging into Lake Okeechobee. As described in the footnotes, the values for the Lower Kissimmee and Indian Prairie sub-watersheds are the values generated by WAM minus the inflow contributions from the Upper Kissimmee and Lake Istokpoga sub-watersheds, respectively. For the WAM simulations, the outflow from the Upper Kissimmee is used as an inflow boundary condition for the Lower Kissimmee model, and the outflow from Lake Istokpoga is used as an inflow for the Indian Prairie model. This was done to generate contributions on a per-watershed basis. **Figure 20** shows annual (water-year) contributions of water volume and nutrient loads to Lake Okeechobee broken down by sub-watershed.

Discharge from the East sub-watershed is split into four parts: the first two are to the east (towards the Atlantic Ocean) and into the South sub-watershed; neither of these contribute to Lake Okeechobee. The remainder either flows directly into Lake Okeechobee, or across the southern part of the Taylor Creek/Nubbin Slough sub-watershed, across what is now the S-135 Basin. As with the other basins that receive flow from upstream basins, the values reported are the totals from the East sub-watershed that reach the lake and the contributions from the East sub-watershed to Taylor Creek/Nubbin Slough are subtracted from the totals given for Taylor Creek/Nubbin Slough.

Discharge from the West sub-watershed is split between flow down the Caloosahatchee River to the west and a direct contribution to Lake Okeechobee that occurs when the lake stage is low. Note that some of this is water that flowed from the lake into the West sub-watershed when the lake stage was high. None of the South sub-watershed discharges to the lake.

Detailed breakdowns by sub-watershed are provided in the following sections. A map is shown for each sub-watershed with land cover and the reach network, with the reach numbers labeled. Charts of annual (by water year) runoff and percolation volume and loads of TN and TP produced at the source cell level categorized by land cover are shown for each sub-watershed. In each of these charts the average over the simulation period is indicated by a dashed red line. In charts showing runoff and percolation, the total annual rainfall volume over the basin (second y-axis, ac-ft) are indicated by squares with green fill. Daily time series charts of flow and nutrient concentrations leaving each sub-watershed covering the entire simulation period from 1994-2013 are presented as well.

Table 10. Annual average runoff and percolation (in acre-feet), and nutrient loadings (in metric tons) produced at the source cell level for the nine sub-watersheds.

	Barren Land	Bay Swamps	Cypress	Freshwater Marshes	Hardwood Conifer Mixed	Hardwoods	Mixed Wetland Hardwoods	Open Water	Pine Palmetto Flatwoods	Wetland Forested Mixed
UK Runoff	16	6	627	76,133	39,301	29	46,233	10,419	271,976	19,778
UK Perc	2				69,751	110,666			50,393	
UK TN Load	0	0	1	103	93	1	63	12	463	27
UK TP Load	0.0	0.0	0.0	3.3	5.2	0.6	2.9	0.3	17.9	1.2
UK TN Conc	0.65	1.60	1.60	1.10	0.69	0.01	1.11	0.90	1.17	1.10
UK TN Conc Max	1.34	1.60	1.60	1.10	9.49	2.98	1.11	0.90	12.34	1.10
UK TN Conc Min	0.52	1.60	1.60	1.10	0.00	0.00	1.11	0.90	0.00	1.10
UK TP Conc	0.065	0.030	0.040	0.035	0.039	0.005	0.050	0.020	0.045	0.050
UK TP Conc Max	0.387	0.030	0.040	0.035	0.565	0.131	0.050	0.020	0.680	0.050
UK TP Conc Min	0.040	0.030	0.040	0.035	0.000	0.004	0.050	0.020	0.000	0.050
LK Runoff			131	44,561	2,737	151	50,602	2,674	198,876	1,137
LK Perc					33				5,018	
LK TN Load			0	60	6	0	69	3	302	2
LK TP Load			0.0	1.9	0.3	0.0	3.1	0.1	10.4	0.1
LK TN Conc			1.60	1.10	1.77	1.12	1.11	0.90	1.20	1.10
LK TN Conc Max			1.60	1.10	6.73	3.73	1.11	0.90	11.62	1.10
LK TN Conc Min			1.60	1.10	0.00	0.51	1.11	0.90	0.00	1.10
LK TP Conc			0.040	0.035	0.097	0.052	0.050	0.020	0.041	0.050
LK TP Conc Max			0.040	0.035	0.558	0.108	0.050	0.020	0.722	0.050
LK TP Conc Min			0.040	0.035	0.004	0.033	0.050	0.020	0.002	0.050
LI Runoff	766	1	8	20,012	11,673	426	29,104	1,457	62,875	6,189

	Barren Land	Bay Swamps	Cypress	Freshwater Marshes	Hardwood Conifer Mixed	Hardwoods	Mixed Wetland Hardwoods	Open Water	Pine Palmetto Flatwoods	Wetland Forested Mixed
LI Perc	52				99,907	17,048			98,189	
LI TN Load	1	0	0	27	33	1	40	2	106	8
LI TP Load	0.0	0.0	0.0	0.9	2.8	0.1	1.8	0.0	4.4	0.4
LI TN Conc	0.51	1.60	1.60	1.10	0.24	0.03	1.11	0.90	0.53	1.10
LI TN Conc Max	4.44	1.60	1.60	1.10	7.68	2.47	1.11	0.90	7.83	1.10
LI TN Conc Min	0.00	1.60	1.60	1.10	0.00	0.00	1.11	0.90	0.00	1.10
LI TP Conc	0.044	0.030	0.040	0.035	0.021	0.006	0.050	0.020	0.022	0.050
LI TP Conc Max	0.942	0.030	0.040	0.035	0.584	0.089	0.050	0.020	0.632	0.050
LI TP Conc Min	0.009	0.030	0.040	0.035	0.002	0.004	0.050	0.020	0.000	0.050
IP Runoff				20,139	3	2,231	33,973	255	31,821	892
IP Perc					5,581				19,834	
IP TN Load				27	0	3	47	0	50	1
IP TP Load				0.9	0.1	0.1	2.1	0.0	1.7	0.1
IP TN Conc				1.10	0.00	1.10	1.11	0.90	0.79	1.10
IP TN Conc Max				1.10	2.36	3.42	1.11	0.90	8.25	1.10
IP TN Conc Min				1.10	0.00	0.34	1.11	0.90	0.00	1.10
IP TP Conc				0.035	0.009	0.053	0.050	0.020	0.027	0.050
IP TP Conc Max				0.035	0.059	0.093	0.050	0.020	0.725	0.050
IP TP Conc Min				0.035	0.009	0.036	0.050	0.020	0.003	0.050
FEC Runoff		2		45,500	139	3,621	65,112	30	117,902	2,142
FEC Perc					2,401				24,091	
FEC TN Load		0		62	0	5	89	0	178	3
FEC TP Load		0.0		2.0	0.0	0.2	4.0	0.0	6.3	0.1

	Barren Land	Bay Swamps	Cypress	Freshwater Marshes	Hardwood Conifer Mixed	Hardwoods	Mixed Wetland Hardwoods	Open Water	Pine Palmetto Flatwoods	Wetland Forested Mixed
FEC TN Conc		1.60		1.10	0.10	1.01	1.11	0.90	1.01	1.10
FEC TN Conc Max		1.60		1.10	4.10	4.08	1.11	0.90	7.13	1.10
FEC TN Conc Min		1.60		1.10	0.00	0.43	1.11	0.90	0.00	1.10
FEC TP Conc		0.030		0.035	0.014	0.051	0.050	0.020	0.036	0.050
FEC TP Conc Max		0.030		0.035	0.307	0.337	0.050	0.020	0.369	0.050
FEC TP Conc Min		0.030		0.035	0.009	0.014	0.050	0.020	0.002	0.050
TCNS Runoff		1	1	11,558	7,193	1,268	10,277	1,173	73,743	536
TCNS Perc					227				643	
TCNS TN Load		0	0	16	22	2	14	1	113	1
TCNS TP Load		0.0	0.0	0.5	0.9	0.1	0.6	0.0	4.3	0.0
TCNS TN Conc		1.60	1.60	1.10	2.39	1.17	1.11	0.90	1.23	1.10
TCNS TN Conc Max		1.60	1.60	1.10	11.44	3.48	1.11	0.90	11.39	1.10
TCNS TN Conc Min		1.60	1.60	1.10	0.00	0.48	1.11	0.90	0.00	1.10
TCNS TP Conc		0.030	0.040	0.035	0.104	0.058	0.050	0.020	0.047	0.050
TCNS TP Conc Max		0.030	0.040	0.035	0.778	0.113	0.050	0.020	0.754	0.050
TCNS TP Conc Min		0.030	0.040	0.035	0.000	0.043	0.050	0.020	0.004	0.050
ESW Runoff			544	14,371	33,824		20,175	264	33,548	28,298
ESW Perc					816					
ESW TN Load			1	19	91		28	0	61	38
ESW TP Load			0.0	0.6	3.9		1.2	0.0	2.3	1.7
ESW TN Conc			1.60	1.10	2.14		1.11	0.90	1.47	1.10
ESW TN Conc Max			1.60	1.10	16.19		1.11	0.90	16.22	1.10
ESW TN Conc Min			1.60	1.10	0.00		1.11	0.90	0.34	1.10

	Barren Land	Bay Swamps	Cypress	Freshwater Marshes	Hardwood Conifer Mixed	Hardwoods	Mixed Wetland Hardwoods	Open Water	Pine Palmetto Flatwoods	Wetland Forested Mixed
ESW TP Conc			0.040	0.035	0.092		0.050	0.020	0.055	0.050
ESW TP Conc Max			0.040	0.035	0.873		0.050	0.020	0.869	0.050
ESW TP Conc Min			0.040	0.035	0.000		0.050	0.020	0.011	0.050
WSW Runoff			232	26,582	9,322	712	14,369	4,429	66,958	1,739
WSW Perc										
WSW TN Load			0	36	24	1	20	5	94	2
WSW TP Load			0.0	1.1	1.5	0.0	0.9	0.1	3.5	0.1
WSW TN Conc			1.60	1.10	2.05	0.89	1.11	0.90	1.14	1.10
WSW TN Conc Max			1.60	1.10	14.36	2.57	1.11	0.90	13.16	1.10
WSW TN Conc Min			1.60	1.10	0.50	0.37	1.11	0.90	0.33	1.10
WSW TP Conc			0.040	0.035	0.132	0.046	0.050	0.020	0.043	0.050
WSW TP Conc Max			0.040	0.035	1.054	0.123	0.050	0.020	0.985	0.050
WSW TP Conc Min			0.040	0.035	0.012	0.030	0.050	0.020	0.005	0.050
SSW Runoff		11	6	195,360	1,036		417	8,383	14,213	11,212
SSW Perc										
SSW TN Load		0	0	265	2		1	9	21	15
SSW TP Load		0.0	0.0	8.4	0.1		0.0	0.2	0.6	0.7
SSW TN Conc		1.60	1.60	1.10	1.45		1.11	0.90	1.18	1.10
SSW TN Conc Max		1.60	1.60	1.10	8.89		1.11	0.90	3.35	1.10
SSW TN Conc Min		1.60	1.60	1.10	0.51		1.11	0.90	0.38	1.10
SSW TP Conc		0.030	0.040	0.035	0.062		0.050	0.020	0.037	0.050
SSW TP Conc Max		0.030	0.040	0.035	0.606		0.050	0.020	0.134	0.050
SSW TP Conc Min		0.030	0.040	0.035	0.014		0.050	0.020	0.006	0.050

Table 11. Water volumes, nutrient loads, and flow-weighted concentrations for each sub-watershed for the simulation period WY 1995-2013.

Sub-Watershed	Discharge (ac-ft)	TN Load (mt)	TP Load (mt)	TN Conc (mg/L)	TP Conc (mg/L)
Upper Kissimmee	632,924	839	25	1.07	0.033
Lower Kissimmee ¹	304,351	396	15	1.06	0.041
Lake Istokpoga	314,531	376	12	0.97	0.030
Indian Prairie ²	106,803	152	5.1	1.16	0.038
Fisheating Creek	249,524	316	12	1.03	0.037
Taylor Creek/Nubbin Slough ³	106,391	142	6	1.08	0.042
East sub-watershed	75,179	111	4	1.14	0.037
West sub-watershed	29,145	42	1.5	1.16	0.042
Total into Lake Okeechobee	1,818,847	2,374	80	1.06	0.036

Table 12. Average rainfall per sub-watershed, and discharge, TN, and TP normalized by sub-watershed area. East and West sub-watersheds are excluded since only a portion of their areas do not contribute to the lake.

Sub-Watershed	Avg Rain (in)	Area Avg Discharge (in)	TN (lb/acre)	TP (lb/ac)
Upper Kissimmee	49	7.4	1.8	0.054
Lower Kissimmee	50	8.5	2.0	0.079
Lake Istokpoga	50	9.6	2.1	0.065
Indian Prairie	42	4.6	1.2	0.040
Fisheating Creek	49	9.4	2.2	0.080
Taylor Creek/Nubbin Slough	46	6.5	1.6	0.062
Average	49	7.8	1.8	0.062

¹ Volume and loads at the mouth of the Kissimmee River minus the contribution from the Upper Kissimmee Sub-watershed.

² Volume and loads entering Lake Okeechobee from Indian Prairie minus the contribution from the Lake Istokpoga Sub-watershed.

³ Volume and loads entering Lake Okeechobee from Taylor Creek/Nubbin Slough minus the contribution from the East Sub-watershed.

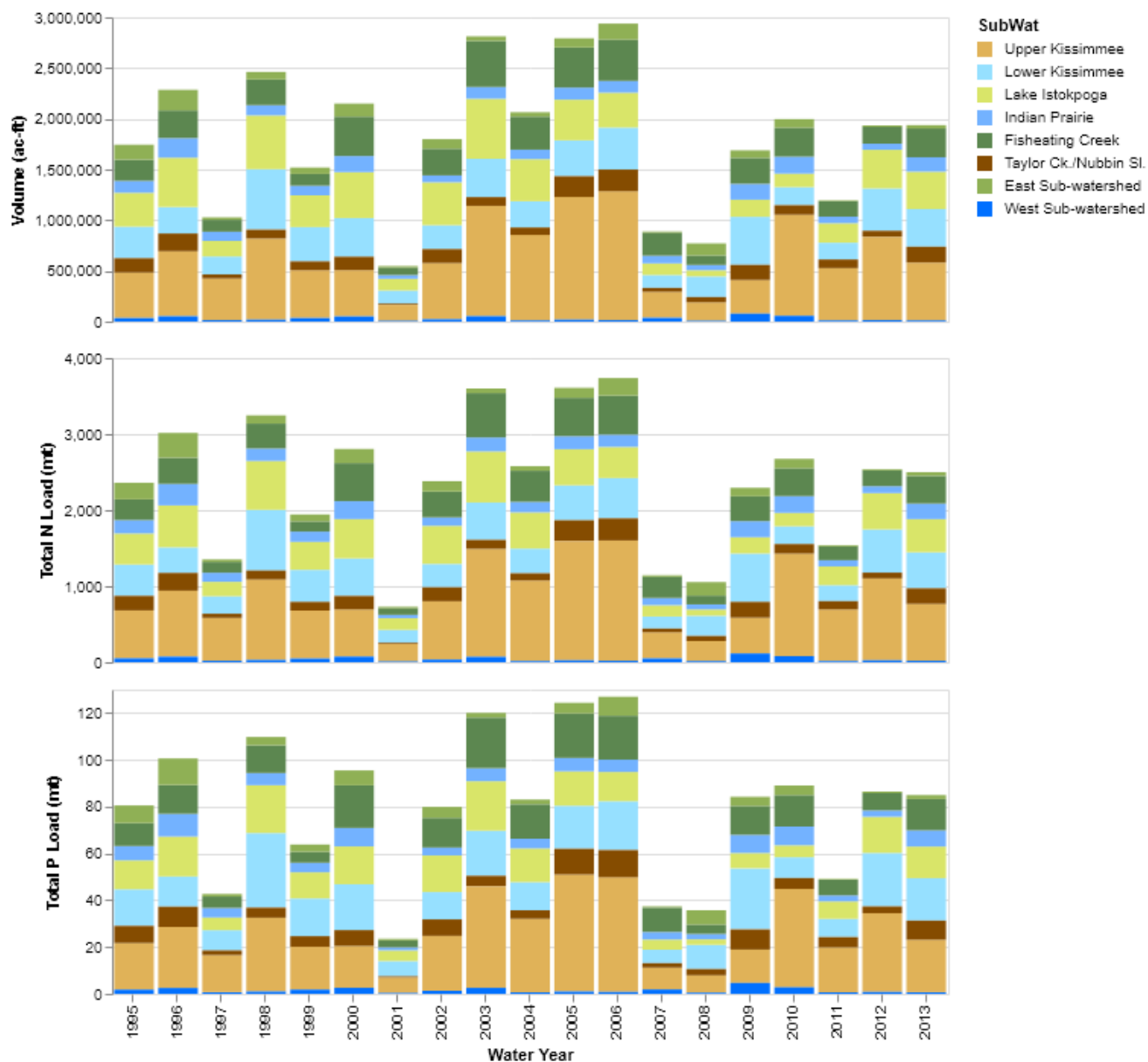


Figure 20. Annual water volumes and nutrient loads discharging into Lake Okeechobee. The top pane shows water volume (acre-feet), the middle pane shows TN loads (mt), and the bottom pane shows TP loads (mt).

3.1 Upper Kissimmee

The Upper Kissimmee sub-watershed is the northernmost of the six sub-watersheds simulated for this project, as well as the largest in area, measuring approximately 1,028,400 acres (**Figure 21**). The Upper Kissimmee sub-watershed encompasses the area from just south of Orlando to the bottom edge of Lake Kissimmee. The basin outlet is the southern end of Lake Kissimmee, with discharge to the Kissimmee River, which under current conditions is controlled by a set of gates at S-65. For the pre-drainage simulations, a set of four weirs of increasing crest elevations was used to mimic a broad area of outflow from Lake Kissimmee (WAM reach 3). The weir elevations are 49, 49.2, 50, and 50.5 feet (14.95, 15, 15.25, and 15.4 meters) (NGVD), while the corresponding widths are 66, 197, 197, and 657 feet (20, 60, 60, 200 meters), respectively. The flow between the lake and WAM reach 2 was used as an inflow boundary condition for the Lower Kissimmee sub-watershed.

The dominant pre-drainage land cover is Pine Palmetto Flatwoods (**Table 2**), followed by Freshwater Marshes and Open Water. As was discussed in **Section 2.1.6**, the Pine Palmetto Flatwoods, Hardwood, Hardwood/Conifer Mixed, and Barren Land cover types (57% of the land cover in the sub-watershed) are run using either the EAAMod or GLEAMS land-source models (depending on the soil type), while 32% are run using the Special Case model, and the remaining 11% is accounted for by direct rainfall to lakes within the stream network (**Table 13**). For the last case, no runoff or percolation is generated, and all attenuation processes occur within the reach network. Note that the “Open Water” acreage in **Table 2** includes the “Lakes” acreage.

Table 13. Breakdown of land cover acreages as run by source cell model in the Upper Kissimmee sub-watershed. Note no source cell model is run on the "Lakes" land cover, since rainfall is passed directly through to the stream network.

Land Cover	GLEAMS	EAAMod	Special Case	None
Pine Palmetto Flatwoods	27,516	394,398		
Hardwoods	63,795	57		
Hardwood Conifer Mixed	73,246	25,655		
Open Water			14,220	
Bay Swamps			14	
Mixed Wetland Hardwoods			94,893	
Cypress			2,705	
Wetland Forested Mixed			61,510	
Freshwater Marshes			154,896	
Barren Land	25			
Lakes				115,496
Percent of Total	16%	41%	32%	11%

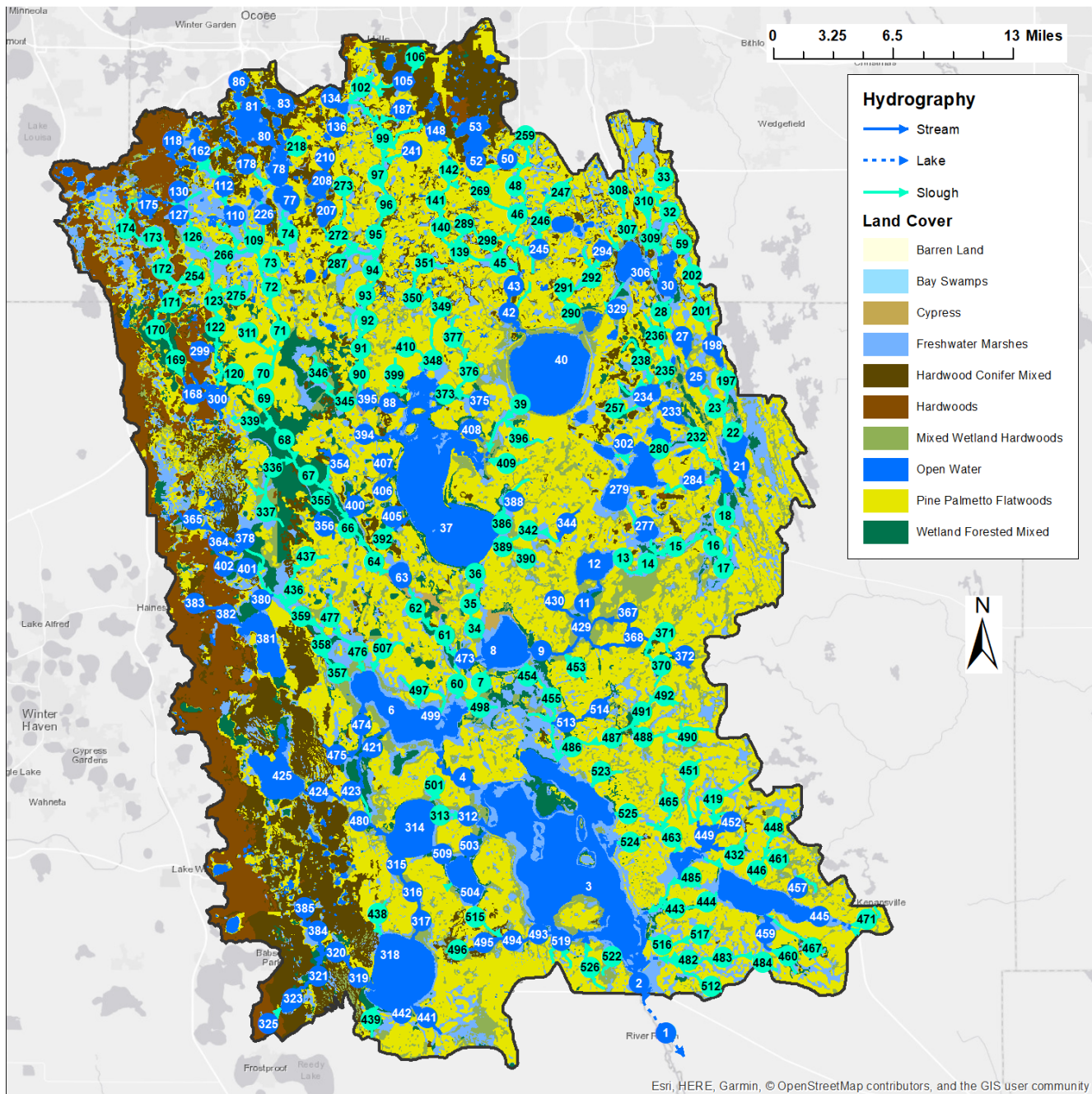


Figure 21. The Upper Kissimmee sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.1.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 22 – 25**. Overall, percolation to groundwater directly from source cells is about 33% of the total cell discharge (i.e., 67% runoff). Because of subsurface attenuation, the fractions of TN and TP loadings tend to be small, consequently, the sum of runoff and percolation TN and TP loads are shown rather than separately. The source cell percolation to groundwater does not include the contribution that originated

from runoff and was routed via overland flow to depressions where it subsequently percolated to groundwater. These amounts are included in the runoff values.

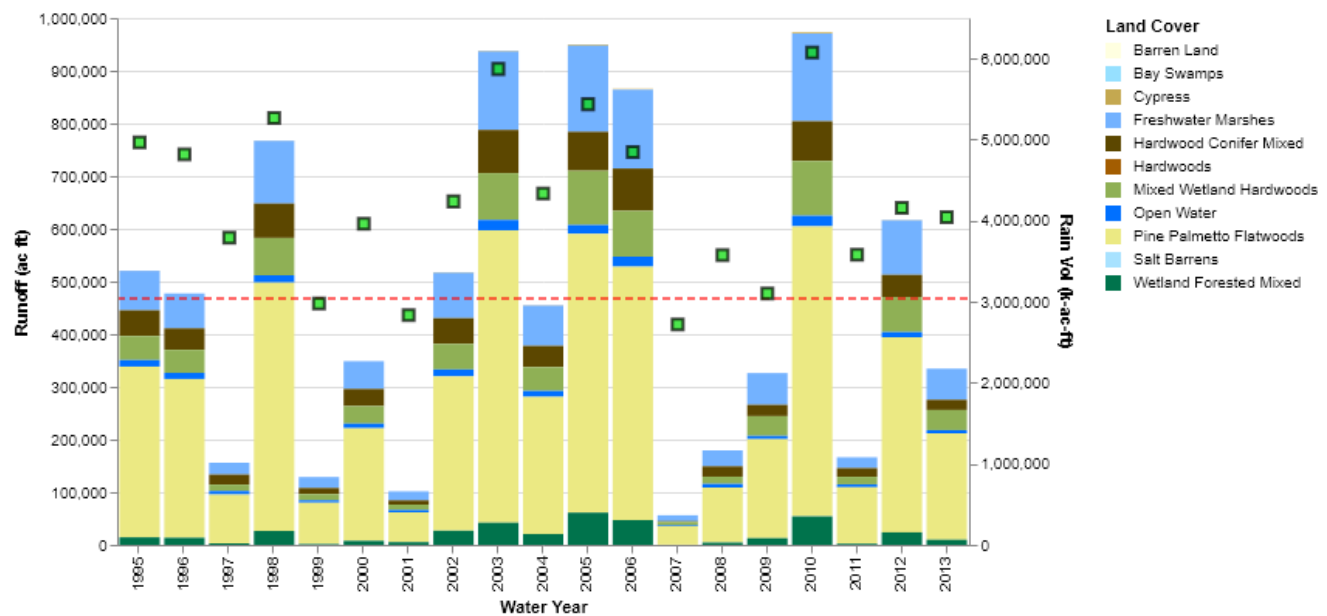


Figure 22. Source cell runoff per year and broken down by land cover in the Upper Kissimmee sub-watershed.

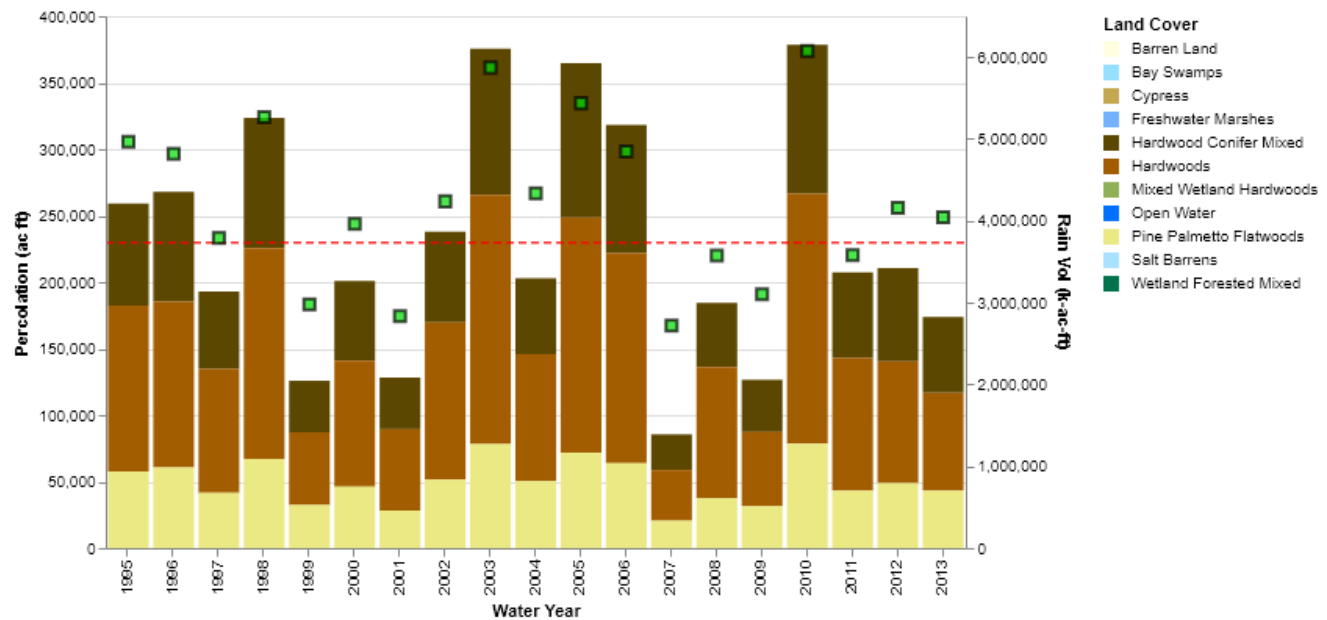


Figure 23. Source cell percolation per year in the Upper Kissimmee sub-watershed.

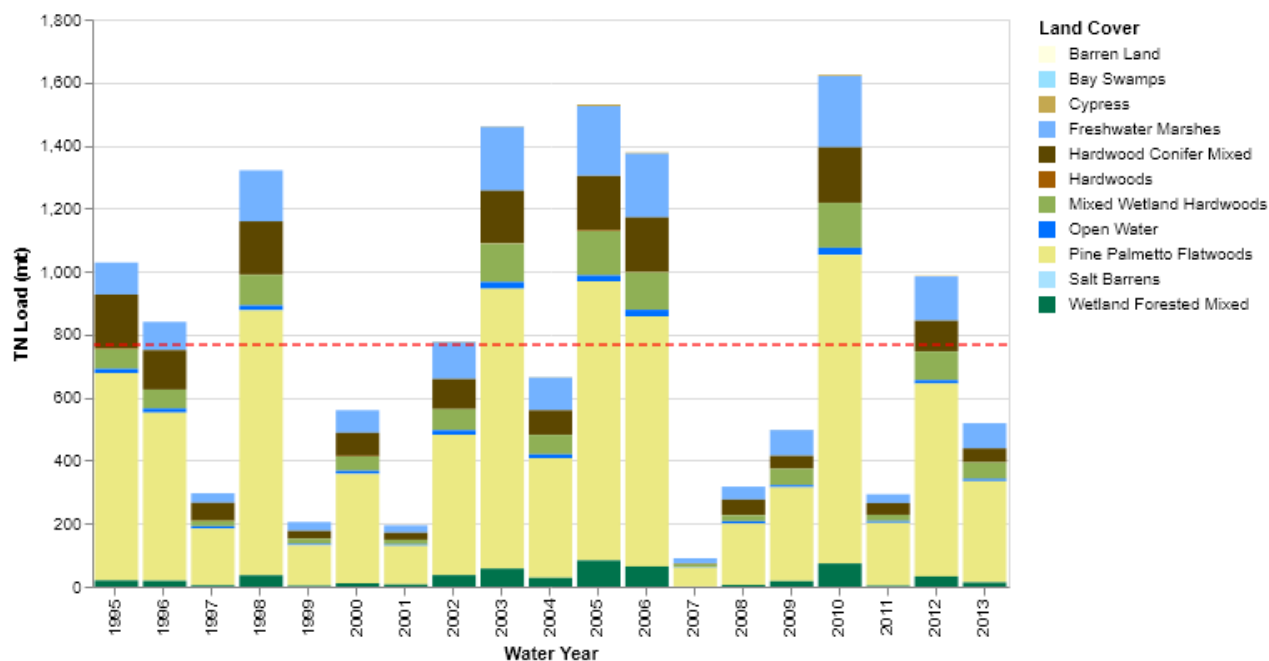


Figure 24. Source cell TN loadings per year in the Upper Kissimmee sub-watershed.

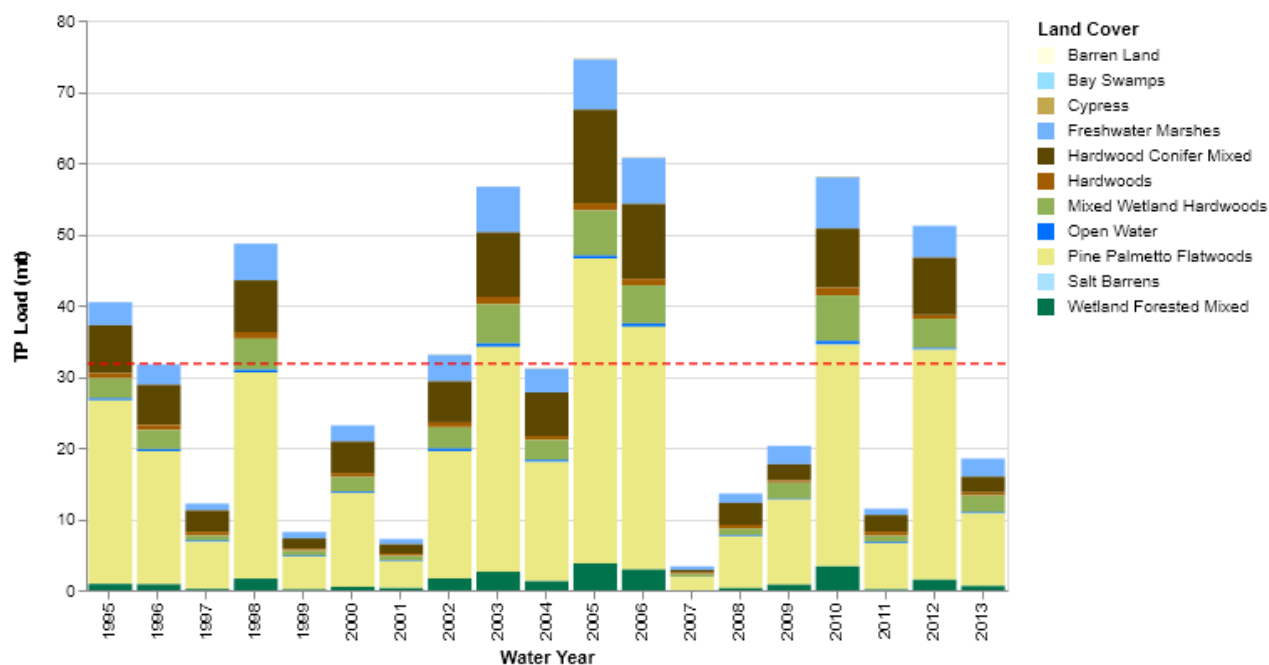


Figure 25. Source cell TP loadings per year in the Upper Kissimmee sub-watershed

3.1.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) leaving the sub-watershed at the southern end of Lake Kissimmee is shown in **Figure 26**. The annual average discharge was slightly over $24 \text{ m}^3/\text{s}$, corresponding to the

annual average volume of over 624,000 acre-feet per year. Peak discharge occurred during the wet years of 2004 and 2005.

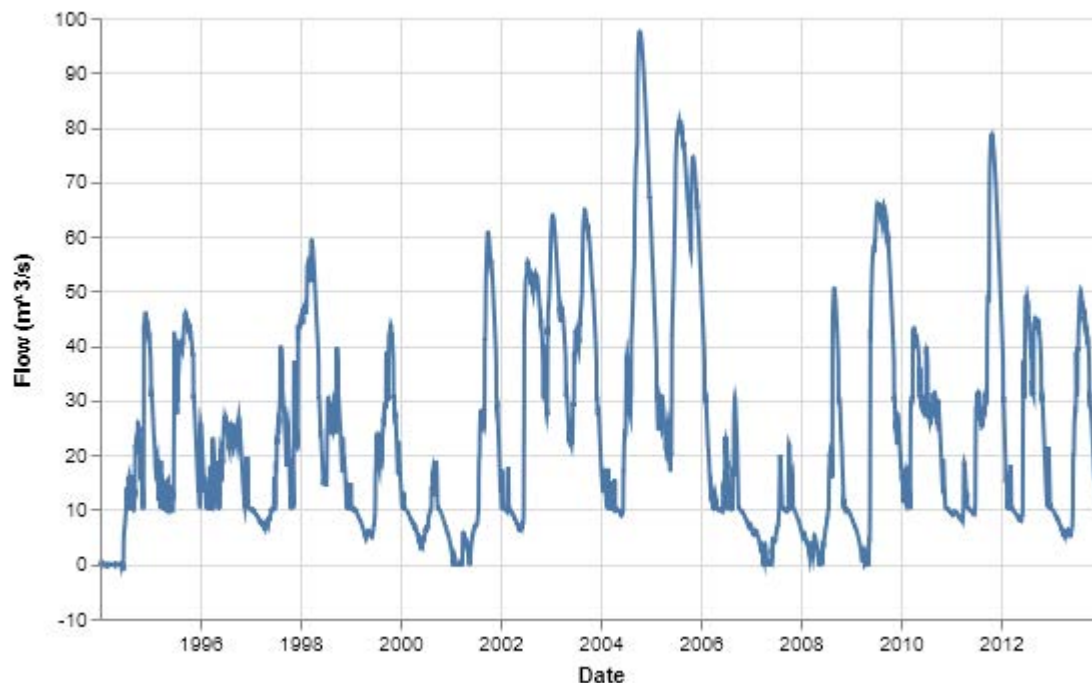


Figure 26. Simulated daily discharge from Lake Kissimmee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 27 and 28**, respectively. The flow-weighted average TN concentration over the entire period was 1.075 mg/L (**Table 11**) with most of the concentrations in the range of 1.0 – 1.3 mg/L, with peaks approaching 1.4 mg/L during low-flow periods. The flow-weighted TP concentration over the entire period was 0.032 mg/L with the bulk of the concentrations in the range of 0.03 – 0.04 mg/L.

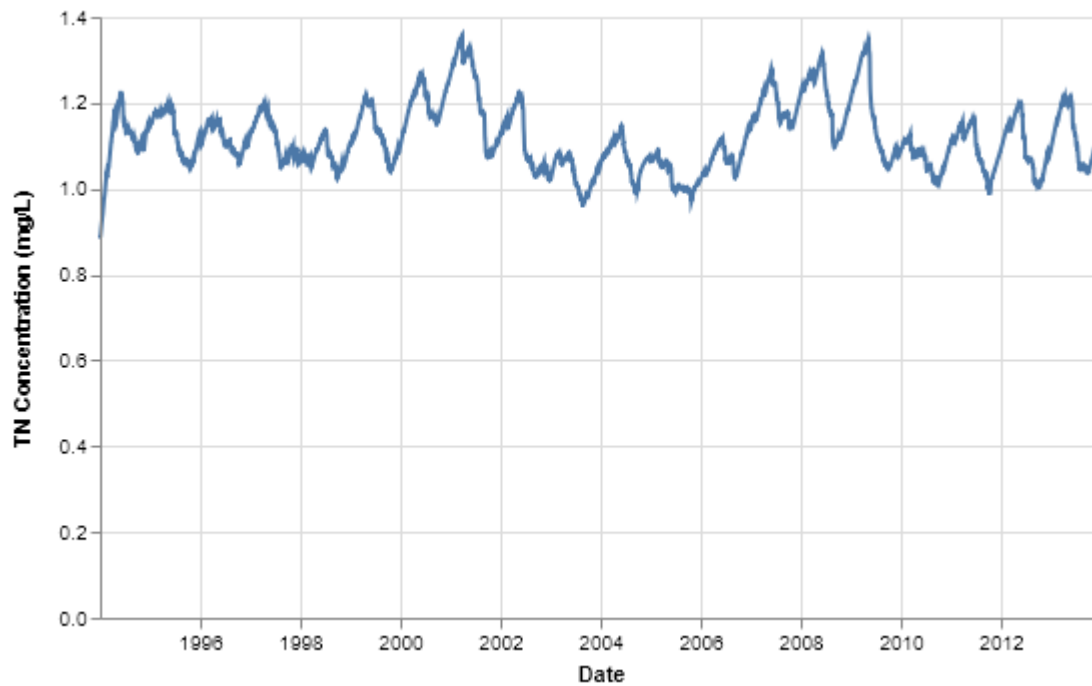


Figure 27. Simulated daily TN concentrations leaving Lake Kissimmee.

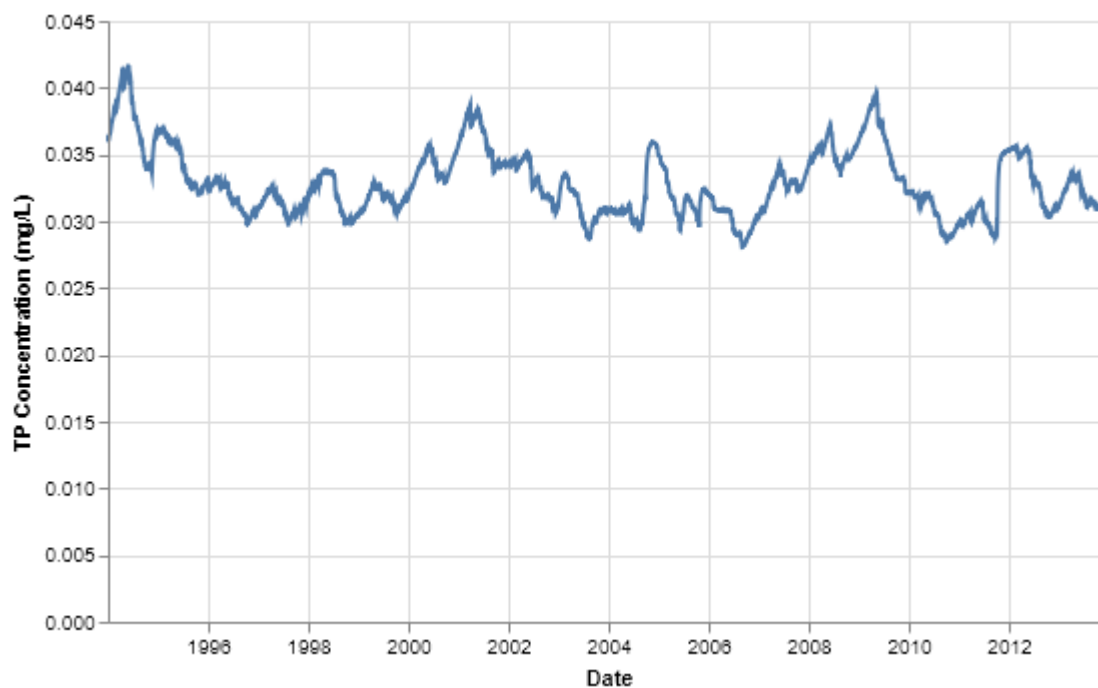


Figure 28. Simulated daily TP concentrations leaving Lake Kissimmee.

3.2 Lower Kissimmee

The Lower Kissimmee sub-watershed lies along the east-central portion of the six sub-watersheds, comprising the area between the Upper Kissimmee and Taylor Creek/Nubbin Slough model domains. It is

approximately 429,170 acres in size (**Figure 29**). The dominant feature through the domain is the Kissimmee River, which runs from the discharge point of Lake Kissimmee at the northern end of the model domain and meanders southward to the current location of the S-65E gates at the southern end of the domain. The northern end of the Kissimmee River receives inflow from Lake Kissimmee. This is simulated in WAM by using the discharge from the lake as the inflow into WAM reach 107, which is modeled as an inflow boundary condition. The outflow at the southern end of the Kissimmee is simulated as a stage boundary condition, but since there is not a time series of stages for pre-drainage conditions the boundary is simulated as a constant stage. Because the goal of this project is to estimate nutrient loading into Lake Okeechobee, the stage was set low enough to capture all of the flow from the river without complications arising from back-water effects. This same methodology was used at all points where discharge from the hydrography network to the lake occurred.

The dominant pre-drainage land cover is Pine Palmetto Flatwoods, followed by Mixed Wetland Hardwoods and Freshwater Marshes (**Table 2**). The Kissimmee River floodplain land cover is dominated by Freshwater Marshes, while Pine Palmetto Flatwoods and Mixed Wetland Hardwoods are evenly distributed across the rest of the area. About 58% of the area is run using either EAAMod or GLEAMS, although since high water table soils are predominant, EAAMod is used to simulate the majority (57%) of the area. The remaining area is simulated using the Special Case model (**Table 14**).

Table 14. Breakdown of land cover acreages as run by source cell model in the Lower Kissimmee sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods	2,727	241,729	
Hardwoods		231	
Hardwood Conifer Mixed	50	4,115	
Open Water			3,876
Mixed Wetland Hardwoods			90,935
Cypress			373
Wetland Forested Mixed			2,636
Freshwater Marshes			82,412
Percent of Total	1%	57%	42%

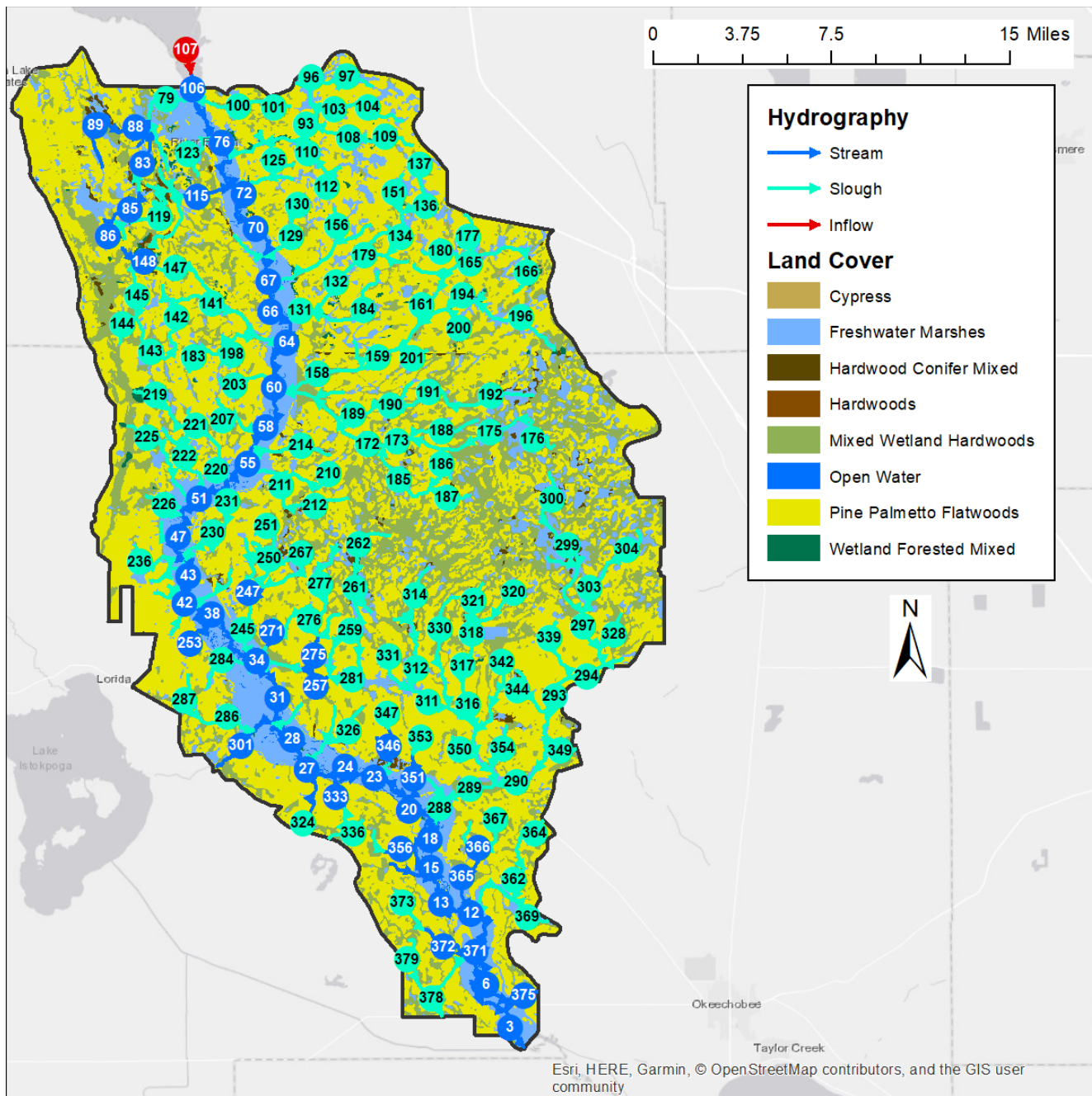


Figure 29. Land cover and hydrography (reach numbers labeled) for the Lower Kissimmee sub-watershed.

3.2.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 30 – 33**. Because of the large amounts of high water table soils, direct percolation to groundwater accounts for about 2% of water leaving source cells. However as before, some runoff water is routed to landscape depressions where it will infiltrate to groundwater. Nutrient loads are dominated by contributions from Pine Palmetto Flatwoods, followed by Mixed Wetland Hardwoods and Freshwater Marshes.

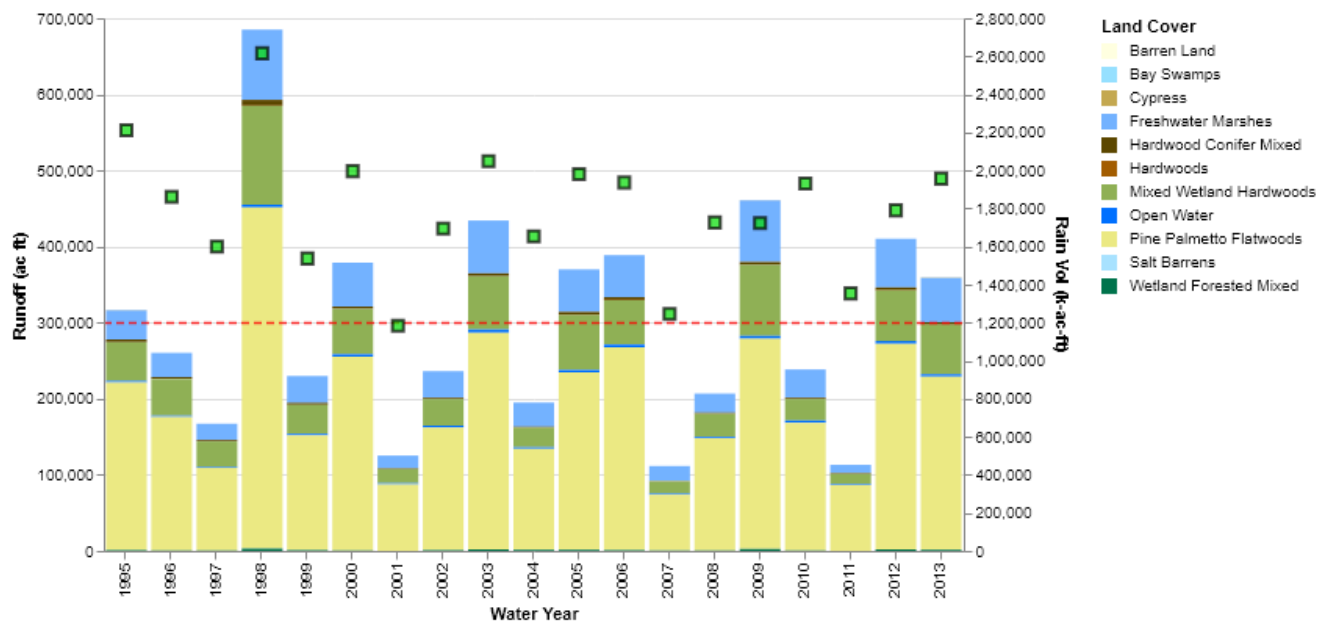


Figure 30. Source cell runoff per year in the Lower Kissimmee sub-watershed.

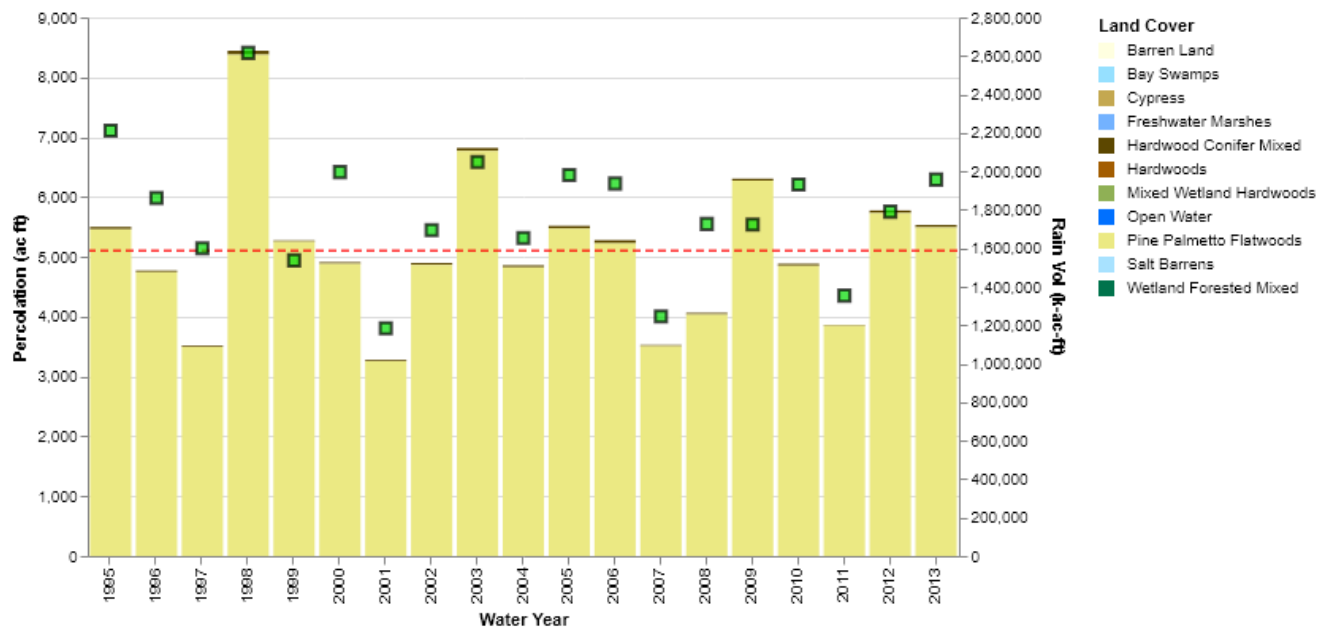


Figure 31. Source cell percolation per year in the Lower Kissimmee sub-watershed.

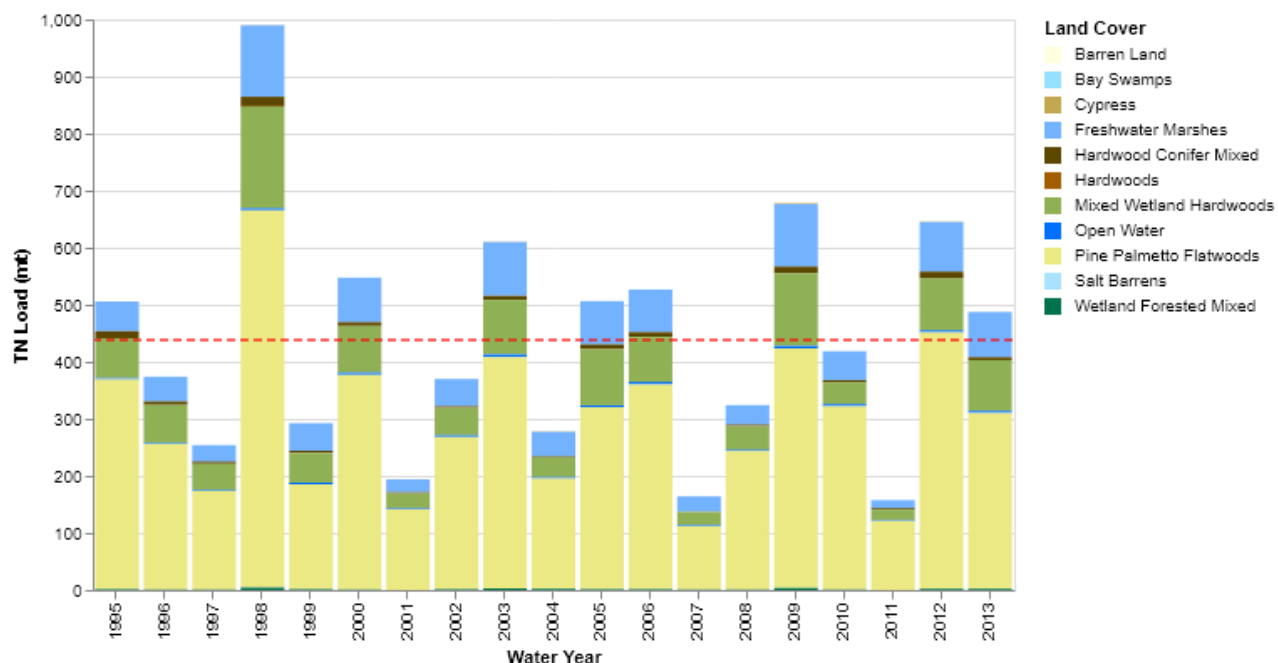


Figure 32. Source cell TN loadings per year in the Lower Kissimmee sub-watershed.

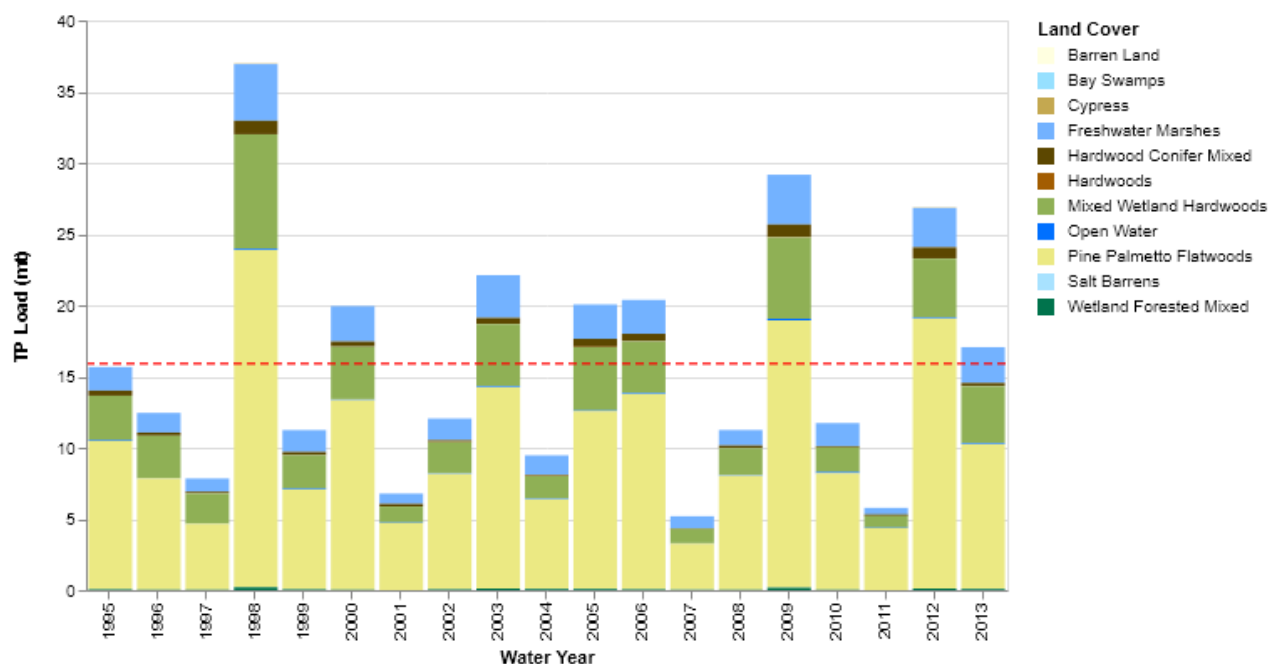


Figure 33. Source cell TP loadings per year in the Lower Kissimmee sub-watershed.

3.2.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge from the Kissimmee River into Lake Okeechobee reflects the inflow of water and nutrients from the Upper Kissimmee sub-watershed as well as the contributions from land within the Lower Kissimmee sub-watershed. The simulated discharge (in m³/s) leaving the sub-watershed at the

southern end of the Kissimmee River is shown in **Figure 34**. The annual average discharge was slightly over 36 m³/s, corresponding to the annual average volume of over 929,000 acre-feet per year. Peak discharge occurred during 2004, 2008, and 2011.

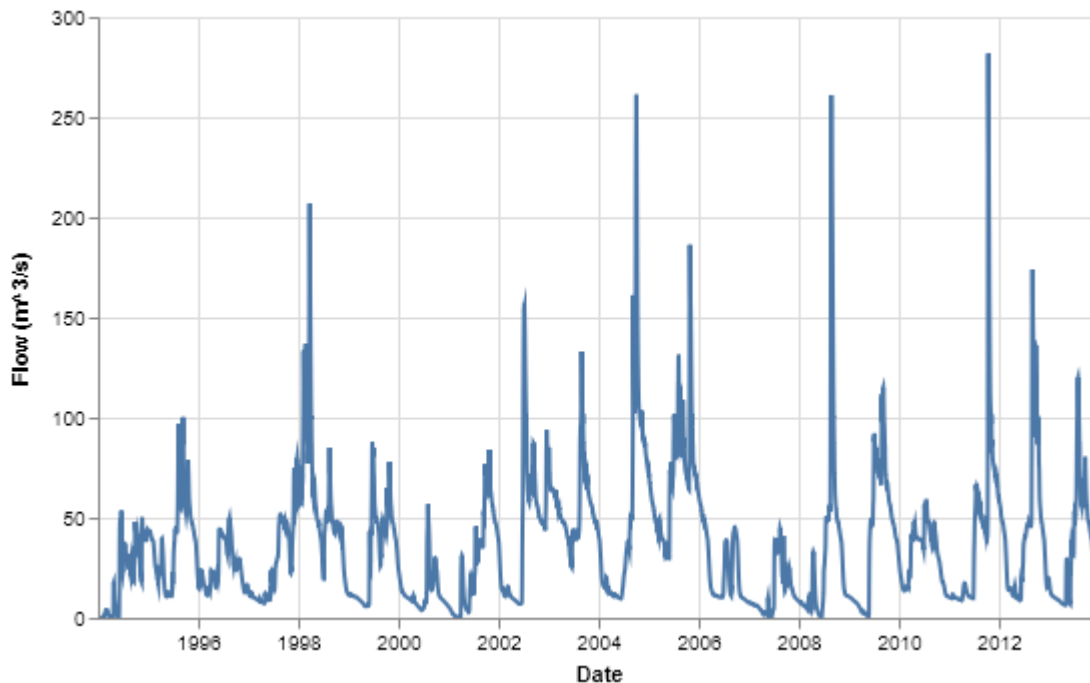


Figure 34. Simulated daily discharge from the Kissimmee River to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 35** and **36**, respectively. The flow-weighted average TN concentration over the entire period was 1.069 mg/L (**Table 11**) with most of the concentrations in the range of 1.0 – 1.2 mg/L, with peaks slightly over 1.2 mg/L and strong dips down to around 0.4 mg/L in 2001 and 2009. The flow-weighted TP concentration over the entire period was 0.035 mg/L with the bulk of the concentrations in the range of 0.03 – 0.05 mg/L, but also showing dips below 0.01 mg/L in 2001 and 0.015 mg/L in 2009. The dips in both TN and TP occur during low-flow periods, when most of the water entering the river is from groundwater with strongly attenuated TN and TP concentrations. This is due to a combination of direct contribution from source cells to groundwater as well as from overland flow into depressions that in turn contribute to groundwater. Since these transient spikes occur during low-flow periods, there is little change to the overall loading to Lake Okeechobee.

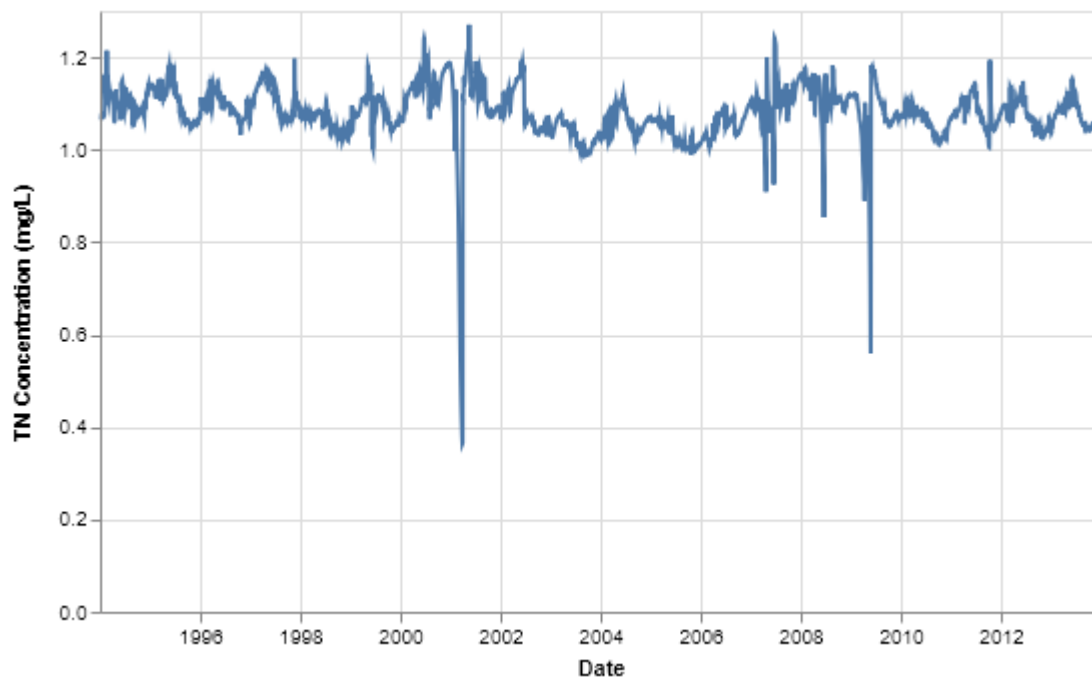


Figure 35. Simulated daily TN concentrations entering Lake Okeechobee from the Kissimmee River.

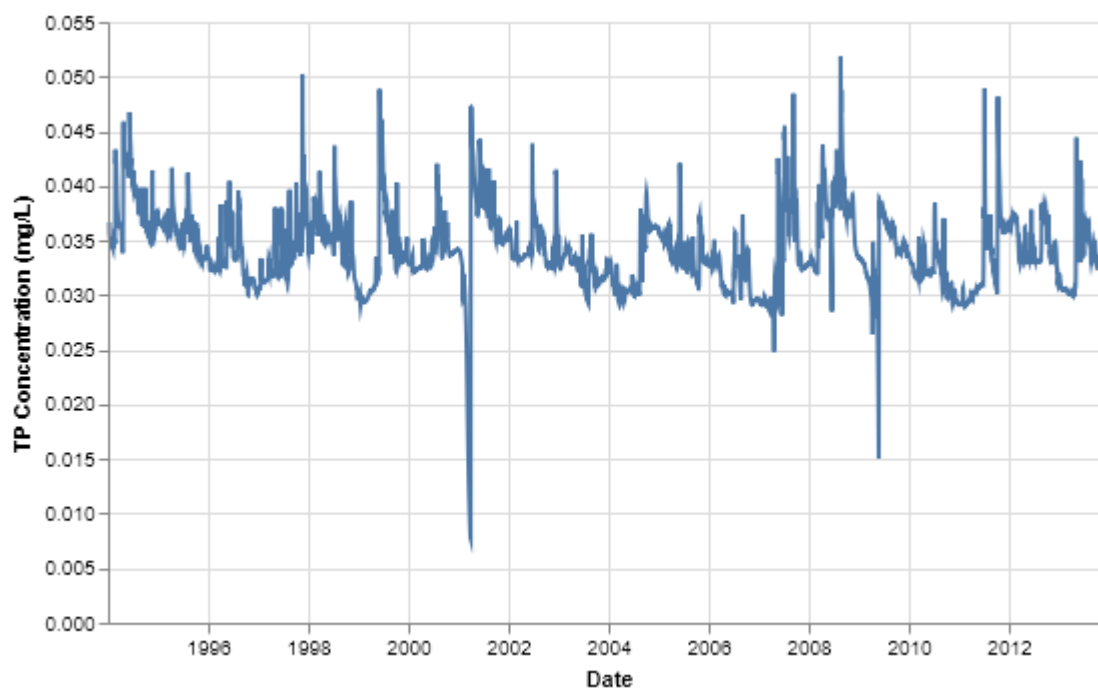


Figure 36. Simulated daily TP concentrations entering Lake Okeechobee from the Kissimmee River.

3.3 Lake Istokpoga

The Lake Istokpoga sub-watershed lies on the west-central portion of the area covered by the six sub-watersheds, between Upper Kissimmee and Fisheating Creek, and contains a sizeable portion of the Lake Wales Ridge along its western edge (**Figure 37**). The sub-watershed is nearly 394,160 acres in area. It is bordered by the Indian Prairie model domain on its southern end. The main outflow from the sub-watershed is at the southern end of Lake Istokpoga (now the S-68 structure). The discharge point is an inflow boundary to the Indian Prairie sub-watershed. The discharge is simulated as a broad-crested weir at the boundary between WAM reaches 2 (Lake Istokpoga) and reach 1 which is meant to represent overflow from the lake into a broad slough. The weir crest elevation is set to 38.4 feet (11.7 meters) (NGVD) and the width is set to 197 feet (60 meters).

The dominant pre-drainage land cover is Pine Palmetto Flatwoods, followed by Hardwood/Conifer Mixed, Mixed Wetland Hardwoods and Open Water (**Table 2**). A small amount of Barren Land is present around some lake shorelines. About 56% of the area is run using either EAAMod or GLEAMS, with the higher, well-drained terrain along the Lake Wales Ridge simulated using GLEAMS, and the eastern part of the sub-watershed with high water table soils simulated with EAAMod. About 30% of the area is run using the Special Case model, while the remaining 14% is direct contribution of rainfall to lakes within the reach network (**Table 15**).

Table 15. Breakdown of land cover acreages as run by source cell model in the Lake Istokpoga sub-watershed. Note no source cell model is run on the "Lakes" land cover, since rainfall is passed directly through to the stream network.

Land Cover	GLEAMS	EAAMod	Special Case	None
Pine Palmetto Flatwoods	48,492	94,148		
Hardwoods	9,597	712		
Hardwood Conifer Mixed	64,272	3,102		
Open Water			1,870	
Bay Swamps			3	
Mixed Wetland Hardwoods			59,052	
Cypress			33	
Wetland Forested Mixed			17,682	
Freshwater Marshes			40,234	
Barren Land	1,028			
Lakes				53,933
Percent of Total	31%	25%	30%	14%

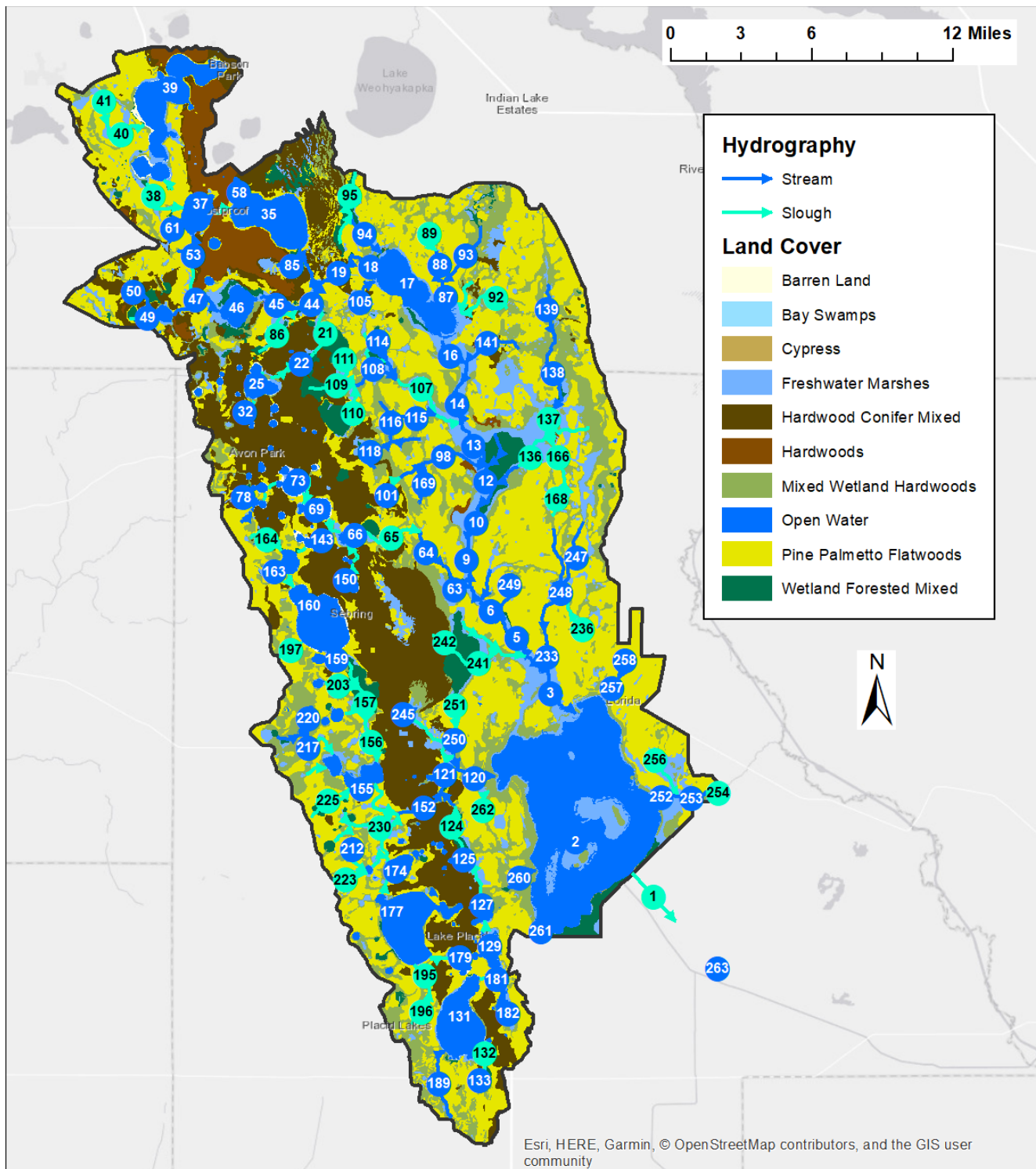


Figure 37. The Lake Istokpoga sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.3.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 38 – 41**. Overall, percolation to groundwater directly from source cells is about 60% of the total discharge from the cells.

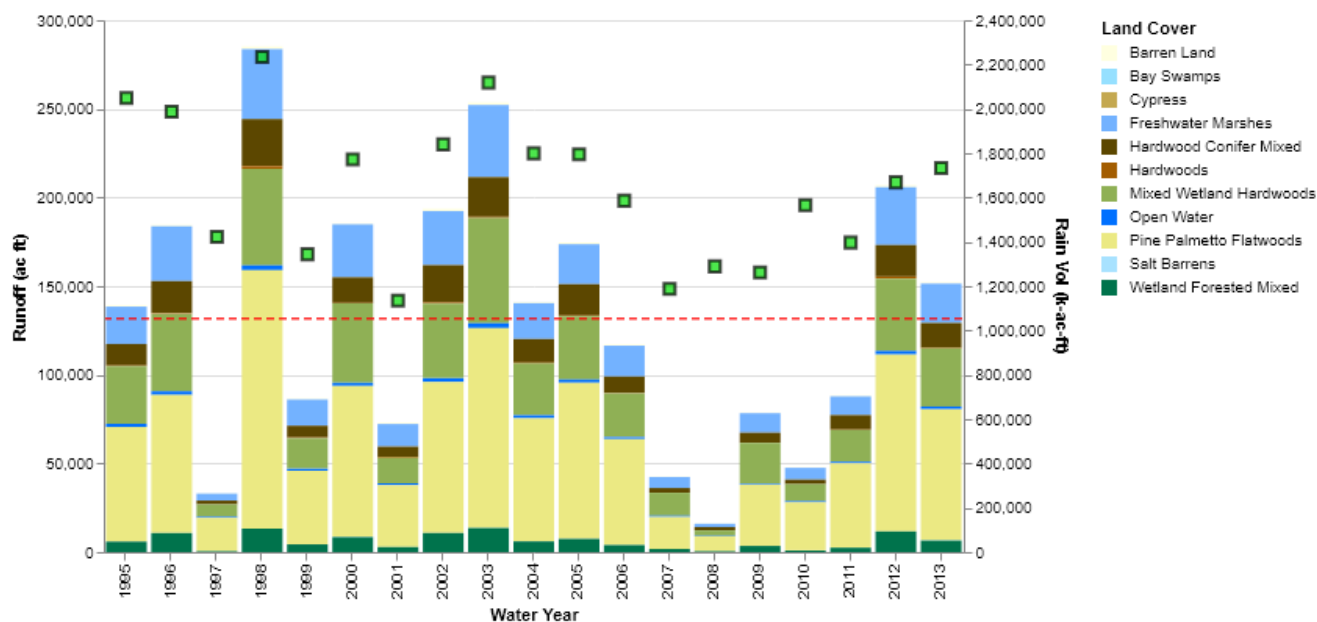


Figure 38. Source cell runoff per year in the Lake Istokpoga sub-watershed.

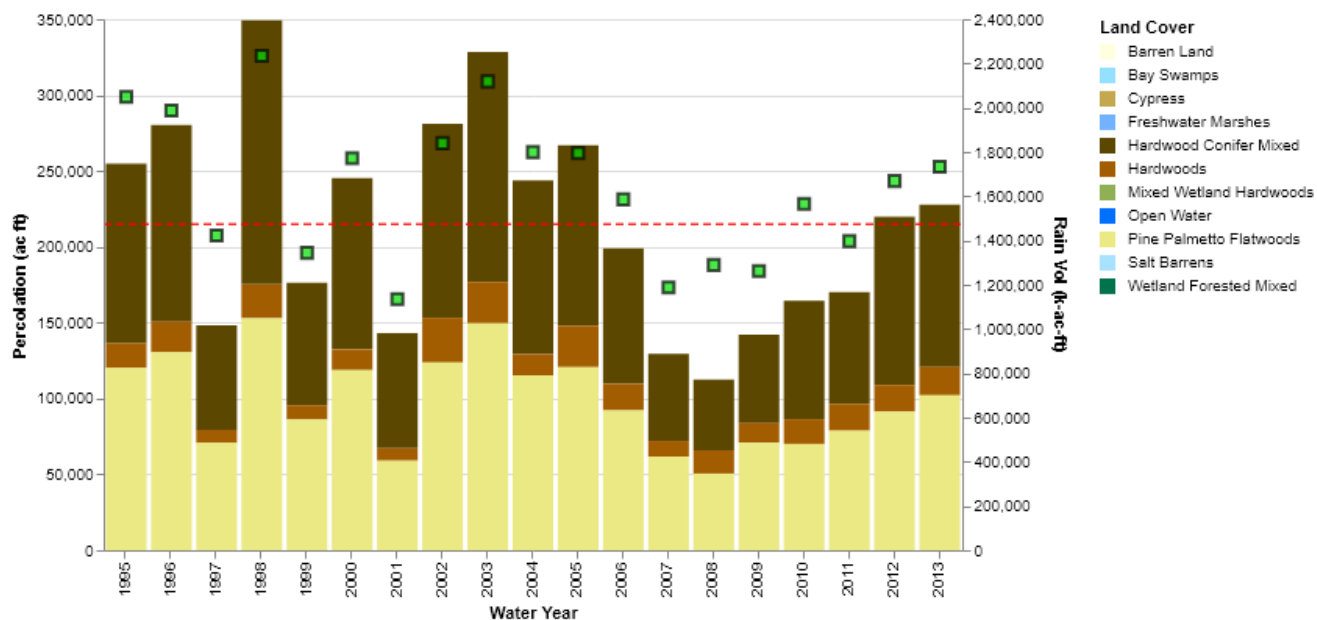


Figure 39. Source cell percolation per year in the Lake Istokpoga sub-watershed.

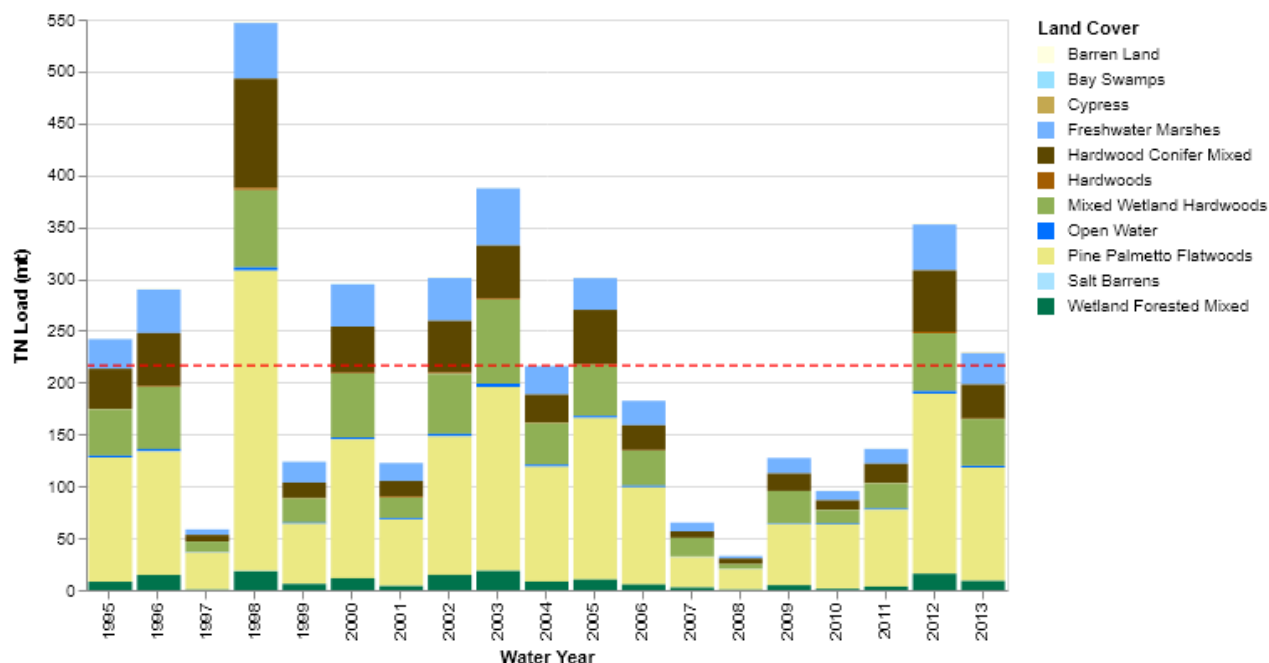


Figure 40. Source cell TN loadings per year in the Lake Istokpoga sub-watershed.

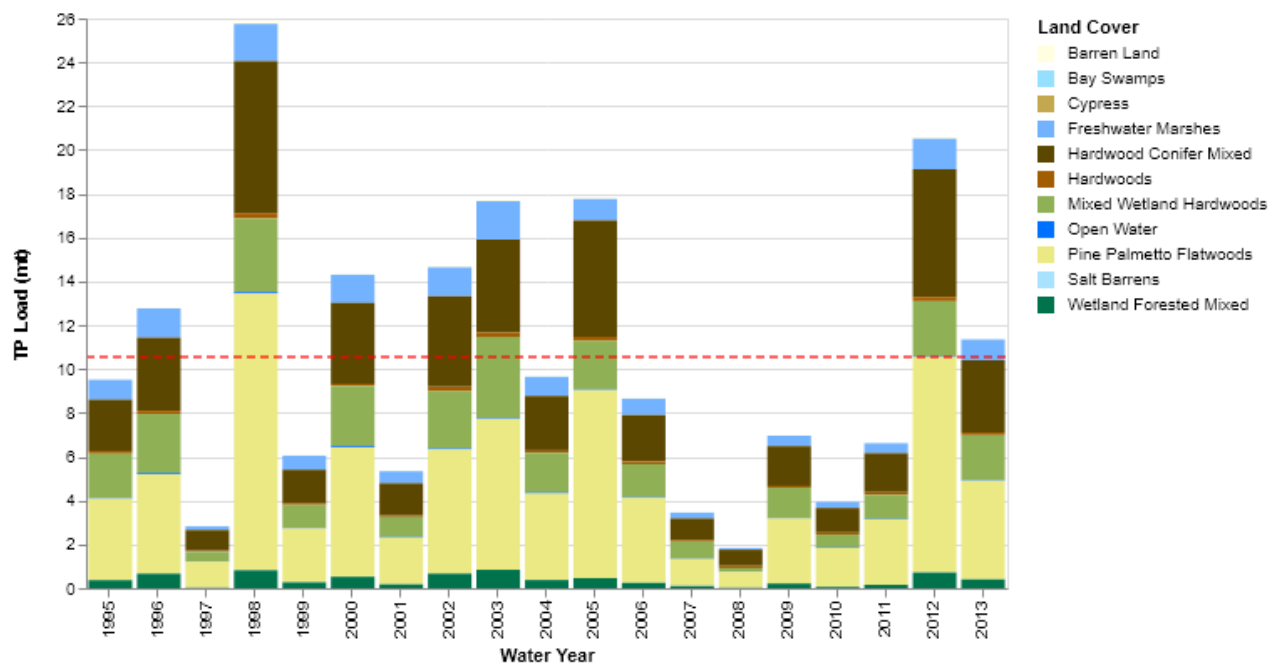


Figure 41. Source cell TP loadings per year in the Lake Istokpoga sub-watershed.

3.3.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) leaving the sub-watershed at the southern end of Lake Istokpoga is shown in **Figure 42**. The annual average discharge was slightly over $12 \text{ m}^3/\text{s}$, corresponding to the annual average volume of nearly 316,000 acre-feet per year. Peak discharge occurred during 2002, with other peak periods in late 1995, 1999, and 2011-2013.

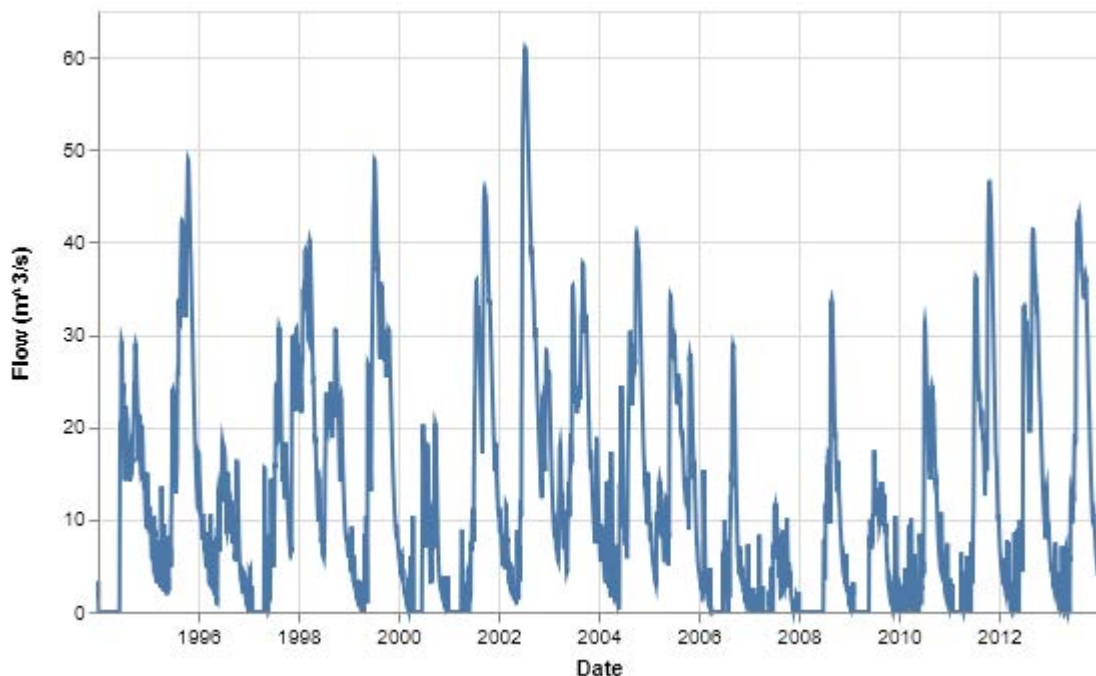


Figure 42. Simulated daily discharge from Lake Istokpoga.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 43 and 44**, respectively. The flow-weighted average TN concentration over the entire period was 0.97 mg/L (**Table 11**) with most of the concentrations in the range of 0.9 – 1.2 mg/L, with peaks slightly over 1.2 mg/L during low-flow periods. The flow-weighted TP concentration over the entire period was 0.03 mg/L with the bulk of the concentrations in the range of 0.027 – 0.035 mg/L.

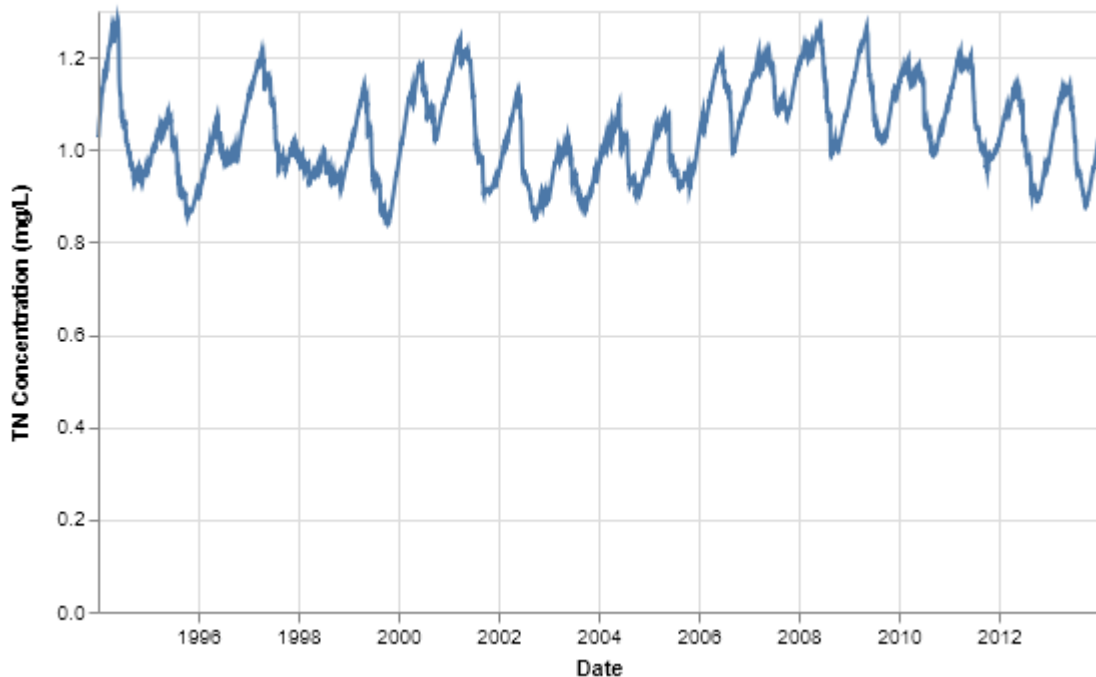


Figure 43. Simulated daily TN concentrations leaving Lake Istokpoga.

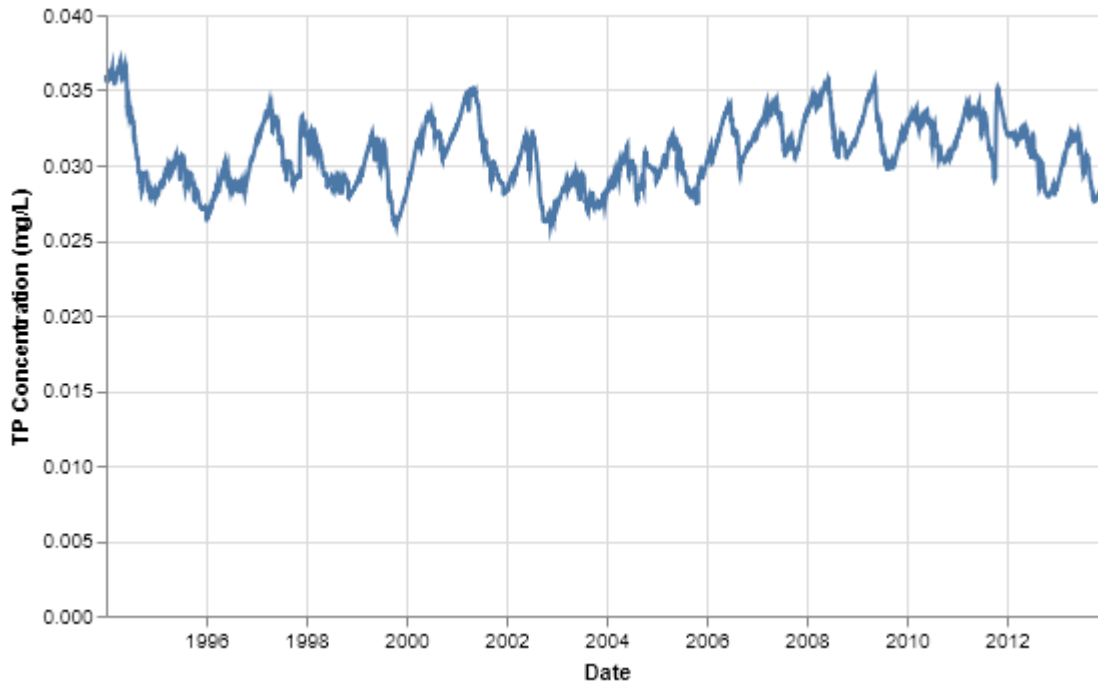


Figure 44. Simulated daily TP concentrations leaving Lake Istokpoga.

3.4 Indian Prairie

The Indian Prairie sub-watershed is located in the south-central portion of the six northern sub-watersheds, lying south of the Lake Istokpoga and Lower Kissimmee model domains and immediately north of Lake Okeechobee (**Figure 45**). The sub-watershed is approximately 276,400 acres in area. In the current state, the Indian Prairie sub-watershed has undergone extensive channelization, with the primary canals running from the discharge point at Lake Istokpoga south-eastward and splitting at several points before discharging into Lake Okeechobee and the Kissimmee river.

For the pre-drainage simulations, the inflow to the Indian Prairie sub-watershed from Lake Istokpoga is modeled as occurring across a broad slough at WAM reach 155. The flow across the landscape is similarly modeled as occurring across a set of broad sloughs that split and recombine at several points. The discharge into Lake Okeechobee is distributed across 14 reaches (3, 23, 38, 83, 109, 120, 127, 143, 146, 150, 151, 152, 153, 154) that are routed into a single collection reach (not shown in **Figure 45**) which subsequently flows into Lake Okeechobee. This step is done for accounting purposes and enables a single discharge to be calculated from the sub-watershed into the lake. No attenuation processes occur within the collection reach.

The dominant land cover is Mixed Wetland Hardwoods, followed by Freshwater Marshes and Pine Palmetto Flatwoods. In contrast to the sub-watersheds discussed above, only about 30% of the domain is simulated by EAAMod (25%) or GLEAMS (5%), with the remaining 70% simulated using the Special Case sub-model (**Table 16**).

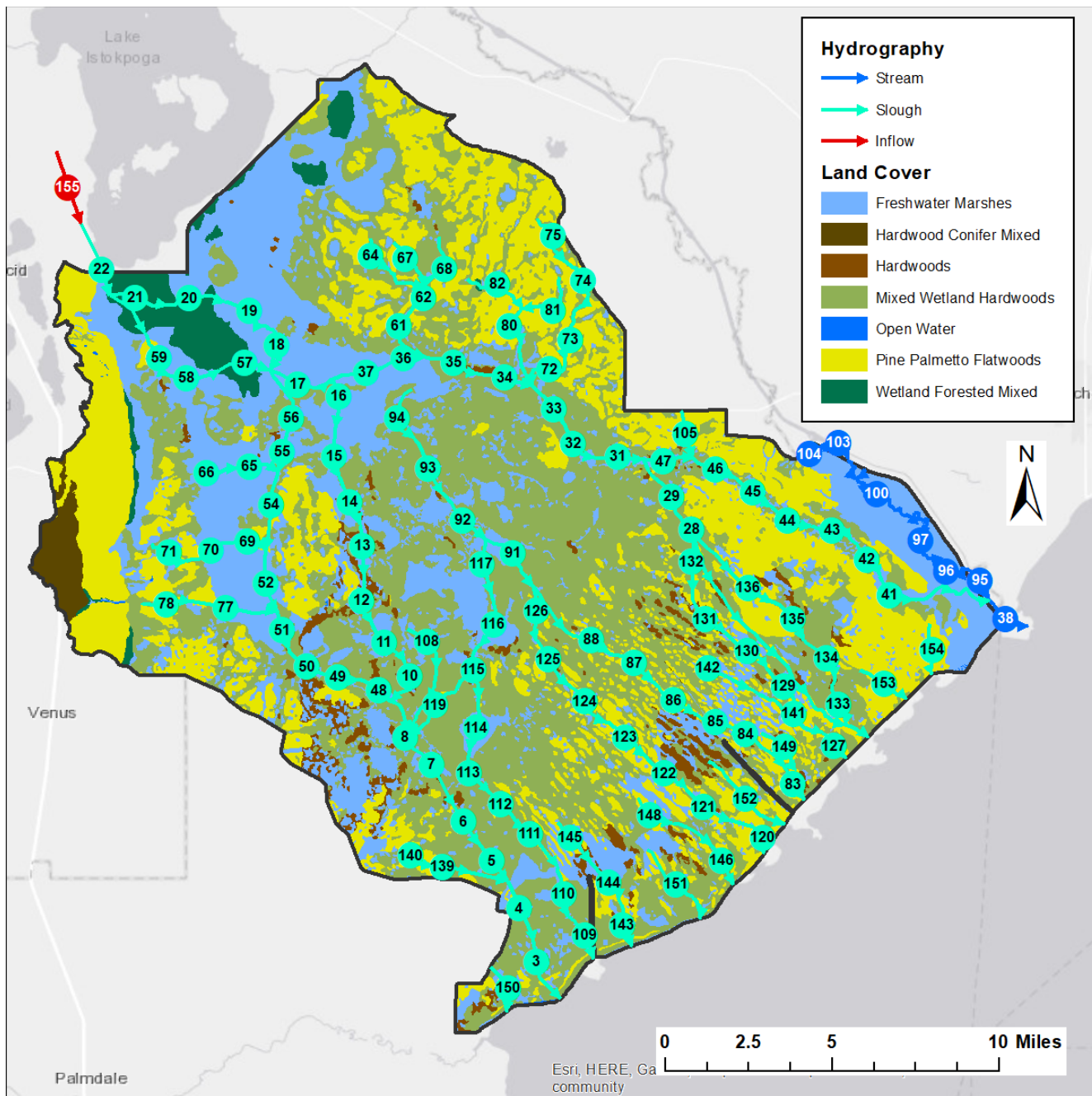


Figure 45. The Indian Prairie sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.4.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 46 - 49**. Direct percolation to groundwater accounts for about 24% of water leaving source cells. However as with other sub-watersheds dominated by high water table soils, some runoff water is routed to landscape depressions where it infiltrates to groundwater. Nutrient loads are dominated by contributions from Mixed Wetland Hardwoods, followed by Freshwater Marshes and Pine Palmetto Flatwoods.

Table 16. Breakdown of land cover acreages as run by source cell model in the Indian Prairie sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods	9,937	62,601	
Hardwoods		7,107	
Hardwood Conifer Mixed	2,501	9	
Open Water			427
Mixed Wetland Hardwoods			113,147
Wetland Forested Mixed			6,677
Freshwater Marshes			74,004
Percent of Total	5%	25%	70%

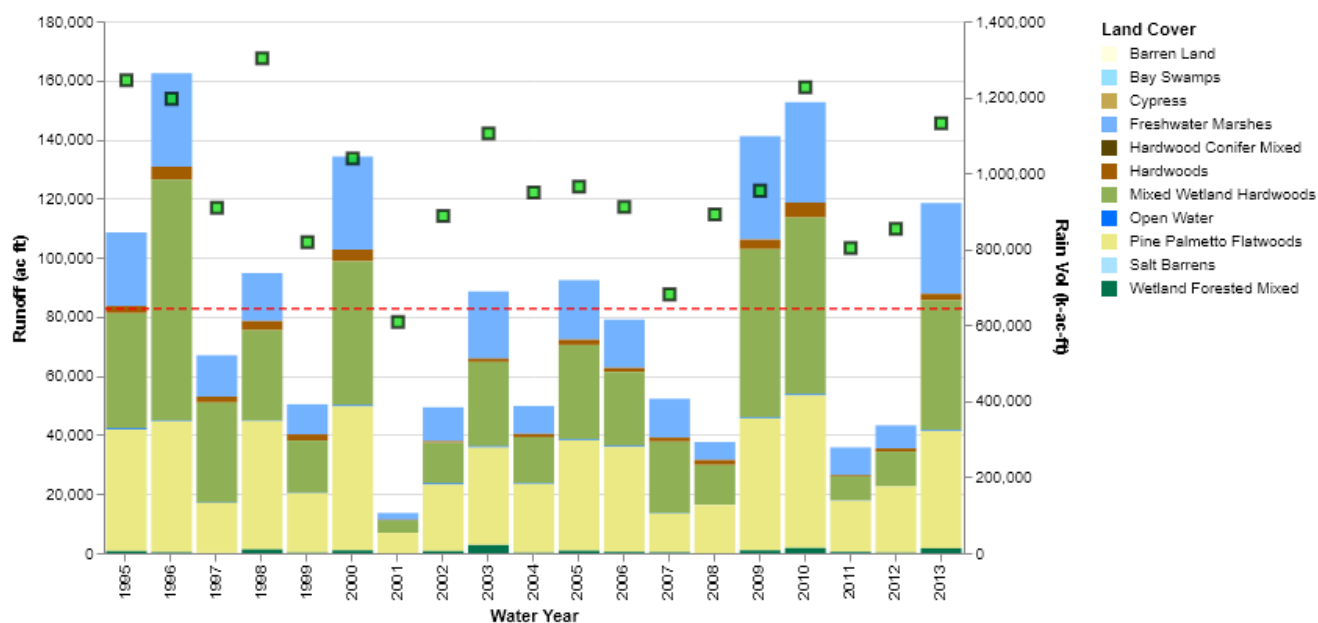


Figure 46. Source cell runoff per year in the Indian Prairie sub-watershed

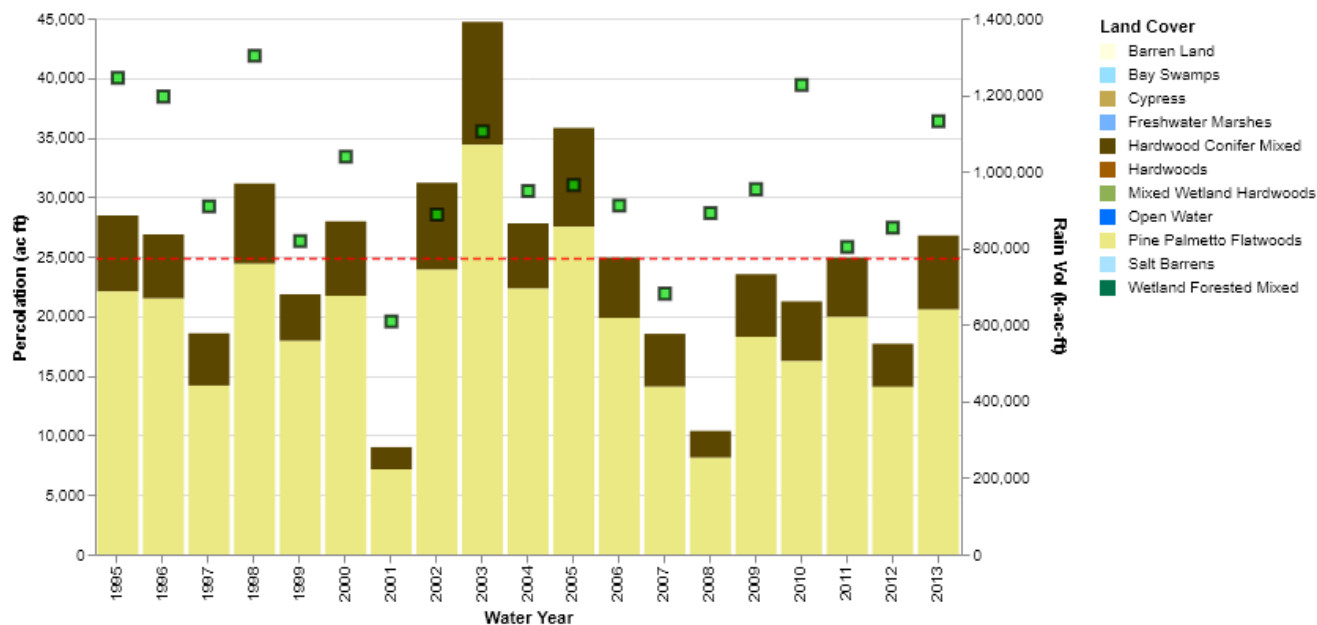


Figure 47. Source cell percolation per year in the Indian Prairie sub-watershed.

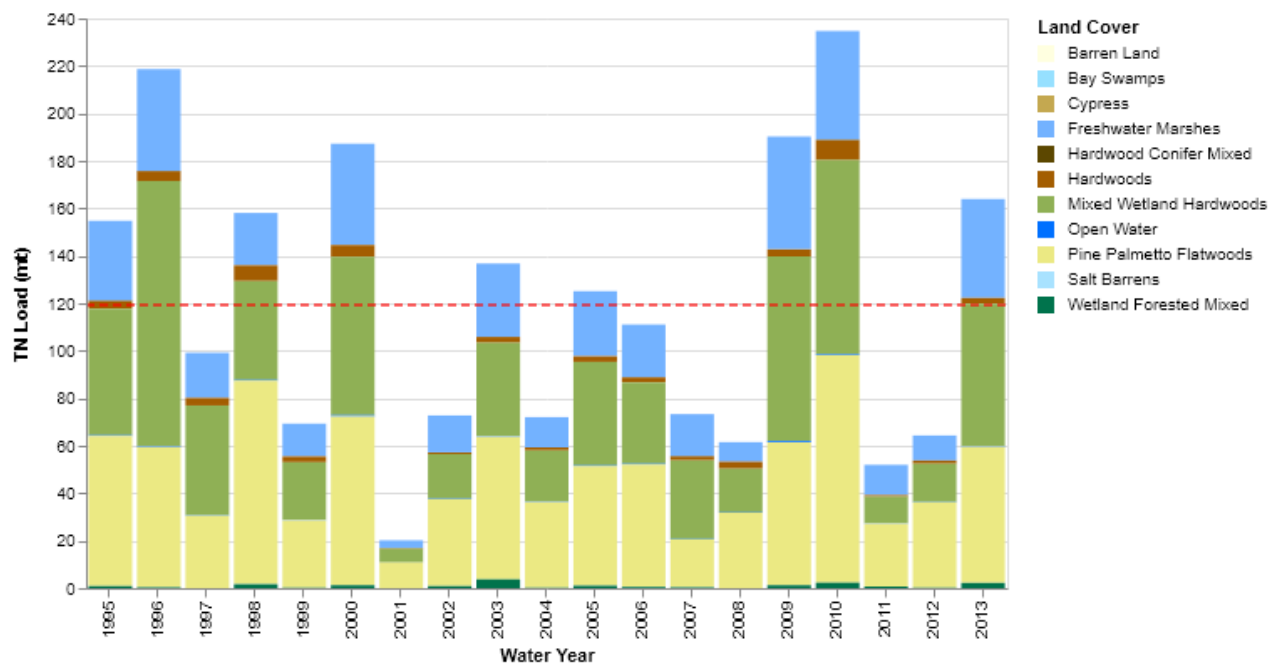


Figure 48. Source cell TN loadings per year in the Indian Prairie sub-watershed.

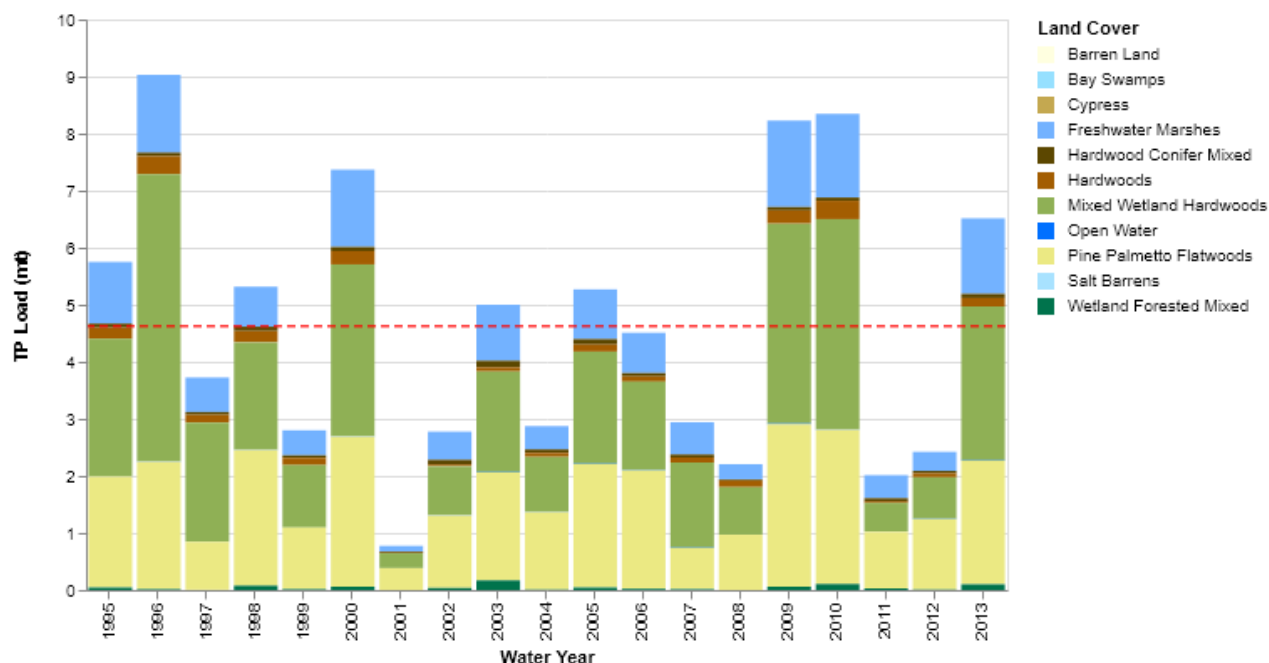


Figure 49. Source cell TP loadings per year in the Indian Prairie sub-watershed.

3.4.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge from Indian Prairie into Lake Okeechobee reflects the inflow of water and nutrients from the Lake Istokpoga sub-watershed as well as the contributions from land within the Indian Prairie sub-watershed. The simulated discharge (in m^3/s) leaving the sub-watershed at the boundary with Lake Okeechobee is shown in **Figure 50**. The annual average discharge was slightly over $16 \text{ m}^3/\text{s}$, corresponding to the annual average volume of over 428,000 acre-feet per year. Peak discharge occurred in late 1995, 1999, and 2008.

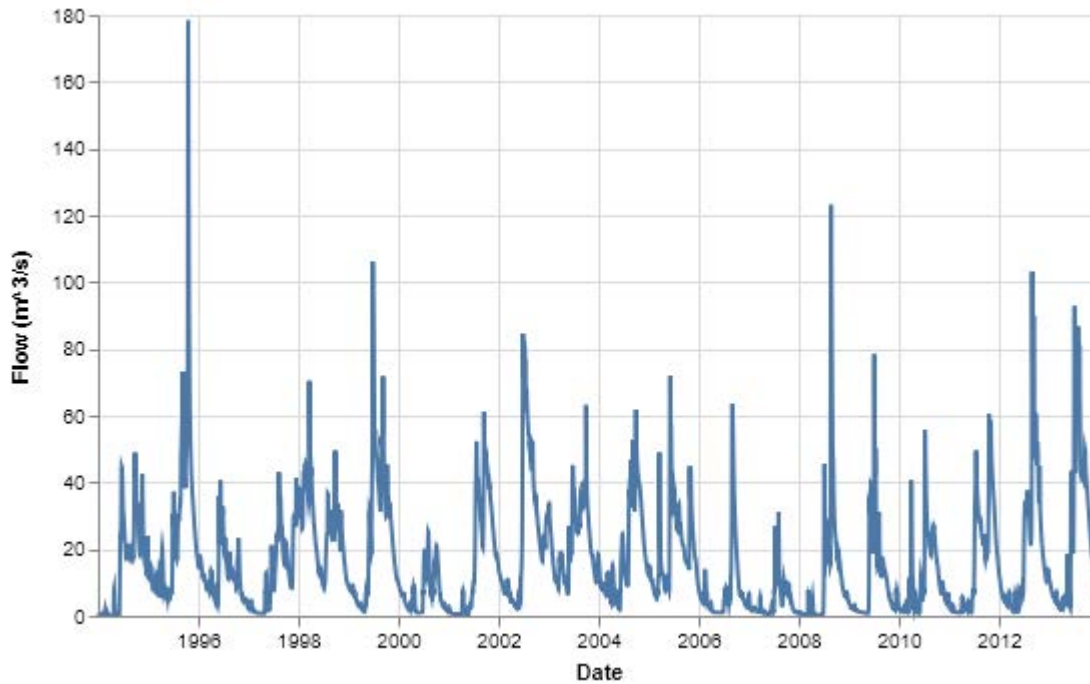


Figure 50. Simulated daily discharge from Indian Prairie to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 51 and 52**, respectively. The flow-weighted average TN concentration over the entire period was 1.016 mg/L (**Table 11**) with most of the concentrations in the range of 0.8 – 1.2 mg/L, with a few dips below 0.8 mg/L in early 1999 and late 2006. The flow-weighted TP concentration over the entire period was 0.032 mg/L with the concentrations oscillating in the range of 0.02 – 0.04 mg/L. As with the nutrient concentration discharging from the Lower Kissimmee sub-watershed, the dips in both TN and TP occur during low-flow periods, indicating a significant contribution from groundwater with attenuated TN and TP concentrations during those periods.

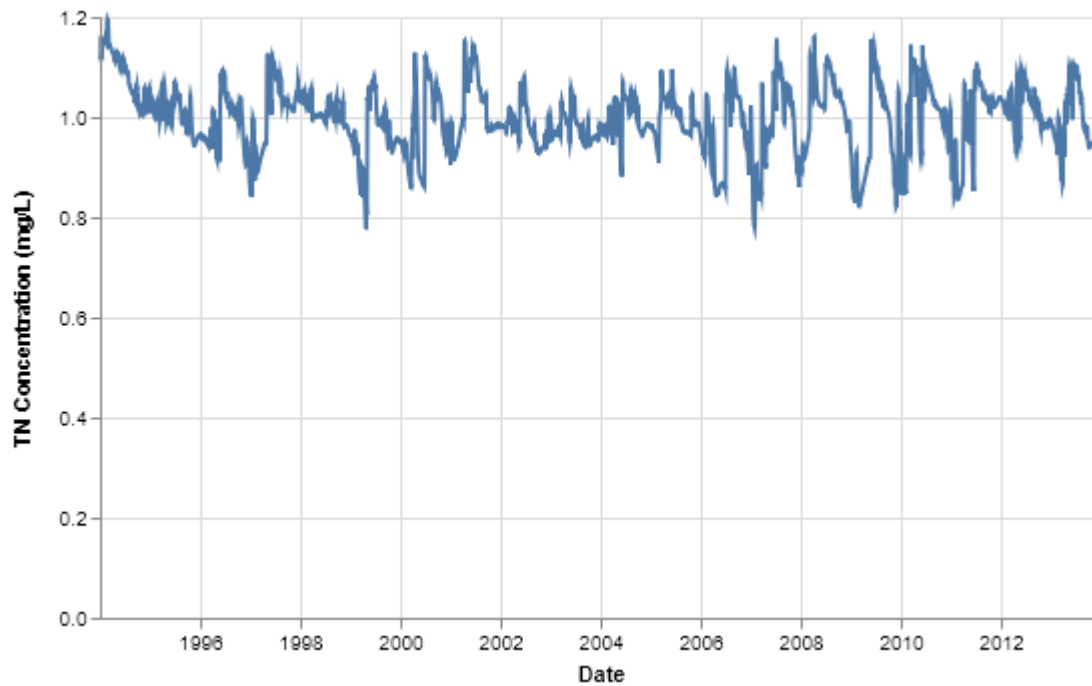


Figure 51. Simulated daily TN concentrations entering Lake Okeechobee from Indian Prairie.

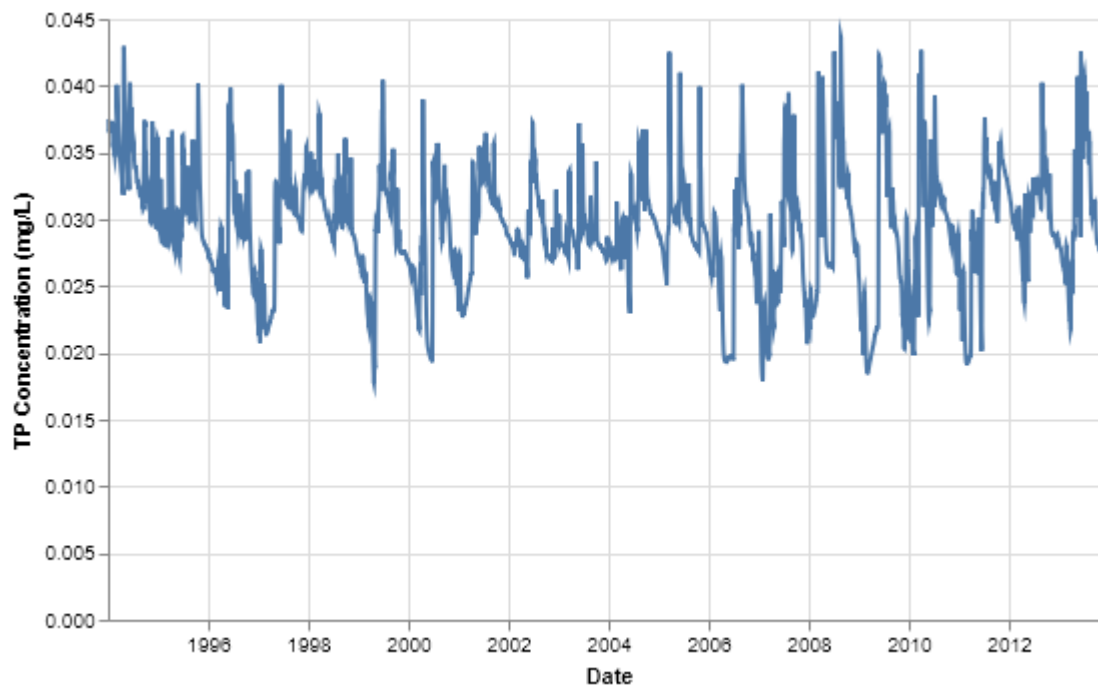


Figure 52. Simulated daily TP concentrations entering Lake Okeechobee from Indian Prairie.

3.5 Fisheating Creek

The FEC sub-watershed is located on the southwestern side of the six northern sub-watersheds. The sub-watershed is approximately 317,500 acres in area, with the southern end of the Lake Wales Ridge

occupying the northeastern part of the sub-watershed. Fisheating Creek drains the sub-watershed, running from north to south along the northern part and making an easterly bend before discharging into Lake Okeechobee. In the current conditions, the sub-watershed is unique in that the discharge to Lake Okeechobee is uncontrolled, i.e., no gates or pumps exist at the mouth. The pre-drainage configuration of the sub-watershed has most of the water and nutrient contribution to Lake Okeechobee occurring via FEC, with two additional sloughs draining areas near the lake. Contributions from these three reaches are combined to determine simulated water and nutrient loads to the lake. The WAM model setup for FEC is shown in **Figure 53**.

The dominant pre-drainage land cover is Pine Palmetto Flatwoods, followed by Mixed Wetland Hardwoods and Freshwater Marshes (**Table 2**). The lower FEC floodplain is dominated by Freshwater Marshes, with Mixed Wetland Hardwoods predominating in the northern part of the sub-watershed, and Pine Palmetto Flatwoods distributed across the area. About 52% of the area is run using either EAAMod (48%) or GLEAMS (4%), with GLEAMS applied along the southern end of the Lake Wales Ridge, and EAAMod elsewhere (**Table 17**). The remaining 48% is run using the Special Case model.

Table 17. Breakdown of land cover acreages as run by source cell model in the FEC sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods	11,436	144,860	
Hardwoods		7,635	
Hardwoods/Conifer mixed	1,128	173	
Open Water			37
Bay Swamps			2
Mixed Wetland Hardwoods			85,187
Wetland Forested Mixed			2,590
Freshwater Marshes			64,996
Percent of Total	4%	48%	48%

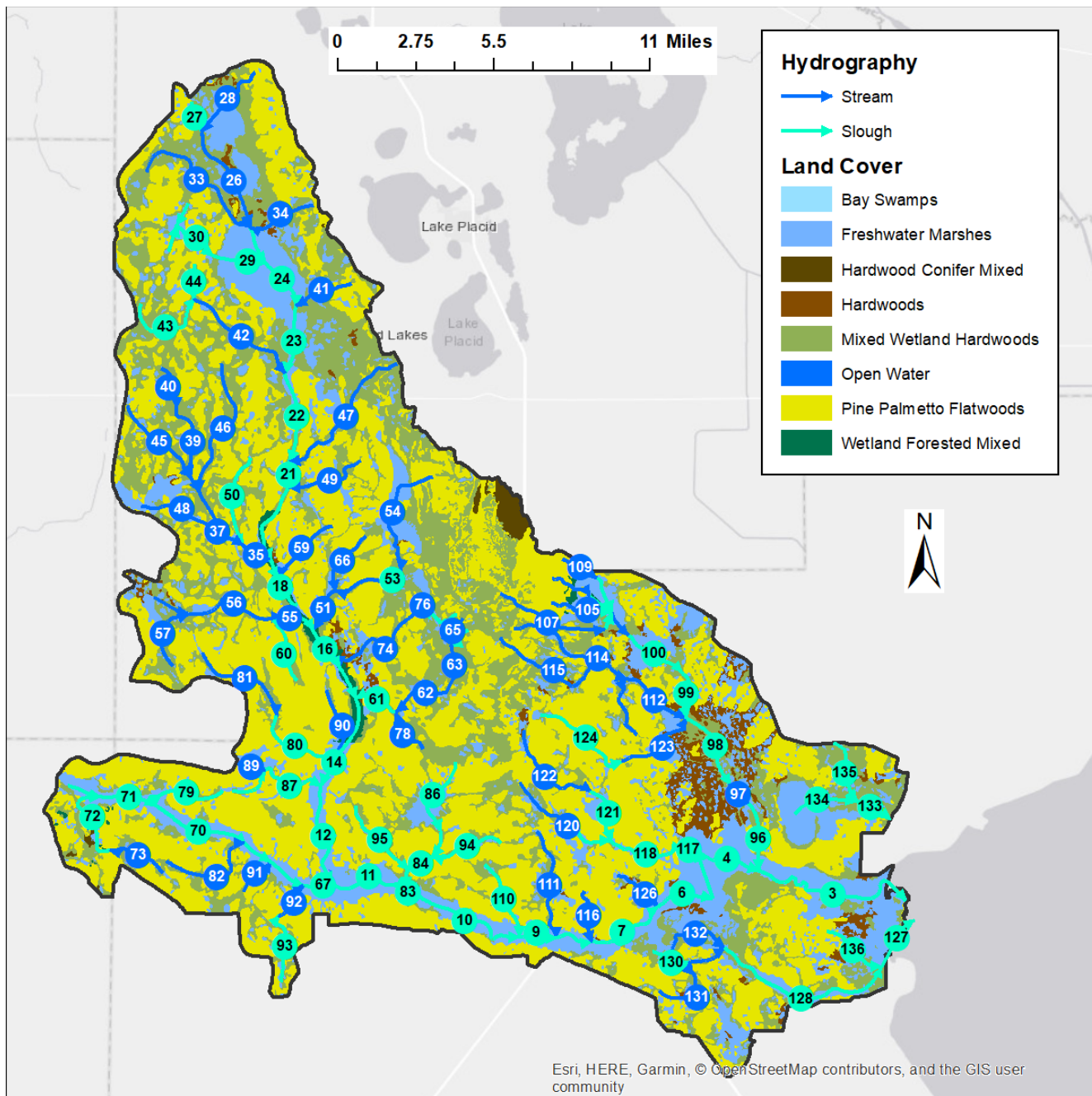


Figure 53. The FEC sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.5.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 54 – 57**. Direct percolation to groundwater accounts for about 10% of water leaving source cells. Nutrient loads are dominated by contributions from Pine Palmetto Flatwoods, followed by Mixed Wetland Hardwoods and Freshwater Marshes.

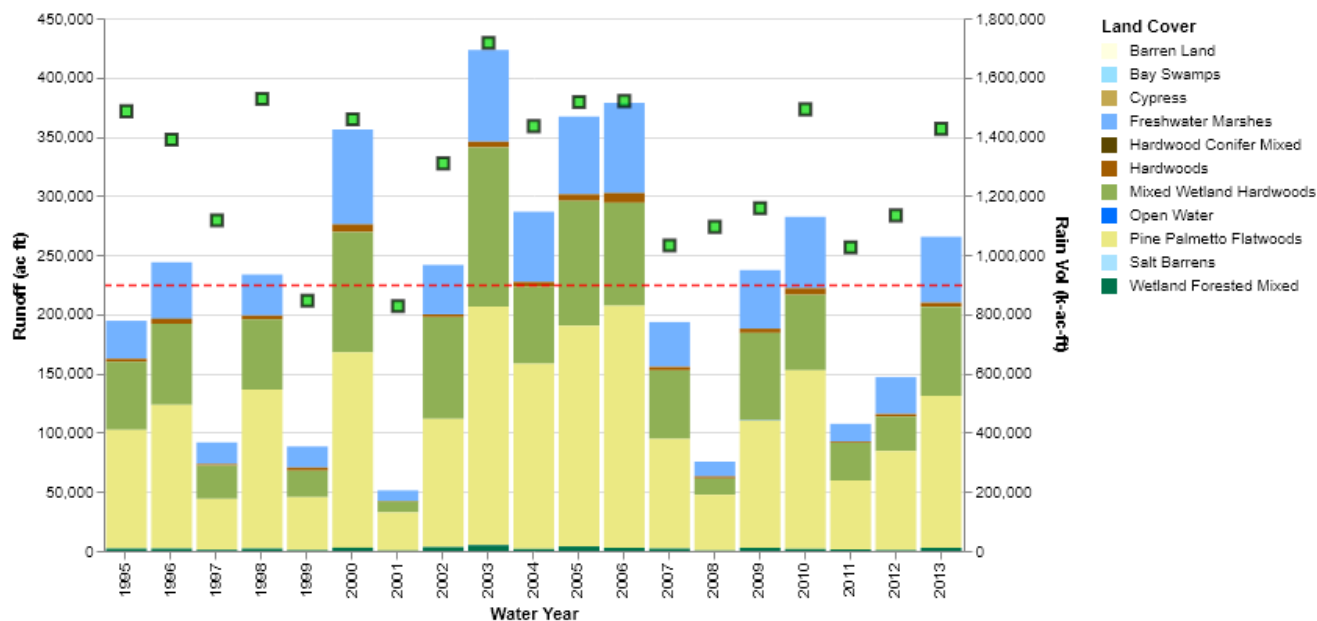


Figure 54. Source cell runoff per year in the FEC sub-watershed

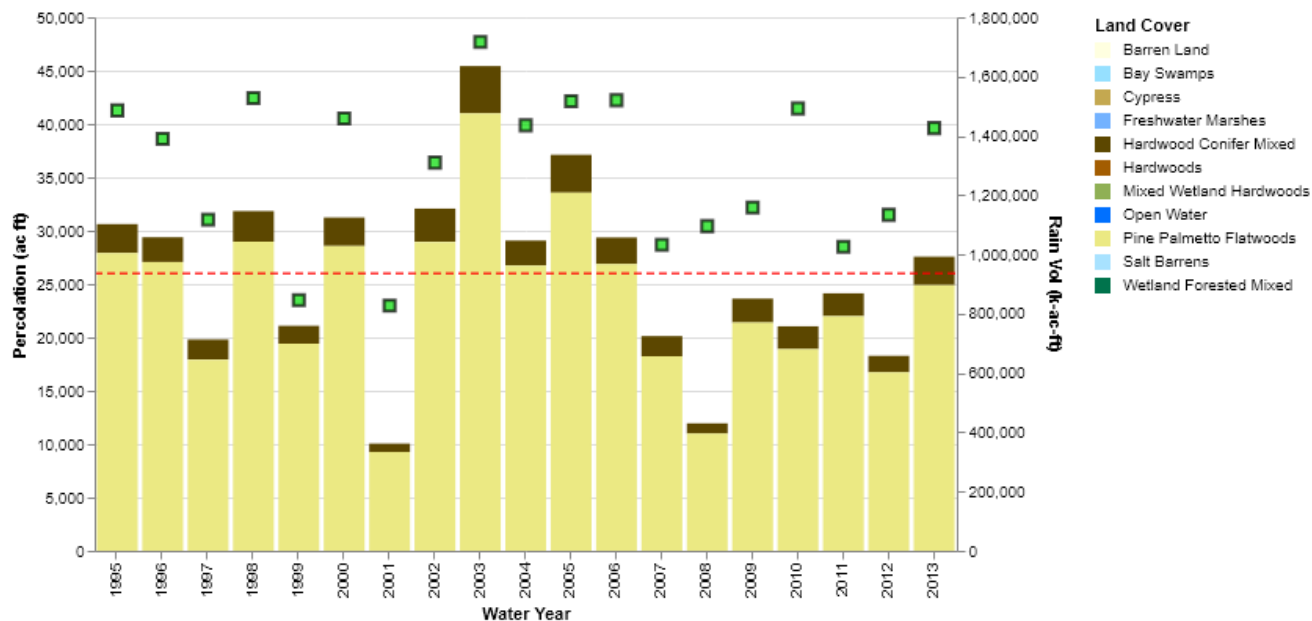


Figure 55. Source cell percolation per year in the FEC sub-watershed.

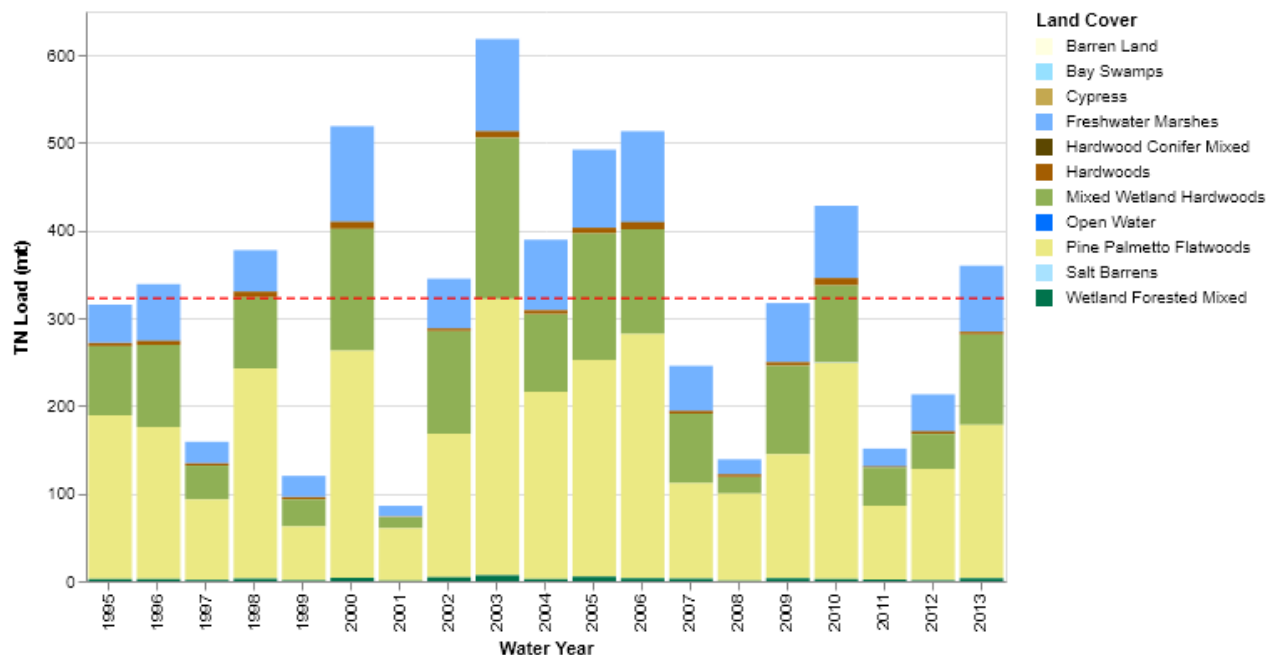


Figure 56. Source cell TN loadings per year in the FEC sub-watershed.

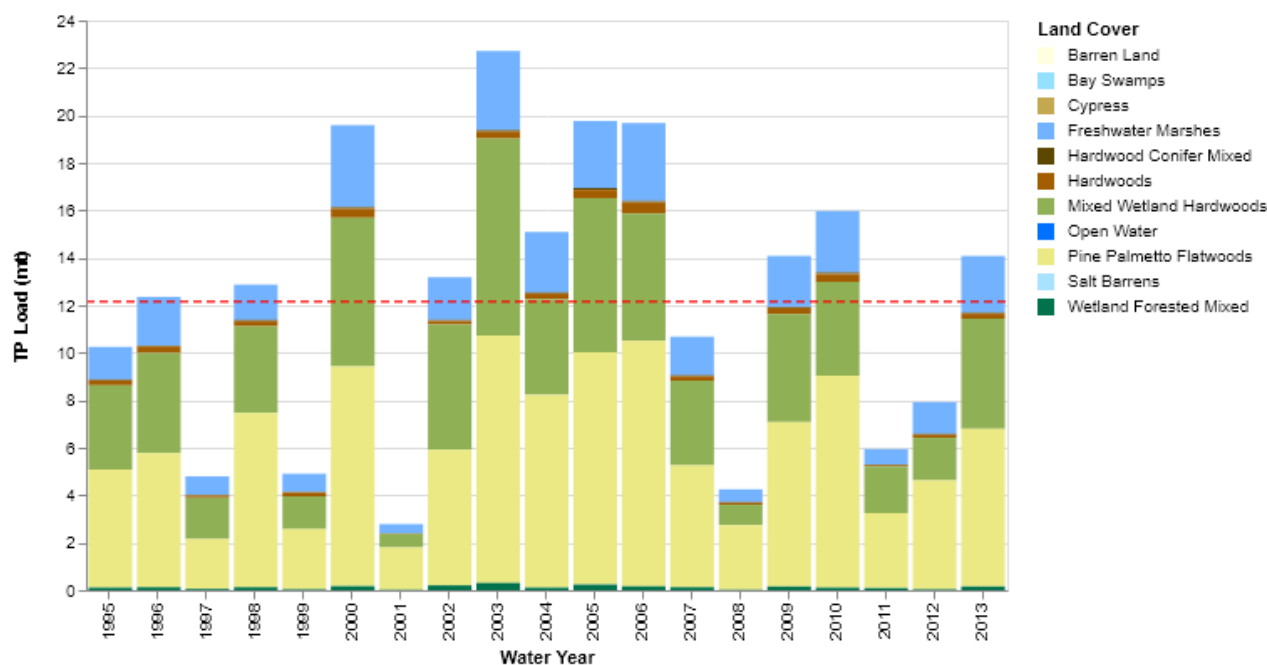


Figure 57. Source cell TP loadings per year in the FEC sub-watershed.

3.5.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) from FEC into Lake Okeechobee is shown in **Figure 58**. The annual average discharge was slightly over $10 \text{ m}^3/\text{s}$, corresponding to the annual average volume of nearly 260,000 acre-feet per year. Peak discharges tended to occur after 2001.

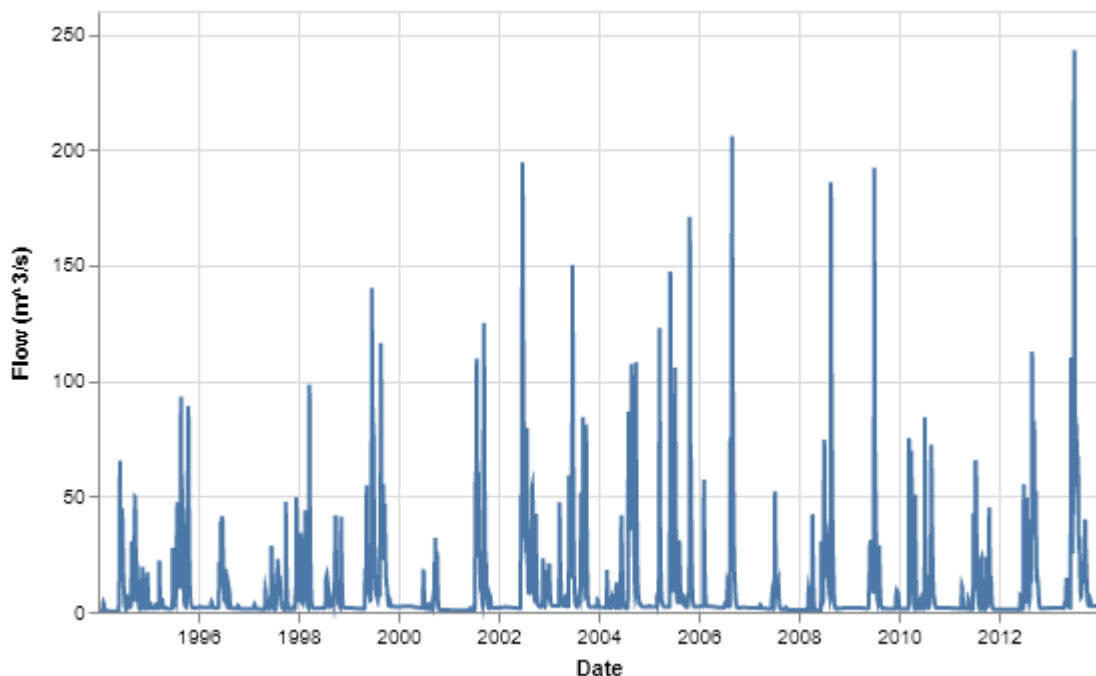


Figure 58. Simulated daily discharge from Fisheating Creek to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 59** and **60**, respectively. The flow-weighted average TN concentration over the entire period was 1.028 mg/L (**Table 11**) with most of the concentrations in the range of 0.7 – 1.1 mg/L. The flow-weighted TP concentration over the entire period was 0.038 mg/L with the bulk of the concentrations in the range of 0.02 – 0.04 mg/L. As was observed in the simulations in the other sub-watersheds, the lowest TN and TP occur during low-flow periods, when most of the water entering the river is from groundwater with attenuated TN and TP concentrations. Since these low concentrations occur during low-flow periods, there is little contribution to the overall loading to Lake Okeechobee.

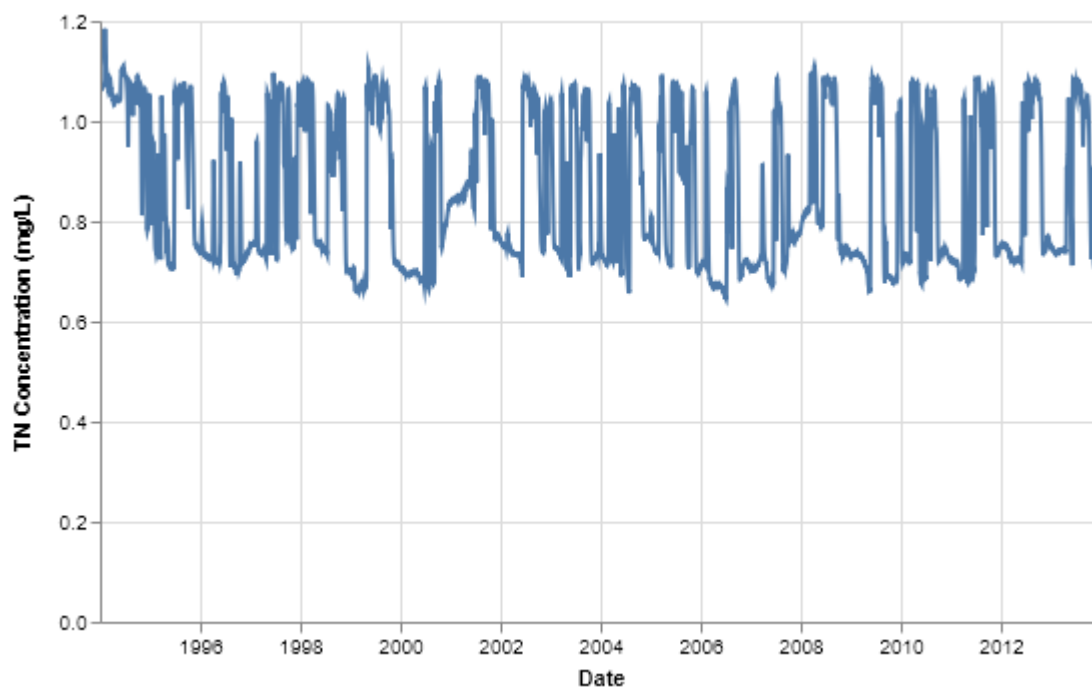


Figure 59. Simulated daily TN concentrations entering Lake Okeechobee from Fisheating Creek.

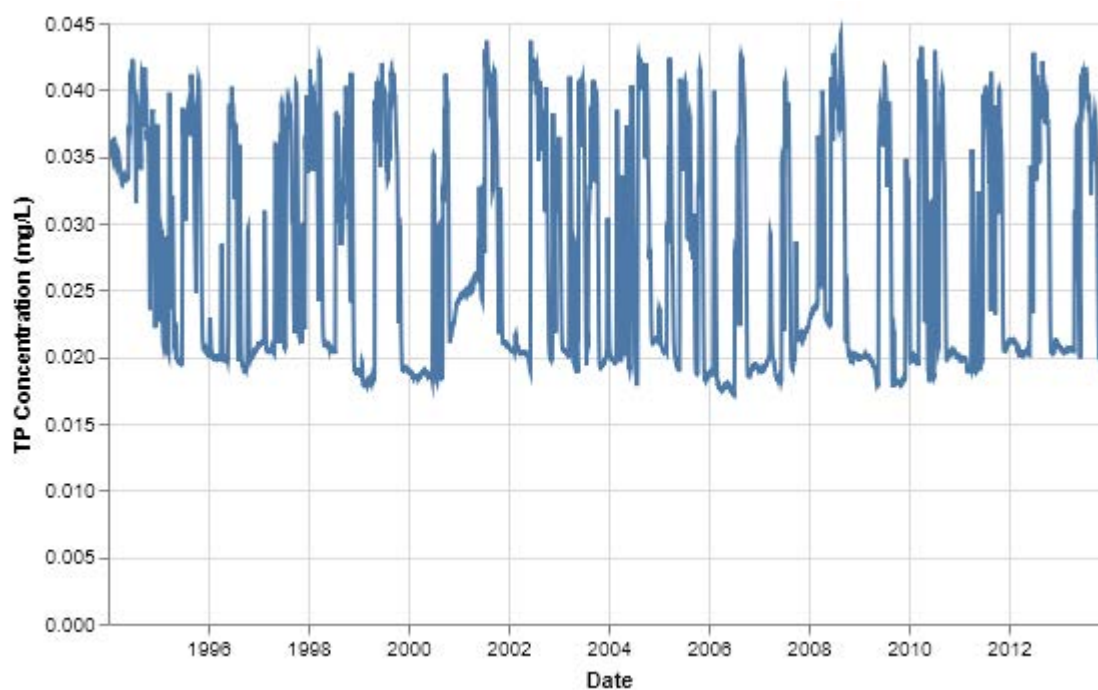


Figure 60. Simulated daily TP concentrations entering Lake Okeechobee from Fisheating Creek.

3.6 Taylor Creek/Nubbin Slough

The Taylor Creek/Nubbin Slough sub-watershed is located along the northern and north-eastern portion of Lake Okeechobee. It is approximately 197,720 acres in area (**Figure 61**). Under current conditions,

discharges to the lake are pump and gate controlled. Taylor Creek drains the north-central part of the model domain, while Nubbin Slough drains the eastern portion. The southern part of the sub-watershed has simulated inflows from the East sub-watershed at WAM reaches 91, 92, 93, and 94. As with the Indian Prairie sub-watershed, discharge into Lake Okeechobee occurs at several reaches (3, 29, 50, 59, 71, 76, 79, 85, 88, 89, 90). Contributions from these reaches are routed into a single collection reach (reach # 2 in the WAM output files, but not shown here) to calculate the total discharge from the sub-watershed into the lake. No attenuation processes occur within the collection reach. Inflow from the East Sub-watershed occurs at what is now the eastern boundary of the S-135 basin. These inflows have been subtracted from the TCNS outflows for the results presented in **Table 11**, similar to how the contribution from the Upper Kissimmee Sub-watershed was subtracted from the Lower Kissimmee results. Note that the daily flows and loads contributing to Lake Okeechobee shown in **Figures 66 - 68** include the contributions from the East Sub-watershed.

The dominant land cover is Pine Palmetto Flatwoods, followed by Freshwater Marshes, Mixed Wetland Hardwoods, and Hardwood/Conifer Mixed. Freshwater Marshes dominate the landscape adjacent to the lake, with Pine Palmetto Flatwoods covering the majority of land away from the lake to the north and east. Mixed Wetland Hardwoods is scattered throughout the area, with Hardwood/Conifer Mixed covering the south-east part of the domain away from the lake. About 63% of the area is simulated using the EAAMod sub-model, with only 1% simulated using GLEAMS sub-models, and the remaining 37% simulated using the Special Case sub-model (**Table 18**).

Table 18. Breakdown of land cover acreages as run by source cell model in the Taylor Creek/Nubbin Slough.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods	655	105,791	
Hardwoods		2,320	
Hardwoods/Conifer mixed	1,100	15,633	
Open Water			2,743
Bay Swamps			11
Mixed Wetland Hardwoods			27,548
Cypress			2
Wetland Forested Mixed			2,804
Freshwater Marshes			39,113
Percent of Total	1%	63%	37%

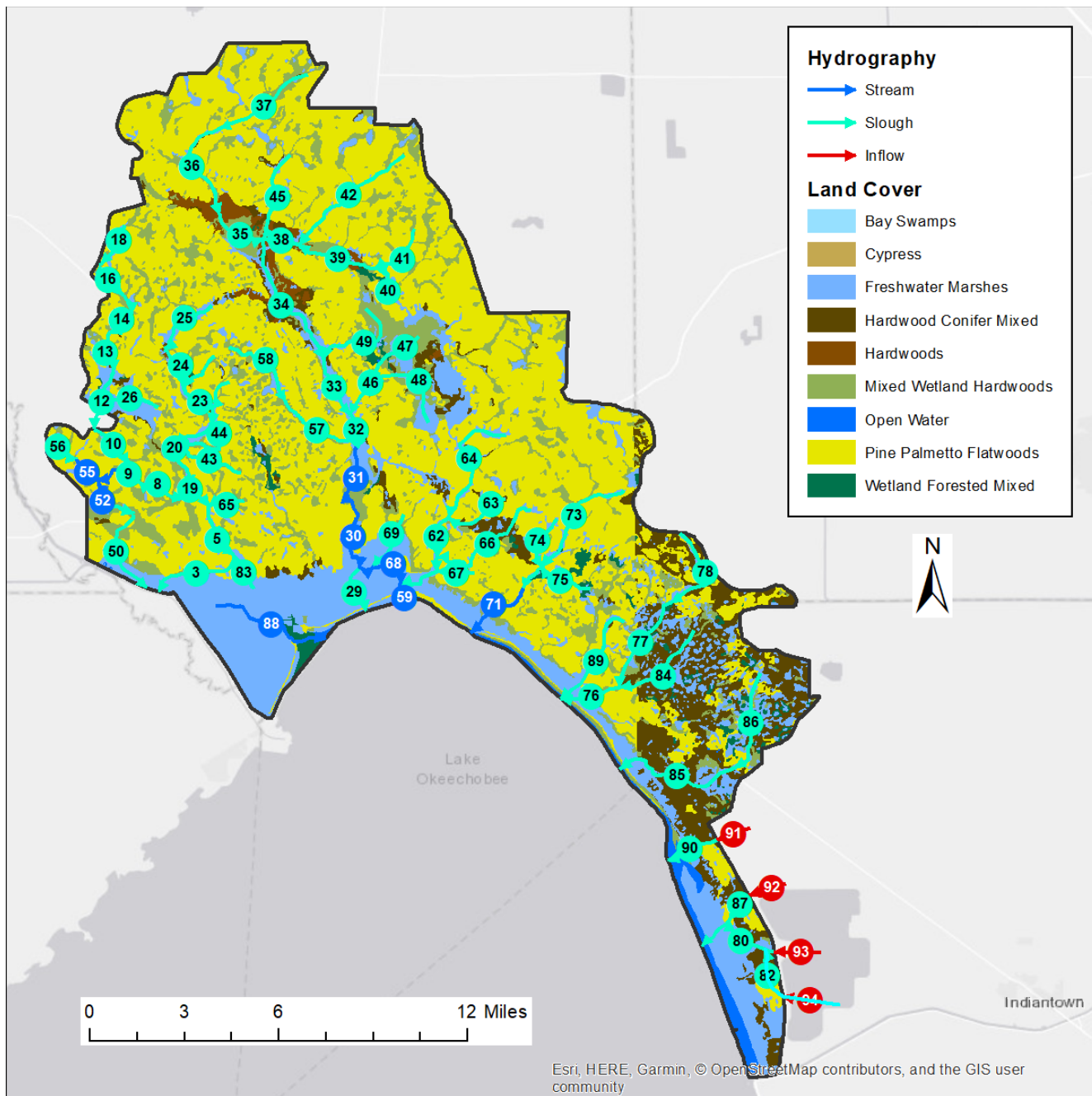


Figure 61. The Taylor Creek/Nubbin Slough sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.6.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 62 – 65**. Because of the large amounts of high water table soils, direct percolation to groundwater accounts for about 0.1% of water leaving source cells. However as before, some runoff water is routed to landscape depressions where it infiltrates to groundwater. Nutrient loads are dominated by contributions Pine Palmetto Flatwoods and Hardwood/Conifer Mixed.

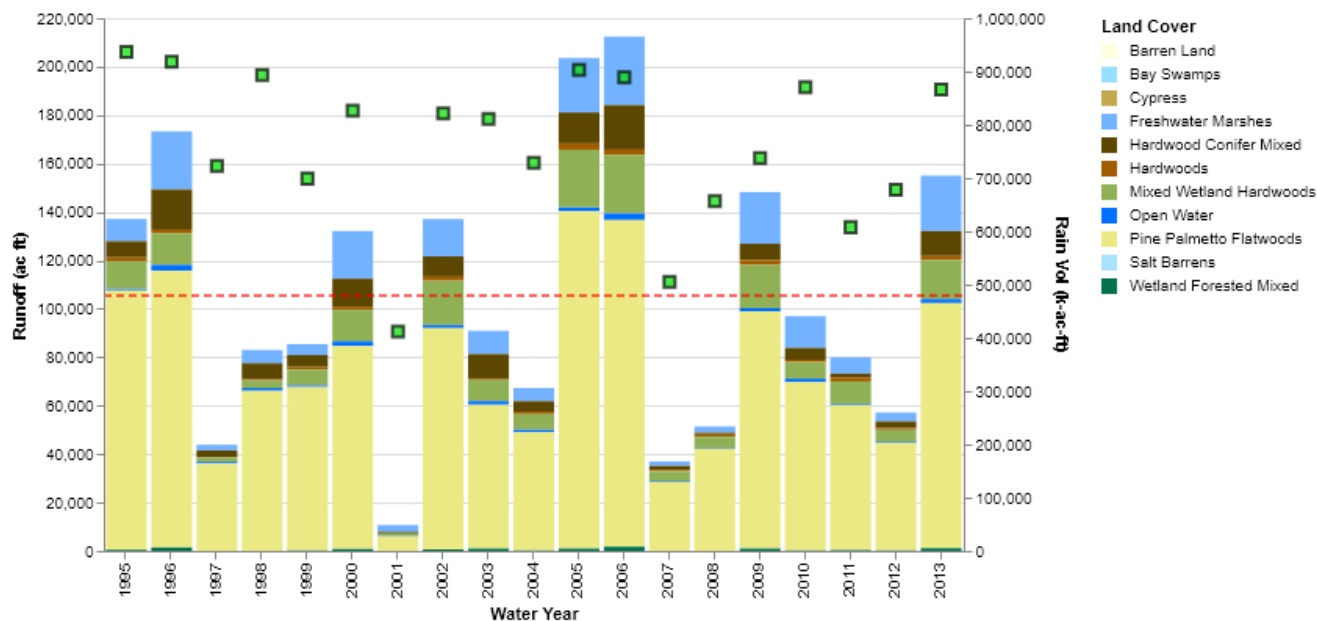


Figure 62. Source cell runoff per year in the Taylor Creek/Nubbin Slough sub-watershed.

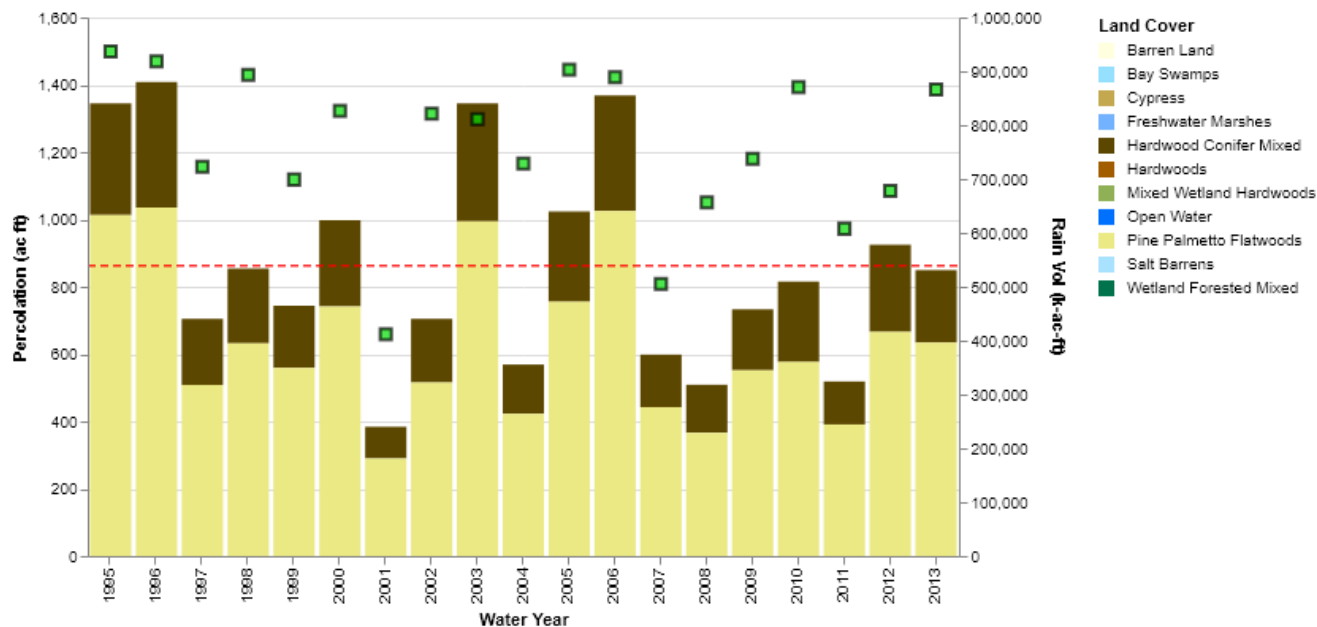


Figure 63. Source cell percolation per year in the Taylor Creek/Nubbin Slough sub-watershed.

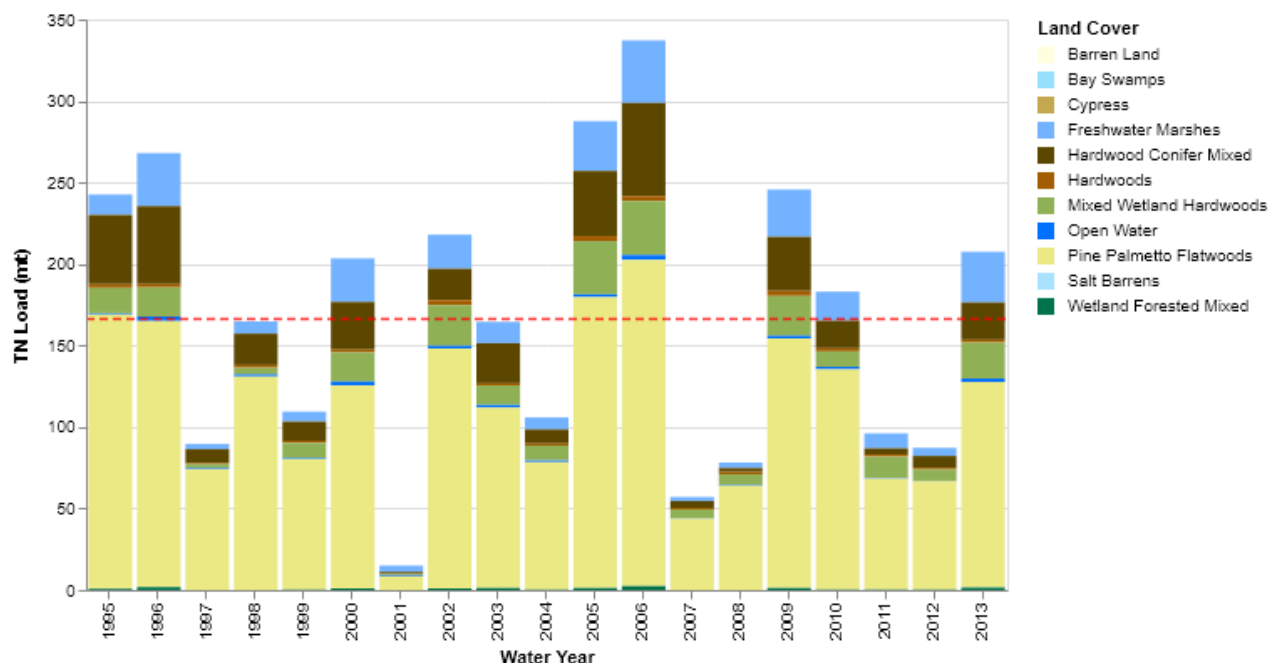


Figure 64. Source cell TN loadings per year in the Taylor Creek/Nubbin Slough sub-watershed.

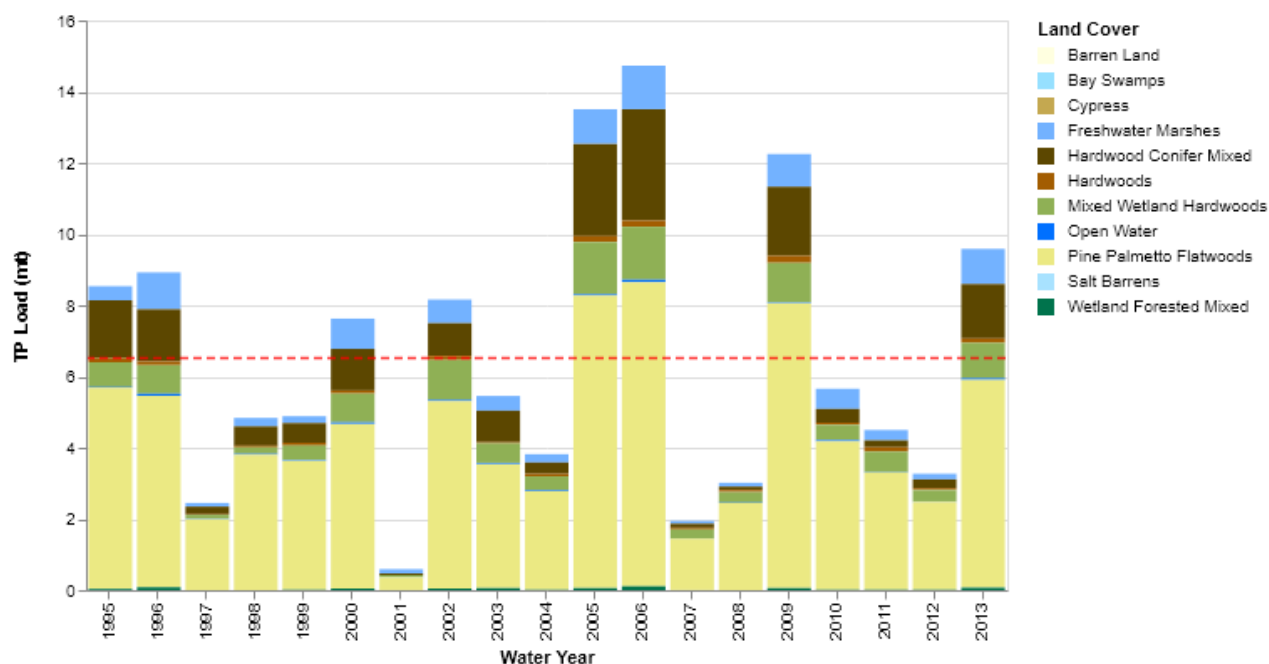


Figure 65. Source cell TP loadings per year in the Taylor Creek/Nubbin Slough sub-watershed.

3.6.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) from Taylor Creek/Nubbin Slough into Lake Okeechobee along the sub-watershed is shown in **Figure 66**. This discharge reflects inflows from the East sub-watershed as well. The annual average discharge was nearly $7 \text{ m}^3/\text{s}$, corresponding to the annual average volume of

about 173,000 acre-feet per year. Peak discharge occurred in 2008 and 2012, with other peaks in 2004 and late 2005.

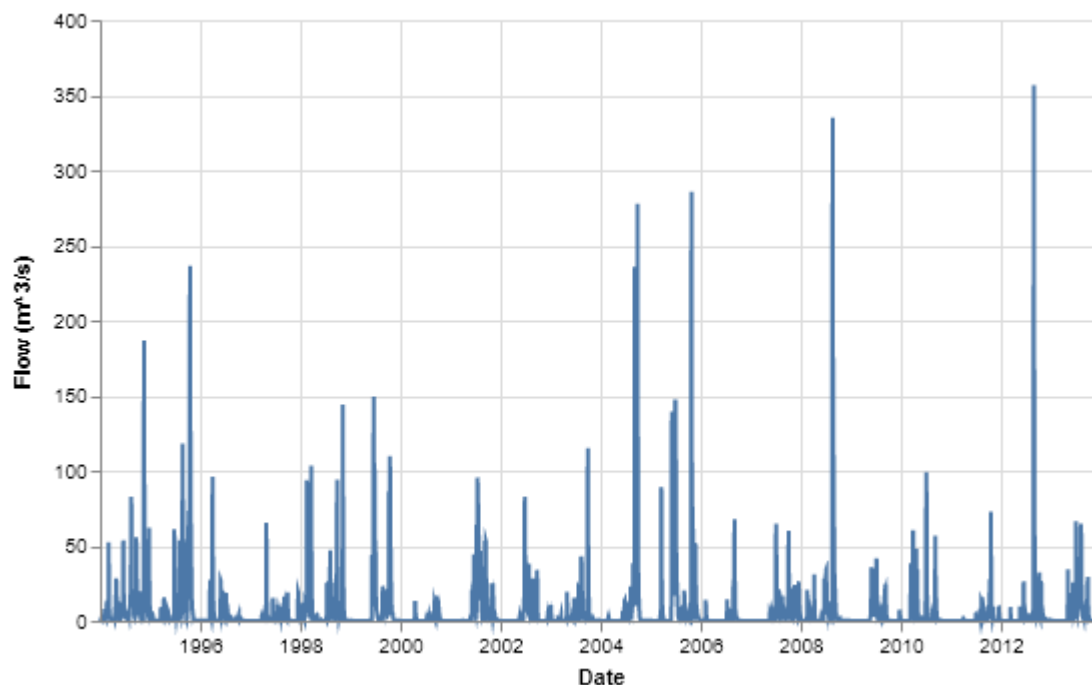


Figure 66. Simulated daily discharge from Taylor Creek/Nubbin Slough sub-watershed to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 67** and **68**, respectively, with both nutrients having a greater degree of variability than other sub-watersheds. The flow-weighted average TN concentration over the entire period was 1.13 mg/L (**Table 11**) with the concentrations oscillating in the range of 0.6 – 1.2 mg/L, with a few dips below 0.6 mg/L in early 1996 and late 2008/early 2009. The flow-weighted TP concentration over the entire period was 0.042 mg/L with the concentrations oscillating in the range of 0.02 – 0.045 mg/L, with peaks up to nearly 0.06 mg/L and dips down to almost 0.01 mg/L.

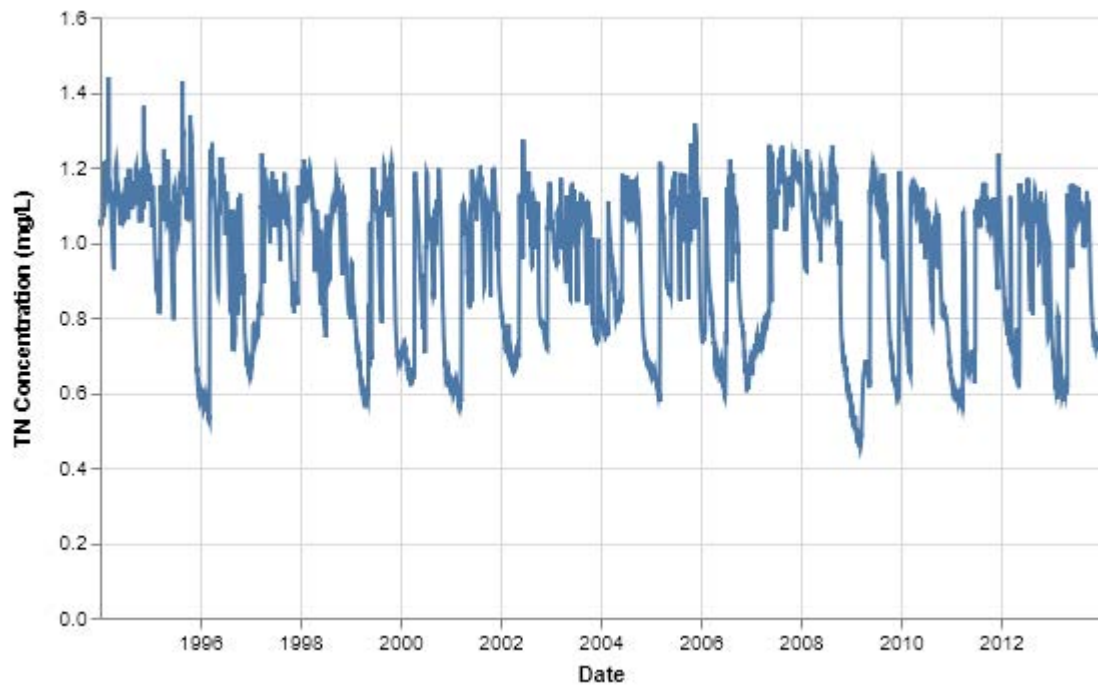


Figure 67. Simulated daily TN concentrations entering Lake Okeechobee from Taylor Creek/Nubbin Slough sub-watershed.

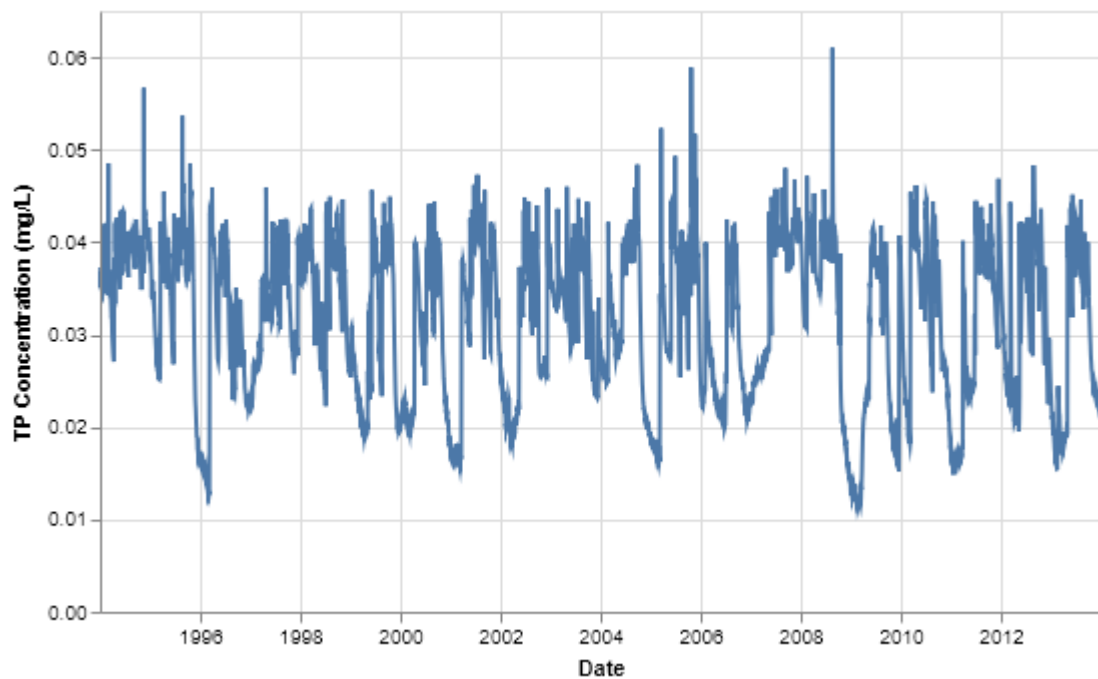


Figure 68. Simulated daily TP concentrations entering Lake Okeechobee from Taylor Creek/Nubbin Slough sub-watershed.

3.7 East Lake Okeechobee Sub-Watershed

The East sub-watershed is located along the eastern and south-eastern portion of Lake Okeechobee. It is approximately 239,014 acres in area (**Figure 69**). Under current conditions, most of the discharge is out of Lake Okeechobee at structure S308, east down the C-44 Canal, and discharging to the east at structure S-80. However, discharge back to the lake occurs as well. In the pre-drainage configuration, Said and Brown (2013) indicate a significant portion of water flows to the west into Lake Okeechobee, across the south-eastern part of the Taylor Creek/Nubbin Slough sub-watershed, to the southwest into the sawgrass plain south of the lake, as well as some discharge east.

Using the topographic coverage provided by the SFWMD, it was determined that most of the overland flow direction was either to Lake Okeechobee or the Southern sub-watershed. To simulate this, a series of broad sloughs were incorporated into the hydrography. The northeastern-most part of the domain discharges to WAM reach 68 while the southeastern part discharges to WAM reach 63. Both reach 63 and 68 are simulated as fixed-head boundary conditions. The rest of the southern half of the domain discharges to the sawgrass plain in the Southern sub-watershed. A small part along the western edge discharges directly to the lake at WAM reaches 58 and 62. The remaining part of the northern half discharges into the Taylor Creek/Nubbin Slough sub-watershed and is included with that sub-watershed's contribution to Lake Okeechobee (see **Figures 66 – 68**).

The dominant land cover is Mixed Wetland Hardwoods, followed by Hardwood/Conifer Mixed, Pine Palmetto Flatwoods, and Freshwater Marshes (**Table 2**). About 35% of the area is simulated using the EAAMod sub-model, while only about 1% uses GLEAMS (14%) (**Table 19**). The remaining 64% is simulated using the Special Case sub-model.

Table 19. Breakdown of land cover acreages as run by source cell model in the East Lake Okeechobee sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods	52	41,533	
Hardwoods/Conifer mixed	2,084	41,380	
Open Water			575
Mixed Wetland Hardwoods			32,786
Cypress			2,536
Wetland Forested Mixed			79,192
Freshwater Marshes			38,876
Percent of Total	1%	35%	64%

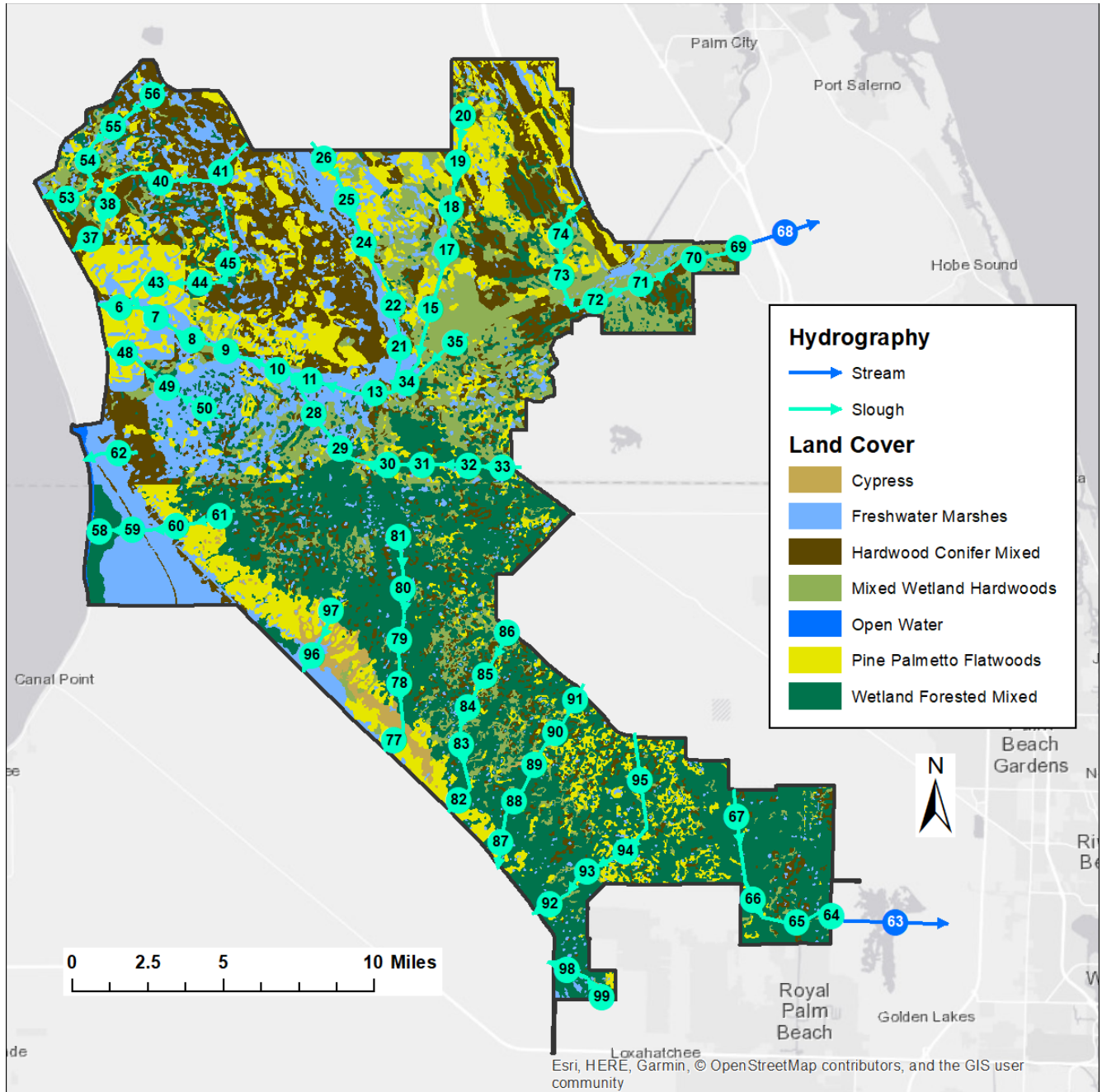


Figure 69. The East sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.7.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 70 – 73**. Direct percolation to groundwater accounts for less than 0.1% of water leaving source cells. Nutrient loads are dominated by contributions from Hardwood/Conifer Mixed, followed by Pine Palmetto Flatwoods.

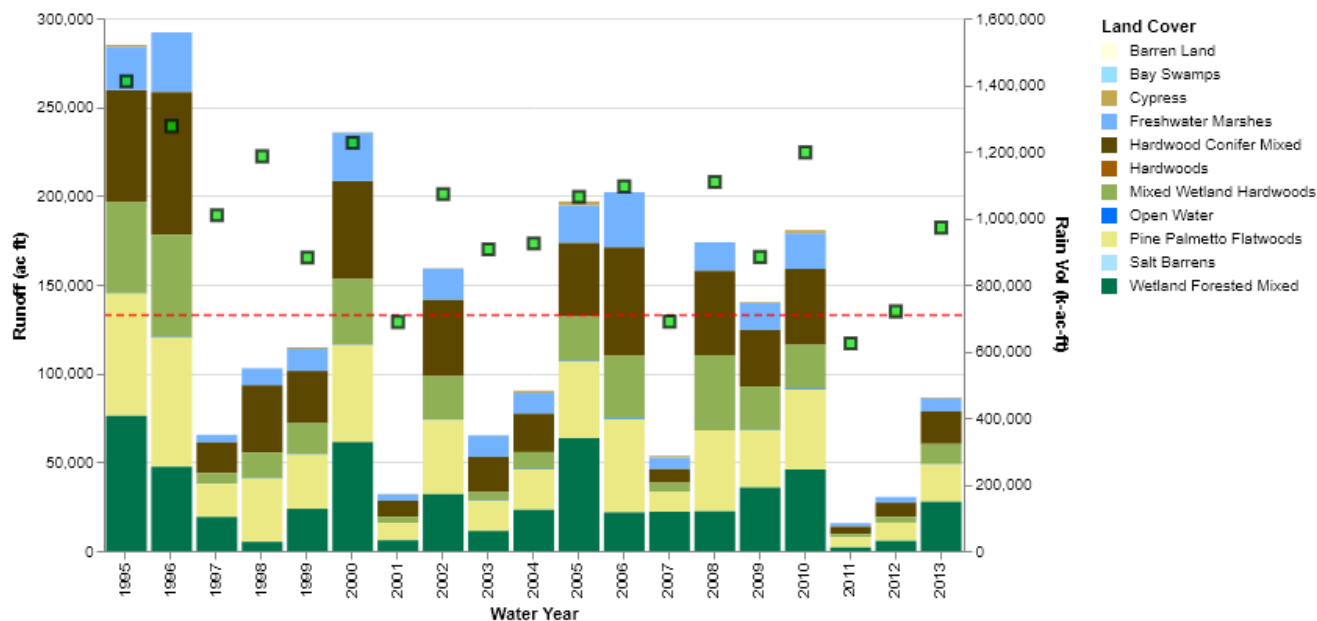


Figure 70. Source cell runoff per year in the East sub-watershed.

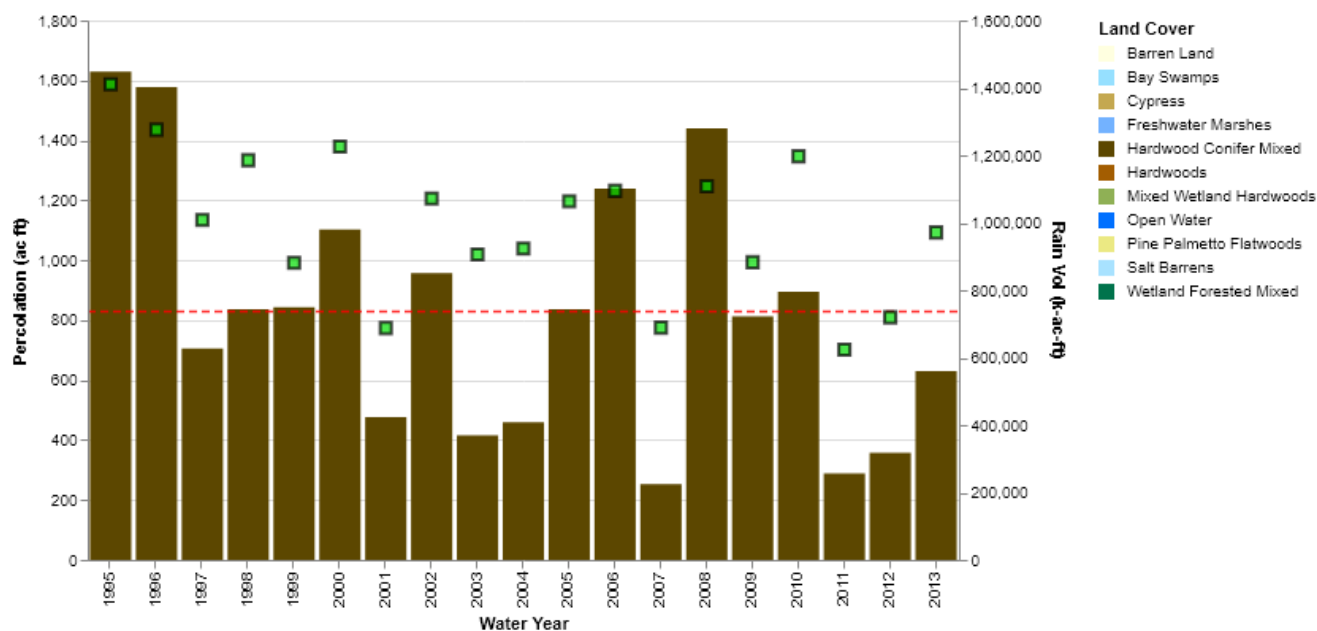


Figure 71. Source cell percolation per year in the East sub-watershed.

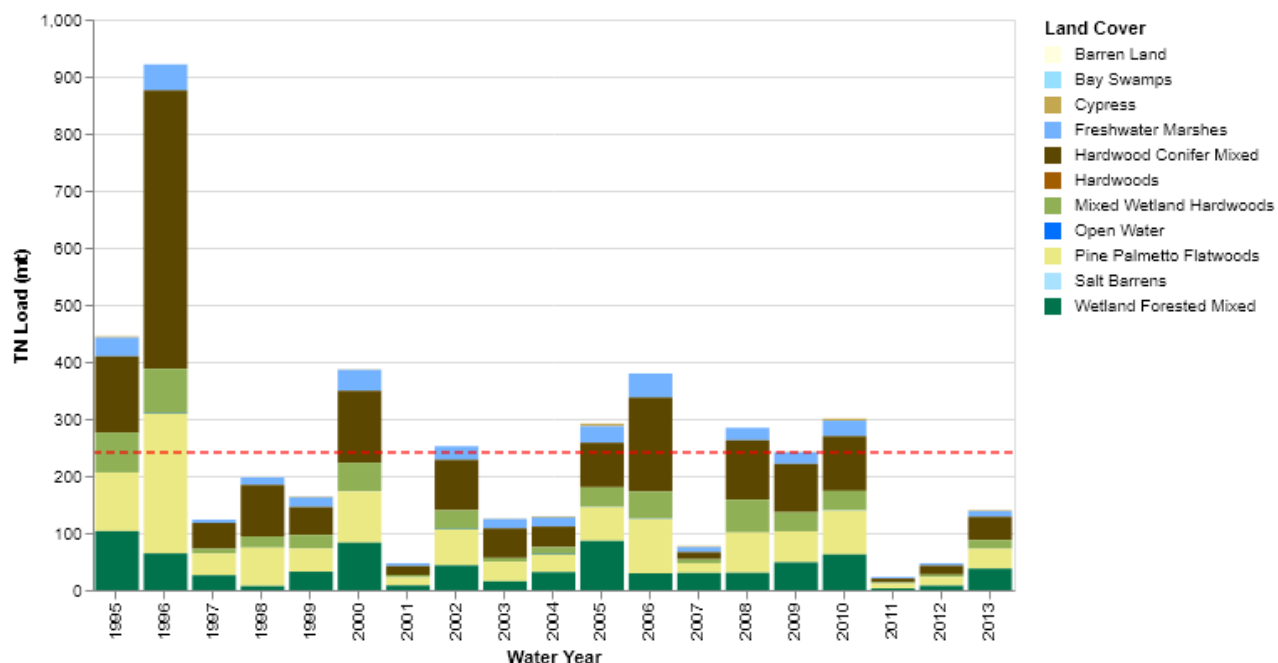


Figure 72. Source cell TN loadings per year in the East sub-watershed.

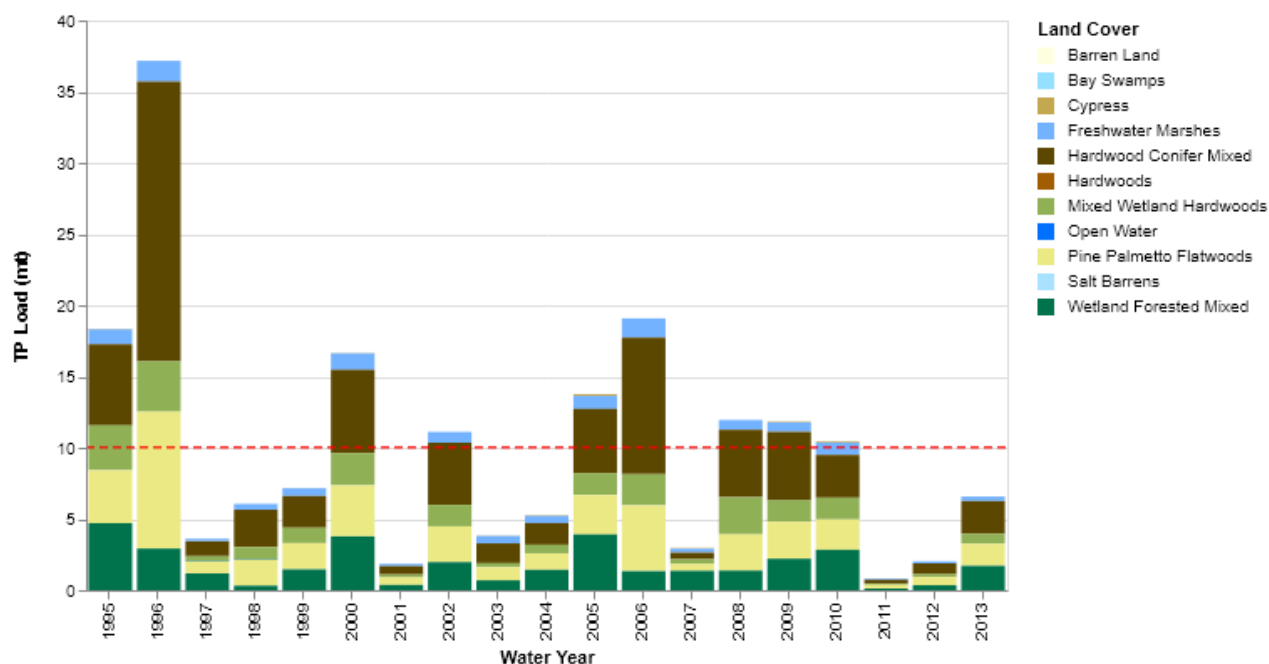


Figure 73. Source cell TP loadings per year in the East sub-watershed.

3.7.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) from the East sub-watershed directly into Lake Okeechobee is shown in **Figure 74**. The annual average discharge was barely over $0.3 \text{ m}^3/\text{s}$, corresponding to the annual average volume of slightly over 8,000 acre-feet per year. Again, this represents only a fraction of the total water discharging from the sub-watershed, with most of the rest of the contribution accounted for in the

discharge from Taylor Creek/Nubbin Slough or not entering the lake at all, i.e., discharging into the South sub-watershed or to the east.

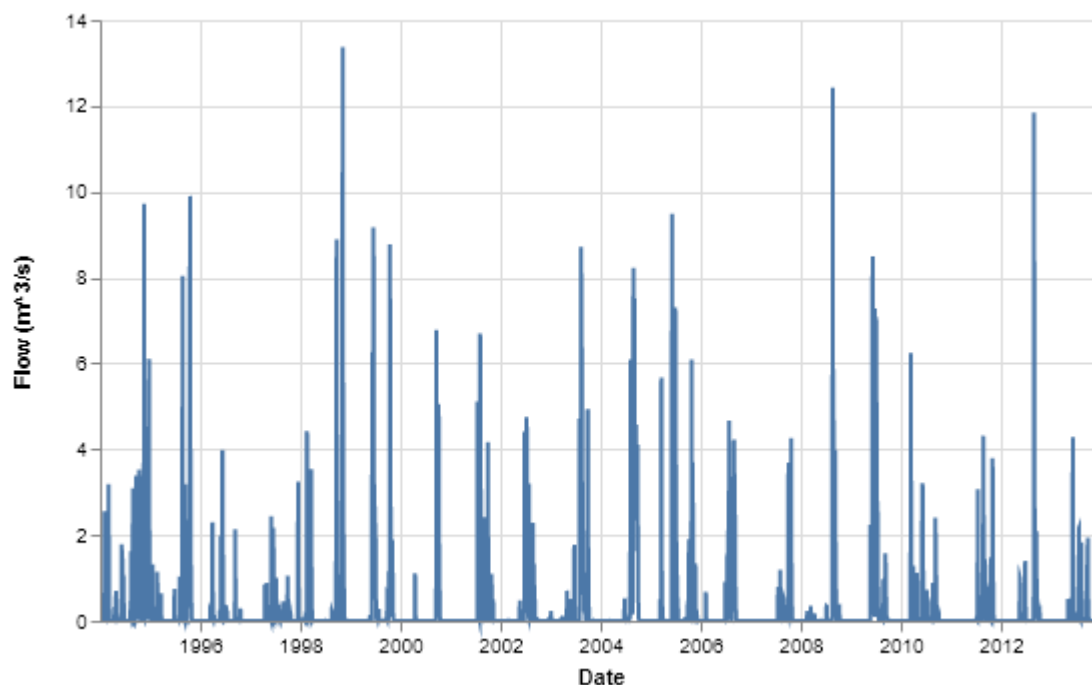


Figure 74. Simulated daily discharge from the East sub-watershed to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 75 and 76**, respectively. The flow-weighted average TN concentration over the entire period was 1.137 mg/L (**Table 11**) with most of the concentrations in the range of 1.0 – 1.2 mg/L, but with frequent downward spikes to 0.4 mg/L. The flow-weighted TP concentration over the entire period was 0.037 mg/L with the bulk of the concentrations in the range of 0.03 – 0.04 mg/L, with a few spikes upward to over 0.05 mg/L. As was observed in the simulations in the other sub-watersheds, the lowest TN and TP concentrations occur during low-flow periods due to groundwater inflow and contribute little to the overall loading to Lake Okeechobee.

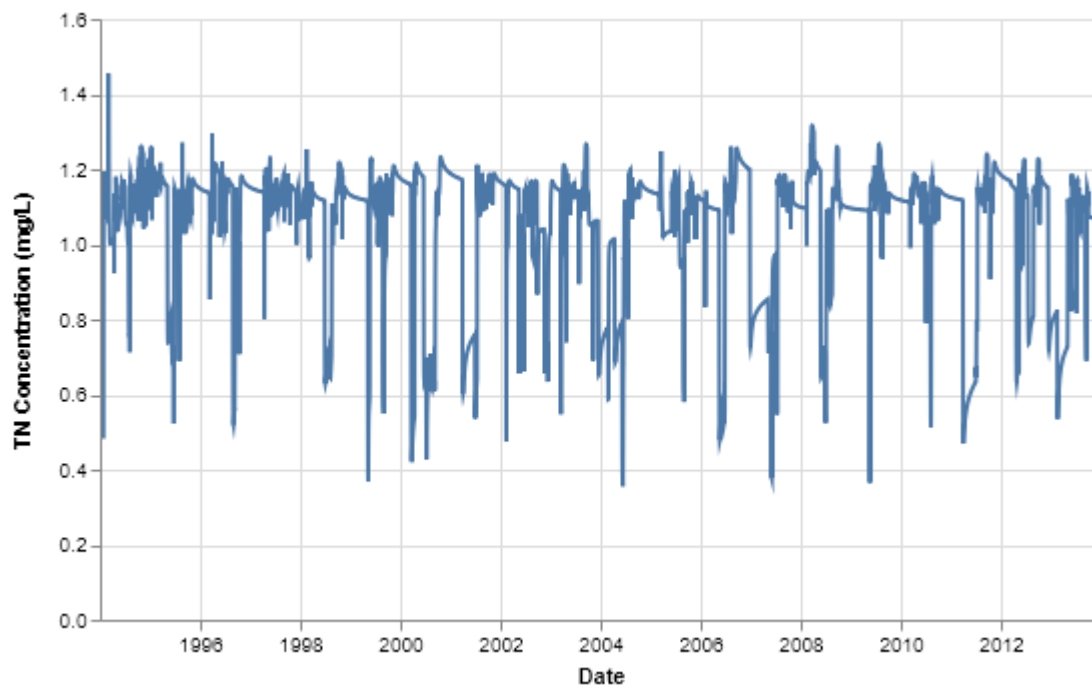


Figure 75. Simulated daily TN concentrations entering Lake Okeechobee from the East sub-watershed.

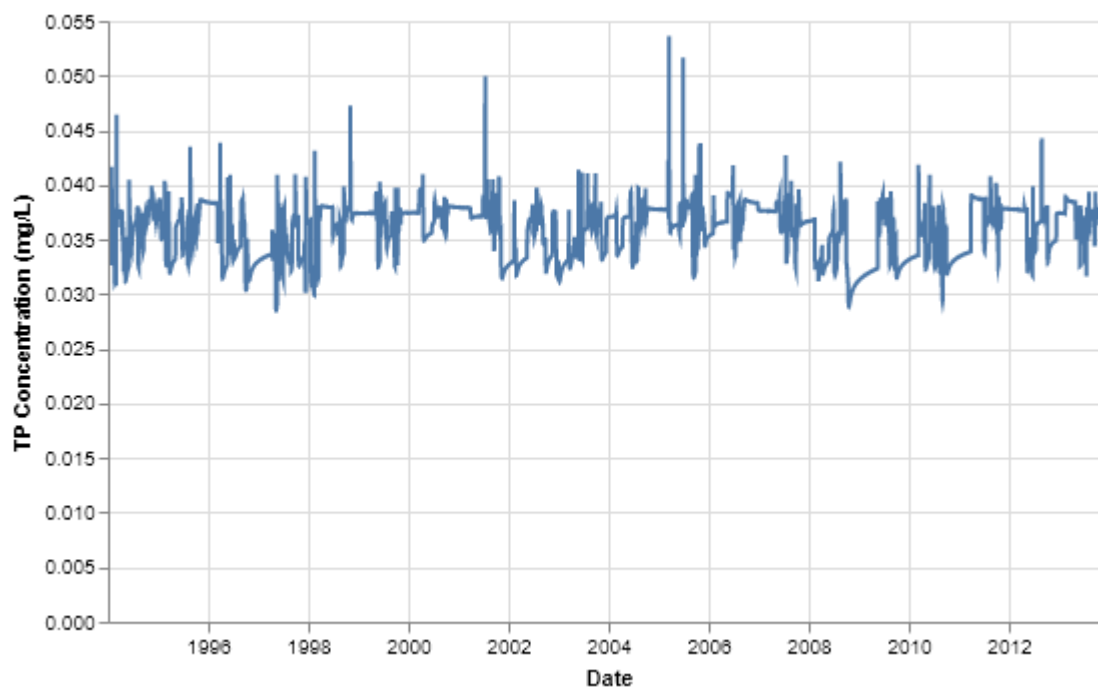


Figure 76. Simulated daily TP concentrations entering Lake Okeechobee from the East sub-watershed.

3.8 West Lake Okeechobee Sub-Watershed

The West sub-watershed is located along the western and south-western portion of Lake Okeechobee. It is approximately 204,095 acres in area (**Figure 77**). Under current conditions, much of the discharge (both to and out of Lake Okeechobee) is from structures C-5A and S-77. In the pre-drainage configuration, Said and Brown (2013) indicate a significant portion of water flow to the west to the headwaters of the Caloosahatchee River, which McVoy et al. (2011) indicated was originally a wide marshy area. This was simulated as a swath of wide sloughs (WAM reaches 53-55 and 74-72) that connect Lake Okeechobee to Lake Hicpochee (WAM reach 37) which is in turn connected to the Caloosahatchee River (from west to east, WAM reaches 2-10). The inflow reach representing Lake Okeechobee is WAM reach 56. The sloughs surrounding Lake Hicpochee form a very flat area that is only slightly elevated relative to the terrain to the east and west of Lake Hicpochee. Only when the water level in Lake Okeechobee is high enough will water discharge from Lake Okeechobee down the Caloosahatchee River. To simulate the stage of Lake Okeechobee, a simple model (**Appendix C, Section 7**) was developed that takes the inflow from the FEC, Indian Prairie, Kissimmee River, and Taylor Creek/Nubbin Slough sub-watersheds and determines a time series of stage elevations. This lake model assumes that discharge from the lake will only occur if the stage is at 20 feet (NGVD, 6.096 m). This same model was used as a stage boundary condition for the Southern sub-watershed, described in the following section.

The dominant land cover is Pine Palmetto Flatwoods, followed by Freshwater Marshes and Mixed Wetland Hardwoods (**Table 2**). About 54% of the area is simulated using the EAAMod sub-model, less than 1% is run using GLEAMS, 43% is simulated using the Special Case sub-model (**Table 20**), with the remaining 3% is direct contribution of rainfall to lakes.

Table 20. Breakdown of land cover acreages as run by source cell model in the West Lake Okeechobee sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case	None
Pine Palmetto Flatwoods		95,655		
Hardwoods		1,235		
Hardwoods/Conifer mixed	405	13,520		
Open Water			1,001	
Mixed Wetland Hardwoods			28,247	
Cypress			684	
Wetland Forested Mixed			3,422	
Freshwater Marshes			53,986	
Lakes				5,940
Percent of Total	0%	54%	43%	3

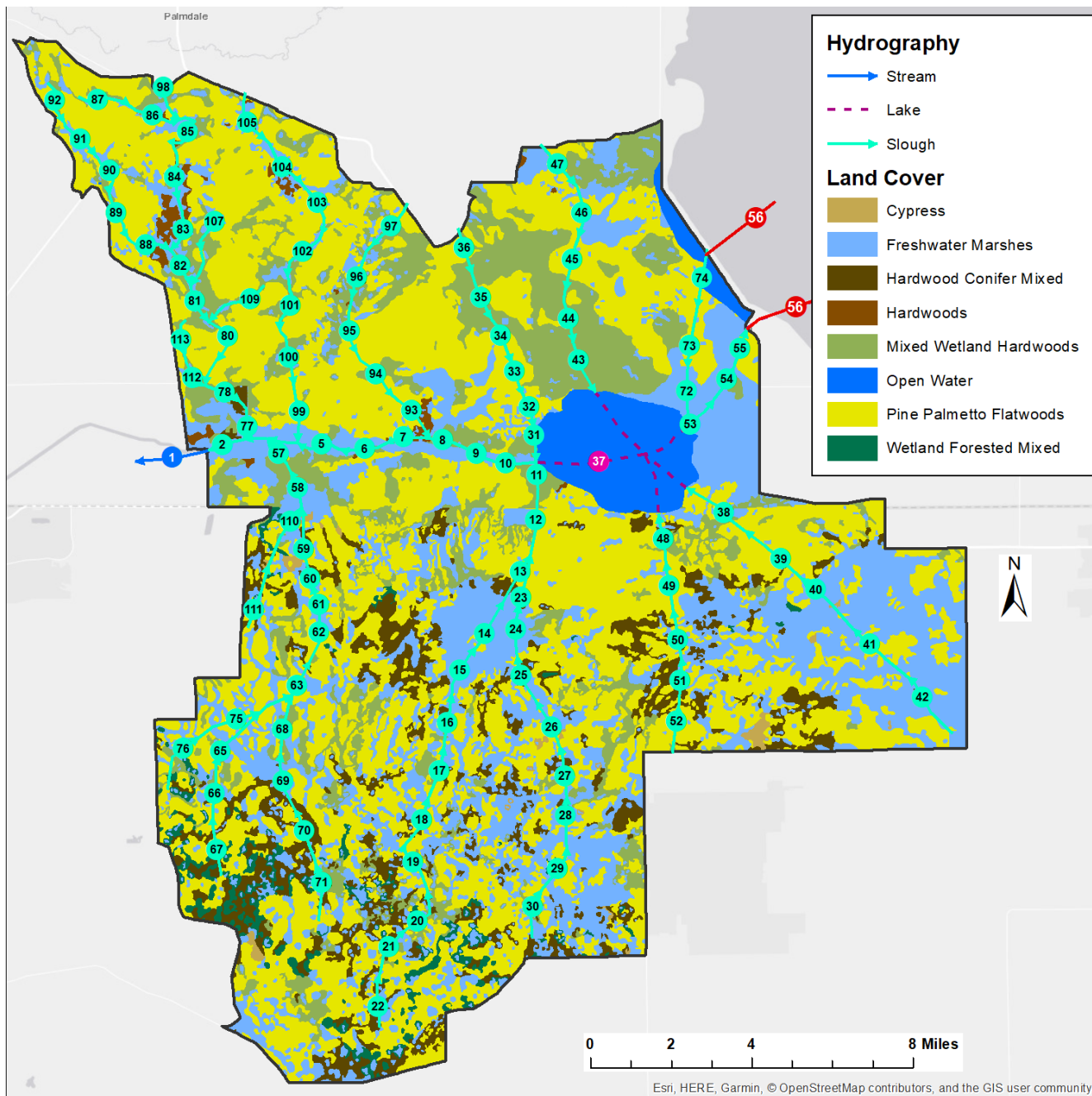


Figure 77. The West sub-watershed, showing pre-drainage land cover and hydrography with reach numbers labeled.

3.8.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 78 – 80**. There is no direct percolation to groundwater in the sub-watershed, but since there are numerous depressions, overland flow to depression areas results in percolation to groundwater. Nutrient loads are dominated by contributions from Pine Palmetto Flatwoods, followed by Freshwater Marshes and Hardwood/Conifer Mixed.

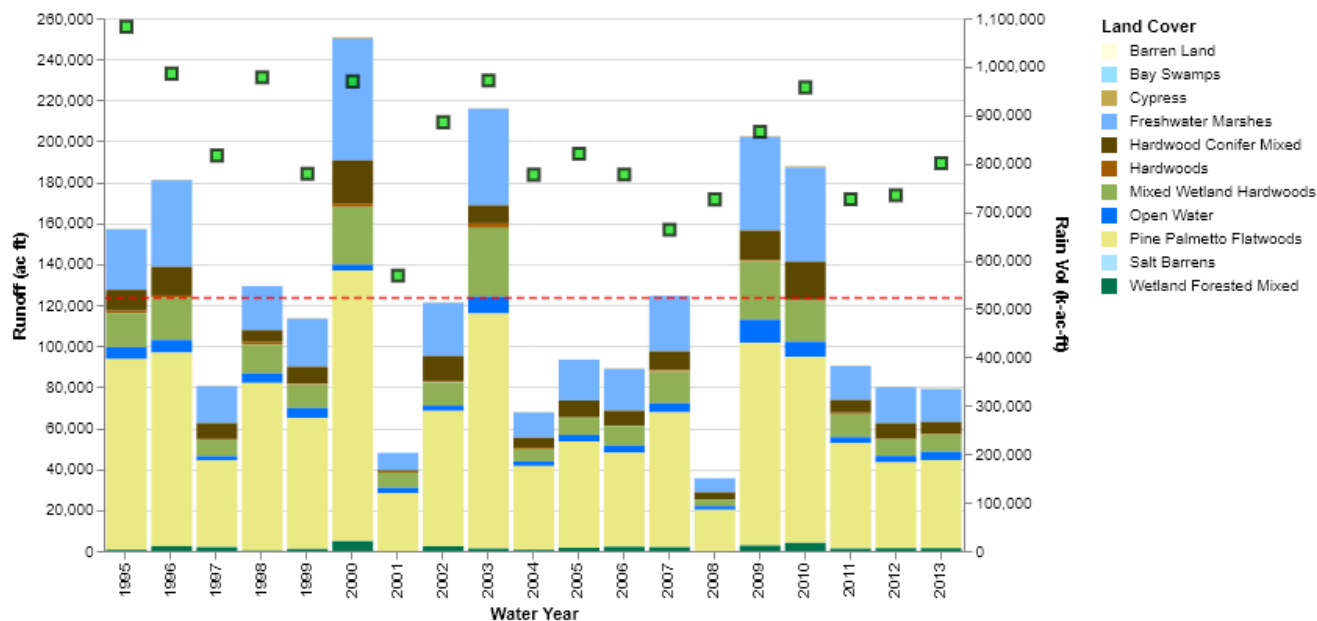


Figure 78. Source cell runoff per year in the West sub-watershed.

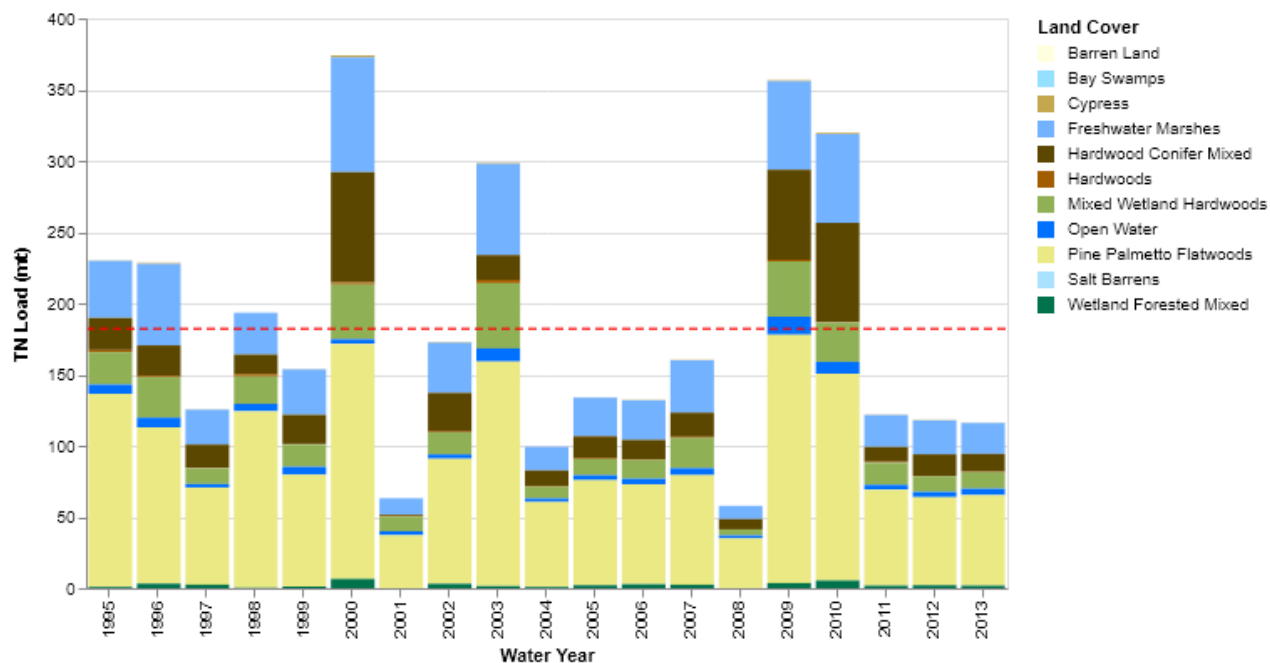


Figure 79. Source cell TN loadings per year in the West sub-watershed.

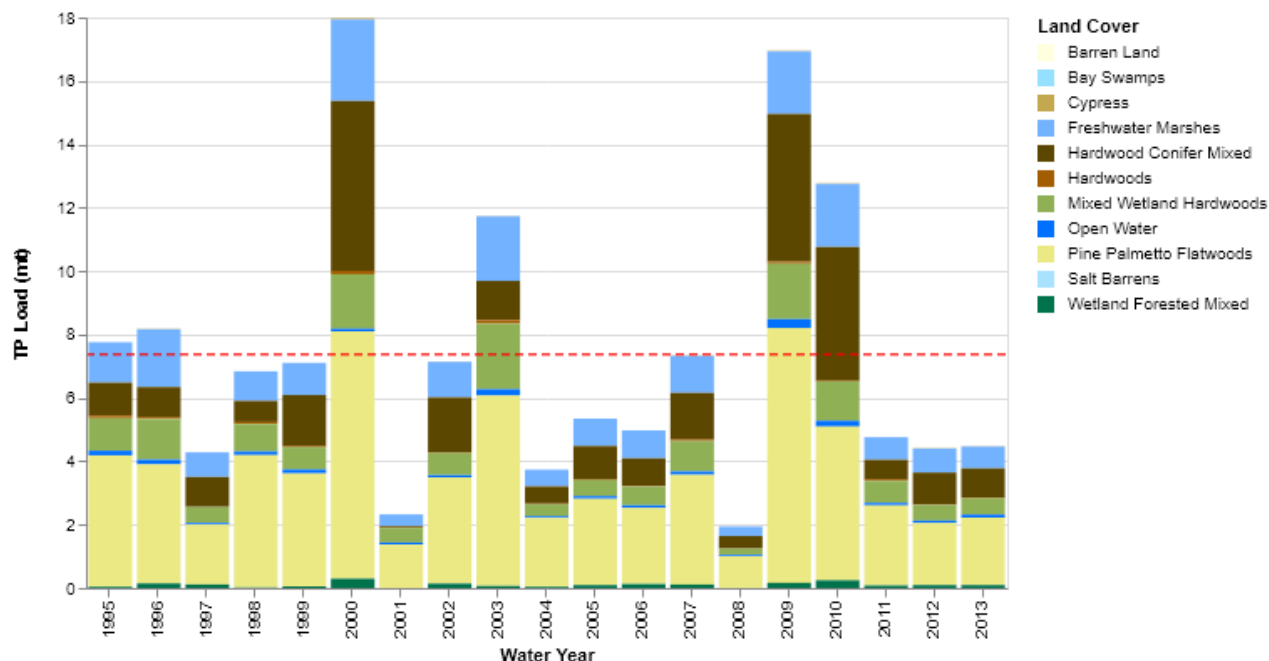


Figure 80. Source cell TP loadings per year in the West sub-watershed.

3.8.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) entering Lake Okeechobee from the West sub-watershed is shown in **Figure 81**. The annual average discharge was slightly over $1 \text{ m}^3/\text{s}$, corresponding to the annual average volume of over 28,000 acre-feet per year. Note that there is some discharge from Lake Okeechobee into the West sub-watershed as indicated by the negative flow values.

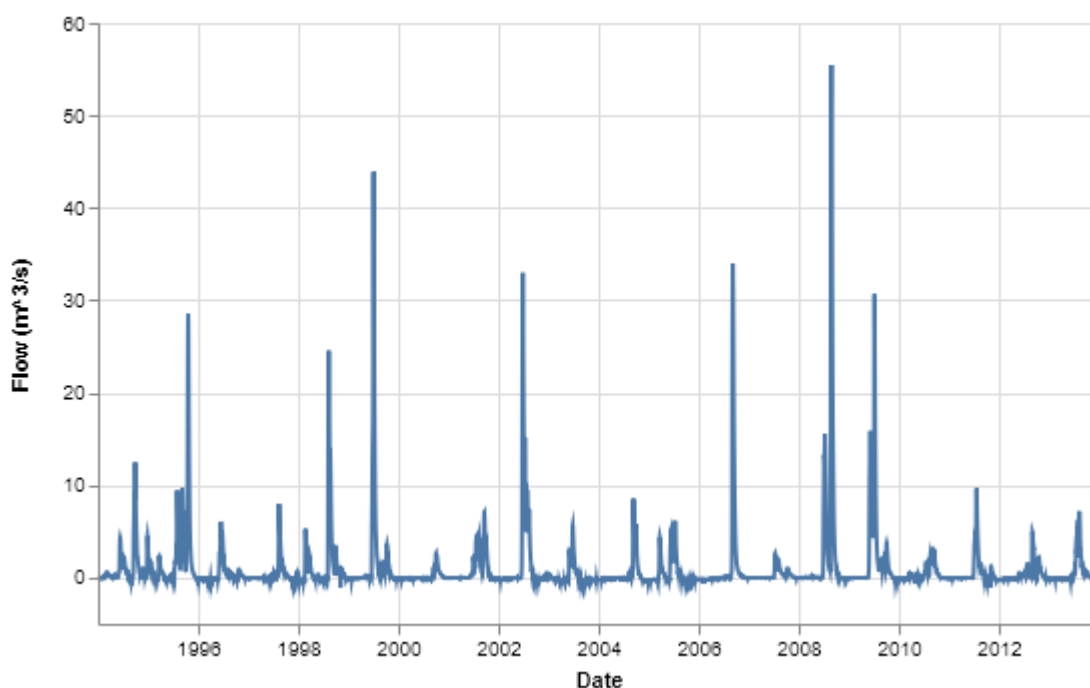


Figure 81. Simulated daily discharge from the West sub-watershed to Lake Okeechobee.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 82** and **83**, respectively, with both nutrients showing some degree of variability. The flow-weighted average TN concentration over the entire period was 1.16 mg/L (**Table 11**) with the concentrations oscillating in the range of 0.4 – 1.4 mg/L. The flow-weighted TP concentration over the entire period was 0.042 mg/L with the concentrations oscillating in the range of 0.04 – 0.06 mg/L, with peaks up to nearly 0.07 mg/L.

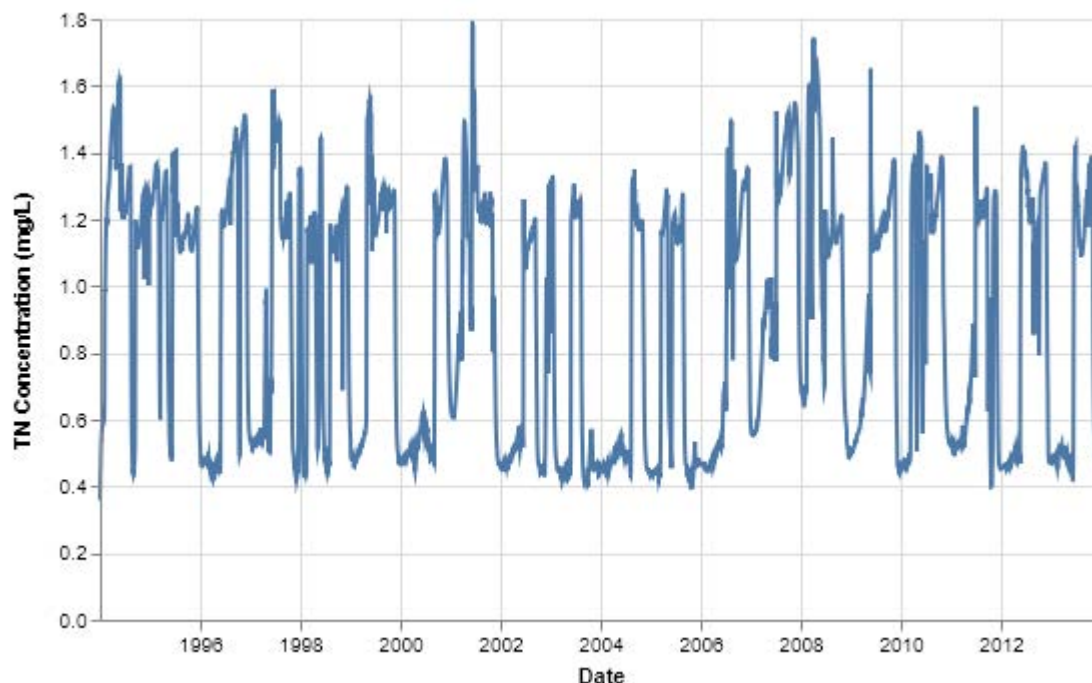


Figure 82. Simulated daily TN concentrations entering Lake Okeechobee from the West sub-watershed.

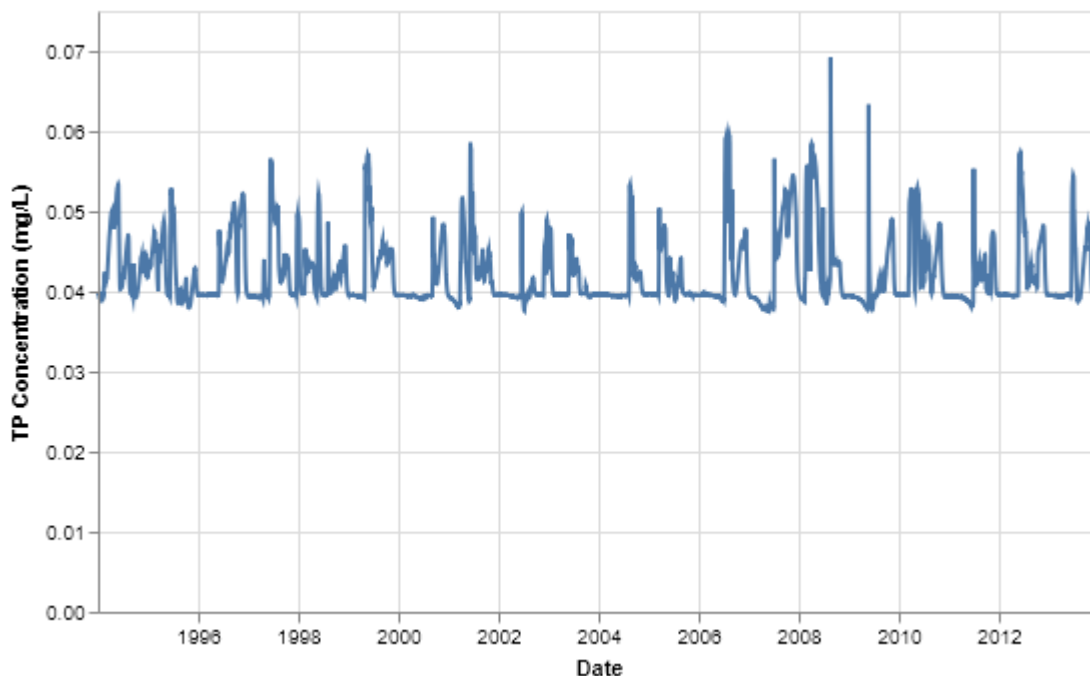


Figure 83. Simulated daily TP concentrations entering Lake Okeechobee from the West sub-watershed.

3.9 South Lake Okeechobee Sub-Watershed

The Southern sub-watershed is dominated by the wide expanse of the sawgrass plain to the south of Lake Okeechobee, which is simulated in WAM as the land cover Freshwater Marshes. Immediately south of the lake is an area of Custard Apple, shown in **Figure 84** (and simulated) as Wetland Forested Mixed. The Southern sub-watershed is approximately 540,450 acres in area. A minor amount of the area along the western edge is simulated as Pine Palmetto Flatwoods (about 3%). The majority of the area (97%) is simulated using the Special Case sub-model, while the 3% is simulated using EAAMod and less than 1% is simulated using GLEAMS (**Table 21**).

The hydrography is simulated as a series of five very broad sloughs, each divided into sets of reaches, with each reach multiple kilometers wide. The sloughs slope very gradually from north to south. Inflow from Lake Okeechobee is determined by using the time series of stages discussed in the previous section. Water flows into the sloughs when the stage exceeds 20 feet (NGVD). A minor amount of inflow from the East sub-watershed occurs via a set of reaches along the eastern part of the domain (WAM reaches 66-71). Note that no flow occurs from the sub-watershed back into Lake Okeechobee, therefore, there are no nutrient contributions from the sub-watershed to the lake.

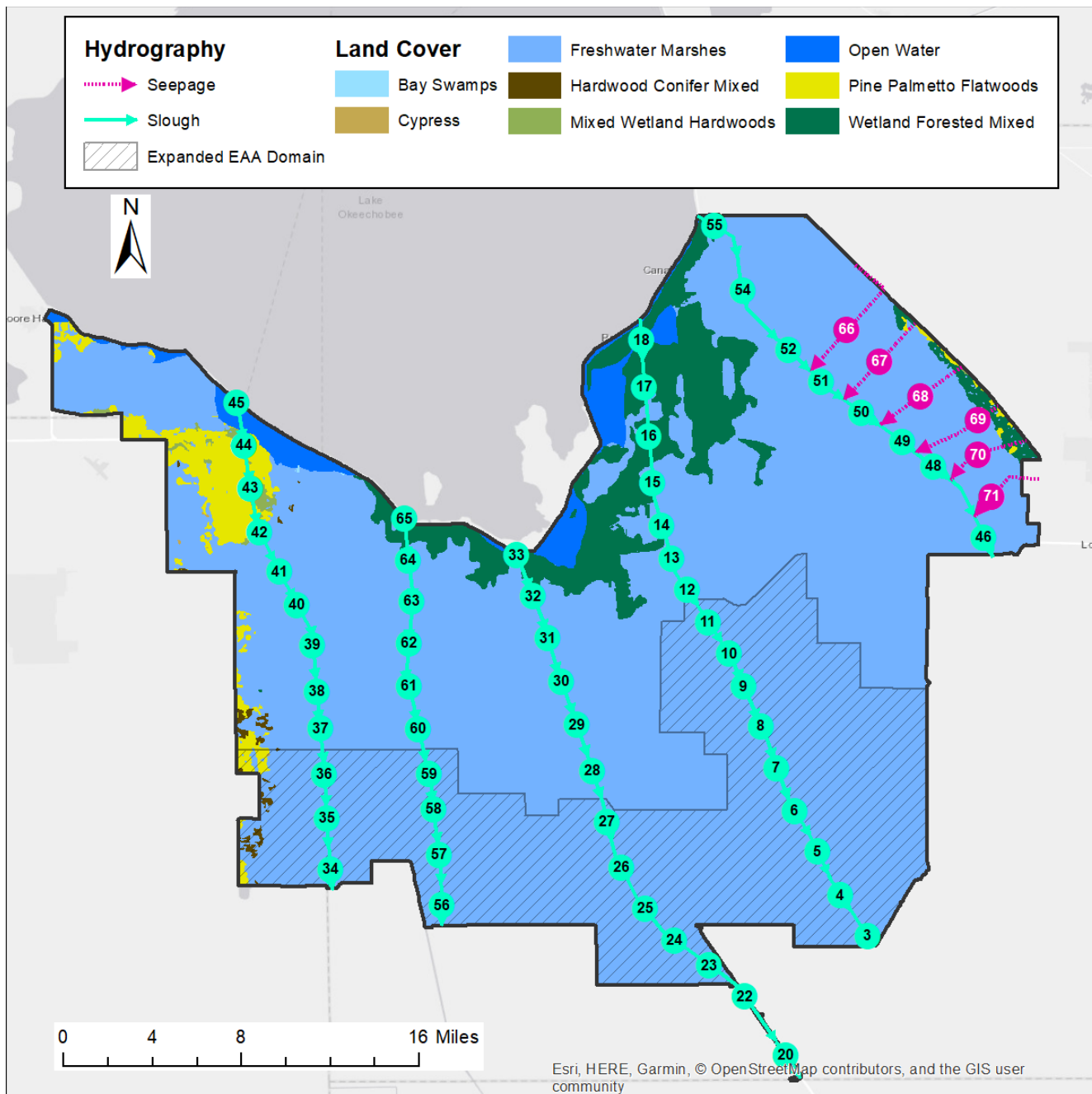


Figure 84. The South sub-watershed (including the expanded area), showing pre-drainage land cover and hydrography with reach numbers labeled.

3.9.1 Water and Nutrient Loads from Source Cells

Annual totals of simulated annual water volumes and nutrient loads leaving source cells are shown in **Figures 85 - 87**. As with the West sub-watershed, there is no direct percolation to groundwater in the sub-watershed. Note that there are no simulated depressions within the sub-watershed, so neither are there contributions to groundwater from that mechanism. Nutrient loads are dominated by contributions from the wide expanse of Freshwater Marshes.

Table 21. Breakdown of land cover acreages as run by source cell model in the South Lake Okeechobee sub-watershed.

Land Cover	GLEAMS	EAAMod	Special Case
Pine Palmetto Flatwoods		14,929	
Hardwoods/Conifer mixed	794	462	
Open Water			13,875
Bay Swamps			30
Mixed Wetland Hardwoods			1,371
Cypress			46
Wetland Forested Mixed			40,639
Freshwater Marshes			468,308
Percent of Total	0%	3%	97%

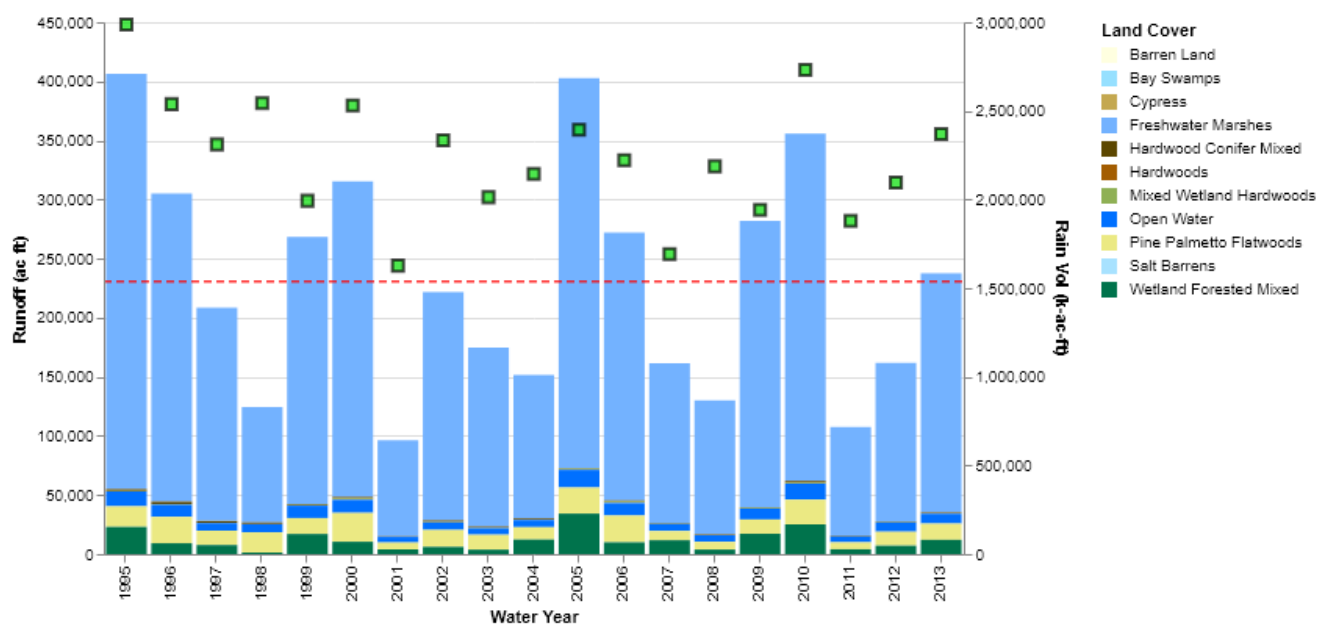


Figure 85. Source cell runoff per year in the South sub-watershed.

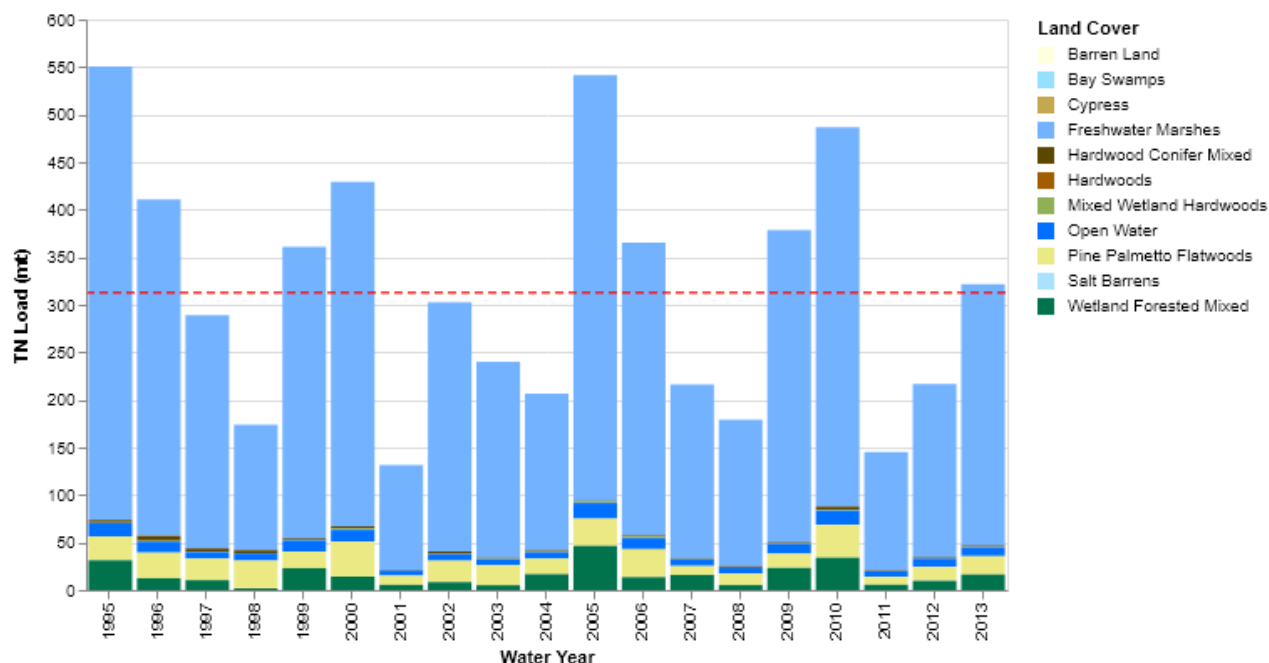


Figure 86. Source cell TN loadings per year in the South sub-watershed.

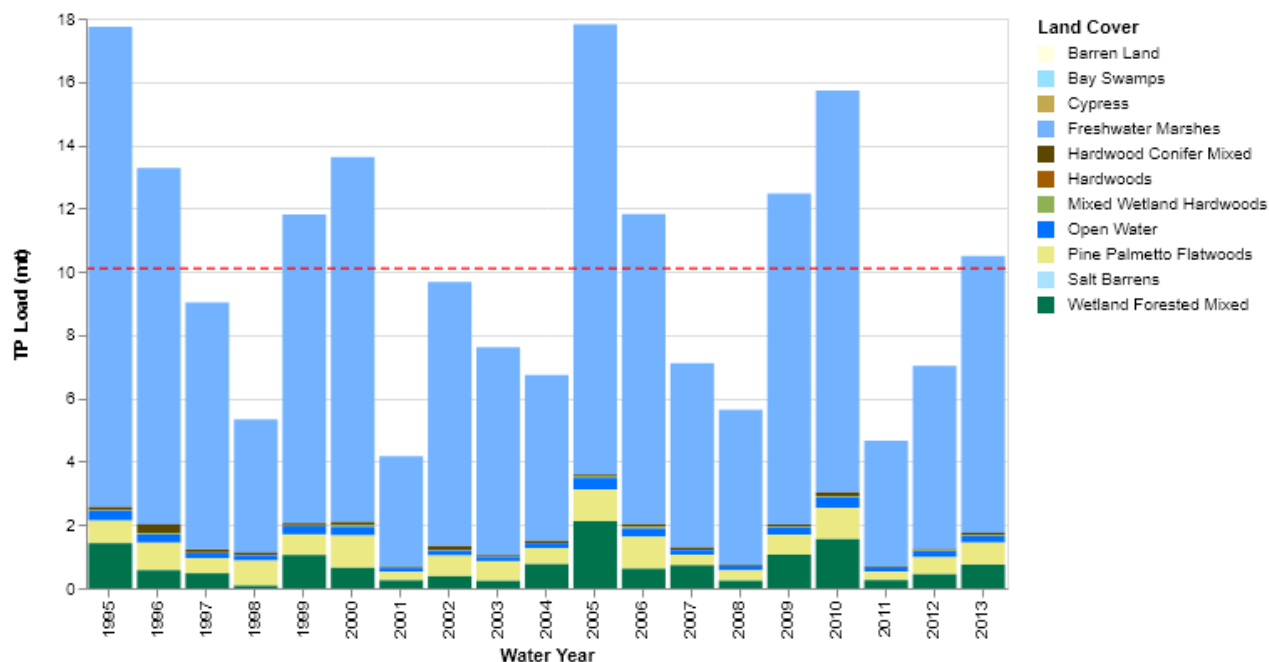


Figure 87. Source cell TP loadings per year in the South sub-watershed.

3.9.2 Water and Nutrient Loads Discharging from the Sub-Watershed

The simulated discharge (in m^3/s) from the southern end of the South sub-watershed directly into the Everglades is shown in **Figure 88**. The annual average discharge was about $70 \text{ m}^3/\text{s}$, corresponding to the annual average volume of over 1.8 million acre-feet per year. Peak discharges are near $250 \text{ m}^3/\text{s}$.

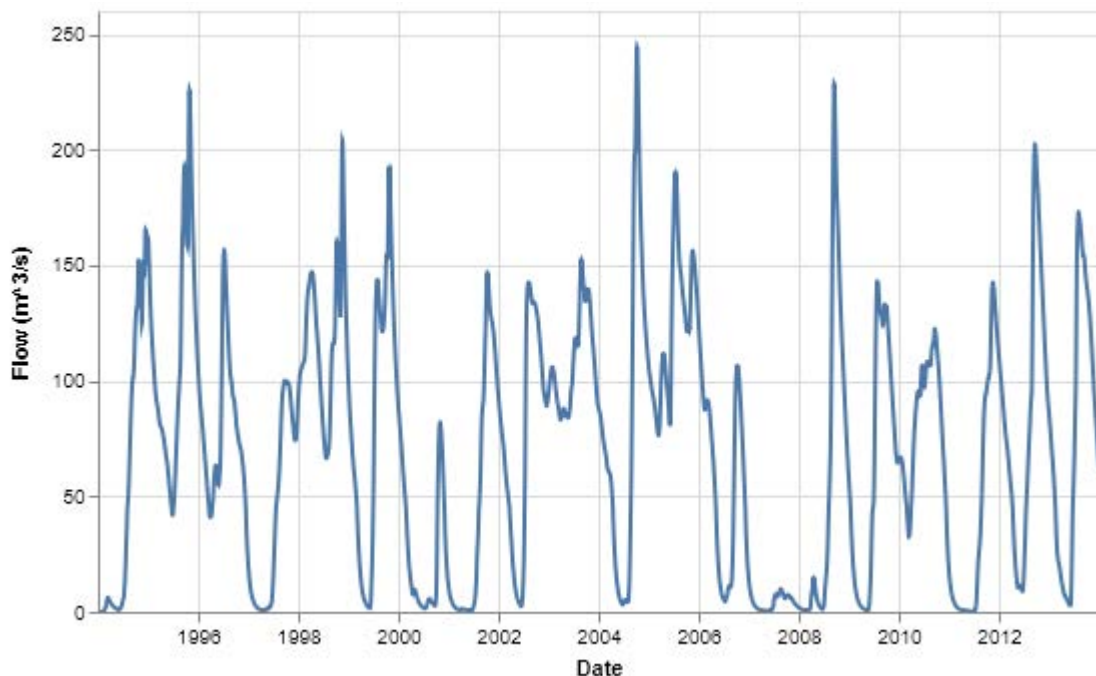


Figure 88. Simulated daily discharge from the South sub-watershed out of the domain.

Simulated concentrations of TN and TP over the modeling period are shown in **Figures 89 and 90**, respectively. The flow-weighted average TN concentration over the entire period was 0.74 mg/L (**Table 11**) with the concentrations oscillating in the range of 0.6 – 1.1 mg/L. The flow-weighted TP concentration over the entire period was 0.013 mg/L with the concentrations in the range of 0.008 – 0.02 mg/L, with peaks slightly over 0.02 mg/L.

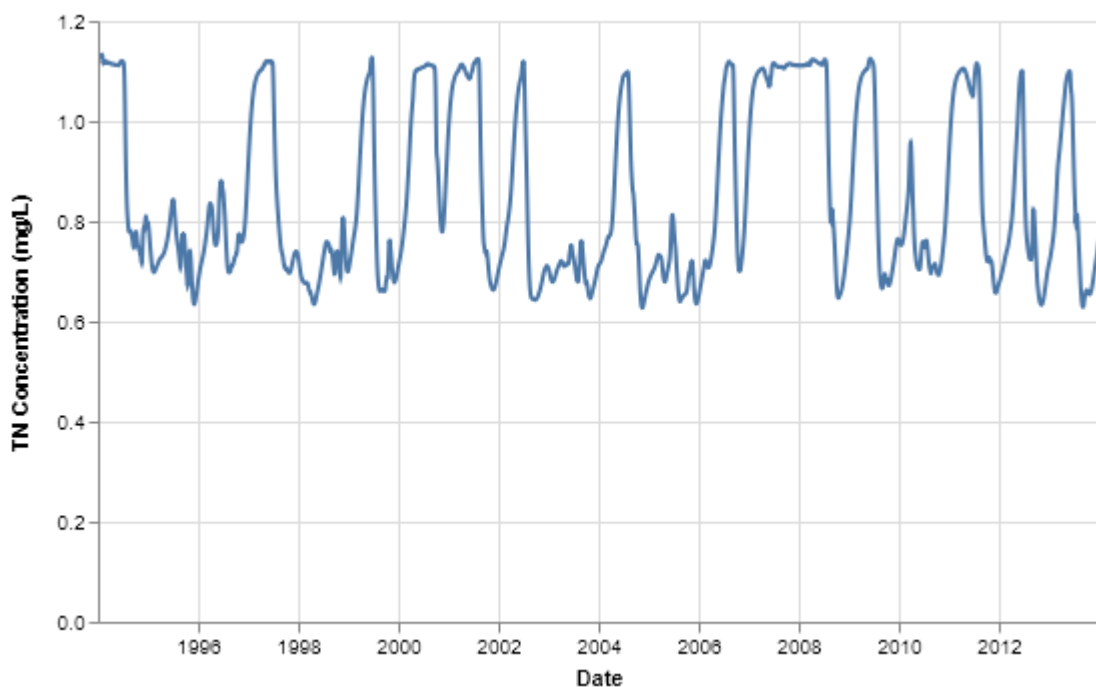


Figure 89. Simulated daily TN concentrations at the south boundary of the South sub-watershed.

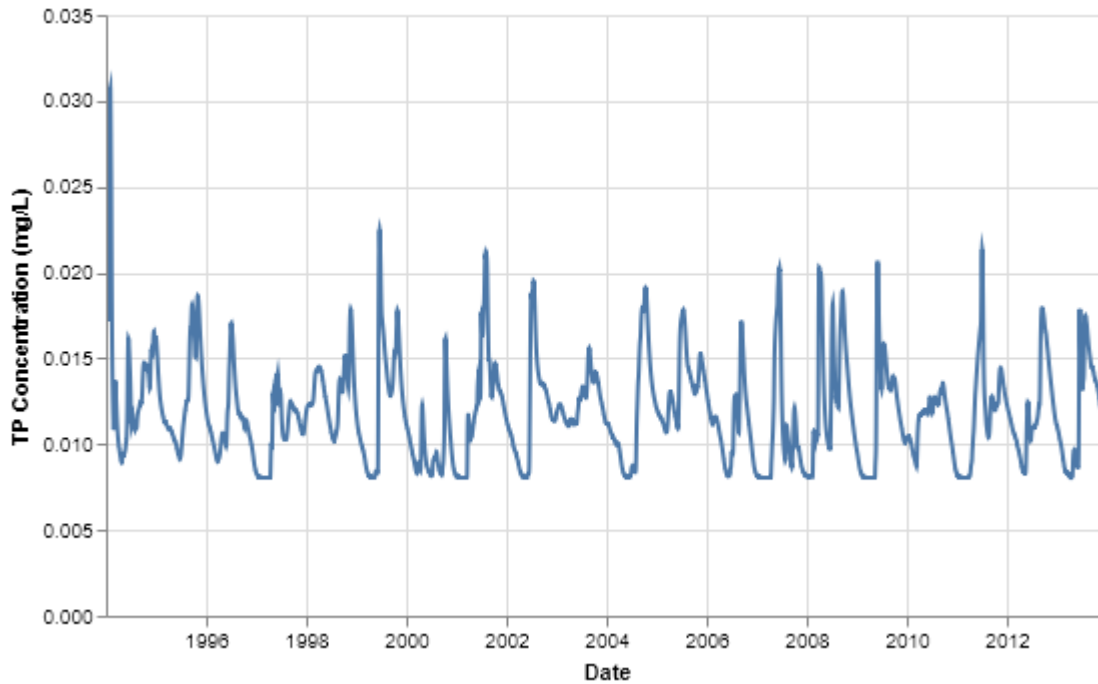


Figure 90. Simulated daily TP concentrations at the south boundary of the South sub-watershed.

3.10 Conclusions

WAM was successfully set up and run to simulate the pre-drainage conditions for the nine sub-watersheds associated with the Lake Okeechobee BMAP. The flows and TN and TP loads to Lake Okeechobee were predicted from these sub-watersheds over a twenty-year simulation period on a daily time scale. The simulated TP concentrations of the water discharging into Lake Okeechobee are similar to the Lake Okeechobee TMDL of 0.04 mg/L. The upland source cell TP concentrations are in the order of 0.045-0.055 mg/L but are attenuated down to less than 0.04 mg/L before reaching the lake. The TN concentrations entering Lake Okeechobee are a little over 1 mg/L, which is only slightly less than existing conditions since most anthropogenic nitrogen inputs are quickly assimilated in the flatwoods and sloughs characteristic of the watershed.

The predicted pre-drainage TP concentrations in water discharging into the Everglades are about 0.013 mg/L, which is slightly higher than the current TP target of 0.01 mg/L for EAA discharges to the conservation areas. These estimates can be improved by mapping a more oligotrophic sawgrass wetland type in the southern part of the EAA to better represent the assimilative capacity and background TP concentrations there.

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5 Appendix A: A Brief Description of the Watershed Assessment Model

5.1 Model Approach

The Watershed Assessment Model (WAM) was chosen to simulate the water quantity and quality discharged from the project area because of its ability to simulate a wide variety of land uses and land use practices while taking into account the geographic and geologic features of the land. WAM uses a GIS grid-based representation to model the physical characteristics of the watershed. One of the first steps is the determination of the specific combination of land use, soil, wastewater service area, and rainfall for each cell in the watershed (**Figure 91**). These four datasets are overlain as part of the modeling process to identify the unique combinations of these inputs. These unique cell combinations characterize the specific conditions that occur on each cell within the watershed.

WAM then creates a spatial map and tabular list of every unique combination of the inputs. The concept of identifying unique cell groupings is critical because it greatly reduces the number of cell level simulations that are needed while still providing the detail of cell level simulated flow and constituent transport for every cell within the watershed.

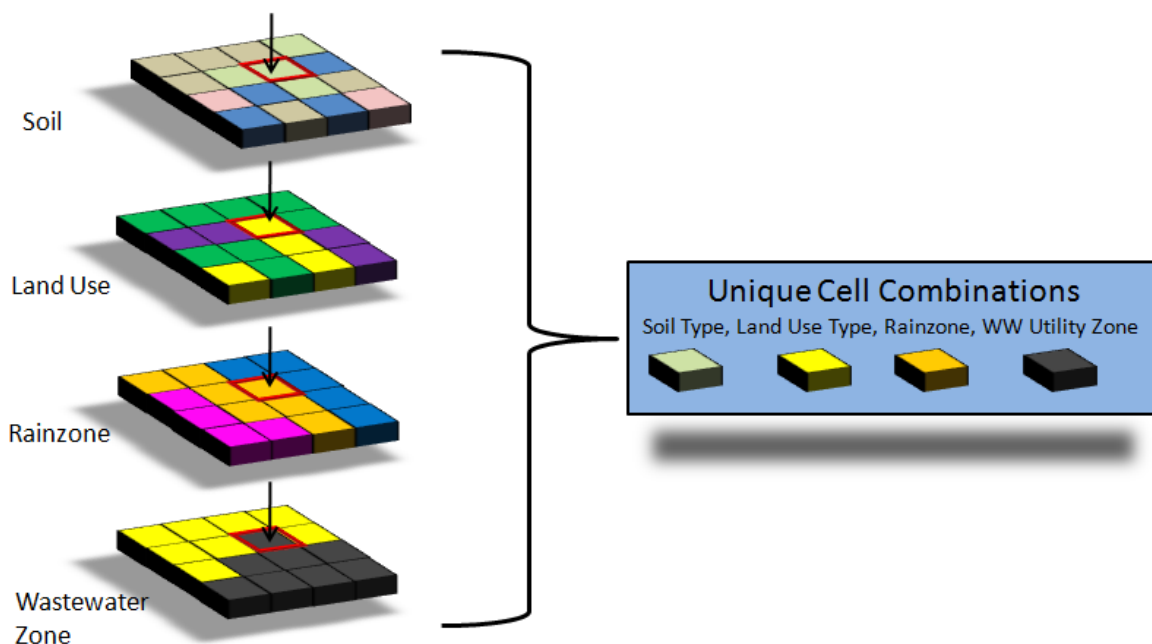


Figure 91. Generation of unique cell combinations.

5.1.1 Source Cell Modeling

The creation of unique cell groupings is also critical because it allows for the most appropriate field-scale sub-model to be used for each unique cell condition, more accurately simulating the daily runoff in terms of both water quality and quantity. Based on the Soil and Land Use combination of the cell, the most appropriate field scale sub-model is selected to simulate that cell as shown in **Figure 92**. The sub-models

include Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) (Knisel, 1993), the Everglades Agricultural Area Model (EAAMod) (Bottcher et al., 1998; SWET, 2008), and a special-case model written specifically for WAM to handle wetland and urban landscapes. These sub-models are bundled into one FORTRAN program called BUCShell (BUC stands for *Basin Unique Cell*).

The individual field scale sub-models used are specifically designed to deal with the particular natural processes that exist between those land use and soils combinations. The daily flows and loads produced by BUCShell are stored in what are referred to as “dayfiles” and contain a daily time series of the amount of nutrients and water leaving each source cell.

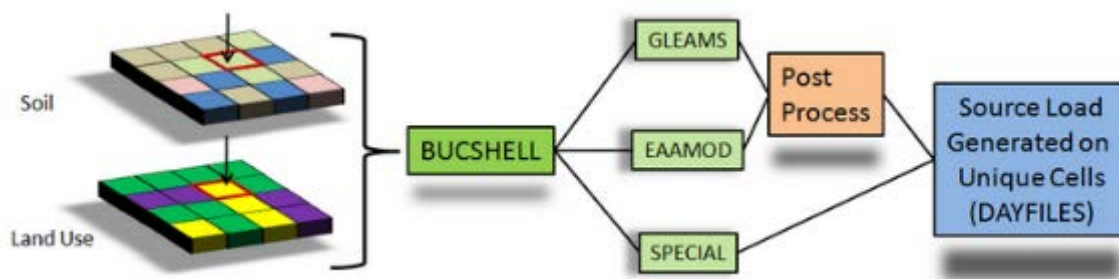


Figure 92. Selection of source cell sub-model and post processing

5.1.1.1 GLEAMS

GLEAMS (Leonard et al., 1987 and Knisel, 1993) is a physically based model used to simulate processes affecting water quality on an agricultural field scale. It has been used extensively and is well documented. GLEAMS is divided into four separate models. These models include:

1. Hydrology
2. Erosion/sediment yield
3. Chemical (pesticide) transport (not currently available within WAM)
4. Nutrient transport

The hydrology component of GLEAMS simulates runoff due to daily rainfall using a modification of the NRCS curve number method. Hydrologic computations for evapotranspiration, percolation, and runoff are determined using a daily time step (Knisel, 1993). Two options are provided in the hydrology component to estimate potential evapotranspiration.

The Priestly-Taylor method (1972) using daily temperature and radiation data computed from mean monthly data is one option. The other option is the Penman-Monteith method (Jensen et al., 1990) and it requires additional data such as wind speed and dew point temperature. Water routing through the soil profile is based on the storage routing concept which allows the downward movement of water in excess of field capacity water content from one layer to the next. Comprehensive detail is provided in Knisel (1993).

The erosion component in GLEAMS uses the universal soil loss equation (USLE) and the concept of continuity of mass to predict erosion and sediment transport under different topographic and cultural conditions. The erosion component considers overland, channel, impoundment, or any combination of these routes. Computation begins at the upper end of the overland slope. The overland flow may be selected from several possible overland flow paths. Its shape may be uniform, convex, concave, or a

combination of these slopes. The processes of detachment and deposition are both considered, and each condition occurs based on the relationship between transport capacity of runoff water and sediment load.

The plant-nutrient component of the GLEAMS model considers both nitrogen and phosphorus cycles. The nitrogen component includes: mineralization, immobilization, denitrification, ammonia volatilization, nitrogen fixation by legumes, crop N uptake, and losses of N in runoff, sediment, and percolation below the root zone. It also considers fertilizer and animal waste application. The phosphorus component includes: mineralization, immobilization, crop uptake, losses to surface runoff, sediment and leaching, and it also includes fertilizer and animal waste application. Tillage algorithms are included in the model to account for the incorporation of crop residue, fertilizer and animal waste. Soil temperature and soil moisture algorithms are also included in the model to provide proper adjustments for ammonification, nitrification, denitrification, volatilization, and mineralization rates. Rainfall nitrogen is an input for the model and may vary depending upon the study region. Initial soil total N and total P are sensitive parameters in the model. For a detailed description of the nutrient component see (Knisel, 1993).

The GLEAMS model provides outputs of soluble inorganic nitrogen (ammonium-N and nitrate-N) and phosphorus (soluble P) in runoff and leachate and sediment-attached N and P in surface runoff. The GLEAMS model does not produce outputs of biological oxygen demand (BOD) or soluble organic N and P. Outputs of these constituents are derived within WAM as a function of total suspended solids (TSS) and from total nitrogen loads in runoff and leachate, respectively.

5.1.1.2 EAAMod

The EAAMod is a field-scale model developed by Soil and Water Engineering Technology, Inc. (SWET) for multi-layered soils with high water tables. Created in the early 1990s, the model grew out of a need to evaluate agricultural BMPs within the Everglades Agricultural Area (EAA) and other high-water table soils in Florida. The model initially focused on water using a hydrography sub-model (WP) and phosphorus (P) movement from histosols (flat organic soils) using the P sub-model PMOVE but was then expanded to all high-water table soils and to handle nitrogen (N) with the inclusion of the nitrogen sub-model (NUTMOD). Histosols require special consideration because of the aerobic mineralization releases of both P and N from organic matter due to drainage and the resulting nutrient impacts downstream. To adequately address this problem, EAAMod simulates water control practices and the impacts of various cultural management scenarios on nutrient transport.

Percolation and runoff in EAAMod is calculated using a vertical two-dimensional hydrologic model (WP). The flow model within EAAMod uses the Dupuit-Forcheimer assumption (zero vertical hydraulic gradient) for two separate flow regimes in the field profile, specifically, above and below an impeding layer such as the spodic horizon in flatwoods soils and the marl cap rock in histosols. The impeding layer is generally highly localized, and while water locally perches above the layer it does not act as a confining layer. The model is conceptually represented in **Figure 93**.

The calculated flow is always for the left side of the cell indicated. Rather than using total water storage in a cell, the water profile algorithm keeps track of air void volume (S). Therefore, a zero value for S would represent a saturated soil condition with no surface ponding. Surface ponding results in a value of S less than zero and typically would indicate that surface runoff is occurring but could be a stagnant surface storage condition.

The air void volume, S , is calculated for each time step t by the following equation:

$$S(i, t) = S(i, t - 1) + \Delta S(i, t) \cdot \Delta T$$

Where:

ΔT is equal to t (current time in hours) minus $t-1$ (previous time step in hours)

To represent actual water management in a field, a series of utility features within the model allow for controlled drainage through a pump, gravity flow through a culvert (bi-directional), flow over a weir, subsurface or surface irrigation, and variable crop ET parameters. Automatic scheduling of irrigation and drainage pump operation is available based upon desired ditch water levels or soil moisture deficit. The flow properties of the pump(s), culvert(s), or weir(s) for specific land use types can be specified by the user in the management section for High Water Table Soils.

Surface water is only allowed to flow to or from the first defined ditch/drainage outlet cell, but this cell may be located anywhere. For flooding, the water profile algorithm allows flows from the ditch to fill each successive cell to the level of the ditch until the time step's flow volume is depleted. The flow volume is limited by the flow rate to the ditch cell and conservation of mass within the ditch. This procedure continues until complete flooding occurs, at which time any subsequent flow due to a rise in ditch levels will be artificially applied to all cells. For surface runoff the procedure is reversed except that artificial ET is used to move the water from the field and move it to the ditch.

5.1.2 Hydrodynamic Routing

The daily outputs from each cell, which includes surface and groundwater flows and constituent concentrations, are simulated they are routed to the streams by the Basin Land Area to Stream Routing model (BLASRoute). BLASRoute is a FORTRAN program that routes the flows and loads based on the distance grids previously calculated and delayed using separate unit hydrographs and delay factors for surface and groundwater. The constituent loads are attenuated based on the landscape features encountered en route to the reach network. The routing process is a complex combination of transport, dispersion, and assimilation that, in most cases, will result in an attenuation, or decrease, in the constituent concentration. The source loads are transported to the reach network via surface and/or ground water.

The transportation path is based on the distance to the closest downhill hydrogeologic feature (reach, wetland or depression) which is identified from the Distance Grids that are calculated by WAM. The transportation path will influence both the time it takes for daily flows to be delivered to the reach network, as well as the attenuation rates that are applied to the constituent concentrations en route to the reach network, depending on the hydrogeologic features encountered. **Figure 94** shows the conceptual routing schemes and flow distances that are calculated for each cell.

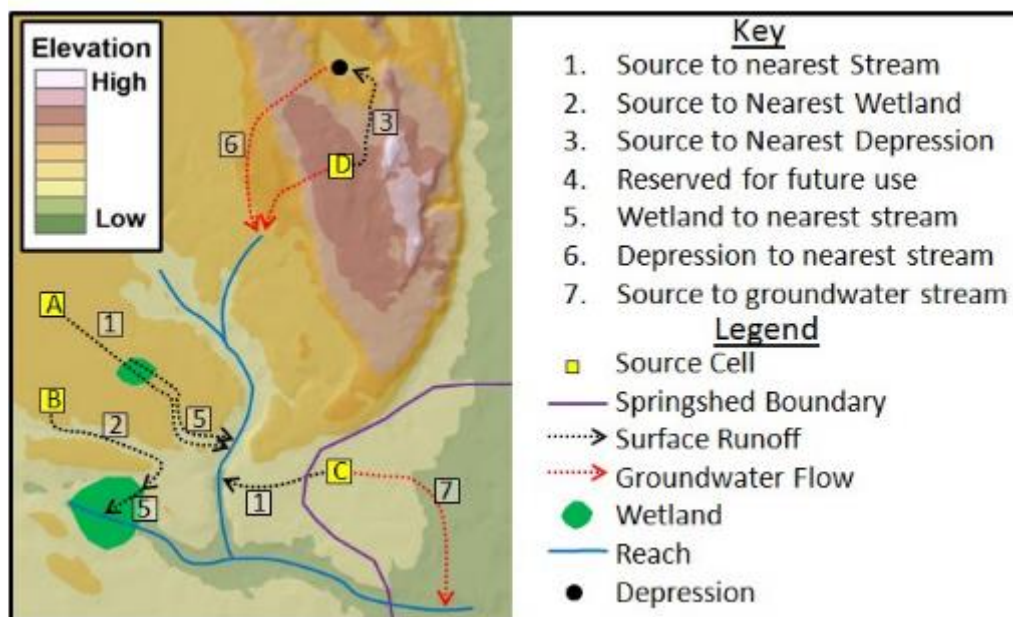


Figure 94. Flow path routing for attenuation distance determination.

WAM includes overland and in-stream attenuation algorithms that function on a daily time step starting at the source cell. From this starting point, nutrients are attenuated during both overland flow, when passing through wetlands, and within streams and canals before finally discharging to the lake.

Each numbered path shown is represented by a GIS grid which includes the distance of the paths. These distances are related back to the original source cell so that the model can extract the needed distance through a downstream geographic feature for each and every grid cell. Destination information is stored in a similar manner. When extracting the distance through a downstream wetland, for example, the type of wetland can also be extracted, which has an associated set of assimilation coefficients.

6 Appendix B: Summary of the 2015 Literature Review

As part of the earlier pre-drainage study (HDR 2015), a comprehensive literature review was conducted to identify, acquire, and assess historic written accounts of the environmental conditions (mainly related to surface hydrology, soils, and vegetation) that most likely characterized the sub-watersheds that make up the LOW Pre-Drainage Characterization study area prior to the construction and operation of the extensive drainage system. This literature review was an important part in the development of the methodology used to create the land cover and hydrography feature classes. Where possible, the same methodology was used to develop the necessary feature classes for the current work; therefore, a brief overview of the literature review is presented here. The interested reader is referred to the report by HDR (2015) for a more detailed assessment of existing literature if desired.

Generally, the term pre-drainage (sometimes also referred to as pre-development) conditions are defined as environmental conditions that existed in the sub-watersheds earlier than the 1850s to 1900s, depending on location. Narrative historic accounts and maps that would facilitate understanding of the pre-drainage hydrology (e.g., water levels, inundation periods, flow magnitudes) in the sub-watersheds were also examined. In addition, available data on the P-loading associated with un-impacted wetlands and native uplands in the LOW were researched. Based upon the literature review feature classes reflecting pre-drainage land cover and hydrography were created for the northern six sub-watersheds in the LOW. The same methodology will be used to generate equivalent feature classes for the southern sub-watersheds in the LOW as part of the deliverables for the current project.

The literature search was primarily intended to support the WAM setup that was used to simulate pre-drainage conditions in the LOW. Accordingly, the search was focused on identifying data that would help characterize “pristine” vegetative and hydrologic conditions. The search was not intended to be a comprehensive evaluation of pre-drainage conditions in the LOW. It was strictly intended to be a compilation of previously reported relevant information and conclusions and should not be considered a validation of the facts reported in the referenced documents or sources. A brief review follows.

6.1 LOW Pre-Drainage Vegetation Communities

A critical part of simulating pre-drainage conditions is determining to the greatest extent possible the vegetative communities that were present since these have perhaps the largest influence on both the hydrology and nutrients that eventually end up in Lake Okeechobee. The literature review was used to determine these vegetative communities by examining historical maps from the 1800s, which were developed both for exploration and military purposes.

The earliest documented records describing conditions in the Kissimmee River Basin are from the period of the Seminole Wars (1830s). The first map to show the Kissimmee River is the map of the “Theatre of Military Operations in Florida during 1835, 36, & 37” (Macomb 1837). A portion of this map shows the “Kissimmee Creek” flowing south from Lake Tohopekaliga, and entering “Okeechobee.” This map was subsequently updated with additional observations and it formed the basis for the “Map of the Seat of War in Florida” (Mackay and Blake 1839).

Mackay and Blake’s 1839 map included relatively accurate positions of features such as Lake Kissimmee, Lake Istokpoga, Lake Okeechobee, Kissimmee River, Peace River, Fisheating Creek, and Caloosahatchee

River. More important for the purposes of the current study is that this map also included some information on vegetation cover. No legends were provided for the symbols used in the map, but most signs are easily interpreted: pines, cabbage palms, oaks, swamps (trees overlain by marsh symbols), marshes, and grasslands. The 1856 map produced by the Lt. Joseph C. Ives showed almost the entire central Florida region depicted as being covered by one of several general vegetation types, delineated in the legend as “SawGrass, Swamp, Marsh, Scrub, Wet Prairie, Dry Prairie, Wet Hammock, and Dry Hammock.”

Bridges (2006) reported on the historic vegetation associated with the Florida dry prairie in the Kissimmee River region. Dry prairie is a rare natural community that is restricted to southcentral peninsular Florida and is a well-defined community distinguished and delineated on many of the pre-settlement land surveys of the region. Vegetation data used by Bridges were obtained from surveys conducted before any extensive alteration of the landscape from logging and drainage, and, therefore, represent a good approximation of natural conditions that occurred within the historic dry prairies.

Bridges (2006) reported that the Kissimmee River dry prairie region was defined as the extent of relatively contiguous prairie on predominantly upland soils, extending to the relatively continuous pinelands on its northern, western, and eastern borders. The pre-settlement extent of the Kissimmee River dry prairie region was determined to be about 2,037 square kilometers (787 square miles or 503,354 acres). This study also distinguishes between two types of “prairies” and classifies different types of marshes as follows:

1. **Dry Prairies** are defined as areas of the pre-settlement extent of “prairie” which were relatively contiguous north of the Kissimmee River marshes on one or both sides of the river. These occurred on poorly drained but rarely flooded soils, mostly spodosols such as the Immokalee, Myakka, Smyrna, Ona, Eau Gallie, and Oldsmar soil series. In some cases, they were also associated with alfisols such as Malabar.
2. **Wet Prairies** are defined as areas with sufficient ponding to lack a well-distributed layer of low shrubs interspersed with grasses and sedges. Shallow inundation occurs for several months during a normal wet season.
3. **Shallow River Floodplain Marshes** are located at the outer zones of the Kissimmee River floodplain marsh. These marshes were dominated by grass and would have been only subjected to infrequent flooding.
4. **Shallow Lakeshore Floodplain Marshes** occurred mostly in the northern part of the region, extending for up to a mile from the permanent water zone of Lake Kissimmee; Lake Tohopekaliga; and, to a lesser extent, from Lake Marian, Lake Jackson, Tiger Lake, Lake Rosalie, Lake Hatchineha, and Cypress Lake.
5. **Shallow Basin Marshes** are mapped as “ponds” or “grass ponds.”
6. **Community Mosaic Complexes** consist of prairie, savanna, and sawgrass areas interspersed within a mosaic of shallower and deeper lakeshore floodplain marshes and mixed in with scattered “islands” of cabbage palm or other trees that are generally located on higher ground.
7. **Savanna** represents areas that had significantly lower pine density than the nearby pinelands over a fairly broad area.

Zahina et al. (2007) created a geospatial database of pre-drainage vegetation within the SFWMD boundary to provide a reliable and comprehensive data source for pre-drainage ecological conditions of the region. The authors conducted a literature search to identify previous studies that provided maps of historical vegetation within the central and south Florida region. A vegetation classification scheme was then developed to define major natural community types that would also meet anticipated data requirements of hydrological models and restoration projects. The authors divided the project area into sub-regions with unique or similar vegetation patterns. A map of historic vegetation was then created for each sub-region based on available predevelopment vegetation map sources acquired during the literature review. A base map was compiled by using a default historic map (usually, the earliest source with the highest resolution) and filling data gaps or areas of questionable accuracy with other historic information. Vegetation communities and descriptions in the base map were converted to the vegetation community classes.

The resulting map and geospatial database were compared to vegetation descriptions in the base map with U.S. General Land Office Survey field note descriptions and maps from the mid- to late-1800s. Data obtained from the Natural Soils Landscape Position/Soils Database⁴ (Zahina et al. 2001) and other available sources of historic vegetation data were used to map and “field verify” pre-drainage vegetation communities across southern Florida.

Information from this study was used to assist in development of the land use/land cover feature classes for sections of the northern sub-watersheds. In a similar fashion, it was used to corroborate the relationship between soil types and historic vegetation communities during development of the pre-drainage land use/land cover feature class for the three southern sub-watersheds.

Table 22. NRCS native vegetation descriptions by soil series. Shaded rows represent the soil series that were added during the extension of the work to the five northern sub-watersheds and were not previously assigned as part of the earlier Fisheating Creek study.

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
ADAMSVILLE	Natural vegetation consists of pines, laurel, and water oaks with a ground cover of saw palmetto, pineland threeawn, indiagrass, bluestem grasses, and several low panicums.	4110
ADAMSVILLE VARIANT	Natural vegetation consists of pines, laurel, and water oaks with a ground cover of saw palmetto, pineland threeawn, indiagrass, bluestem grasses, and several low panicums.	4110
ANCLOTE	Native vegetation consists of cypress, bay, popash, pond pine, cabbage palm, red maple, and juncus species.	6220
ANKONA	longleaf pine, slash pine, sawpalmetto, waxmyrtle, gallberry, fetterbush, creeping bluestem, chalky bluestem, lopsided Indiagrass, low panicums and pineland threeawn	4110
APOPKA	bluejack oak, turkey oak, post oak, live oak, and longleaf pine	4270

⁴ The Natural Soils Landscape Position/Soils Database essentially used the NRCS Soil Survey Geographic database county soil survey information to determine the historic vegetation communities that resided on soil types. This is available for 19 counties in southern Florida and was completed in 2000.

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
ARCHBOLD	Most of this soil is in native scrub forest of sand pine, bluejack oak, sawpalmetto, pricklypear cactus and scattered stands of pineland threeawn.	3200
ARENTS	Community Undetermined	N/A
ASTATULA	Natural vegetation consists of bluejack, blackjack, turkey oaks, longleaf pine, sand pine, and an understory of rosemary, pineland threeawn, bluestem, paspalum, lopsided indiagrass, and panicum.	4340
ASTOR	Natural vegetation in swamps consists of sweetgum, red maple, water oak, laurel oak, and a few slash pine or loblolly pine	6410
BASINGER	The natural vegetation consists of waxmyrtle, St. Johnswort, maidencane, pineland threeawn, cypress, slash pine, longleaf pine, pond pine, and other water tolerant plants.	6172
BOCA	Native vegetation consists of gallberry, sawpalmetto, cabbage palmettos, slash pine, and an understory of pineland threeawn.	4110
BRADENTON	Natural vegetation consists of slash pine, laurel oak, live oak, cabbage palm, southern bayberry, sweetbay magnolia, American holly, water oak, sweetgum, bluestems, longleaf uniola, and panicums.	4250
BRIGHTON	Natural vegetation consists mostly of Jamaica sawgrass, prairie iris, ferns, bull-tongue, greenbriar, buttonbush, maidencane, sedges, and arrow arums in some areas, with other areas being dominated by baldcypress, red bay, white bay, and red maple.	6220
CANDLER	Native vegetation consists of bluejack oak, turkey oak, post oak, live oak, and longleaf pine with a sparse understory of indiagrass, chalky bluestem, pineland threeawn, hairy panicum, and other annual forbs.	4270
CANOVA	The vegetation is dominated by reeds, sedges, sawgrass, lilies, scattered cypress, maple, gum, bay, and myrtle.	6430
CASSIA	The native vegetation consists of scattered slash pine, longleaf pine, and saw palmetto.	4110
CHOBEE	Most of the soils remain in their natural state and have vegetation consisting of pickerelweed, lilies, sawgrass, and scattered swamp maples in treeless areas.	6410
DAYTONA	The native vegetation consists of sand pine with an understory of creeping bluestem, broomsedge bluestem, splitbeard bluestem, lopsided indiagrass, pineland threeawn, switchgrass, panicum, and paspalums.	3200
DELRAY	Natural vegetation includes southern bayberry, pickerelweed, sedges, reeds, water tolerant grasses, and cypress, bay, tupelo and other water tolerant trees.	6410
DUETTE	The natural vegetation is chiefly sand pine, sand live oak, rosemary, sawpalmetto, running oak, pricklypear cactus, fetterbush, and pineland threeawn.	3200

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
EATON	The native vegetation is chiefly loblolly pine, longleaf pine, and slash pine, but includes magnolia, water oak, sweetgum, and bay.	4140
EAUGALLIE	Natural vegetation consists of longleaf pine, South Florida slash pine, and sawpalmetto.	4110
ELECTRA	Most areas remain in native vegetation consisting of dwarf live oak, a few longleaf and sand pine, running oak, sawpalmetto, and blueberry.	4340
FELDA	Natural vegetation consists of cypress, waxmyrtle, pond pine, slash pine, cabbage palm, pineland threeawn, and various grasses, vines, and shrubs.	6172
FLORAHOME	Natural vegetation includes laurel oak, live oak, hickory, sweetgum, slash pine, and longleaf pine.	4140
FLORIDANA	Natural vegetation consists of sand cordgrass, cabbage palmetto, myrtle, and pineland threeawn.	6410
FORT MEADE	Native vegetation is longleaf pine or slash and loblolly pine, laurel, live, post, and turkey oaks, and some dogwood, hickory, cabbage palm, and magnolia,	4340
FT. DRUM	The natural vegetation consists of slash pine, south Florida slash pine, and cabbage palm.	4110
GATOR	Native vegetation is mostly cordgrass or Jamaica sawgrass, maidencane, Coastal Plain willow, redosier dogwood, or swamp vegetation including baldcypress, sweetgum, red maple, and American hornbeam.	6410
GENTRY	Most areas remain in native vegetation of pond cypress, red maple, sweetgum, wax myrtle, pickerelweed, and maidencane.	6210
HALLANDALE	Native vegetation consists of pineland threeawn, paspalum spp., bluejoint panicum, blue maidencane, bluestem, scattered cypress, saw palmettos, and slash pine.	4110
HAPLAQUENTS	Community Undetermined	N/A
HICORIA	Natural vegetation consists of cypress, willow, sweetbay, red bay, pickerel weed, arrowhead, maidencane, sawgrass, chalky bluestem, bushybeard bluestem, sand cordgrass, waxmyrtle, and other water tolerant plants.	6410
HOBE	The vegetations primarily consists of sandpine, scattered slash pine, sand live oak, running oak, sand heath, sawpalmetto, fetterbush, and a few widely spaced pineland threeawn and panicum grasses.	4140
HOLOPAW	Native vegetation is scattered slash and pond pine, cabbage and sawpalmettos, scattered cypress, myrtle, sand cordgrass, and pineland threeawn.	6220
HONTOON	Native vegetation is loblolly, bay, maple, gum, and scattered cypress trees with a ground cover of greenbriers, ferns, and other aquatic plants.	6220

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
IMMOKALEE	Principal vegetation is longleaf and slash pines and undergrowth of sawpalmetto, gallberry, waxmyrtle, and pineland threeawn.	4110
JONATHAN	The native vegetation consists of slash pine, sawpalmetto, sand live oak, running oak, gallberry, fetterbush, pricklypear, and pineland threeawn.	4140
JUPITER	Natural vegetation on the low hammocks consists of cabbage palm, laurel oak, water oak, scattered south Florida slash pine, red mulberry, and redbay with an understory of marlberry, waxmyrtle, wild coffee, greenbriars, ferns, longleaf uniola, Eastern gamagrass, chalky bluestem, maidencane, and switchgrass.	4140
KALIGA	A large part of this soil is in natural vegetation of sawgrass, pickerelweed, maidencane, cattails, flags and scattered thickets of woody button bush.	6410
KENDRICK	Natural vegetation is longleaf, loblolly, and slash pines; hickory, magnolia, dogwood; and laurel, live, and water oaks.	4140
LAKE	Natural vegetation consists of bluejack, blackjack, turkey and live oaks, scattered longleaf pine, and an understory of scattered palmetto, pineland threeawn, bluestem, and paspalum.	4210
LAUDERHILL	Most areas are in natural vegetation of sawgrass, sedges, lilies, spikerush, willow, elderberry and cypress.	6410
LAWNWOOD	The principal vegetation is longleaf pine and slash pine with an understory of sawpalmetto, waxmyrtle, inkberry, fetterbush, creeping bluestem, chalky bluestem, Florida threeawn and pineland threeawn.	4110
LOCHLOOSA	Native vegetation consists of slash and loblolly pine, dogwood, hickory, live, laurel and water oak, sweetgum, red maple, and magnolia.	4230
LOKOSSEE	Native vegetation consists of slash pine, waxmyrtle, cabbage palm, sawpalmetto, pineland threeawn wiregrass, chalky bluestem, and carpet grass.	4110
LYNNE	The native vegetation consists of slash pine, longleaf pine, creeping bluestem, chalky bluestem, indiagrass, panicum, pineland threeawn, saw palmetto, fetterbush, gallberry, and wax myrtle.	4110
MALABAR	Native vegetation consists of scattered slash pine, cypress wax myrtle, cabbage palm, pineland threeawn, and maidencane.	6410
MANATEE	Natural vegetation consists of red maple, gum, cabbage palm and widely spaced cypress.	6170
MILLHOPPER	Native vegetation consists of live oak, laurel oak, post oak, water oak, sweetgum, cherry laurel, few hickory, and slash and longleaf pine.	4340
MINERAL SOIL	Soil that is mainly mineral material and low in organic material. Its bulk density is more than that of organic soil. Used Placid	6410
MYAKKA	Native vegetation includes longleaf and slash pines with an undergrowth of sawpalmetto	4110

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
NARCOOSSEE	Native vegetation is dominantly water oak, willow oak, live oak, laurel oak, longleaf pine, slash pine, greenbrier, sawpalmetto, pineland threeawn, creeping bluestem, panicum, purple lovegrass, and lopsided Indiangrass.	4110
NEILHURST	Natural vegetation is very sparse and consists of scattered slash pines, pineland threeawn, and broomsedge.	4110
NITTAW	Native vegetation is mixed hardwoods of bald cypress, red maple, sweetgum, and hickory with an understory of wax myrtle, greenbrier, wild grape, cabbage palm, and few shade and water tolerant forbes and grasses.	6170
OKEELANTA	Native vegetation consists of sawgrass, lilies, sedges, and other water tolerant plants.	6410
OKLAWAHA	Most areas are in natural vegetation of sawgrass, lilies, sedges, cypress, bay, maple, and blackgum and used for range, wildlife habitat, or water storage areas.	6410
OLDSMAR	Native vegetation consists of cabbage palmetto, sawpalmetto, live oak, slash pine, with an undergrowth of laurel, wax myrtle, and pineland threeawn.	4110
ONA	Natural vegetation is slash pine and longleaf pine, gallberry, widely spaced sawpalmettos, huckleberry, and pineland threeawn.	4110
ORLANDO	Natural vegetation is longleaf pine, laurel, live and turkey oaks, dogwood, hickory, and sweetbay	4120
ORSINO	Native vegetation consists primarily of scrub vegetation with sand live oak, Chapman oak, myrtle oak, and scrub hickory.	3200
PAISLEY	Native vegetation consists of slash, longleaf, and loblolly pine, swamp white oak, swamp maple, and sweetgum with an understory of wax myrtle, cabbage palmetto, bluestem, and native grasses.	4110
PAOLA	Native vegetation consists of sand pine, slash pine, longleaf pine, scrub live oak, scattered turkey oak, and bluejack oak.	3200
PARKWOOD	The dominant vegetation consists of cabbage palm, live oak, water oak, red cedar, magnolia	4280
PENDARVIS	The vegetation consists of scattered longleaf pine and sand pine with a dense understory of myrtle oak, chapman oak, sand live oak, sawpalmetto, and running oak.	4110
PINEDA	Natural vegetation consists of slash pine, cypress, myrtle, cabbage palm, blue maidencane, chalky bluestem, bluepoint panicum, sedges, pineland threeawn, and sand cordgrass.	6172
PINELLAS	The natural vegetation consists of cabbage palm, sawpalmetto, scattered slash pine, inkberry, maidencane, and pineland threeawn.	4280
PITS	Community Undetermined	4110

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
PLACID	Natural vegetation consists of pond pine, bay, cypress, gum, pickerel weed, and coarse grasses.	6410
PLACID VARIANT PLANTATION	Natural vegetation consists of pond pine, bay, cypress, gum, pickerel weed, and coarse grasses. The native vegetation consists of sawgrass, paspalum, maidencane, and cutthroat grass.	6220 6410
POMELLO	Native vegetation is dominated by scrub oak, dwarf live oak, sawpalmetto, longleaf pine, slash pine, and pine land threeawn.	3200
POMONA	The native vegetation consists of slash pine (<i>Pinus Elliottii</i>), longleaf pine (<i>Pinus Palustris</i>), and south Florida slash pine	4110
POMPANO	Natural vegetation consists of palmetto, widely spaced cypress, gum, and slash pine, and native grasses.	3200
POPLE	Natural vegetation is principally cabbage palms, liveoaks, longleaf pine, and slash pine with an understory of sawpalmetto, running oak, waxmyrtle, various bluestems, and in places gallberry.	4250
RIVIERA	Native vegetation consists of slash pine, cabbage, and sawpalmetto, scattered cypress, maidencane, and pineland threeawn.	6240
SALERNO	The native vegetation consists of slash pine	4110
SAMSULA	Natural vegetation is loblolly bay with scattered cypress, maple, gum, and pine trees with a ground cover of greenbriers, ferns, and other aquatic plants.	6410
SANIBEL	Most areas are in natural vegetation which consists mostly of sawgrass, melaleuca, and waxmyrtle.	6410
SATELLITE	Native vegetation consists of south Florida slash pine, saw palmetto, pineland threeawn, and other native grasses.	3200
SEFFNER	The natural vegetation consists of longleaf pine, laurel oak, and water oak	4140
SMYRNA	Natural vegetation consists of longleaf and slash pines with an undergrowth of sawpalmetto, running oak, gallberry, waxmyrtle, and pineland threeawn.	4110
SPARR	Native vegetation consists of longleaf pine, slash pine, loblolly pine, magnolia, dogwood, hickory, and live oak, laurel oak, and water oak.	4140
ST. AUGUSTINE	Some areas have natural vegetation of southern red cedar and cabbage palm with an understory of waxmyrtle, blackberry, greenbrier, and panicums.	4300
ST. JOHNS	Principal vegetation of the forested areas is longleaf pine, slash pine, and pond pine with an undergrowth of sawpalmetto, gallberry, waxmyrtle, huckleberry, and pineland threeawn.	4140
ST. LUCIE	Vegetation is dominated by sand live oak, sand pine, dwarf willow, sawpalmetto, rosemary, pricklypear cactus, and lichens.	3200

COMPNAME	ASSOCIATED VEGETATION	FLUCCS
TAVARES	In most places the natural vegetation consists of slash pine, longleaf pine, a few scattered blackjack oak, turkey oak, and post oak with an undercover of pineland threeawn.	4340
TEQUESTA	The natural vegetation consists of needlegrass, pickerelweed, maidencane, ferns, waxmyrtle, and scattered cypress.	6410
TERRA CEIA	The natural vegetation consists of sawgrass, lilies, sedges, reeds, maidencane, spikerush, and other aquatic plants.	6430
UDORTHENTS	Community Undetermined	N/A
URBAN LAND	Community Undetermined. Assume upland pine lands	4110
VALKARIA	Natural vegetation is palms, cabbage palmettos, St. Johnswort, waxmyrtle, blue maidencane, chalky bluestem, pineland threeawn, and widely spaced pine and cypress.	6172
VERO	Most areas are in native vegetation of longleaf and slash pines, scattered cabbage palms, sawpalmetto, waxmyrtle, gallberry, fetterbush, creeping bluestem, chalky bluestem, and pineland threeawn.	4110
WABASSO	The natural vegetation consists of longleaf pine, slash pine, cabbage palm, live oak	4140
WATER	Community Undetermined	5100
WAUBERG	Most areas of these soils remain in native vegetation consisting of low panicums, bushybeard, creeping and chalky bluestems, bulrush, cutgrass, maidencane, carpetgrass, dogfennel, briars, thistle, and waxmyrtle.	3200
WAUCHULA	The natural vegetation consists of longleaf pine, slash pine, sawpalmetto	4110
WAVELAND	The principal vegetation is longleaf pine and slash pine	4140
WINDER	Natural vegetation consists of cordgrass, maidencane, cabbage palmetto, saw palmetto, and pineland threeawn.	4110
ZOLFO	Native vegetation consists of scattered turkey, laurel, or water oaks; long leaf or slash pine	4140

Table 23 was created using FLUCCS codes estimated from NRCS and PDL D codes. Where the entry in the NRCS FLUCCS code is “PDL D”, the FLUCCS code from PDL D dataset was assigned to the polygon based on its location. If the entry is, for example, “PDL D/4100” the PDL D code was used unless it was not present, in which case 4100 was assigned.

Table 23. The lookup table created to assign FLUCCS codes to soil mapunit names.

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Adamsville fine sand, 0 to 2 percent slopes	Adamsville	4110
Adamsville fine sand, organic substratum	Adamsville	4110
Adamsville sand, 0 to 2 percent slopes	Adamsville	4110
Adamsville variant fine sand, 0 to 5 percent slopes	Adamsville variant	4110
Adamsville variant sand	Adamsville Variant	4110
Adamsville-Urban land complex	Adamsville	4110
Anclote and Myakka soils	Anclote	6220
Anclote fine sand	Anclote	6220
Anclote mucky fine sand, frequently ponded, 0 to 1 percent slopes	Anclote	6220
Anclote sand, depressional, 0 to 1 percent slopes	Anclote	6220
Anclote sand, frequently ponded, 0 to 1 percent slopes	Anclote	6220
Anclote-Basinger fine sand, frequently flooded	Anclote	6220
Ankona fine sand	Ankona	4110
Ankona-Urban land complex	Ankona	4110
Apopka fine sand, 0 to 5 percent slopes	Apopka	4270
Apopka sand, 0 to 5 percent slopes	Apopka	4270
Apopka sand, 5 to 12 percent slopes	Apopka	4270
Aquents, organic substratum	Aquents	PDLD
Archbold fine sand, 0 to 5 percent slopes	Archbold	3200
Archbold sand, 0 to 5 percent slopes	Archbold	3200
Arents	Arents	PDLD/4110
Arents, 0 to 2 percent slopes	Arents	PDLD/4110
Arents, 0 to 5 percent slopes	Arents	PDLD/4110
Arents, 45 to 65 percent slopes	Arents	PDLD/4110
Arents, clayey substratum	Arents	PDLD/4110
Arents, nearly level	Arents	PDLD/4110
Arents, organic substratum	Arents	PDLD/4110
Arents, organic substratum, 0 to 5 percent slopes	Arents	PDLD/4110
Arents, organic substratum-Urban land complex	Arents	PDLD/4110
Arents, sandy	Arents	PDLD/4110
Arents, very steep	Arents	PDLD/4110
Arents-Urban land complex, 0 to 5 percent slopes	Arents	PDLD/4110

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Arents-Urban land complex, organic substratum	Arents	PDLD/4110
Arents-Water complex	Arents	PDLD/4110
Astatula sand, 0 to 5 percent slopes	Astatula	4340
Astatula sand, 12 to 20 percent slopes	Astatula	4340
Astatula sand, 5 to 12 percent slopes	Astatula	4340
Astatula-Urban land complex, 0 to 8 percent slopes	Astatula	4340
Astor fine sand, depressional	Astor	6410
Basinger and Myakka sands, depressional	Basinger	6210
Basinger and Placid soils, depressional	Basinger	6172
Basinger fine sand	Basinger	6172
Basinger fine sand, 0 to 2 percent slopes	Basinger	6172
Basinger fine sand, depressional, 0 to 1 percent slopes	Basinger	6172
Basinger fine sand, frequently ponded, 0 to 1 percent slopes	Basinger	6172
Basinger mucky fine sand, depressional	Basinger	6172
Basinger sand, 0 to 2 percent slopes	Basinger	6172
Basinger, St. Johns, and Placid soils	St. Johns	6172
Boca fine sand	Boca	4110
Boca fine sand, 0 to 2 percent slopes	Boca	4110
Boca sand	Boca	4110
Boca sand, depressional	Boca	6210
Borrow Pits	Borrow pits	4270
Bradenton fine sand	Bradenton	4250
Bradenton fine sand, 0 to 2 percent slopes	Bradenton	4250
Brighton muck	Brighton	6220
Candler fine sand, 0 to 5 percent slopes	Candler	4270
Candler fine sand, 5 to 12 percent slopes	Candler	4270
Candler sand, 0 to 5 percent slopes	Candler	4270
Candler sand, 12 to 40 percent slopes	Candler	4270
Candler sand, 5 to 12 percent slopes	Candler	4270
Candler sand, 5 to 8 percent slopes	Candler	4270
Candler-Apopka fine sands, 5 to 12 percent slopes	Candler	4270
Candler-Urban land complex, 0 to 5 percent slopes	Candler	4270
Candler-Urban land complex, 5 to 12 percent slopes	Candler	4270
Canova muck, moderately deep, drained	Canova	6430

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Cassia fine sand, 0 to 2 percent slopes	Cassia	4110
Cassia sand	Cassia	4110
Chobee fine sandy loam	Chobee	6410
Chobee fine sandy loam, frequently flooded	Chobee	6410
Chobee fine sandy loam, frequently ponded, 0 to 1 percent slopes	Chobee	6410
Chobee fine sandy loam, limestone substratum, depressional	Chobee	6410
Chobee loamy fine sand, frequently ponded, 0 to 1 percent slopes	Chobee	6410
Chobee muck, frequently ponded, 0 to 1 percent slopes	Chobee	6410
Dania muck, drained, frequently ponded, 0 to 1 percent slopes	Dania	6411
Daytona sand	Daytona	3200
Daytona sand, 0 to 5 percent slopes	Daytona	3200
Delray loamy fine sand, depressional	Delray	6410
Delray sand, depressional	Delray	6410
Denaud muck	Denaud	6410
Denaud-Gator mucks	Denaud	6400
Duette fine sand	Duette	3200
Duette sand, 0 to 5 percent slopes	Duette	3200
Eaton mucky fine sand, depressional	Eaton	4140
EauGallie fine sand	EauGallie	4110
EauGallie fine sand, 0 to 2 percent slopes	EauGallie	4110
EauGallie sand, 0 to 2 percent slopes	EauGallie	4110
Electra fine sand	Electra	4340
Felda fine sand	Felda	6172
Felda fine sand, 0 to 2 percent slopes	Felda	6172
Felda fine sand, 0 to 2 percent slopes, frequently flooded	Felda	6172
Felda fine sand, frequently ponded, 0 to 1 percent slopes	Felda	6172
Florahome fine sand, 0 to 5 percent slopes	Florahome	4140
Florahome-Urban land complex, 0 to 5 percent slopes	Florahome	4140
Floridana fine sand, 0 to 1 percent slopes, frequently flooded	Floridana	6410
Floridana fine sand, frequently ponded, 0 to 1 percent slopes	Floridana	6410
Floridana mucky fine sand, frequently ponded, 0 to 1 percent slopes	Floridana	6410
Floridana sand, frequently ponded, 0 to 1 percent slopes	Floridana	6410
Floridana, Astor, and Felda soils, frequently flooded	Floridana	6410
Floridana, Placid, and Okeelanta soils, frequently flooded	Floridana	6410

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Floridana, Riviera, and Placid soils, depressional	Floridana	6410
Fort Meade sand, 0 to 5 percent slopes	Fort Meade	4340
Ft. Drum fine sand	Ft. Drum	4110
Gator and Tequesta mucks	Gator	6410
Gator muck, frequently ponded, 0 to 1 percent slopes	Gator	6410
Gentry fine sand	Gentry	6210
Gentry fine sand, depressional	Gentry	6410
Hallandale fine sand, 0 to 2 percent slopes	Hallandale	4110
Hallandale fine sand, slough	Hallandale	4110
Hallandale sand	Hallandale	4110
Hallandale sand, 0 to 2 percent slopes	Hallandale	4110
Hallandale sand, depressional	Hallandale	4110
Hallandale-Pople complex	Hallandale	4110
Haplaquents clayey	Haplaquents	4110
Hicoria mucky sand, depressional	Hicoria	6410
Hobe fine sand, 0 to 5 percent slopes	Hobe	4140
Hobe sand, 0 to 5 percent slopes	Hobe	4140
Holopaw fine sand, 0 to 2 percent slopes	Holopaw	6220
Holopaw fine sand, frequently ponded, 0 to 1 percent slopes	Holopaw	6220
Holopaw sand, 0 to 2 percent slopes	Holopaw	4200
Holopaw sand, frequently ponded, 0 to 1 percent slopes	Holopaw	6400
Holopaw sand, limestone substratum	Holopaw	6430
Hontoon muck, frequently ponded, 0 to 1 percent slopes	Hontoon	6220
Hydraquents, clayey	Hydraquents, clayey	PDLD
Immokalee fine sand	Immokalee	4110
Immokalee fine sand, 0 to 2 percent slopes	Immokalee	4110
Immokalee sand	Immokalee	4110
Immokalee sand, 0 to 2 percent slopes	Immokalee	4110
Jonathan sand, 0 to 5 percent slopes	Jonathan	4140
Jupiter fine sand, 0 to 2 percent slopes	Jupiter	4140
Jupiter sand	Jupiter	4140
Kaliga muck, frequently flooded	Kaliga	6410
Kaliga muck, frequently ponded, 0 to 1 percent slopes	Kaliga	6410
Kendrick fine sand, 0 to 5 percent slopes	Kendrick	4140

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Kendrick sand, 0 to 5 percent slopes	Kendrick	4140
Kendrick sand, 5 to 8 percent slopes	Kendrick	4140
Lake sand, 0 to 5 percent slopes	Lake	4210
Lake sand, 5 to 12 percent slopes	Lake	4210
Lauderhill muck, drained, frequently ponded, 0 to 1 percent slopes	Lauderhill	6411
Lawnwood and Myakka fine sands	Myakka	4110
Lawnwood and Myakka sands	Lawnwood	4110
Lochloosa fine sand	Lochloosa	4230
Lochloosa sand	Lochloosa	4230
Lokosee fine sand	Lokosee	4110
Lynne sand	Lynne	4110
Malabar fine sand	Malabar	6410
Malabar fine sand, 0 to 2 percent slopes	Malabar	6410
Malabar fine sand, depressional	Malabar	6410
Malabar fine sand, depressional, 0 to 1 percent slopes	Malabar	6410
Malabar fine sand, frequently ponded, 0 to 1 percent slopes	Malabar	6410
Malabar fine sand, high, 0 to 2 percent slopes	Malabar	6410
Malabar sand, 0 to 2 percent slopes	Malabar	6410
Malabar sand, frequently ponded, 0 to 1 percent slopes	Malabar	6410
Manatee loamy fine sand, frequently ponded, 0 to 1 percent slopes	Manatee	6170
Manatee, Floridana, and Tequesta soils, frequently flooded	Manatee	6170
Margate mucky sand, prairie	Margate	6411
Margate sand	Margate	6411
Millhopper fine sand, 0 to 5 percent slopes	Millhopper	4340
Millhopper-Urban land complex, 0 to 5 percent slopes	Millhopper	4340
Myakka fine sand, 0 to 2 percent slopes	Myakka	4110
Myakka fine sand, frequently ponded, 0 to 1 percent slopes	Myakka	4110
Myakka sand, 0 to 2 percent slopes	Myakka	4110
Myakka sand, depressional	Myakka	4110
Myakka-Immokolee-Urban land complex	Myakka	4110
Myakka-Myakka, wet, sands, 0 to 2 percent slopes	Myakka	4110
Myakka-Urban land complex	Myakka	4110
Narcoossee fine sand, 0 to 2 percent slopes	Narcoossee	4110
Narcoossee sand	Narcoossee	4110

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Neilhurst sand, 1 to 5 percent slopes	Neilhurst	4110
Nittaw muck	Nittaw	6170
Nittaw sandy clay loam, frequently flooded	Nittaw	6170
Okeechobee muck	Okeechobee	6411
Okeelanta and Dania soils, depressional	Okeelanta	6410
Okeelanta muck	Okeelanta	6410
Okeelanta muck, drained, frequently ponded, 0 to 1 percent slopes	Okeelanta	6410
Okeelanta muck, frequently ponded, 0 to 1 percent slopes	Okeelanta	6410
Oklawaha muck	Oklawaha	6410
Oldsmar fine sand	Oldsmar	4110
Oldsmar fine sand, 0 to 2 percent slopes	Oldsmar	4110
Oldsmar sand, 0 to 2 percent slopes	Oldsmar	4110
Oldsmar sand, depressional	Oldsmar	4110
Oldsmar sand, limestone substratum	Oldsmar	4110
Ona fine sand, 0 to 2 percent slopes	Ona	4110
Ona-Ona, wet, fine sand, 0 to 2 percent slopes	Ona	4110
Ona-Urban land complex	Ona	4110
Orlando fine sand, 0 to 5 percent slopes	Orlando	4120
Orsino fine sand	Orsino	3200
Orsino sand, 0 to 5 percent slopes	Orsino	3200
Pahokee muck, drained, 0 to 1 percent slopes	Pahokee	6411
Pahokee muck, drained, frequently ponded, 0 to 1 percent slopes	Pahokee	6411
Paisley fine sand, 0 to 1 percent slopes	Paisley	4110
Paola and St. Lucie sands, 0 to 8 percent slopes	Paola	3200
Paola sand, 0 to 5 percent slopes	Paola	3200
Paola sand, 0 to 8 percent slopes	Paola	3200
Paola-Basinger sands, rolling	Paola	3200
Parkwood fine sand	Parkwood	4280
Parkwood loamy fine sand, occasionally flooded	Parkwood	4280
Pendarvis and Pomello sands, 0 to 5 percent slopes	Pomello	4110
Pineda and Riviera fine sands	Pineda	6172
Pineda fine sand, 0 to 2 percent slopes	Pineda	6172
Pineda fine sand, frequently ponded, 0 to 1 percent slopes	Pineda	6172
Pineda sand, 0 to 2 percent slopes	Pineda	6172

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Pineda sand, depressional	Pineda	6172
Pineda sand, limestone substratum	Pineda	4200
Pinellas fine sand	Pinellas	4280
Pits	Pits	4110
Pits, 0 to 5 percent slopes	Pits	4110
Placid and Basinger fine sands, depressional	Placid	6410
Placid and Myakka fine sands, depressional	Placid	6410
Placid and Myakka sands, depressional	Placid	6410
Placid fine sand, frequently flooded	Placid	6410
Placid fine sand, frequently ponded, 0 to 1 percent slopes	Placid	6410
Placid sand, frequently ponded, 0 to 2 percent slopes	Placid	6410
Placid variant fine sand	Placid variant	6220
Plantation muck	Plantation	6410
Plantation muck, depressional	Plantation	6410
Plantation muck, drained	Plantation	6410
Pomello fine sand	Pomello	3200
Pomello fine sand, 0 to 2 percent slopes	Pomello	3200
Pomello fine sand, 0 to 5 percent slopes	Pomello	3200
Pomello sand, 0 to 5 percent slopes	Pomello	3200
Pomello-Urban land complex	Pomello	3200
Pomello-Urban land complex, 0 to 5 percent slopes	Pomello	3200
Pomona fine sand	Pomona	4110
Pomona fine sand, 0 to 2 percent slopes	Pomona	4110
Pompano fine sand	Pompano	3200
Pompano fine sand, 0 to 2 percent slopes	Pompano	3200
Pompano fine sand, frequently ponded, 0 to 1 percent slopes	Pompano	3200
Pompano sand	Pompano	3200
Pompano sand, 0 to 2 percent slopes	Pompano	3200
Pople fine sand	Pople	4250
Punta fine sand	Punta	4110
Quartzipsamments, shaped, 0 to 5 percent slopes	Quartzipsamments	PDLD
Riviera fine sand, 0 to 2 percent slopes	Riviera	6240
Riviera fine sand, frequently ponded, 0 to 1 percent slopes	Riviera	6240
Riviera sand, frequently ponded, 0 to 1 percent slopes	Riviera	6240

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Riviera sand, limestone substratum	Riviera	6430
Riviera sand, limestone substratum, depressional	Riviera	6400
Salerno and Punta sands	Punta	4110
Salerno sand	Salerno	4110
Samsula muck, frequently ponded, 0 to 1 percent slopes	Samsula	6410
Samsula-Hontoon-Basinger association, depressional	Samsula	6410
Sanibel muck	Sanibel	6410
Sanibel muck, depressional	Sanibel	6410
Sanibel muck, drained	Sanibel	6410
Satellite fine sand, 0 to 2 percent slopes	Satellite	3200
Satellite sand, 0 to 2 percent slopes	Satellite	3200
Satellite-Basinger-Urban land complex	Satellite	3200
Seffner fine sand, 0 to 2 percent slopes	Seffner	4140
Seffner sand	Seffner	4140
Smyrna and Myakka fine sands	Smyrna	4110
Smyrna fine sand, 0 to 2 percent slopes	Smyrna	4110
Smyrna sand, 0 to 2 percent slopes	Smyrna	4110
Smyrna-Smyrna, wet, fine sand, 0 to 2 percent slopes	Smyrna	4110
Smyrna-Urban land complex	Smyrna	4110
Sparr sand, 0 to 5 percent slopes	Sparr	4140
St. Augustine sand	St. Augustine	4300
St. Johns fine sand	St. Johns	4140
St. Johns sand	St. Johns	4140
St. Lucie fine sand, 0 to 5 percent slopes	St. Lucie	3200
St. Lucie sand, 0 to 5 percent slopes	St. Lucie	3200
St. Lucie sand, 0 to 8 percent slopes	St. Lucie	3200
St. Lucie-Urban land complex, 0 to 5 percent slopes	St. Lucie	3200
Swamp	Organic soil	6410
Tavares fine sand, 0 to 5 percent slopes	Tavares	4340
Tavares sand, 0 to 5 percent slopes	Tavares	4340
Tavares-Basinger-Sanibel complex, rolling	Tavares	4340
Tavares-Millhopper complex, 0 to 5 percent slopes	Tavares	4340
Tavares-Urban land complex	Tavares	4340
Tavares-Urban land complex, 0 to 5 percent slopes	Tavares	4340

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Tequesta muck, drained	Tequesta	6410
Tequesta muck, frequently ponded, 0 to 1 percent slopes	Tequesta	6410
Terra Ceia muck, drained	Terra Ceia	6411
Terra Ceia muck, drained, frequently ponded, 0 to 1 percent slopes	Terra Ceia	6411
Terra Ceia muck, frequently ponded, 0 to 1 percent slopes	Terra Ceia	6411
Torry muck	Torry	6173
Tusawilla fine sand	Tusawilla	4200
Udifluvents	Udifluvents	4110
Udorthents	Udorthents	PDLD/6410
Udorthents, 0 to 35 percent slopes	Udorthents	PDLD/6410
Udorthents, 2 to 35 percent slopes	Udorthents	PDLD/6410
Udorthents, excavated	Udorthents	PDLD/6410
Urban land	Urban land	PDLD/4110
Valkaria fine sand, 0 to 2 percent slopes	Valkaria	6172
Valkaria fine sand, depressional	Valkaria	6172
Valkaria sand	Valkaria	6172
Wabasso and Oldsmar fine sands, depressional	Wabasso	4140
Wabasso fine sand	Wabasso	4140
Wabasso fine sand, 0 to 2 percent slopes	Wabasso	4140
Wabasso sand, 0 to 2 percent slopes	Wabasso	4140
Wabasso sand, limestone substratum, 0 to 2 percent slopes	Wabasso	4140
Wabasso-Urban land complex	Wabasso	4140
Water	Water	5100
Water-Udorthents complex, 0 to 35 percent slopes	Water	6411
Wauberg fine sand	Wauberg	3200
Wauchula fine sand	Wauchula	4110
Waveland and Immokalee fine sands	Waveland	4140
Waveland and Lawnwood fine sands, depressional	Waveland	4140
Waveland-Lawnwood complex, depressional	Waveland	4140
Winder fine sand, frequently ponded, 0 to 1 percent slopes	Winder	4110
Winder loamy fine sand	Winder	4110
Winder sand, depressional	Winder	4110
Wulfert and Durbin mucks, tidal	Wulfert	4110
Zolfo fine sand, 0 to 2 percent slopes	Zolfo	4140

Mapunit Name (MUNAME)	COMPNAME	NRCS FLUCCS
Zolfo-Urban land complex	Zolfo	4140

Table 24. PDLD vegetation descriptions.

VEG CODE	DESCRIPTION	FLUCCS
100	Water Permanently inundated site; includes freshwater, estuary and marine systems.	5100
400	Forested Freshwater Wetland: Forested freshwater wetlands (swamps).	6220
410	Cypress Swamp: Freshwater swamp dominated by cypress with few large hardwood trees.	6210
420	Hardwood Swamp: Freshwater swamp dominated by broadleaf trees; may also contain some cypress.	6110
500	Non-Forested Freshwater Wetland: Freshwater wetland dominated by herbaceous vegetation; non-forested.	6410
510	Long-hydroperiod Marsh: Freshwater marsh with hydroperiods extending from 11 to 12 months on average.	6400
511	Ridge and Slough Marsh: Everglades-specific community mosaic of alternating open water sloughs and sawgrass ridges interspersed with tree islands.	6411
512	Sawgrass Plain: Northern Everglades-specific community consisting of a generally unbroken expanse of sawgrass across a large spatial extent.	6411
520	Medium-hydroperiod Marsh: Freshwater marsh with hydroperiods extending from 6 to 10 months on average.	6400
521	Marsh with Scattered Cypress: Freshwater marsh that contains scattered stunted cypress.	6400
522	Everglades Marl Marsh: Historical Everglades community consisting of a medium-hydroperiod marsh with marl soils derived from calcareous algae; most extensive in the southern Everglades.	6430
530	Wet Prairie: Short-hydroperiod treeless wetlands that have hydric soils, hydroperiods extending from 2 to 6 months, and inundation to 1 foot on average.	6430
531	Wet prairie with scattered trees and shrubs, including pine, cypress and bay.	6439
532	Wet prairie with scattered cypress.	6431
600	Hydric Upland: Moist woodlands on non-hydric soils in level, low landscapes than may have some short-duration flooding each year. Fire frequency is the primary factor in shaping dominant vegetation type.	4200
610	Hydric Flatwood: Hydric flatwoods typically are dominated by open pine forest with a herbaceous ground cover.	6250

VEG CODE	DESCRIPTION	FLUCCS
620	Hydric Hammock: Hydric hammocks typically are dense forests dominated by hardwood species.	6170
700	Mesic Upland: Mesic communities are found on upland (non-hydric) soils; short-duration flooding may occur only during high-rainfall events. Fire frequency is the primary factor shaping dominant vegetation type.	4110
710	Dry Prairie: Non-forested upland community composed primarily of grasses and palms; high fire frequency.	3100
720	Mesic Pine Flatwood: Forested upland community composed primarily of pines; moderate fire frequency.	4110
730	Mesic Hammock: Forested upland community composed primarily of broadleaf trees; low fire frequency.	4200

7 Appendix C: Lake Okeechobee Stage Model

A model was developed to provide a time series of stage in Lake Okeechobee because such a time series is needed as a boundary condition for the three southern sub-watersheds. Under pre-drainage conditions it is assumed that the southern shore of the lake acts as a very wide broad-crested weir, i.e., water will discharge into these basins only water levels go above 20 feet (NGVD) and in accordance with the weir equation. Therefore, the model for estimating the daily stage in the lake was developed based on maintaining a complete water balance within the lake on a daily basis. The following processes are represented in the model:

- WAM simulated inflows to Lake Okeechobee
- Rainfall onto Lake Okeechobee and its upland vegetated floodplain
- ET off the open water with Lake Okeechobee
- Runoff from the upland vegetated floodplain
- Discharges from Lake Okeechobee based on lake stage and weir equation.

The above processes can be represented in the following equations:

$$\Delta S = I + A_o(R_o - Et_o) + A_v(R_v - Et_v) - Q$$

Where ΔS is the change in lake storage volume S (m^3/d), I is the total simulated WAM inflow to the lake (m^3/d), A_o is the open water area (m^2), A_v is the vegetated area within the lake boundary (m^2), R_o and R_v are the rainfall onto open water and vegetated areas (cm/d), respectively, Et_o and Et_v are the estimated evapotranspiration from open water and vegetated areas (cm/d), respectively, and Q is the calculated discharge (m^3/d) based on a weir equation (below).

At time t (d), the storage is then given by:

$$S_t = S_{t-1} + \Delta S$$

The daily lake stage D is calculated based on the stage versus S relationship provided in **Figure 95**. The previous day S_{t-1} is used to calculate the current discharge rate from the lake using the following equation:

$$Q = 1000 \cdot (D - 6.096)^{1.5} \cdot 86,400$$

Where 1000 is the weir crest length (m), 6.096 is weir crest elevation (m), and 1.5 is the weir coefficient.

The model used an average rainfall from seven rainfall stations located around the lake as net rainfall onto the lake. The model also assumes 100% of this rain enters the lake when falling on its open water, but only 20% of the rain falling on the upland vegetated areas within the lake boundary will runoff into the lake.

The above equations and referenced data are programed into an Excel spreadsheet named "LakeO-Model.xlsx" that was used to calculate the daily lake stage, which was then used to generate the required Lake Okeechobee stage boundary file for the southern three sub-watersheds.

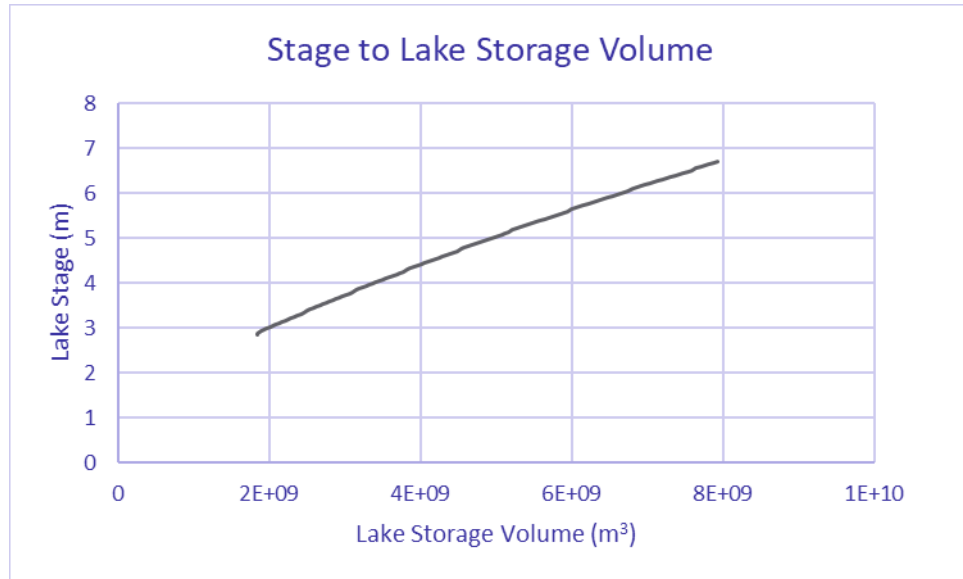


Figure 95. Relationship of Lake Okeechobee stage to storage volume.