CHAPTER 3: WATERSHED HYDROLOGY

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Acronyms and Abbreviations

General

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
CARL	Conservation and Recreation Lands
CR	County Road
DCIA	Directly Connected Impervious Area
EFDC model	Environmental Fluid Dynamics Code
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
fasl	feet above sea level
FDEP	Florida Department of Environmental Protection
FLUCCS	Florida Land Use and Cover Classification System
GIS	Geographic Information System
HSPF	Hydrological Simulation Program–FORTRAN
LOCB	Lower Orange Creek Basin
LORB	Lower Oklawaha River Basin
LSJRB	Lower St. Johns River Basin
MCA	Marsh Conservation Area
MFLs	Minimum Flows and Levels
MSJRB	Middle St. Johns River Basin
MTWCD	Melbourne-Tillman Water Control District
NAPP	National Aerial Photography Program
NAVD88	North American Vertical Datum of 1988
NDCIA	Nondirectly Connected Impervious Area
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NSE	Nash–Sutcliffe efficiency statistic
NSRA	Lake Apopka North Shore Restoration Area
NWS	National Weather Service
PEM	Percent error of the mean
PEST	Parameter Estimation (software suite)
PI Key	Photo Interpretation Key
PLRG	Pollutant Load Reduction Goals
RA	Retention Areas

SJRWMD	St. Johns River Water Management District
SR	State Road
SSURGO	Soil Survey Geographic
TCR	Taylor Creek Reservoir
TMDL	Total Maximum Daily Loads
TP SJ97-1	Technical Publication SJ97-1
UOCB	Upper Orange Creek Basin
UORB	Upper Oklawaha River Basin
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
USJRB	Upper St. Johns River Basin
WDM	Watershed Data Management file for input/output to HSPF
WDMUtil	Watershed Data Management Utility
WMA	Water Management Area
WSIS	Water Supply Impact Study

Hydrological Simulation Program – Fortran (HSPF) Specific Acronyms

AGWET	Active Groundwater Evapotranspiration – HSPF parameter
AGWETP	Active Groundwater Evapotranspiration – HSPF parameter
AGWRC	Base groundwater recession – HSPF parameter
DEEPFR	Fraction of groundwater inflow to deep recharge – HSPF parameter
FTABLE	HSPF Formatted TABLE for stage-area-storage-flow relationships
HYDR	Simulation of hydraulics for RCHRES in HSPF
IMPLND	Impervious land element in HSPF
INFILT	Index to infiltration capacity – HSPF parameter
INTFW	Interflow inflow – HSPF parameter
IRC	Interflow recession – HSPF parameter
IWATER	Simulation of impervious hydrology for IMPLND in HSPF
LZEPT	Lower zone evapotranspiration – HSPF parameter
LZSN	Lower zone nominal soil moisture storage – HPSF parameter
PERLND	Pervious land element in HSPF
PWATER	Simulation of pervious hydrology for PERLND in HSPF
RCHRES	Reaches/Reservoir in HSPF

RETSC	Retention Storage Capacities – HSPF parameter
UZSN	Upper zone nominal soil moisture

1 INTRODUCTION

The hydrologic modeling this chapter encompasses and tracks the full hydrologic cycle water budget. These models represent surface flows and surficial groundwater flows to the streams and rivers of the St. Johns River watershed. Water passing to deeper aquifers is accounted for, but the processes are not actively modeled. Water welling up from deep aquifers (spring flows and fractures in geological formations) was added to the model simulations as external point source flows. A complete description of the hydrologic processes modeled is provided in Section 5.2.

This chapter provides a general description of the major basins of the St. Johns River watershed and presents model input parameters and model construction and results by major basin. This chapter discusses the development and calibration of the HSPF hydrologic models under 1995 conditions and estimates the effect of projected 2030 land use, new water resources projects, and water supply withdrawals. These HSPF hydrologic models are used in the determination of the surface runoff and surficial groundwater flow components of the water budget. As part of the input data needed for the HSPF hydrologic and EFDC hydrodynamic models, rainfall and evaporation data processing, and management are also described in this chapter. The appendices provide details of the calibration efforts, hydrologic and model information, watershed mapping, graphical and tabular results, and result statistics for 47 gauged watersheds within the St. Johns River basin. The calibration period is from 1995 through 2006 using land use, structures, and management as was in place in 1995.

In 2002, the St. Johns River Water Management District (SJRWMD) determined that the development of basin-scale framework computer models would best meet current and future needs to assist SJRWMD in managing water resources in a cost and time efficient manner. A framework model is a large-scale computer model that simulates the hydrologic and water quality processes in a basin with adequate detail to be meaningful. The simulation environment must address relevant issues related to the computer simulation of hydrologic, hydrodynamic, and water quality processes in selected SJRWMD watersheds and SJRWMD-receiving water bodies. For watershed modeling, SJRWMD chose the HSPF hydrologic model and the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) interface as the modeling framework. The Environmental Protection Agency (EPA) has sponsored the BASINS and HSPF projects for many years for hydrologic and water quality simulations. These models combined are used by the EPA and stakeholders across the country to assist in the development of Total Maximum Daily Loads (TMDLs) and they are part of the EPA's TMDL toolkit.

The HSPF hydrologic model simulates hydrology and water quality in natural and man-made water systems. The HSPF hydrologic model is designed for application to most watersheds using existing meteorologic and hydrologic data. Although data requirements are extensive, the HSPF hydrologic model is the most appropriate management tool presently available for the continuous simulation of hydrology and water quality in watersheds. However, only the hydrology modules of the models are used for this work effort. The model input parameters consist of many physical and empirical parameters. The physical parameters are watershed areas, land use, precipitation, evaporation, slope, roughness, and hydraulics of the system. Some of the empirical parameters are surface storage, upper zone and lower zone storage, infiltration, interception storage, various evaporation components, active groundwater recession, etc.

In the past, SJRWMD's Hydrology and Water Quality Section developed HSPF hydrologic models for most of the watersheds that contribute to the St. Johns River. Several different engineers and hydrologists developed these models at different times for different projects. Some of the models were developed to assist in setting minimum flows and levels (MFLs) or to establish pollutant load reduction goals (PLRGs). Other uses have been to estimate water levels behind levees, estimate flood flows and stages, determine structure operational requirements, and to develop discharge inputs for receiving water body models. Simulation periods covered different time spans, and land use target years were different in the various models. Calibration methods varied by engineer or hydrologist, so there were wide ranges of model parameters for the different calibrated models. The WSIS project required consistency in the development, application, and calibration of the HSPF hydrologic models. The modelers held regular working meetings to discuss methods and approaches to the redevelopment of the HSPF hydrologic models for the entire river basin. Parameter ESTimation (PEST) was used to provide consistency among model parameters during calibration. PEST is a software package created by John Doherty (2004) for the optimization of model parameters. By applying parameters from the 47 gauged/calibrated subwatersheds to ungauged areas, a total of 97 models were developed to simulate flows from over 900 subwatersheds.

SJRWMD staff identified three potential locations on the St. Johns River and a fourth on the lower Ocklawaha River (Figure 3–1). The preliminary withdrawal amounts for the St. Johns River locations are based on MFL regulations (Robinson 2004), where the estimated potential withdrawal from the Ocklawaha River was established from a water allocation study requested in 1994 by the Florida Legislature (Hall 2005).

The St. Johns River is simulated with the Environmental Fluid Dynamics Code (EFDC), a finite-difference, three-dimensional hydrodynamic model, which has been developed for the main stem of the St. Johns River from downstream of SR 46 to its mouth at Jacksonville. The EFDC hydrodynamic model application is documented in Chapter 5, River Hydrodynamics Calibration and Chapter 6, River Hydrodynamics Results. The watershed simulations in this chapter provide surface flows for input into the EFDC hydrodynamic model and analyze the areas of the river outside of the EFDC hydrodynamic model domain. The withdrawal locations outside of the EFDC hydrodynamic model domain are the Lake Poinsett and the lower Ocklawaha River. The potential withdrawal in the lower Ocklawaha River basin (LORB) is included in WSIS only to evaluate the impact on the lower St. Johns River. Because of much lower consumptive demand for water in the Ocklawaha River basin, this withdrawal point is unlikely to be developed in the near future.

Scenario names were developed to succinctly include each condition that was part of that scenario run. The names are simple concatenation of codes that represent each condition consisting of withdrawal, watershed, USJRB projects, and sea level rise condition codes as described in Table 3–1.

Twenty scenarios were established for WSIS that encompass a series of base conditions and a range of possible future conditions (Table 3–2). To establish long-term comparison statistics among the scenario simulations, they were run for a 32-year time period using meteorologic data from 1975 through 2008. Although the scenario simulations use rainfall and evaporation data from 1975 through 2008 in the models, the land use, water control structures, and management operations are represented as they existed in 1995, or as expected 2030 conditions depending on the scenario.

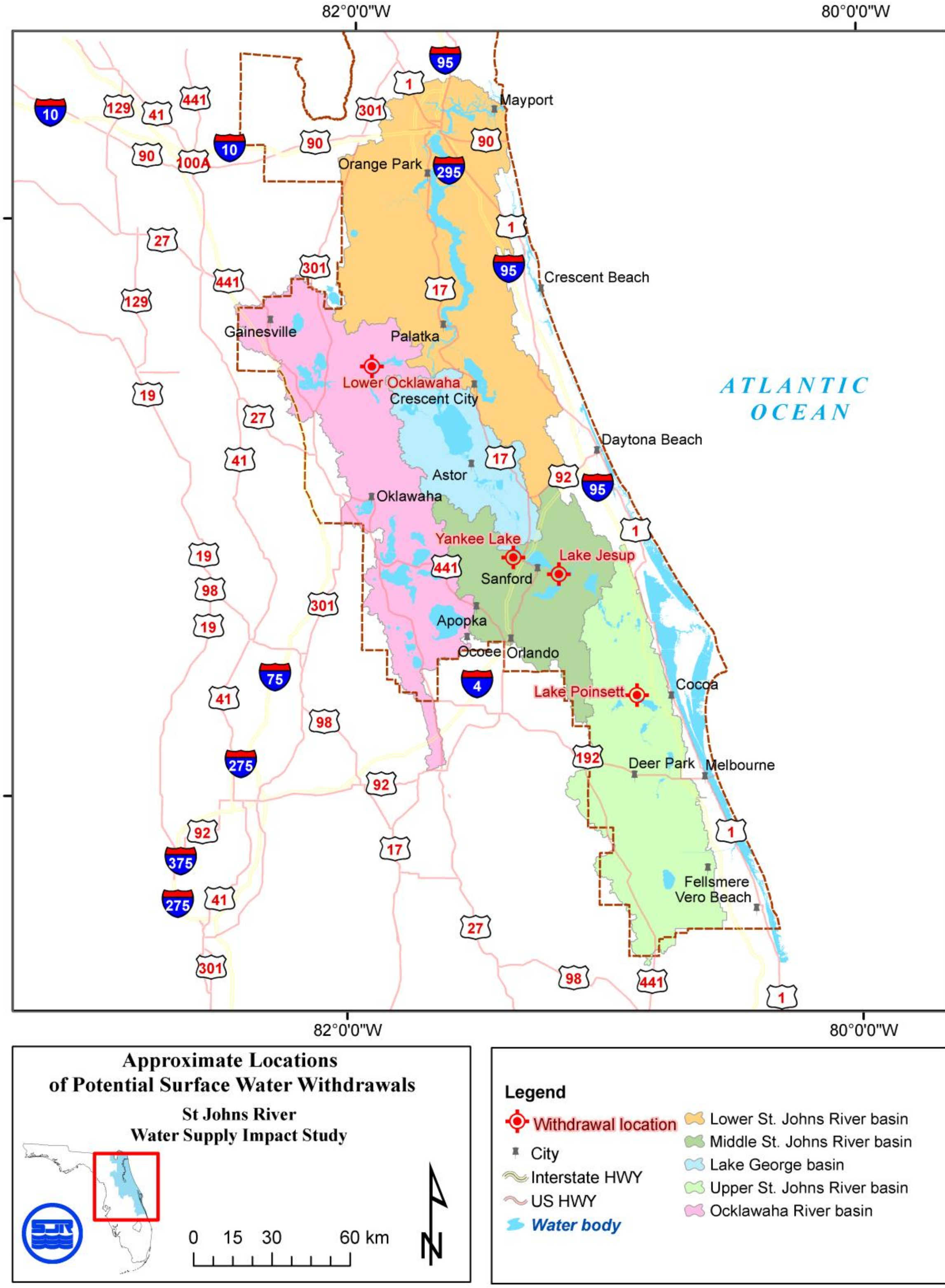

Figure 3–1. Approximate locations of potential surface water withdrawals.

Table 3–1. Scenario naming convention.

Scenario Condition	Scenario Name Parts				Condition Description
	First	Second	Third	Fourth	
Withdrawal condition	Base				no surface water withdrawal
	Half				half of the surface water withdrawal from the St. Johns River
	Full				full surface water withdrawal from the St. Johns River
	FwOR				full surface water withdrawal from St. Johns River along with surface water withdrawal from Ocklawaha
Watershed condition – year representing the land use, management and operation		1995			land use, and operation and management of USJRB projects as was in 1995
		2030			land use, and operation and management of USJRB projects as projected to occur in 2030
Completion and operation of USJRB flood control, water quality, and ecosystem restoration projects			N		No projects in operation (test scenario since some of the USJRB projects are either complete or slated for completion in the near future.
			P		USJRB projects complete and operational.
Sea level rise (addressed by the hydrodynamic model in Chapters 5 and 6)				N	Observed rate of sea level rise
				S	Possible sea level rise

Table 3–2. WSIS scenario descriptions.

Scenario	Watershed Conditions[1]	USJRB Projects Implemented	Sea Level Rise[2]	Surface Water Withdrawal Locations (mgd)			
				Lake Poinsett	Yankee Lake	SR46 Lake Jesup[3]	Lower Ocklawaha
Base1995NN	1995	No	Observed	0.0	0.0	0.0	0.0
Half1995NN	1995	No	Observed	27.5	25.0	25.0	0.0
Full1995NN	1995	No	Observed	55.0	50.0	50.0	0.0
FwOR1995NN	1995	No	Observed	55.0	50.0	50.0	107.0
Base1995PN	1995	Yes	Observed	0.0	0.0	0.0	0.0
Half1995PN	1995	Yes	Observed	27.5	25.0	25.0	0.0
Full1995PN	1995	Yes	Observed	55.0	50.0	50.0	0.0
FwOR1995PN	1995	Yes	Observed	55.0	50.0	50.0	107.0
Base1995PS	1995	Yes	2030 Estimate	0.0	0.0	0.0	0.0
Half1995PS	1995	Yes	2030 Estimate	27.5	25.0	25.0	0.0
Full1995PS	1995	Yes	2030 Estimate	55.0	50.0	50.0	0.0
FwOR1995PS	1995	Yes	2030 Estimate	55.0	50.0	50.0	107.0
Base2030PS	2030	Yes	2030 Estimate	0.0	0.0	0.0	0.0
Half2030PS	2030	Yes	2030 Estimate	27.5	25.0	25.0	0.0
Full2030PS	2030	Yes	2030 Estimate	55.0	50.0	50.0	0.0
FwOR2030PS	2030	Yes	2030 Estimate	55.0	50.0	50.0	107.0
Base2030PN	2030	Yes	Observed	0.0	0.0	0.0	0.0
Half2030PN	2030	Yes	Observed	27.5	25.0	25.0	0.0
Full2030PN	2030	Yes	Observed	55.0	50.0	50.0	0.0
FwOR2030PN	2030	Yes	Observed	55.0	50.0	50.0	107.0

See Chapter 6, River Hydrodynamics Results, for detailed discussion of the WSIS scenarios.

1. Watershed condition defines the year for estimation of land use and operation of USRJB projects.
2. Sea level rise only influences the results of the main stem St. Johns River evaluated as part of the EFDC hydrodynamic model described in Chapter 5, River Hydrodynamics Calibration and 6, River Hydrodynamics Results.
   Observed = Sea levels observed from 1995-2006.
   2030 Estimate = Observed sea level with median expected rise of 14 cm in 2030.
3. Withdrawal from the St. Johns River near where SR46 crosses the mouth of Lake Jesup.

2 WATERSHED PHYSIOGRAPHY

2.1 WATERSHED, MAJOR BASIN, PLANNING UNIT, AND SUBWATERSHED BOUNDARIES

The terminology used in this chapter to describe the hydrologic boundaries mostly follows Technical Publication SJ97-1 (Adamus, Clapp and Brown 1997).

(1) Watershed: A collection of major basins that contribute to a single water body. Five major basins numbered 3 through 7 comprise the St. Johns River watershed (see Table 3–3 and Figure 3–2).
(2) Major Basin: The SJRWMD is divided into ten major basins (Table 3–3) numbered one through ten.
(3) Planning Unit: The major basins are subdivided into planning units. Planning unit boundaries are based on tributary areas for larger rivers and streams or areas with similar characteristics. Each major basin has a varying number of planning units uniquely labeled with a capital letter starting with "A."
(4) Subwatershed: In Technical Publication SJ97-1 this is analagous to "Planning Unit ID," which is also described as "7.5-Minute Quad Basin." Aside from minor edits, the subwatersheds boundaries used in the modeling for this study matches the boundaries of the in Technical Publication SJ97-1. The "Planning Unit ID" in SJ97-1 and subwatersheds in this study are uniquely numbered within each planning unit starting with "1". The subwatershed numbers used for the WSIS were assigned to make the hydrologic connection apparent and do not match the Planning Unit ID numbers in Technical Publication SJ97-1.

The SJRWMD has jurisdiction over all or parts of eighteen counties in northeast Florida encompassing approximately 11,177 mi^2. In general, SJRWMD boundary follows major hydrologic boundaries as they were estimated when the five water management districts were developed. The St. Johns River is one of the few northward flowing rivers in the United States. It is about 300 mi long from its headwaters near Florida's Turnpike in Okeechobee and Indian River counties to its mouth at Jacksonville, Florida. The river has a total fall of approximately 25 ft over its length, thus having an average gradient of less than 0.1 ft mi^{-1}. The major basins that make up the St. Johns River watershed account for approximately 65% of SJRWMD's jurisdictional land area.

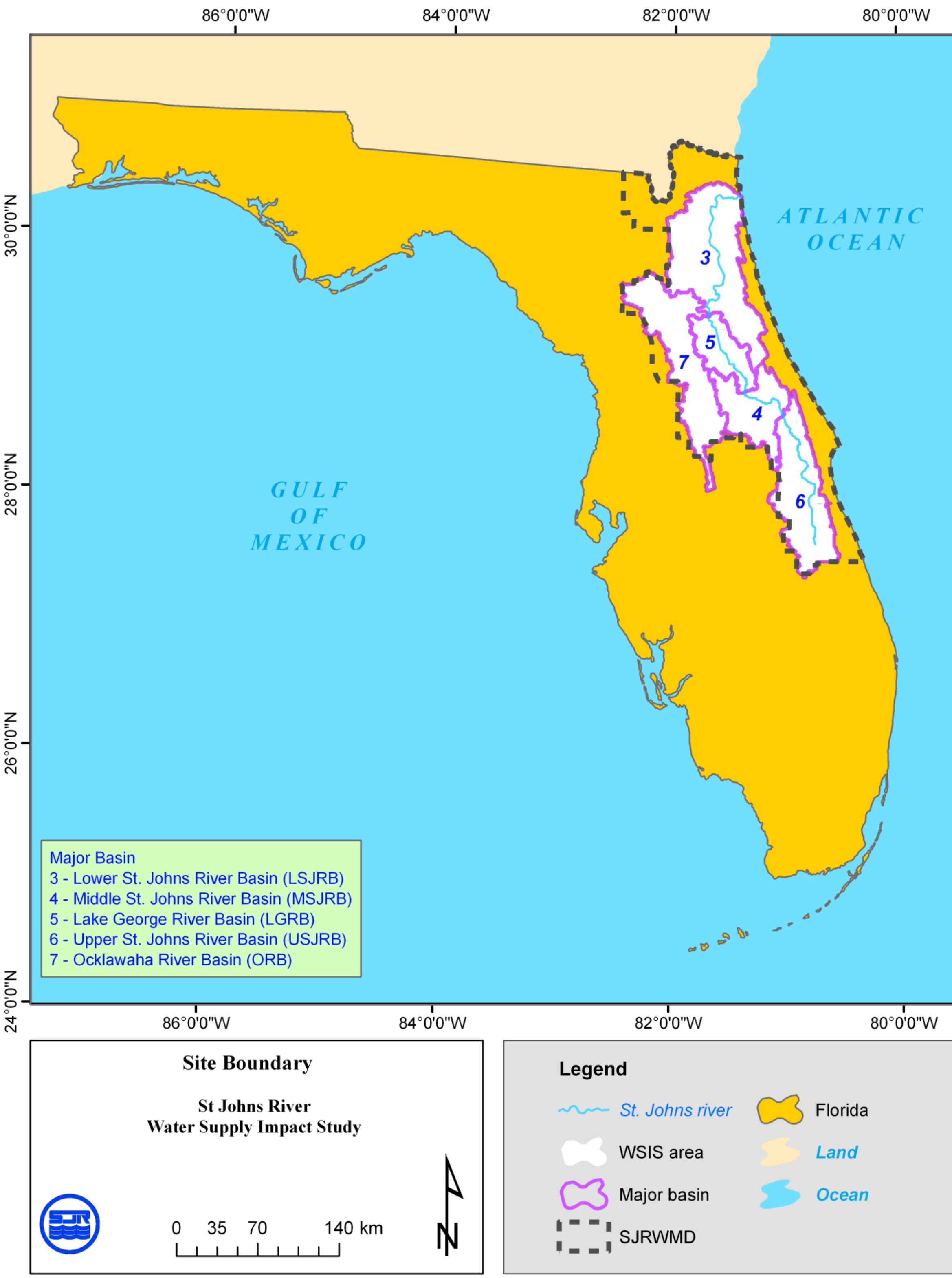

Figure 3–2. Water Supply Impact Study (WSIS) project boundary

Table 3–3. Area estimates for all major basins within SJRWMD's jurisdiction from TP SJ97-1 (Adamus, Clapp and Brown 1997)

Number	Major Basin Name	Area (mi^2)	
		St. Johns River Watershed (WSIS Project Area)	Other SJRWMD Major Basins
1	Nassau River Basin		432
2	St. Mary's River Basin		951
3	Lower St. Johns River Basin	2,755	
4	Middle St. Johns River Basin	1,205	
5	Lake George Basin	817	
6	Upper St. Johns River Basin	1,748	
7	Ocklawaha River Basin	2,116	
8	Florida Ridge Basin		692
9	Northern Coastal Basin		681
10	Indian River Lagoon Basin *		1,163
Total area of the St. Johns River Watershed (WSIS project area)		8,641	
Total area of SJRWMD major basins outside of the WSIS project area			2,536

*Includes 134-mi^2 Interbasin Diversion Planning Unit (6D) which historically was part of the upper St. Johns River, and depending upon the time period, completion of restoration projects, and management of operations can be hydrologically split between the Indian River Lagoon and upper St. Johns River major basins.

The best estimate for the total area of the St. Johns River watershed is found in Technical Publication SJ97-1 (TP SJ97-1) (Adamus, Clapp and Brown 1997) and is approximately 8,641 mi^2. There is a difference in total watershed area and the area used in the HSPF hydrologic models. These differences come from four sources: updates in watershed boundaries; subtraction of the river surface area not modeled in the HSPF hydrologic model; subwatersheds that do not contribute surface water runoff; and shift of watershed boundaries due to flood, water quality, and environmental restoration projects. This modeled area of the watershed is called the contributing area. The contributing area to the St. Johns River is approximately 7,466 mi^2. Unless specified explicitly, watershed areas for this chapter are the contributing areas. Table 3–4 illustrates the differences between total and contributing areas.

At the major basin level described in Table 3–4 there is likely little difference in watershed boundaries, but at the planning unit and subwatershed levels described later (see Section 4.1), the watershed boundaries in the current HSPF hydrologic models were reviewed and adjustments were made to remove gaps, eliminate overlaps, and make other modifications based on new hydrologic information.

Table 3–4. Comparison of area estimates for the major basins within the St. Johns River Watershed, arranged approximately upstream to downstream.

Major Basin Number	Major Basin Name	TP SJ97-1 Major Basin Area (mi^2)*	Model Major Basin Area (mi^2)
6	Upper St. Johns River Basin	1,748	1,739
4	Middle St. Johns River Basin	1,205	1,020
5	Lake George Basin	817	512
7	Ocklawaha River Basin	2,116	1,590
3	Lower St. Johns River Basin	2,755	2,605
	Total	8,641	7,466

Source: TP SJ97-1 (Adamus, Clapp and Brown 1997)
* Included acreage that does not contribute to surface runoff

2.2 SOILS AND IMPERVIOUS AREAS

Other hydrologic components that can determine runoff volumes are soil type and impervious area. The Natural Resources Conservation Service classifies soils into four major categories—A, B, C, and D—based on different properties. Soils with the highest soil storage, high porosity, greatest depth to the water table, and highest infiltration rates are assigned to the A class. Soils with the inverse characteristics of A soils are assigned to the D class. Rainfall runoff does not begin until after an initial abstraction is fulfilled. The initial abstraction is comprised of interception, infiltration, and surface storage. It is calculated as a percentage of the soil storage. Soils in the A class which have the highest soil storage, have the least potential for producing runoff and soils in the D class have the highest potential for runoff. The SJRWMD contains approximately 65% D soils as shown in Table 3–5. However, the middle St. Johns River basin (MSJRB) and the Ocklawaha River basin are comprised of 43% and 67% A soils, respectively, based on soil type only and would be expected to have lower runoff rates than the upper St. Johns River basin (USJRB), which has 84% class D soils.

Table 3–5. Overall soil type distribution within SJRWMD's major basins.

Soil Type	Upper St. Johns	Middle St. Johns	Lake George	Ocklawaha River	Lower St. Johns	Entire St. Johns River Basin
A	1%	43%	24%	67%	23%	18%
B	11%	27%	10%	16%	35%	9%
C	4%	10%	6%	10%	24%	8%
D	84%	20%	61%	7%	18%	65%

Table 3–6 summarizes the soil types associated with existing urban land uses in the study area. In Florida, wetlands are protected from development by environmental resource permit programs and other regulations. Wetland soils are typically categorized as D soils. Therefore, most of the urban development is constructed over A and B soil types. This pattern of urban development covers soils with high infiltration (lower runoff) rates with impervious surfaces like buildings,

roads, and parking lots. This impervious area is independent of soil types and a large portion, as much as 90% or more, of the rainfall is converted to runoff, whereas pervious areas respond to rainfall based on the infiltration rate and soil storage. This impervious area, specifically Directly Connected Impervious Area (DCIA), leads to a high percentage of the rainfall that falls on DCIA to be converted to runoff. This conversion of pervious undeveloped land to impervious urban land changes the response of an A or B soil to that of a D soil.

Table 3–6. Existing urban soil type within SJRWMD's major basins.

Soil Type	Upper St. Johns	Middle St. Johns	Lake George	Ocklawaha River	Lower St. Johns	Entire St. Johns River Basin
A	15%	35%	79%	62%	16%	38%
B	70%	28%	12%	20%	34%	32%
C	9%	11%	3%	8%	22%	15%
D	6%	25%	5%	10%	29%	15%

Table 3–7 provides the percentage of DCIA within the watershed areas for SJRWMD's major basins and for only the urban land use areas within the basins. Based on the discussion and Table 3–7, the more heavily developed MSJRB and lower St. Johns River basin (LSJRB) would be expected to produce more runoff for the same rainfall.

Table 3–7. Percentage of land that is Directly Connected Impervious Area (DCIA).

	Upper St. Johns	Middle St. Johns	Lake George	Ocklawaha River	Lower St. John	Entire St. Johns River Basin
Watershed	1%	5%	1%	2%	3%	3%
Urban Land Uses	19%	22%	13%	17%	23%	21%

2.3 LAND USE

2.3.1 1995 LAND USE

The 1995 aerial interpretation of land use for this study was developed under contract to Geonex, Inc. based on 1994 and 1995 color-infrared aerial photography of the entire SJRWMD. These data layers support many projects throughout SJRWMD as a snapshot of land use and land cover.

The aerial photography was produced by the National Aerial Photography Program (NAPP) from Jan 1994 through Dec 1995, with the bulk of photos taken in 1994.

A photo interpretation key (PI key) was developed to facilitate a uniform assessment across SJRWMD and establish other necessary interpretation standards. The minimum mapping unit areas from the PI Key are found in Table 3–8.

Table 3–8. Minimum mapping size for aerial photography interpretation to establish land use

Land Use	Minimum Mapping Unit
Upland classes	2.0 ac
Water and wetland classes	0.5 ac
Rivers and canals	10 m or greater in width and continuous
Roads and railroads	All major transportation corridors
Utility corridors	30 m or greater in width

For this effort, the detailed land uses were grouped into categories according to similar hydrologic response. There are 15 main land use groupings. The wetland land use category is split into two parts depending on whether they are riparian (adjacent to the river or stream) or non-riparian (i.e., an upland wetland). This split of wetland areas allowed a better hydrologic representation of the watershed. Wetland areas listed in this document are a summation of riparian and non-riparian wetland areas unless specified otherwise. In portions of the Ocklawaha basin, the forestland use group was divided into a forest (90% of the area) and a forest regeneration land use (10% of the area). The land use groups are listed in Table 3–9 and described in detail in Appendix 3.A.

Table 3–9. Land use groups for HSPF hydrologic modeling.

HSPF Hydrologic Modeling Land Use Number		HSPF Hydrologic Modeling Land Use Group	Special Category	Note
1		Low-density residential	–	< 2 dwelling units per acre
2		Medium-density residential	–	2 to 5 dwelling units per acre
3		High-density residential	–	> 5 dwelling units per acre
4		Industrial and commercial	–	–
5		Mining	–	–
6		Open and barren land	–	–
7		Pasture	–	–
8		Agriculture general	–	–
9		Agriculture tree crops	–	–
10		Rangeland	–	–
		Forest	–	–
	11*		Forest	90% of Forest land use area: only used in portions of the Ocklawaha River Basin
	14*		Forest Regeneration	10% of Forest land use area: only used in portions of the Ocklawaha River Basin
12		Water	–	–
		Wetland	–	–
	13*		Riparian Wetlands	Wetland land use is split between riparian and non-riparian wetlands according to the drainage pattern within each subwatershed
	15*		Non-riparian Wetlands	

*In some cases calculated as part of another land use category

2.3.2 2030 Population Prediction and Corresponding Land Use

The St. Johns River WSIS Steering Committee selected 1995 and 2030 as the years of the baseline and future computer simulations, respectively. The 2030 future condition is also the planning horizon in SJRWMD's water supply plan (SJRWMD 2006). Land use grouping and spatial processing for both 1995 and 2030 land uses were prepared for SJRWMD by GIS Associates, Inc., using SJRWMD's watershed boundaries and land use layers.

The 2030 projected land use was based on the parcel level 2030 population projections developed by GIS Associates, Inc. using the University of Florida's Bureau of Economic and Business Research (BEBR 2009). GIS Associates, Inc. developed parcel based population projections for the 2010 Water Supply Plan for SJRWMD (GIS Associates, Inc. 2009). GIS Associates, Inc. identified all new residential growth areas that intersect the St. Johns River watershed Land uses were changed to account for the predicted population growth by associating the future parcel population densities predicted in the water supply plan with the residential land use densities shown in Table 3–10. The increased area for urban land was created by converting adjacent open, range, forest, and agricultural land uses to urban land uses. Wetland and water areas were held constant between 1995 and 2030.

The 1995 commercial/industrial land use was increased to support the growth in population. There was not a method to predict the commercial/industrial land use growth, so the following method was developed. It was assumed that the commercial/industrial land use in 1995 was adequate to support the 1995 residential use; thus, the 2030 commercial/industrial land use growth rate would match the population growth rate. The following steps were used to develop the 2030 future industrial/commercial land use estimates.

(1) Summarize the 1995 and 2030 parcel-level population by watershed.
(2) Calculate the population growth percentage from 1995 to 2030 for each watershed.
(3) Multiply the population growth percentage times the acreage of any 1995 industrial/commercial land uses within the watershed.

The result is the projected 2030 industrial/commercial acreage increase by watershed.

Figure 3–3 provides a representative relationship of observed and predicted population and urban land uses from 1990 through 2030 for the MSJRB. The U.S. Census was used for population values in 1990 and 2000, and population projections were developed from 2004 to 2030. Although there is variation in the population-land use relationships for 2000 and 2004, the population-land use relationships for 1995 (interpolated population between 1990 and 2000) and 2030, which are the two years of interest in WSIS, appear to be reasonable.

It should be kept in mind that the 2030 land use is an estimate of the land use required to support the Bureau of Economic and Business Research 2030 population prediction developed in 2008. Florida experienced unprecedented population growth from 1995 to 2006. For example, two counties in the study area, St. Johns and Flagler, were in the fastest growing counties in the country for several years during the study period (U.S. Census Bureau 2007). If the economic downturn in 2009 and 2010 were taken into account, the 2030 population prediction would be somewhat less. Even though the future land use label throughout this study and report is identified as 2030, the underlying population prediction, whenever that may happen, is a better interpretation of what the future land use scenario represents.

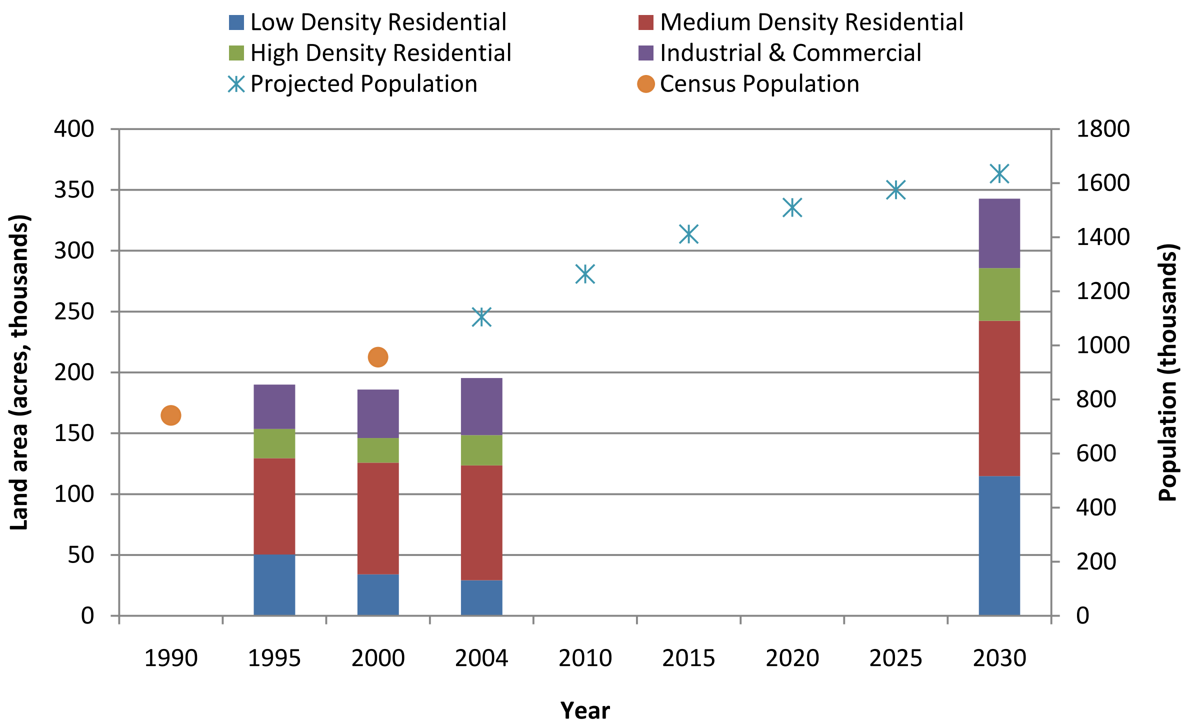

Figure 3–3. Comparison of observed and predicted population and land use for the middle St. Johns River basin (MSJRB).

A summary of the 1995 and projected 2030 land use for the St. John's River basin is presented in Table 3–10. Detailed summaries for each planning unit are provided in individual basin description sections.

Table 3–10. Summary of the 1995 and 2030 land uses in the St. Johns River Basin.

HSPF Hydrologic Modeling Land Use Number and Group	1995 Land Use (acres)		2030 Land Use (acres)	
1. Low-density residential	263,841	4.9%	787,264	14.7%
2. Medium-density residential	247,710	4.6%	540,955	10.1%
3. High-density residential	78,947	1.5%	169,659	3.2%
4. Industrial and commercial	140,282	2.6%	301,998	5.6%
5. Mining	20,515	0.4%	14,973	0.3%
6. Open and barren land	112,207	2.1%	58,512	1.1%
7. Pasture	505,701	9.4%	343,102	6.4%
8. Agriculture general	267,970	5.0%	148,201	2.8%
9. Agriculture tree crops	144,268	2.7%	72,500	1.3%
10. Rangeland	272,895	5.1%	136,985	2.5%
11. Forest	1,659,119	30.9%	1,139,307	21.2%
12. Water	286,016	5.3%	286,016	5.3%
13. Wetlands	1,374,656	25.6%	1,374,656	25.6%
Total	5,374,127	100.0%	5,374,127	100.0%

3 METEOROLOGY

3.1 RAINFALL

The SJRWMD maintains both point rain gauge and Doppler radar rainfall data sets. A contractor creates for SJRWMD a daily Doppler radar rainfall data set on a 2-km grid adjusted to a network of rain gauges. This adjustment forces the Doppler total rainfall over long periods to match the total from the coincident rain gauges. The Doppler radar rainfall data starts in 1995 and continues to the present. The SJRWMD also acquired National Weather Service (NWS) data for the simulation period (1974 to 2008) from 25 separate daily and hourly point rain gauges throughout the St. Johns River watershed. The Doppler and point rain gauges form fundamentally different data sets and cannot be intermingled. The primary difference is that Doppler averages rainfall over a relatively large area (2 × 2 km) while gauges provide data at a specific point (0.2 m circle). Because of the difference in spatial scale, Doppler records rainfall that the rain gauges miss and averages intense rainfall over the grid cell.

Although many of the watershed models that formed the foundation of this project were already calibrated using the Doppler radar data set, long-term statistics and analyses were needed for WSIS that would cover at least 30 years. The Doppler radar data set only provides 13 years of rainfall data, whereas some NWS stations have data back to the early 1900s. This long-term simulation requirement forced the use of the NWS point rain gauges for the scenario simulations. Because the Doppler and rain gauge data sets are fundamentally different and should not be intermingled, the watershed models were recalibrated and all scenarios run with the long-term NWS rain gauge data. The period chosen for the model scenario simulations ran from 1975 through 2008. The weather and climate was variable during this time and can be considered a good representation of long-term rainfall and evaporation patterns.

A Thiessen polygon network was developed to establish the area of influence for the NWS rain gauges used in this study, but was not used to weight the rainfall amounts (Figure 3–4). Even though more evenly distributed rain volumes can be obtained by area weighting of the multiple rain gauges that cover each watershed, this process can also reduce rainfall intensities. Rainfall intensity is a major factor in determining surface runoff. A reduction in intensity by area weighting can arbitrarily shift the model parameters to increase infiltration and reduce simulated runoff. Therefore, a single rain gauge was selected for each subwatershed based on the Thiessen polygon area that covers the majority of the subwatershed.

Average annual rainfall varies from 46 to 57 in. across SJRWMD (Figure 3–5). Note that in most of SJRWMD, the 1995 through 2006 average rainfall is slightly higher than the longer-term average from 1960 through 2006. The primary cause of this difference is increased hurricane and tropical storm landfall within SJRWMD. Rainfall amounts vary greatly on an annual basis. Figure shows the annual variation of SJRWMD annual averages for Orlando and Jacksonville International Airport. There is no easily identifiable trend either spatially or in time.

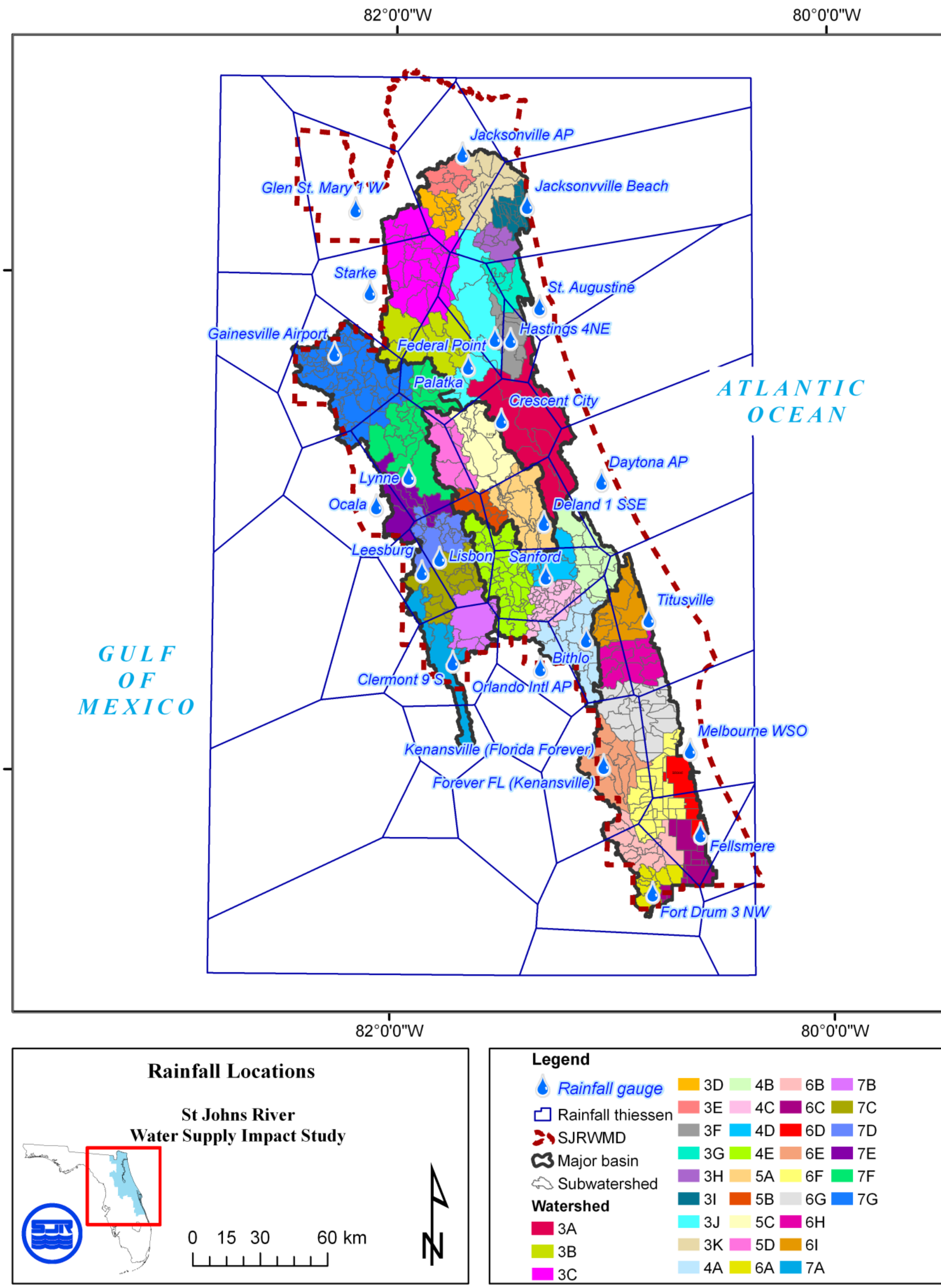

Figure 3–4. Rain gauge station locations and Thiessen polygons indicating area of influence.

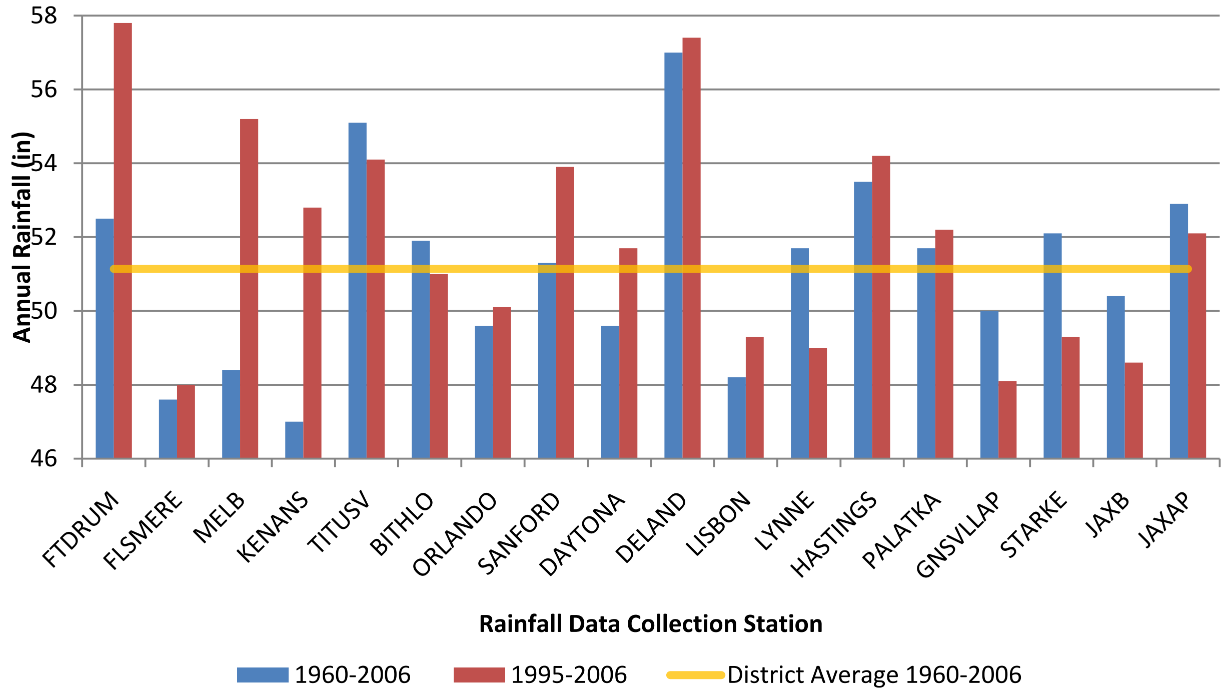

Figure 3–5. Average annual precipitation at rainfall gauge stations, arranged approximately south to north.

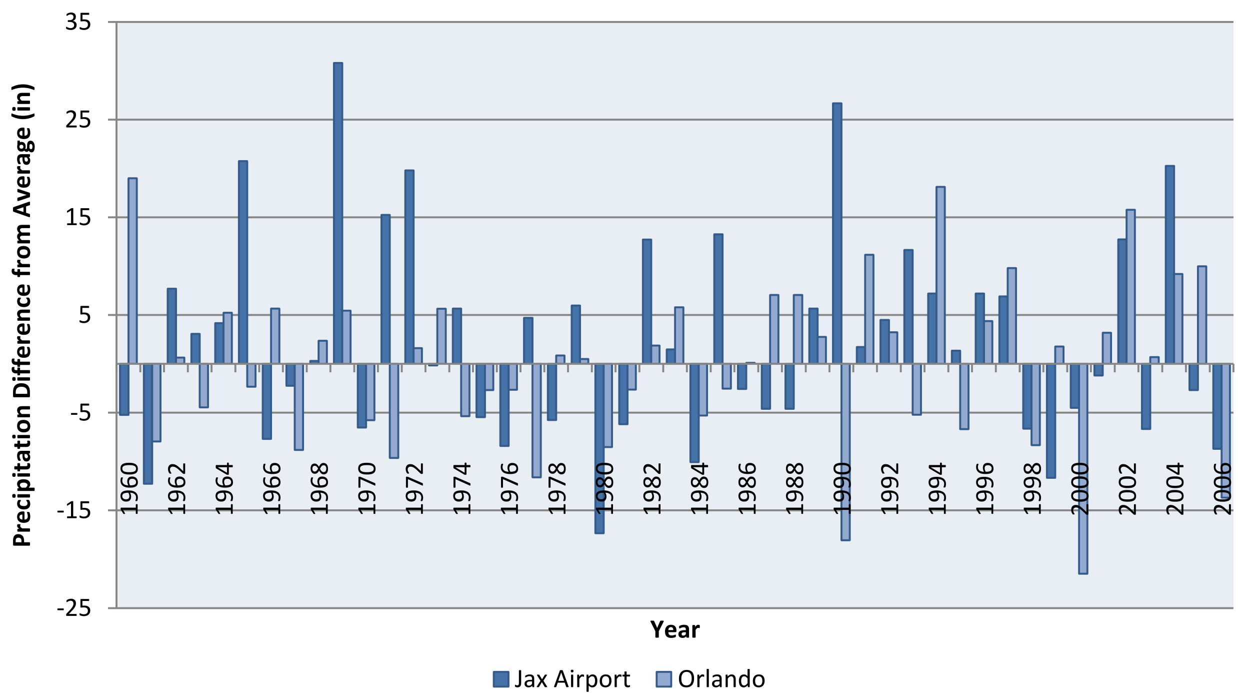

Figure 3–6. Yearly difference from station average in precipitation at Jacksonville International Airport and Orlando rain gauges.

The spatial distribution of rainfall varies widely across the St. Johns River watershed. The entire river watershed receives rain on the same day less than 0.5% of the time and receives no rain 14% of the time. It rains an average of 104 days yr^{-1} with a range throughout the St. Johns River watershed of 75 to 120 days as shown on Figure 3–7.

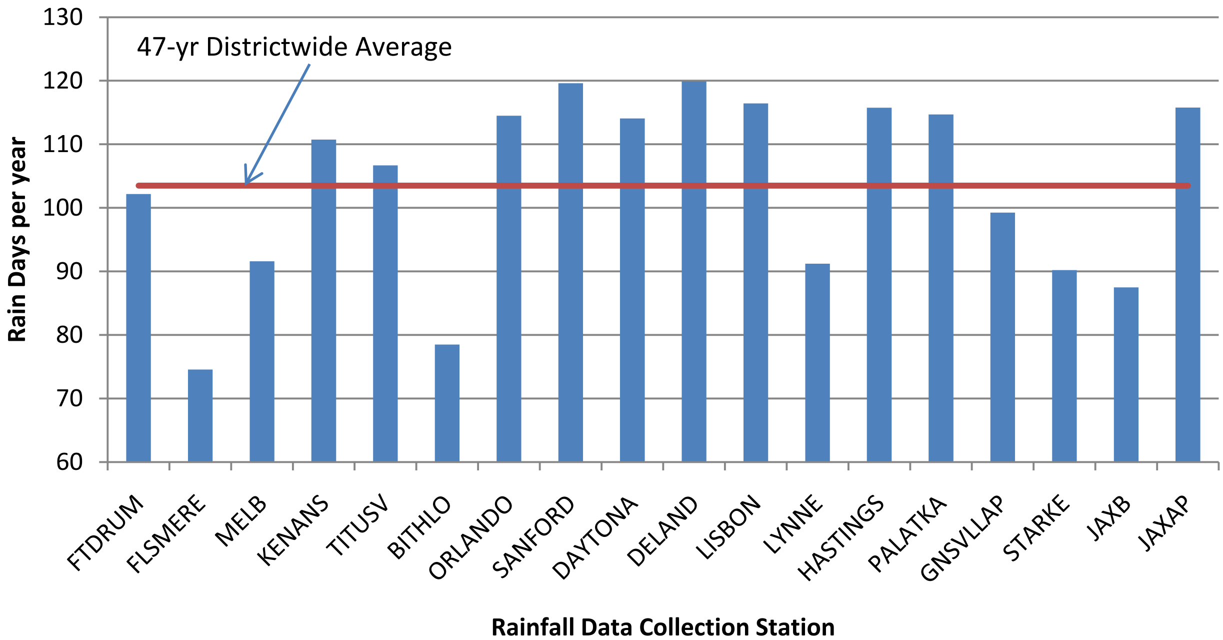

Figure 3–7. Days per year with precipitation at rainfall gauge stations, arranged approximately south to north

3.2 Rainfall Data Processing

The NWS rain data are not processed by the NWS to fill in missing values or address other data issues. NWS uses flags when a value is good, missing, or accumulated (indicating a total value from several previous time intervals). To be useful for modeling and compilation of statistics, all missing data must be filled in with estimated data and all data marked as accumulated must be disaggregated into the appropriate previous time steps.

The processing of the rainfall data involved the following three steps

(1) Disaggregating accumulated data and assigning values to previous time intervals so that the total over those previous intervals equals the accumulated value
(2) Filling in missing data
(3) If daily, then disaggregating daily data to hourly data

3.2.1 Disaggregation of Accumulated Data

The precipitation records from the NWS stations sometimes have flagged records indicating an accumulation since the last recorded value. For example, an hourly gauge may have a value for 1:00 A.M. and an accumulated value at 5:00 A.M. There is no information about the period between the data points, so the 5:00 A.M. point is an accumulation of rain since 1:00 A.M. Distributing accumulated values into the hourly values within the aggregation interval involves the following process:

- Distribute accumulated rainfall across the period using the closest volumetric rainfall from nearby hourly stations. The nearest station gets priority as a reference; however, if a secondary station is significantly closer to the total accumulated rainfall, the secondary station is used as a reference for distributing accumulated data.
- If none of the nearby stations have a reasonable distribution, then a triangular distribution is used to estimate data. Small events (under 0.5 in.) may generally fall in 1 hr in the afternoon or evening. Larger events should follow a triangular distribution over three to five hrs.

3.2.2 Filling In Missing Data

All hourly NWS stations have a separate daily recorder, except Lynne (Table 3–11). Missing hourly rainfall data are estimated by using the daily values from the same location. If the rainfall volumes are consistent, the missing hourly data are estimated from the daily data according to the process described above for aggregated data. The hourly data are compared against monthly and annual totals from the daily rain data set to make sure a significant rainfall event was not missed in the hourly rainfall data.

Table 3–11. Rain accumulation interval at rain gauges sorted from upstream to downstream (south to north)

Rain Gauge	Daily Recorder	Hourly Recorder
Fort Drum	X	
Fellsmere	X	
Melbourne	X	X
Kenansville	X	
Titusville	X	
Bithlo	X	
Orlando	X	X
Sanford	X	
Daytona	X	X
DeLand	X	
Lisbon	X	X
Lynne		X
Ocala	X	
Crescent City	X	
Hastings	X	
Palatka	X	
Gainesville Airport	X	X
Starke	X	
Jacksonville Beach	X	
Jacksonville Airport	X	X

3.2.3 Disaggregation of Daily to Hourly

The software package Watershed Data Management Utility (WDMUtil) was used to disaggregate daily rainfall data to hourly rainfall data described in Section 3.2.1. WDMUtil is a powerful tool for hydrologic data visualization, statistics, editing, and management of Watershed Data Management (WDM) files (Lumb, Carsel and Kittle 1988). WDMUtil is now part of the BASINS project funded by the EPA.

The rainfall data were loaded into a WDM file where WDMUtil was used to estimate an hourly rainfall distribution for each site, when necessary. As stated above, the two closest hourly rainfall stations to each daily rainfall station were used for this estimation. Only long-term National Oceanic and Atmospheric Administration (NOAA) hourly stations were used to disaggregate the long-term NWS rainfall data.

3.3 Evaporation

Potential evaporation is defined as the evaporation from a shallow body of water. Traditional potential evaporation data are estimated by measuring the water level in a shallow pan of water called a “Class A” pan. A factor of around 0.75 is applied to pan evaporation data to account for all of the unknowns (such as heating of the pan itself) that would tend to overestimate potential evaporation. This pan factor variable among “Class A” pans dependent on local conditions, but in all cases, it is set by professional judgment. Rarely are all of the site requirements satisfied for a “Class A” pan. Pan evaporation data within SJRWMD are sparse, problematic, inaccurate, and highly variable among the few data collection sites available.

Because of the problems with the pan evaporation estimates, potential evaporation estimates were developed for this project using the Hargreaves method scaled with a factor to a detailed evaporation estimate using the Priestly-Taylor method. The Priestly-Taylor method was applied by the USGS in a cooperative project with SJRWMD and others to use satellite measurements of radiation for the evaporation estimate. This method provides a consistent evaporation estimate both spatially (2 × 2 km) and temporally across SJRWMD. Unfortunately, the period of record only runs from 1995 to 2007 and simulation of the WSIS scenarios required input data from 1975 through 2008. As part of the plan to standardize long-term input data to the HSPF hydrologic models, an estimate of potential evaporation was developed based on the Hargreaves equation. The Hargreaves method requires only measured maximum and minimum air temperature data and seems to be less sensitive than other methods (including Priestly-Taylor) by the condition of the data collection site, such as arid or semiarid climate and vegetated or non-vegetated land cover. Other than temperature, the Hargreaves method requires solar information including extraterrestrial radiation and sunlight hours, which is calculated from the time of year and the latitude of the station. Various studies have compared Hargreaves method against measured and estimated potential evaporation for 11 locations and Hargreaves method ranked the most accurate of all methods that require only temperature (Hargreaves and Allen 2003).

A Thiessen network was developed to assign evaporation data from the 20 available meteorological stations used to calculate potential evaporation (Figure 3–8). The selection of the meteorological stations to use in each watershed was based on the station that covers the most area in the watershed based on the Thiessen network.

Temperature data obtained from 20 meteorological stations in four basins for the period of 1975 to 2006 were used to compute Hargreaves potential evaporation. For the purpose of validation, potential evaporation estimated using Hargreaves was compared against satellite-based Penman potential evaporation for three of the sites. The Hargreaves estimates are then adjusted to the Priestly-Taylor estimates using a regression coefficient for each of the sites.

The Hargreaves method that was used is summarized as follows. Extraterrestrial radiation is computed as a function of the declination of the sun and latitude using Equations 3–1 and 3–2. Equation 3–1 calculates declination of the sun (dec) where declination is in radians.

$$\boldsymbol{dec = 0.4101 \sin\left[\frac{2\pi(J-80)}{365}\right]} \qquad \textbf{[Eq. 3–1]}$$

Equation 3–2 converts latitude to radians ($lrad$), where latitude is in decimal degrees (e.g., 12.45).

$$\boldsymbol{lrad = latitude \frac{\pi}{180}} \qquad \textbf{[Eq. 3–2]}$$

Extraterrestrial radiation (R_a) is estimated using the dec and $lrad$ computed in Equations 3–1 and 3–2.

$$\boldsymbol{R_a = \frac{118}{\pi}\{\cos^{-1}(-\tan(dec)\tan(lrad))\sin(lrad)\sin(dec) + \cos(lrad)\cos(dec)\sin[\cos^{-1}(-\tan(dec)\tan(lrad))]\}} \qquad \textbf{[Eq. 3–3]}$$

where

$\boldsymbol{R_a}$ units $= \boldsymbol{MJ\ m^2/day}$.

Hargreaves potential evaporation (mm day^{-1}) is computed using Equation 3–4. In Equation 3–4, K is a regression constant obtained by regressing Hargreaves potential evaporation against Priestly-Taylor potential evaporation.

$$\boldsymbol{potential\ evaporation = K\{0.408 * 0.0023 * R_a * (T_{mean} + 17.8) * \sqrt{T_{max} - T_{min}}\}} \qquad \textbf{[Eq. 3–4]}$$

An example of the process to adjust the Hargreaves estimates is presented in Figure 3–9 and Figure 3–10. The coefficient for each evaporation station is presented in Table 3–12.

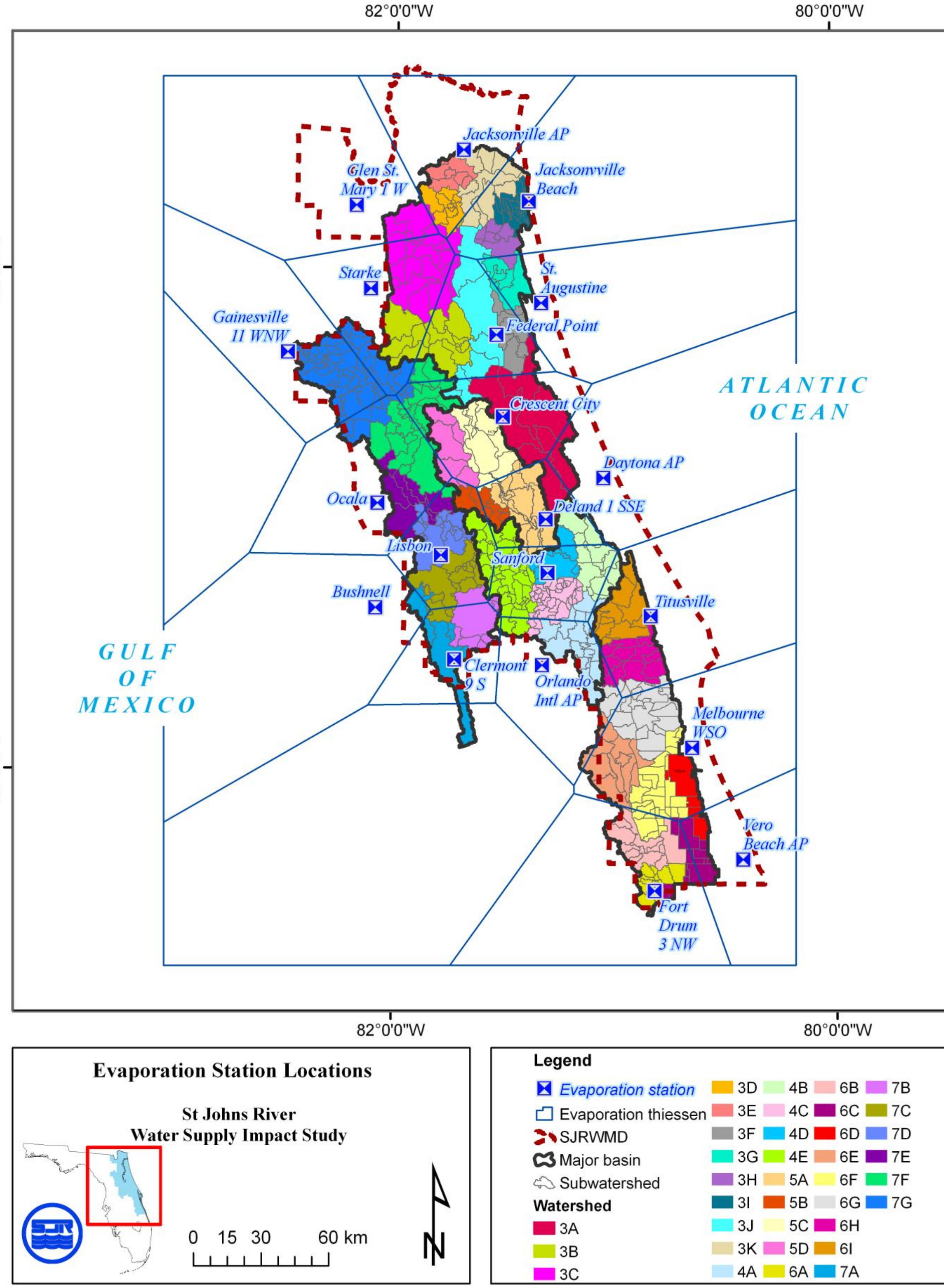

Figure 3–8. Evaporation station locations, where potential evaporation is computed, and Thiessen polygons defining each area of influence.

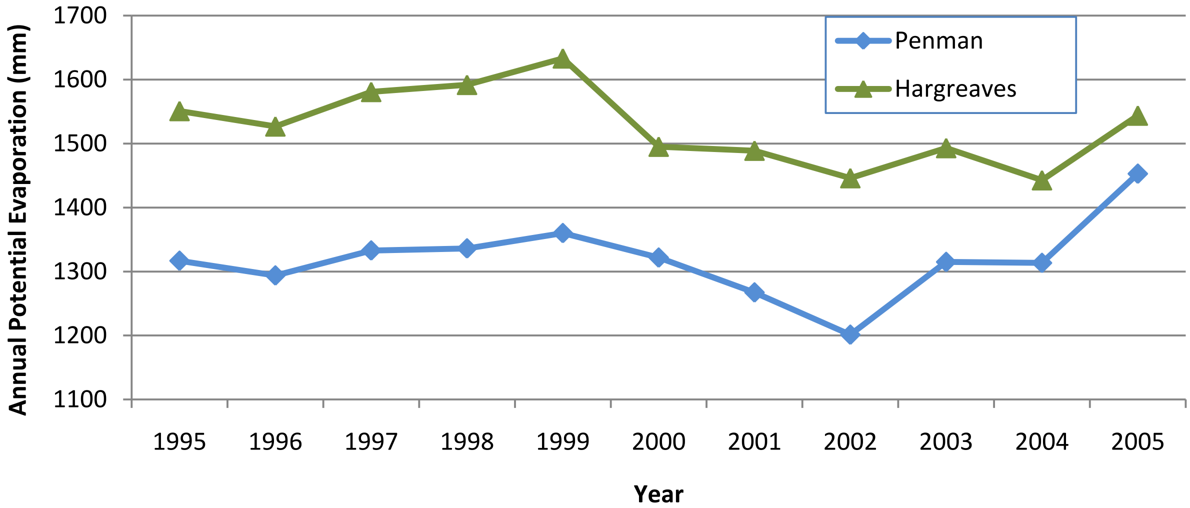

Figure 3–9. Annual potential evaporation comparison between Priestly-Taylor (with satellite radiation measurements) and Hargreaves for Gainesville.

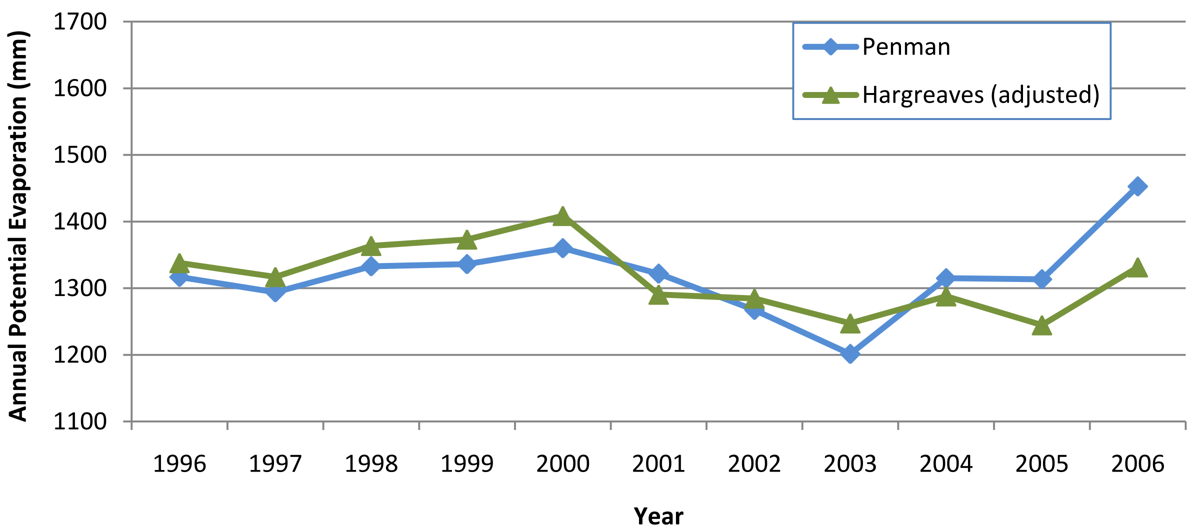

Figure 3–10. Annual potential evaporation comparison after Hargreaves method was adjusted for Gainesville.

Table 3–12. Coefficients used to adjust Hargreaves potential evaporation estimate to Priestly-Taylor

Evaporation Stations		Hargreaves Coefficient
Name	Abbreviation	
Bushnell	BUSHNELL	0.8425
Clermont	CLERMONT	0.8714
Crescent City	CRESCENT	0.9056
Daytona Beach	DAYTONA	0.9342
DeLand	DELAND	0.8726
Federal Point	FEDPT	0.9057
Ft Drum	FTDRUM	0.8663
Gainesville	GNSVILLE	0.8431
Glen St. Mary	GLNSTMRY	0.8663
Jacksonville International Airport	JAXAP	0.9381
Jacksonville Beach	JAXB	1.1193
Lisbon	LISBON	0.9114
Melbourne	MELB	0.9264
Ocala	OCALA	0.8101
Orlando	ORLANDO	0.9109
Sanford	SANFORD	0.8888
St. Augustine	STAUG	0.9952
Starke	STARKE	0.8665
Titusville	TITUSV	0.9940
Vero Beach	VERO_BCH	0.9582

3.4 Evaporation Results

The estimated annual evaporation is higher in the southern area of the river near Vero Beach and lower in the northern area near Jacksonville. This difference is expected because the average temperature is higher in the southern area of the river. There is also a difference in evaporation between the eastern coastal areas and the western ridge areas, with higher evaporation in the inland areas and lower evaporation near the more humid coast. These differences in evaporation are summarized in Figure 3–11.

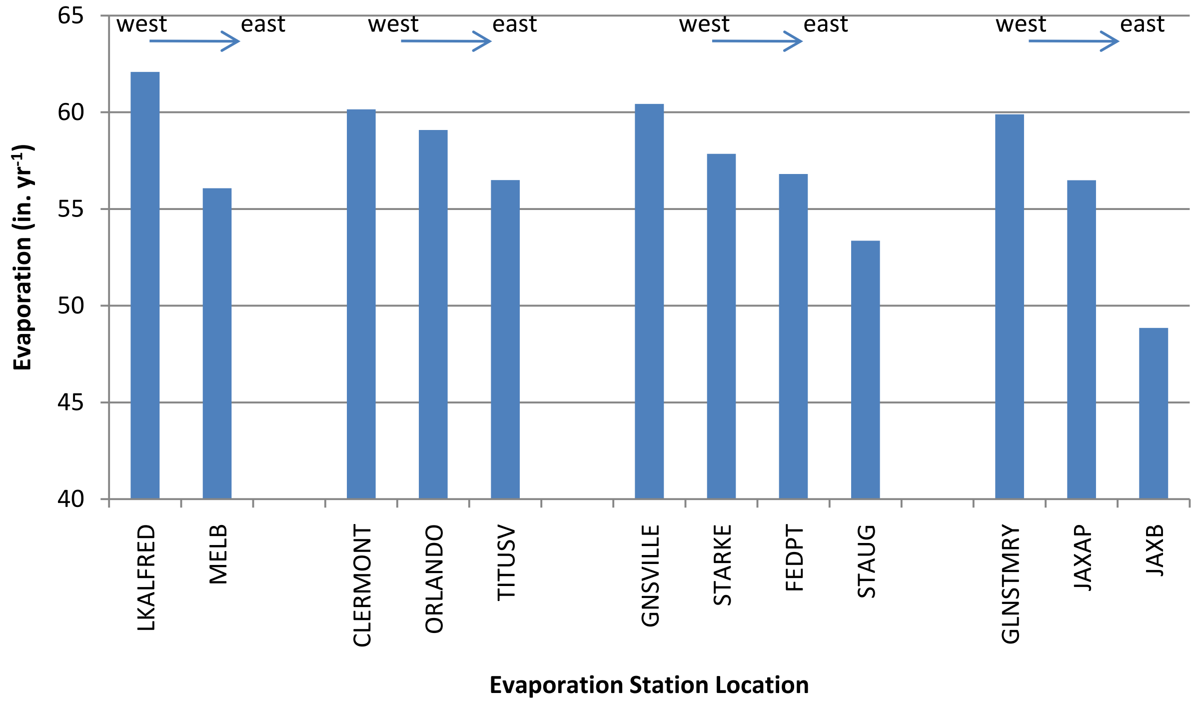

Figure 3–11. Average annual potential evaporation arranged in four approximate west to east cross-sections, with cross-sections arranged from south to north.

4 Major Basin Descriptions

4.1 Major Basin Descriptions

Each major basin is subdivided into planning units (e.g., 6A, 6B, 6C, etc.), and each planning unit includes subwatersheds (see Section 2.1 for definitions). Planning units are shown in a figure and table under each basin description presented below.

The major basins that make up the St. Johns River watershed along with the corresponding appendices, sorted roughly from upstream to downstream are presented in Table 3–13. Detailed maps in the appendices show the subwatersheds that make up each calibrated model.

Table 3–13. Major basins that make up the St. Johns River watershed and corresponding calibration appendices.

Major Basin	Appendix for Calibrated Subwatershed Reports
Upper St. Johns River Basin (6)	Appendix 3.I
Middle St. Johns River Basin (4)	Appendix 3.J
Lake George Basin (5)	Appendix 3.K
Ocklawaha River Basin (7)	Appendix 3.L
Lower St. Johns River Basin (3)	Appendix 3.M

4.1.1 UPPER ST. JOHNS RIVER BASIN (6)

The Upper St. Johns River Basin (USJRB) comprises approximately 1,750 mi^{-2} of watershed area draining into the St. Johns River from its headwaters near Vero Beach to its confluence with the Econlockhatchee River south of SR 46 in east central Florida (Figure 3–12). The basin is a mixture of natural systems and manmade components. The St. Johns River begins as a series of marshes underlain by fibrous peat deposits. Historically, rainfall fell on the headwater marshes and moved downstream as sheet flow.

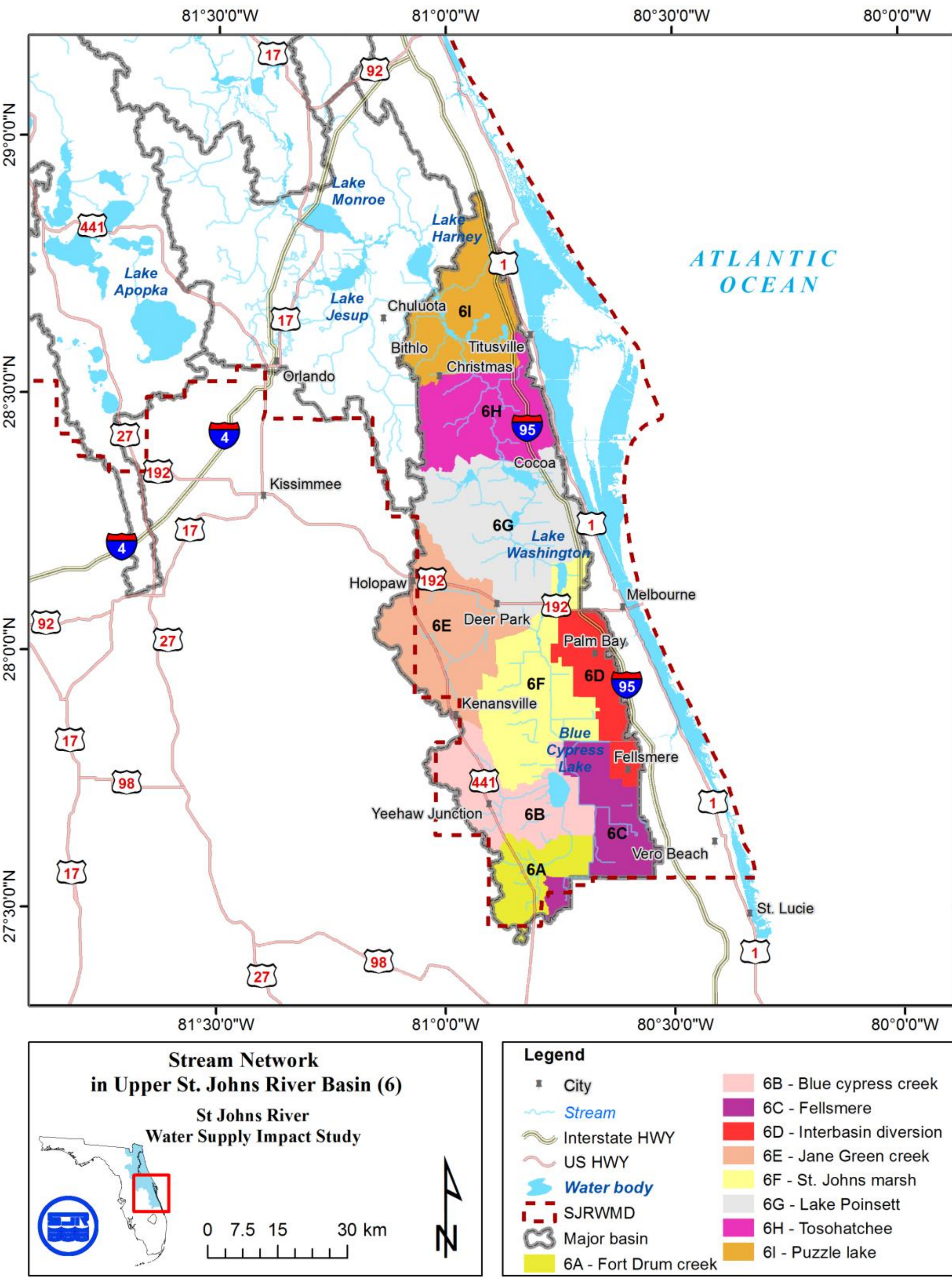

Figure 3–12. Stream network showing planning units 6A through 6I in the upper St. Johns River basin (6)

A well-defined river channel does not appear until 30 mi downstream of Lake Hell 'n Blazes. South (upstream) of the lake, the USJRB is largely comprised of marsh or drained marshland converted to agriculture. Here the main stem of the river passes through a wide valley dotted with palmetto islands and marshes.

Land uses in the basin include agriculture and rangeland, upland forests, and wetlands. Almost 27% of the USJRB land use consists of pasture to support cattle grazing, largely west of the river. Indian River citrus is an important commercial crop, mainly on the southeast side of the river. Urban and developed land uses occupy about 3.7% of the basin and are largely concentrated along the central to northeastern boundary, with most development in Brevard County.

The United States Army Corps of Engineers (USACE) started planning a flood control project in the USJRB in the 1950s as part of the Central and South Florida Flood Control Project (USACE 1963). Construction of the flood control project in the USJRB began in 1968, halting in 1972 to allow for the preparation of an Environmental Impact Statement (EIS). Major project components already completed included the C-54 canal and its associated structures: S-96 and S-157; L-73S and S-161 in the Jane Green Creek watershed; and L-73N and S-164 to form Taylor Creek Reservoir. Based upon the EIS, the original project plan was cancelled in 1973 due to significant adverse environmental impacts

In the late 1970s, SJRWMD and the USACE began to redesign the USJRB project. The new project plan was approved in 1987. The revised USJRB project has multiple benefits, including flood control, water supply, water quality improvement, wetland restoration, and public recreation. The project included construction of over 100 mi of flood control levees with spillways and water control culverts and acquisition of about 234 mi^2 (150,000 ac) of farmland and floodplain to provide flood control storage and environmental restoration. Construction of the revised project, which began in 1988, slowed significantly from 1995 until 2006 when the USACE commenced the final component of the project with construction of Three Forks Marsh Conservation Area. The project was nearly completed by the end of 2009 at a total cost of over $200 million. The selection of 1995 as the baseline year for the WSIS was partially due to the relatively constant condition of the USJRB project between 1995 and 2006.

The USJRB project area, located primarily between US 192 and the Florida Turnpike (Figure 3–13, has been compartmentalized into a number of storage areas for flood control and environmental management with regulation of water levels and discharges occurring by numerous water control structures. Figure 3–13 presents various storage areas created by the project as shaded areas together with water control structures in each storage area. There are a number of other areas in the USJRB in addition to those shown in Figure 3–13 where some environmental restoration and/or conservation activity is either planned or currently taking place, and these areas are included in the 2030 conditions scenarios.

The storage areas are classified as Marsh Conservations Areas (MCAs), Water Management Areas (WMAs), or Retention Areas (RAs). There are four MCAs, four WMAs, and two RAs.

The four MCAs are

- Fort Drum MCA
- Blue Cypress MCA
- Three Forks MCA
- St. Johns MCA

The four WMAs are

- Blue Cypress WMA
- St. Johns WMA
- Fellsmere WMA (under construction)
- Sawgrass Lake WMA

The RAs are

- C-54 RA
- C-1 RA

The MCAs were formed by expanding the floodplain that existed under the pre-project conditions (i.e., by restoring additional areas into wetlands). MCAs receive discharges from the upland subwatersheds and other adjacent drainage areas and provide temporary storage for floodwaters and long-term conservation storage to restore and preserve floodplain wetlands. The USACE developed regulation schedules for the Blue Cypress MCA, Blue Cypress WMA, and St. Johns WMA for release of flood discharges based on desirable water levels within the MCA or WMAs during various seasons. These schedules seasonally divide water levels into Zone A and Zone B. Zone A is flood zone and when the water stages rise above the regulation schedule into this zone, discharges are to be made up to the design maximum. If water levels are below the regulation schedule in Zone B," discharges are regulated primarily to promote restoration and preservation of a healthy marsh-floodplain ecosystem.

The WMAs were constructed on former agricultural lands that had considerable soil subsidence and formed ideal deepwater storage reservoirs. Nutrient-laden agricultural discharges (i.e., discharges from the agricultural subwatersheds) are directed into the WMAs. Water stored in the WMAs may be reused as irrigation water, and the excess floodwaters flow into the St. Johns River. Thus, the WMAs greatly contribute to improving water quality by storing water to allow for biological and physical treatment, separating agricultural discharges from better quality water in the St. Johns marsh and other MCAs, and by facilitating reuse of agricultural water for irrigation. The Fellsmere WMA is still in the planning, design, and construction stage.

The WMAs and MCAs together replace a portion of the floodplain storage that was lost because of historic floodplain encroachment by agricultural development. The increased storage capacity available in these areas, and the other efforts being made to recapture and redivert part of the drainage flowing east, greatly reduce the diversion of flood discharges into the Indian River Lagoon through the C-54 and C-1 canals; such sudden and large quantities of freshwater discharges are injurious to the Indian River Lagoon ecosystem.

It should be noted that only part of the Interbasin Diversion Planning Unit (6D) currently drains to the USJRB. The SJRWMD has several flood control, environmental management, and water quality projects either, completed, planned, or under construction as part of the C-1 re-diversion project, which will re-divert additional surface flows back to the USJRB from the Indian River Lagoon.

The USJRB consists of nine major planning units that contain 112 subwatersheds. The nine planning unit areas are listed in Table 3–14 and the land use for 1995 and 2030 is in Table 3–15. There are currently municipal water withdrawals from Lake Washington and Taylor Creek Reservoir in the USJRB.

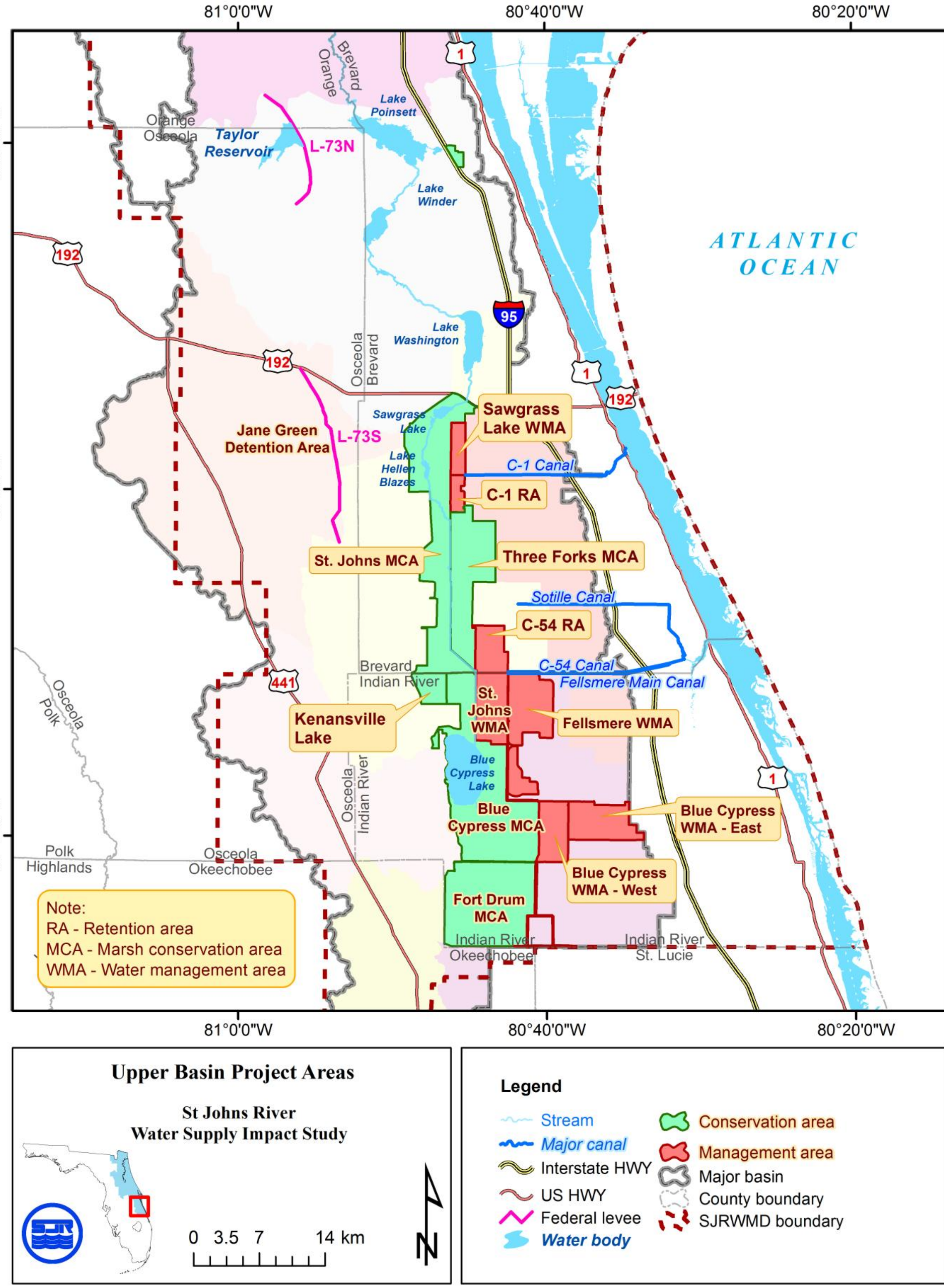

Figure 3–13. Upper basin project areas.

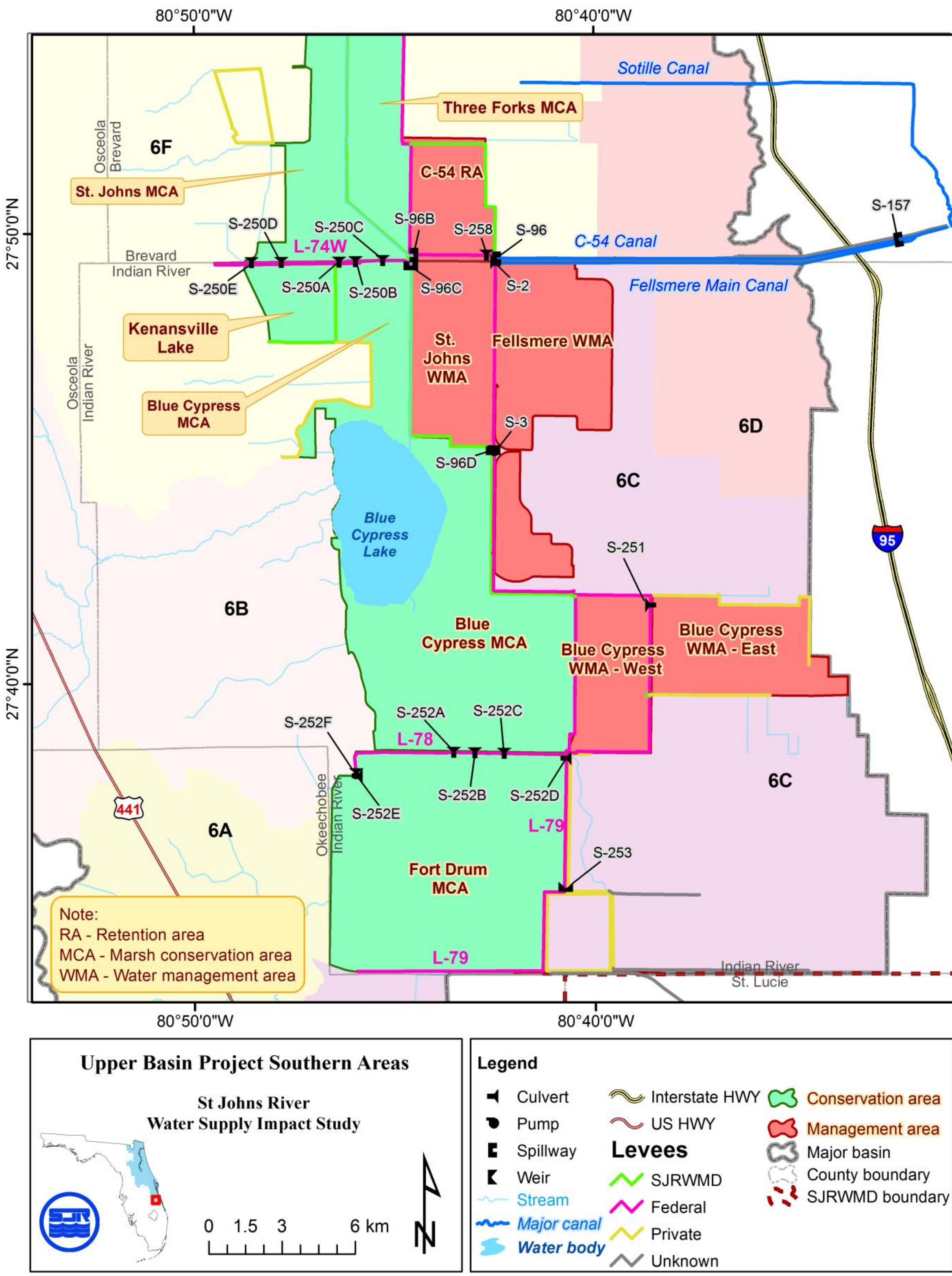

Figure 3–14. Southern upper basin project areas.

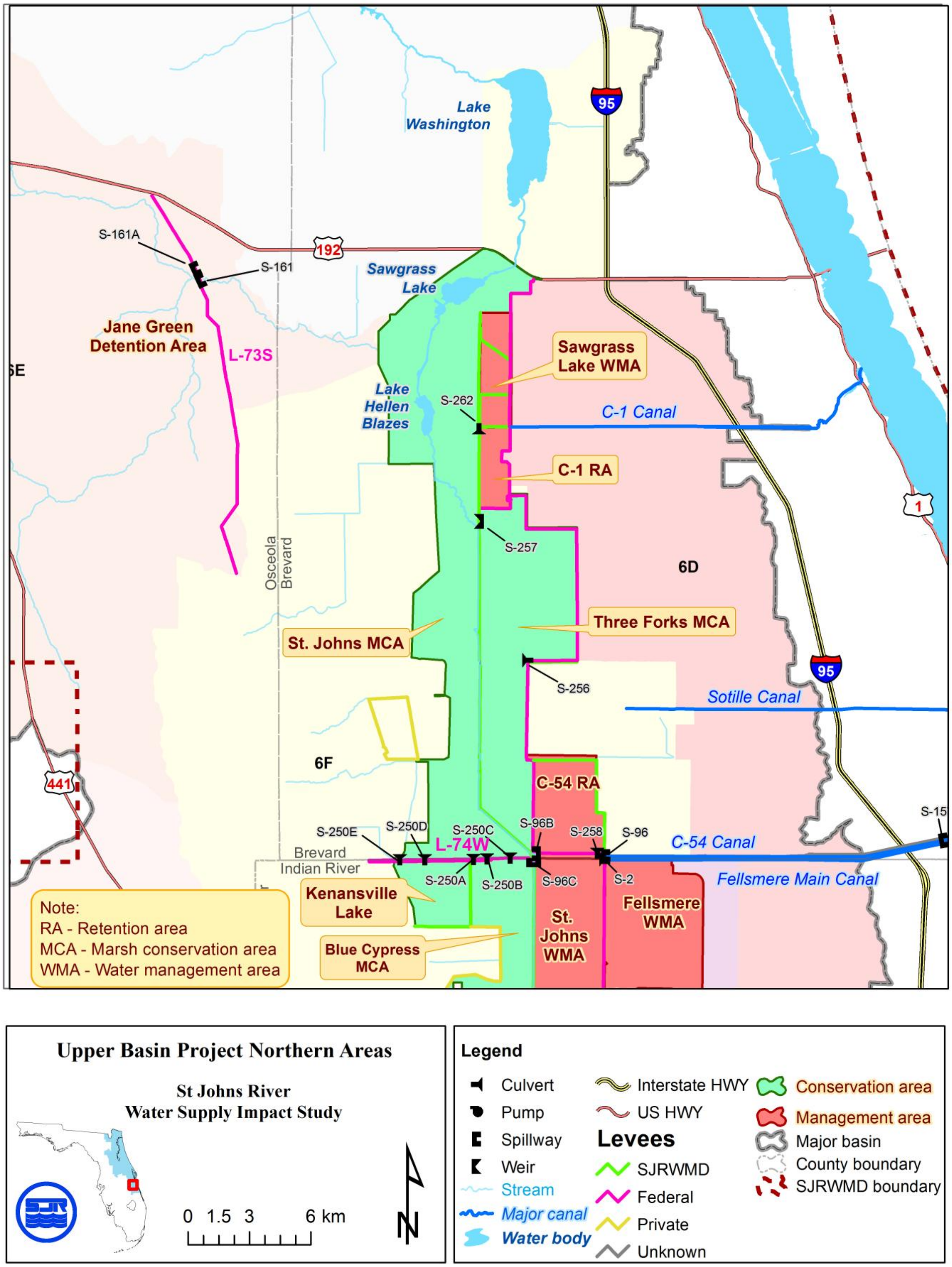

Figure 3–15. Northern upper basin project areas.

Table 3–14. Planning units in the Upper St. Johns River Basin (USJRB) (6), excluding area that does not contribute to surface water runoff.

Planning Unit Number	Planning Unit Name	TP SJ97-1 Area (acres)*	Model Area (acres)
6A	Fort Drum Creek Planning Unit	72,491	69,079
6B	Blue Cypress Creek Planning Unit	131,451	151,007
6C	Fellsmere Planning Unit	83,866	109,672
6D	Interbasin Diversion Planning Unit	85,549	Only C-1 Rediversion in “with project” scenarios
6E	Jane Green Creek Planning Unit	167,712	176,179
6F	St. Johns Marsh Planning Unit	152,927	139,780
6G	Lake Poinsett Planning Unit	222,126	219,810
6H	Tosohatchee Planning Unit	133,455	134,216
6I	Puzzle Lake Planning Unit	155,572	142,494

Source: TP SJ97-1 (Adamus, Clapp and Brown 1997)

Table 3–15. Upper St. Johns River Basin (USJRB) 1995 and 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		2030 Land Use (acres)	
Low-density residential	20,341	1.7%	179,401	15.0%
Medium-density residential	25,771	2.2%	71,973	6.0%
High-density residential	5,014	0.4%	33,296	2.8%
Industrial and commercial	9,262	0.8%	33,370	2.8%
Mining	5,548	0.5%	4,291	0.4%
Open and barren land	21,324	1.8%	9,365	0.8%
Pasture	319,491	26.7%	225,006	18.8%
Agriculture general	50,533	4.2%	30,951	2.6%
Agriculture tree crops	64,945	5.4%	43,728	3.7%
Rangeland	87,227	7.3%	49,294	4.1%
Forest	140,920	11.8%	69,701	5.8%
Water	44,605	3.7%	44,605	3.7%
Wetlands	399,708	33.5%	399,708	33.5%
Total	1,194,689	100.0%	1,194,689	100.0%

Fort Drum Creek Planning Unit (6A)

There are 12 subwatersheds in the Fort Drum Creek planning unit and Fort Drum Creek is the main tributary. The main river course is predominantly a marsh and swamp floodplain with Florida’s Turnpike (US 441) and SR 60 as the upstream and the downstream boundaries (Figure 3–16). The area slopes from southwest to northeast from an elevation of about 38.00 to 24.00 ft referenced to the National Geodetic Vertical Datum, 1929 (NGVD29) and discharges during low stages takes place along the northern edge of the reach where elevations dip to about 23.00 ft

NGVD29. The elevations at the western boundary of the reach exceed 30.00 ft NGVD29, except at the northwest corner.

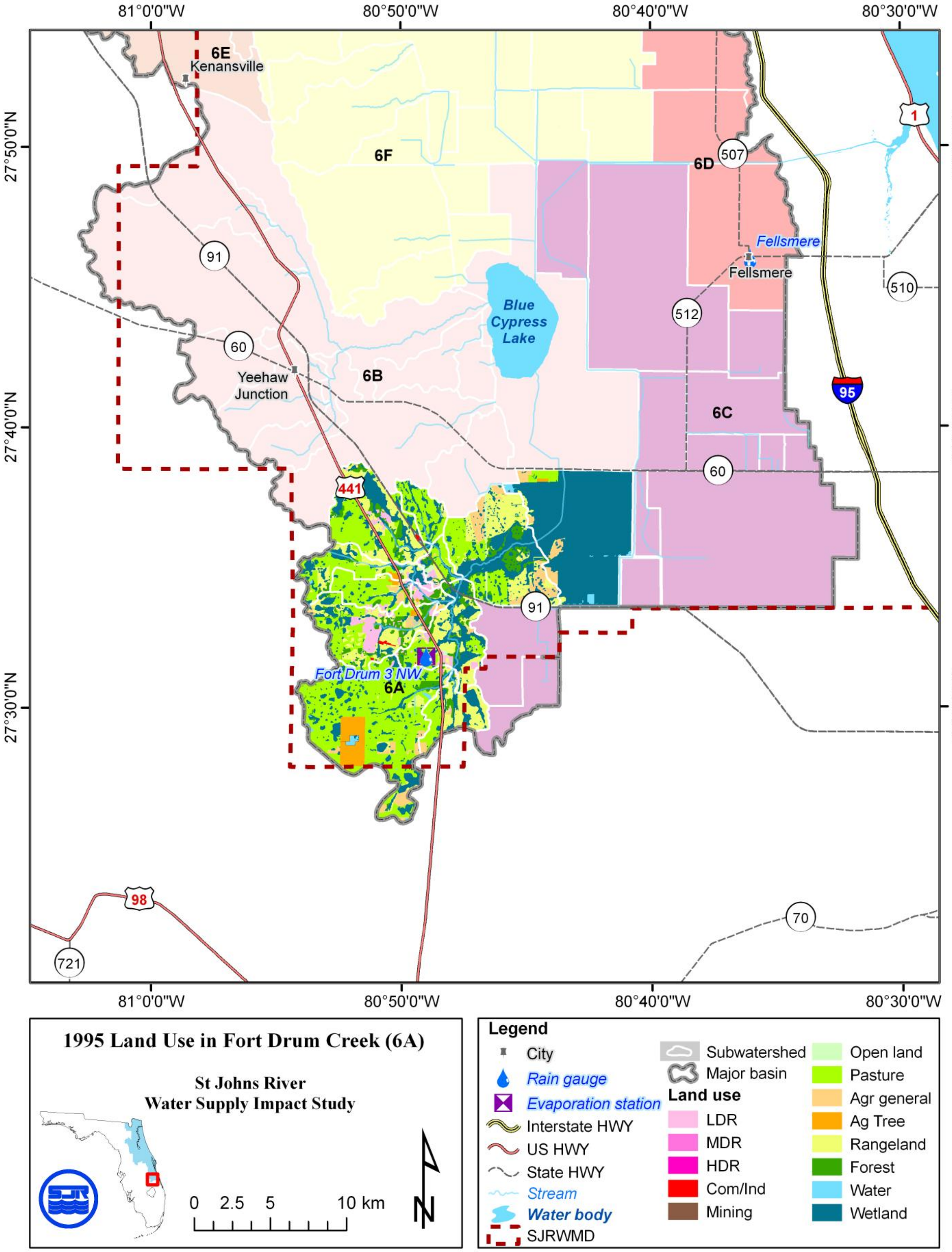

Figure 3–16. 1995 land use in Fort Drum Creek Planning Unit (6A).

The Fort Drum MCA, at the northeast corner of the planning unit, has an area of about 32 mi^2 (20,630 ac). It is enclosed by the USACE levees L-78 on the north and L-79 on the east and south. The western boundary is approximately the Okeechobee-Indian River county line. Inflows to Fort Drum MCA include direct rainfall and discharges from the western side of the planning unit. Discharges from the eastern side of the watershed do not enter Fort Drum MCA but are conveyed to Blue Cypress WMA through the C-52 Flow-way. Backflow from Fort Drum MCA to the south during low stages is prevented by S-253, a 160-ft–long sheet-pile weir with crest elevation at 25.50 ft NGVD29 constructed across C-52.

Outflow from Fort Drum MCA takes place through the S-252 structures (A, B, C, and D) in addition to loss of water by evapotranspiration. Structures S-252A, B, and C discharge northward to Blue Cypress MCA, while S-252D discharges to C-52 just before it passes under SR 60 and empties into Blue Cypress WMA. Originally, the USACE developed a discharge-rating curve and design discharges for S-252A, B, and C, but the higher marsh elevations north of SR 60 in Blue Cypress MCA hindered achieving the design discharges. Efforts have been made to improve the flow conditions by digging a getaway channel in the Blue Cypress MCA north of SR 60 where the three structures are located. S-252A, B, and C are located opposite the existing bridges on SR 60. S-252B and S-252C are single uncontrolled culverts, while S-252A is a pair of gated culverts that, under current operation, are always kept open.

S-252D was added to the project design to provide a second flow path to the Fort Drum MCA waters through C-52. It has historically been kept open at all times except when the downstream water levels were higher. The structure was also temporarily closed to create favorable tail water conditions for discharges occurring from the St. Johns Improvement District (SJID) reservoir. Recent study (2008) of the Fort Drum MCA indicated that the additional discharge through this structure was over draining the system and so it is now kept closed. The USACE developed a discharge-rating curve based on the hydraulic head and the structure design for S-252D, which has been used in modeling discharges through the structure.

Structures S-252E and S-252F—built in the northwest portion of the Fort Drum MCA—serve the purpose of preventing backflow from Fort Drum MCA to the west during high water stages and directing flow from the western subwatersheds to Blue Cypress MCA by an alternative route. S-252E is a set of flap-gated culverts that allow flow only eastward into Fort Drum MCA from the west. Discharges from the land west of Fort Drum MCA are diverted through S-252F to a flow-way between SR 60 and L-78. This flow-way directs the discharge to the bridges under SR 60 near S-252A and S-252B.

The predominant land uses are pasture and wetlands and are essentially unchanged from 1995 to 2030 (Table 3–16).

Table 3–16. Fort Drum Creek Planning Unit (6A) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		2030 Land Use (acres)	
Low-density residential	2,086	3.0%	2,637	3.8%
Medium-density residential	0	0.0%	0	0.0%
High-density residential	0	0.0%	0	0.0%
Industrial and commercial	297	0.4%	369	0.5%
Mining	124	0.2%	124	0.2%
Open and barren land	341	0.5%	334	0.5%
Pasture	22,337	32.3%	22,087	32.0%
Agriculture general	3,144	4.6%	3,122	4.5%
Agriculture tree crops	1,393	2.0%	1,387	2.0%
Rangeland	10,472	15.2%	10,267	14.9%
Forest	3,838	5.6%	3,706	5.4%
Water	501	0.7%	501	0.7%
Wetlands	24,547	35.5%	24,547	35.5%
Total	69,080	100.0%	69,080	100.0%

Blue Cypress Creek Planning Unit (6B)

There are 11 subwatersheds in this planning unit and Blue Cypress Creek is the main tributary. The main river course, excluding Blue Cypress Lake, is a marsh floodplain with SR 60 and Fellsmere Grade as the upstream and the downstream boundaries, respectively (Figure 3–17). The marsh elevation dips from about 24.0 ft at SR 60 to about 22.5 ft NGVD29 at Fellsmere Grade at the northeastern edge of the planning unit. During low water stages, the canals on the eastern side of the marsh (Lateral “M” and Zigzag canals) carry the discharge.

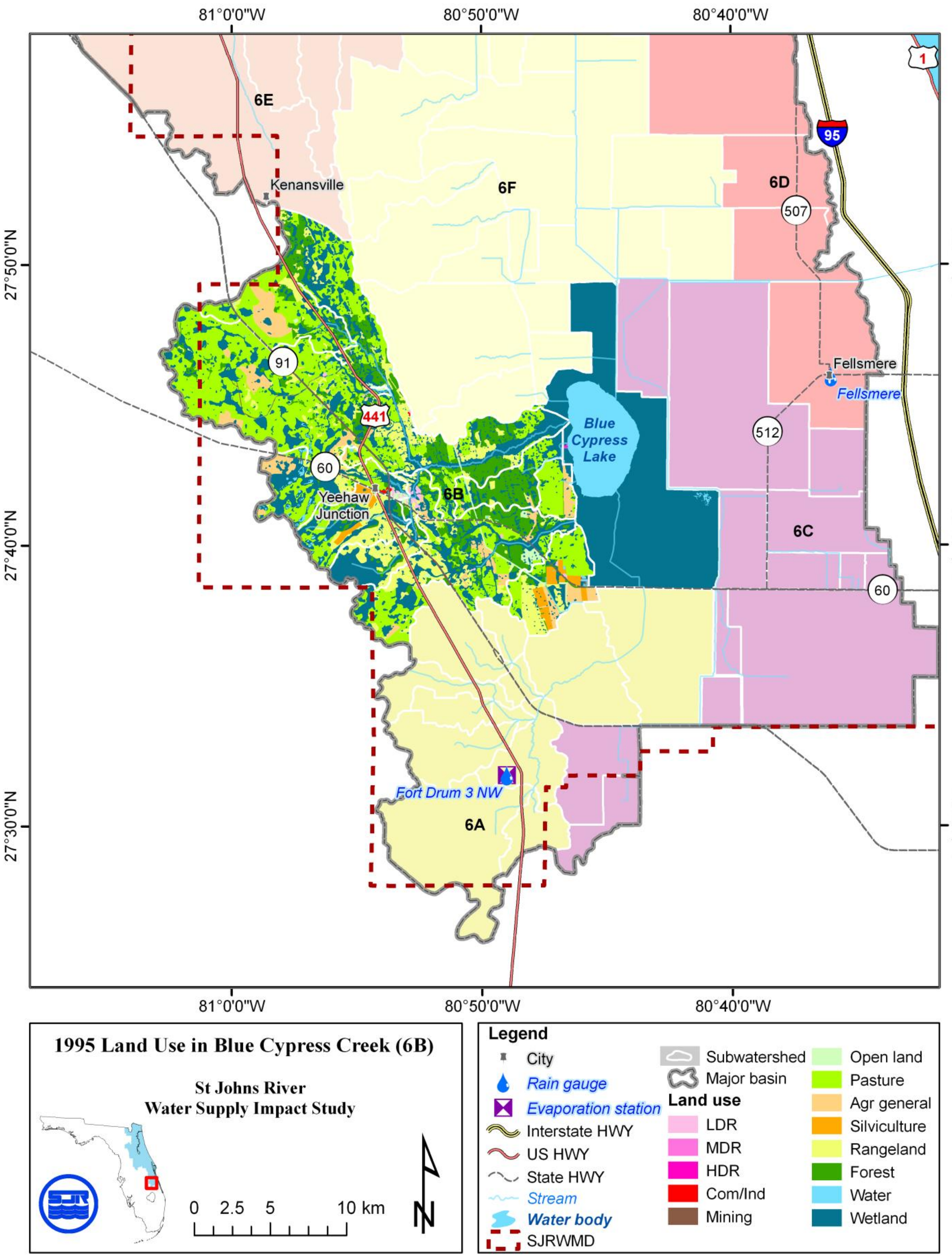

Figure 3–17. 1995 land use in Blue Cypress Creek Planning Unit (6B).

The Blue Cypress MCA is predominantly a marsh area with the 6,500-ac Blue Cypress Lake located in the center. Blue Cypress MCA is enclosed on the north, east, and south by USACE and SJRWMD levees. The western boundary of Blue Cypress MCA consists of SJRWMD levee at Kenansville Lake and private levees to the south with drainage occurring from Blue Cypress Creek and Padgett Branch through their natural flow paths. The adjacent project areas include Blue Cypress WMA, St. Johns WMA, Fellsmere WMA, and Kenansville Lake.

Outflows occur northward through S-250A, S-250B, S-250C, and S-96C. The three smaller S-250A, B, and C structures are culvert/weir structures, with culverts having risers at 22.00 ft NGVD29 and the weirs set at crest elevation 25.00 ft NGVD29. S-96C is a large operable USACE spillway with a sill at 11.80 ft NGVD29 and a maximum capacity of 969 mgd (1,500 cfs). Kenansville Lake also drains north, originally through S-250D, a set of uncontrolled culverts that have historically had reduced effective capacity due to vegetation and high downstream marsh elevations. This drainage has been supplemented by the construction of S-250E, a weir set at 23.5 ft NGVD29 with a small low flow culvert at 21.00 ft NGVD29.

Predominant 1995 land uses in the Blue Cypress Creek watershed are pasture and wetlands and it is anticipated that significant single-family residential development will occur by 2030, displacing forest, pasture, and rangeland uses (Table 3–17).

Table 3–17. Blue Cypress Creek Planning Unit (6B) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	424	0.3%	24,764	19.9%
Medium-density residential	0	0.0%	284	0.2%
High-density residential	17	0.0%	17	0.0%
Industrial and commercial	504	0.4%	3,846	3.1%
Mining	190	0.2%	80	0.1%
Open and barren land	836	0.7%	428	0.3%
Pasture	34,074	27.4%	21,273	17.1%
Agriculture general	5,064	4.1%	3,986	3.2%
Agriculture tree crops	1,341	1.1%	1,132	0.9%
Rangeland	11,989	9.6%	7,424	6.0%
Forest	12,663	10.2%	3,868	3.1%
Water	7,370	5.9%	7,370	5.9%
Wetlands	49,901	40.1%	49,901	40.1%
Total	124,373	100.0%	124,373	100.0%

Fellsmere Planning Unit (6C)

Fellsmere Grade acts as a dam impounding waters during high stages. The basin is dominated by water control features (Figure 3–14). Some of the water control features are under the management of SJRWMD, while others are managed by various state-chartered water control districts and large farms.

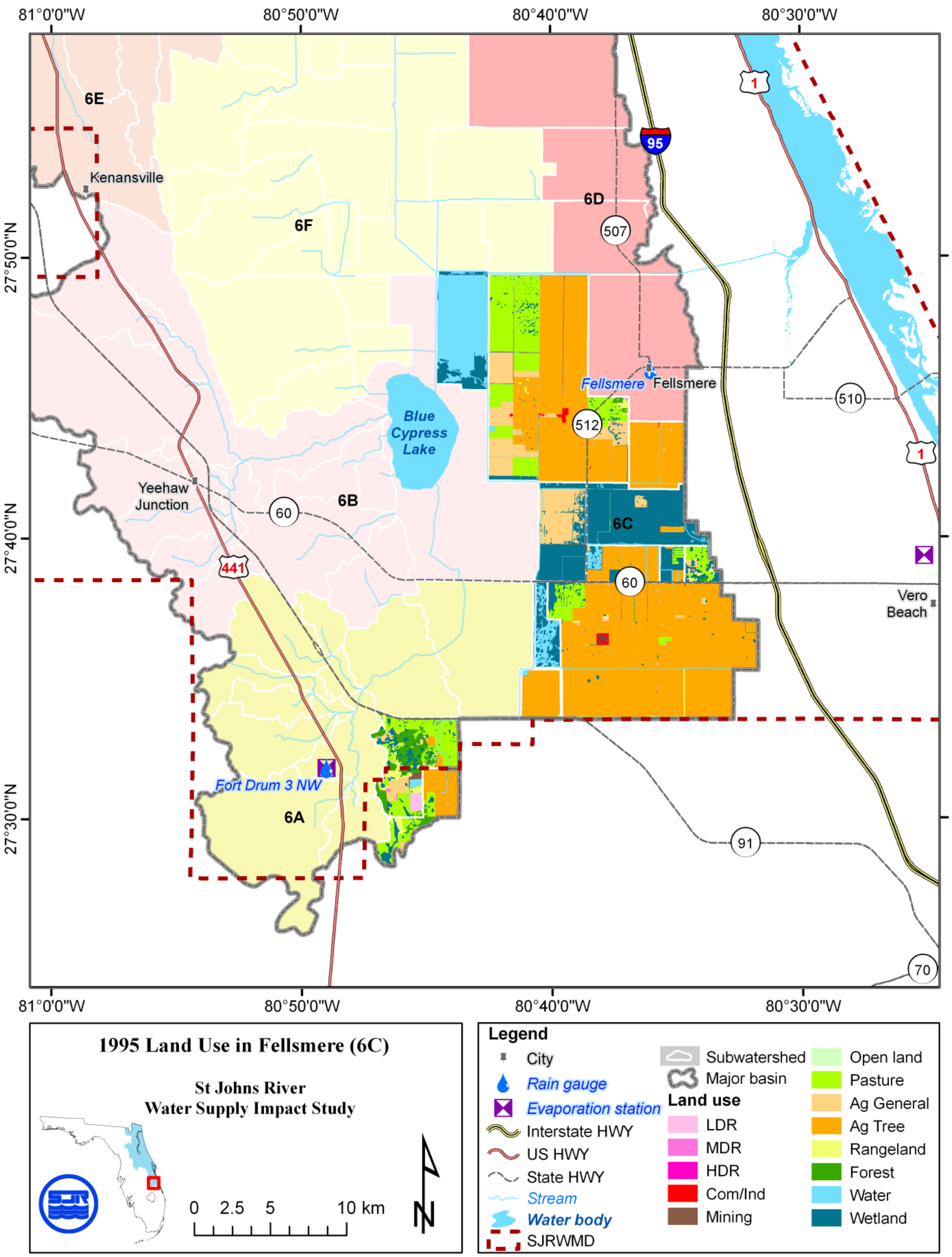

Figure 3–18. 1995 land use in Fellsmere Planning Unit (6C).

Just south of planning unit 6C, there are three agricultural subwatersheds with pumped drainage that flow into the upper basin across the S-253 weir, which was constructed to prevent backflow to the south into the South Florida Water Management District (SFWMD) drainage system. These subwatersheds, totaling approximately 20 mi^2, are considered as part of planning unit 6C for modeling purposes.

St. Johns Improvement District, formerly known as St. Johns Water Control District, is a major agricultural entity in this planning unit, with a subwatershed area of about 29,000 ac that includes an irrigation reservoir of 1,760 ac. The reservoir, with an average ground elevation of 23.00 ft NGVD29, receives runoff by pumping and has a gated outlet spillway with top of the gates at 26.7 ft NGVD29. When the reservoir water levels exceed 26.7 ft NGVD29, outflow is initially a spill over the gates, and if water levels exceed 27.5 ft NGVD29, some of the gates are opened to increase the discharge capacity.

Fellsmere Water Control District is another major agricultural entity in the project area with a total subwatershed area exceeding 50,000 ac. Prior to 2001, it had an irrigated area of about 25,000 ac and had a permit to draw water from St. Johns WMA to irrigate 20,000 ac; the remaining area was irrigated by groundwater. About 60% of the excess drainage from Fellsmere Water Control District was discharged into the Indian River Lagoon through Fellsmere Canal and the remainder to St. Johns WMA. The SJRWMD has purchased 10,244 ac of the Fellsmere Water Control District adjacent to the St. Johns WMA for the construction of the Fellsmere WMA reservoir. The Fellsmere WMA is currently under construction and its proposed management schedule is described in later in this section The Blue Cypress WMA is a major nesting area in Florida for Snail Kite (*Rostrhamus sociabilis plumbeus)*, a federally listed endangered species, and receives special attention in maintaining its water levels for protection of this species (Miller, Lee, et al. 1996); (Miller, Tremwell and Minno 2003). State Road (SR) 512 separates Blue Cypress WMA into two parts (East and West), which are connected by S-251 (see Figure 3–13). S-251 is a gated culvert structure and is closed if water levels in the western part are higher. The two parts are modeled separately. Inflows to Blue Cypress WMA include direct rainfall over Blue Cypress WMA, the discharge received through C-52, and drainage from agricultural areas immediately to the north and south. Outflow from Blue Cypress WMA normally occurs through S-96D and S-3 into St. Johns WMA with rare overflows over S-254 into Blue Cypress MCA (only observed once, following Tropical Storm Fay in 2008) and by evapotranspiration. Historically there also were irrigation withdrawals by the surrounding farms.

When Blue Cypress WMA water levels are in the flood control mode, defined as the range of stages within Zone A, the target discharge through S-96D and S-3 combined is 646 mgd (1,000 cfs). When the head available on the structures is low, both of the structures are operated together to achieve the targeted discharge or the maximum achievable if the target cannot be reached. When Blue Cypress WMA water levels are low, in Zone B, low flow releases may be made up to 194 mgd (300 cfs) to prevent low water levels in St. Johns WMA and in some years to draw down Blue Cypress WMA itself for environmental reasons.

S-254 is a 1,500-ft long concrete and sheet-pile weir structure with a crest elevation of 26.6 ft NGVD29. Overflow from Blue Cypress WMA to Blue Cypress MCA occurs when water levels in Blue Cypress WMA exceed 26.6 ft NGVD29.

The St. Johns WMA is a 6,500-ac storage area with an average ground elevation of 16.0 ft NGVD29. It receives inflows from S-96D/S-3 structures and pumping from the Fellsmere Water Control District agricultural land to the east, in addition to direct rainfall, and serves as a source of irrigation water for SB 18N and SB 18S. It has major flood control features, discharging water through three water-control structures (S-96B, S-258, and S-96).

The St. Johns WMA has regulation schedules that govern the flood control releases (Zone A) and low flow environmental releases ("Zone B"). In "Zone A", excess floodwaters are discharged first through S-96B then also through S-258 to C-54 RA if water levels in St. Johns WMA exceed 24.8 ft NGVD29. No discharge is made to C-54 RA if water levels in C-54 RA exceed 25.0 ft NGVD29. When both C-54 RA and St. Johns WMA water levels exceed 25.0 ft NGVD29, discharge is made through S-96 to the Indian River Lagoon via C-54 in addition to the S-96B discharges. S-96B originally discharged water into C-40, the principal flow-way through St. Johns MCA, until the fall of 2008, when it was redirected via a new flow-way into the south end of the still incomplete Three Forks MCA.

As a deep-water reservoir, St. Johns WMA supports a quality sport fishery in addition to serving as a flood control and water supply reservoir. No detailed environmental hydrologic criteria are developed for St. Johns WMA, however, because of the flood control and water supply constraints (Miller, Tremwell and Minno 2003). Thus, there are currently no "Zone B" discharges defined.

The Fellsmere WMA is still in the planning and early construction stages. The preferred water management plan has a regulation schedule, which varies from 21.0 ft NGVD29 in the wet months to 23.0 ft NGVD29 in the dry months. "Zone B" water supply discharges of 55 mgd (85 cfs) from Fellsmere WMA and 32 mgd (50 cfs) from St. Johns WMA would be allowed to occur when water is available (from March through June). In a long-term simulation study, this resulted in a mean elevation of 19.3 ft NGVD29. During the 51-yr period that was modeled, the water elevation was below 17.3 ft for 7% of the time and above 21.3 ft for 5% of the time. There were only 12 occurrences that had water levels below 19.0 ft during December, January, and February. It should be noted that S-96 was not needed as a flood control release for the St. Johns WMA under these conditions. The HSPF hydrologic model used only a rating curve to deliver the discharge from Fellsmere WMA to Three Forks MCA. The actual routing would be determined in the conceptual design.

The preferred design plan is to use the northeast corner of St. Johns WMA as a flow-way to pass water from Fellsmere WMA to the C-54 RA and then to Three Forks MCA. This would be accomplished by constructing a 1,000-ft section of levee across the northeast corner of St. Johns WMA to the C-54 RA. Five hundred feet of L-74-E Levee would have to be removed to connect to the C-54 RA along with 5 mi of flow-way along the south and west sides of the C-54 RA. Control for the combined WMA would be a gated structure discharging to the Three Forks MCA. S-96 would then function as the emergency spillway for Fellsmere WMA. S-2 and S-258 would provide for additional discharge from St. Johns WMA to Fellsmere WMA and then through S-96 if needed.

The construction of Fellsmere WMA would result in the elimination of all direct pumped discharge from agricultural lands to St. Johns WMA. These pumped discharges would be directed into Fellsmere WMA, where the water would be stored prior to any discharge to Three Forks MCA. Once the Fellsmere WMA is completed, the only inflow to St. Johns WMA would be through S-96D.

Table 3–18 provides the 1995 and anticipated 2030 land use for the Fellsmere planning unit. The major land use is citrus (agriculture tree crops) (Table 3–18). Low-density residential development is expected to increase by 2030, displacing citrus (Agriculture Tree Crops), pasture, and other agricultural land uses.

Table 3–18. Fellsmere Planning Unit (6C) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	352	0.4%	14,909	15.8%
Medium-density residential	22	0.0%	22	0.0%
High-density residential	0	0.0%	0	0.0%
Industrial and commercial	405	0.4%	2,794	3.0%
Mining	1,157	1.2%	1,049	1.1%
Open and barren land	27	0.0%	9	0.0%
Pasture	11,739	12.4%	9,616	10.2%
Agriculture general	6,860	7.2%	5,514	5.8%
Agriculture tree crops	47,987	50.7%	35,217	37.2%
Rangeland	1,325	1.4%	1,035	1.1%
Forest	2,079	2.2%	1,786	1.9%
Water	7,400	7.8%	7,400	7.8%
Wetlands	15,310	16.2%	15,310	16.2%
Total	94,663	100.0%	94,663	100.0%

Interbasin Diversion Planning Unit (6D)

Because of a series of past drainage projects, surface water discharges were shifted from the St. Johns River to the Indian River Lagoon. The SJRWMD has several projects in the Interbasin Diversion Planning Unit to bring that water back to the St. Johns River, but SJRWMD must accomplish this without an increased risk of flooding. These projects will also benefit the Indian River Lagoon, which was receiving too much fresh water.

The 1995 land use in the Interbasin Diversion Planning Unit was divided among residential, forest, pasture, and open land (Table 3–18). Given the predicted population increases by 2030 low and medium-density residential land use will triple in the area (Table 3–19).

Currently, none of this area drains to the upper basin, although there are some areas that were formerly diverted to the Indian River Lagoon but restored to the upper basin drainage before the Interbasin Diversion Planning Unit was demarcated. These rediverted areas are now part of planning units 6C and 6F. However, in the modeling scenarios that include the completed additional Upper Basin projects, Phase 1 of the C-1 Rediversion Project will restore approximately one third of the long-term average flow from an area of approximately 85 mi^2 to the upper basin. These flows are added to the applicable models as a point source having been estimated using a linked HSPF-SWMM model in a previous effort.

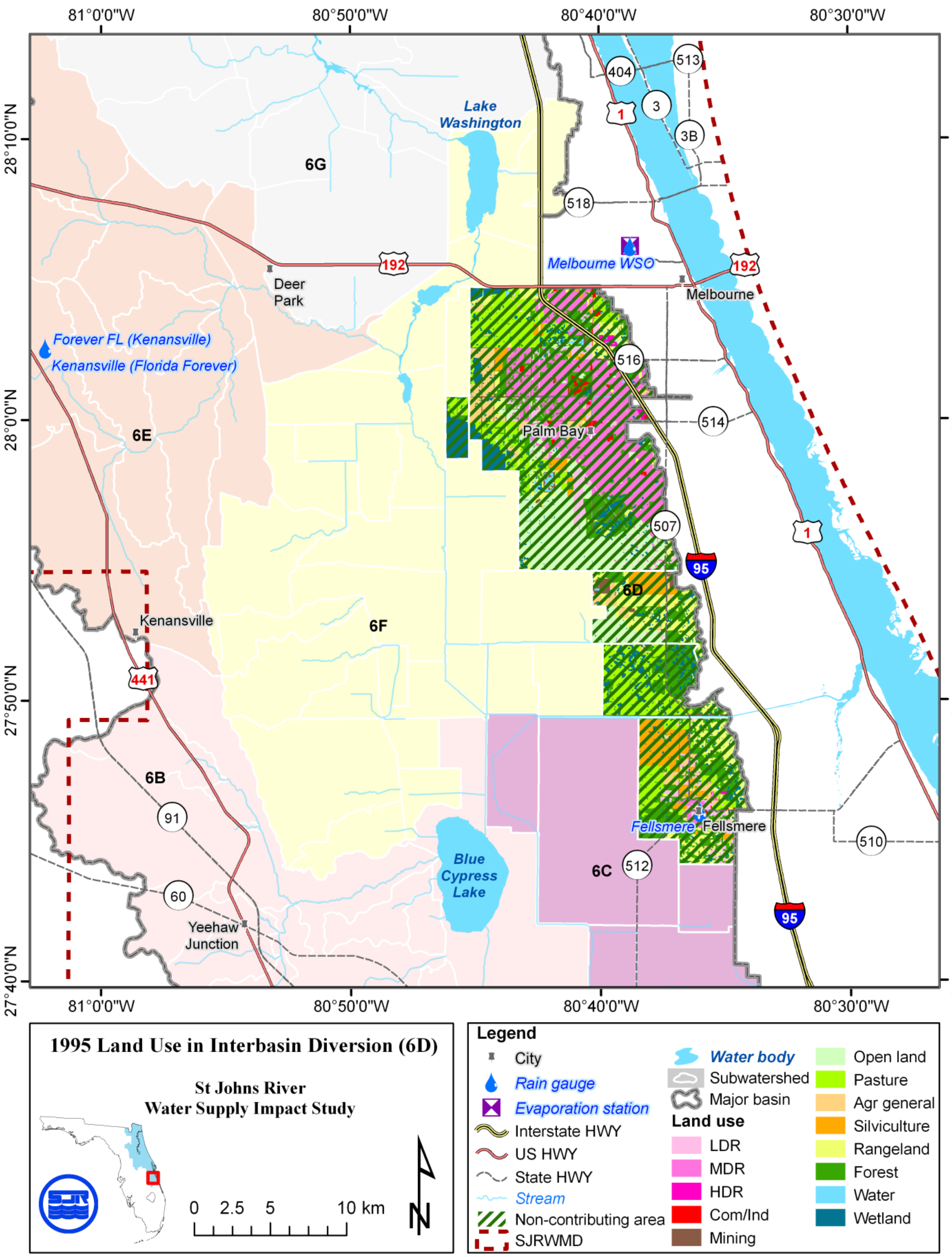

Figure 3–19. 1995 land use in Interbasin Diversion Planning Unit (6D).

Table 3–19. Interbasin Diversion Planning Unit (6D) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	3,440	4.3%	14,995	18.6%
Medium-density residential	14,974	18.6%	31,069	38.6%
High-density residential	339	0.4%	892	1.1%
Industrial and commercial	1,178	1.5%	2,204	2.7%
Mining	1,448	1.8%	1,192	1.5%
Open and barren land	10,907	13.5%	4,755	5.9%
Pasture	11,408	14.2%	3,850	4.8%
Agriculture general	3,397	4.2%	1,787	2.2%
Agriculture tree crops	4,385	5.4%	1,207	1.5%
Rangeland	8,552	10.6%	4,396	5.5%
Forest	12,124	15.0%	5,806	7.2%
Water	1,059	1.3%	1,059	1.3%
Wetlands	7,360	9.1%	7,360	9.1%
Total	80,571	100.0%	80,571	100.0%

Jane Green Creek Planning Unit (6E)

Jane Green Creek is predominantly a marsh floodplain (Figure 3–20). It is dominated by the Jane Green Detention Area, which comprises all but the downstream end of the planning unit. Much of the Jane Green Detention Area is covered by the Bull Creek and Triple-N Ranch Wildlife Management Areas.

The Jane Green Detention Area covers about 22,000 ac west of USACE Levee L-73S. It is currently managed by the Florida Fish and Wildlife Conservation Commission (FWC). Discharges from Jane Green Detention Area occur through S-161, which was completed in 1971 under the 1962 project, and S-161A, which was completed in 1990 under the present USJRB project. S-161 is an ogee spillway with crest elevation at 35.0 ft NGVD29 and two 3-ft by 4-ft box culverts with an invert elevation of 26.0 ft NGVD29 located in the sidewalls. S-161A is also an ogee spillway with crest elevation at 26.1 ft NGVD29 and two 3-ft by 4-ft box culverts with an invert elevation of 21.5 ft NGVD29 located in the sidewalls. In addition, in 2008, two 8-ft by 8-ft gated box culverts were cut underneath the original sill with an invert of 19.0 ft NGVD29, while the original upper gate was removed.

Both structures and the side box culverts in S-161A are kept open under normal conditions to keep Jane Green Detention Area elevations in the range of 19.00 to 22.00 ft NGVD29. During flood conditions, a temporary detention of flood discharges occurs in the Jane Green Detention Area with discharges taking place per the hydraulic capacity of the two structures. If stages at US 192, however, exceed 19.50 ft NGVD29, both structures, including the side culverts, are closed until the peak stages at US 192 pass and then they are re-opened.

Below the project area, the creek widens out into a marsh with intermittent braided channels, eventually draining into a marsh that seeps into the St Johns River north of Lake Hell'n Blazes.

Land use in the Jane Green Detention Area was predominantly pasture and wetlands in 1975. This overall pattern of land use is expected to continue in 2030 (Table 3–20).

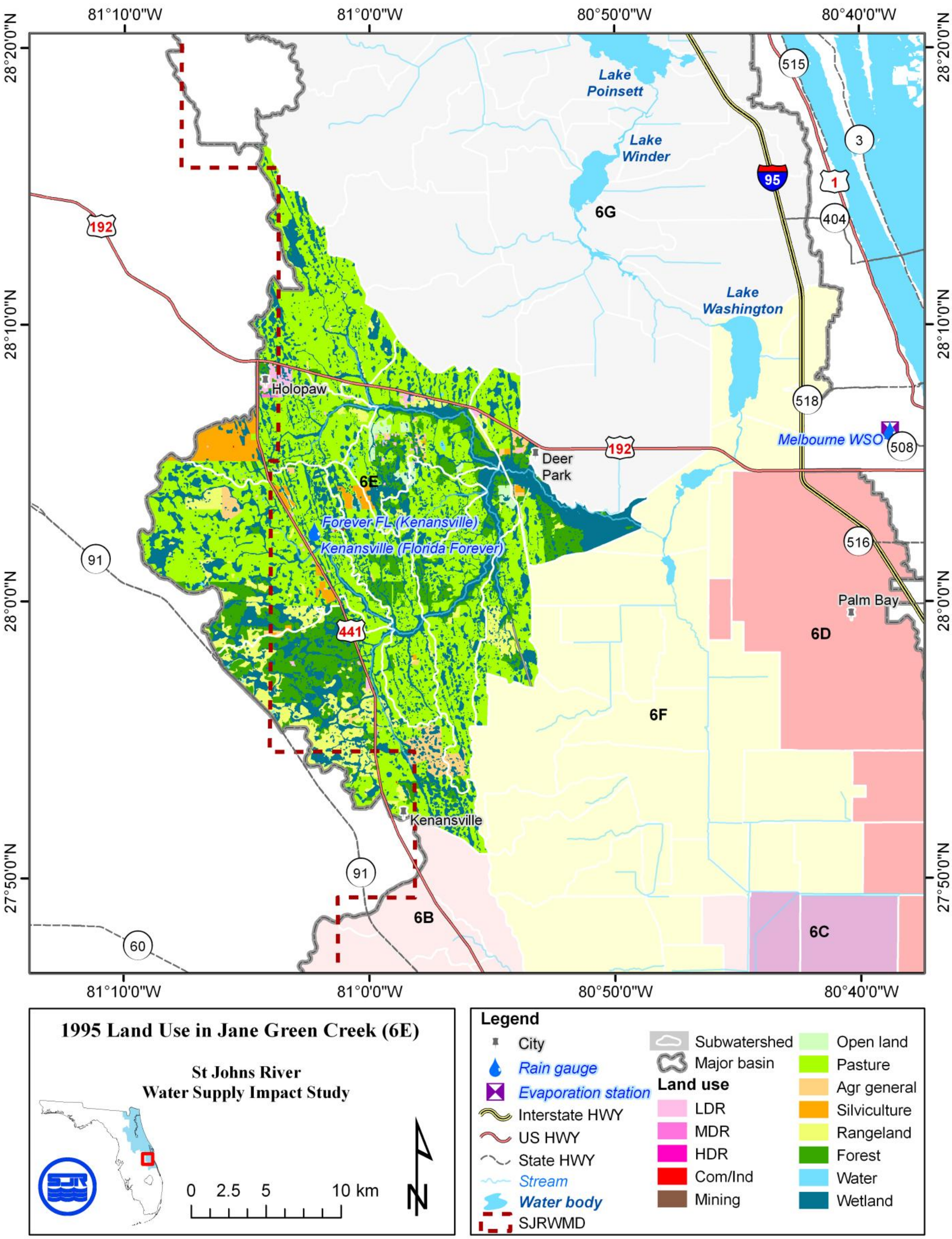

Figure 3–20. 1995 land use in Jane Green Creek Planning Unit (6E).

Table 3–20. Jane Green Creek Planning Unit (6E) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	1,493	0.9%	6,804	4.1%
Medium-density residential	47	0.0%	801	0.5%
High-density residential	3	0.0%	5,435	3.3%
Industrial and commercial	103	0.1%	854	0.5%
Mining	435	0.3%	434	0.3%
Open and barren land	1,297	0.8%	1,160	0.7%
Pasture	81,008	48.9%	72,588	43.9%
Agriculture general	2,555	1.5%	2,279	1.4%
Agriculture tree crops	3,870	2.3%	3,767	2.3%
Rangeland	10,752	6.5%	10,033	6.1%
Forest	17,960	10.9%	15,368	9.3%
Water	520	0.3%	520	0.3%
Wetlands	45,460	27.5%	45,460	27.5%
Total	165,503	100.0%	165,503	100.0%

St. Johns Marsh Planning Unit (6F)

St. Johns Marsh planning unit consists of 166,175 ac. The predominant land uses are wetlands and pasture. A majority of the 66,764 ac of wetlands are contained in the St. Johns MCA. The St. Johns MCA is completely bordered by a levee on the east, while some private levees and natural upland areas form the western boundary. The northern and southern boundaries are US 192 and the Fellsmere Grade, USACE Levee L-74W. St. Johns MCA is characterized by wetland, pasture, forest, and shallow lakes (Lake Hell'n Blazes and Sawgrass Lake) (Figure 3–21). The marsh slopes from an elevation of 22.5 ft NGVD29 at Fellsmere Grade to about 14.0 ft NGVD29 near US 192. During low stages, the canals on both sides of the marsh, C-40 on the east and Mormon Canal on the west, carry the discharge. Drainage from Melbourne-Tillman Water Control District and Mary-A Ranch East was diverted to the Indian River Lagoon.

In 1986, in an attempt to establish sheet flow conditions in the marsh, SJRWMD constructed nine earthen canal plugs, eight in C-40 (E1-E8) and one in Mormon Canal (W-2). These plugs, however, were found to cause severe backwater conditions impeding flood discharges from the project structures, especially on the east. Consequently, all of the eastern plugs except E-7 were breached over the period 1992 to 1999, and E-7 was equipped with gated culverts to allow more flow during the dry season. Although some of the plugs still existed in 1995, their effects were localized and temporary, and had very little impact on flows at the next downstream gauge at Melbourne. Therefore, only the E-7 plug was considered for the modeling.

Until 2008, S-96B discharged into St. Johns MCA, but its flow was then diverted into Three Forks MCA via a new flow-way. In the interim condition, this flow rejoins St. Johns MCA via the S-256 flow-way through a new cut in its southern levee. In the final condition, the flow rejoins St. Johns MCA farther downstream at the new S-257 weir and culvert.

Flood stages in St. Johns MCA would occur from various discharges received at different locations. Since 1996, low flow augmentation of St. Johns MCA is provided by a release of 48 mgd (75 cfs) from S-96C when Blue Cypress MCA is under “Zone B” regulation.

St. Johns MCA environmental objectives include promoting a healthy marsh ecosystem with maintenance of adequate low flow conditions with inflows free of pollutants. The environmental hydrologic criteria are developed for three locations: Six Mile Marsh, Mulberry Mound, and Big Bend Marsh. Long-term simulated data show that, in general, most of the criteria would be met.

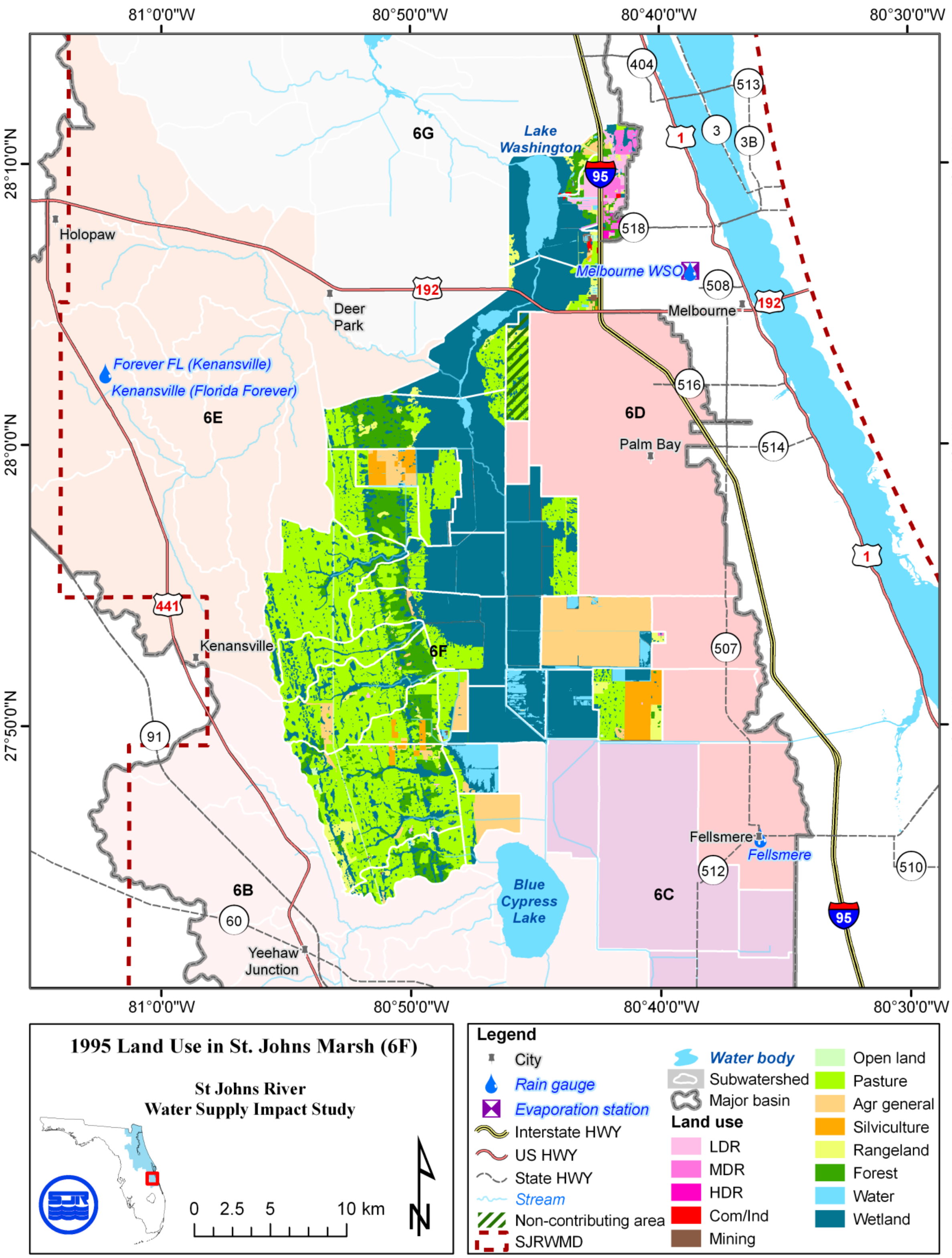

Figure 3–21. 1995 land use in St. Johns Marsh Planning Unit (6F).

C-54 Retention Area: C-54 RA has an area of about 3,550 ac with a ground elevation of 16.0 ft NGVD29. It serves as a waterfowl management area for the Florida Fish and Wildlife Conservation Commission. Maintaining C-54 RA as a productive waterfowl area is the environmental objective for this area. In addition to direct rainfall, when St. Johns WMA is above 24.8 C-54 RA receives flood discharges from St. Johns WMA until stages in C-54 RA reach 25.5 ft NGVD29thereby delaying flow diversion to the Indian River Lagoon. Outflows from C-54 RA occur (in addition to evapotranspiration) at a rate of 65 mgd (100 cfs) by pumping into Three Forks MCA when stages in C-54 RA exceed 22.0 ft NGVD29. The final plan for Fellsmere WMA adds a flow-way around the southern and western edges to pass discharge from Fellsmere WMA to Three Forks MCA via a planned gated structure at the northwest corner of C-54 RA.

Three Forks Marsh Conservation Area: Three Forks MCA is a vast 13,740-ac environmental restoration area fully enclosed by levees. The EIS was completed in 2003 and construction is nearing completion. The topographic elevations range from 19.5 ft NGVD29 in the south to about 13.0 ft NGVD29 in the north. When completed, Three Forks MCA will be a mixed area of emergent marsh habitat, slough, and open water. In addition to rainfall, it would receive discharges from C-54 RA, S-96B, and Fellsmere WMA.

Three Forks MCA discharges to St. Johns MCA through two outlet structures: S-257 (two gated 60-in. culverts) and a 600-ft broad-crested weir with crest elevation at 20.0 ft NGVD29. S-257 is operated to meet various environmental criteria and for low flow augmentation to the St. Johns River. It will be fully open between the stages 19.0 and 20.0 ft NGVD29 and closed if stages exceed 20.0 ft NGVD29. When stages start receding below 19.0 ft NGVD29, discharges are made for five consecutive days, reducing the discharge by 13 mgd (20 cfs) each day (i.e., 65 mgd [100 cfs] on the day when the stage is at 19.0 ft NGVD29, 52 mgd [80 cfs] the next day, 39 mgd [60 cfs] the following day, etc.). Discharge is stopped after the fifth day. Gate opening of S-257 will be adjusted to achieve the necessary discharges.

When stages in Lake Washington are below 12.0 ft NGVD29, a release of 19 mgd (30 cfs) is made to improve water supply benefits of Lake Washington as long as stages in Three Forks MCA are above 14.0 ft NGVD29. If S-257 is already discharging greater than 19 mgd (30 cfs), no additional release is made. In addition, when planned water supply releases from Fellsmere WMA and/or St. Johns WMA are being made, these releases will pass through S-257 downstream.

Sawgrass Lake Water Management Area: Sawgrass Lake WMA is a 2,250-ac wetland treatment area with an average ground elevation of 15.0 ft NGVD29. Recently completed, its two pump stations that will supply water for treatment are awaiting connection to the local power grid. Located in the northwest area of the Melbourne Tillman Water Control District, Sawgrass Lake WMA and C-1 RA were built as a part of the C-1 re-diversion project. The Melbourne-Tillman Water Control District was historically an integral part of the USJRB, but it was separated from the St. Johns Marsh planning unit by an eastern levee, which caused an interbasin diversion of the area drainage to the Indian River Lagoon. Under pre-project conditions, Melbourne-Tillman Water Control District had an area of 100 mi^2 and large storm water discharges carried by C-1, sometimes exceeding 2,585 mgd (4,000 cfs) in Turkey Creek, which have been a cause of Indian

River Lagoon degradation. Creation of Three Forks MCA, C-1 RA, and Sawgrass Lakes WMA has reduced the area of Melbourne-Tillman Water Control District by about 17 mi^2, but will only have minor impact on flood discharges. A Phase 1 water management plan has been finalized for the Melbourne-Tillman Water Control District that defines pumping much of the volume from low flow events into the St. Johns River through Sawgrass Lake WMA and moderates peak discharges into the Indian River Lagoon. Further rediversion will be evaluated in Phase 2 in the near future.

Excess storm drainage collects in C-1 RA and C-1 Detention Area up to an elevation of 18.0 ft NGVD29, and Sawgrass Lake WMA receives this discharge by pumping. The average discharge from Sawgrass Lake WMA to St. Johns MCA through S-262 under Phase 1 is estimated to be about 26 to 32 mgd (40 to 50 cfs). The detention periods in Sawgrass Lake WMA provide stormwater treatment to filter pollutants, and the discharge released to St. Johns MCA is expected to meet the same water quality standards as the receiving water body. A minimum water level of 16.75 ft NGVD29 is maintained in Sawgrass Lake WMA, below which S-262 is closed.

Lake Washington is the primary drinking water supply source for the City of Melbourne. To protect the water supplies of the lake, a semi-permanent dam was built in 1961 with a crest elevation at 12.00 ft. NGVD29 across the narrow channel of the St. Johns River about 0.5 mi. downstream of the lake outlet. Washouts of this dam occurred at times, necessitating repairs by sand bags. In 1976, a sheet-pile weir with a crest elevation at 13.50 ft. NGVD29 and a length of 160 ft was built at the north end of the lake. The lake has a surface area of about 4,000 ac at 13.50 ft NGVD29, with an average depth of about 5 to 6 ft. The average water supply withdrawal from the lake under pre-project conditions was 14 mgd. At the request of South Brevard Water Authority, SJRWMD conducted special studies in the mid-1980s to evaluate Lake Washington's water supply potential under various socio-economic and environmental constraints (Rao and Tai 1987). The study concluded that completion of the USJRB project would considerably improve the water supply potential of Lake Washington; the study did not establish a limiting value for the water supply potential, but stated that withdrawals exceeding 30 mgd would be possible. The study also recommended replacing the existing sheet-pile weir with a permanent structure having a weir crest elevation at 14.00 ft NGVD29. Although a 13.50-ft weir also would provide a 30 mgd water supply benefit, a 14.00-ft weir was projected to provide improved conditions for drought mitigation, water quality, and fish protection. Construction of a new structure replacing the sheet-pile weir was completed in 2000, which had a weir crest partially at 13.50 ft and partially at 14.00 ft NGVD29. The Lake Washington weir also provides beneficial backwater effects that prevent over-draining of upstream floodplain marsh. The structure is also provided with two sluice gates for low flow releases, a gated one with a 4-ft × 4-ft opening, generally kept closed, and the other an ungated 2-ft × 2-ft opening, both at an invert elevation of 7.25 ft NGVD29.

The major use of uplands in the St. Johns MCA is pasture, while wetlands comprise the majority of the area. Although wetland acreage will remain steady, upland land use is expected to significantly shift toward low-density residential uses by 2030 (Table 3–21).

Table 3–21. St. Johns Marsh Conservation Area Planning Unit (6F) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	1,872	1.1%	57,217	34.4%
Medium-density residential	1,230	0.7%	3,102	1.9%
High-density residential	127	0.1%	442	0.3%
Industrial and commercial	373	0.2%	1,523	0.9%
Mining	1,113	0.7%	654	0.4%
Open and barren land	1,128	0.7%	450	0.3%
Pasture	55,082	33.1%	22,645	13.6%
Agriculture general	12,267	7.4%	4,942	3.0%
Agriculture tree crops	3,525	2.1%	87	0.1%
Rangeland	3,994	2.4%	719	0.4%
Forest	12,502	7.5%	1,432	0.9%
Water	7,198	4.3%	7,198	4.3%
Wetlands	65,764	39.6%	65,764	39.6%
Total	166,175	100.0%	166,175	100.0%

Lake Poinsett Planning Unit (6G)

This planning unit has three relatively large western upland tributary basins, which are drained by the tributaries of Pennywash, Wolf, and Taylor creeks, and smaller drainages along the eastern side at much lower elevations. The main river passes through Lake Winder and Lake Poinsett. Even though these lakes are not regulated by water control structures, they have considerable attenuating effect on peak stages. The two lakes have a bottom elevation of about 6.00 ft. NGVD29 and an average depth of about 6 ft. The area outside the lakes consists of riparian wetlands (Figure 3–22). Private levee systems on both the eastern and western sides of the marsh protect the adjacent lands from flooding. Excess runoff from these subwatersheds is pumped into the St. Johns River marsh.

The 1962 USJRB Project included constructing flood control detention reservoirs on the upland creeks. For this purpose, construction of Levee L-73N to impound the waters of Pennywash, Wolf, Cox, and Taylor creeks was almost completed by 1968 when the project was halted. Only Taylor Creek and Cox Creek were impounded by L-73N, however, forming the Taylor Creek Reservoir with control structure S-164, a gated spillway. L-73 was left incomplete with 800- and 700-ft gaps, respectively, where Pennywash and Wolf creeks cross L-73. Completed structures near each creek, built away from the thalweg (center of the channel) at significantly higher invert, were abandoned; therefore, the flow of these two creeks is uninterrupted.

Taylor Creek Reservoir receives drainage from an area of about 41,000 ac and is operated primarily for water supply. Withdrawals for the City of Cocoa began in 2000 and average 8 mgd with a permitted limit of 12 mgd. The reservoir has a regulation schedule, which enhances fisheries. The schedule is saw-toothed with a low of 39.0 ft NGVD29 in the wet season and a high of 43.0 ft NGVD29 during the dry season.

The major land uses in the Lake Poinsett area are pasture and wetlands. It is expected that the area of residential, industrial, and commercial land uses will increase by 2030 (Table 3–22).

The Lake Poinsett planning unit contains two features that will be discussed in detail later in the results section of this report. The first is the Taylor Creek Reservoir, located on the western side of the St. Johns River, represented as a large water body in Figure 3–22. The other is the USGS monitoring station at SR 520 (Cocoa). This station plus the next downstream station at SR 50 (Christmas), which lies at the outlet of the Tosohatchee Unit (6H), were selected for detailed analysis of changes in stage and flow that may result from water withdrawals to supply the reservoir (Figure 3–23).

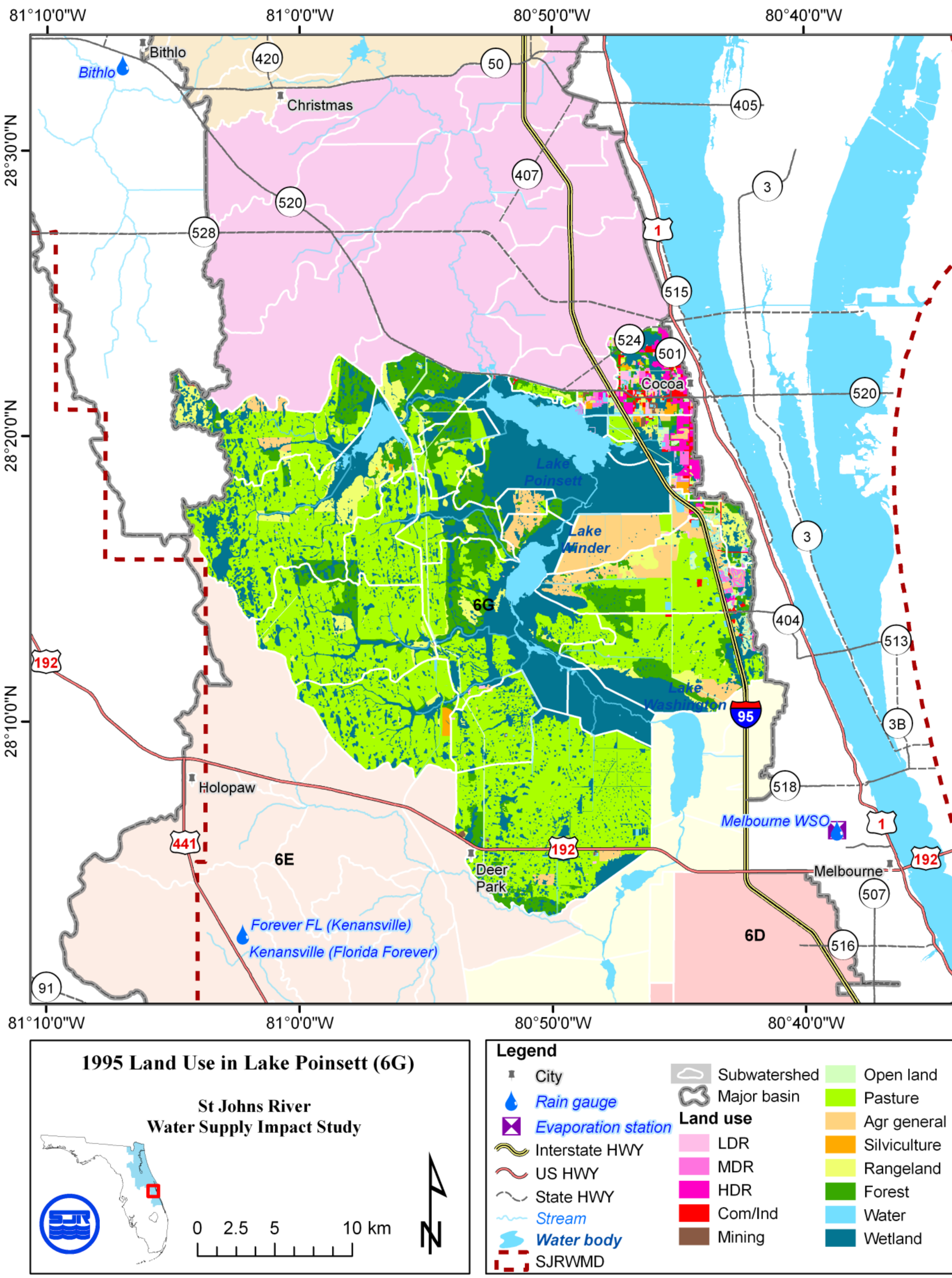

Figure 3–22. 1995 land use in Lake Poinsett Planning Unit (6G).

Table 3–22. Lake Poinsett Planning Unit (6G) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	838	0.4%	9,588	4.4%
Medium-density residential	1,263	0.6%	8,242	3.8%
High-density residential	2,262	1.0%	22,894	10.5%
Industrial and commercial	1,963	0.9%	6,871	3.2%
Mining	442	0.2%	318	0.1%
Open and barren land	2,553	1.2%	1,485	0.7%
Pasture	94,813	43.6%	68,429	31.4%
Agriculture general	10,927	5.0%	7,167	3.3%
Agriculture tree crops	732	0.3%	508	0.2%
Rangeland	10,498	4.8%	7,200	3.3%
Forest	20,779	9.5%	14,369	6.6%
Water	9,290	4.3%	9,290	4.3%
Wetlands	61,258	28.1%	61,258	28.1%
Total	217,618	100.0%	217,618	100.0%

Tosohatchee Planning Unit (6H)

Tosohatchee State Preserve is a major feature of the watershed, bordering 13 mi of the western shore of the St. Johns River from Lake Poinsett north to SR 50 (Figure 3–23). Three western upland creeks—Tootoosahatchee, Jim, and Second—drain the northern part of Cocoa and the western part of Titusville. Parts of SR 50 and SR 520 form the northern and southern boundaries of the watershed, respectively.

Wetlands and forest dominate the land use in this watershed with some growth in residential and industrial and commercial land use expected by 2030 (Table 3–23).

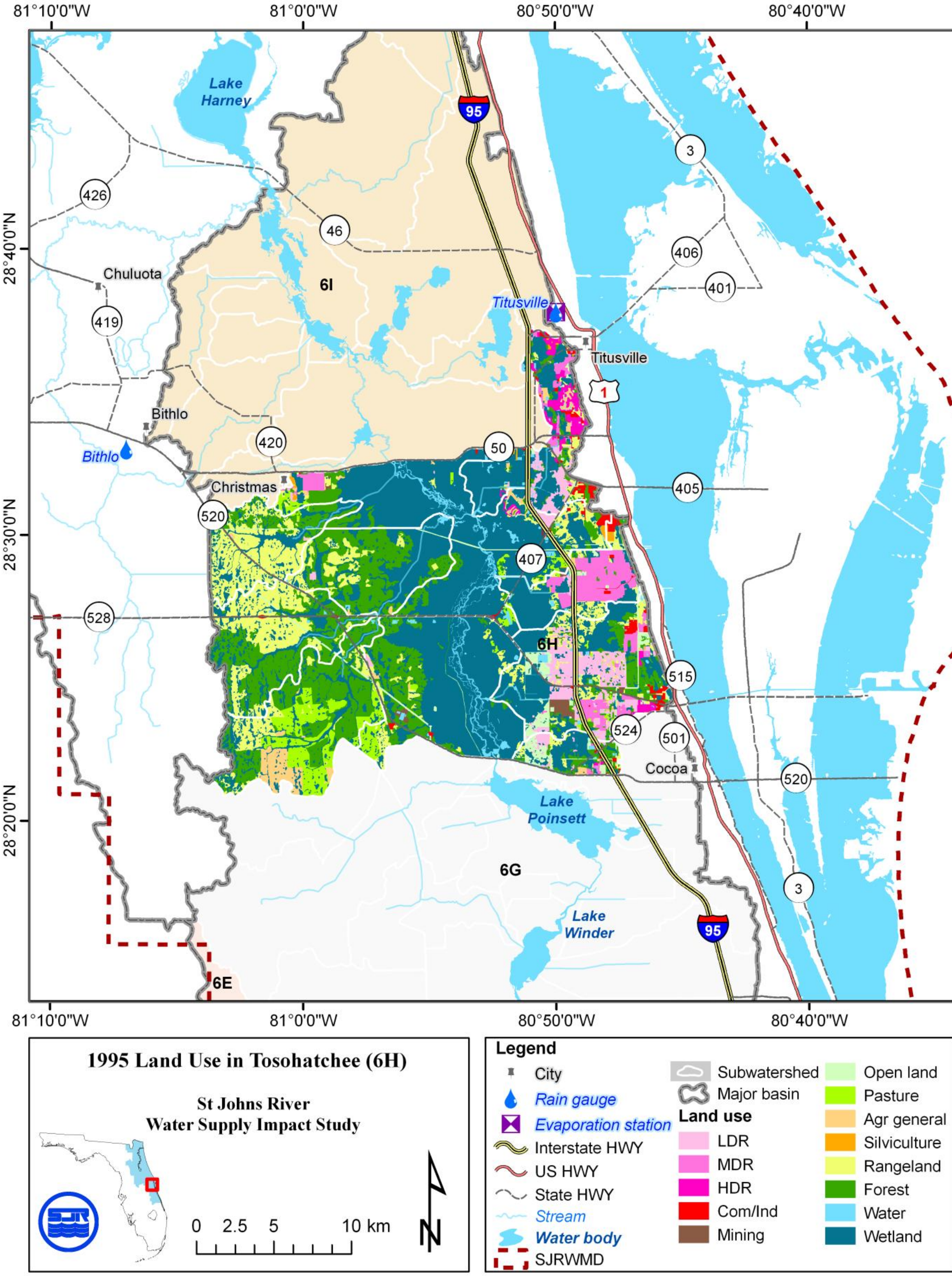

Figure 3–23. 1995 land use in Tosohatchee Planning Unit (6H).

Table 3–23. Tosohatchee Planning Unit (6H) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	5,419	4.0%	13,678	10.2%
Medium-density residential	5,163	3.8%	18,892	14.1%
High-density residential	1,709	1.3%	2,840	2.1%
Industrial and Commercial	2,810	2.1%	7,231	5.4%
Mining	537	0.4%	382	0.3%
Open and Barren Land	3,242	2.4%	580	0.4%
Pasture	5,450	4.1%	3,946	2.9%
Agriculture general	2,357	1.8%	1,551	1.2%
Agriculture tree crops	299	0.2%	49	0.0%
Rangeland	18,113	13.5%	6,093	4.5%
Forest	27,902	20.8%	17,758	13.2%
Water	2,575	1.9%	2,575	1.9%
Wetlands	58,640	43.7%	58,640	43.7%
Total	134,216	100.0%	134,216	100.0%

Puzzle Lake Planning Unit (6I)

Most of the eastern area of this planning unit is primarily wetlands, while a number of minor creeks (Savage, Joshua, Christmas, Buscombe, Roberts, Turkey, and Jackson) drain into the St. Johns River from the western uplands (Figure 3–24).

The main channel of the St. Johns River consists of braided streams. The Econlockhatchee River joins the St. Johns River just north of Puzzle Lake and although it technically is not included in the Puzzle Lake watershed, it is included in a USGS gauging station that collects stage and discharge data at SR 46, which represents outflow from the USJRB plus the Econlockhatchee River basin.

Over two-thirds of the land in this unit is wetlands. There is expected to be growth in residential, industrial, and commercial land use by 2030 (Table 3–24).

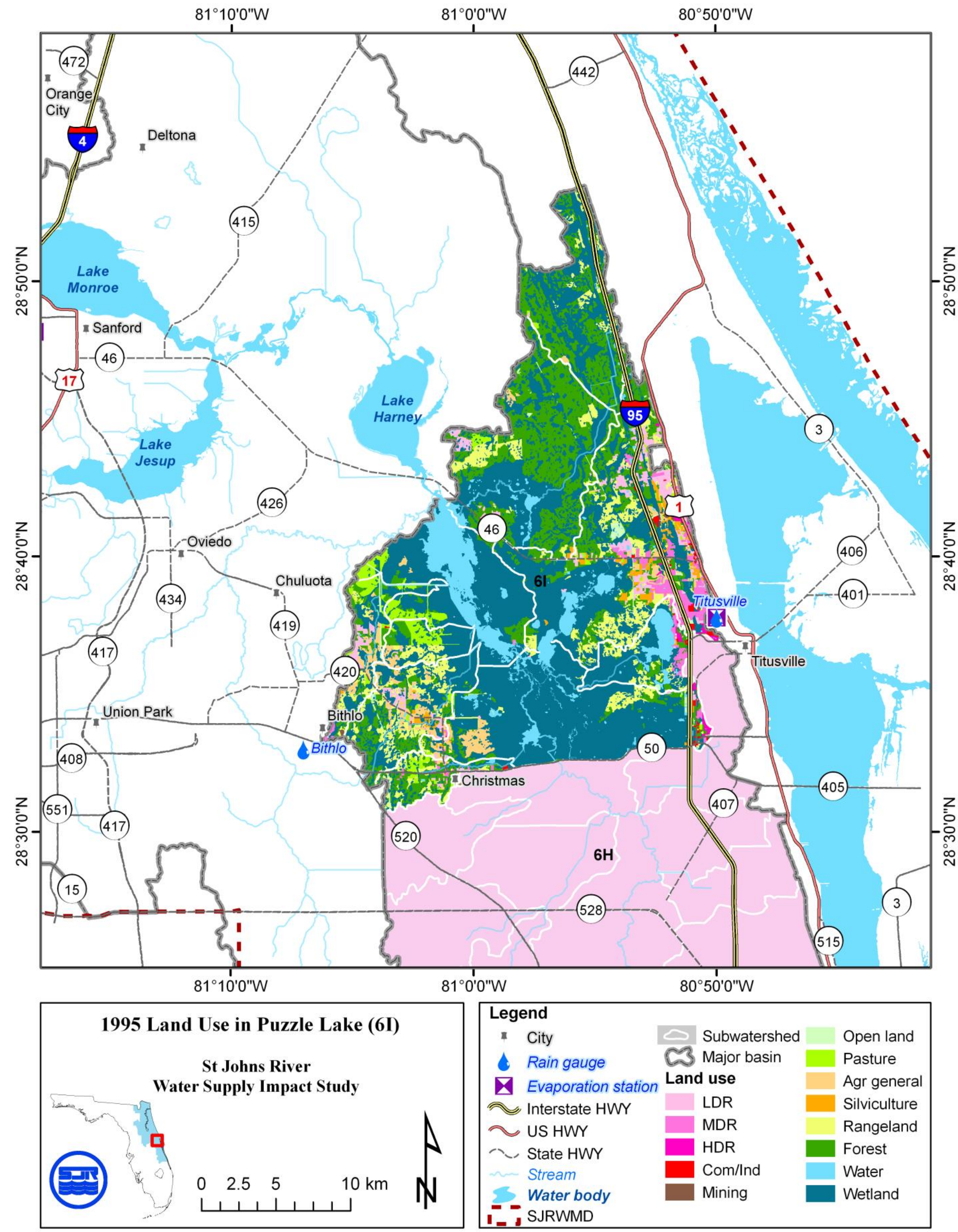

Figure 3–24. 1995 land use in Puzzle Lake Planning Unit (6I).

Table 3–24. Puzzle Lake Planning Unit (6I) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	4,418	3.1%	34,810	24.4%
Medium-density residential	3,071	2.2%	9,562	6.7%
High-density residential	557	0.4%	776	0.5%
Industrial and Commercial	1,630	1.1%	7,678	5.4%
Mining	101	0.1%	57	0.0%
Open and Barren Land	993	0.7%	166	0.1%
Pasture	3,580	2.5%	570	0.4%
Agriculture general	3,963	2.8%	603	0.4%
Agriculture tree crops	1,414	1.0%	377	0.3%
Rangeland	11,531	8.1%	2,126	1.5%
Forest	31,073	21.8%	5,607	3.9%
Water	8,694	6.1%	8,694	6.1%
Wetlands	71,468	50.2%	71,468	50.2%
Total	142,493	100.0%	142,493	100.0%

4.1.2 MIDDLE ST. JOHNS RIVER BASIN (4)

The MSJRB extends from the inflow of the Econlockhatchee River upstream of Lake Harney northward to the confluence with the Wekiva River, just south of DeLand (Figure 3–25). The MSJRB includes several major tributaries and their drainage basins including the Econlockhatchee River, Deep Creek, and the Wekiva River. Lakes Jesup, Monroe, and Harney are the three major lakes in the basin. The basin area encompasses over 1,200 mi^2 that include a sizable portion of Lake, Volusia, Seminole, and Orange counties and much smaller parts of Marion and Brevard counties. The MSJRB is comprised of a variety of landscapes, including highly urbanized areas such as the northeastern portion of Orlando, rapidly urbanizing areas such as Winter Park, and largely undeveloped areas such as the Deep Creek watershed.

The MSJRB consists of five major planning units that contain 104 watersheds (Adamus, Clapp and Brown 1997). The five planning units are listed in Table 3–25. There are a number of watersheds that do not contribute direct runoff to surface water flows due to highly pervious karst geology. These “closed basins” are not included in the acreage totals for the five planning units.

The MSJRB has recently seen a rapid increase in urban development. The percent of urban land use in 1995 was approximately 24.4%, while the projected percent of urban land use for 2030 is 44% (Table 3–26). This increase in impervious area is projected to have an associated increase in stormwater runoff, which is reflected in the HSPF hydrologic model results.

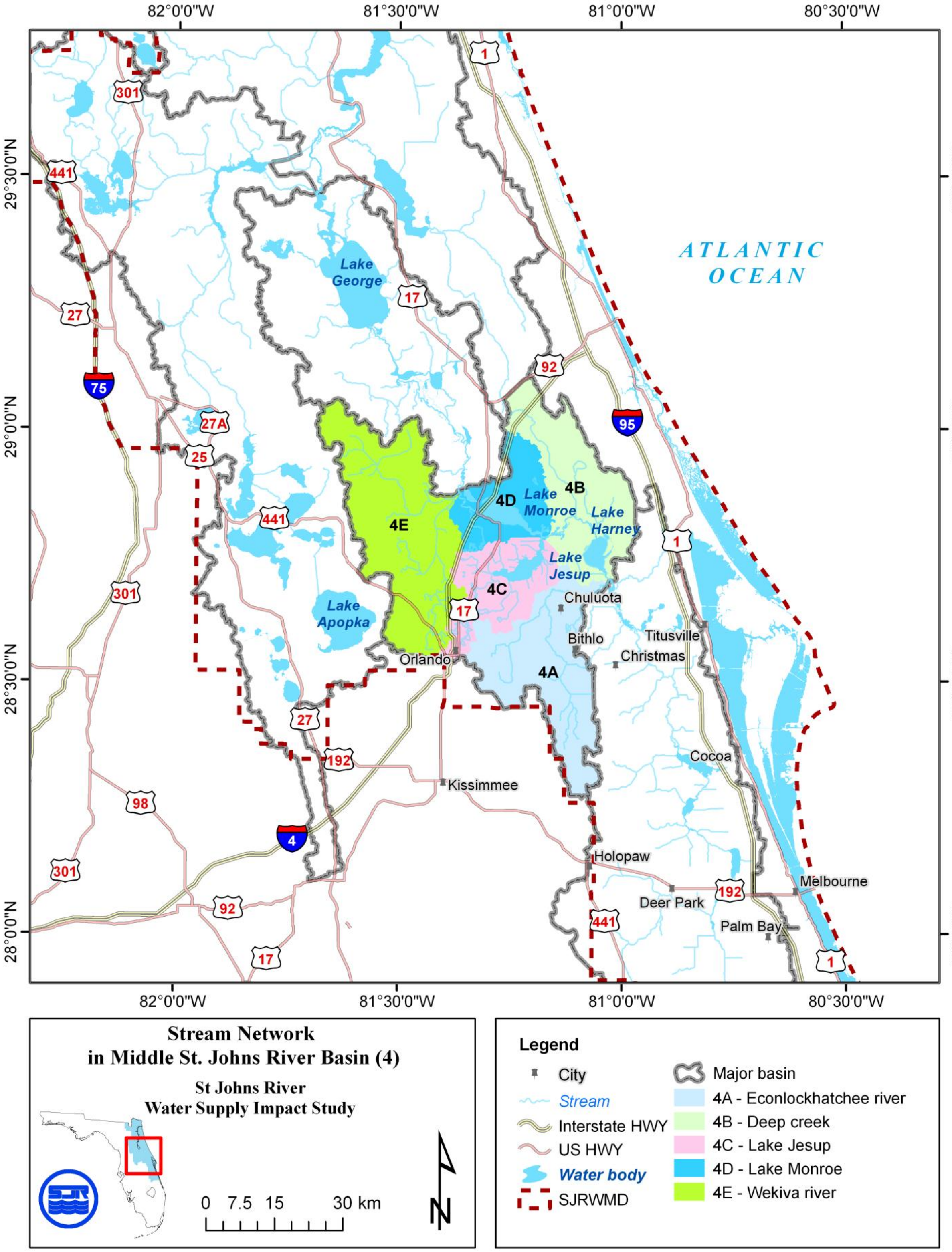

Figure 3–25. Stream network showing planning units 4A through 4E in the Middle St. Johns River Basin (4).

Table 3–25. Planning units in the Middle St. Johns River Basin (MSJRB) (4), excluding area that does not contribute to surface water runoff.

Planning Unit Number	Planning Unit Name	TP SJ97-1 Area (acres)*	Model Area (acres)
4A	Econlockhatchee River Planning Unit	173,143	174,189
4B	Deep Creek Planning Unit	175,454	150,436
4C	Lake Jesup Planning Unit	92,809	85,707
4D	Lake Monroe Planning Unit	88,938	51,209
4E	Wekiva River Planning Unit	240,722	191,574

Source: TP SJ97-1 (Adamus, Clapp and Brown 1997)

Table 3–26. Middle St. Johns River Basin (MSJRB) (4) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	43,415	6.15%	105,881	15.00%
Medium-density residential	71,301	10.10%	112,091	15.88%
High-density residential	23,112	3.27%	39,727	5.63%
Industrial and Commercial	34,333	4.86%	53,513	7.58%
Mining	1,091	0.15%	708	0.10%
Open and Barren Land	19,492	2.76%	9,610	1.36%
Pasture	41,808	5.92%	28,854	4.09%
Agriculture general	26,330	3.73%	16,938	2.40%
Agriculture tree crops	9,633	1.36%	4,221	0.60%
Rangeland	42,906	6.08%	27,468	3.89%
Forest	151,431	21.46%	105,268	14.92%
Water	55,722	7.90%	55,735	7.90%
Wetlands	185,168	26.24%	145,729	20.65%
Total	705,742	100.0%	705,742	100.0%

Econlockhatchee River Planning Unit (4A)

The Econlockhatchee River watershed is located within central Florida, including parts of Orange, Seminole, and Osceola counties. Local municipalities and residential areas in this planning unit include portions of Orlando, Oviedo, Winter Park, Casselberry, Bithlo, and Wedgefield. The total drainage area of the Econlockhatchee River watershed is approximately 272 mi^2. The 36-mi long Econlockhatchee River originates in the Econlockhatchee Swamp in northern Osceola County. It flows from south to north and then eastward into the St. Johns River just upstream of Lake Harney. The Little Econlockhatchee River, the largest tributary to the Econlockhatchee River, is about 15 mi long and has a drainage area of approximately 89 mi^2. Other major tributaries include Mills Creek, Silcox Branch, Mills Branch, Long Branch, Hart

Branch, Cowpen Branch, Green Branch, Turkey Creek, Little Creek, and Fourmile Creek. In addition, many water bodies, including Lake Pickett, Mills Lake, Lake Corrine, Lake Barton, and detention ponds exist within the watershed. They serve as storage facilities for stormwater runoff and provide significant benefits for the improvement of water quality.

The Econlockhatchee River is designated by the state of Florida as an Outstanding Florida Water. At a program level, an Outstanding Florida Water designation is applied to waters that are deemed worthy of a special protection because of their natural attributes.

The Econlockhatchee River watershed mostly overlies the Osceola Plain physiographic area. The Osceola Plain is generally flat and has many intermittent ponds, swamps, and mashes (Doolittle and Schellentrager 1989). Elevations (in North American Vertical Datum of 1988 [NAVD 88]) of the Econlockhatchee River watershed range from -1 ft to 127 ft above sea level with an average elevation of 64 ft. The headwater areas of Econlockhatchee River have an average elevation of approximately 69 ft. The elevation falls gradually to 0 ft at the confluence of the St. Johns River. Soils of the watershed are generally poorly drained and sandy throughout (Doolittle and Schellentrager 1989).

There is a mixture of land uses in the Econlockhatchee River watershed (Figure 3–26 and Table 3–27). Wetlands make up 25.9% of the watershed and are located mainly in the headwater areas and along the main stem of the Econlockhatchee River. Urban areas, including residential, industrial, and commercial uses, cover 23.8% of the watershed. Most of these urban areas are located in the Little Econlockhatchee River watershed. Urban development along the Econlockhatchee River has been increasing rapidly in the last two decades and is projected to double by 2030. Other major land uses in the watershed are pasture, rangeland, and forest.

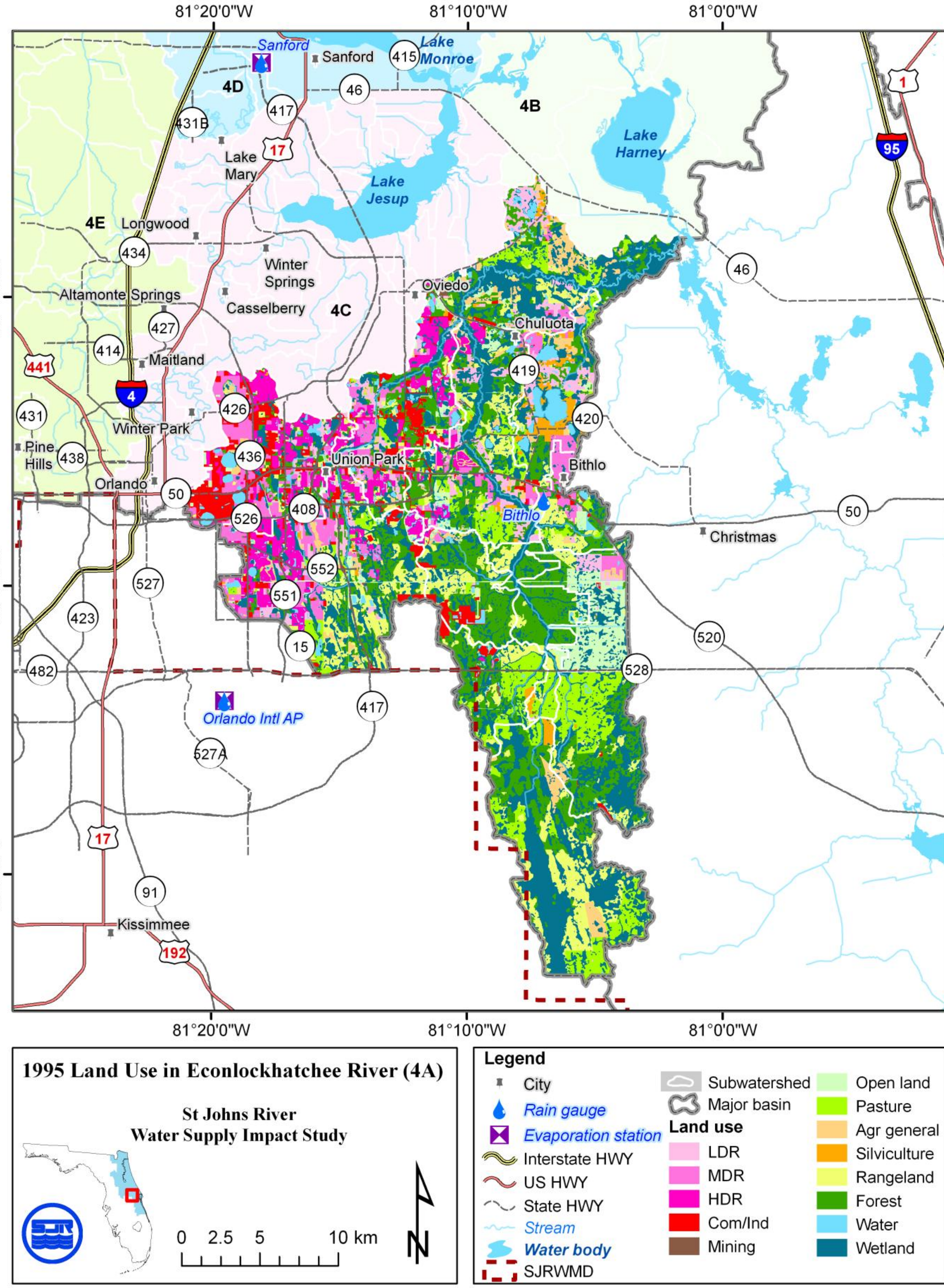

Figure 3–26. 1995 land use in Econlockhatchee River Planning Unit (4A).

Table 3–27. Econlockhatchee River Planning Unit (4A) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	8,252	4.7%	19,889	11.4%
Medium-density residential	11,449	6.6%	18,968	10.9%
High-density residential	11,407	6.5%	20,769	11.9%
Industrial and Commercial	10,424	6.0%	21,213	12.2%
Mining	294	0.2%	137	0.1%
Open and Barren Land	6,921	4.0%	1,779	1.0%
Pasture	14,736	8.5%	10,026	5.8%
Agriculture general	5,850	3.4%	2,571	1.5%
Agriculture tree crops	2,465	1.4%	761	0.4%
Rangeland	17,938	10.3%	9,872	5.7%
Forest	32,965	18.9%	16,717	9.6%
Water	6,459	3.7%	6,459	3.7%
Wetlands	45,051	25.9%	45,051	25.9%
Total	174,211	100.0%	174,211	100.0%

The Florida Department of Environmental Protection (FDEP) identified 35 permitted point source discharges in the Econlockhatchee River watershed ((Florida Department of Environmental Protection 2003)). Of these point sources, 21 are domestic wastewater treatment facilities, nine are industrial wastewater facilities, three are concrete batch plants, and one is a petroleum cleanup site. The three largest domestic wastewater treatment plants are explicitly modeled in HSPF: Orlando/Iron Bridge Regional Water Reclamation Facility, Orange County Utilities Division/Easterly Subregional Wastewater Treatment Plant, and Alafaya Utility Wastewater Treatment Facility. The flow data for these three point sources were obtained from FDEP. The other 18 point sources are permitted to discharge 0.1 mgd or less.

Deep Creek Planning Unit (4B)

The Deep Creek watershed includes portions of Volusia and Seminole counties. The total drainage area of the watershed is approximately 246 mi^2, about 12 mi^2 of which are in Lake Harney. Within the study area, the St. Johns River flows approximately 20 mi from its confluence with the Econlockhatchee River to the outlet of Lake Jesup. Lake Harney is a “run of the river” lake and is a part of St. Johns River’s main stem. Major tributaries in the watershed include Deep Creek, Deep Creek Diversion Canal, and Cow Creek. Lake Ashby is a major lake in the Deep Creek watershed and is located north of Lake Harney. Lake Ashby drains to the St. Johns River through Deep Creek.

The Deep Creek watershed mostly overlies the Osceola Plain and Eastern Valley physiographic areas. The Osceola Plain and Eastern Valley are generally flat areas and have many intermittent ponds, swamps, and mashes (Doolittle and Schellentrager 1989). Elevations of the Deep Creek watershed range from -1 ft to 98 ft above sea level, with an average elevation of 25 ft. Soils of the watershed are generally poorly drained and sandy throughout (Doolittle and Schellentrager 1989)

The majority of the 1995 land use in the Deep Creek watershed was undeveloped (Figure 3–27and Table 3–28). Wetlands and forest comprised 36.5% and 34.5% of the watershed, respectively. The watershed has experienced rapid urban development since 1995, mostly in the form of low density, large lot, single family home sites, which is projected to cover about a third of the watershed by 2030. Other major land uses in the Deep Creek watershed are pasture, rangeland, agriculture, and residential.

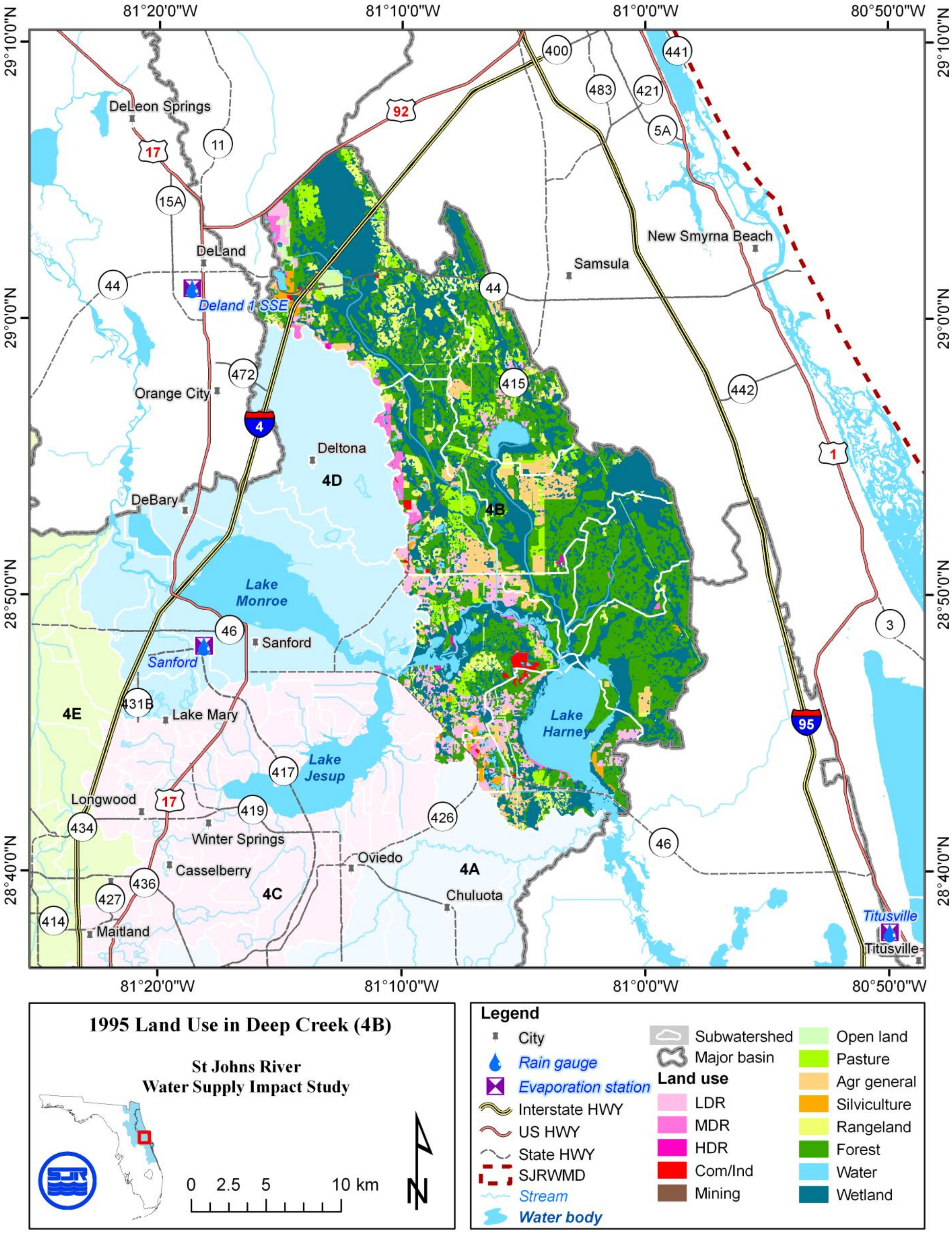

Figure 3–27. 1995 land use in Deep Creek Planning Unit (4B).

Table 3–28. Deep Creek Planning Unit (4B) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	9,612	6.4%	48,611	32.3%
Medium-density residential	1,941	1.3%	4,009	2.7%
High-density residential	148	0.1%	570	0.4%
Industrial and Commercial	1,029	0.7%	3,986	2.6%
Mining	135	0.1%	84	0.1%
Open and Barren Land	1,770	1.2%	455	0.3%
Pasture	6,727	4.5%	2,694	1.8%
Agriculture general	7,017	4.7%	3,010	2.0%
Agriculture tree crops	1,219	0.8%	316	0.2%
Rangeland	9,218	6.1%	2,565	1.7%
Forest	51,957	34.5%	24,473	16.3%
Water	4,704	3.1%	4,704	3.1%
Wetlands	54,963	36.5%	54,963	36.5%
Total	150,440	100.0%	150,440	100.0%

Lake Jesup Planning Unit (4C)

The Lake Jesup watershed is located in Seminole County and includes a small portion of Orange County. The total drainage area of the Lake Jesup watershed is approximately 152 mi^2, of which about 17 mi^2 is the water surface of Lake Jesup. Lake Jesup is connected to the St. Johns River through a narrow channel at the northern end of the lake. The watershed drains to Lake Jesup through three large tributaries—Howell Creek, Gee Creek, and Soldier Creek—and a number of smaller tributaries and canals (e.g., Sixmile Creek, Salt Creek, Sweetwater Creek, Navy Canal, Kentucky Canal, and Cameron Canal). In addition, many water bodies, including Lake Virginia, Lake Maitland, Lake Howell, and detention ponds exist within the watershed. They serve as storage facilities for stormwater runoff and provide significant benefits for the improvement of water quality.

Lake Jesup and its adjacent surrounding drainage areas overlie the Eastern Plain physiographic area, and the remaining areas of the watershed overlie the Osceola Plain physiographic area (Schellentrager and Hurt 1990). The Eastern Plain and the Osceola Plain are both broad and flat areas. Elevations of the study area range from -1 ft to 125 ft above sea level, with an average elevation of 45 ft. Soils of the watershed are generally sandy and well drained, with the exception of some large marsh areas adjacent to Lake Jesup (Schellentrager and Hurt 1990) (Keesecker 1992).

The Lake Jesup watershed is a highly urbanized watershed (Figure 3–28 and Table 3–29). Urban areas, including residential, industrial, and commercial uses, made up 49.7% of the watershed in 1995 and are expected to comprise over 60% of the watershed by 2030. Numerous lakes and wetlands cover 28.1% of the watershed. Open areas, pasture, rangeland, forest, and agriculture areas make up the other major land uses in the watershed.

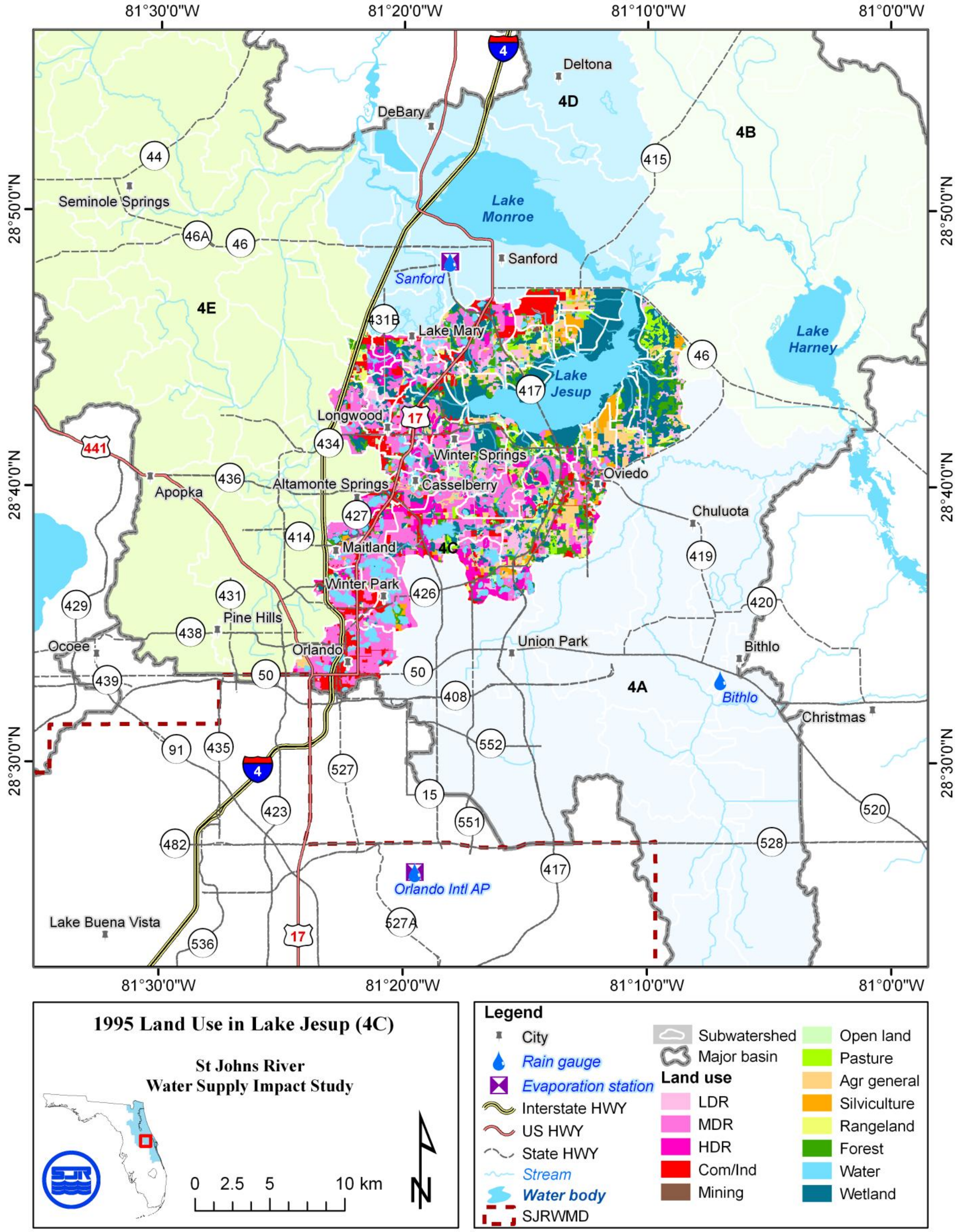

Figure 3–28. 1995 land use in Lake Jesup Planning Unit (4C).

Table 3–29. Lake Jesup Planning Unit (4C) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	7,103	7.9%	10,720	11.9%
Medium-density residential	20,558	22.9%	23,375	26.0%
High-density residential	5,841	6.5%	8,479	9.4%
Industrial and commercial	11,197	12.4%	13,394	14.9%
Mining	109	0.1%	65	0.1%
Open and barren land	2,262	2.5%	987	1.1%
Pasture	1,840	2.0%	1,052	1.2%
Agriculture general	4,417	4.9%	1,718	1.9%
Agriculture tree crops	2,266	2.5%	861	1.0%
Rangeland	2,184	2.4%	1,101	1.2%
Forest	6,817	7.6%	2,837	3.2%
Water	6,063	6.7%	6,063	6.7%
Wetlands	19,279	21.4%	19,279	21.4%
Total	89,936	100.0%	89,936	100.0%

Lake Monroe Planning Unit (4D)

The Lake Monroe watershed includes portions of Volusia and Seminole counties. The total drainage area of the Lake Monroe watershed is approximately 132 mi^2. Lake Monroe is a “run of the river” lake and is a part of St. Johns River main stem. Within the watershed, the St. Johns River flows approximately 17 mi from its confluence with Lake Jesup to its confluence with the Wekiva River. A major tributary in the Lake Monroe watershed is the Lockhart Smith Canal. In addition, numerous water bodies, including Big Lake, Little Lake, Lake Gleason, and detention ponds exist within the study area. They serve as storage facilities for stormwater runoff and provide significant benefits for the improvement of water quality.

The Lake Monroe watershed mostly overlies the Osceola Plain and Eastern Valley physiographic areas. The Osceola Plain and the Eastern Valley are generally flat areas and have many intermittent ponds, swamps, and mashes (Doolittle and Schellentrager 1989). Elevations of the Lake Monroe watershed range from -1 ft to 114 ft above sea level, with an average elevation of 31 ft. Soils of the watershed are generally sandy and well drained, with the exception of some large marsh areas adjacent to Lake Monroe (Doolittle and Schellentrager 1989).

The Lake Monroe watershed is highly developed (Figure 3–29 and Table 3–30). Urban areas, including residential, industrial, and commercial uses, made up approximately 39.4% of the watershed in 1995 and are expected to comprise over 50% of the watershed in 2030. Wetlands make up 20.6% of the watershed and are located mainly in the east and west shores of Lake Monroe. Open water, forest, rangeland, pasture, and agriculture areas make up the other major land uses in the Lake Monroe watershed.

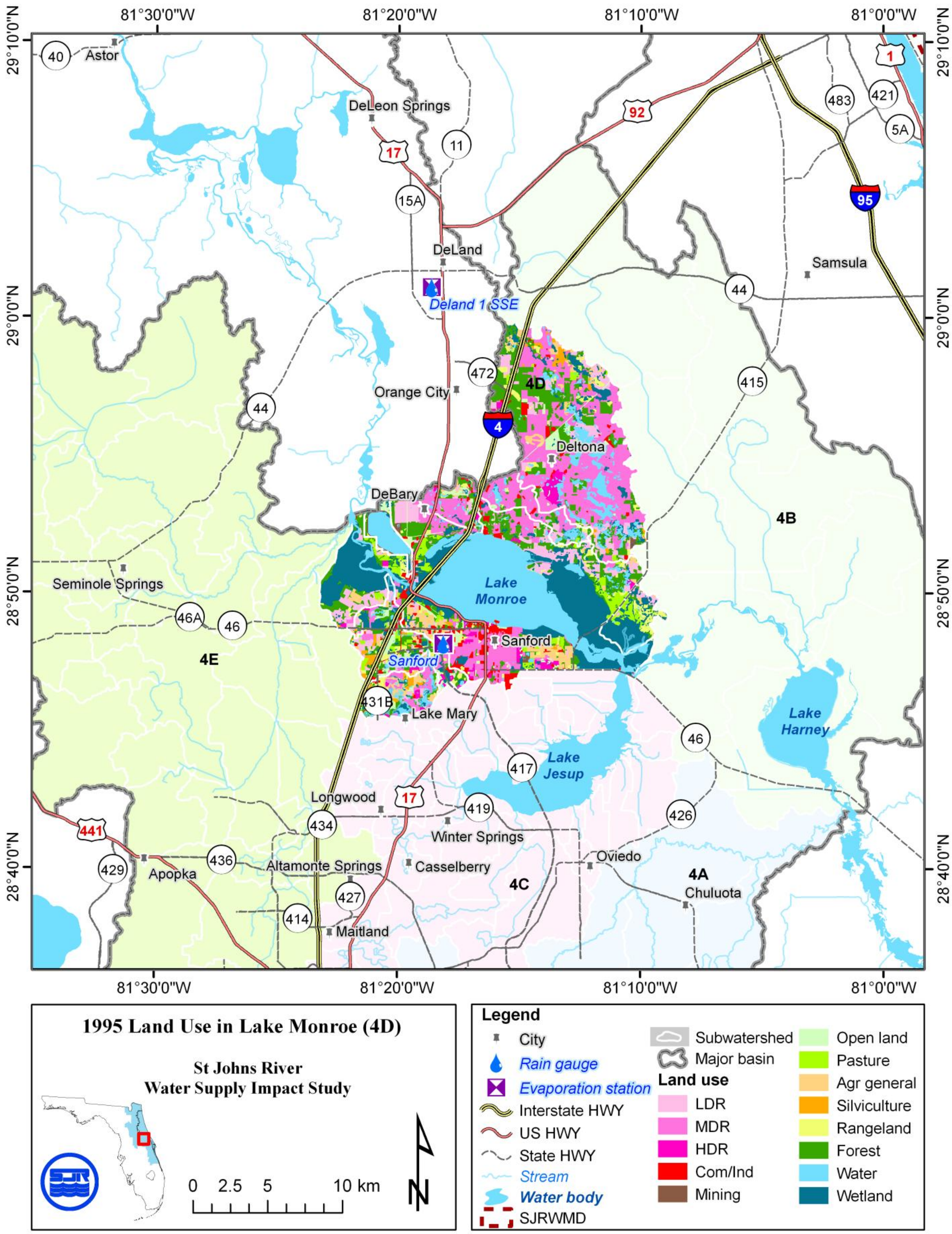

Figure 3–29. 1995 land use in Lake Monroe Planning Unit (4D).

Table 3–30. Lake Monroe Planning Unit (4D) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	6,728	8.9%	10,704	14.2%
Medium-density residential	17,953	23.8%	20,965	27.8%
High-density residential	1,490	2.0%	3,371	4.5%
Industrial and commercial	3,521	4.7%	5,192	6.9%
Mining	330	0.4%	197	0.3%
Open and barren land	2,041	2.7%	1,213	1.6%
Pasture	2,466	3.3%	1,664	2.2%
Agriculture general	3,238	4.3%	1,798	2.4%
Agriculture tree crops	986	1.3%	549	0.7%
Rangeland	2,772	3.7%	1,712	2.3%
Forest	12,240	16.2%	6,400	8.5%
Water	6,052	8.0%	6,052	8.0%
Wetlands	15,527	20.6%	15,527	20.6%
Total	75,344	100.0%	75,344	100.0%

Wekiva River Planning Unit (4E)

The Wekiva River planning unit is located within portions of Orange, Seminole, Lake, and Marion counties. Local municipalities and urbanized areas within this unit include Lake Mary, Apopka, Altamonte Springs, Maitland, Eatonville, Winter Park, Orlando, Orlovista, and Mount Plymouth. Much of the hydraulic and hydrologic character of the Wekiva River was previously compiled in the draft report Surface Water Modeling and Environmental Validation Study: Wekiva River System Minimum Flows and Levels (Clapp, Robison and Hupalo 1999).

The Wekiva River planning unit has 376 mi^2 of watershed with three major watercourses: the Wekiva River, the Little Wekiva River, and Black Water Creek. Approximately 76.7 mi^2 along the watershed's western edge is landlocked and does not have a surface water connection with the Wekiva River (noncontributing area). The Black Water Creek drains 164.8 mi^2 of the northern portion of the watershed. The Little Wekiva River drains 55.9 mi^2 of the southeast portion of the watershed. The Wekiva River drains 78.6 mi^2 of the central portion of the watershed, not including the Little Wekiva drainage.

The Wekiva River contains both spring-fed and black water streams. Black water streams receive most of their flow from precipitation, while the spring-fed steams are perennial watercourses supplied from the Floridan aquifer (Table 3-32). Rock Spring Run, Sulphur Run, Seminole Creek, the Wekiva River, the Little Wekiva River, and the lower reaches of Black Water Creek are sustained by significant spring flow.

Upstream of the confluence of the spring-fed Seminole Creek, the base flow of Black Water Creek is maintained by groundwater seepage. Lake Dorr in the Ocala National Forest forms the headwaters of Black Water Creek. Black Water Creek is the longest stream in the Wekiva River system, falling 1.9 ft mi-1 over its 16-mile run. It has an expansive floodplain and a braided channel downstream of its confluence with Seminole Creek.

The Wekiva River forms at the confluence of Wekiva Springs Run and Rock Springs Run and continues for approximately 14.2 mi before entering the St. Johns River. The inflow from springs is very significant in this subwatershed. The soil characteristics are very sandy with a large portion occurring in an area of high aquifer recharge.

The Little Wekiva River watershed is approximately 15% of the Wekiva River planning unit. Major lakes in this planning unit include Lawne Lake, Lake Orlando, Lake Fairview, Bear Lake, Lake Lotus, and Spring Lake.

The Wekiva and Little Wekiva Rivers downstream of SR 434 have been designated Outstanding Florida Waters by the state. The Wekiva River has also been designated by the federal government as a National Wild and Scenic River and by the state as a Scenic and Wild River. In 1988, the Florida Legislature passed the Wekiva River Protection Act, which provides controls to deter wetland losses and authorizes local governments to create rules to protect habitat and treat runoff. The Wekiva River has special basin criteria for environmental resource permits that are regulated by SJRWMD.

Almost half of the Wekiva River planning unit is protected through public ownership. The Wekiva Basin GEOpark, Seminole State Forest, Ocala National Forest, state reserves, and the Wekiva-Ocala Greenway Conservation and Recreation Lands (CARL) project are examples of these publicly owned lands. The southern end of the subwatershed is part of a highly urbanized area northwest of downtown Orlando (Figure 3–30 and Table 3–31). Upland forests with some agricultural use predominant along the northern reaches of the Wekiva River. Residential uses are expected to more than double in the area by 2030.

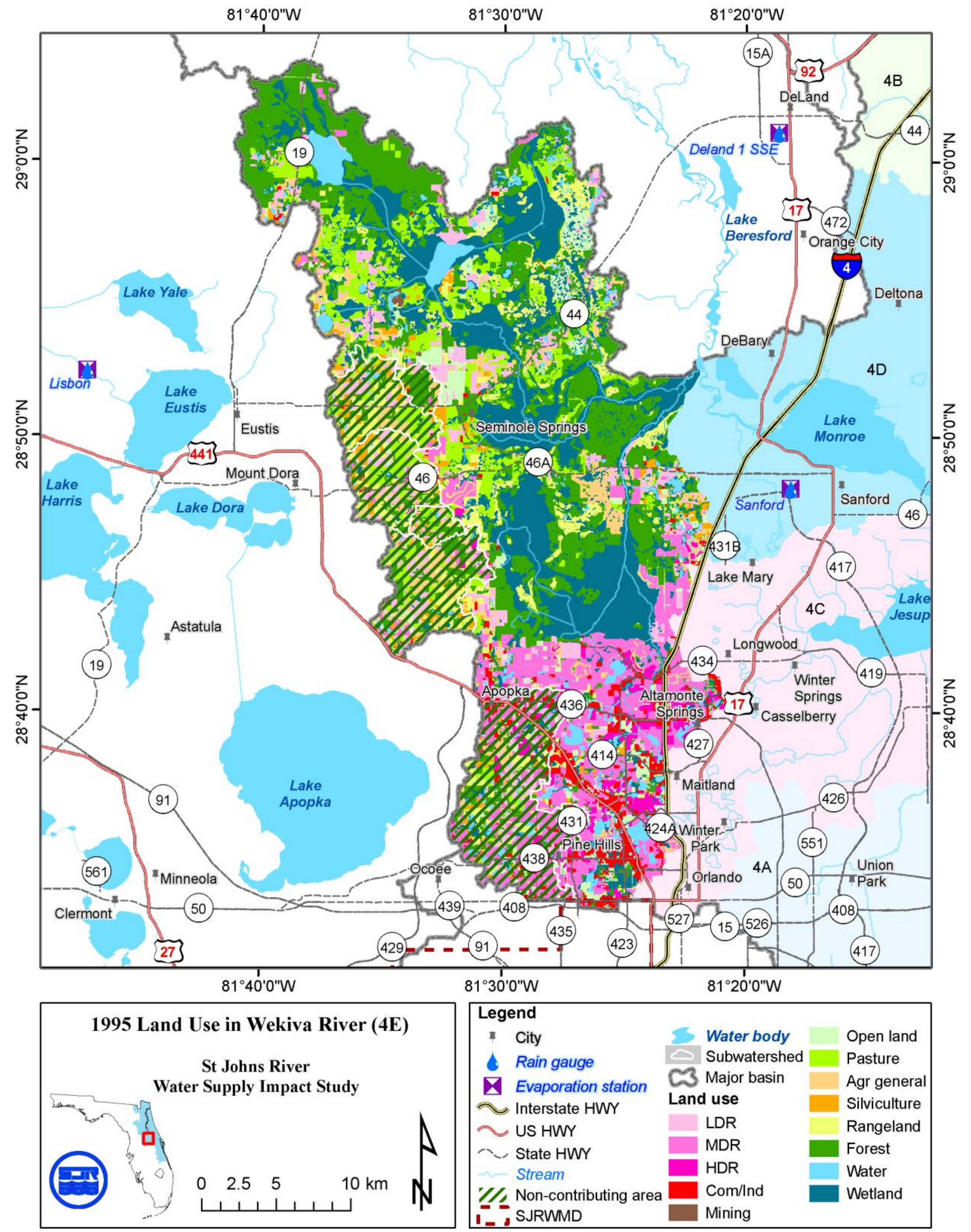

Figure 3–30. 1995 land use in Wekiva River Planning Unit (4E).

Table 3–31. Wekiva River Planning Unit (4E) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	18,989	7.7%	25,176	10.3%
Medium-density residential	28,582	11.6%	61,793	25.2%
High-density residential	5,944	2.4%	11,133	4.5%
Industrial and commercial	12,228	5.0%	15,772	6.4%
Mining	556	0.2%	409	0.2%
Open and barren land	8,088	3.3%	3,439	1.4%
Pasture	21,340	8.7%	11,849	4.8%
Agriculture general	10,327	4.2%	6,503	2.6%
Agriculture tree crops	6,041	2.5%	1,677	0.7%
Rangeland	17,301	7.0%	8,933	3.6%
Forest	54,524	22.2%	37,216	15.2%
Water	10,567	4.3%	10,566	4.3%
Wetlands	51,065	20.8%	51,065	20.8%
Total	245,552	100.0%	245,552	100.0%

Table 3–32. Spring flow in the Wekiva River Basin.

Spring Name	River System	Record	Measurement interval	Average Flow (mgd)
Messant Spring	Black Water Creek	Apr 1972 to Jul 1995	annual	9.3
Seminole Spring	Black Water Creek	Mar 1932 to Oct 1991	annual to decade	23.6
Rock Spring	Wekiva River	Feb 1931 to current	daily to quarterly	36.8
Wekiva Spring	Wekiva River	Feb 1931 to current	daily to quarterly	42.5
Miami Spring	Wekiva River	Aug 1945 to current	daily to quarterly	3.2
Additional minor springs	Wekiva River	—	one to few	15.0
Palm Spring	Little Wekiva River	Nov 1941 to current	quarterly to decade	4.0
Sanlando Spring	Little Wekiva River	Nov 1941 to current	quarterly to decade	12.3
Starbuck Spring	Little Wekiva River	Jul 1945 to current	quarterly to decade	8.8

4.1.3 LAKE GEORGE BASIN (5)

The Lake George Basin is located in northeast Florida in the heart of the St. Johns River watershed (Figure 3–31). The area of the basin is 0.5 million ac (782 mi^2) and represents approximately 6.2% of SJRWMD. The Lake George Basin includes parts of Volusia, Marion, Lake, and Putnam counties. The major springs in the basin are Alexander Springs, Silver Glen Springs, Blue Springs, and Salt Springs. There are numerous large and small lakes in the basin, including Lake Delancy, Lake Margaret, Lake Louise, Lake Dexter, Lake Kerr, and Lake Woodruff.

The St. Johns River meanders about 50 mi through the basin, entering from the south and leaving the north side of the basin after passing through Lake George. The portion of the St. Johns River located in the Lake George Basin is influenced by tides with the tidal effect greater in the northern (downstream) section. Many large and small tributaries discharge into the St. Johns River as the river flows through the basin.

Due to the flatness of the riverbed, the Lake George portion of the St. Johns River is surrounded by marshlands and swamps. Most of the tributaries in the Lake George major basin discharge their water into these riverine swamps. The river is relatively narrow in the south and widens to the north after passing through Lake George. There are many lakes in the Lake George Basin, which range from less than 1 ac to about 50,000 ac. Lake George is the largest lake in the basin and the second largest lake in Florida with an area of 73 mi^2. The lake is shallow (3–12 ft deep) and is a river flow and tidal lake.

The Lake George Basin consists of 37 landlocked and surface water contributing subwatersheds. These subwatersheds discharge their surface runoff via streambeds and/or sheet flows into the St. Johns River, Lake George, and/or the basin's lakes. Some of the subwatersheds are landlocked basins, with seepage being the only conveyance to downstream surface waters. These basins are not modeled with the HSPF hydrologic model.

The Lake George Basin encompasses four major planning units: the watershed surrounding Lake George itself, Alexander Creek, the wide river floodplain around Lake Woodruff, and the Ocala National Forest ridge west of Lake George (Figure 3–34 and Figure 3–34). For the HSPF hydrologic modeling, the basin was divided into three regions. Because much of the Ocala National Forest is a noncontributing subsurface area, Alexander Creek was used in the calibration process.

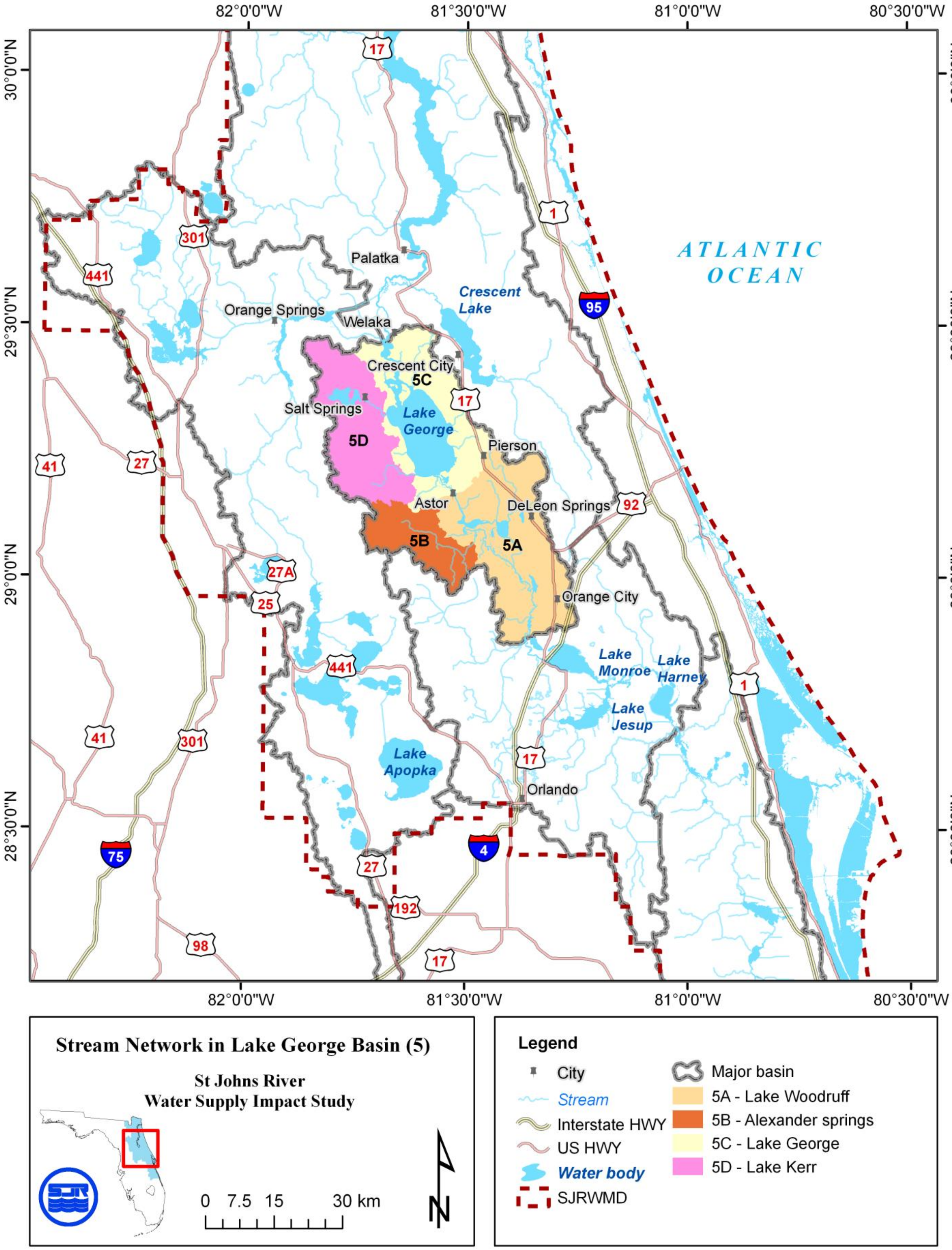

Figure 3–31. Stream network showing planning units 5A through 5D in the Lake George basin (5).

Table 3–33. Planning units in the Lake George Basin (5).

Planning Unit Number	Planning Unit Name	SJ97-1 Area (acres)	Model Area (acres)
5A	Lake Woodruff Planning Unit	176,898	148,144
5B	Alexander Creek Planning Unit	63,953	42,757
5C	Lake George Planning Unit	161,249	136,799
5D	Lake Kerr Planning Unit	120,498	not modeled

West of Lake George and the river is the Ocala National Forest, where the dominant land uses are forest and wetland and development is minimal. East of the lake and the river is mostly private land that has scattered development and more varied land uses, but the dominant land uses remain forest and wetland.

The topography within the majority of the Lake George Basin is generally flat. The middle of the basin consists of wetlands and marsh areas. Moving east and west from the river, elevations increase, and ridges and terraces are apparent. Due to the flatness of the basin, there are numerous lakes, depressions, and swamps throughout the region. In the western portion of the Lake George Basin, many ridges have formed parallel to the ocean shoreline that are the remnants of dunes formed in the previous interglacial period. Surface elevations in the basin range from 150 ft at Riverside Island to 3 ft at the Norwalk marshland.

The upland areas west of the river are sand hills comprised of mostly A soils, while B soils are prevalent in the uplands east of the river. The vast river marshes in the Lake Woodruff and Hontoon Island areas are comprised of B soils, while wetland areas in the rest of the basin are mostly D soils. In low-lying areas of flatwoods and floodplains, the soil contains higher organic matter, its hydraulic conductivity is lower, and the water table is shallow. These areas are associated with marshlands and swampy areas near water bodies. In the poorly to moderately drained upland and wooded areas, the soil is sandy from 20 in. to more than 40 in. deep. The water table fluctuates throughout the year, usually on a seasonal basis, and may exceed the ground surface in low-lying areas. In well-drained uplands, the soil is sandy to a depth of about 40 in. In the excessively drained uplands, the soil is mainly sandy to a depth of 80 in. or more. These soil characteristics lead to significant subsurface flow that bypasses tributaries and intercepts the main stem of the river.

The groundwater contribution to the surface water system in the Lake George Basin is abundant and is derived from three distinct aquifers: the surficial aquifer, intermediate aquifer, and the Floridan aquifer. The surficial aquifer is composed of interbedded sand, shell, and clay sediments. Depending on the presence and the amount of the clay in the profile, the surficial aquifer can form a good water bearing strata. The thickness of the surficial aquifer varies in the basin, ranging from 25 ft to 80 ft. In Volusia County, the surficial aquifer is composed of sand, shell, clay, and limestone. Water supply potential in this aquifer is limited, but in the areas where the Floridan aquifer contains marginal quality water, this water could be used for agriculture and municipal purposes. In the Lake George Basin, the intermediate aquifer is located 40 to 90 ft below the ground surface. The Floridan aquifer is a discharge aquifer for a portion of this basin and contributes significantly to subsurface flows via tributary springs and to the river itself.

Springs are the interception points of the groundwater with land surface. There are many small and large springs throughout the Lake George Basin. Most often, these springs drain into Lake George or directly into the river. Three of the four first magnitude springs found in SJRWMD are in the Lake George Basin: Blue Springs, Alexander Springs, and Silver Glen Springs. All of these springs average over 64 mgd (100 cfs) of discharge.

For the Alexander Creek (5B) planning unit, the spring flow for Alexander Creek was added into the model to aid calibration. This flow was subtracted from the time-series passed to the EFDC hydrodynamic model, as that model independently includes spring flows. Thus, the time-series provided by the HSPF hydrologic model was reduced to include only surface runoff. This was not a factor in the Lake George (5C) or Lake Woodruff (5A) planning units, as spring flows were not included in the HSPF hydrologic model.

Land use in the Lake George Basin is dominated by the Ocala National Forest and other public lands and is approximately 90% undeveloped (Table 3–34. Although residential use is expected to double by 2030, it will still comprise less than 15% of the watershed.

Table 3–34. Lake George Basin (5) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	21,381	4.6%	42,849	9.2%
Medium-density residential	13,859	3.0%	24,453	5.3%
High-density residential	1,035	0.2%	1,747	0.4%
Industrial and commercial	3,709	0.8%	6,973	1.5%
Mining	541	0.1%	437	0.1%
Open and barren land	5,202	1.1%	3,493	0.8%
Pasture	11,737	2.5%	7,503	1.6%
Agriculture general	11,986	2.6%	7,604	1.6%
Agriculture tree crops	2,937	0.6%	1,423	0.3%
Rangeland	8,984	1.9%	6,202	1.3%
Forest	253,285	54.5%	231,241	49.9%
Water	14,649	3.2%	14,650	3.2%
Wetlands	115,085	24.8%	115,084	24.8%
Total	464,390	100.0%	464,390	100.0%

Lake Woodruff Planning Unit (5A)

The Lake Woodruff planning unit is a unique area in the St. Johns River Basin (Figure 3–32). The river flows through an extensive marsh system with several small lakes and channels. The 5-ft (NGVD29) contour line divides the marsh floodplain from the uplands in this area. To represent surface runoff into the river system, these marshes were delineated as their own subwatersheds using the 5-ft (NGVD29) contour line as a boundary with the uplands. In total, five of these subwatersheds were created to represent the floodplain in the Lake Woodruff planning unit. The large basin east of Blue Springs was not modeled, as it is a noncontributing basin. In the Lake Woodruff planning unit the spring flows were not included in the HSPF hydrologic model because spring flows are accounted for separately in the EFDC hydrodynamic model.

The Lake Woodruff and Alexander Creek planning units are generally similar in soil type, have the same overall land use, and use the same rainfall and potential evaporation station. Four of the subwatersheds in the northeast portion of the Lake Woodruff planning unit used parameters from the adjacent Crescent Lake parameter set.

Land use in the Lake Woodruff planning unit is dominated by wetlands and forest. Residential land use is expected to shift from 14.1% to almost 30% between 1995 and projected 2030 population (Table 3–35).

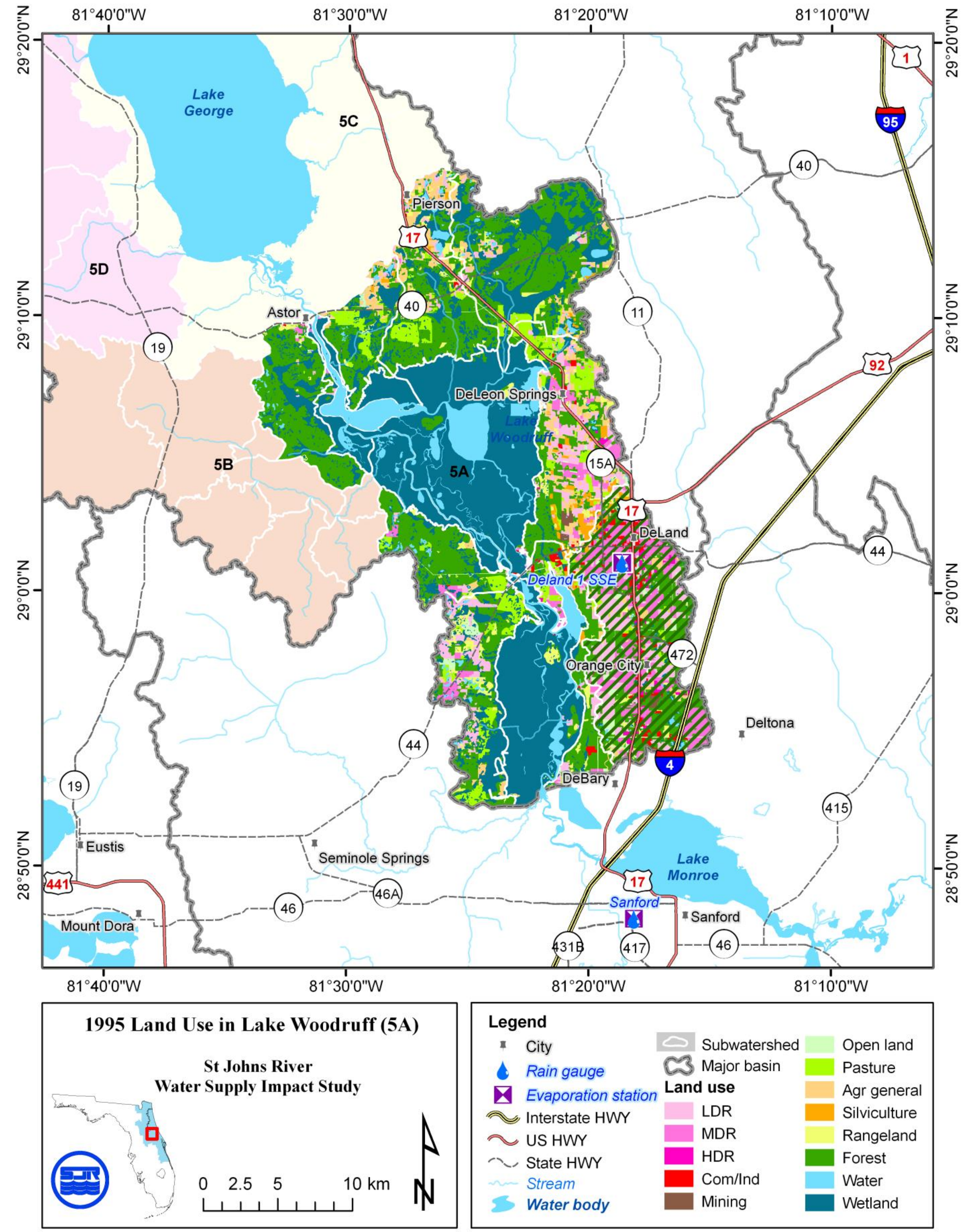

Figure 3–32. 1995 land use in Lake Woodruff Planning Unit (5A).

Table 3–35. Lake Woodruff Planning Unit (5A) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	12,160	7.2%	24,991	14.8%
Medium-density residential	10,695	6.3%	18,689	11.1%
High-density residential	948	0.6%	1,451	0.9%
Industrial and commercial	3,134	1.9%	5,017	3.0%
Mining	367	0.2%	268	0.2%
Open and barren land	2,204	1.3%	1,073	0.6%
Pasture	7,829	4.6%	4,458	2.6%
Agriculture general	7,104	4.2%	4,271	2.5%
Agriculture tree crops	2,085	1.2%	763	0.5%
Rangeland	4,494	2.7%	2,772	1.6%
Forest	52,463	31.0%	39,199	23.2%
Water	3,981	2.4%	3,982	2.4%
Wetlands	61,889	36.5%	61,889	36.7%
Total	169,353	100.0%	169,353	100.0%

Alexander Creek Planning Unit (5B)

The Alexander Creek planning unit (Figure 3–33) was used to calibrate the HSPF hydrologic model for the Lake George Basin. There are two gauges on the creek, one at County Road (CR) 445 and another just upstream of the Tracy Canal inflow. These are the only flow gauges present in the Lake George Major Basin.

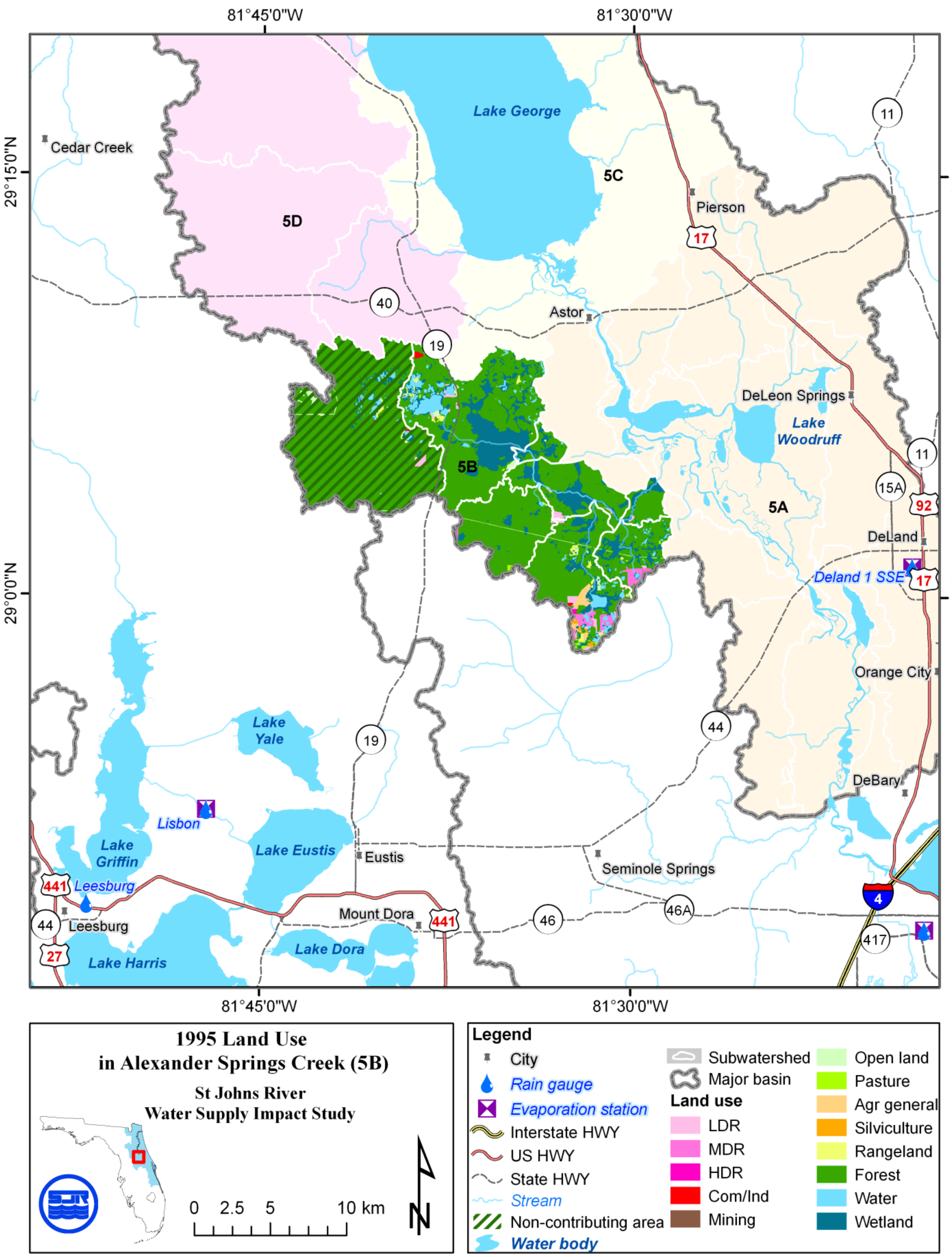

Figure 3–33. 1995 land use in Alexander Creek Planning Unit (5B).

The Alexander Creek planning unit is divided in seven subwatersheds. Alexander Creek itself is separated into upper, middle, and lower sections, with the flow gauges mentioned above marking the subwatershed divisions. Upstream of CR 445, several small tributaries are combined into a single watershed. The inlets from these tributaries into Alexander Creek are interconnected wetlands that are not individually well defined. The largest of the combined tributaries, Nine Mile Creek, has a large portion of watershed that was determined to be noncontributing through a field visit. Approximately 20,000 ac were removed from the planning unit as noncontributing to surface runoff.

Spring flow from Alexander Springs was used as a surrogate measure for flows in the adjacent tributaries to Lake Woodruff. The flow data was added to the HSPF hydrologic model to calibrate to the gauges and subtracted from the overall flow passed on to the EFDC hydrodynamic model, because spring flows are already accounted for in the EFDC hydrodynamic model. The spring flow was estimated based on monthly flows during the simulation period.

The Alexander Spring basin is over three-quarters forest. The basin is located almost entirely within the Ocala National Forest and consequently has very little residential development (Table 3–36).

Table 3–36. Alexander Springs Planning Unit (5B) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	649	1.0%	1,081	1.7%
Medium-density residential	743	1.2%	1,394	2.2%
High-density residential	28	0.0%	53	0.1%
Industrial and commercial	117	0.2%	157	0.2%
Mining	0	0.0%	0	0.0%
Open and barren land	528	0.8%	525	0.8%
Pasture	189	0.3%	102	0.2%
Agriculture general	373	0.6%	103	0.2%
Agriculture tree crops	75	0.1%	57	0.1%
Rangeland	483	0.8%	425	0.7%
Forest	49,614	78.2%	48,903	77.1%
Water	2,305	3.6%	2,305	3.6%
Wetlands	8,315	13.1%	8,315	13.1%
Total	63,419	100.0%	63,419	100.0%

Lake George Planning Unit (5C)

The Lake George planning unit is characterized by a number of small spring-fed tributaries and wetlands (Figure 3–34). The subwatersheds of the Lake George planning unit are aggregated or split to match the requirement for input into the EFDC hydrodynamic model. Thus, the subwatersheds do not always follow a specific stream or tributary and some small reaches have been combined into a single system.

The Alexander Creek upstream gauge parameters were applied to the Juniper Springs, Salt Springs Run, and West Bank Lake George subwatersheds. These areas were similar to the upstream basins of Alexander Creek with significant areas of upland sand hill with A soils prevalent and very little B and C soils. The Alexander Creek downstream gauge parameters were applied to the Blue Creek and Lake Laura Outlet subwatersheds. These subwatersheds were more diversified in their soil composition and had significant wetlands. The remaining subwatersheds were unlike Alexander Creek; thus, parameters calibrated in the adjacent Crescent Lake basin were applied to the remaining subwatersheds.

As with other watersheds in the Lake George Basin, there is relatively little residential development in the Lake George planning unit (Table 3–34). The basin is more than two-thirds forest and wetlands.

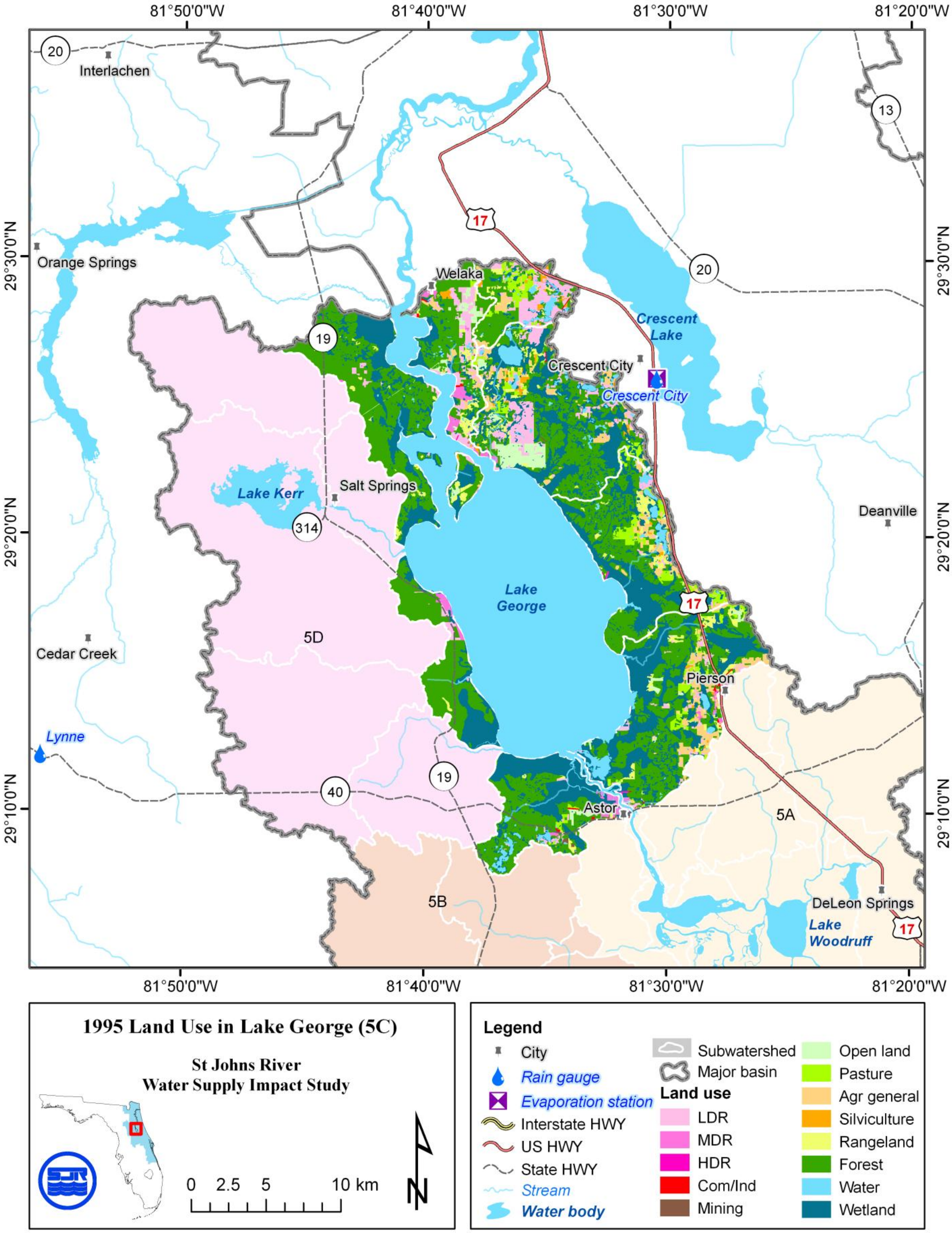

Figure 3–34. 1995 land use in Lake George Planning Unit (5C).

Table 3–37. Lake George Planning Unit (5C) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	7,393	6.6%	15,242	13.7%
Medium-density residential	1,549	1.4%	3,464	3.1%
High-density residential	59	0.1%	196	0.2%
Industrial and commercial	379	0.3%	1,687	1.5%
Mining	131	0.1%	128	0.1%
Open and barren land	2,340	2.1%	1,765	1.6%
Pasture	3,630	3.3%	2,888	2.6%
Agriculture general	4,491	4.0%	3,211	2.9%
Agriculture tree crops	730	0.7%	556	0.5%
Rangeland	3,431	3.1%	2,440	2.2%
Forest	49,270	44.3%	41,629	37.5%
Water	3,875	3.5%	3,875	3.5%
Wetlands	33,919	30.5%	33,919	30.6%
Total	111,197	100.0%	111,197	100.0%

Lake Kerr Planning Unit (5D)

Only two tributaries of Lake George within the Lake Kerr planning unit were modeled because the majority of the area is a noncontributing watershed (Figure 3–35. The contributing area to two major spring runs in the unit, Salt Springs and Juniper Springs, were modeled to establish surface runoff estimates for the EFDC hydrodynamic model, as they directly contribute to Lake George. The Juniper Springs subwatershed is further divided into contributing and noncontributing portions that were determined from site visits and analysis of topography, wetlands, and recharge areas. Approximately 30,000 ac were separated as noncontributing. As with other springs, the flows supplied to the EFDC hydrodynamic model are surface flows only and the EFDC hydrodynamic model include spring contribution separately.

There is minimal developed land use in the Lake Kerr basin and little change is projected because the majority of the basin is contained within the Ocala National Forest (Table 3–38). The basin is nearly 85% forest and 9% wetlands.

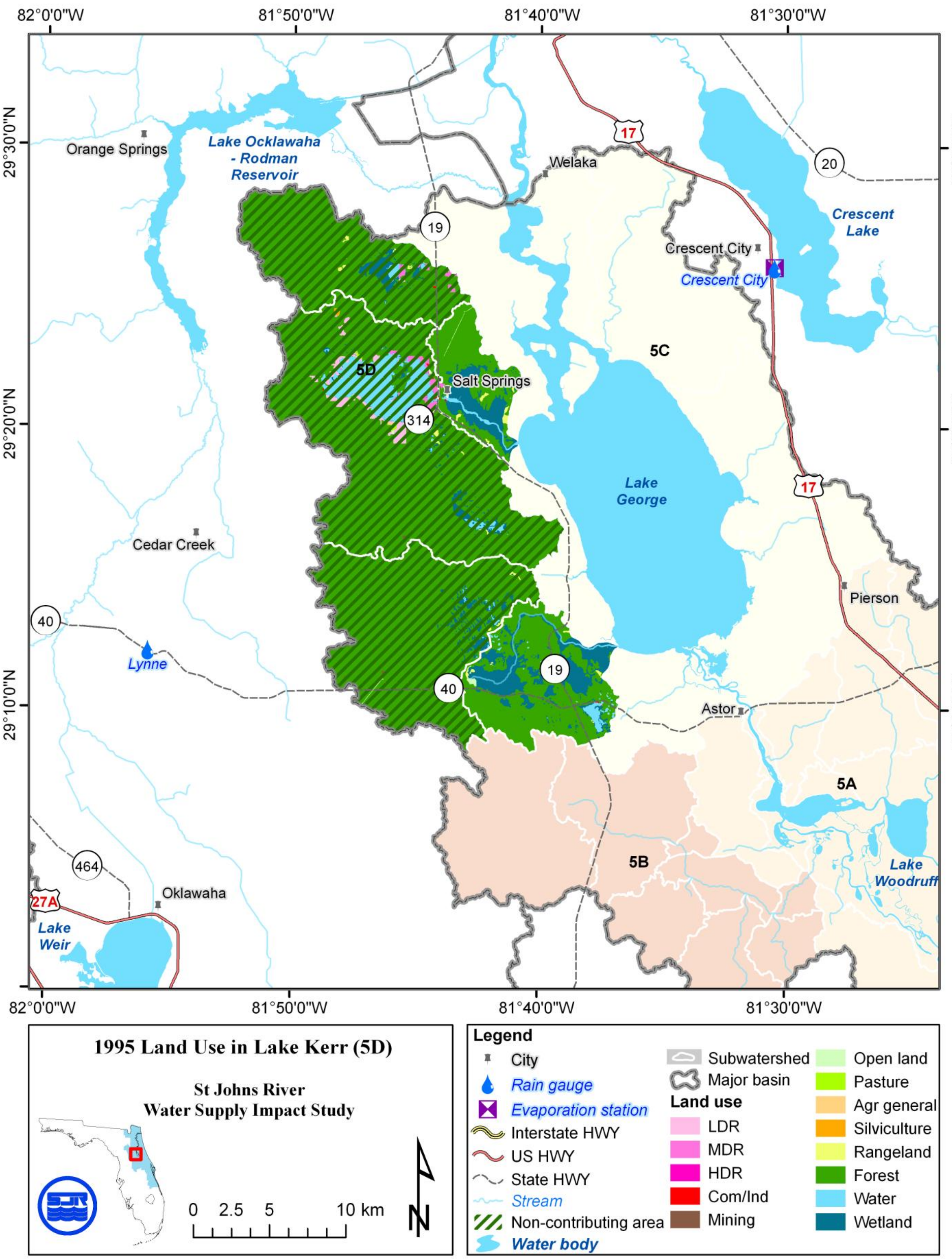

Figure 3–35. 1995 land use in Lake Kerr Planning Unit (5D).

Table 3–38. Lake Kerr Planning Unit (5D) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	1,179	1.0%	1,535	1.3%
Medium-density residential	872	0.7%	906	0.8%
High-density residential	0	0.0%	48	0.0%
Industrial and commercial	79	0.1%	112	0.1%
Mining	42	0.0%	42	0.0%
Open and barren land	130	0.1%	130	0.1%
Pasture	89	0.1%	56	0.0%
Agriculture general	19	0.0%	19	0.0%
Agriculture tree crops	47	0.0%	47	0.0%
Rangeland	576	0.5%	566	0.5%
Forest	101,938	84.7%	101,510	84.3%
Water	4,488	3.7%	4,488	3.7%
Wetlands	10,961	9.1%	10,961	9.1%
Total	120,420	100.0%	120,420	100.0%

4.1.4 OCKLAWAHA RIVER BASIN (7)

The Ocklawaha River basin is located in central Florida along the western edge of the St. Johns River watershed (Figure 3–36). It comprises about 2,116 mi^2 of watershed area draining into the Rodman Reservoir that then drains into the St. Johns River upstream of Palatka. The preexisting modeling in the Ocklawaha River basin had been accomplished in three sections for different purposes. Models were constructed in the upper Ocklawaha River Basin (UORB), lower Ocklawaha River Basin (LORB), and the upper portion of the Orange Creek Planning Unit (OC). The connection between the upper portion of Orange Creek and the LORB was developed as a new model. The UORB consists of planning units 7A through 7D. The LORB is represented by planning units 7E and 7F. The Orange Creek planning unit 7G, completes the Ocklawaha River basin (Table 3–40).

Flow in the UORB originates from the Green Swamp–Palatlakaha River and Lake Apopka. Virtually all of the surface water flow is regulated by water control structures. These structures have dampened the natural periodic fluctuations in lake stages and stream discharges. As a result, the lakes function hydrologically as managed reservoirs rather than natural water bodies.

In 1995, all urban land uses comprised 12.7% of the watershed while the projected 2030 urban land use increases to 29.4% (Table 3–40).

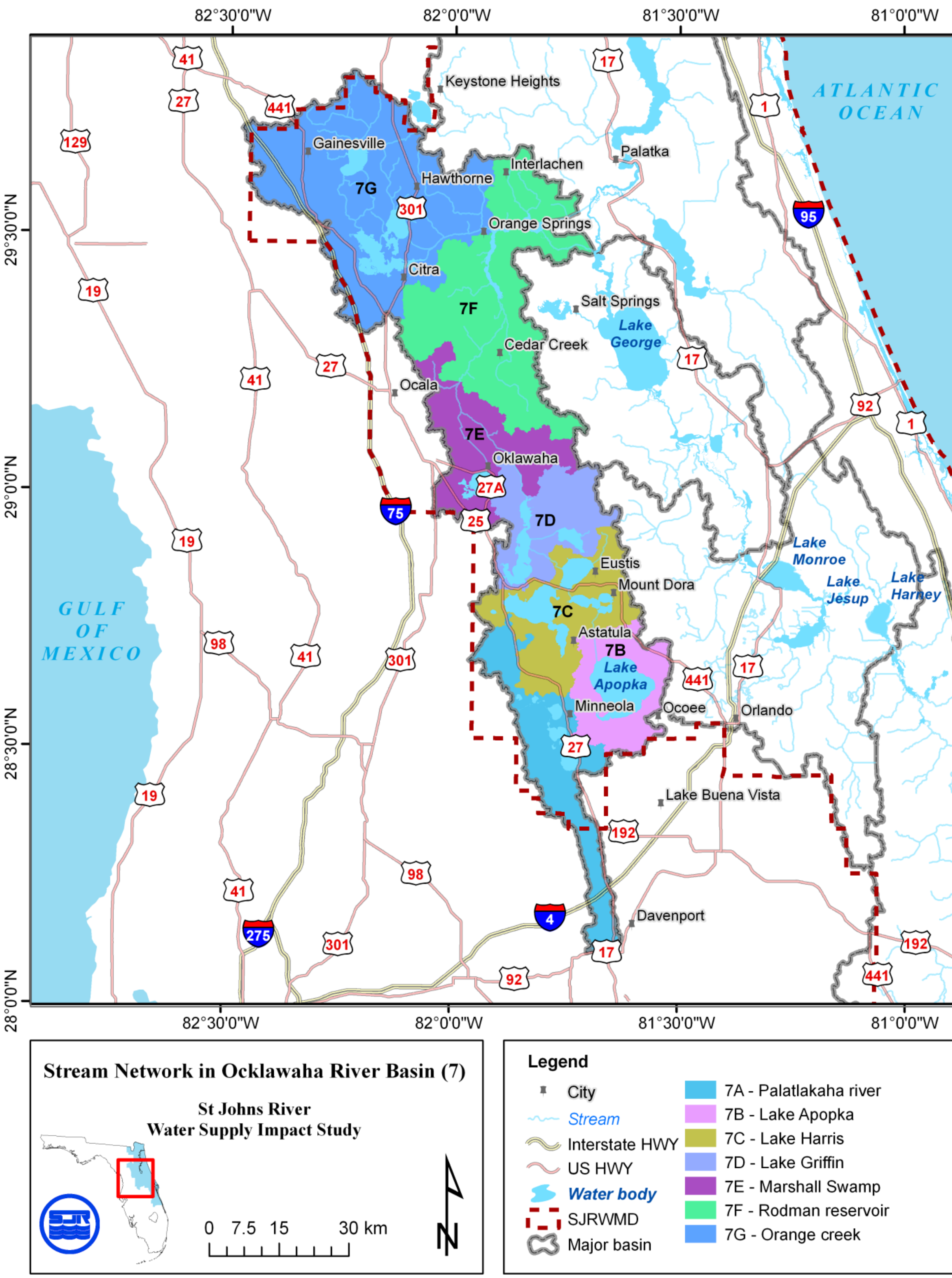

Figure 3–36. Stream network showing planning units 7A through 7G in the Ocklawaha River Basin (7).

Table 3–39. Planning units in the Ocklawaha River Basin (7).

Planning Unit Number	Planning Unit Name	SJ97-1 Area (acres)*	Model Area (acres)
Upper Ocklawaha River Basin			
7A	Palatlakaha River Planning Unit	142,535	not modeled measured time-series used instead of simulation results
7B	Lake Apopka Planning Unit	117,340	94,707
7C	Lake Harris Planning Unit	153,864	101,799
7D	Lake Griffin Planning Unit	148,270	65,695
Lower Ocklawaha River Basin			
7E	Marshall Swamp Planning Unit	104,941	109,713
7F	Rodman Reservoir Planning Unit	302,088	234,417
Orange Creek Basin/Planning Unit (simulated by three models)			
7G	Newnans Lake	79,308	73,470
7G	Orange Lake	217,066	106,917
7G	Orange Creek	88,702	88,705

*Source: TP SJ97-1 (Adamus, Clapp and Brown 1997)

Table 3–40. Ocklawaha River Basin (7) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	86,462	6.4%	151,007	11.2%
Medium-density residential	45,202	3.4%	141,384	10.5%
High-density residential	10,554	0.8%	35,355	2.6%
Industrial and commercial	27,845	2.1%	68,987	5.1%
Mining	6,646	0.5%	4,541	0.3%
Open and barren land	25,897	1.9%	15,416	1.1%
Pasture	81,091	6.0%	54,061	4.0%
Agriculture general	83,518	6.2%	54,309	4.0%
Agriculture tree crops	60,379	4.5%	21,105	1.6%
Rangeland	73,939	5.5%	30,331	2.3%
Forest	426,313	31.7%	351,349	26.1%
Water	155,300	11.6%	155,300	11.6%
Wetlands	260,713	19.4%	260,713	19.4%
Total	1,343,859	100.0%	1,343,859	100.0%

Upper Ocklawaha River Basin: Planning Units 7A, 7B, 7C, and 7D

The UORB is located in the central part of Florida just west of the MSJRB. It includes parts or all of Polk, Lake, Orange, and Marion counties. In accordance with SJRWMD's organizational scheme, the basin includes Palatlakaha River, Lake Apopka, Lake Harris and Lake Griffin (Figure 3–36). Flow in the Palatlakaha River subwatersheds is regulated by a series of structures before entering Lake Harris at the M1 structure. The Lake Harris planning unit is divided into four subwatersheds: the Lake Beauclair, Lake Dora, Lake Harris with Little Lake Harris, and Lake Eustis. The Lake Griffin planning unit is divided into Lake Griffin and Lake Yale subwatersheds.

The subwatersheds in the UORB can best be described as a set of interconnected lakes with surrounding watersheds draining to each of the lakes. The general flow direction is south to north. As barge and steamship traffic increased during the late 1800s, the surface water resources in the UORB were developed for tourism and for agricultural and commercial industry. Visitors were attracted to the region for its outstanding fishing and other aquatic recreation. The construction of water control structures and channelization of the river to facilitate navigation began as early as 1893. The present configuration of locks and dams was completed in 1974.

Much of the agricultural land around the major lakes and the Ocklawaha River consists of drained wetlands. About 15,000 ac of floodplain wetlands in the UORB were drained for agriculture. Interior drainage ditches, pump stations, and perimeter levees often drained these muck farms with drainage water pumped into adjacent water bodies.

Water quality and aquatic and wetland habitats in the basin declined dramatically over the last century. The Ocklawaha River was dredged for navigation and 15 mi of the upper river channel were abandoned; floodplain wetlands were drained for agriculture; three dams stabilized water levels; and urban growth became a major factor in the basin. The impacts of urban and agricultural development on water quality within the basin were first documented during the late 1940s. Pollutants from upstream Lake Apopka and in storm water and wastewater discharges promoted algae growth in the basin lakes, dead algae accumulated as deep organic sediments on lake bottoms, and aquatic plants died because sunlight could not penetrate the murky waters. Stabilized water levels and reduced flows contributed to further degradation of water quality.

The SJRWMD has acquired more than 10,000 ac of former muck farms in the UORB and has begun restoration of wetland habitat on these lands. This restoration effort focuses on reducing nutrients and other pollutants in basin water bodies, reestablishing more natural water level fluctuations and flows, restoring the original Ocklawaha River channel, and restoring aquatic and wetland habitats at former muck farms (Figure 3–38).

The Upper Ocklawaha River is primarily located within the Central Lakes Subdivision of the Central Lake District Physiographic Province (Brooks 1982). The Central Lakes Subdivision is a large lowland area between the Mount Dora Ridge to the east and the Ocala Uplift District to the west. In many areas, the valley floor intersects the potentiometric surface of the Floridan aquifer resulting in large spring discharges and spring-fed lakes. As a result, surface waters receive a considerable portion of their total water budget from groundwater (Canfield 1981). In addition, surface inflows for the region generally originate in calcareous, nutrient-rich soils. Consequently, the lakes of the region, with few exceptions, are naturally eutrophic hard-water lakes. Although the lakes are naturally eutrophic, urbanization and intensive agricultural practices have substantially increased surface water nutrient loads. Therefore, eutrophication has increased to detrimental levels and recreational, aesthetic, and commercial values have declined.

Gourd Neck Springs, located in the southwest corner of Lake Apopka, is considered one of two headwaters of the Harris Chain of Lakes. Water flows north through Lake Apopka into Lake Beauclair and through the Apopka-Beauclair Canal. Lake Beauclair is included in the Harris Chain of Lakes and drains directly into Lake Dora, which drains through the Dora Canal into Lake Eustis. The Clermont Chain of Lakes in the Palatlakaha basin serves as another headwater to the Harris Chain of lakes. They drain into Lake Harris, which connects through the Dead River with Lake Eustis. Lake Eustis connects through Haines Creek and the Burrell Lock and Dam to Lake Griffin. Lake Yale also connects through the Yale-Griffin Canal to Lake Griffin. The Burrell Lock and Dam on Haines Creek are operated by SJRWMD to maintain a desired regulation range of 62.00 ft to 63.50 feet NGVD29 in Lake Eustis. Water elevations in lakes Harris, Little Harris, Dora, and Beauclair are also affected by the Burrell structure.

The Ocklawaha River technically starts at the north end of Lake Griffin and is controlled by the Moss Bluff Lock and Dam. The SJRWMD operates the Moss Bluff Lock and Dam as the local sponsor for the Four River Basins Project in accordance with regulations prescribed by the USACE to maintain a desired elevation range of 58.00 ft to 59.50 feet NGVD29 in Lake Griffin (USACE 1993). The Moss Bluff structure also influences water levels in Lake Yale. Lake Weir is partially controlled by a fixed crest weir, which allows outflow through its outlet canal only when lake levels exceed 57.44 ft NGVD29. The UORB is maintained as a series of cascading pools. The Apopka-Beauclair Lock and Dam is operated by SJRWMD for the regulation of water levels in Lake Apopka. The Burrell Lock and Dam are operated by SJRWMD to regulate water levels in lakes Harris, Eustis, Dora, and Beauclair. The SJRWMD also operates the Moss Bluff Lock and Dam to regulate water levels in Lake Griffin. A representative figure illustrating the seasonal regulation schedule for Lake Griffin is provided. Similar schedules are used to manage the other lakes. Wet season regulation levels are typically lower than those in the dry season to accommodate additional storage that may be needed during tropical hurricane season. For a more technical description of the structures, the reader is referred to the Army Corps of Engineers (USACE 1993).

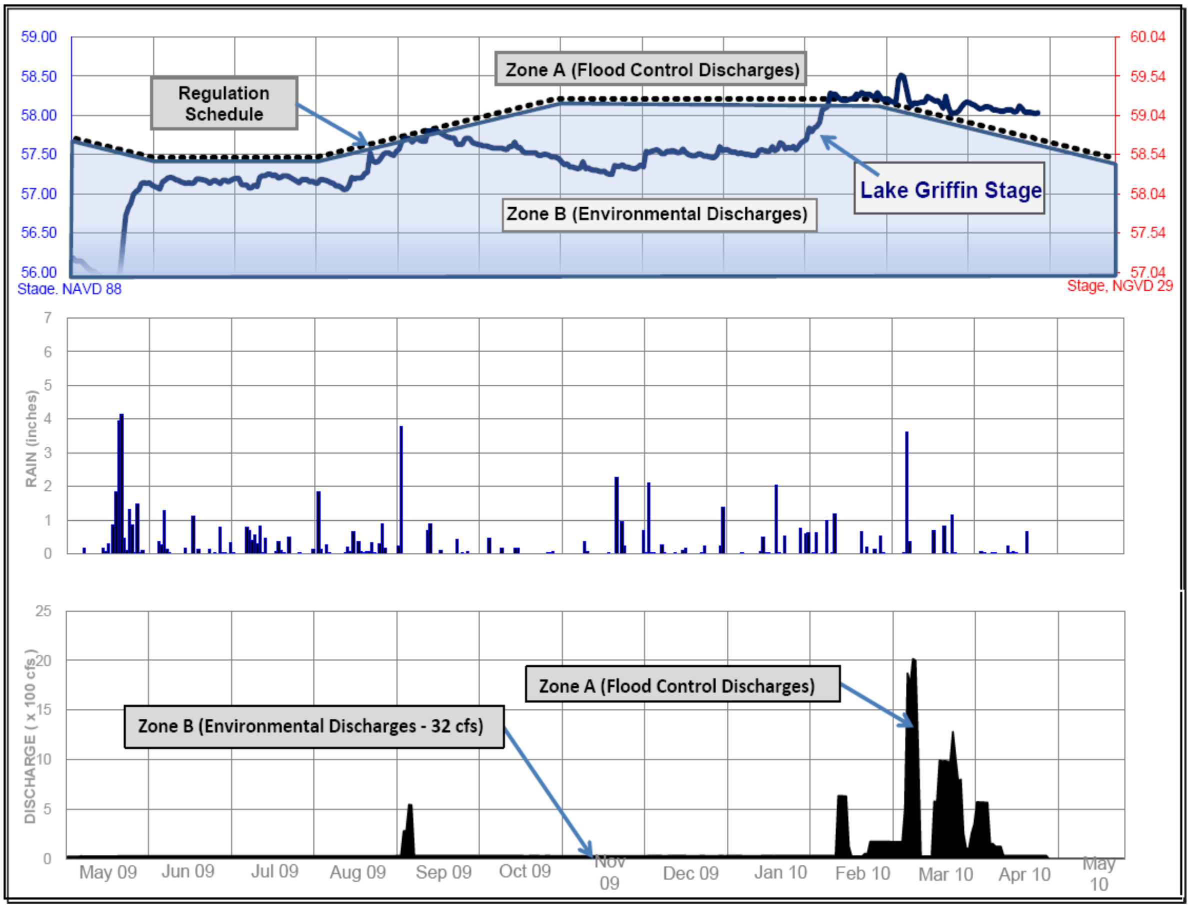

Figure 3–37. Lake Griffin regulation schedule illustrates seasonal regulation changes and Zones A and B discharges typical of upper Ocklawaha River basin (UORB) lakes.

Table 3–41. Upper Ocklawaha River Basin lake regulation schedules.

Lake Name	Dry Season Elevation (29 ft NGVD29)	Wet Season Elevation (29 ft NGVD29)
Apopka	67.25	66.75
Eustis, Harris, Dora & Beauclair	63.25	62.50
Griffin	59.50	58.50

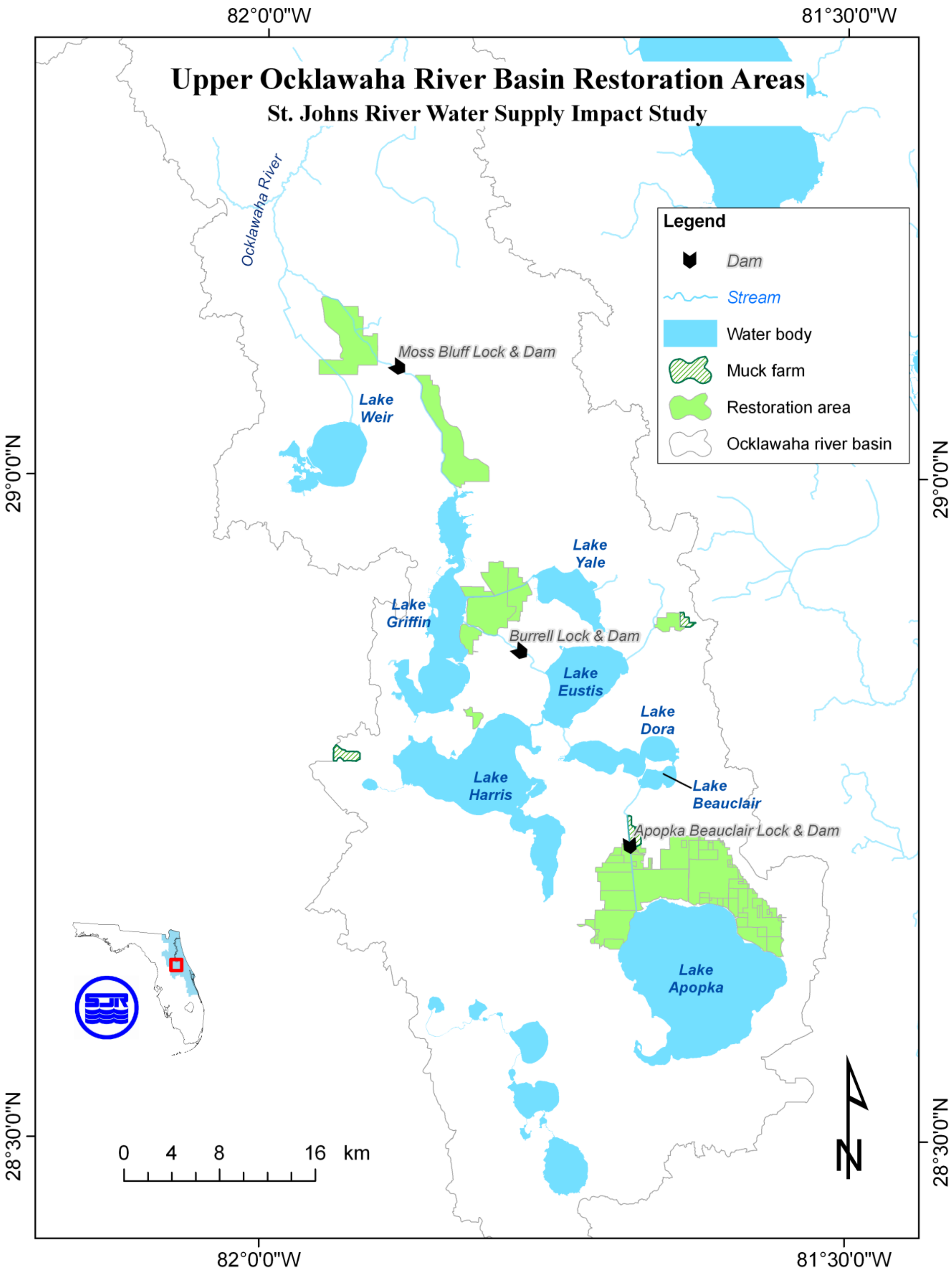

Figure 3–38. Upper Ocklawaha River restoration areas.

Palatlakaha River Planning Unit (7A)

The behavior of the Palatlakaha River Planning Unit is difficult to model because it is influenced by the Green Swamp; a large area of wetlands that provides the headwaters for four separate rivers and the portion contributing to Lake Harris is regulated by control structures. Watershed delineation in the swamp is very difficult, and the other three rivers—Withlacoochee, Peace, and Hillsborough—are part of the South West Florida Water Management District and are not included in this study. Once water from the swamp enters the Palatlakaha River, flow is regulated by a series of structures before entering Lake Harris at the M1 structure. The Lake County Water Authority operates the structures according to a set of management guidelines that make it very difficult to calibrate because the guidelines can be overridden due to circumstances that are not represented in the model.

Previous modeling attempts provided poor results for the Palatklaha River Planning Unit. The Nash–Sutcliffe statistic is a common measure of model performance. A perfect match between simulated values and observations would give a Nash–Sutcliffe statistic of 1, whereas a 0 means that the average of the observed time-series is a better predictor of all the variation than the simulated values. The Nash–Sutcliffe results for the previous modeling efforts were negative because of the difficulties mentioned (Table 3–42). Because of the poor performance of previous models, and the relatively small contributing area of the Palatlakaha River Planning Unit, we decided to not model this area but instead include the measured flows as an external time series into Lake Harris. The area is therefore shown as a non-modeled planning unit (Figure 3–39).

Table 3–42. Palatlakaha River Nash–Sutcliffe modeling statistics from the previous modeling effort simulating the years 1996 to 1998.

1996	1997	1998	Overall
0.44	-11.36	-22.83	-5.60

Urban land use is projected to increase from about 8% in 1995 to almost 50% in 2030 as this area is located adjacent to the Walt Disney World/Lake Buena Vista complex and the I-4 corridor, which is one of the fastest developing areas of the United States (Table 3–43). Development in this basin will take the place of rangeland, pasture, forest, and agricultural lands.

Because this planning unit is represented with observed data, there are no means of estimating the increased flow due to land use development for the projected 2030 land use scenario. The increase between the 1995 and projected 2030 land use scenarios can be shown to have a minimal effect on the flow estimates from the Ocklawaha River Basin for the same reasons that allow the use of the observed flow: small area relative to the entire Ocklawaha major basin, and structural management and storage of the flow.

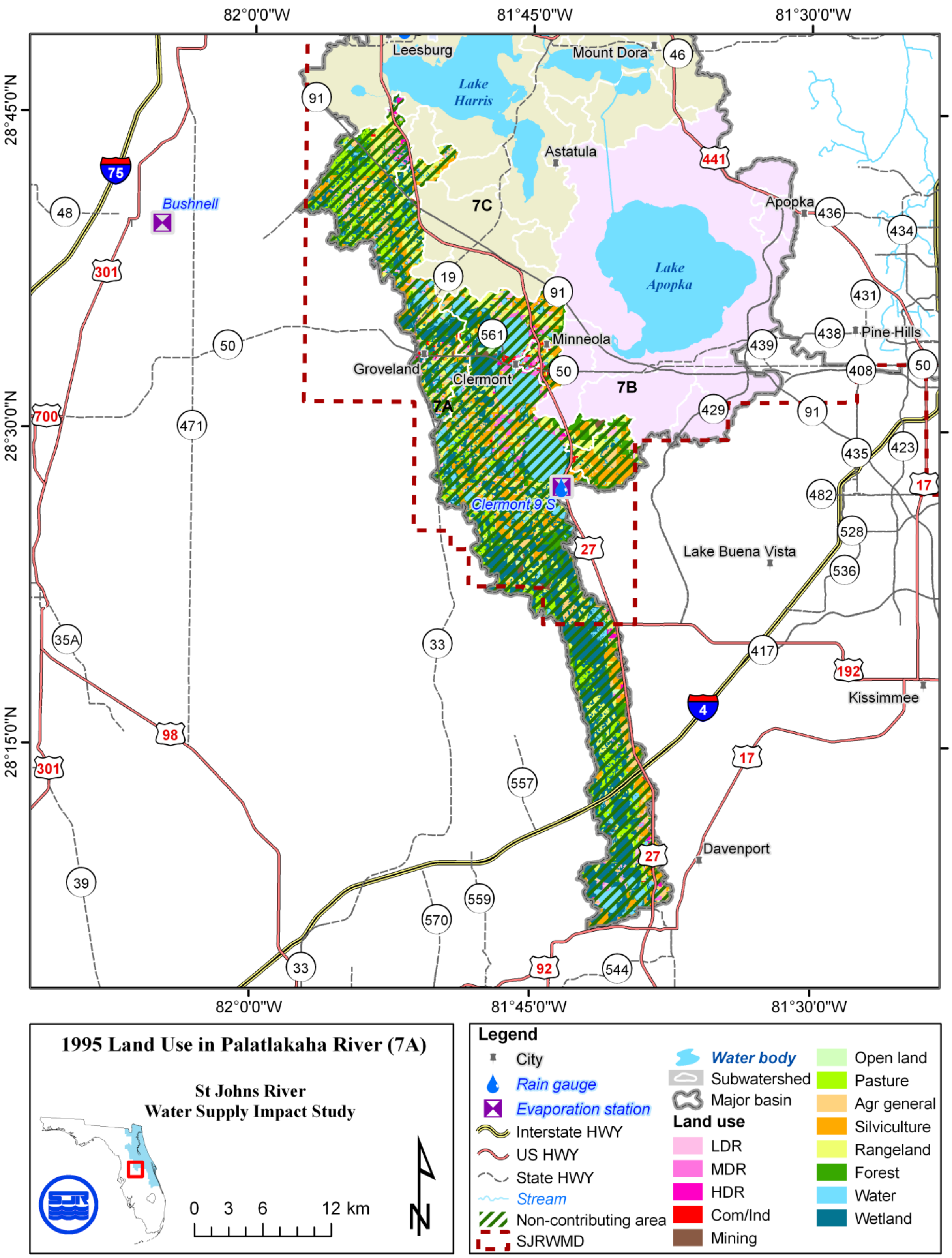

Figure 3–39. 1995 land use in Palatlakaha River Planning Unit (7A).

Table 3–43. Palatlakaha River Planning Unit (7A) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	5,520	3.9%	9,986	7.0%
Medium-density residential	3,102	2.2%	31,141	21.9%
High-density residential	790	0.6%	14,136	9.9%
Industrial and commercial	2,143	1.5%	11,907	8.4%
Mining	1,310	0.9%	652	0.5%
Open and barren land	1,424	1.0%	368	0.3%
Pasture	10,303	7.2%	1,818	1.3%
Agriculture general	7,417	5.2%	2,065	1.4%
Agriculture tree crops	22,470	15.8%	6,037	4.2%
Rangeland	21,464	15.1%	4,823	3.4%
Forest	9,582	6.7%	2,593	1.8%
Water	16,954	11.9%	16,954	11.9%
Wetlands	39,957	28.1%	39,957	28.1%
Total	142,436	100.0%	142,436	100.0%

Lake Apopka Planning Unit (7B)

Lake Apopka, the fourth largest lake in Florida, is a headwater lake for the Ocklawaha River. The Lake Apopka planning unit is located within Orange and Lake counties and includes the towns of Monteverde and Astatula. The area of the Lake Apopka drainage basin, including the surface of the lake, is approximately 119,773 ac. Several subwatersheds contribute either direct storm water runoff or runoff through small tributaries during rainfall events. Many portions of the drainage basin, however, contribute runoff infrequently. More than 60 small lakes are scattered throughout the basin but they are generally landlocked except in periods of extreme runoff events.

The water surface of Lake Apopka is approximately 30,800 ac at a lake surface elevation of 66.5 ft NGVD29. Average depth at this surface elevation is 5.4 ft. The only surface water outflow from Lake Apopka is the Apopka-Beauclair Canal, which flows north into Lake Beauclair. Discharge from the canal is controlled at the Apopka-Beauclair Lock and Dam, which therefore influences lake stage.

The water control structure in the canal has altered the natural periodic fluctuation of Lake Apopka stage and discharge. In 1950, the first water control structure was constructed by local interests to stabilize lake level for the purposes of agricultural water supply and navigation (Schelske, Kenney and Whitmore 2001). In 1956, the present concrete structure was installed by Lake County Water Authority (Schelske, Kenney and Whitmore 2001). A regulation schedule is enforced on the Lake Apopka water level since 1952 to stabilize the lake level (Friends of Lake Apopka 2011). When lake level is above regulation, discharges are made up to the maximum. When the lake level is below regulation schedule, a minimum discharge of 23 cfs is released to satisfy downstream environmental requirements. Because of the regulation schedule the lake level fluctuates in a narrow range, varying from 62.6 ft to 68.7 ft NGVD with a mean of 66.5 ft NGVD from 1952 through 2011.

The seasonal regulation schedule is nearly the opposite of natural fluctuations in water level; the lake is lowered during the summer-wet season in order to provide flood storage capacity as needed; during winter-spring season, the lake level is raised to hold more water in the lake (Figure 3–40). This reversal of the natural hydrologic cycle may have negative impacts on the aquatic habitats and fisheries in the basin.

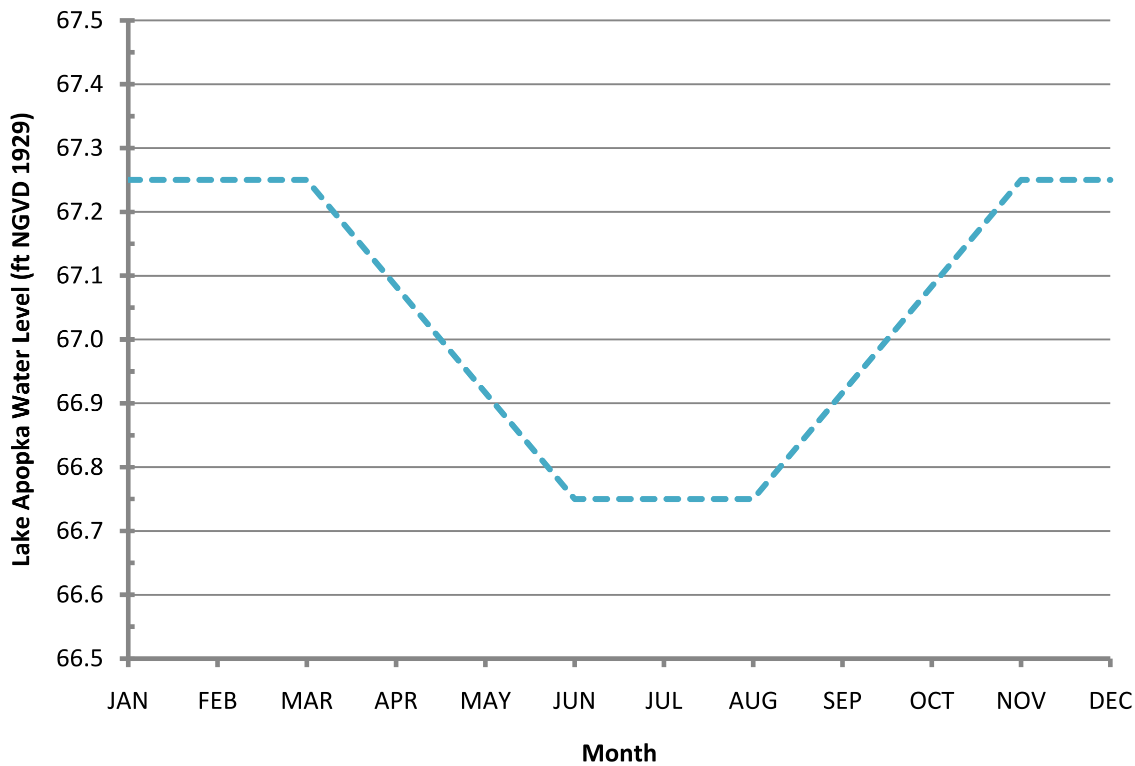

Figure 3–40. Lake Apopka regulation schedule.

Lake Apopka historically covered approximately 50,000 ac and had an average depth of 8 to 9 ft. The northern third of the lake was a shallow marsh system, which afforded habitat for abundant fish and wildlife populations and provided filtration of water flowing out of the lake. Prior to its decline, the lake provided superb sport fishing of national renown. During periods of high water, the lake likely drained to the northwest into Little Lake Harris through an area known as Double Run Swamp.

Numerous activities in the nineteenth and twentieth centuries have contributed to the decline of the lake. Significant human impact affecting Lake Apopka probably began with the construction of the Apopka-Beauclair Canal, which altered the hydrology of the lake. In order to create a waterway for navigation and agricultural use, dredging of the Apopka-Beauclair Canal lowered the water surface of Lake Apopka by about 4 ft leaving approximately 20,000 ac of wetlands dry enough for farming (Shofner 1982). Crop production was mostly unsuccessful due to difficulty in water table management and a series of freezes in the mid and late 1890s. A hurricane struck in 1926 and the entire north shore farm area reverted to marshland "under six to eight feet of water" (Shofner 1982). Due to improved technology, farming returned during World War II. In 1941, the Zellwood Drainage and Water Control District was created by a special act of the Florida Legislature and charged with facilitating agricultural production activities. In 1941, the mean elevation of the lake was approximately 67 ft (NGVD29), the same elevation as the muck and peat land along the northern shore at that time. These lands were inundated when the lake rose above the mean elevation and during lower lake stages, these lands drained into the lake or into the Apopka-Beauclair Canal. Under the management of Zellwood Drainage and Water Control District a levee was constructed along the north lakeshore, effectively separating the marshes from the lake and allowing drainage of the farm fields (Shofner 1982). Agricultural production peaked in the muck farms during the 1980s, with 18,000 ac of farmed land. With the final government purchase of the remaining muck farms on Aug. 20, 1999, Zellwood Drainage and Water Control District was dissolved in Febuary 2000 by mandate of the 1999 Florida Legislature.

Apopka Spring (also known as Gourd Neck Spring) is the largest spring in the basin and it discharges into Gourd Neck, a narrow water body located in the southwest corner of the lake. The spring opening is at a depth of approximately 37 ft (Rao and Clapp 1996). Fed by the Floridan aquifer, the spring discharges from a single submerged, oval-shaped opening that is 5–6 ft in diameter. The average discharge rate of Apopka Spring was approximately 29.9 cfs from 1988 through 1998, depending on the lake stage level (German 2006). Three other named springs exist in the basin; however, discharge information is not available. Holt Lake Spring is located just south of Holt Lake; Bear Spring and Wolf's Head Spring are located just southwest of Clay Island.

Land use in the basin is predominantly wetlands and agriculture Figure 3–41 and Table 3–44). Residential, industrial, and commercial land uses are expected to increase from a 1995 level of nearly 12% to as high as 34% by 2030 (Table 3–44).

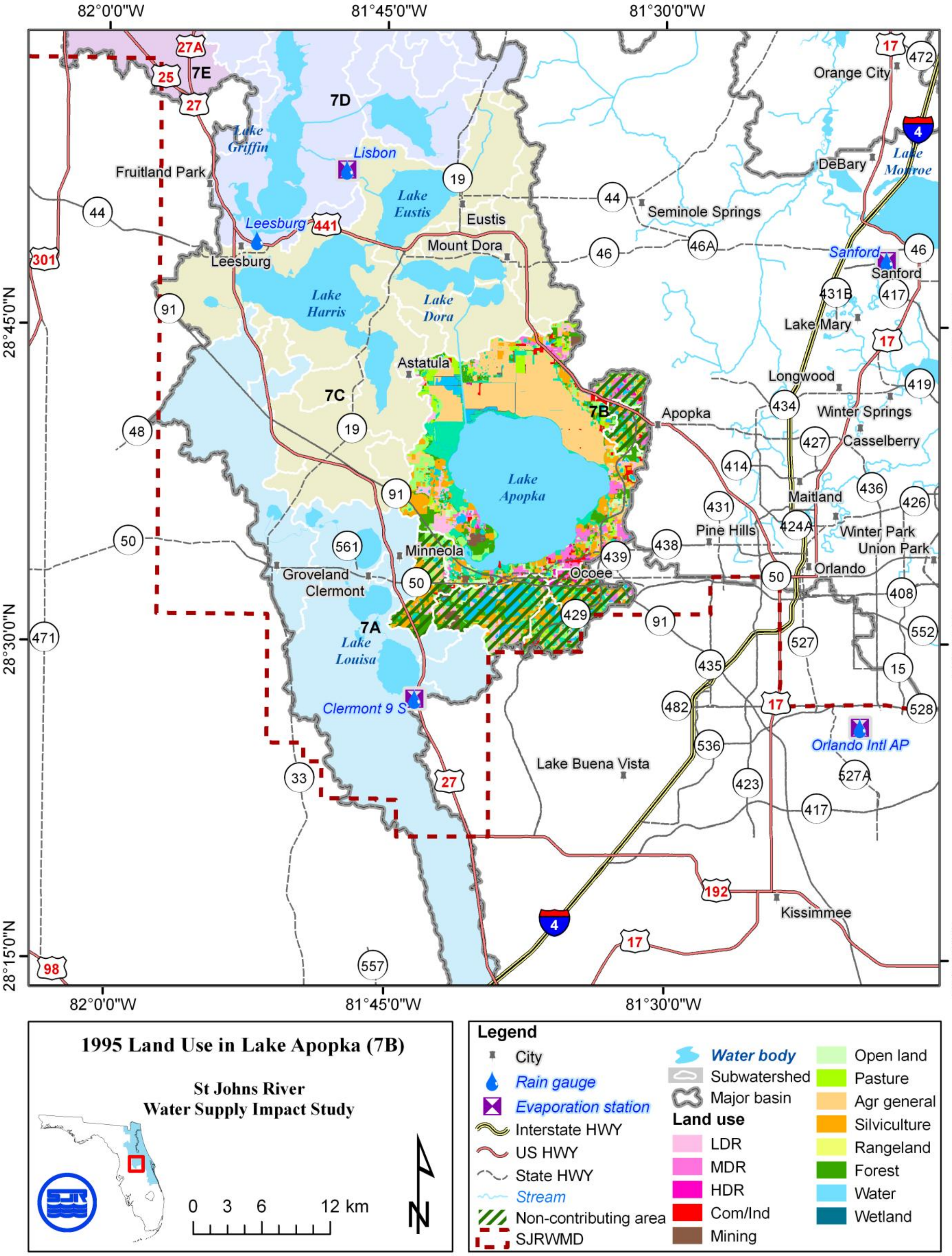

Figure 3–41. 1995 land use in Lake Apopka Planning Unit (7B).

Table 3–44. Lake Apopka Planning Unit (7B) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	5,528	4.7%	10,375	8.8%
Medium-density residential	4,512	3.8%	14,301	12.2%
High-density residential	623	0.5%	5,382	4.6%
Industrial and commercial	3,273	2.8%	9,446	8.1%
Mining	1,673	1.4%	1,054	0.9%
Open and barren land	1,564	1.3%	580	0.5%
Pasture	3,563	3.0%	1,999	1.7%
Agriculture general	19,765	16.8%	14,653	12.5%
Agriculture tree crops	13,388	11.4%	5,420	4.6%
Rangeland	8,544	7.3%	3,700	3.2%
Forest	8,462	7.2%	3,985	3.4%
Water	35,889	30.6%	35,889	30.6%
Wetlands	10,534	9.0%	10,534	9.0%
Total	117,318	100.0%	117,318	100.0%

Lake Harris Planning Unit (7C)

Gourd Neck Springs, located in the southwest corner of Lake Apopka, is considered one of two headwaters of the Harris Chain of Lakes. Water flows north through Lake Apopka into Lake Beauclair and through the Apopka-Beauclair Canal. Lake Beauclair is included in the Harris Chain of Lakes and drains directly into Lake Dora, which drains through the Dora Canal into Lake Eustis. The Clermont Chain of Lakes in the Palatlakaha basin serves as another headwater to the Harris Chain of lakes. They drain into Lake Harris, which connects through the Dead River with Lake Eustis. Lake Eustis connects through Haines Creek and the Burrell Lock and Dam to Lake Griffin. Lake Yale also connects through the Yale-Griffin Canal to Lake Griffin. The Burrell Lock and Dam on Haines Creek is operated by SJRWMD to maintain a desired regulation range of 62.00 ft to 63.50 feet NGVD29 in Lake Eustis. Water elevations in lakes Harris, Little Harris, Dora, and Beauclair are also affected by the Burrell structure.

The Ocklawaha River technically starts at the north end of Lake Griffin and is controlled by the Moss Bluff Lock and Dam. The SJRWMD operates the Moss Bluff Lock and Dam as the local sponsor for the Four River Basins Project in accordance with regulations prescribed by the USACE to maintain a desired elevation range of 58.00 ft to 59.50 feet NGVD29 in Lake Griffin (USACE 1993). The Moss Bluff structure also influences water levels in Lake Yale. Lake Weir is partially controlled by a fixed crest weir, which allows outflow through its outlet canal only when lake levels exceed 57.44 ft NGVD29.

The water regulatory structures have altered the natural periodic fluctuations in lake stages and stream discharges. In addition, the seasonal regulation schedules are nearly the opposite of natural seasonal fluctuations in water levels; the lakes are held at their lowest levels during the summer-wet season in order to provide flood storage capacity. These reversals of the natural hydrological cycles may contribute to loss of habitat and deterioration in water quality in the basin.

The drainage boundaries are specified as contributing or noncontributing inflow. Noncontributing areas, comprising 32% of the total area, are typically upland lakes and/or wetlands landlocked by wide ridges (Figure 3–42).

The Lake Harris planning unit's 1995 land use is represented in Figure 3–42 and a summary of 1995 and projected 2030 land use is provided in Table 3–45. Urban land use in the Lake Harris planning unit is projected to increase from 17% in 1995 to 44% in 2030 (Table 3–45). Development will predominantly replace agriculture, rangeland, forest, and pasture uses.

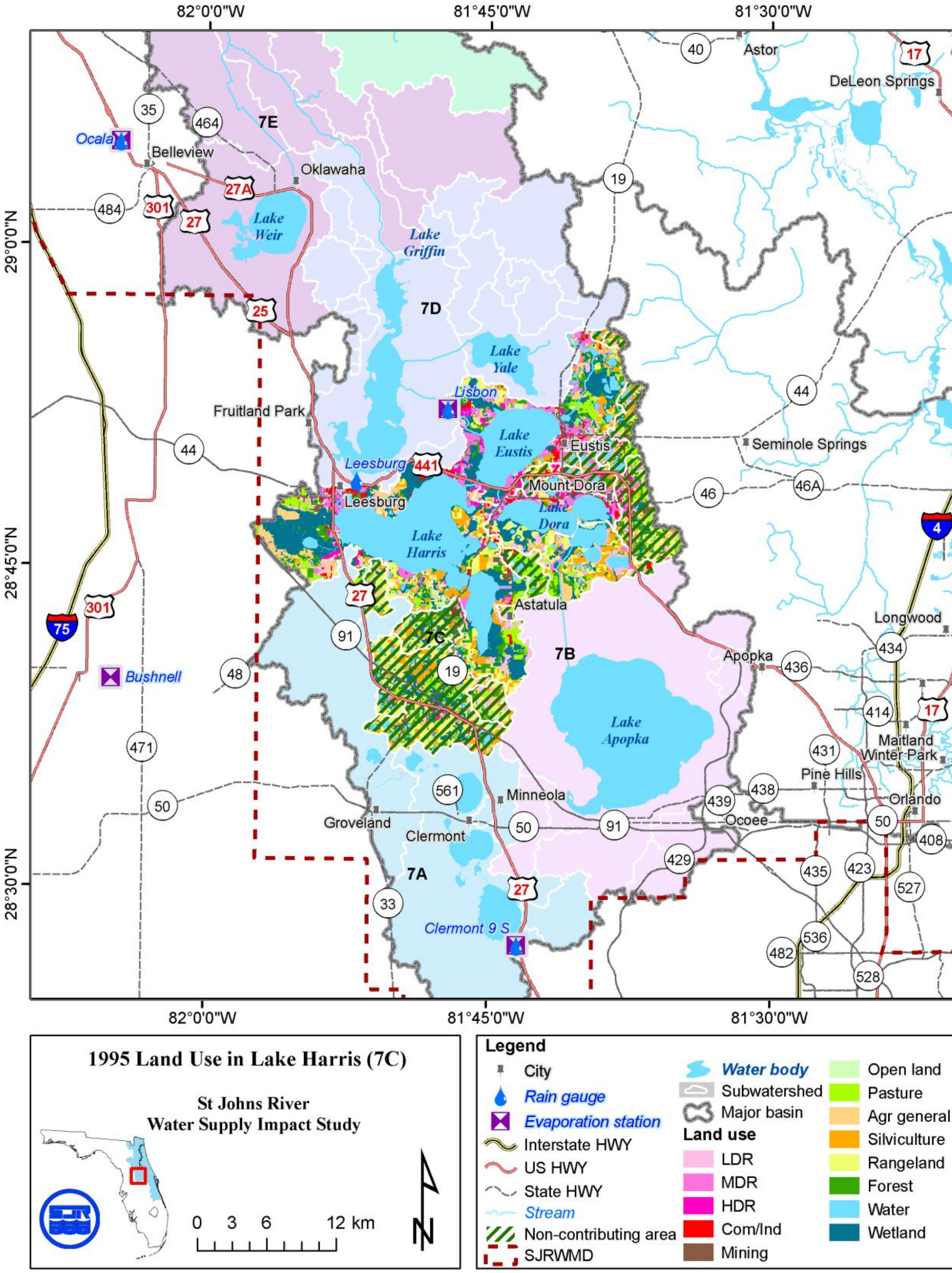

Figure 3–42. 1995 land use in Lake Harris Planning Unit (7C).

Table 3–45. Lake Harris Planning Unit (7C) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	8,774	5.7%	12,957	8.5%
Medium-density residential	8,830	5.8%	34,429	22.5%
High-density residential	2,683	1.8%	5,078	3.3%
Industrial and commercial	5,519	3.6%	14,612	9.6%
Mining	807	0.5%	414	0.3%
Open and barren land	2,877	1.9%	1,018	0.7%
Pasture	8,117	5.3%	3,598	2.4%
Agriculture general	7,233	4.7%	3,180	2.1%
Agriculture tree crops	13,756	9.0%	4,280	2.8%
Rangeland	21,181	13.9%	6,766	4.4%
Forest	10,315	6.8%	3,762	2.5%
Water	39,065	25.6%	39,065	25.6%
Wetlands	23,564	15.4%	23,564	15.4%
Total	152,721	100.0%	152,721	100.0%

Lake Griffin Planning Unit (7D)

The total drainage area of Lake Griffin is approximately 97 mi^2 excluding the Lake Yale basin. Two major tributaries—Haines Creek and the Yale-Griffin Canal—discharge directly into Lake Griffin. Haines Creek receives discharge from upstream Harris Chain of Lakes and Apopka Basin at the Burrell Lock and Dam structure. The Yale-Griffin Canal connects the two lakes and delivers flow from Lake Yale into Lake Griffin. Most of the land surface areas around the lakes and the Ocklawaha River are low-lying wetlands and have been developed for agricultural production, predominantly muck farms. In most of these agricultural areas, drainage systems with perimeter levees and pump stations were constructed to provide flood protection. Most upland areas or ridges were used for citrus groves, with most contributing minimal runoff because they typically have high infiltration rates. There is urban or community development throughout the region, both in waterfront and ridge areas.

From Lake Griffin, water flows northward through the J. D. Young Canal (C-231) to the Moss Bluff Lock and Dam, which controls water levels in Lake Griffin. The Moss Bluff structure is located on the Ocklawaha River, 12 mi downstream from Lake Griffin. Most of the river between Lake Griffin and SR 40 has been channelized. Flow has been altered from the natural river course into canals for most of this reach, and much of the floodplain has been converted to farmland.

The water surface elevation of Lake Griffin is currently regulated to allow a narrow fluctuation of 0.75 ft from 58.50 to 59.25 ft NGVD29. However, levels regularly deviate from these control elevations due to rainfall and drought conditions. This fluctuation range is designed to facilitate navigation and to provide limited floodwater storage capacity. Because of the shallow nature of the lake, any minor change in water surface elevation beyond the specified operating range would either flood waterfront properties or cause navigation problems: When the water level reaches or exceeds 60.00 ft NGVD29, some shoreline properties will be inundated; if the water level falls below 58.00 ft NGVD29, many areas become too shallow for normal boating activities.

Land use in the Lake Griffin watershed is represented in Figure 3–43 and a summary of 1995 and projected 2030 land use is provided in Table 3–46. Consistent with other watersheds in the central Florida area, urban land use in the Lake Griffin basin is projected to nearly triple from 12% in 1995 to about 33% in 2030 (Table 3–46). Development will replace forest, rangeland, pasture, and agriculture land uses, although over 20% of the basin will remain in forest.

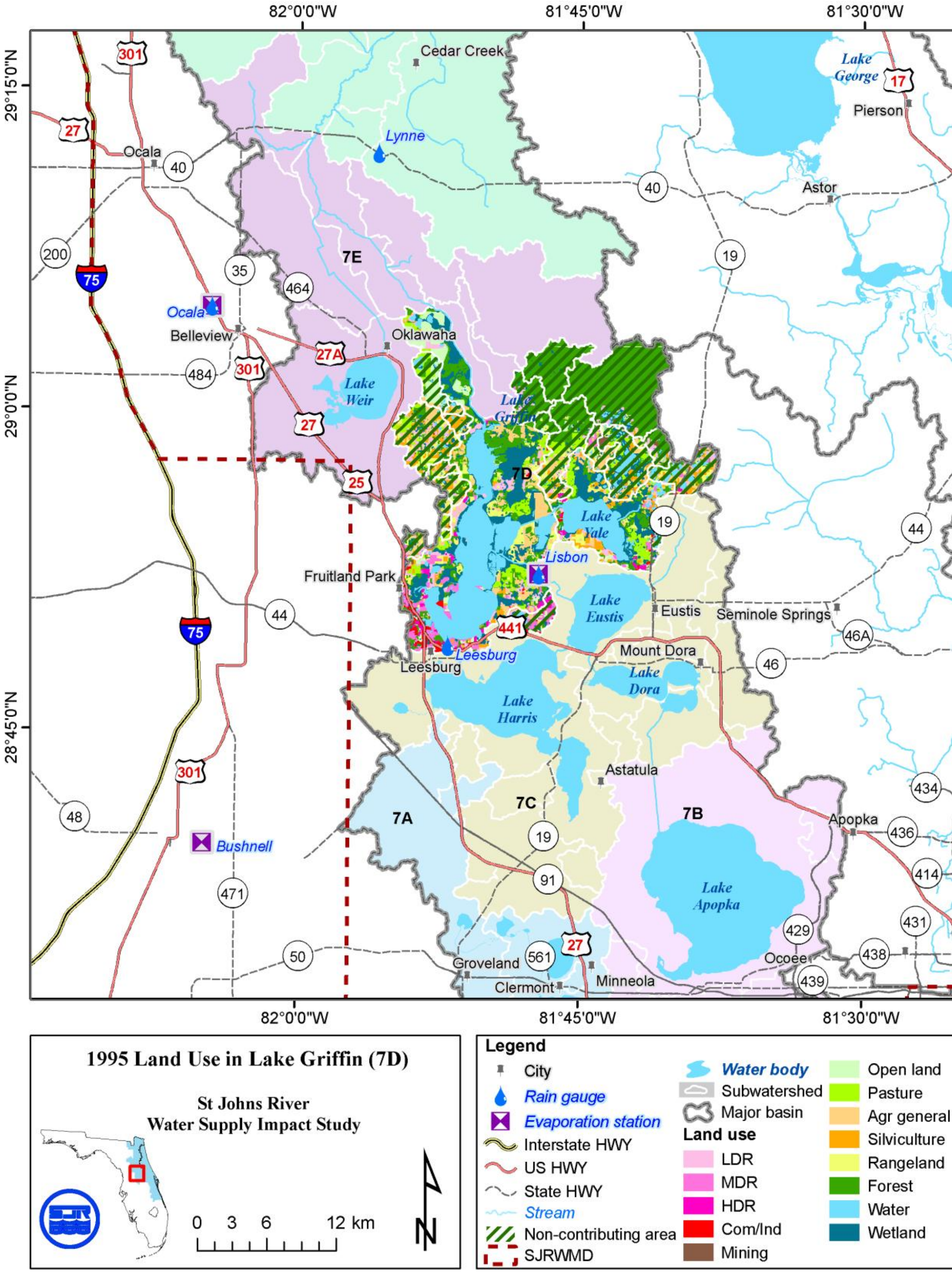

Figure 3–43. 1995 land use in Lake Griffin Planning Unit (7D).

Table 3–46. Lake Griffin Planning Unit (7D) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	7,234	6.1%	13,038	11.0%
Medium-density residential	3,257	2.8%	18,494	15.6%
High-density residential	1,361	1.2%	1,618	1.4%
Industrial and commercial	2,098	1.8%	5,435	4.6%
Mining	587	0.5%	347	0.3%
Open and barren land	4,643	3.9%	2,841	2.4%
Pasture	6,769	5.7%	3,218	2.7%
Agriculture general	7,982	6.8%	3,840	3.2%
Agriculture tree crops	6,485	5.5%	2,374	2.0%
Rangeland	6,541	5.5%	2,599	2.2%
Forest	32,399	27.4%	25,553	21.6%
Water	20,611	17.4%	20,611	17.4%
Wetlands	18,249	15.4%	18,249	15.4%
Total	118,216	100.0%	118,216	100.0%

Lower Ocklawaha River Basin: Planning Units 7E and 7F

The LORB starts at the Moss Bluff Lock and Dam and continues downstream to the Ocklawaha River's confluence with the St Johns River. The LORB includes drainage from Marshall Swamp and Lake Weir, Silver River, Orange Creek, the UORB, and other smaller tributaries. It encompasses an area of approximately 472 mi^2 in Putnam and Marion counties.

The river floodplain lies primarily within the Ocklawaha Valley of the Ocala Uplift District (Brooks 1982). This is a lowland of flatwoods and swamplands between the xeric terrain of the Ocala Scrub paleo-sand dune field of the Central Lake District to the east and the Anthony Hills of the Ocala Uplift District to the west. The northern reaches of the LORB occur in the St. Johns Offset, an area of flatwoods and swamplands between the xeric ridges of the Interlachen Sandhills to the north and the Ocala Scrub to the south, all within the Central Lake District. In many areas, the valley floor intersects the potentiometric surface of the Floridan aquifer, resulting in springs and spring-fed lakes. As a result, surface waters receive a considerable portion of their total water budget from nutrient-rich groundwater (Canfield 1981).

Silver River, the largest tributary of the Ocklawaha River, enters the Ocklawaha River near SR 40 east of Ocala. It receives its flow from several springs collectively known as Silver Springs. Its discharges originate from the Upper Floridan Aquifer system. According to SJRWMD's estimate, Silver Springs' groundwater contributing area is approximately 1,100 mi^2. Silver Springs accounts for approximately 80% of the base flow of the Ocklawaha River. Unlike selected spring and diffuse groundwater flows in the MSJRB and Lake George Basin, the springs in the Ocklawaha Basin are included in the hydrograph that forms the input into the EFDC hydrodynamic model. The Rodman Reservoir (Lake Ocklawaha) located near the mouth of the Ocklawaha River, is the main surface water body within the LORB. The reservoir was created in

1968 by impounding the lower Ocklawaha River as a part of the now deauthorized Cross Florida Barge Canal project. The Cross Florida Barge Canal project was initiated in 1964; however, further work on the project was suspended by the President of the United States in 1971 for environmental reasons. Water flow in the Ocklawaha River is released from Kirkpatrick (Rodman) Dam to the St. Johns River according to the following schedule operated by Florida Office of Greenways and Trails:

The water level of Rodman Reservoir should be allowed to fluctuate consistently up to 2 ft above and 2 ft below the mean water elevation of 18.00 ft NGVD29 on a schedule mimicking the hydroperiod for northeast Florida.

The reservoir should be drawn down every third or fourth year to

- Oxidize and compact bottom sediment
- Encourage the expansion of native aquatic plants
- Improve the sport fishery
- Temporarily control problem aquatic plants
- Rejuvenate the reservoir ecosystem.

The 1995 and projected 2030 land uses for the Marshall Swamp and Rodman Reservoir planning units of the LORB show that forest and wetlands land are the predominant 1995 land uses (Figure 3–44and Figure 3–45) between 10% and 15% low-density residential use predicted for 2030 (Table 3–47 and Table 3-48). Due to the remote nature of these watersheds, less intense urban development is projected to support the predicted 2030 population than for most of SJRWMD.

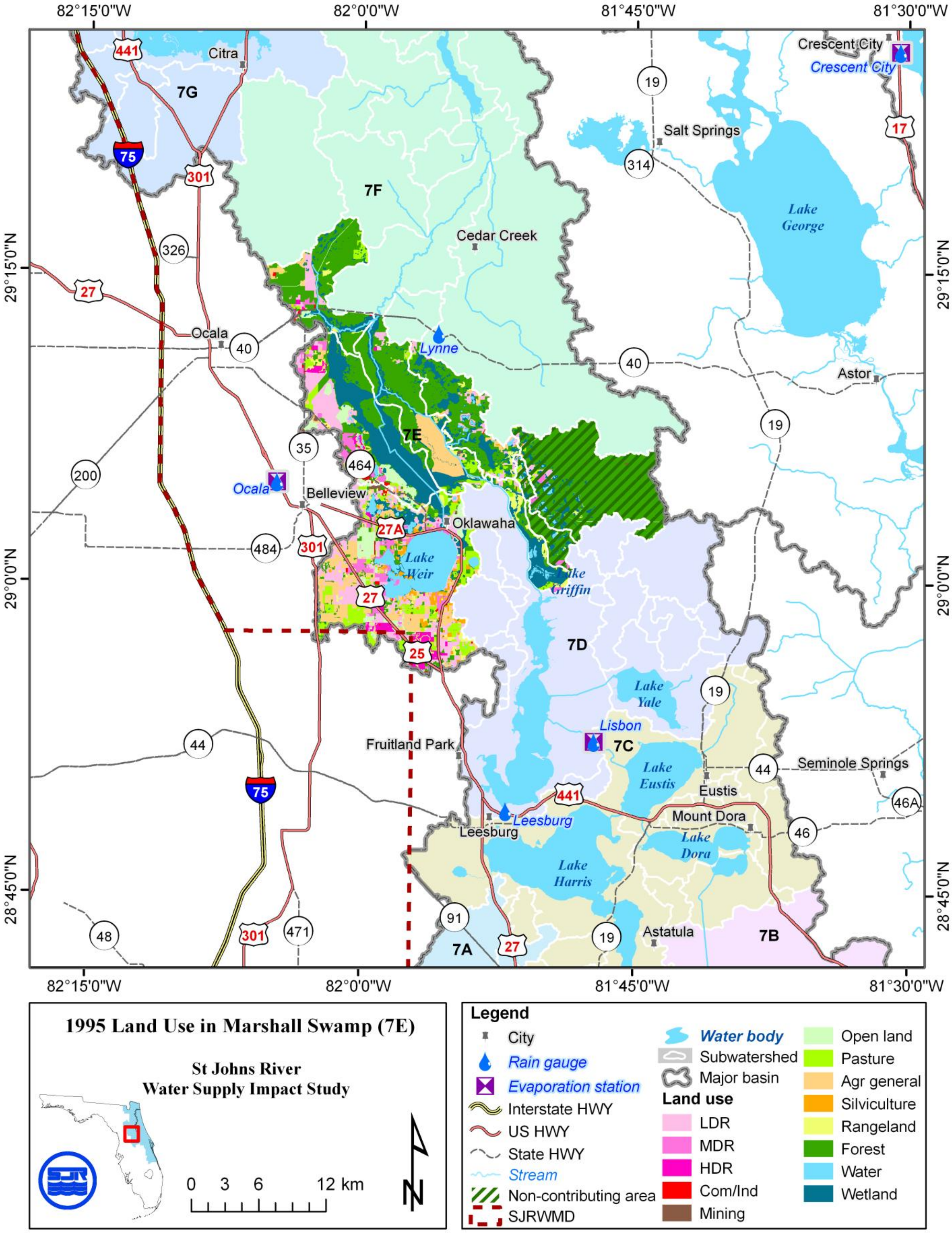

Figure 3–44. 1995 land use in Marshall Swamp Planning Unit (7E).

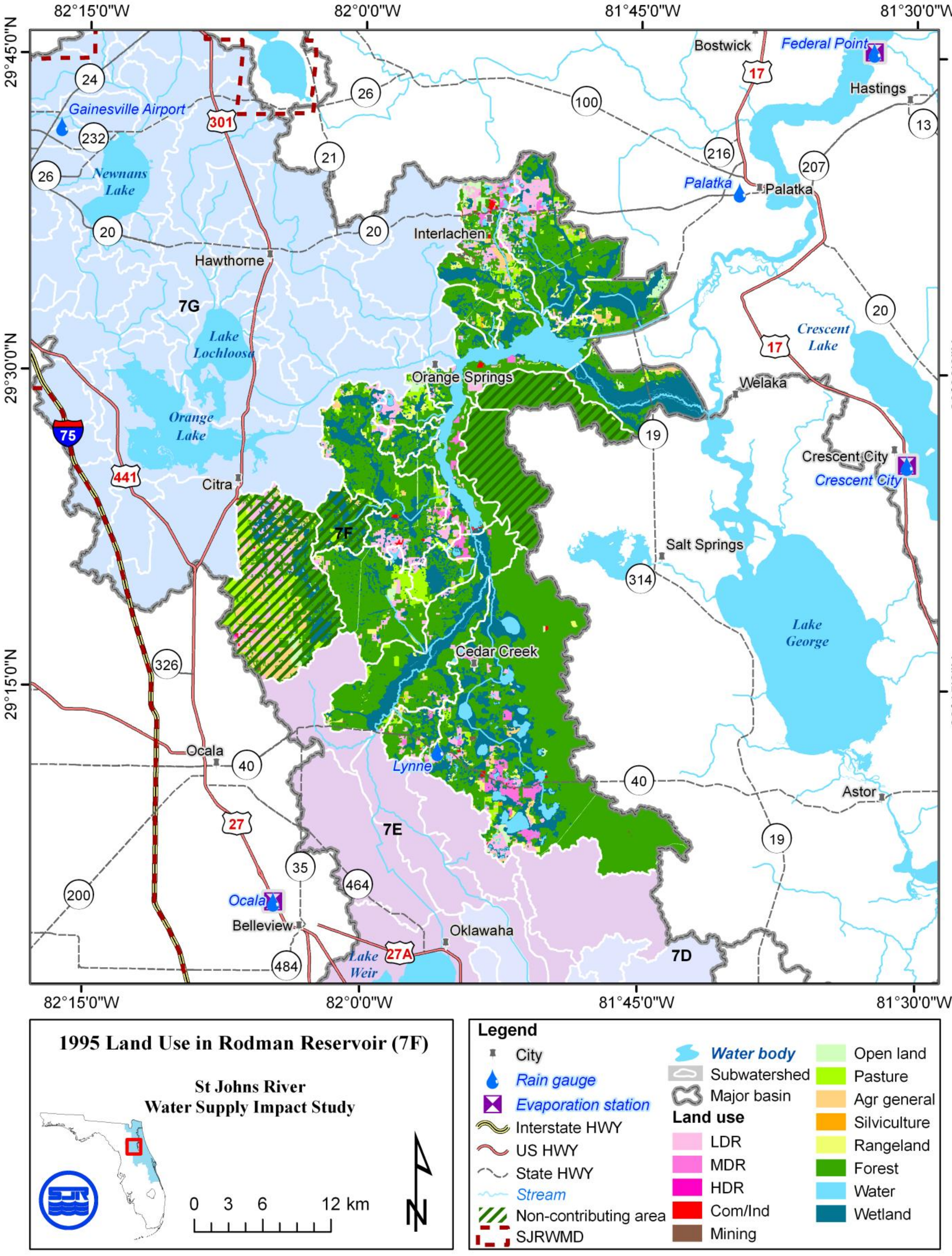

Figure 3–45. 1995 land use in Rodman Reservoir Planning Unit (7F).

Table 3–47. Marshall Swamp Planning Unit (7E) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	14,460	10.6%	21,170	15.6%
Medium-density residential	4,535	3.3%	10,514	7.7%
High-density residential	2,095	1.5%	3,443	2.5%
Industrial and commercial	1,202	0.9%	2,192	1.6%
Mining	389	0.3%	352	0.3%
Open and barren land	5,235	3.9%	3,265	2.4%
Pasture	8,338	6.1%	5,949	4.4%
Agriculture general	10,981	8.1%	7,450	5.5%
Agriculture tree crops	1,967	1.4%	1,202	0.9%
Rangeland	3,179	2.3%	2,582	1.9%
Forest	53,384	39.3%	47,646	35.1%
Water	8,044	5.9%	8,044	5.9%
Wetlands	22,042	16.2%	22,042	16.2%
Total	135,851	100.0%	135,851	100.0%

Table 3–48. Rodman Reservoir Planning Unit (7F) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	19,767	6.8%	30,194	10.3%
Medium-density residential	4,375	1.5%	7,446	2.5%
High-density residential	60	0.0%	554	0.2%
Industrial and commercial	941	0.3%	1,478	0.5%
Mining	815	0.3%	791	0.3%
Open and barren land	3,899	1.3%	3,308	1.1%
Pasture	13,329	4.6%	11,470	3.9%
Agriculture general	6,715	2.3%	4,725	1.6%
Agriculture tree crops	188	0.1%	125	0.0%
Rangeland	5,329	1.8%	4,290	1.5%
Forest	162,581	55.6%	153,618	52.5%
Water	11,094	3.8%	11,094	3.8%
Wetlands	63,289	21.6%	63,289	21.6%
Total	292,382	100.0%	292,382	100.0%

Orange Creek Planning Unit 7G

The 1995 land use distribution in the Orange Creek planning unit shows major land uses as forest (39%) and wetlands (22%) with residential areas being predominantly low density (Table 3–49).

In the Orange Creek planning unit, urban land uses are projected to nearly double from 1995 (15%) to 2030 (28%).

For modeling purposes, the Orange Creek planning unit is split into two areas based on differences in hydrology. The upper portion of Orange Creek planning unit is predominantly a series of interconnected lakes, whereas the lower portion of Orange Creek planning unit is primarily a creek system.

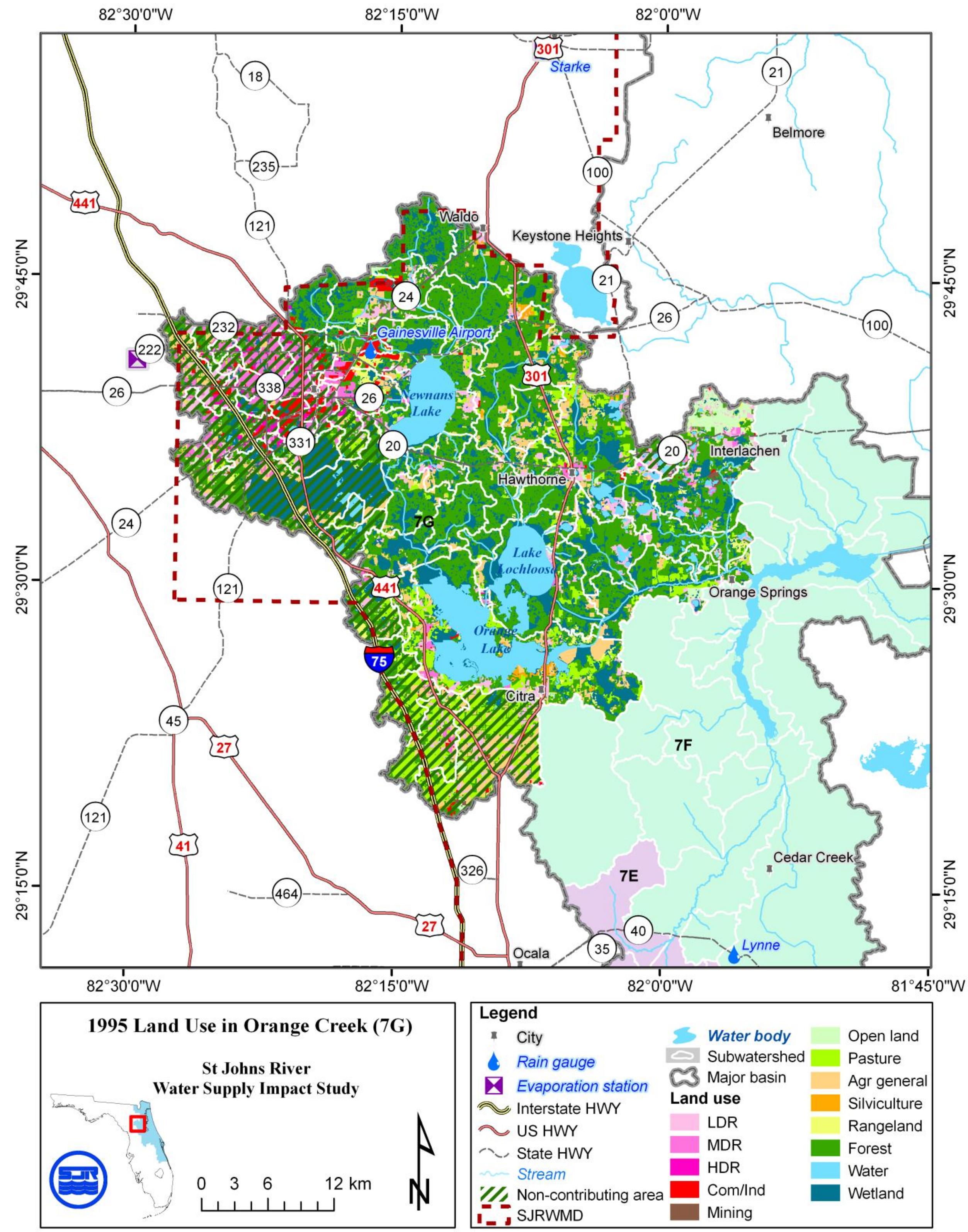

Figure 3–46. 1995 land use in Orange Creek Planning Unit (7G).

Table 3–49. Orange Creek Planning Unit (7G) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	25,179	6.5%	53,288	13.8%
Medium-density residential	16,590	4.3%	25,059	6.5%
High-density residential	2,941	0.8%	5,143	1.3%
Industrial and commercial	12,669	3.3%	23,917	6.2%
Mining	1,066	0.3%	932	0.2%
Open and barren land	6,255	1.6%	4,036	1.0%
Pasture	30,673	8.0%	26,008	6.8%
Agriculture general	23,425	6.1%	18,397	4.8%
Agriculture tree crops	2,125	0.6%	1,667	0.4%
Rangeland	7,701	2.0%	5,572	1.4%
Forest	149,589	38.9%	114,192	29.7%
Water	23,643	6.1%	23,643	6.1%
Wetlands	83,079	21.6%	83,079	21.6%
Total	384,935	100.0%	384,935	100.0%

Upper Portion of the Orange Creek Planning Unit

The subwatersheds in the upper portions of Orange Creek planning unit are underlain by limestone, or karst, topography with complex surface water–groundwater interactions. Upper Orange Creek includes broad shallow lakes, level prairies, irregular drainage patterns, and several large sinkholes. Several water bodies in the Orange Creek planning unit have been designated as Outstanding Florida Waters because of their exceptional richness of aquatic and wetland wildlife habitats.

Three major lakes—Newnans, Lochloosa, and Orange—lie within the upper portion of the Orange Creek Planning Unit. Upper Orange Creek is primarily in Alachua County to the east of Gainesville and at the westernmost edge of the St. Johns River watershed. Two surface water discharges flow from this upper marsh portion of Orange Creek into the lower creek portion of Orange Creek Planning Unit. The primary exit is from Orange Lake directly into Orange Creek. A weir located north of Citra and immediately east of US 301 controls this discharge. The second discharge is from Lochloosa Lake into Lochloosa Slough. This exit is controlled by a culvert under U.S. 301 about 3 mi north of the Orange Creek weir.

Newnans Lake discharges through Prairie Creek on the south end of the lake. The Prairie Creek discharge historically entered Paynes Prairie, where it ultimately drains to the Upper Floridan aquifer through Alachua Sink. In 1927, Camps Canal was built to divert water through the River Styx into Orange Lake so that Paynes Prairie was effectively drained to become rangeland. Different operations of this diversion have been maintained over time to meet varying management goals. For the 1995 to 2006 calibration period, about 40% of the flow from Prairie Creek discharged into Paynes Prairie and about 60% of the flow discharged through Camps Canal into Orange Lake.

Upper Orange Creek has several noncontributing areas. In addition to Paynes Prairie described above, the following basins are also considered noncontributing areas to upper Orange Creek.

- Lake Tuscawilla
- Irving Sink
- Reddick Quarry
- Hawthorne Prairie

Upper Orange Creek is dominated by large pine flatwood plantations, which are either owned or leased by major logging companies. Because of the intense and continuous logging activity, an additional land use category called forest regeneration was incorporated within the Orange Lake planning unit models. The forestland use is split 90%/10% with forest regeneration land use. The forest regeneration land use is given different model parameters than forest, but is not directly mapped. Except for the Forest Creek and Little Hatchet basins, the soils in the Orange Lake planning unit are primarily in the C and D hydrologic soil groups. The upland portions of most of the watersheds in upper Orange Creek are sand hills, which drain into expansive shallow wetland storage areas.

The Hawthorne Formation, which in most areas of Florida divides the Surficial and Floridan aquifers, is very thin and fractured in upper Orange Creek. This causes sinks and springs to occur in the basin. The largest sink in the basin is the Orange Lake Sink on the southwest side of Orange Lake. A smaller sink upstream of the stream gauge on Hatchet Creek has been observed. In addition to these two observed recharges to groundwater, recharge to groundwater was also included in the model for Newnans Lake. Groundwater recharge maps indicate that Newnans Lake has both recharge and discharge areas to the aquifer. Observed data indicates and our modeling reflects that during the drought of 2000 and 2001, Newnans Lake reached 60.86 ft NGVD29, a level well below the minimum outlet for Newnans Lake of 63.5 ft NGVD29. The most reasonable explanation for why the lake reached this elevation is that Newnans Lake recharged more water to the aquifer than it received. For this reason, the Newnans Lake subwatershed is modeled as a sink (i.e., noncontributing area).

Small springs are located in the downstream section of Lochloosa Creek. Groundwater recharge maps are similar to those for Newnans Lake and indicate that both recharge and discharge areas may occur for Lochloosa Lake. The observed data, as reflected in the model, however, indicate that Lochloosa Lake receives net discharge from the aquifer.

Lower Portion of the Orange Creek Planning Unit

Lower Orange Creek is the lower portion of the Orange Creek planning unit, which is a tributary of the lower Ocklawaha River. The 139-mi^2 (88,705-ac) area is delineated into 11 subwatersheds ranging from 907 ac to 19,121 ac. A significant portion of the lower Orange Creek subwatersheds falls within Putnam County with small portions in Alachua and Marion counties. Orange Creek is the major stream component in the watershed and it receives flow from tributaries that drain northern portions of the watershed. Cowpen Lake subwatershed is landlocked with water flow mostly occurring as groundwater discharge. Lower Orange Creek receives flow from Lochloosa Lake and Orange Lake through Orange Creek and Lochloosa

Slough, respectively. A surface water inflow to the lower Orange Creek also exists between Lake Alto and Bee Tree Creek through a culvert under US 301. This culvert allows small amounts of water to discharge from Lake Alto into Bee Tree Creek basin during high flow periods. Orange Creek eventually discharges into Rodman Reservoir, which is an impounded segment of the lower Ocklawaha River.

Topography is generally of low gradient for western portions of the watershed with an average land surface slope of less than 6%. Northeastern portions of the watershed, encompassing parts of Cabbage Creek and Cowpen Lake, have high relief topography with slopes up to 46%. Soils at the western and northern regions are classified as somewhat poorly drained to very poorly drained, while soils to the northeast are moderately well drained to excessively drained. Soil composition in the lower portion of Orange Creek Planning Unit is 38% A, 25% B, 15% C, and 17% D.

4.1.5 LOWER ST. JOHNS RIVER BASIN (3)

The LSJRB is comprised of 11 planning units encompassing 2,740 mi^2 (Figure 3–47and Table 3–51). The basin is located in northeast Florida and represents 22% of the area within SJRWMD. The LSJRB extends from Lake George to the mouth of the river at the Atlantic Ocean near Jacksonville.

Landscape features in the LSJRB are relatively low and flat. Surface elevations range from 200 ft in the western part of the basin to sea level at the mouth. The average gradient of the river is only 0.1 ft mi^{-1}. Due to this low gradient, tides affect the entire LSJRB along with the lower reaches of its tributaries, making the river an elongated, shallow estuary with an extensive floodplain. Out of the 11 planning units on the LSJRB, nine are named after long, dendritic creek systems, which flow directly into the St. Johns River. The South and North Main Stem planning units contain smaller watersheds immediately adjacent to the river with small tributaries and urban drainage.

Although the LSJRB contains the largest city by area in the country, the 1995 urban land use only represented 16% of the total area Table 3–50. However, it is projected that 2030 urban land use will cover approximately 40% of the basin.

Table 3–50. Planning units in the Lower St. Johns River Basin (3).

Planning Unit Number	Planning Unit Name	SJ97-1 Area (acres)*	Model Area (acres)
3A	Crescent Lake Planning Unit	393,209	381,058
3B	Etonia Creek Planning Unit	227,097	228,426
3C	Black Creek Planning Unit	326,939	325,312
3D	Ortega River Planning Unit	67,764	66,927
3E	Trout River Planning Unit	59,599	61,361
3F	Deep Creek Planning Unit	95,114	88,378
3G	Simile Creek Planning Unit	73,582	81,774
3H	Julington Creek Planning Unit	67,624	62,324
3I	Intracoastal Waterway Planning Unit	63,124	66,153
3J	South Main Stem Planning Unit	235,209	246,438
3K	North Main Stem Planning Unit	153,910	155,771

Source: TP SJ97-1 (Adamus, Clapp and Brown 1997)

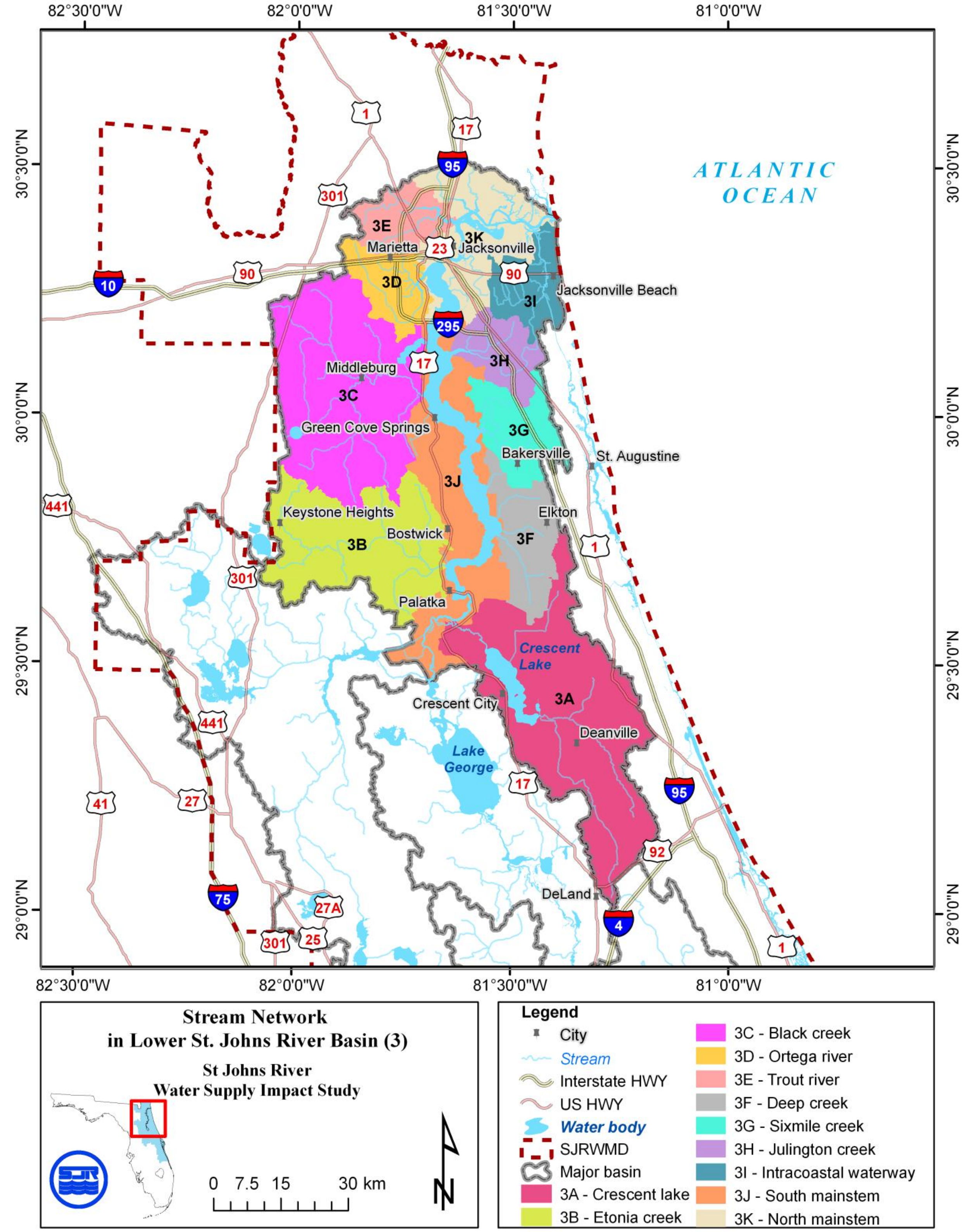

Figure 3–47. Stream network showing planning units 3A through 3K in the Lower St. Johns River Basin (3).

Table 3–51. Lower St. Johns River Basin (3) 1995 and projected 2030 land use estimates.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	85,208	5.2%	299,089	18.2%
Medium-density residential	83,795	5.1%	175,493	10.7%
High-density residential	38,235	2.3%	55,932	3.4%
Industrial and commercial	63,131	3.8%	135,678	8.3%
Mining	6,355	0.4%	4,808	0.3%
Open and barren land	38,966	2.4%	22,222	1.4%
Pasture	46,274	2.8%	29,151	1.8%
Agriculture general	91,093	5.6%	39,638	2.4%
Agriculture tree crops	3,050	0.2%	2,027	0.1%
Rangeland	53,372	3.3%	26,871	1.6%
Forest	680,231	41.5%	398,835	24.3%
Water	37,617	2.3%	37,617	2.3%
Wetlands	413,266	25.2%	413,265	25.2%
Total	1,640,593	100.0%	1,640,593	100.0%

Crescent Lake Planning Unit (3A)

The Crescent Lake planning unit is located east of the St. Johns River and east of Lake George. Its discharge point into the St. Johns River is south of San Mateo, just downstream of Murphy Island. Crescent Lake encompasses an area of 595 mi^2 and extends over parts of Putnam, Flagler, and Volusia counties. The major components of the stream flow system are Dunns Creek, Crescent Lake, and Haw Creek. Important tributaries include Middle Haw Creek, Little Haw Creek, and Black Branch. The general direction of the flow is from southeast to northwest, and the planning unit discharges ultimately through Dunns Creek into the St. Johns River at RM 139.

The planning unit has relatively low gradient topography for the most part; however, the western portions have high elevations. The elevation range is from 5.0 to 115.0 ft with topography yielding mostly 0% to 6% slopes. Soils in Crescent Lake and throughout the planning unit are moderately to very poorly drained (Bergman 1992). The Wabassa-Myakka-Felda and Meggett-Felda soil type associations dominate. Bordering Crescent Lake and along Haw Creek soils are poorly to very poorly drained and are subject to flooding.

Crescent Lake planning unit is delineated into five subwatersheds: Little Haw, Middle Haw, Haw, Dunns-Crescent, and Salt. Middle Haw Creek drains Haw Creek, which drains into Crescent Lake. Little Haw Creek and Salt Creek ditches drain directly into Crescent Lake. Water from Crescent Lake flows into Dunns Creek, which eventually discharges into the St. Johns River (Bergman 1992).

In general, wetland (34%) and forest (43%) were the dominant land use in this area in 1995 (Figure 3–48). The planning unit was relatively undeveloped in 1995 (6% urban), but has and is projected to continue to undergo significant development, resulting in approximately 25% urban land use by 2030 (Table 3–52).

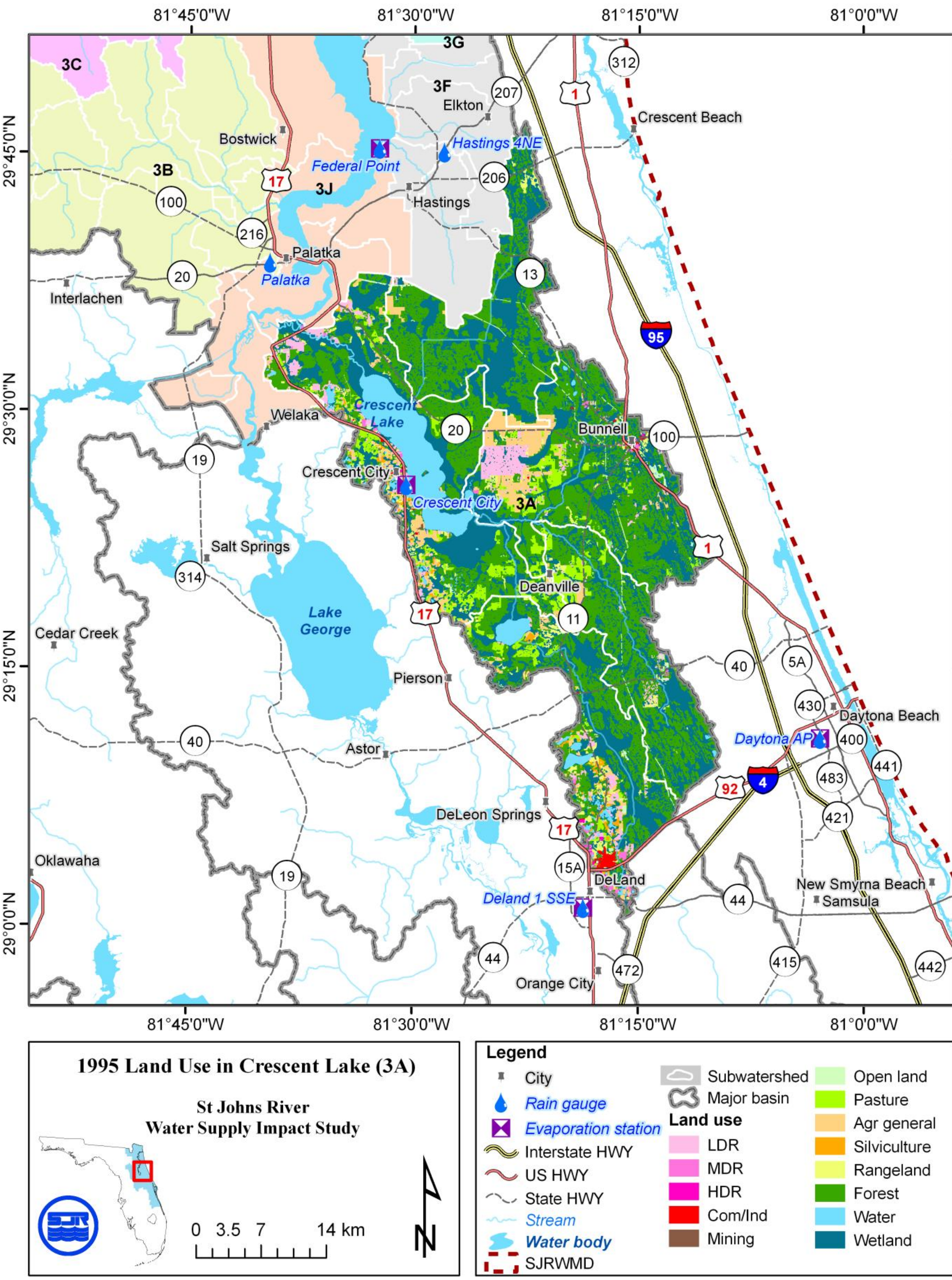

Figure 3–48. 1995 land use in Crescent Lake Planning Unit (3A).

Table 3–52. Crescent Lake Planning Unit (3A) 1995 and projected 2030 land use area.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	15,053	4.2%	71,984	19.9%
Medium-density residential	2,355	0.7%	10,523	2.9%
High-density residential	320	0.1%	680	0.2%
Industrial and commercial	2,077	0.6%	8,371	2.3%
Mining	227	0.1%	165	0.0%
Open and barren land	3,183	0.9%	1,922	0.5%
Pasture	19,601	5.4%	13,189	3.6%
Agriculture general	16,729	4.6%	9,837	2.7%
Agriculture tree crops	2,491	0.7%	1,734	0.5%
Rangeland	8,914	2.5%	5,250	1.5%
Forest	156,773	43.3%	104,069	28.7%
Water	7,094	2.0%	7,094	2.0%
Wetlands	127,211	35.1%	127,211	35.1%
Total	362,028	100.0%	362,028	100.0%

Little Haw Subwatershed

Little Haw Creek begins as far south as the City of DeLand. On its way north, it crosses various swamps, so that the streambed is not always well defined. Little Haw (3a1) is a 106- mi^2 (67,599-ac) subwatershed located south of Crescent Lake planning unit. Little Haw Creek, a tributary of Crescent Lake, drains from south to north. Topography in the subwatershed is relatively flat (slope less than 3%) in eastern portions of the creek, but has steep surfaces with slopes up to 21% to the west as it nears Crescent Lake. Forest and wetlands are the predominant land uses. Soils in the area are composed of mainly poorly drained B/D (62%) and D (19%) soils, with excessively drained A (7%) soils in southwestern portions near municipalities of DeLand and Deleon Springs. A B/D soil will respond as a B soil if a drainage system is in place, otherwise it responds as a D soil.

A USGS flow gauging station is located at the outlet of Little Haw subwatershed near Seville, downstream of Lake Disston. Flow records date from 1951 to the present. Rainfall and evapotranspiration measurements for this area are recorded at a weather station in DeLand. Long-term records (1942 to 2005) for the DeLand station show average annual precipitation of 56.5 in. (143.5 cm).

Middle Haw Subwatershed

The 83-ac Middle Haw Creek subwatershed discharges into Haw Creek. The stream flows from southeast to northwest towards Crescent Lake. Topography in the area is relatively flat with slopes averaging less than 1.5%. Forest and wetlands are the predominant land uses. The subwatershed did not have any high-density residential, industrial/commercial, or agriculture tree crops land uses in 1995. Soils in the area are composed of mainly poorly drained B/D (60%) and D (18%) soils.

A USGS flow gauging station is located upstream of the subwatershed outlet at the intersection of Middle Haw Creek and SR 11 near Korona. Flow records for this station date from 1 Jul 1975. Rainfall and evapotranspiration measurements for this area are recorded at a weather station in Daytona. The long-term record (1942 to 2005) for the Daytona station shows average annual precipitation to be 49.8 in. (126.5 cm).

<u>Etonia Creek Planning Unit (3B)</u>

The Etonia Creek planning unit is 357 mi^2 in size and is located west of the St. Johns River just north of Palatka. The majority of the watershed is contained in Putnam County. The upstream portion is on the Trail Ridge, which is a subdivision of the Sea Island District formation. The downstream portion includes Rice Creek Swamp, which is a subdivision of the Eastern Flatwoods District formation (Brooks 1982). The final segment (2 mi) of the river is named Rice Creek, but because Etonia Creek makes up most of the watershed, the entire basin is identified as Etonia Creek Basin by SJRWMD. Elevations range from about 240.00 ft NGVD29 in the west to near sea level at the confluence with the St. Johns River.

Major tributaries are Etonia Creek, Simms Creek, and Rice Creek. The headwaters of this tributary system originate on the eastern slopes of the Trail Ridge. The general flow direction is east.

A large part of the basin consists of moderately to poorly drained soils. These are of the Myakka-Wauchula-Placid association. Along Rice Creek and near its confluence with the St. Johns River, some swampy areas occur. These areas are subject to flooding. In the western headwaters, the soils are largely well drained sandy soils that seldom contribute direct runoff.

Etonia Creek planning unit is divided into 13 subwatersheds. At its outlet into the St. Johns River, the watershed area is 356.9 mi^2. Of this total, the 172 ac in Gold Head State Park containing Sheeler Lake is considered noncontributing to surface runoff and is therefore not directly modeled. Likewise, the 1,024-ac water treatment reservoir owned by Georgia Pacific contributes no runoff and is not included in the HSPF hydrologic model.

Halfmoon Lake is located in the headwaters of the Etonia Creek basin and is the largest subwatershed. Halfmoon Lake itself is downstream of a long chain of lakes. The only recorded times this subwatershed contributed runoff was in 1961 and 1973. Lake Grandin also consists of a long chain of lakes and likewise was initially judged noncontributing. However, because the wetland area between Lake Grandin and Etonia Creek has an outlet canal into Etonia Creek, the east half of the subwatershed was reconfigured to be a contributing subwatershed. The land use and soil characteristics for the whole subwatershed were cut in half with half being noncontributing and half being contributing (this is not portrayed in the figure or tables).

The 1995 land use is predominantly forest (50%) and wetlands (20%) (Figure 3–49 and Table 3–53). A minor component is low-density residential (10%) but much of this is vacant lots on dirt roads in rural areas left over from unsuccessful land development projects going back to the mid-1950s. Less than 3% of the watershed in 1995 was residential or industrial/commercial land. The amount of residential and industrial/commercial land use is expected to double by 2030, largely at the expense of forest.

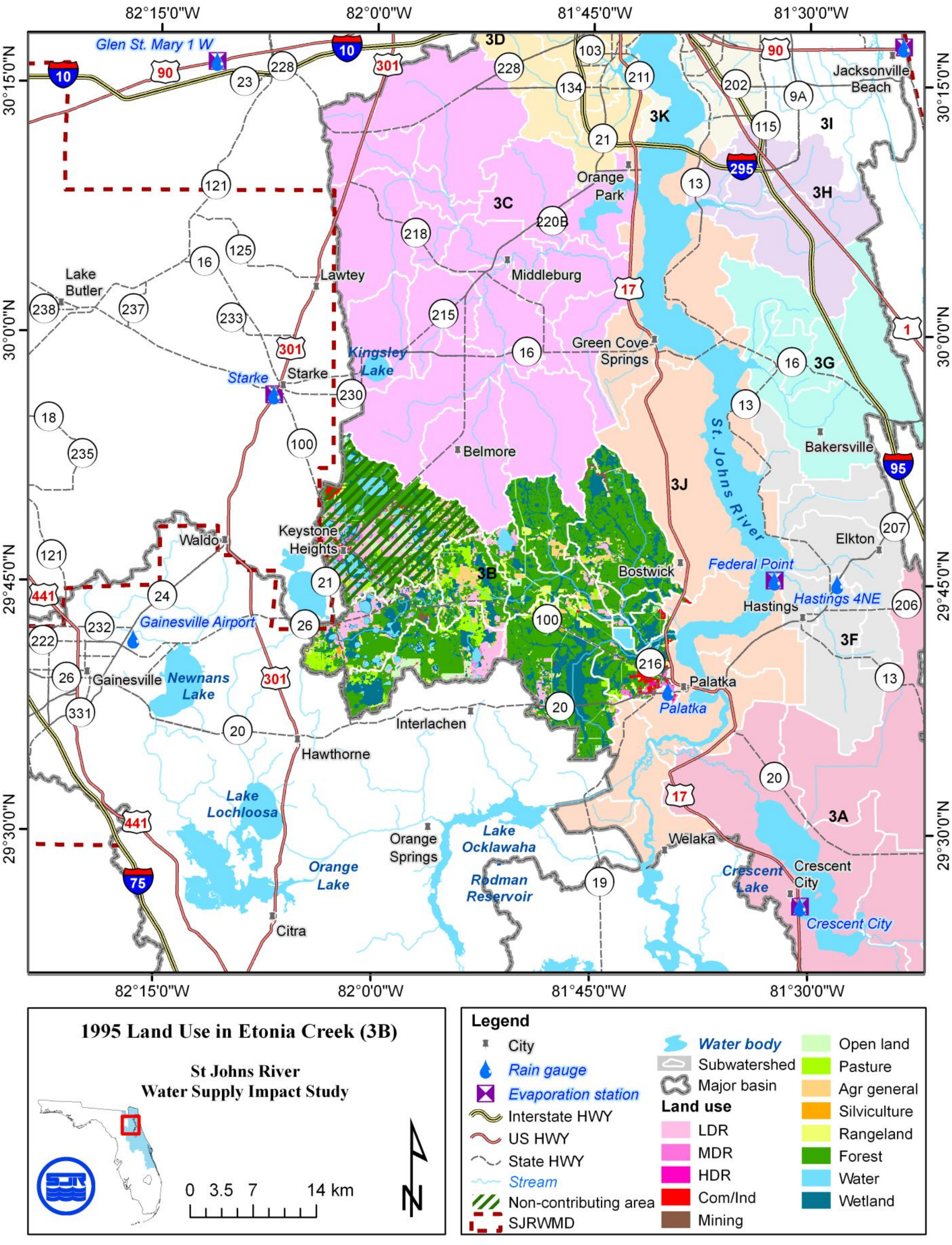

Figure 3–49. 1995 land use in Etonia Creek Planning Unit (3B).

Table 3–53. Etonia Creek Planning Unit (3B) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	22,375	9.8%	44,194	19.3%
Medium-density residential	2,897	1.3%	5,281	2.3%
High-density residential	175	0.1%	454	0.2%
Industrial and commercial	3,239	1.4%	7,478	3.3%
Mining	1,395	0.6%	1,296	0.6%
Open and barren land	6,683	2.9%	4,177	1.8%
Pasture	9,551	4.2%	7,937	3.5%
Agriculture general	5,721	2.5%	4,459	2.0%
Agriculture tree crops	228	0.1%	185	0.1%
Rangeland	8,498	3.7%	6,612	2.9%
Forest	113,055	49.5%	91,744	40.2%
Water	9,849	4.3%	9,849	4.3%
Wetlands	44,758	19.6%	44,758	19.6%
Total	228,424	100.0%	228,424	100.0%

The USGS Etonia Creek gauging station at Bardin has the largest drainage area of 219 mi^2. Annual mean discharge is 61.6 mgd (95.3 cfs); records are rated by the USGS as poor quality. The USGS Simms Creek gauging station near Bardin has a drainage area of 47.3 mi^2. Mean annual discharge is 31.7 mgd (49.0 cfs); records are rated as fair. The USGS Rice Creek gauging station near Springside has a drainage area of 43.2 mi^2. Annual mean discharge is 28.2 mgd (43.7 cfs); records are rated as fair.

The Etonia Creek gauge, as well as the downstream area of the river, is influenced by the water use of Georgia Pacific Pulp and Paper Corporation’s paper mill. The plant is located just northwest of Palatka, about 2.7 mi upstream from the confluence of Etonia and Rice creeks with the St. Johns River. It occupies 5,414 ac of land including a 27.2-ac water supply reservoir, a primary wastewater clarifier and sludge lagoon, and a 900-ac aerated stabilization basin for secondary biological wastewater treatment. Georgia Pacific Pulp and Paper Corporation has 13 water supply wells upstream of the plant that discharge into Etonia Creek or its tributaries. Overall water use in Etonia Creek planning unit is shown in Table 3–54. Etonia Creek transports the well water downstream to the plant where it is pumped out into the storage reservoir. There are six 20-in., five 12-in., and two 6-in. wells. The farthest well is 8 mi upstream of the Georgia Pacific Pulp and Paper Corporation storage reservoir. The wells are grouped into six inflow points along Etonia Creek or its tributaries. Until recently, the wells supplied over half the water needs of the plant. In 2001, however, Georgia Pacific Pulp and Paper Corporation began to implement water conservation measures that have drastically reduced the need for water.

Table 3–54. Water use in the Etonia planning unit.

Water Use	Average Monthly Flow (mgd)		
	Min	Mean	Max
1995 to 2000 (1975 to 1994 average used)			
Wells	0.00	15.83	53.67
Pumps	25.06	30.98	39.66
Rice Creek spring	1.29	1.29	1.29
2001 to 2008			
Wells	0.00	2.89	16.56
Pumps	13.53	24.47	30.02
Rice Creek spring	1.29	1.29	1.29
Projected to 2012			
Wells	–	1.30	–
Pumps	–	25.00	–

Black Creek Planning Unit (3C)

The Black Creek planning unit is located west of the St. Johns River and discharges between Green Cove Springs and Doctors Lake. The total area is approximately 508 mi^2 with elevations ranging from 250 ft south of Kingsley Lake to sea level at the confluence with the St. Johns River. The basin drains nearly all of Clay County and portions of southwestern Duval County. The basin also drains very small portions of Baker, Bradford, and Putnam counties. Physiographically, it belongs to the Duval Upland formation. The headwaters of Black Creek originate on the Trail Ridge.

Major tributaries are the North and South forks of Black Creek and Little Black Creek. The contributing areas of both forks are almost equal in magnitude: 176 mi^2 for North Fork and 141 mi^2 for South Fork. The confluence of the North and South forks is near Middleburg. From this point, Black Creek runs an additional 13 mi to the St. Johns River. Tidal effects are evident in the lower 8 mi of the North Fork and South Fork, as well as in the lower 13 mi of Black Creek. Also included in the Black Creek planning unit are the subwatersheds surrounding and contributing to Doctors Lake. Due to its wide opening to the St. Johns River, the lake is actually a low-salinity estuary and, as such, is part of the EFDC hydrodynamic model.

The North Fork of Black Creek begins at Kingsley Lake near Camp Blanding. The North Fork initially flows north and curves nearly 135 degrees to the southeast near Maxville. The average gradient of the North Fork channel is approximately 5.0 ft mi^{-1} with bank elevations ranging from 170.00 ft NGVD29 near Lake Kingsley to 10.00 ft NGVD29 near Middleburg. The North Fork continues southeast to its confluence with the South Fork.

The South Fork begins at Varnes Lake in the Camp Blanding State Wildlife Management Area. The South Fork flows north-northeast through Penney Farms and continues to its confluence with the North Fork. The average gradient of the South Fork channel is approximately 4.8 ft mi-1 with bank elevation ranging from 120.00 ft NGVD29 near Lake Varnes to 10.00 ft NGVD29 near Middleburg.

The average channel gradient of Black Creek flattens noticeably from Middleburg to the St. Johns River. It is approximately 0.5 ft mi^{-1} with bank elevations ranging from 10.00 ft NGVD29 at Middleburg to less than 5.00 ft NGVD29 at the outfall to the St. Johns River.

Landscape features within the Black Creek planning unit range from relatively low and flat in the far northern portion of the basin to moderate slopes in the southern portion of the basin. Ground slopes are as low as 0.1% in the northern area and as high as 5% in the southern area. Surface elevations range from 5.00 ft NGVD29 at the outfall to the St. Johns River to greater than 200.00 ft NGVD29 in the westernmost part of the basin on the Trail Ridge. The average slopes around surface water features are approximately 0.6%. Isolated slopes near streams may be as high as 10%.

For the most part, soils in the basin belong to the Mascotte-Leon-Surrency and the Alpon-Blanton series, although other types are also present. Grouped by Hydrologic Soil Group there are 17% A soils, 35% B/D soils, 24% C soils, and 17% D soils in the basin.

The largest land uses in the basin are forest (58%) and wetlands (19%) (Figure 3–50. Urban land uses are expected to triple from 1995 levels of 12% to over 37% by 2030 (Table 3–55).

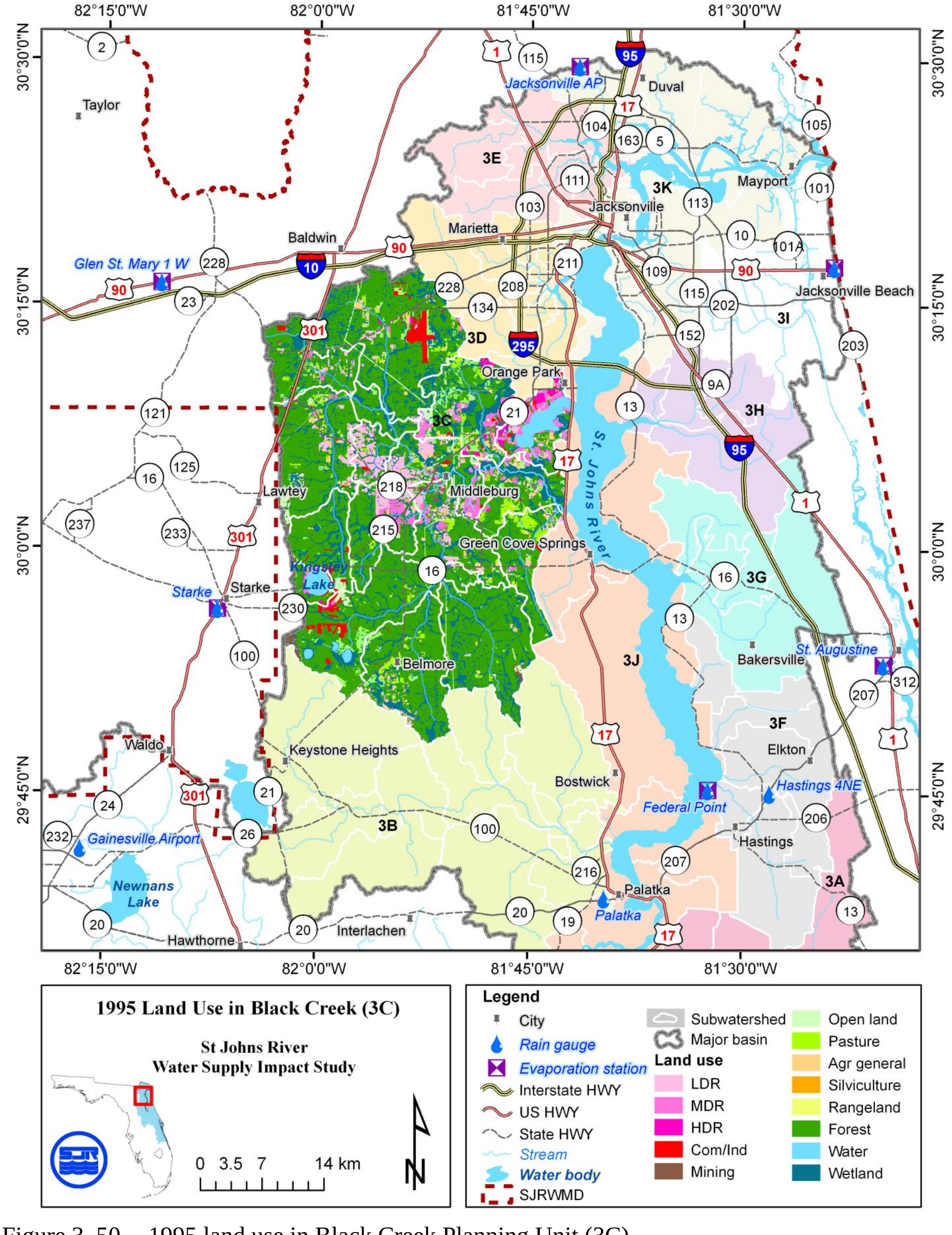

Figure 3–50. 1995 land use in Black Creek Planning Unit (3C).

Table 3–55. Black Creek Planning Unit (3C) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	17,810	5.5%	68,022	21.1%
Medium-density residential	12,419	3.9%	16,895	5.3%
High-density residential	2,069	0.6%	6,951	2.2%
Industrial and commercial	7,055	2.2%	27,824	8.7%
Mining	2,173	0.7%	1,628	0.5%
Open and barren land	5,189	1.6%	2,841	0.9%
Pasture	7,568	2.4%	4,011	1.2%
Agriculture general	4,831	1.5%	2,139	0.7%
Agriculture tree crops	71	0.0%	33	0.0%
Rangeland	9,653	3.0%	4,683	1.5%
Forest	186,363	57.9%	120,173	37.4%
Water	4,661	1.4%	4,661	1.4%
Wetlands	61,786	19.2%	61,786	19.2%
Total	321,648	100.0%	321,648	100.0%

Ortega River Planning Unit (3D)

The Ortega River planning unit is west of the St. Johns River and includes the southwest area of metropolitan Jacksonville and adjacent semirural areas, including a small part of Clay County. It encompasses approximately 104 mi^2. The Ortega River begins about 90 fasl at its headwaters and runs a distance of 23.5 mi before discharging into the St. Johns River. The lower 10 mi of the river is almost flat. The upper 13 mi of the watershed is also flat, hovering around 85 ft, but the river channel cuts rather sharply through this area as it drops to the low-lying coastal area. The lower third of the watershed levels off at around 25.00 ft NGVD29 and tapers off to sea level along the tidal Ortega River estuary. The tidal interface for the Ortega River is at Collins Road (about 0.5 mi downstream of I-295), while the tidal interface for Cedar River is at Lane Avenue (just over 2 mi upstream of SR 21)(Camp, Dresser, and McKee Inc. 1989).

The watershed is separated into 10 subwatershed basins. Major tributaries are Fishing Creek, McGirts Creek, Cedar River, Butcher Pen Creek, and Wills Branch (Camp, Dresser, and McKee Inc. 1989). Big Fishweir Creek drains at the mouth of the Ortega River. The headwaters of McGirts Creek originate in the St. Marys Upland, which is a physiographic subdivision of the Duval Upland. McGirts Creek, which eventually becomes the Ortega River, flows southeast before crossing Blanding Boulevard (SR 21) then flows north-northeast. The flow direction of Cedar River, the largest tributary of the Ortega River, is predominantly southeast. Wills Branch, Butcher Pen Creek, and Fishing Creek are tributaries of Cedar River. The 1995 land use and Soil Survey Geographic (SSURGO) soil maps are used to characterize the watershed (Figure 3–51). The area is largely urbanized, with most of the urban area drained by Cedar River.

Surface water area is normally part of the Reach/Reservoir (RCHRES) routing module, but the estuary EFDC hydrodynamic model extends into the Ortega watershed. That surface area of the

EFDC estuary model is included in the accounting of the total surface water area within the watershed but is not included in the HSPF hydrologic model.

Soils in the basin belong to the following soil groups: Pelham-Mascotte-Sapelo, Leon-Ortega, and Leon-Ridgeland-Wesconnett. The three largest hydrologic soil groups are 46% B/D soils, 17% C soils, and 13% D soils. Most of the watershed west of I-295 consists of Leon-Ridgeland-Wesconnett soils (Stem, et al. 1978).These nearly level, poorly drained soils are sand throughout. Elevations are mostly in the 60 to 90 ft range. The area east of I-295 consists of Pelham-Mascotte-Sapelo soils. These nearly level, poorly drained soils are sandy to a depth of 20 in. or more and are loamy below that. Elevations are generally around 25.00 ft NGVD29. Between these two areas, where the land slopes rather sharply, are a few areas of moderately drained sandy soils of the Leon-Ortega classification. The lower Ortega River floodplain consists of Wesconnett-Maurepas-Stockade soils. These are level, very poorly drained soils that may be sandy, loamy, or organic. This poorly drained soil exists due to the high water table and flat terrain.

The four urban land uses cover 50% of the watershed with medium-density residential being the largest land use (Figure 3–51). Forest, wetlands, and rangeland together cover 40% of the watershed. Urban land use is projected to increase by about 25% from 1995 to 2030, consistent with other developing areas in SJRWMD (Table 3–56).

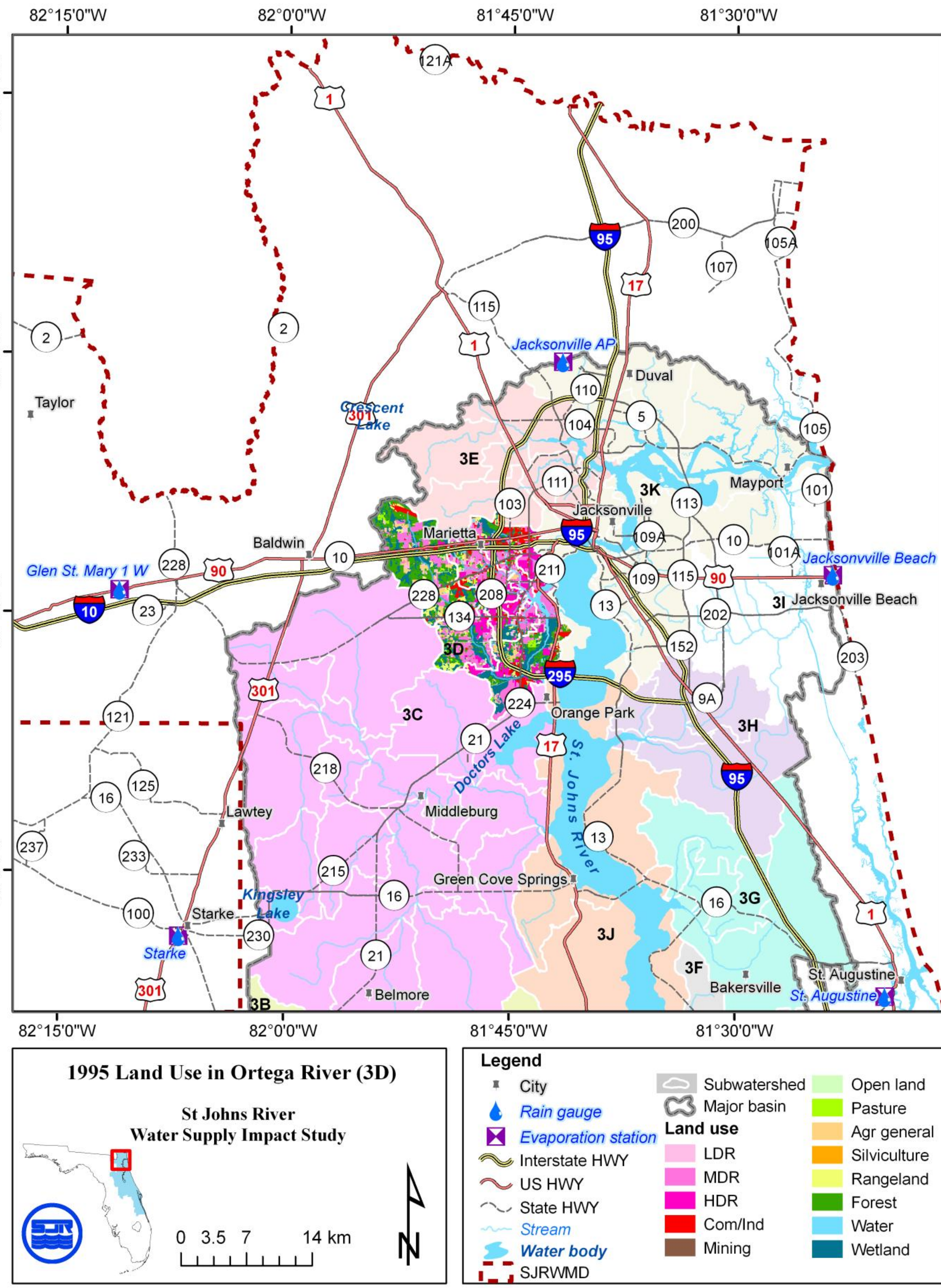

Figure 3–51. 1995 land use in Ortega River Planning Unit (3D).

Table 3–56. Ortega River Planning Unit (3D) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	2,381	3.6%	5,419	8.2%
Medium-density residential	13,144	19.9%	20,533	31.1%
High-density residential	8,742	13.3%	10,867	16.5%
Industrial and commercial	8,643	13.1%	12,609	19.1%
Mining	173	0.3%	68	0.1%
Open and barren land	1,360	2.1%	439	0.7%
Pasture	836	1.3%	87	0.1%
Agriculture general	2,452	3.7%	461	0.7%
Agriculture tree crops	15	0.0%	2	0.0%
Rangeland	2,745	4.2%	495	0.7%
Forest	12,598	19.1%	2,117	3.2%
Water	1,108	1.7%	1,109	1.7%
Wetlands	11,774	17.8%	11,774	17.8%
Total	65,971	100.0%	65,971	100.0%

Trout River Planning Unit (3E)

The Trout River lies west of the St. Johns River and flows in at the point where the St. Johns River turns east toward the Atlantic Ocean (Camp, Dresser, and McKee Inc. 1989). The total Trout River drainage area is approximately 94 mi^2. Elevations range from near sea level to about 100.00 ft NGVD29. The basin is heavily influenced by tidal fluctuations. It belongs to the Dinsmore Plain, which is a physiographic subdivision of the Northern Coastal Strip. Major tributaries are Little Trout River, Moncrief Creek, Ribault River, Sixmile Creek, Blockhouse Creek, West Branch, Half Creek, and Gulley Branch.

Soil types in the basin belong to the Leon-Ridgeland-Wesconnett series or to the Pelham-Mascotte-Sapelo series. The basin average hydrologic soil groups are 11% A soils, 13% B soils, and 76% D soils (Camp, Dresser, and McKee Inc. 1989).

HSPF hydrologic model parameters applied within the Trout River planning unit are obtained from the calibrated Ortega River model.

The 1995 land uses were urban (36%) and agricultural (Figure 3–52) with more residential, industrial, and commercial development (68%) expected in the future (Table 3–57).

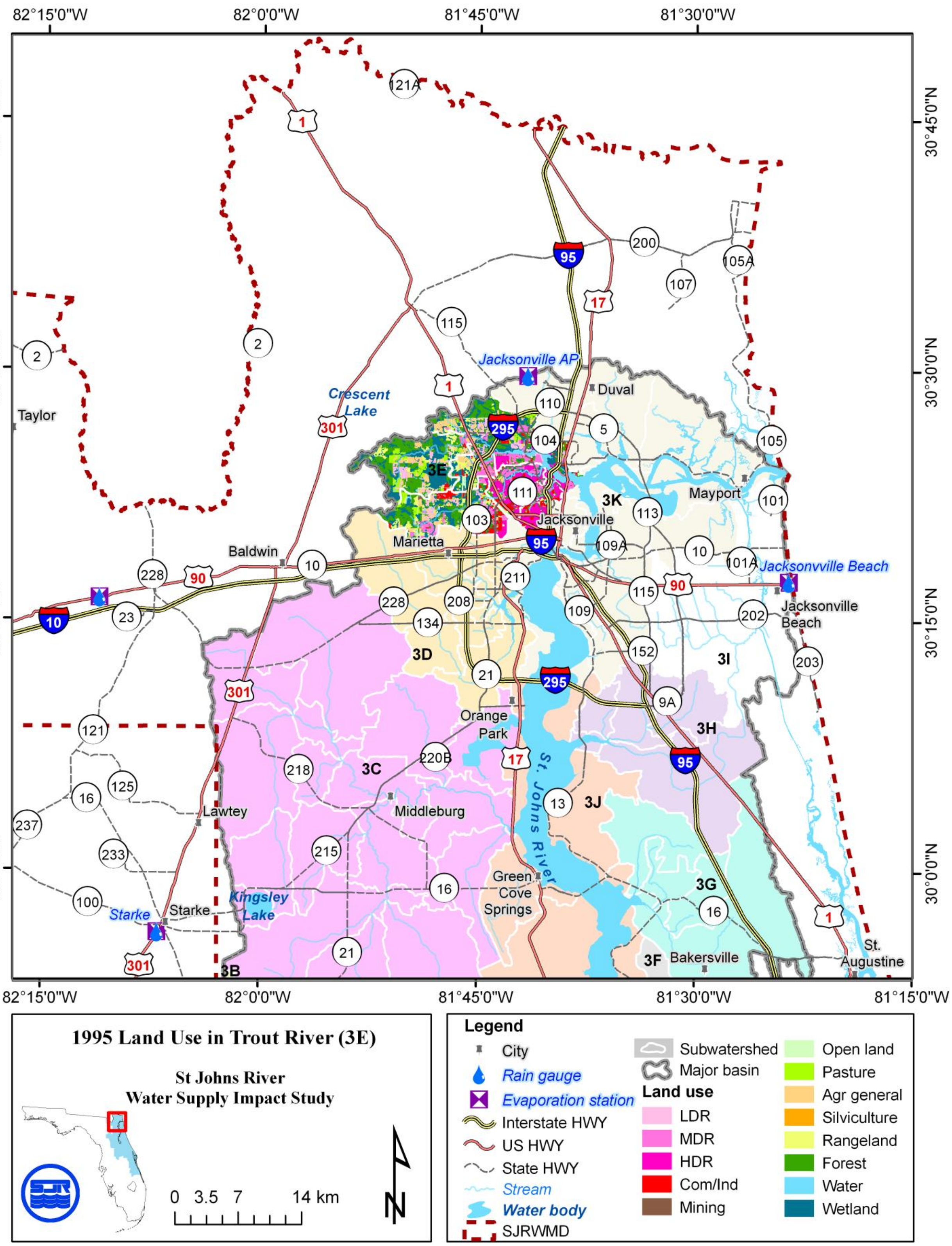

Figure 3–52. 1995 land use in Trout River Planning Unit (3E).

Table 3–57. Trout River Planning Unit (3E) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	4,259	7.1%	10,352	17.3%
Medium-density residential	5,513	9.2%	11,742	19.6%
High-density residential	6,356	10.6%	8,561	14.3%
Industrial and commercial	5,617	9.4%	10,283	17.2%
Mining	130	0.2%	71	0.1%
Open and barren land	1,635	2.7%	636	1.1%
Pasture	2,258	3.8%	342	0.6%
Agriculture general	3,799	6.3%	623	1.0%
Agriculture tree crops	3	0.0%	2	0.0%
Rangeland	3,501	5.9%	684	1.1%
Forest	12,956	21.6%	2,730	4.6%
Water	1,143	1.9%	1,143	1.9%
Wetlands	12,676	21.2%	12,676	21.2%
Total	59,846	100.0%	59,846	100.0%

Deep Creek Planning Unit (3F)

The Deep Creek planning unit is located east of the St. Johns River and almost entirely in St. Johns County (Adamus, Clapp and Brown 1997). Elevations range from approximately 30.00 ft NGVD29 in the eastern part of the basin to near sea level at the mouth. The boundary delineation has been updated and is 88,380 ac (76 mi^2). The watershed is separated into seven subwatershed basins. The Deep Creek watershed includes several independent drainage systems: Tocoi Creek, McCullough Creek, and Moccasin Branch. Each has its own outlet into the lower St. Johns River.

The soils are predominantly poorly drained with 63% of the soils grouped into the B/D hydrologic soil group, 20% classified within the C/D hydrologic soil group, and 14% classified within the D hydrologic soil group.

The 1995 land use and SSURGO soil maps are used to characterize the watershed. The three largest land covers in 1995—forest, agriculture, and wetlands—cover 83% of the watershed area (Figure 3–53 and Table 3–58). The fourth largest land cover was open and barren land, which lies entirely within the Sixteenmile Creek subwatershed and covers 35% of that subwatershed. This area is more accurately identified as an unfinished residential development. There are roads and improved drainage with very few cleared lots; the vast majority of the area remains forested. This watershed is in a rapidly developing bedroom community area for the City of Jacksonville, and low and medium-density residential development is projected to increase to nearly 50% of the watershed area by 2030 (Table 3–58).

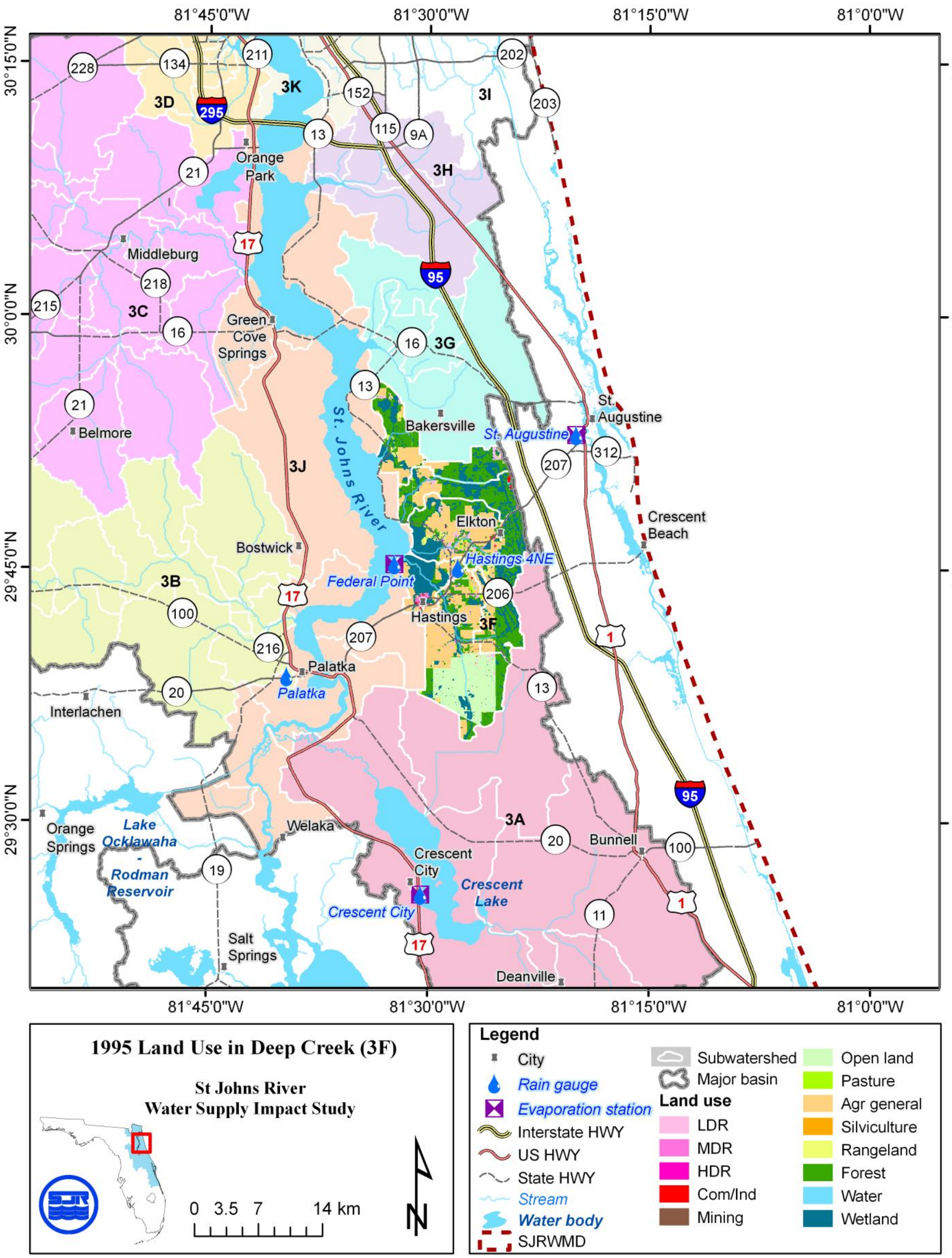

Figure 3–53. 1995 land use in Deep Creek Planning Unit (3F).

Table 3–58. Deep Creek Planning Unit (3F) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	2,540	2.9%	22,608	25.6%
Medium-density residential	452	0.5%	20,931	23.7%
High-density residential	7	0.0%	284	0.3%
Industrial and commercial	438	0.5%	3,669	4.2%
Mining	0	0.0%	0	0.0%
Open and barren land	9,583	10.9%	6,454	7.3%
Pasture	237	0.3%	61	0.1%
Agriculture general	25,378	28.8%	6,494	7.4%
Agriculture tree crops	8	0.0%	1	0.0%
Rangeland	1,485	1.7%	207	0.2%
Forest	26,096	29.6%	5,516	6.3%
Water	418	0.5%	418	0.5%
Wetlands	21,525	24.4%	21,525	24.4%
Total	88,167	100.0%	88,167	100.0%

Sixmile Creek Basin Planning Unit (3G)

The Sixmile Creek planning unit is located in St. Johns County and has a total area of approximately 122 mi^2. It belongs to the Hastings Plain, which is a physiographic subdivision of the Palatka Anomalies.

Sixmile Creek is the major tributary in the basin; Mill Creek, Trout Creek, and Turnbull Ward Creek are other important tributaries. Trout Creek and Sixmile Creek join the St. Johns River independently, approximately 50 mi from the mouth. Mill Creek and Turnbull Ward Creek, on the other hand, are tributaries of Sixmile Creek.

Drainage of the soils is generally poor. Elevation of the land is less than 25.00 ft NGVD29. Soils belong to the Tavares-Leon association, which are well to poorly drained soils, not subject to flooding. Near the mouth of Sixmile Creek are swamps, which drain very poorly and are subject to prolonged flooding.

HSPF hydrologic model parameters applied within the Sixmile Creek Basin are obtained from the calibrated Deep Creek model.

Land use in 1995 was primarily related to agricultural production and forest (Figure 3–54). Row crop farming occurs along Sixmile Creek and forest is dominant in the eastern part of the basin. Urban land use is projected to increase to over 30% of the basin by 2030 (Table 3–59).

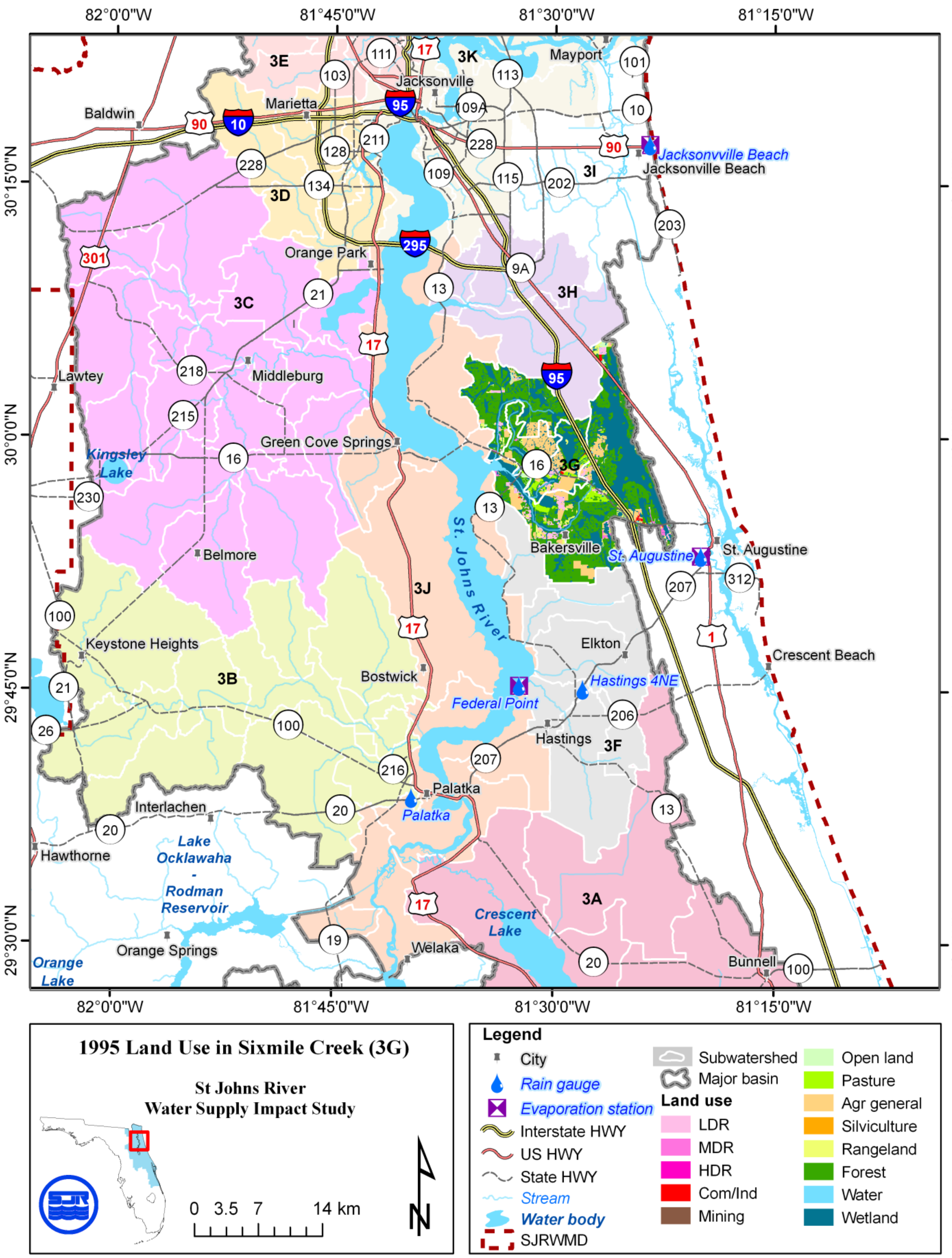

Figure 3–54. 1995 land use in Sixmile Creek Planning Unit (3G).

Table 3–59. Sixmile Creek Planning Unit (3G) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	2,933	3.6%	8,806	10.8%
Medium-density residential	537	0.7%	12,189	15.0%
High-density residential	2	0.0%	600	0.7%
Industrial and commercial	958	1.2%	3,016	3.7%
Mining	5	0.0%	0	0.0%
Open and barren land	560	0.7%	416	0.5%
Pasture	1,895	2.3%	1,286	1.6%
Agriculture general	9,055	11.1%	4,254	5.2%
Agriculture tree crops	0	0.0%	0	0.0%
Rangeland	2,184	2.7%	1,548	1.9%
Forest	34,461	42.3%	20,475	25.1%
Water	443	0.5%	443	0.5%
Wetlands	28,421	34.9%	28,421	34.9%
Total	81,454	100.0%	81,454	100.0%

Julington Creek Planning Unit (3H)

The Julington Creek planning unit is located on the eastern side of the St. Johns River and extends over the southern part of Duval County and the northern part of St. Johns County. The drainage area is approximately 97 mi^2. Elevations are near sea level at the confluence with the St. Johns River and 30.00 ft NGVD29 to the east.

Major tributaries are grouped into five subwatersheds: Durbin Creek, Big Davis Creek, upper and lower Julington Creek, and Oldfield Creek. The headwaters of Julington Creek and Pottsburg Creek are hydraulically connected via Pottsburg Creek Swamp. During larger storm events, flow from the Pottsburg Creek could cross the ridge into the Julington Creek subwatershed. In a similar way, a hydraulic connection exists between Big Davis Creek and Pablo Creek in the neighboring Intracoastal Waterway Basin (Camp, Dresser, and McKee Inc. 1989). Interconnections also exist between Julington Creek basin and Sixmile Creek basin via Sampson Creek and Twelvemile Swamp (Camp, Dresser, and McKee Inc. 1989). Tidal effects in the watershed extend to approximately 1 mi upstream of the confluence with Durbin Creek. Hydrologic soil group percentages are as follows: 6% A soils, 8% B soils, 15% C soils, and 72% D soils.

The Julington Creek HSPF hydrologic model was calibrated with 1995 to 2006 data from the USGS Big Davis Creek gauge station located at the downstream end of the culvert on US 1. Big Davis Creek begins in a wetland east of US 1 and extends to the west toward Julington Creek. The total contributory drainage area is 13.6 mi^2 at the gauge site, and the mean annual discharge from1995 to 2006 is 7.4 mgd (11.4 cfs).

The 1995 land use shows 42% forest, 35% water/wetlands, and a combination of 17% urban and industrial and commercial land use (Figure 3–55). Urban land use is projected to increase to 56% of the basin by 2030, primarily from forest (Table 3–60).

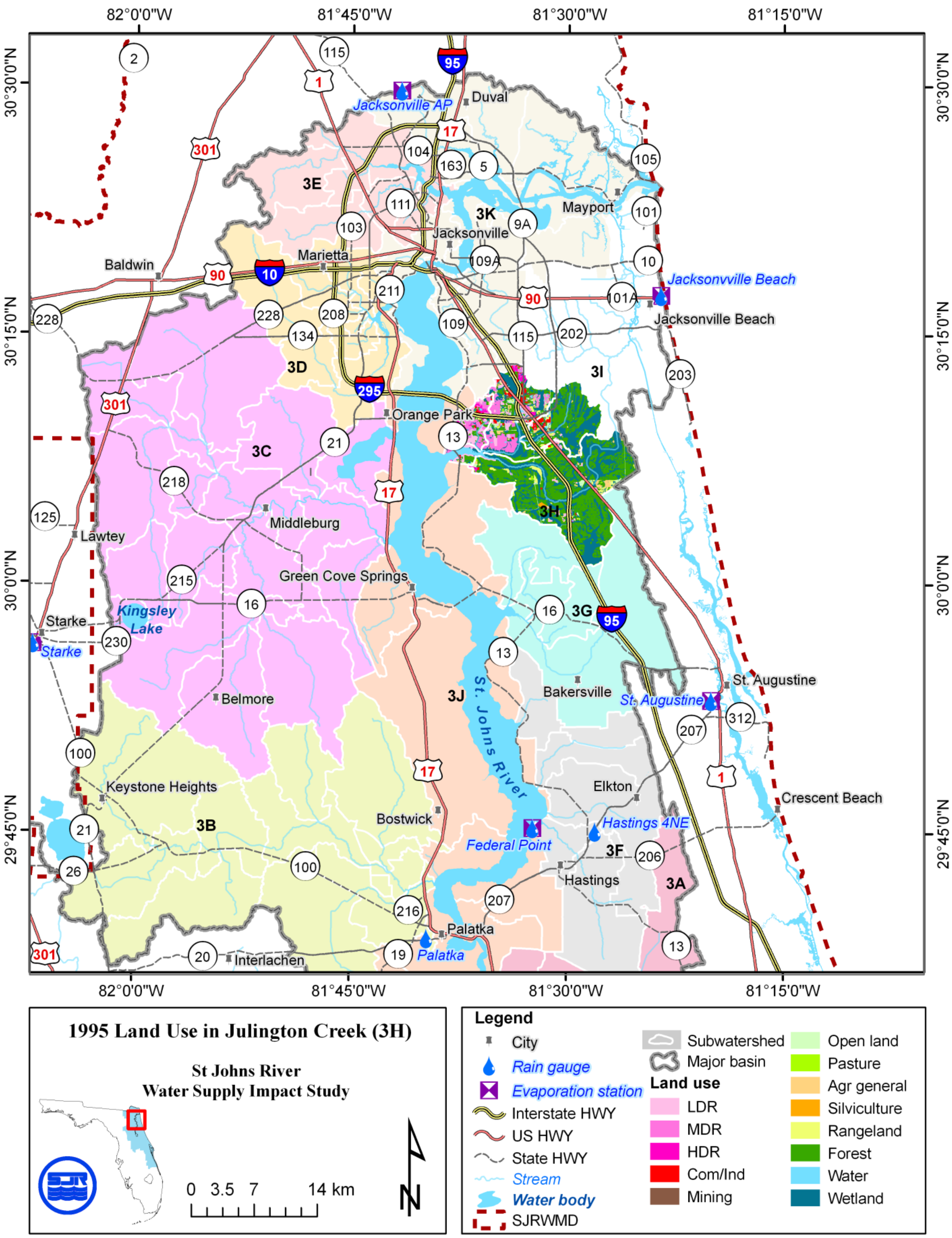

Figure 3–55. 1995 land use in Julington Creek Planning Unit (3H).

Table 3–60. Julington Creek Planning Unit (3H) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	3,049	4.9%	11,116	17.9%
Medium-density residential	4,018	6.5%	12,197	19.6%
High-density residential	965	1.6%	2,607	4.2%
Industrial and commercial	2,658	4.3%	9,136	14.7%
Mining	110	0.2%	18	0.0%
Open and barren land	1,034	1.7%	233	0.4%
Pasture	200	0.3%	31	0.0%
Agriculture general	1,082	1.7%	206	0.3%
Agriculture tree crops	125	0.2%	5	0.0%
Rangeland	1,401	2.3%	279	0.4%
Forest	25,997	41.9%	4,839	7.8%
Water	1,430	2.3%	1,430	2.3%
Wetlands	20,024	32.2%	20,024	32.2%
Total	62,093	100.0%	62,093	100.0%

Intracoastal Waterway Planning Unit (3I)

The Intracoastal Waterway planning unit is located in eastern Duval County and south of the St. Johns River outlet at the Atlantic Ocean. The total acreage is 102 mi^2 excluding the EFDC estuary model area. According to the stream network and flow pattern, the basin is divided into two segments: the Pablo Creek subwatershed and the Intracoastal Waterway subwatershed, which are west and east of the Intracoastal Waterway, respectively.

No applicable gauged discharge data were available for calibration of the surface runoff simulated by the Intracoastal Waterway basin HSPF hydrologic model. The calibrated HSPF hydrologic model parameters from Pablo Creek subwatershed were applied to the Intracoastal Waterway HSPF hydrologic model using rainfall and evaporation data from Jacksonville Beach. Jacksonville Beach rainfall and evaporation stations were used because of their proximity with the understanding that the coastal meteorology is not the best choice for an inland watershed. In August 1995, Jacksonville Beach had 30 in. of rainfall, which may have been from very localized storms. The HSPF hydrologic model calibration period was from October 1995 to September 2002. The Pablo Creek gauge station was discontinued after that.

Pablo Creek is a dendritic tributary basin. The Pablo Creek Basin is west of the Intracoastal Waterway with a total area of 49 mi^2. The USGS Pablo Creek gauge station is located 0.5 mi upstream of Cedar Swamp Creek, 4.8 mi upstream from the mouth, and 12.5 mi southeast of Main Street Bridge in Jacksonville. This gauge station measures the storm water from the 27 mi^2 drained by Puncheon Swamp Branch, Mill Dam Branch, Sawmill/Buckhead Branch, and Ryals Swamp subwatersheds. Box Branch and Cedar Swamp enter Pablo Creek downstream of the gauge station.

The Intracoastal Waterway subwatershed is located to the east of and discharges directly into the Intracoastal Waterway. The Intracoastal Waterway has 10 tributaries. Stage-area-storage relationships (FTABLEs) for the reaches of Sherman Creek, Hopkins Creek, Hogpen Creek, and Open Creek were derived from the detailed hydraulic properties of the major channels (Camp, Dresser, and McKee Inc. 1992). The six remaining tributaries are scattered along the Intracoastal Waterway, do not have well-defined channels, and drain directly into the nearby estuary. The stormwater runoff from these subwatersheds was modeled by totaling the sum of the HSPF hydrologic model simulated runoff from pervious and impervious land surfaces.

The 1995 land use distribution in the Intracoastal Waterway basin includes 32% forest, 26% wetlands, and a combination of 20% residential and other urban land uses (Figure 3–56 and Table 3–61). The entire basin had slightly higher forest (42%) and wetland (30%) percentages than those at the calibration site. For the 2030 future land use coverage, the percentage of forest and rangeland decrease as urban land uses increases to 60% of the basin (Table 3–61).

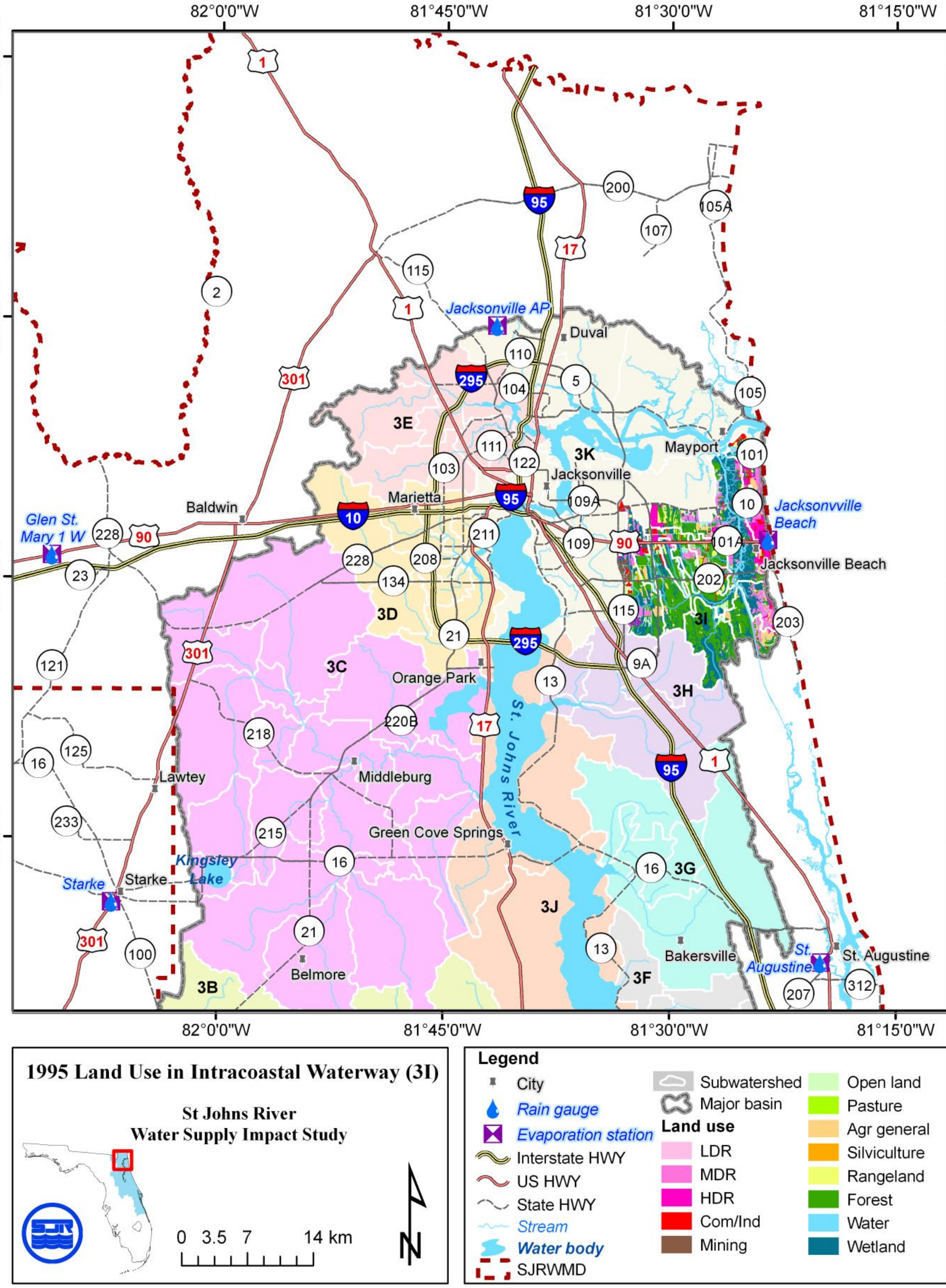

Figure 3–56. 1995 land use in Intracoastal Waterway Basin Planning Unit (3I)

Table 3–61. Intracoastal Waterway Basin Planning Unit (3I) 1995 and projected 2030 land use comparison

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	868	1.4%	9,063	14.4%
Medium-density residential	6,345	10.1%	11,988	19.1%
High-density residential	5,038	8.0%	7,628	12.1%
Industrial and commercial	3,981	6.3%	9,210	14.7%
Mining	491	0.8%	321	0.5%
Open and barren land	2,386	3.8%	681	1.1%
Pasture	230	0.4%	38	0.1%
Agriculture general	2,638	4.2%	906	1.4%
Agriculture tree crops	0	0.0%	0	0.0%
Rangeland	2,073	3.3%	503	0.8%
Forest	20,192	32.1%	3,906	6.2%
Water	2,395	3.8%	2,395	3.8%
Wetlands	16,210	25.8%	16,210	25.8%
Total	62,847	100.0%	62,847	100.0%

South Main Stem Planning Unit (3J)

This planning unit is the collection of streams and creeks in the lower St. Johns River that are not included in other tributary basins and that drain directly into the St. Johns River up to I-295. The St. Johns River covers 25% of the total area (97 mi^2), which is entirely modeled by the EFDC estuary model and is subtracted from the water land use category. The HSPF modeled area is 288 mi^2.

The small streams discharging directly into the St. Johns River are Deep Bottom Creek, Governor Creek, Clarkes Creek, Cedar Creek, Camp Branch, Mill Branch, Dog Branch, and Tocoi Creek. The predominant soil type is D (65%). Because no suitable discharge gauge stations were available for HSPF hydrologic model calibration, the calibrated HSPF hydrologic modeling parameters from Julington Creek were applied to the HSPF hydrologic model for south main stem tributaries on the east side of the St. Johns River. On the west side of the St. Johns River, rainfall and evapotranspiration data from Federal Point were applied to the northern three subwatersheds, and Palatka rainfall and Crescent City evapotranspiration data were used for the southern three subwatersheds.

The predominant 1995 land uses were forest and wetlands (Figure 3–57 and Table 3–62). Urban land use is projected to increase from 18% in 1995 to 46% in 2030 (Table 3–62).

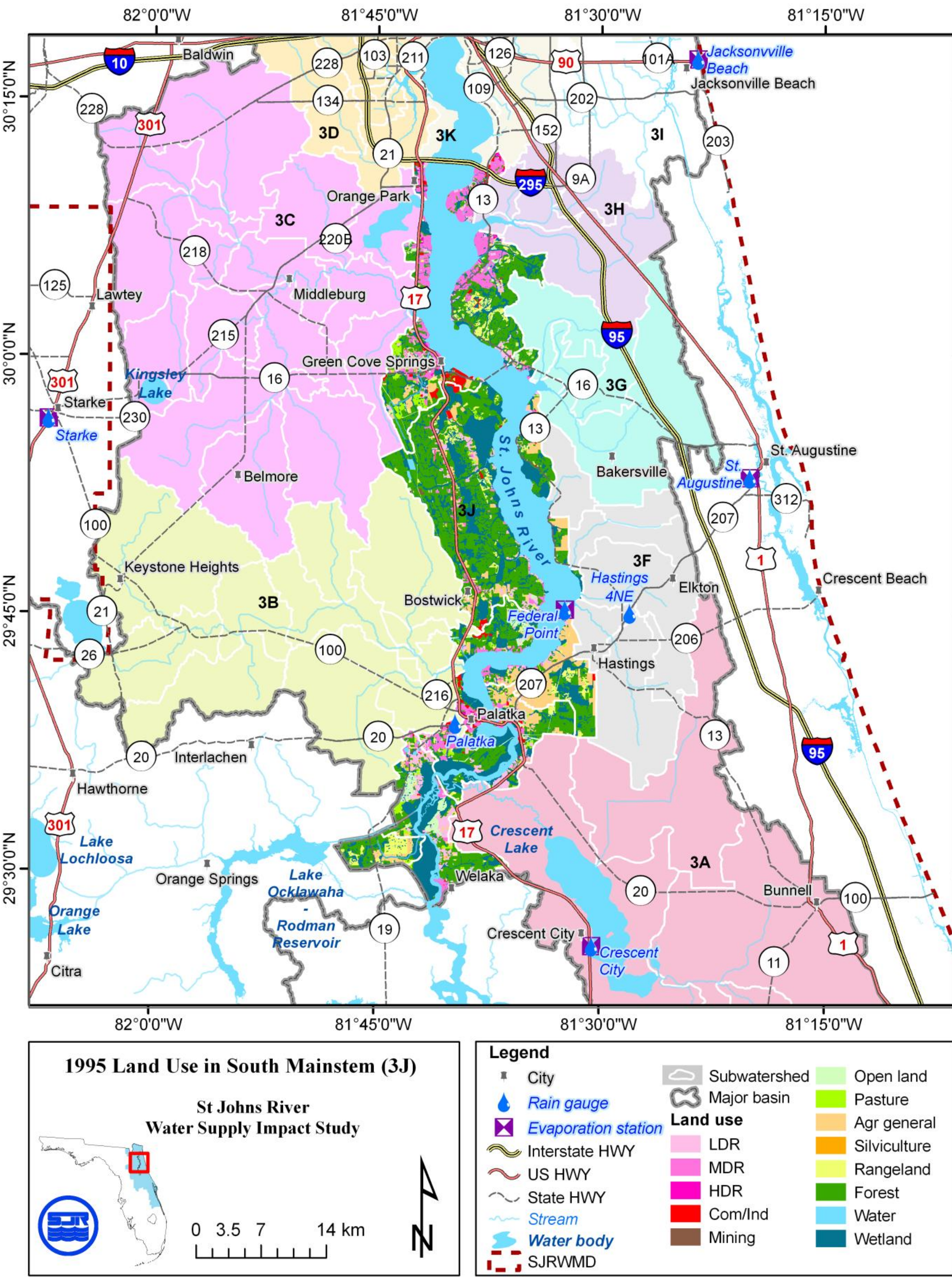

Figure 3–57. 1995 land use in South Main Stem Planning Unit (3J).

Table 3–62. South Main Stem Planning Unit (3J) 1995 and projected 2030 land use comparison

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	10,923	5.9%	42,134	22.9%
Medium-density residential	15,392	8.4%	25,326	13.7%
High-density residential	576	0.3%	1,662	0.9%
Industrial and commercial	5,426	2.9%	15,028	8.2%
Mining	289	0.2%	267	0.1%
Open and barren land	4,031	2.2%	2,452	1.3%
Pasture	3,070	1.7%	1,914	1.0%
Agriculture general	15,961	8.7%	8,207	4.5%
Agriculture tree crops	100	0.1%	58	0.0%
Rangeland	8,159	4.4%	4,148	2.3%
Forest	70,220	38.1%	32,952	17.9%
Water	3,755	2.0%	3,755	2.0%
Wetlands	46,315	25.1%	46,315	25.1%
Total	184,217	100.0%	184,217	100.0%

North Main Stem Planning Unit (3K)

The North Main Stem Planning Unit consists of 243 $mi^2$and is grouped into eight segments according to the stream network and topography. Twenty percent of the area (51 mi^2) is the St. John River itself, which is modeled by the EFDC hydrodynamic estuary model and subtracted from the areas contributing to the HSPF hydrologic model.

According to the hydrologic soil mapping, approximately 52% of the soils belong to the soil group D, and the remaining soil consists of 15% soil group A, 19% soil group B, and 15% soil group C.

Jacksonville Airport rainfall and evapotranspiration data were used for calibrating all subwatersheds except for Dunn Creek subwatershed, which was calibrated with Jacksonville Beach rainfall and evapotranspiration data.

In 1995, just over one-third of the land use in this planning unit, mostly north of the St. Johns River, is wetlands and forest (Figure 3–58 and Table 3–63). The developed portion is mostly medium-density residential, high-density residential, and industrial and commercial land use. An increase to 63% is projected for urban land use in 2030 (Table 3–63).

St. Johns River North Main Stem Subwatershed

This subwatershed includes the collection of streams and creeks that drain directly to the St. Johns River from I-295 to the Atlantic Ocean. The St. Johns River covers 46 of the 77 mi^2 of water land use acreage in the basin. Besides a higher industrial and commercial land use (13%), the remaining area is rather evenly distributed among residential, agricultural, and other land uses.

Elevations range from near sea level to nearly 30.00 ft NGVD29. The basin includes many of the urbanized streams and ditches of downtown Jacksonville, such as Hogan Creek, Long Branch, Deer Creek, Big Fishweir Creek, Little Fishweir Creek, Christopher Creek, Craig Creek, and Miller Creek.

Arlington River Subwatershed

The Arlington River subwatershed is located east of the St. Johns River in the City of Jacksonville. It covers approximately 36 mi^2 with elevations ranging from 70.00 ft NGVD29 to sea level (Camp, Dresser, and McKee Inc. 1989). Physiographically, it belongs to the Northern Coastal Strip. The Arlington River discharges into the St. Johns River at RM 21.5 and is more characteristic of an estuary than a river. Its tributary system consists of Pottsburg Creek Little Pottsburg Creek, Strawberry Creek, and Red Bay Branch. The tides affecting Pottsburg Creek extend as far as Beach Boulevard (US 90) in Jacksonville. The headwaters of Pottsburg Creek are hydraulically connected with the headwaters of Julington Creek via the Pottsburg Creek Swamp. Outside of some wetlands at the headwaters of Arlington River, this subwatershed is largely urbanized.

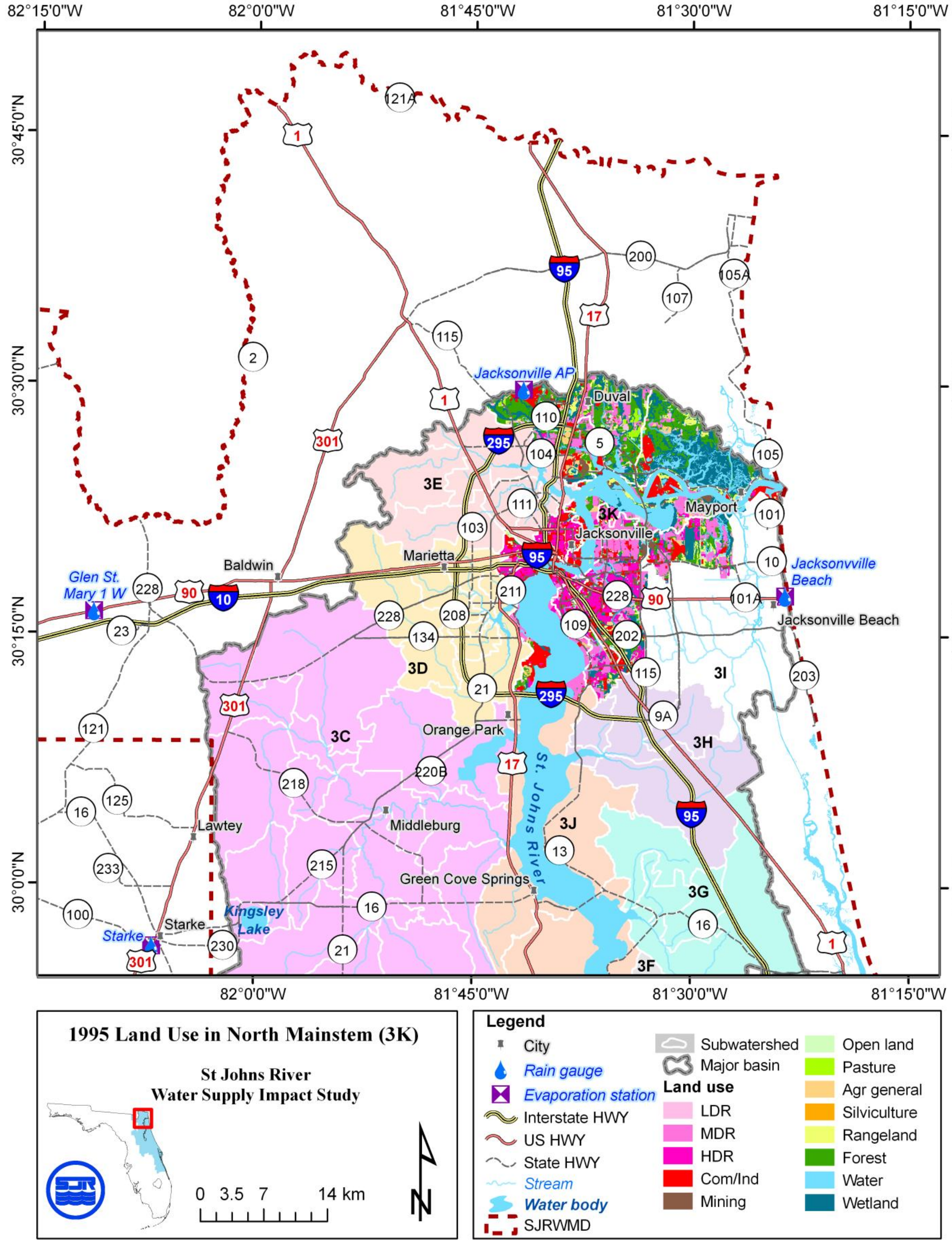

Figure 3–58. 1995 land use in North Main Stem Planning Unit (3K).

Table 3–63. North Main Stem Planning Unit (3K) 1995 and projected 2030 land use comparison.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use (acres)		Projected 2030 Land Use (acres)	
Low-density residential	3,017	2.4%	5,390	4.4%
Medium-density residential	20,723	16.7%	27,887	22.5%
High-density residential	13,985	11.3%	15,639	12.6%
Industrial and commercial	23,040	18.6%	29,054	23.5%
Mining	1,361	1.1%	974	0.8%
Open and barren land	3,323	2.7%	1,972	1.6%
Pasture	827	0.7%	256	0.2%
Agriculture general	3,447	2.8%	2,053	1.7%
Agriculture tree crops	10	0.0%	6	0.0%
Rangeland	4,759	3.8%	2,462	2.0%
Forest	21,520	17.4%	10,314	8.3%
Water	5,321	4.3%	5,321	4.3%
Wetlands	22,565	18.2%	22,565	18.2%
Total	123,898	100.0%	123,898	100.0%

Tiger Pond Creek/Mt. Pleasant Creek Subwatershed

This basin has a contributing area of approximately 19 mi^2 with elevations ranging from sea level to 90.00 ft NGVD29 along Monument Road south of Fort Caroline and near the mouth of Mt. Pleasant Creek (Camp, Dresser, and McKee Inc. 1989). Physiographically, it belongs to the Northern Coastal Strip. Major tributaries within the basin are Newcastle Creek, Jones Creek, Ginhouse Creek, Tiger Pond Creek, Mt. Pleasant Creek, and Greenfield Creek.

In 1995, about half of the lands in this subwatershed are undeveloped and include wetlands (18%), forest (15 %), and water (5 %). The developed part (41%) is mostly medium-density residential (18%) and commercial and industrial land use (19%). The remaining 10% of land use is agriculture and open and barren lands.

Dunn Creek Subwatershed

The Dunn Creek tributary subwatershed is located in the northern part of Duval County, north of the St. Johns River and east of the Broward River drainage basin. The area is approximately 23 mi^2 and elevations range from near sea level to approximately 30.00 ft NGVD29. There is little topographic relief. Physiographically, the Dunn Creek tributary basin belongs to the Dinsmore Plain of the Northern Coastal Strip. The general flow direction is north to south. Delineation of the basin is rather difficult in areas where headwaters originate due to the flatness of the topography and the possible interconnection with the Nassau River basin (Camp, Dresser, and McKee Inc. 1989). Tributaries to Dunn Creek are Terrapin Creek and Rushing Creek; Caney Branch is a tributary to Rushing Creek. Tidal effects in the drainage basin extend to New Berlin

Road, which is about 2 mi north of the confluence of Rushing Creek and Caney Branch (Camp, Dresser, and McKee Inc. 1989).

The 1995 land use data show that the subwatershed is over half in forest (33%) and wetlands (23%). Just over a quarter of the subwatershed is in urban land uses.

Broward River Subwatershed

The Broward River tributary subwatershed is located in the northern part of Duval County, flowing in a southeasterly direction from Jacksonville International Airport to its mouth at the St. Johns River between Drummond Point and Broward Point (Camp, Dresser, and McKee Inc. 1989). The drainage area is approximately 29 mi^2. Physiographically, it belongs to the Dinsmore Plan, which is a subdivision of the Northern Coast Strip. The topography of the basin is rather flat, although at some locations elevations of 80.00 ft NGVD29 occur. Major tributaries are Cedar Creek—the upstream extension of Broward River—and Little Cedar Creek, which joins Cedar Creek between I-95 and US 17.

According to 1995 land use data, more than half of the subwatershed was in natural land uses of forest (30%) and wetlands (19%), with 31% in urban areas. Jacksonville International Airport is one of the dominant land use features in the watershed representing almost 15% of the basin.

Additional Subwatersheds

The remaining subwatersheds are Goodbys Creek (including Christopher Branch, New Rose Creek, Craig Creek, and Miller Creek), McCoy Creek (including Hogan Creek, Deer Creek, and Long Branch), and Clapboard Creek (including Nichols Creek and Browns Creek). Goodbys Creek and McCoy Creek are highly developed with about 77% and 87% urban areas, respectively. On the other hand, Clapboard Creek subwatershed has only about 8 % of urbanized land use.

5 Calibration for Water Quantity

5.1 Observed Flow and Water Level Data

An important and underappreciated aspect of almost all published stream flow data is that stream flow is not measured directly but estimated from a stage-discharge relationship. A stage-discharge relationship serves as a model relating an easy to measure water level with very difficult, time-consuming, and expensive flow measurements. Even though stage-discharge relationships are well known and can be an efficient and effective method to estimate stream flows, only a small portion of large watersheds are gauged.

When developing a stage-discharge relationship, flow measurements are plotted with their corresponding stages, and a curve is approximately fitted through the points. That curve becomes the relationship for estimating flow, given stage within the range of flow measurements. For flows outside the range of the flow measurements, the curves are extended using logarithmic plotting, velocity-area studies, or using the results of indirect measurements.

The stage-discharge relationship is subject to change because of changes in the physical features that affect the gauge site. The stage-discharge relationship can be changed temporarily because of aquatic growth or debris, downstream flow obstructions may produce backwater effects that reach the gauge, and upstream obstructions may also change the cross sectional area of flow.

WSIS uses USGS stream flow data for calibration except for a few stations. The USGS rating curve model has errors associated with the estimated flow. Even though there are several ways to estimate the rating curve error (Dymond and Christian 1982), the USGS has established a subjective estimate of annual flow data quality based on a review of measured data, datum shifts, and other characteristics of the flow measurement station. Table 3–64 describes the USGS system of data quality estimation (Kennedy 1983). The USGS system provides a general site-specific estimate of error, and there may be significantly more error where there are few flow measurements in the rating curve (e.g., at high and low flows). USGS gives a single quality category for each year of data.

There are other inherent difficulties in flow measurement in Florida due to the shallow slope, poorly defined cross sections, and tidal influences. Most USGS flow measurement stations in Florida are rated "Fair." Although it would be difficult to collate the data for each station and each year, only about 10% of Florida's stations rate a "Good" classification. An "Excellent" rating for a station in Florida is very rare.

Table 3–64. USGS flow data quality categories.

Quality Category	Description
Excellent	95% of daily discharges within 5% of "true"
Good	95% of daily discharges within 10% of "true"
Fair	95% of daily discharges within 15% of "true"
Poor	Daily discharge have less than "fair" accuracy

Source: (Kennedy 1983)

The overall locations of the flow observation stations and their corresponding gauged watersheds are presented Figure 3–59 and additional detail for each gauged watershed is presented in the calibration appendices (Appendix 3.H through 3.M).

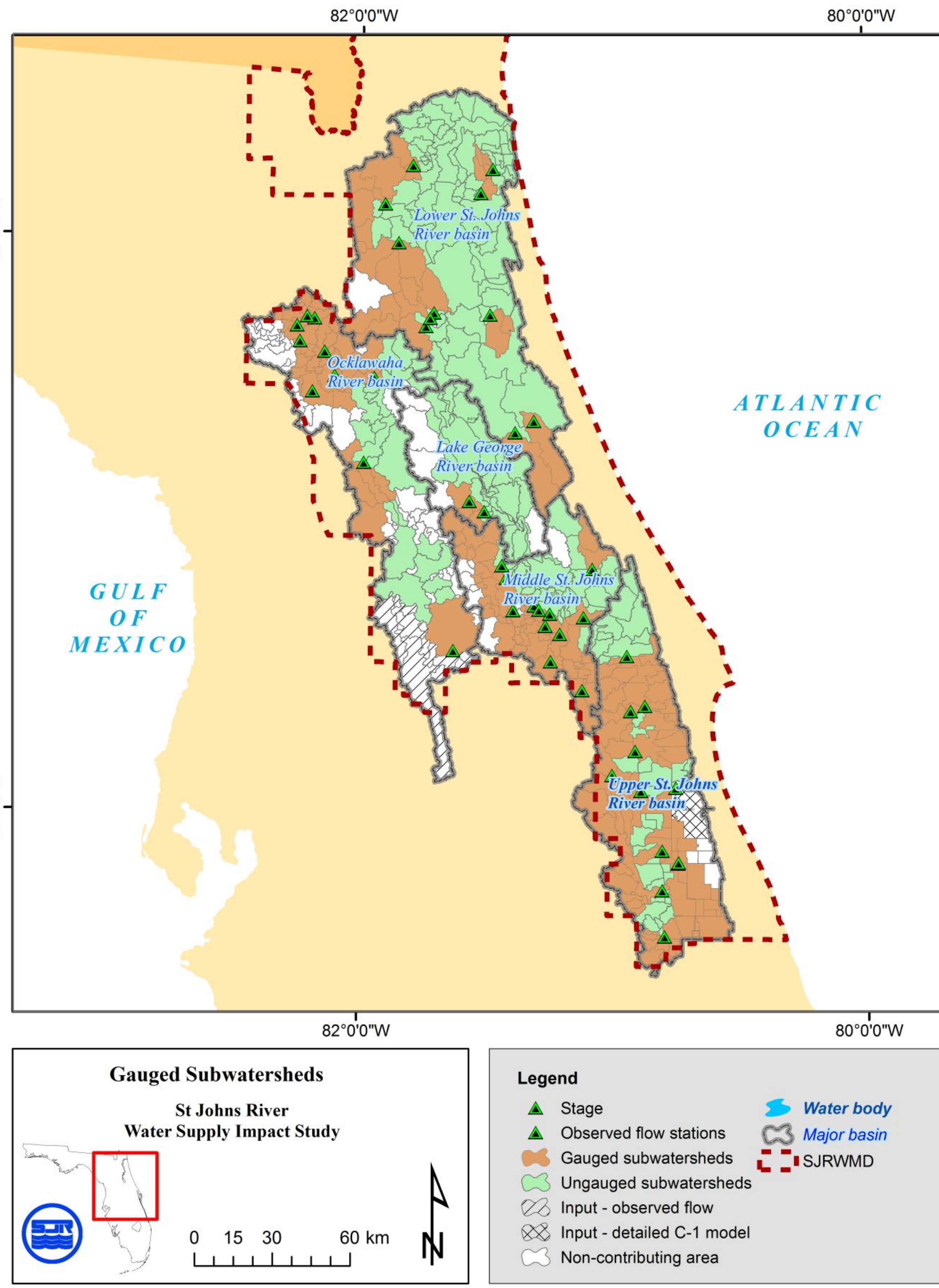

Figure 3–59. Map of flow and water level gauges, and gauged, ungauged, special input and noncontributing watersheds for St. Johns River watershed.

Table 3–65. Statistics from flow stations used in the Water Supply Impact Study (WSIS) sorted roughly from upstream to downstream.

HSPF Hydrologic Model	Planning Unit*	Planning Unit Subwatersheds	Flow Station	Mean (mgd)	Median (mgd)	Min (mgd)	Max (mgd)
Upper St. Johns River Basin (6)							
Fort Drum Creek	6A: Fort Drum Creek	1, 2, 3, 4, 5, 6, 10	USGS 02231342	34.6	9.7	-0.0	907.2
Blue Cypress Creek	6B: Blue Cypress Creek	5, 6, 7, 8, 9, 10	USGS 02231396	71.2	13.6	0.0	2107.0
S-96C	6B: Blue Cypress Creek	1, 2, 18	SJRWMD 0098	131.1	50.9	-138	1221.5
S-96B	6C	3, 4, 5, 8, 10, 11, 12, 16, 17	SJRWMD 0096	92.2	0.0	0.0	1109.8
Crabgrass Creek	6E: Jane Green Creek	8	USGS 02231565	17.6	2.7	0.0	748.5
Jane Green Creek	6E: Jane Green Creek	1, 2, 3, 4, 5, 6, 7, 9	USGS 02231600	125.7	27.8	0.0	3421.6
Sixmile Creek	6F: St. Johns Marsh	2	USGS 02231454	5.9	0.5	0.0	385.2
St Johns River near Melbourne	6F: St. Johns Marsh	7	USGS 02232000	520.6	219.4	-59.5	5215.9
Wolf Creek near Deer Park	6G: Lake Poinsett	4	USGS 02232200	19.6	2.7	0.0	2184.6
St Johns River near Cocoa	6G: Lake Poinsett	5, 6, 8, 10, 11, 12, 13	USGS 02232400	793.3	429.6	-80.8	4886.2
Taylor Creek	6G: Lake Poinsett	15, 16, 17	USGS 02232415	33.5	1.0	0.0	717.4
St. Johns River near Christmas	6H: Tosohatchee 6I: Puzzle Lake	1, 2, 3, 4, 5, 6, 7, 8	USGS 02232500	919.1	543.0	-88.6	4881.1

HSPF Hydrologic Model	Planning Unit*	Planning Unit Subwatersheds	Flow Station	Mean (mgd)	Median (mgd)	Min (mgd)	Max (mgd)
Middle St. Johns River Basin (4)							
Econlockhatchee River at Magnolia Ranch	4A: Econlockhatchee River	1	USGS 02233001	18.6	1.8	0.0	252.7
Little Econlockhatchee River near Union Park	4A: Econlockhatchee River	11	USGS 02233200	26.3	13.6	0.8	833.8
Little Econlockhatchee River at SR 434	4A: Econlockhatchee River	11, 12, 13	USGS 02233475	91.1	47.2	7.1	1202.2
Econlockhatchee River near Chuluota	4A: Econlockhatchee River	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13	USGS 02233500	221.9	100.2	18.7	3677.5
Deep Creek near Osteen	4B: Deep Creek	2, 4	USGS 02234100	39.8	9.1	0.0	1674.0
Howell Creek near Slavia	4C: Lake Jesup	1, 2, 4, 5, 6	USGS 02234324	19.5	9.1	0.4	326.4
Howell Creek at SR 434	4C: Lake Jesup	1, 2, 4, 5, 6, 7, 8, 9	USGS 02234344	46.5	25.2	2.0	567.5
Gee Creek near Longwood	4C: Lake Jesup	10, 12, 13, 14, 15	USGS 02234400	10.8	4.7	0.0	169.3
Soldier Creek near Longwood	4C: Lake Jesup	17, 18, 19, 20, 21, 23	USGS 02234384	8.7	3.7	0.1	172.6
Blackwater Creek near DeBary	4E: Wekiva River	8, 9, 10, 12	SJRWMD 30143084	97.9	73.9	31.0	789.5
Wekiva River near Sanford	4E: Wekiva River	19, 25, 26, 27, 28	USGS 2235000	201.0	174.1	90.0	911.5
Little Wekiva River	4E: Wekiva River	20, 21, 22, 23, 24	SJRWMD 09502132	54.4	40.1	9.1	418.8
Lake George Basin (5)							
Alexander Creek at CR 445	5B: Alexander Springs	1, 2	SJRWMD 18523784	82.0	76.9	60.8	258.5
Alexander Creek at Tracy Canal	5B: Alexander Springs	3, 4, 5	SJRWMD 18553786	92.0	82.7	64.0	355.5

HSPF Hydrologic Model	Planning Unit*	Planning Unit Subwatersheds	Flow Station	Mean (mgd)	Median (mgd)	Min (mgd)	Max (mgd)
Ocklawaha River Basin (7)							
Ocklawaha River at Conner	7E: Marshall Swamp 7F: Rodman Reservoir	1, 2, 3, 4, 23, 5	USGS 02240000	612.7	501.5	256.6	2223.3
Lower Orange Creek	7G: Orange Creek	6, 7, 8, 9, 10	USGS 02243000	46.6	14.2	0.0	1008.3
Bee Tree Creek	7G: Orange Creek	6, 7	SJRWMD 02850235	6.2	0.0	0.0	1229.8
Hatchet Creek	7G: Orange Creek	1, 2, 3, 4, 5	SJRWMD 01950193	13.6	1.5	0.0	711.0
Little Hatchet Creek	7G: Orange Creek	9	SJRWMD 02840233	2.6	1.1	0.0	82.7
Prairie Creek	7G: Orange Creek	8, 10, 11, 12, 13	SJRWMD 08631958	34.4	20.7	0.0	624.3
Lochloosa Creek	7G: Orange Creek	16, 17, 18, 19	SJRWMD 01930189	8.6	0.6	0.0	728.4
Orange Lake Weir	7G: Orange Creek	20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37	SJRWMD 02601462	20.5	0.0	0.0	595.0

HSPF Hydrologic Model	Planning Unit*	Planning Unit Subwatersheds	Flow Station	Mean (mgd)	Median (mgd)	Min (mgd)	Max (mgd)
Lower St. Johns River Basin (3)							
Little Haw Creek	3A: Crescent Lake	1	USGS 02244420	65.2	20.2	0.0	1169.8
Middle Haw Creek	3A: Crescent Lake	3	USGS 02244320	59.6	8.4	0.0	2197.5
Etonia Creek	3B: Etonia Creek	21, 26, 31, 41, 42, 43	USGS 02245050	45.1	30.4	9.1	1150.4
Rice Creek	3B: Etonia Creek	2	USGS 02244473	27.1	7.1	1.1	1137.5
Simms Creek	3B: Etonia Creek	44	USGS 02245140	34.6	13.6	2.9	1454.2
North Fork Black Creek	3C: Black Creek	6, 10, 11, 15, 16, 17	USGS 02246000	112.7	45.9	1.9	6463.2
South Fork Black Creek	3C: Black Creek	1, 2, 3	USGS 02245500	85.9	36.8	5.0	4395.0
Ortega at Jacksonville	3D: Ortega River	1	USGS 02246300	27.4	9.1	0.0	2307.4
Ortega at Kirwin Road[1]	3D: Ortega River	1, 2	USGS 02246318	37.1	16.2	0.1	704.5
Deep Creek at Spuds	3F: Deep Creek	2	USGS 02245260	39.2	14.9	-40.1	1602.9
Deep Creek near Hastings[1]	3F: Deep Creek	1, 2	USGS 02245255	8.9	2.1	0.0	546.1
Big Davis Creek at Bayard	3H: Julington Creek	3	USGS 02246150	7.3	3.1	0.0	305.7
Pablo Creek at Jacksonville	3I: Intracoastal Waterway	2, 4, 5, 6, 3	USGS 02246828	24.7	12.3	0.5	1079.4

1. Not used for calibration because of poor record or shore period of record.

Table 3–66. Water level stations used for the Water Supply Impact Study (WSIS).

HSPF Hydrologic Model	Planning Unit	Planning Unit Subwatersheds	Water Level Station	Mean (ft)	Median (ft)	Min (ft)	Max (ft)
Ocklawaha River Basin (7)							
Apopka	7B: Lake Apopka 7C: Lake Harris 7D: Lake Griffin	9	SJRWMD 30003000	42.8	43.1	40.5	44.1
Newnans Lake	7G: Orange Creek	8, 10, 11, 12, 13	SJRWMD 04831007	42.1	42.1	39.3	46.0
Lochloosa Lake	7G: Orange Creek	20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37	SJRWMD 71481615	36.9	37.1	34.9	39.4
Orange Lake	7G: Orange Creek	20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37	SJRWMD 02611465	36.1	36.9	32.0	39.3

5.2 Hydrological Simulation Program–FORTRAN (HSPF)

The Hydrological Simulation Program–FORTRAN (HSPF) is a comprehensive hydrology (water quantity) and water quality modeling system. Currently HSPF is part of the BASINS modeling environment. HSPF is highly regarded as a complete and defensible watershed model for the simulation of hydrology and water quality for both conventional and toxic pollutants. The simulation results of the HSPF model consist of a time history of the runoff flow rate and can include sediment load and nutrient and pesticide concentrations along with a time history of water quantity and quality at nearly any point in a watershed.

The model was developed in the early 1960s as the Stanford Watershed Model. In the 1970s, water-quality processes were added. Development of a FORTRAN version, incorporating several related models using software engineering design and development concepts, was funded by the Athens, Georgia, EPA Research Lab in the late 1970s. In the 1980s, pre-processing and post-processing software, algorithm enhancements, and use of the USGS WDM system were developed jointly by the USGS and EPA. The HSPF model has been successfully applied in climatic conditions around the world. The HSPF model currently enjoys the joint sponsorship of both the EPA and the USGS and continues to undergo refinement and enhancement of its component simulation capabilities, along with user support and code development. (United States Geological Survey 2010)

A watershed is conceptually represented in HSPF as a series of storage compartments (e.g., surface depressions, soil zones, groundwater zones, river segments). Based on the principal of mass conservation, HSPF performs continuous budget analysis of water quantity and quality for these storage compartments. Given the inputs of meteorological time series and the parameter values related to watershed characteristics, HSPF generates time series of runoff, stream flow, loading rates, and concentrations of various water quality constituents.

Although most parameters of HSPF can be specified by watershed spatial and physical data (e.g., land use, topography, stream characteristics, and soil properties), a few parameters, such as those related to infiltration, evaporation, and instream kinetics, need to be determined in the model calibration process. Model calibration is the process of adjusting values of model parameters to accurately reproduce the observed flow and water quality data for a given compartment. Once calibrated, the HSPF model is considered to accurately represent the hydrologic and water quality processes in a watershed and can be used for scenario analysis.

A watershed and its stream network are characterized in HSPF by various pervious land segments (PERLND), impervious land segments (IMPLND), and reaches/reservoirs (RCHRES) based on subwatershed delineation, land uses, and the impervious percentage for each land use. As described in Section 2.3 of this chapter, land uses in the WSIS watersheds are grouped into 13 categories, with two additional special categories. These consolidated land uses are further divided into pervious and impervious fractions. The pervious portion of a land use category is represented as PERLND, and the impervious portion of a land use category is represented as IMPLND. For modeling purposes, the stream network in a subwatershed is grouped together and represented as RCHRES. The geometric and hydraulic properties of a RCHRES are represented in HSPF by FTABLEs, which describe the relationships among stage, surface area, volume, and discharge for the reach segment. Detailed description of these submodules can be found in Bicknell, et al. (2001).

A series of model simulation graphics are provided to illustrate the HSPF model (Figure 3–60, Figure 3–61, Figure 3–62, and Figure 3–63). Hydrologic simulation for PERLND and IMPLND is carried out in the PWATER submodule (Figure 3–61) and the IWATER submodule (Figure 3–62). The simulated hydrologic processes for PERLND include interception, infiltration, evapotranspiration, runoff, and deep percolation. The simulated processes for IMPLND are similar to those for PERLND except there are no infiltration and subsequent subsurface processes. Hydraulic behaviors in RCHRES are simulated in the HYDR submodule (Figure 3–63).

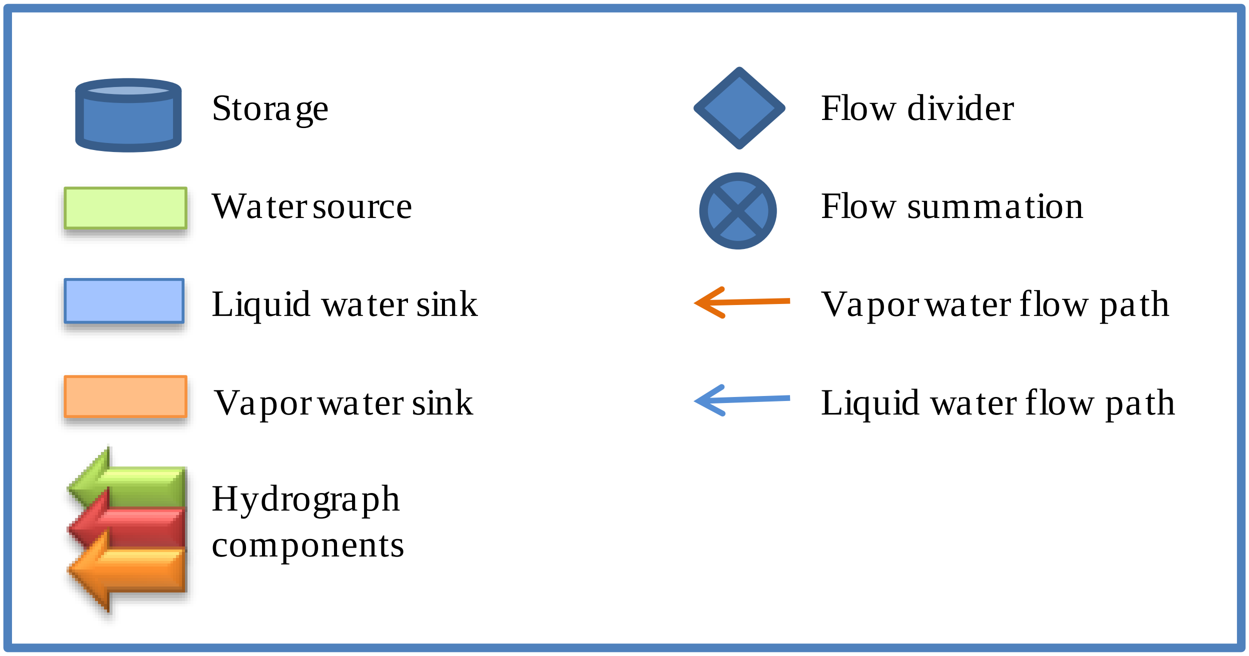

Figure 3–60. Legend for HSPF model simulation graphics in Figure 3–61, Figure 3–62, and Figure 3–63.

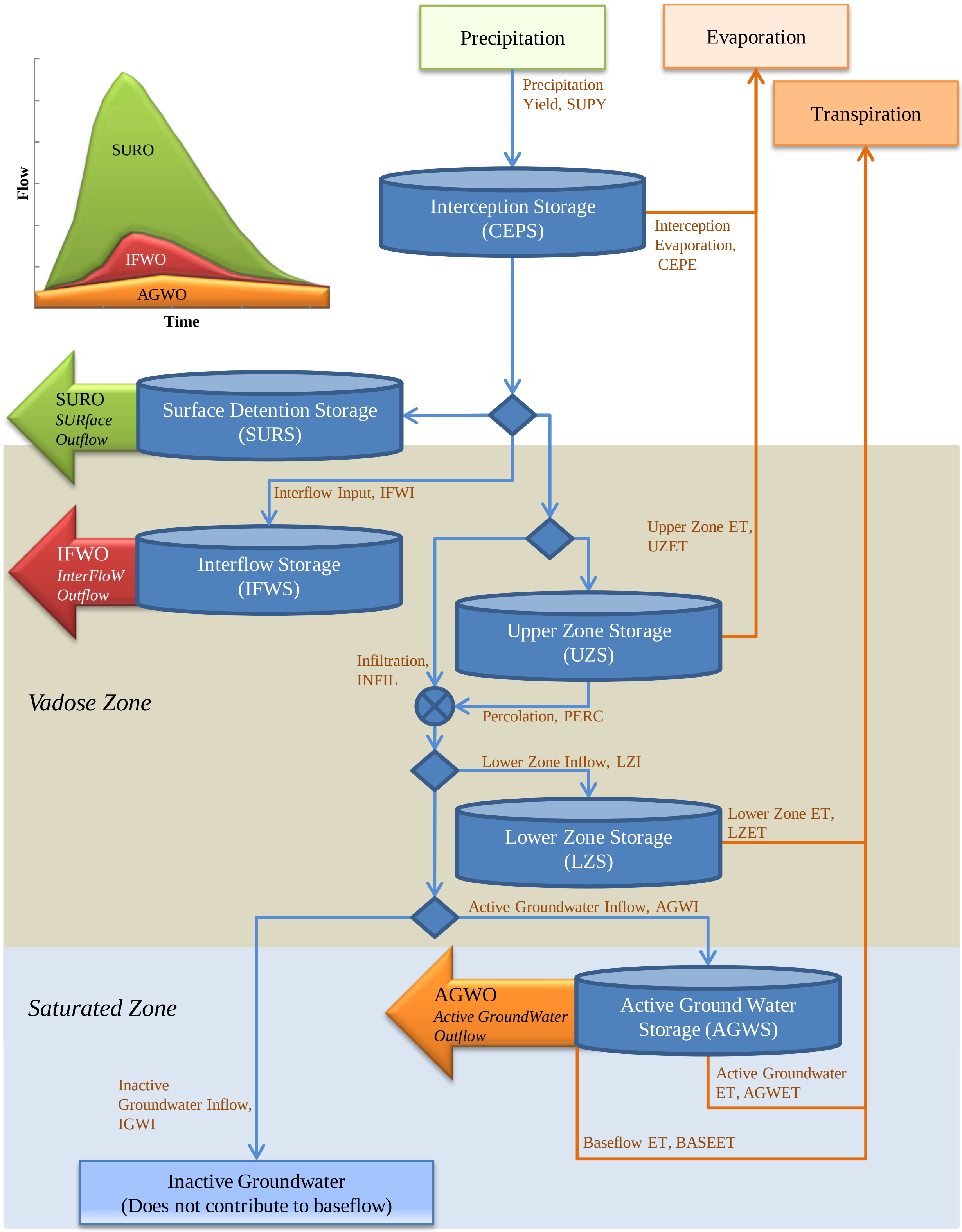

Figure 3–61. Illustration of water storage and movement in the HSPF model pervious land element (PERLND).

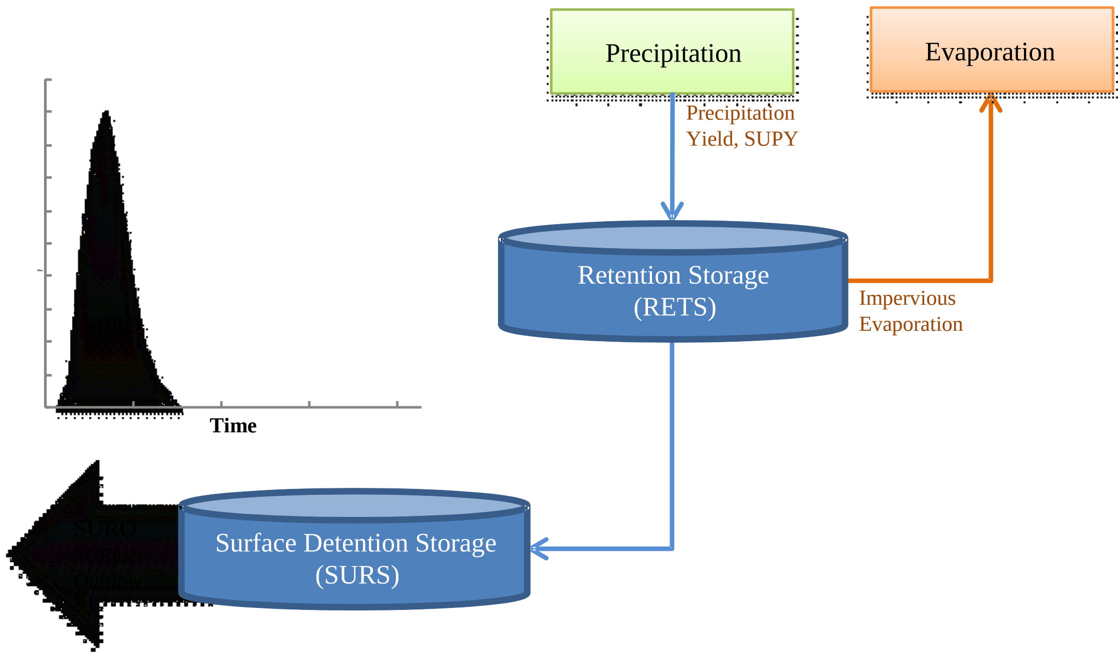

Figure 3–62. Illustration of water storage and movement in the HSPF model impervious land element (IMPLND).

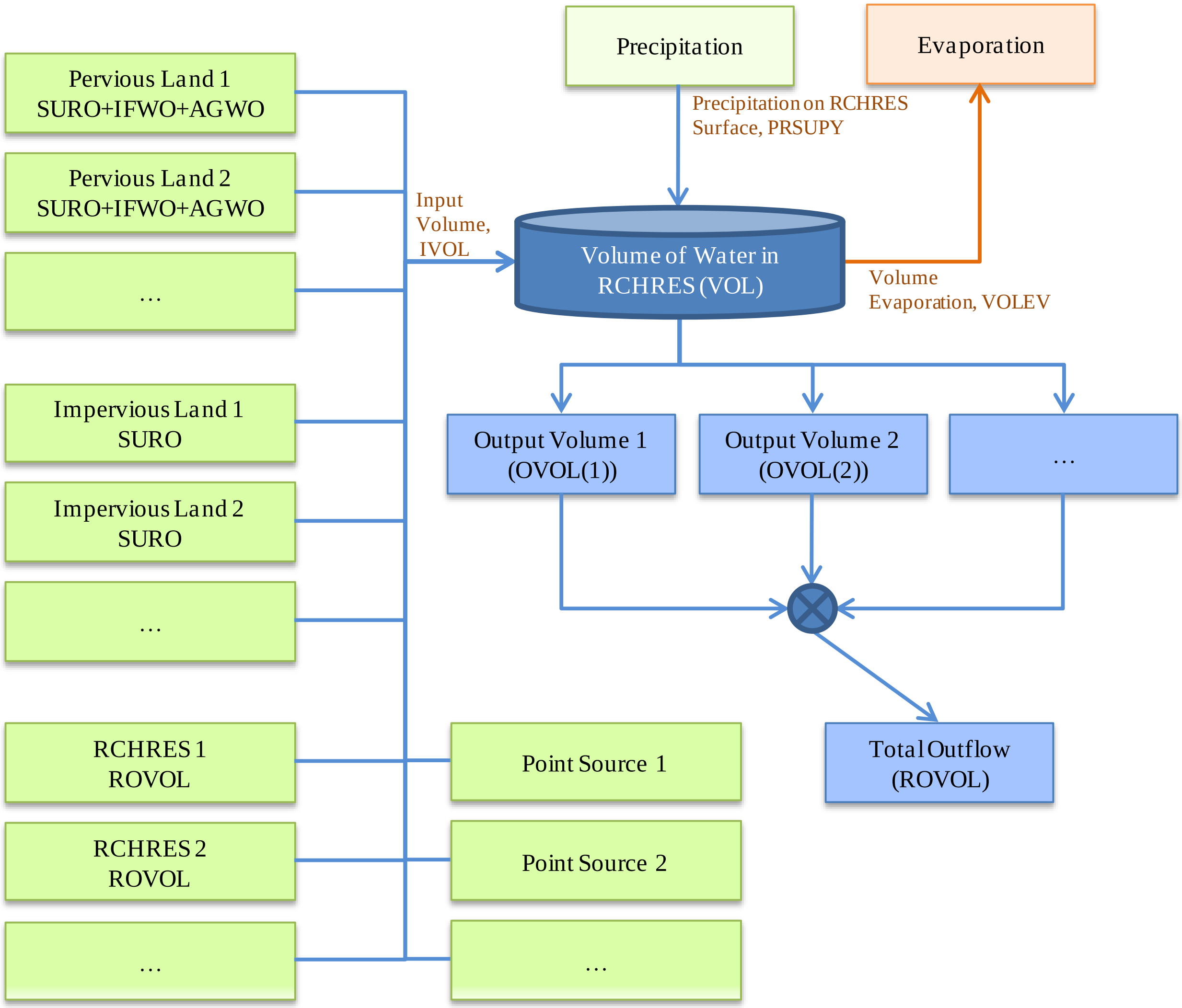

Figure 3–63. Illustration of water collection and movement in the HSPF model reach/reservoir element (RCHRES).

5.3 Calibration Process

The modeled time period is dependent on the question that needs to be answered. Flood control analysis will calibrate using a single storm event, multiple storm events, or a “design” (synthetic) storm event. Water supply, MFLs, and certain environmental analyses require long-term continuous modeling simulations. The land use/cover is set for a point in time and a set of historical rainfall records are selected that match the length of time needed for the simulation. Synthetic rainfall can be produced, as in the design storm used in flood control analysis, but bias in the rainfall could be introduced. Using the historic rainfall record is more accurate, as it is assumed that the rainfall in the future will approximate the amount and patterns of the past. These are random events and, if the period of record is long enough, there should not be a discernable bias in the data.

The calibration period selected for the WSIS HSPF hydrologic models is from 1995 to 2006. This period was selected for three reasons:

- The baseline for groundwater planning programs at SJRWMD is 1995.
- Due to extensive data and computer run time requirements, the EFDC hydrodynamic model of the main stem of the St. Johns River simulates from 1995 to 2006.
- A major portion of the USJRB project was completed by 1995 and project activities were relatively stable between 1995 and 2006.

The actual time period of meteorological data and land and stream gauge data is used as input data for the HSPF hydrologic models. The calibration period for the individual basin models falls within the 1995 to 2006 time period depending on data available for calibration.

5.3.1 Model Input Parameters–Common Logic

The changes to the model concerning land use, precipitation, and evaporation require a complete examination of the model parameters. Different SJRWMD engineers originally modeled watersheds with the HSPF hydrologic model for various purposes and developed model parameters that were characteristic of the individual basins. For the WSIS program, SJRWMD has developed a common logic (Appendix 3.B) describing reasonable parameter value ranges for all HSPF hydrologic models in SJRWMD. This HSPF common logic was derived from an evaluation of the possible range of model parameters for Florida's unique hydrology, extensive SJRWMD experience, and the parameter ranges common in other parts of the world (EPA July 2000).

5.3.2 Land Use and Directly Connected Impervious Area (DCIA)

The HSPF hydrologic model has many parameters used to define water storage and interactions, and many parameters are defined for each land use. The SJRWMD has developed 13 land use categories for hydrologic modeling as presented in the basin land use tables throughout this chapter (Appendix 3.A). These 13 land use categories were developed by aggregating 140 Florida Land Use and Cover Classification System (FLUCCS) codes (State of Florida 1999) by hydrologic similarity. There are two "special" land use categories that are derived as part of others, forest regeneration is 10% of forest category in certain areas and wetland land use is split between riparian and non-riparian.

Impervious areas include all surface areas that prevent water from infiltrating into the ground. Typical impervious areas are buildings/roofs, roads, and parking lots. These impervious areas can be classified into two categories: DCIA and nondirectly connected impervious area (NDCIA). DCIAs are the impervious areas that directly connect to the drainage network with no opportunity for infiltration (e.g., a parking lot that drains directly to a creek). NDCIAs are the impervious areas that drain to pervious areas (e.g., a rural home surrounded by a vegetated area). In this study, only DCIAs are modeled as IMPLND and NDCIAs are part of the PERLND land use element.

Among the 13 land uses, the four urban land categories are assumed to have some DCIA. The four urban land groups are low-density residential, medium-density residential, high-density residential, and industrial and commercial. Estimation of the percent DCIA for WSIS in each urban land use category stems from observed flows of small storm events, because most runoff during small storms is generated from DCIA. Impacts of changing percentages of DCIA on total mass balance and seasonal flow distribution were also considered. The proportion of DCIA in each urban land use category is attributed to IMPLND for the HSPF hydrologic model (Table 3–67). The remaining nine land use categories are assumed to consist of pervious (PERLND) elements.

Table 3–67. Percentages of Directly Connected Impervious Area.

HSPF Hydrologic Modeling Land Use Group	% Imperviousness
Low-density residential	5
Medium-density residential	15
High-density residential	35
Industrial and commercial	50

5.3.3 Development of FTABLEs for Stream Networks

In HSPF hydrologic modeling, the stream network in a subwatershed is grouped together and represented as a reach segment, which could be either a free-flowing stream or a mixed lake. The FTABLEs for stream reaches are developed based on Manning's equation. Channel cross-section characteristics are based on survey data, field visits, USGS quad maps, and other data sources. For example, the stream reaches in the urbanized Lake Jesup watershed are modeled as streams with uniform trapezoidal cross-sections. Stream length, slope, and elevation are estimated based on the stream network and digital elevation maps available at SJRWMD. Manning's "n" coefficients for these streams are estimated by comparing the calculated stage-discharge relationships with the measured relationships at several USGS flow gauge sites. The coefficient is used to adjust the model outcomes to more closely resemble flows observed in the real world.

5.3.4 Parameter Estimation Model Optimization

Calibration of the HSPF hydrologic model is an iterative process of changing parameters, running simulations, checking results, and repeating until an acceptable match is made between the simulated and observed data. A calibrated model is one that most closely resembles the behavior of the systems in the real world. When manually performed, model calibration can be a time consuming endeavor. In addition, it can be difficult to maintain a consistent approach of parameter adjustments among a diverse group of engineers, such as the nine HSPF modelers for the WSIS project. For this reason, a parameter estimation model optimization tool called PEST was used to assist in model calibration (Doherty 2004).

PEST is a nonlinear parameter estimator that will adjust model parameters to minimize the discrepancies between model-generated numbers and corresponding real-world measurements. It does this by running the model as many times as is necessary to optimize multiple objective functions. The objective functions are usually some form of weighted, squared, model-to-measurement differences. Because the problem of calibrating the HSPF hydrologic model is nonlinear, parameter estimation is an iterative process. PEST evaluates parameter changes based on the improvement to the objective functions and decides whether to undertake repeated optimization until no further improvement is achieved. The modeler must not only define the objective functions, but must also select pertinent parameters and set the permissible parameter's upper and lower bounds for adjustment.

Because the objective is to simulate inflow to the St. Johns River from surrounding watersheds, the objective functions take the form of matching simulated to gauged daily flow, monthly flow, annual flow, and flow duration curves. Gauged and simulated flows are compared within these four objective functions to address daily flow variability, seasonal variability, annual discharge characteristics, and overall discharge characteristics. The modeler assigns weights to each objective function based on the importance of each discharge component that will obtain the best overall match between gauged and simulated discharge.

The PEST utility was used to optimize the parameters lower zone nominal soil moisture storage (LZSN), lower zone evapotranspiration (LZEPT), index to infiltration capacity (INFILT), upper zone nominal soil moisture (UZSN), base groundwater recession (AGWRC), interflow inflow (INTFW), interflow recession (IRC), fraction of groundwater inflow to deep recharge (DEEPFR) (Appendix 3.C) and the wetland surface runoff FTABLE storage-runoff relationship. Relative values of parameters were established by the modelers among land uses to produce expected relative runoff amounts. Urban land, including impervious area, produces the most runoff, agriculture produces the next largest runoff, open land and rangeland produce less, and forest and wetlands produce the least runoff. PEST allows parameters to be "tied" to a "parent" parameter. In this way, all of the tied parameters are adjusted equally among the various land uses. In general, LZSN, LZEPT, INFILT, and UZSN parameters are tied together among land uses. The exception to this is wetlands. Wetland parameters give emphasis to larger upper zone storage and lower infiltration rates. For this reason, wetland parameter sets are not comparable to other land uses and are adjusted independently. The parameters AGWRC and DEEPFR are applied to the entire watershed. In addition, PEST allows parameters to be "fixed" and not adjusted. For example, in many cases of INTFW and IRC, these parameters usually are given a restricted range close to zero or fixed to zero or a very small number (see the Common Logic for INTFW in Appendix 3.B).

5.3.5 HSPF Hydrologic Model Special Actions

HSPF hydrologic modeling permits the user to perform certain "Special Actions" during the course of a run. A special action instruction specifies the following:

- The operation on which the action is to be performed (e.g., PERLND 10)
- The date/time at which the action is to be taken.
- The variable name and element (if the variable is an array) to be updated.
- The action to be performed—The most common actions are to reset the variable to a specified value and to increment the variable by a specified value, but a variety of mathematical functions are available.

The special action facility is used to accommodate unique characteristics of a watershed, such as

- Modeling human interventions in a watershed: Events such as plowing, cultivation, fertilizer and pesticide application, and harvesting can be simulated in this way.
- Changing parameter values: For example, a user may wish to alter the value of a parameter for which 12 monthly values cannot be supplied. This can be done by specifying a special action for that variable. The parameter could be reset to its original value by specifying a later special action.
- Preventing double accounting for water and wetland areas: Special Actions were used to separate the riparian wetland PERLND areas and RCHRES water areas. Different areas of water and wetlands were assigned to PERLND and RCHRES so the model would not use the same area at the same time during simulations. For most basins, the RCHRES area is dynamically subtracted from the PERLND water and wetland area. If these areas were not separated, it would cause some double counting of rainfall and evaporation during high water levels and some undercounting during low water levels. As long as the overlap is small, this error is considered insignificant to the overall model, but when the RCHRES variable area becomes large, the error can become significant.
- Describing connections between groundwater and surface water bodies: Special Actions for connections between groundwater and surface water was used to estimate recharge through sinks into the groundwater or discharge from the groundwater through spring flow or seepage.
- Accounting for different conditions during a calibration period: Special Actions for variable rating curves at different times at a single location were used to account for different conditions during the calibration period.
- Accounting for backwater effects: Special Actions for Cross Creek were used to calculate flows from Lochloosa Lake to Orange Lake using elevations in both lakes instead of just elevations in Lochloosa Lake to account for backwater effects.
- Apportioning water in cases of diversions: Special Actions to calculate discharge diverted into Paynes Prairie from Prairie Creek were used to proportion the appropriate volume of water into Paynes Prairie.
- Mimicking the operation of a dam or water control structure: In order to mimic the operation of Kirkpatrick (Rodman) Dam, special action codes were set up in the model to simulate the gate openings to reflect the stage regulation of Rodman Reservoir between 16 and 20 ft and during periodic drawdowns.

5.3.6 PEER REVIEW

A peer review of the all of the initial HSPF hydrologic model calibrations was performed by Intera Incorporated (Intera). Intera's detailed report was completed in September 2009 and contained recommendations for improvement of the models. The full review is included as Appendix 3.G to this report. Following are Intera's five main recommendations for model improvement:

- Examination of land use and 2030 predicted land use: Current land use changes show a decrease in wetland area of approximately 19 percent. Given current mitigation requirements, justification for this decrease is needed.

- Re-examination of directly connected impervious area (DCIA) values: For some basins, the DCIA values, particularly for industrial and commercial use, seem higher than accepted values. Since DCIA is used to determine the areas of PERLND and IMPLND segments, the model is highly sensitive to changes in these values. It is also very important to remain systematic in the definition of the parameters. Justification is necessary to describe basin-to-basin differences in any model parameters based on the same mapping data.
- Consideration of changes to retention storage capacities (RETSC) for IMPLND segments. Since these segments are not routed to storage attenuation reaches, but rather directly to discharge reaches, RETSC should be increased in order to account for storage in conveyance systems and ponds that most impervious runoff undergoes prior to discharge.
- Re-examination of active groundwater evapotranspiration (AGWET). Currently, the majority of segments have no AGWET. This should be calibrated accordingly in the context of the depth of the water table and vegetation type.
- Implementation of storage attenuation for PERLND and IMPLND segments. This can be accomplished using storage attenuation reaches.

The SJRWMD reviewed these recommendations and implemented them in the following manner.

<u>Examination of 1995 land use and 2030 predicted land use</u>

The wetland land use is not expected to change between 1995 and 2030 because there are regulations in place to have no net loss of wetlands. GIS Associates, Inc(2009)provided an updated land use that holds the 2030 wetlands land use equal to the 1995 wetlands land use acreage. The new projected 2030 land use is now included in the model.

<u>Re-examination of Directly Connected Impervious Area values</u>

The DCIA values were generally too high and varied among the models. In many cases, DCIA values were simply adopted from predecessor models, which were not always focused on water supply issues. What had been conservative assumptions for other purposes (e.g., flooding or water quality) were not necessarily appropriate for the WSIS. In no case were DCIA values adjusted to calibrate the models. A set of DCIA percentages for the WSIS was developed and is described in detail in Section 0. The new DCIA values are; 5% of lower density residential, 15% of medium-density residential, 35% of high-density residential, and 50% of industrial/commercial which are much closer to the recommended values from Intera.

<u>Consideration of changes to retention storage capacities (RETSC) for IMPLND segments</u>

The RETSC value was too small and it was increased from various values to a standard of 0.1 in. Though increased to a larger value we did not adjust RETSC to represent detention storage. RETSC affects both peak and volume strongly, whereas detention storage affects peak strongly but affects volume only weakly.

Re-examination of active groundwater evapotranspiration (AGWET)

The use of AGWET parameter was not sufficient for many of the models that have shallow water tables. The AGWET parameter values were compared to the depth to water table map. The AGWET parameter was changed in all models to a range of values consistent with the depth to water table map for that subwatershed.

Implementation of storage attenuation for PERLND and IMPLND segments

Additional storage was necessary to have a better representation of the hydrology. Surface FTABLEs were used to implement this storage, which are part of the high water table algorithms in the HSPF hydrologic model. The surface FTABLEs are used to represent the storage in non-riparian wetlands.

In the original HSPF hydrologic model construction, the 13 land uses (in PERLNDs and IMPLNDs) were routed directly to their associated streams (RCHRES). The Intera peer review suggested that routing some of the flow from upland surface areas to upland wetlands would provide a better representation of the subwatershed. The initial model construction implicitly represented this storage by adjusting other model parameters in the calibration process.

Wetlands tend to slow movement of water because of surface storage. One result of this is that wetland areas have a larger potential for evapotranspiration. HSPF hydrologic modeling provides the option to define surface outflow as a function of surface detention depth. This feature allows improved representation of the surface storage and attenuated surface runoff typical of wetlands.

The first step in this process is the definition of the upland surface areas that would drain to these wetlands. The SJRWMD contains thousands of wetlands that range in size from less than one acre to thousands of acres. The wetlands were classified as either riparian (directly connected or adjacent to a reach) or non-riparian (not directly connected to a reach). An additional wetland land use classification was created for the non-riparian wetlands. Drainage areas for the non-riparian wetlands were determined by using SJRWMD Digital Elevation Model overlaid by the HSPF hydrologic modeling land use groups to determine the drainage area of each non-riparian wetland. The processing generated tables showing the portion of each land use that drained to the non-riparian wetlands for each subwatershed.

A surface FTABLE was developed for each upland wetland. The area used in the FTABLE matched the area of the wetland. Development of the storage-outflow relationship begins with the general function:

$$Q = ay^{\mathrm{m}} \qquad \textbf{[Eq. 3–1]}$$

where

Q	**=**	**fraction of storage that runs off per hour**
y	**=**	**normalized depth above the invert**
a,m	**=**	**general coefficient and exponent**

PEST was used to optimize the wetland storage-outflow relationship by adjusting the depth of incipient flow and equation parameters. The lower and upper bounds for the depth of incipient flow are 0.01 to 11.99 in. The lower and upper bounds for the equation coefficient are 0.00 to 0.10. The lower and upper bounds for the equation exponent are 1 to 10. The storage-outflow relationship is typically used to populate the FTABLE at depths of 12, 24, and 36 in.

Separation of the watershed into areas that drain to non-riparian wetlands and the reach is an easy Geographical Information System (GIS) exercise for the 1995 land use. The land use prediction to support the estimated 2030 population was based on shifting land uses across the entire subwatershed but did not otherwise have a spatial component so it could not be split with GIS into non-riparian and riparian drainage areas. The area percentage split in 1995 between non-riparian and reach was maintained for 2030 for each non-urban land use. The new urban land use was prorated between non-riparian and riparian areas based on its percentage of total urban lands. See Section 2.3.2 for an example calculation for one of the subwatersheds.

Table 3–68. Example of the division of projected 2030 land use between riparian wetlands and upland wetlands for Wekiva River, Planning Unit 4E, subwatershed 18.

HSPF Hydrologic Modeling Land Use Group	1995 Land Use			Land Use Supporting Predicted 2030 Population		
	Drains to Reach*	Drains to Non-riparian Wetlands*	Total Acres*	Drains to Reach†	Drains to Non-riparian Wetlands†	Total Acres ‡
Low-density residential	1,349.0	124.2	1,473.2	1,319.5	306.3	1,625.8
Medium-density residential	203.0	108.3	311.3	2,693.4	625.2	3,318.6
High-density residential	5.0	0.3	5.4	26.8	6.2	33.0
Industrial and Commercial	130.0	3.6	133.7	297.5	69.1	366.5
Mining	37.3	39.8	77.1	3.5	3.8	7.3
Open and Barren Land	160.9	14.5	175.4	19.6	1.8	21.4
Pasture	1,253.5	371.5	1,625.0	572.9	169.8	742.7
Agriculture General	582.5	173.4	755.8	239.9	71.4	311.3
Agriculture Tree Crops	663.1	112.5	775.6	160.5	27.2	187.7
Rangeland	999.7	343.5	1,343.2	398.7	137.0	535.6
Forest	529.3	189.8	719.1	177.3	63.6	240.9
Water	61.3	6.3	67.6	61.3	6.3	67.6
Wetlands	1.6	170.1	171.7	1.6	170.1	171.7
TOTALS	5,976.2	1,657.8	7,634.1	5,972.5	1,657.8	7,630.1

* From 1995 land use geographic information system
† Calculated land use shifts based on percentages of each upland/riparian split in 1995 land use.
‡ From GIS Associates, Inc. population/land use model

5.4 CALIBRATION RESULTS

A review of the data for the tributary stream gauges can reveal differences in the hydrologic response of these streams. One simple measure of response is to represent the flow measurements as a flow rate per square mile of watershed. The discharge in cubic feet per second per square mile (cfs/mi^{-2}) allows a direct comparison of observed and simulated (calibrated) flows for the 50 gauged site locations used in the surface water models for the WSIS (Figure 3–64). These flows are averaged over the calibration period and reduced to cfs mi^{-2}. Most of the flows are less than 2.0 cfs mi^{-2}, with the exceptions being those discharges that contain spring flows. Note that the lower discharge per unit area watersheds typically had non-contributing surface area in the basin.

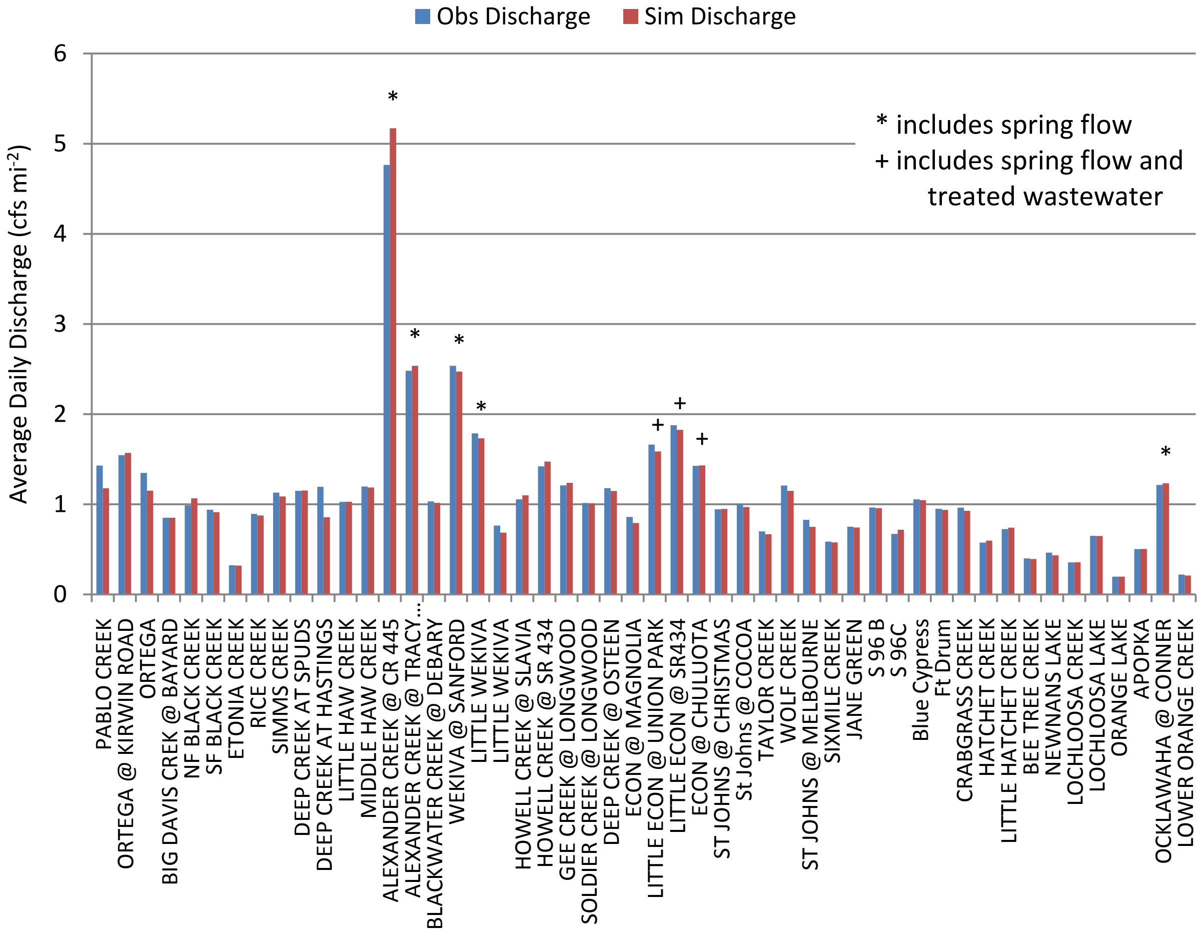

Figure 3–64. Comparison of observed (Obs) and simulated (Sim) discharge at calibration sites used in the WSIS watershed hydrology models.

The difference between the observed and simulated flows is small, which, along with the other model statistics reported in Appendices 3.H through 3.M, indicate than the models are a good representation of the watershed hydrology. The differences in reported versus simulated flows may be explained by a limited number of hydrologic factors, which all may affect runoff characteristics.

A very common measure of the performance of a hydrologic model is the Nash–Sutcliffe statistic (Moriasi, Arnold, et al. 2007). The Nash–Sutcliffe statistic ranges from zero to one, where zero would mean that the average of observations is a better model and one is a perfect match between simulated and observed data (Table 3–69). Negative Nash–Sutcliffe values are possible, although they do not have a particular meaning.

Table 3–69. Grading model calibration performance with the Nash–Sutcliffe statistic (NSE) and the Percent Error of the Mean (PEM)*

Performance Rating	Nash–Sutcliffe (Monthly)	Percent Error of the Mean (Monthly)
Very good	0.75 < NSE < 1.00	< ±10
Good	0.65 < NSE < 0.75	±10 < PEM < ±15
Satisfactory	0.50 < NSE < 0.65	±15 < PEM < ±25
Unsatisfactory	< 0.50	> ±25

*Adapted from (Moriasi, Arnold, et al. 2007)

The calibration performance results for the WSIS watersheds show that the calibrated model is rated “good” or “very good” for 30 of 39 flows and “unsatisfactory” for only 2 of 39 flows (

Table 3–70). Performance of calibration results for dynamically managed structures were rated “good” for one of four structures and “unsatisfactory” for two of four structures (Table 3–71). This result is not unexpected, as human influence on the structures is extensive and is not readily reproduced in a model. For example, flows at S96C and S96B discharged into the same receiving water pool during the model period, causing backwater effects, which reduced cumulative flow from the structures. Decisions as to which structure would be closed to allow for design discharge from the other structure were based on a multitude of factors, including upstream agricultural pumping, distribution of regional rainfall, and anticipated atmospheric conditions. These ratings were not deemed critical, as the differences in parameters, such as flow and stage, from the model scenarios would drive the environmental evaluations, not their absolute values. Calibration performance for water levels were rated “very good” for 4 of 4 lakes modeled (). In two cases, flow observations were not used for calibration because of poor (“unsatisfactory”) flow records or short periods of record. In several cases, flow observations not used for calibration because the watersheds were instead calibrated against water level observations of nearby lakes (Table 3–72).

Table 3–70. Calibration performance between simulated and observed flows at USGS and SJRWMD stations.

HSPF Hydrologic Model	Planning Unit	Subwatersheds	Flow/Water Level Station	Nash–Sutcliffe (Performance Rating)*	Percent Error of the Mean
Lower St. Johns River Basin (3)					
Little Haw Creek	3A: Crescent Lake	1	USGS 02244420	0.62 (Satisfactory)	1.94
Middle Haw Creek	3A: Crescent Lake	3	USGS 02244320	0.74 (Good)	1.72
Etonia Creek	3B: Etonia Creek	21, 26, 31, 41, 42, 43	USGS 02245050	0.69 (Good)	-1.77
Rice Creek	3B: Etonia Creek	2	USGS 02244473	0.80 (Very good)	3.08
Simms Creek	3B: Etonia Creek	44	USGS 02245140	0.66 (Good)	3.11
North Fork Black Creek	3C: Black Creek	6, 10, 11, 15, 16, 17	USGS 02246000	0.81 (Very good)	1.12
South Fork Black Creek	3C: Black Creek	1, 2, 3	USGS 02245500	0.75 (Very good)	2.78
Ortega at Jacksonville	3D: Ortega River	1	USGS 02246300	0.70 (Good)	13.19
Deep Creek at Spuds	3F: Deep Creek	2	USGS 02245260	0.68 (Good)	-0.34
Big Davis Creek at Bayard	3H: Julington Creek	3	USGS 02246150	0.65 (Good)	1.79
Pablo Creek at Jacksonville	3I: Intracoastal Waterway	2, 4, 5, 6, 3	USGS 02246828	0.65 (Good)	4.93

HSPF Hydrologic Model	Planning Unit	Subwatersheds	Flow/Water Level Station	Nash–Sutcliffe (Performance Rating)*	Percent Error of the Mean
Middle St. Johns River Basin (4)					
Econlockhatchee River at Magnolia Ranch	4A: Econlockhatchee River	1	USGS 02233001	0.22 (Unsatisfactory)	-17.88
Little Econlockhatchee River near Union Park	4A: Econlockhatchee River	11	USGS 02233200	0.61 (Satisfactory)	5.62
Little Econlockhatchee River at SR 434	4A: Econlockhatchee River	11, 12, 13	USGS 02233475	0.83 (Very good)	3.00
Econlockhatchee River near Chuluota	4A: Econlockhatchee River	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13	USGS 02233500	0.72 (Good)	1.23
Deep Creek near Osteen	4B: Deep Creek	2, 4	USGS 02234100	0.79 (Very good)	-0.08
Howell Creek near Slavia	4C: Lake Jesup	1, 2, 4, 5, 6	USGS 02234324	0.70 (Good)	-1.31
Howell Creek at SR 434	4C: Lake Jesup	1, 2, 4, 5, 6, 7, 8, 9	USGS 02234344	0.73 (Good)	0.74
Gee Creek near Longwood	4C: Lake Jesup	10, 12, 13, 14, 15	USGS 02234400	0.60 (Satisfactory)	-0.77
Soldier Creek near Longwood	4C: Lake Jesup	17, 18, 19, 20, 21, 23	USGS 02234384	0.64 (Satisfactory)	0.39
Blackwater Creek near DeBary	4E: Wekiva River	8, 9, 10, 12	SJRWMD 30143084	0.80 (Very good)	1.35
Wekiva River near Sanford	4E: Wekiva River	19, 25, 26, 27, 28	USGS 02235000	0.68 (Good)	2.36
Little Wekiva River	4E: Wekiva River	20, 21, 22, 23, 24	SJRWMD 09502132	0.66 (Good)	1.56
Lake George Basin (5)					
Alexander Creek at CR 445	5B: Alexander Springs	1, 2	SJRWMD 18523784	0.79 (Very good)	-1.02
Alexander Creek at Tracy Canal	5B: Alexander Springs	3, 4, 5	SJRWMD 18553786	0.80 (Very good)	-2.57

HSPF Hydrologic Model	Planning Unit	Subwatersheds	Flow/Water Level Station	Nash–Sutcliffe (Performance Rating)*	Percent Error of the Mean
Upper St. Johns River Basin (6)					
Fort Drum Creek	6A: Fort Drum Creek	1, 2, 3, 4, 5, 6, 10	USGS 02231342	0.72 (Good)	1.31
Blue Cypress Creek	6B: Blue Cypress Creek	5, 6, 7, 8, 9, 10	USGS 02231396	0.52 (Satisfactory)	0.69
Crabgrass Creek	6E: Jane Green Creek	8	USGS 02231565	0.43 (Unsatisfactory)	3.55
Sixmile Creek	6F: St. Johns Marsh	2	USGS 02231454	0.60 (Satisfactory)	0.40
St Johns River near Melbourne	6F: St. Johns Marsh	7	USGS 02232000	0.88 (Very good)	6.22
Wolf Creek near Deer Park	6G: Lake Poinsett	4	USGS 02232200	0.61 (Satisfactory)	4.86
St Johns River near Cocoa	6G: Lake Poinsett	5, 6, 8, 10, 11, 12, 13	USGS 02232400	0.85 (Very good)	3.47
St Johns River near Christmas	6HI: Tosohatchee-Puzzle Lake	1, 2, 3, 4, 5, 6, 7, 8	USGS 02232500	0.88 (Very good)	-0.42
Ocklawaha River Basin (7)					
Ocklawaha River at Conner	7EF: Marshall Swamp-Rodman Reservoir	1, 2, 3, 4, 23, 5	USGS 02240000	0.98 (Very good)	0.01
Lower Orange Creek	7G: Newnans Lake-Orange Lake-Orange Creek	6, 7, 8, 9, 10	USGS 02243000	0.94 (Very good)	4.45
Bee Tree Creek	7G: Newnans Lake-Orange Lake-Orange Creek	6, 7	SJRWMD 02850235	0.86 (Very good)	1.68
Hatchet Creek	7G: Newnans Lake-Orange Lake-Orange Creek	1, 2, 3, 4, 5	SJRWMD 01950193	0.80 (Very good)	0.05
Little Hatchet Creek	7G: Newnans Lake-Orange Lake-Orange Creek	9	SJRWMD 02840233	0.78 (Very good)	0.01
Lochloosa Creek	7G: Newnans Lake-Orange Lake-Orange Creek	16, 17, 18, 19	SJRWMD 01930189	0.86 (Very good)	0.65

*See Table 3–69 for the performance rating scale.

Table 3–71. Calibration performance between simulated and observed flows at dynamically managed structures.

HSPF Hydrologic Model	Planning Unit	Subwatersheds	Flow/Water Level Station	Nash–Sutcliffe (Performance Rating)	Percent Error of the Mean
Upper St. Johns River Basin (6)					
S-96C	6B: Blue Cypress Creek	1, 2, 18	SJRWMD 0098	0.57 (Satisfactory)	-6.75
S-96B	6C: Fellsmere	3, 4, 5, 8, 10, 11, 12, 16, 17	SJRWMD 0096	0.11 (Unsatisfactory)	0.92
Jane Green Creek	6E: Jane Green Creek	1, 2, 3, 4, 5, 6, 7, 9	USGS 02231600	0.69 (Good)	0.09
Taylor Creek	6G: Lake Poinsett	15, 16, 17	USGS 02232415	0.29 (Unsatisfactory)	-5.74

*See Table 3–69 for the performance rating scale.

Table 3–72. Calibration performance between simulated and observed water level measurements at lakes.

HSPF Hydrologic Model	Planning Unit	Subwatersheds	Flow/Water Level Station	Nash–Sutcliffe (Performance Rating)	Percent Error of the Mean
Ocklawaha River Basin (7)					
Apopka	7BCD: Lake Apopka-Lake Harris-Lake Griffin	9	SJRWMD 30003000	0.85 (Very good)	-0.05
Newnans Lake	7G: Orange Creek	8, 10, 11, 12, 13	SJRWMD 04831007	0.86 (Very good)	0.05
Lochloosa Lake	7G: Orange Creek	20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37	SJRWMD 71481615	0.88 (Very good)	-0.05
Orange Lake	7G: Orange Creek	20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33, 34, 35, 36, 37	SJRWMD 02611465	0.97 (Very good)	0.03

*See Table 3–69 for the performance rating scale.

6 SCENARIO SIMULATIONS AND RESULTS FOR WATER QUANTITY

The scenarios for environmental analysis separate the effects of surface water withdrawals from the St. Johns River from other factors. The set of scenarios analyzed for the WSIS varies the magnitude of surface water withdrawals only, while keeping other model characteristics constant, such as channel morphology, land use, surface water and groundwater inflows, and meteorological conditions.

6.1 SCENARIO DESCRIPTIONS

The SJRWMD's Division of Water Resources has the responsibility of planning for consumptive uses of water. As part of that responsibility, they identified four potential water supply withdrawal points from the river shown in Figure 3–1 and defined as the following:

- Lake Poinsett in the Upper St. Johns River Basin
  An average withdrawal of either 0, 27.5, or 55 mgd (depending on scenario) is pumped into Taylor Creek Reservoir (TCR) from a canal on the west side of St. Johns River just north of SR 520/Lake Poinsett. The pump rate was allowed to vary within the simulation from 0 to 84 mgd depending on river flow, scenario, and whether TCR was full.
- A constant withdrawal of either 0, 25, or 50 mgd (depending on scenario) from the St. Johns River near the mouth of Lake Jesup in the Middle St. Johns River Basin
- A constant withdrawal of either 0, 25, or 50 mgd (depending on scenario) from Yankee Lake in the Middle St. Johns River Basin, west side of St. Johns River north of I-4 crossing
- A constant withdrawal of either 0, or 107 mgd (depending on scenario) from the lower Ocklawaha in the Ocklawaha River basin, at the upstream end of the Rodman Reservoir

Withdrawals at the Lake Jessup and Yankee Lake sites were analyzed directly by the EFDC hydrodynamic model discussed in Chapters 5 and 6. The Lake Poinsett and Ocklawaha River basin sites are outside of the boundaries of the EFDC hydrodynamic model and have been modeled using the HSPF hydrologic models.

The EFDC hydrodynamic model of the St. Johns River required 97 surface water inflow points to the river for its scenario analysis. The subwatershed models were calibrated at 47 locations. The parameters from the calibration models were applied to the 50 subwatershed models that were ungauged. This process allowed for development of all scenario runs for every subwatershed within the St. Johns River watershed. The subwatersheds were then aggregated as needed to develop flow input into the EFDC hydrodynamic model (Figure 3–65).

Several subwatersheds throughout SJRWMD have no surface water flow. In a subwatershed that is noncontributing to surface water flows, all rainfall is accounted for through evapotranspiration and recharge into the aquifer (Figure 3–59).

The 1995 scenario uses SJRWMD's 1995 land use conditions, permitted water withdrawals, and the 1995 status of the USJRB USACE Project. The 1995 condition models were modified to create 2030 condition models. The 2030 condition models are based on the projected 2030 land use, projected additional permitted water withdrawals, completion of the USJRB USACE Project, and completion of new environmental restoration projects that are currently under construction (Table 3–2). Both model scenarios were run and the flow time series for both were transferred to the EFDC hydrodynamic modeling and environmental analysis teams. These two scenario runs provide input for 84 of the inflow points to the EFDC hydrodynamic model. Additional scenarios were run for the USJRB and the Ocklawaha River basin that involved potential surface water withdrawals.

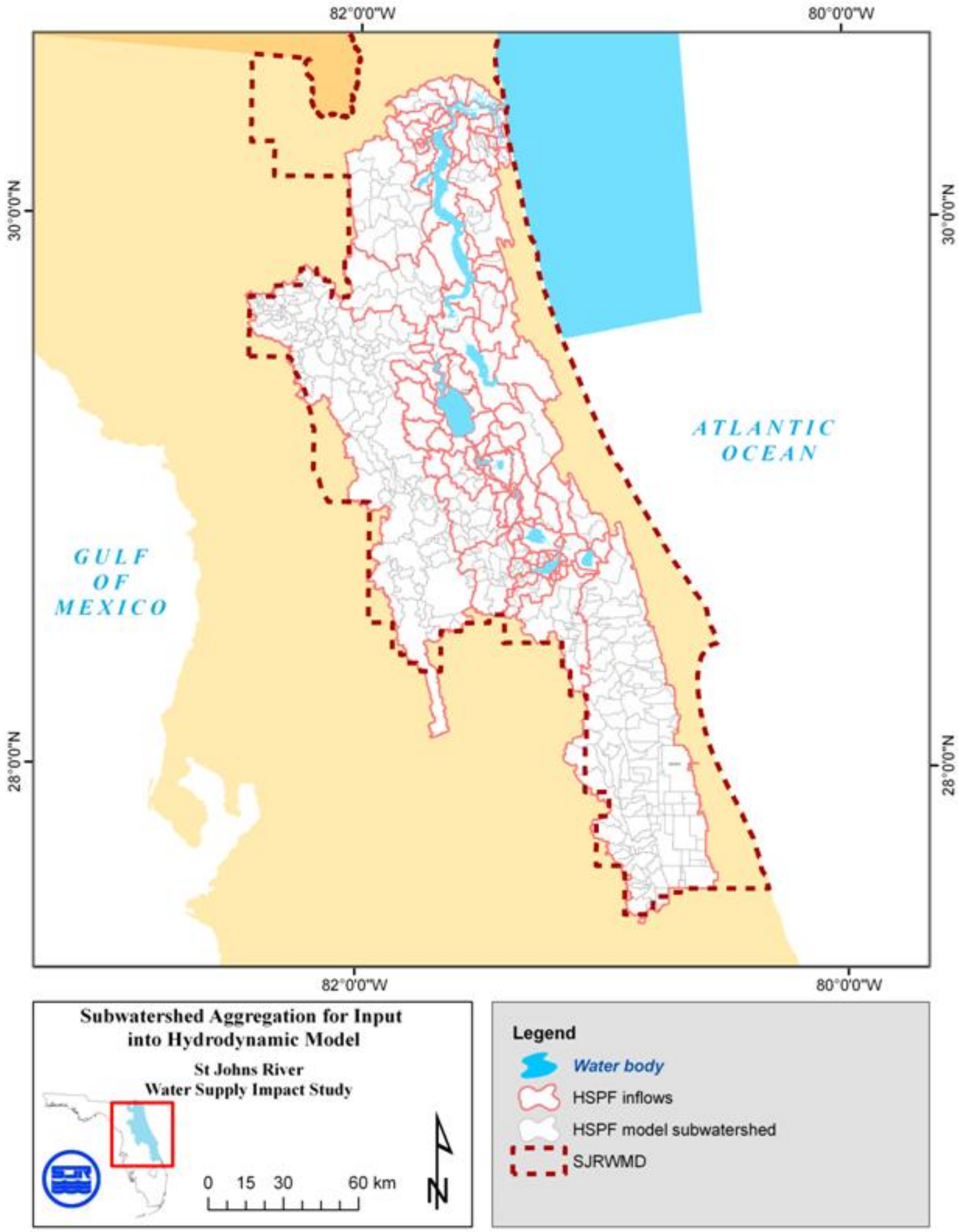

Figure 3–65. Subwatershed aggregation for input into the EFDC hydrodynamic model.

6.2 Scenario Simulation Results

Two watershed hydrology scenarios were developed for the Middle St. Johns, Lake George, and Lower St. Johns major basins since there were no withdrawals from those major basins. The Ocklawaha had four scenarios to account for the withdrawal condition, while the Upper St. Johns River major basin had nine watershed hydrology scenarios. Table 3–73 illustrated the mapping between the watershed hydrology scenarios and the WSIS scenarios evaluated in Chapter 6. Table 3–2). One flow time series represents the 1995 Base Condition and another time series represents the 2030 Base Condition. The flow time series from the major tributaries were used as direct input to the EFDC hydrodynamic model of the St. Johns River. Areas adjacent to the river with multiple small drainage systems (natural or constructed) were disaggregated and input into the EFDC hydrodynamic model at various points along the river. In addition, USJRB and Ocklawaha River basin time series for the various withdrawal scenarios were also provided as input to the EFDC hydrodynamic river model.

Table 3–73. Mapping between watershed hydrology scenarios and the WSIS scenarios.

Watershed Hydrology Model Scenarios per Major Basin			
USJRB (9 Scenarios)	**Ocklawaha (4 Scenarios)**	**Middle St. Johns, Lake George, Lower St. Johns (2 Scenarios)**	**WSIS Scenario**
Base1995N	Base1995	Base1995	Base1995NN
Half1995N	Base1995	Base1995	Half1995NN
Full1995N	Base1995	Base1995	Full1995NN
Full1995N	FwOR1995	Base1995	FwOR1995NN
Base1995P	Base1995	Base1995	Base1995PN
Half1995P	Base1995	Base1995	Half1995PN
Full1995P	Base1995	Base1995	Full1995PN
Full1995P	FwOR1995	Base1995	FwOR1995PN
Base1995P	Base1995	Base1995	Base1995PS
Half1995P	Base1995	Base1995	Half1995PS
Full1995P	Base1995	Base1995	Full1995PS
Full1995P	FwOR1995	Base1995	FwOR1995PS
Base2030P	Base2030	Base2030	Base2030PS
Half2030P	Base2030	Base2030	Half2030PS
Full2030P	Base2030	Base2030	Full2030PS
Full2030P	FwOR2030	Base2030	FwOR2030PS
Base2030P	Base2030	Base2030	Base2030PN
Half2030P	Base2030	Base2030	Half2030PN
Full2030P	Base2030	Base2030	Full2030PN
Full2030P	FwOR2030	Base2030	FwOR2030PN

A higher average flow was generated in the projected 2030 land use scenario than in the 1995 scenario. This was expected due to increased impervious surfaces associated with urbanization, which causes higher storm water flows. The two planning units with the largest increase of average flow, MSJRB and LSJRB, also have the largest urban expansion. The relative increase in flow is larger in the MSJRB due to the region's soils having characteristically higher infiltration rates associated with type A or B soils. Therefore, the increase in the impervious area associated with development produces an increase in surface water runoff when replacing areas that allow much higher infiltration in their undeveloped state.

The results of the 1995 and projected 2030 land use scenarios developed for the St. Johns River watershed were compared for daily average, median, minimum, and maximum flows, respectively (Table 3–74, Table 3–75, Table 3–76, and Table 3–77). These statistics were generated by using longer-term rainfall data (1975 through 2006) than were used for calibration of the HSPF hydrologic models. The 32-year period represents results that would occur if land use conditions were held constant as conditions were in 1995 and should not be evaluated for calibration purposes or used for comparison with historic changes in flow or stage data.

Table 3–74. Comparison of daily average surface flow estimates for the 1995 (Base1995P) and projected 2030 (Base2030P) land use scenarios.

Basin Number	Basin Name	1995 Land Use Average Discharge (mgd)	2030 Land Use Average Discharge (mgd)	% Increase
6	Upper St Johns River Basin	842	932	10.7%
4	Middle St Johns River Basin	625	711	13.8%
5	Lake George Basin	188	207	10.1%
7	Ocklawaha River Basin	759	796	4.9%
3	Lower St Johns River Basin	1,412	1,605	13.7%
	Total	3,826	4,251	10.6%

Table 3–75. Comparison of daily median surface flow estimates for the 1995 (Base1995) and 2030 (Base2030P) land use scenarios.

Basin Number	Basin Name	1995 Land Use Median Discharge (mgd)	2030 Land Use Median Discharge (mgd)	% Increase
6	Upper St Johns River Basin	546	633	15.9%
4	Middle St Johns River Basin	29	32	10.3%
5	Lake George Basin	130	146	12.3%
7	Ocklawaha River Basin	633	662	4.6%
3	Lower St Johns River Basin	780	888	13.8%
	Total	2,118	2,361	11.4%

Table 3–76. Comparison of daily minimum surface flow estimates for the 1995 (Base1995P) and projected 2030 (Base2030P) land use scenarios.

Basin Number	Basin Name	1995 Land Use Minimum Discharge (mgd)	2030 Land Use Minimum Discharge (mgd)	% Increase
6	Upper St Johns River Basin	35	57	62.9%
4	Middle St Johns River Basin	29	32	10.3%
5	Lake George Basin	7	10	42.9%
7	Ocklawaha River Basin	112	114	1.8%
3	Lower St Johns River Basin	51	53	3.9%

Table 3–77. Comparison of daily maximum surface flow estimates for the 1995 (Base1995P) and projected 2030 (Base2030P) land use scenarios,

Basin Number	Basin Name	1995 Land Use Maximum Discharge (mgd)	2030 Land Use Maximum Discharge (mgd)	% Change
6	Upper St Johns River Basin	6,635	7,348	10.7%
4	Middle St Johns River Basin	17,204	18,740	8.9%
5	Lake George Basin	3,442	3,798	10.3%
7	Ocklawaha River Basin	5,402	5,823	7.8%
3	Lower St Johns River Basin	41,663	46,656	12.0%

The HSPF hydrologic modeling of 1995 (Base1995P) and 2030 (Base2030P) scenarios without withdrawals predicts an average 11% increase in surface flows to the St. Johns River. The overall water budget for each basin does not change significantly between scenarios; therefore, the greater surface water flow generated by increased impervious area must be balanced by a decrease in other water budget components. Water budgets developed for each planning unit show that total evapotranspiration decreases as flow increases due to increased impervious area (see Figure 3–66). There was very little difference in deep recharge relative to the increase in evapotranspiration or storm water runoff.

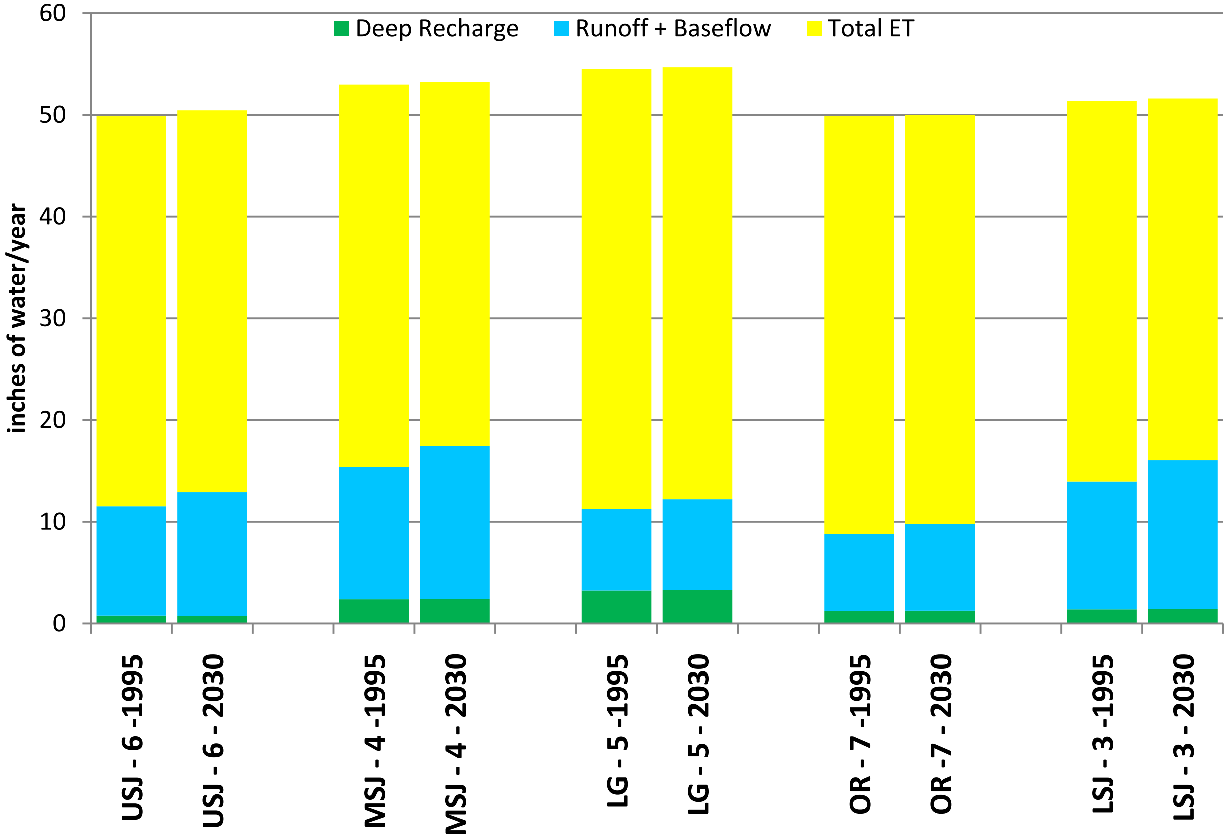

Figure 3–66. Water budget for surface processes (excludes open water and noncontributing areas) comparing Base1995P and Base2030P scenarios.

While additional storm water runoff from developed land would mitigate impacts to flow and stage from future withdrawals, it is very likely that the runoff and withdrawals will occur concurrently. If development occurs slower than projected, then water demand will resultantly be reduced. An additional consideration that remains to be evaluated is the potential negative affect on water quality of adding additional stormwater runoff to a receiving water body. This question was raised by the National Research Council review panel, and is addressed in Appendix 3.E, which evaluates the water quality associated with increased storm water runoff for a selected watershed.

6.3 Ocklawaha River Basin (7)

Four scenarios were run for the Ocklawaha River Basin (Table 3–78). Two scenarios use the 1995 land use, while two use the 2030 projected land use. Under 1995 conditions, the North Shore Restoration Area on the north shore of Lake Apopka was an agricultural area. It is currently being restored to wetlands and is modeled as a wetland under 2030 conditions. Also in 2030 conditions, a proposed withdrawal of 5 mgd for the City of Apopka is included. Runs with and without the primary withdrawal of 107 mgd from Rodman Reservoir were modeled for both 1995 and 2030 conditions.

Table 3–78. Scenario characteristics for the Ocklawaha River Basin.

Scenario Components	1995 Condition (Base1995)	1995 Full Withdrawal (FwOR1995)	2030 Condition (Base2030)	2030 Full Withdrawal (FwOR2030)
Land Use	1995	1995	2030	2030
NSRA Land Use	Agriculture	Agriculture	Wetland	Wetland
NSRA Withdrawal	0	0	5 mgd	5 mgd
Rodman Withdrawal	0	107 mgd	0	107 mgd

NSRA = North Shore Restoration Area

6.4 Ocklawaha River Basin (7) Results

The HSPF hydrologic model simulation shows that withdrawals from the Ocklawaha River basin cause a decrease of 0.14 ft (4.3 cm) in mean stage at Rodman Reservoir if implemented with either Base1995 or projected Base2030 conditions. However, projected 2030 conditions raise the mean stage by 0.04 ft (1.2 cm) over the 1995 conditions in the withdrawal or no withdrawal scenarios (Table 3–79). The mean outflow from Rodman Reservoir decreases 14% due to withdrawals under both land use scenarios, while the increased flows of 2030 add 5% over 1995. This results in a decline of 0.10 ft (3 cm) in mean stage and a net decrease of 9% in mean flow for the 2030 withdrawal scenario compared to 1995 base conditions.

An analysis of the detailed impacts of the reduction in flow to the Ocklawaha River itself may be considered later if warranted by demand. Currently there is less water supply pressure on the Ocklawaha River basin than in the St. Johns River Basin.

Table 3–79. Scenario results for the Ocklawaha River Basin (7).

Ocklawaha River Basin Scenarios	Rodman Mean Stage (ft NGVD29)	Rodman Mean Flow (mgd)	Change in Flow (%)
1995 Condition (Base1995)	18.46	755	NA
1995 Full Withdrawal (FwOR1995)	18.32	648	-14.2%
2030 Condition (Base2030)	18.50	792	4.9%
2030 Full Withdrawal (FwOR2030)	18.36	685	-9.3%

6.5 Upper St. Johns River Basin (6)

Nine scenarios were run for the upper St. Johns River (Table 3–80). Three scenarios use the 1995 land use; three scenarios use the 1995 land use plus completed or near-future USJRB Flood Control Projects, and three use the 2030-projected land use with the USJRB projects. The intermediate and final set of scenarios modeled the USJRB Flood Control Projects that are either completed or currently under construction.

- Phase I C-1 Re-diversion Project (2011)
- Fellsmere Water Management Area (2015)
- Three Forks Marsh Conservation Area (2012)
- Lake Washington Weir Replacement (2001)
- S-250 E Construction (2006)

Each of these projects is described in more detail in the basin descriptions earlier in Section 4 of this chapter. The 2030 set of scenarios represent the same completed USJRB project conditions, as proposed additional changes to the project are in the planning stages. All scenarios include the existing 11.6 mgd constant water supply withdrawal from Lake Washington for the City of Melbourne.

Each set consists of a base run with no withdrawal, a “half” withdrawal of 27.5 mgd, and a “full” withdrawal of 55 mgd from Taylor Creek Reservoir. For the withdrawal scenarios, the reservoir operation of is modified by raising its flood control schedule from seasonally varying ranging from 39.00 to 43.00 ft NGVD29 to a constant 46.00 ft NGVD29, with an added minimum flow release of 11 mgd (17 cfs).

In order to meet the Taylor Creek Reservoir withdrawal, water is pumped into the reservoir from the main stem of the river at the downstream end of Lake Poinsett. This pumping is subject to certain limitations, based on flows at the Christmas USGS gauge. If this flow is at or below a threshold of 194 mgd (300 cfs), then no pumping occurs. Flow in excess of the threshold up to a cap (58 mgd [90 cfs] for full withdrawal, 29 mgd [45 cfs] for half withdrawal) is pumped to Taylor Creek Reservoir. Withdrawals remain constant at this cap as the flow increases until it reaches 388 mgd (600 cfs). Flow in excess of this higher threshold is also pumped to Taylor

Creek Reservoir with a cap of total pumping set at 84 mgd for full withdrawal and 42 mgd for half withdrawal. In both cases, the long-term average pumping from the river to Taylor Creek Reservoir closely matches the modeled withdrawal from the reservoir.

Table 3–80. Scenario characteristics for the Upper St. Johns River Basin.

Scenario Components	1995 Land Use						2030 Land Use		
	No Projects			Projects			Projects		
	Base	Half Withdrawal	Full Withdrawal	Base	Half Withdrawal	Full Withdrawal	Base	Half Withdrawal	Full Withdrawal
	Base1995N	Half1995N	Full1995N	Base1995P	Half1995P	Full1995P	Base2030P	Half2030P	Full2030P
Land use	1995	1995	1995	1995	1995	1995	2030	2030	2030
Melbourne withdrawal (mgd)	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.6
USJRB Flood Control and Restoration Projects Implemented									
C-1 Rediversion	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Fellsmere WMA	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Three Forks MCA	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Lake Washington Weir	Old	Old	Old	New	New	New	New	New	New
S-250E	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Lake Poinsett Withdrawal to Taylor Creek Reservoir (TCR)									
Lower flow threshold (mgd)	NA	194	194	NA	194	194	NA	194	194
Ramped to lower withdrawal cap (mgd) when SJR flow above lower flow threshold	0	29	58	0	29	58	0	29	58
Upper flow threshold (mgd)	NA	388	388	NA	388	388	NA	388	388
Ramped to total withdrawal cap (mgd) when SJR flow above upper flow threshold	0	42	84	0	42	84	0	42	84
Water Supply Withdrawal from Taylor Creek Reservoir (TCR)									
TCR withdrawal (mgd)	0	27.5	55.0	0	27.5	55.0	0	27.5	55.0
TCR min release (cfs)	0	17	17	0	17	17	0	17	17
TCR flood control schedule (ft NGVD29)	39 to 43*	46	46	39 to 43*	46	46	39 to 43*	46	46
TCR cutoff stage (ft NGVD29)	NA	30	30	NA	30	30	NA	30	30

* Changes seasonally

6.6 Upper St Johns River Basin (6) Results

The proposed withdrawal from the SJR into the Taylor Creek Reservoir was simulated as a withdrawal from Lake Poinsett. The Taylor Creek Reservoir is located in the Poinsett Planning Unit, west of the St. Johns River (Figure 3–31). Two USGS monitoring stations were used for calibration of the model were selected for analysis of the change in stage and flow because of the withdrawal. The first (Cocoa/USGS 02232400 at SR 520) essentially represents Lake Poinsett itself. The Cocoa station provides what may be viewed as the maximum impact from the withdrawal in the model. The second (Christmas/USGS 02232500 at SR 50) is located two reaches downstream of the withdrawal point, and provides some attenuation of withdrawal effects. It also includes discharges from Taylor Creek Reservoir for MFLs and flood releases, which are inserted in the river downstream of the Cocoa gauge and are not included in the Cocoa gauge (Figure 3–31).

In previous water supply evaluations for Taylor Creek Reservoir, it was determined that the simulated low flows were higher than the observed low flows. The decision was made to post-process the modeled low flow to match the observed flows during the calibration period. There are three possible explanations for the low flow uncertainty: 1) the low flow data measured at the USGS stations (rated poor) are not sufficiently accurate to model at low flows; 2) the very low slope of the river, and not stage, determines flows, unlike the classic hydraulic stage-discharge relationships in higher slope systems, for which the relatively simple HSPF hydraulics is best suited; 3) the HSPF hydrologic model needs additional improvement in modeling the riverine wetlands to accommodate the complex nature of wetting and drying associated with the area’s floods and droughts. Additional discussion of river slope dictating flow in the MSJRB and LSJRB is provided in the companion report on EFDC hydrodynamic modeling (See Chapter 5, River Hydrodynamics Calibration and Chapter 6, River Hydrodynamics Results).

After the flows were post-processed, stages needed to be determined at the five transects in the USJRB, which are used by environmental scientists to evaluate the withdrawals. The USJRB HSPF hydrologic model has four reaches totaling 25 mi in length, which encompass these transects. The HSPF hydrologic model treats each of these reaches as a level pool, creating a step in elevation at each change in river reach. These reaches vary in length from 6.14 mi to 12.7 mi in length. One method of providing the elevations needed at each transect would be to generate an approximate water surface elevation at each transect without considering the actual hydraulic differences among channel sections. A better way of developing the water surface elevations is to process the flows through a hydraulic model that includes the actual channel characteristics. Hydraulic Engineering Center–River Analysis System (HEC-RAS) was used to develop a flow-stage rating curve. This rating curve was applied to the post-processed flows to generate corresponding stages. These stages were provided to the environmental scientists for evaluation. A detailed discussion of the post-processing is contained in Appendix 3.C.

The modeled impacts of Full (55 mgd) and Half (27.5 mgd) withdrawals from the St. Johns River at Lake Poinsett via Taylor Creek Reservoir on mean stage and flow at the Cocoa and Christmas gauges were analyzed for 1995 base (Base1995N), 1995-plus-projects (Base1995P), and 2030-plus-projects conditions (Base2030P) (Table 3–81).

The 1995 Full withdrawal scenario (Full1995N) resulted in a reduction in average stage and flow of 0.18 ft and 45 cfs (8.4%), respectively, from the 1995 Base scenario (Base1995N) at the Cocoa withdrawal location. The impacts on the downstream Christmas location were lower, 0.17 ft and 8.1%, respectively, as the effect of the withdrawal is attenuated downstream. The 1995 withdrawal scenario results should not be considered realistic, as they do not include the USJRB projects that are either completed or soon to be completed, and the effect of land development that has or will occur. However, it does test the veracity of the model and represents what would have happened if the proposed withdrawals occurred in 1995. The Half withdrawal scenarios (Half1995N and Half2030N) exhibited similar results, with a corresponding reduction in impacts.

A goal of the USJRB project was to provide protection of agricultural lands in the upper basin from flooding. Another goal of the project was to return previously diverted flow to the Indian River Lagoon back to the river. The return of flow back to the river may be observed with the results of the 1995-plus-projects scenarios that included water withdrawals. The Full withdrawal-plus-projects scenario (Full1995P) actually projected a 0.04 ft. increase in average stage at the Cocoa site above the 1995 Base scenario (Base1995P), while decreases in average flow were reduced to 36 cfs (6.7%). Modeled changes at Christmas showed similar trends, with an increase in average stage and a reduced average flow change.

All average stages and flows increased when projected 2030 land use changes were combined with USJRB projects and withdrawals (Base2030P). The average stage at Cocoa increased 0.18 ft, and average flow increased 6 cfs (1.1%) above the 1995 Base scenario (Base1995P). Land use development contributes additional runoff to all basins, as the increase in average flow of 15 cfs at Christmas suggests. It should be reiterated that the projected 2030 land use for this study is an estimate of the land use required to support the Bureau of Economic and Business Research 2030 population prediction developed in 2008. Florida experienced unprecedented population growth from 1995 through 2006; however, it also had a serious downturn in population growth from 2008 to 2011. The SJRWMD has recently received 2010 population and land use information, and these data will be developed and used when assessing how the river will respond to requested surface water withdrawals in the Consumptive Use Permit program.

Table 3–81. Scenario results for the Upper St. Johns River Basin (6).

USJRB Scenario	WSIS Scenario Name	Cocoa Mean Stage (ft NGVD29)	Cocoa Mean Flow (mgd)	Change in Flow at Cocoa (%)	Christmas Mean Stage (ft NGVD29)	Christmas Mean Flow (mgd)	Change in Flow at Christmas (%)
1995 Base	Base1995N	11.72	536	NA	6.11	668	NA
1995 + Half St. Johns River Withdrawal	Half1995N	11.62	513	-4.3%	6.03	639	-4.3%
1995 + Full St. Johns River Withdrawal	Full1995N	11.54	491	-8.4%	5.94	614	-8.1%
1995 + USJB Projects	Base1995P	11.95	546	+1.9%	6.27	676	+1.2%
1995 + USJB Projects + Half St. Johns River Withdrawal	Half1995P	11.84	522	-2.6%	6.17	647	-3.1%
1995 + USJB Projects + Full St. Johns River Withdrawal	Full1995P	11.76	500	-6.7%	6.09	621	-7.0%
2030 Base	Base2030P	12.09	587	+9.5%	6.47	740	+10.8%
2030 + Half St. Johns River Withdrawal	Half2030P	11.99	564	+5.2%	6.37	710	+6.3%
2030 + Full St. Johns River Withdrawal	Full2030P	11.91	542	+1.1%	6.29	683	+2.2%

7 SUMMARY

The first step in the scientific foundation of WSIS was to evaluate surface water runoff of the St. Johns River watershed using the HSPF hydrologic model. Ninety-seven individual HSPF runoff models were developed, and 47 were directly calibrated to observed hydrologic data using 1995 land use conditions and 1995 through 2006 atmospheric data. This period was selected, in part, due to relatively constant physical conditions in the watershed. The calibration resulted in an acceptable fit for average daily discharges and a good fit for monthly and yearly results. Of the 47 calibrated watersheds, there were 21 very good, 22 good and satisfactory, and only four unsatisfactory values for the Nash–Sutcliffe statistic, which is a common rating of the performance of hydrologic models. The parameters from the calibration models were then applied to the 50 watershed models that did not have gauges for calibration. This process allowed for development of a 1995 condition model for every subwatershed within the St. Johns River watershed. The subwatersheds were then aggregated as needed to develop flow input into the EFDC hydrodynamic model.

A 32-yr record of atmospheric data was used to generate longer-term statistics for comparison of flows among different modeling scenarios of the 1995 and 2030 water supply planning horizon. These scenario flow results are snapshots in time of a static 1995 or 2030 condition and are should not be compared to observed flow data. The flow and water level results generated by the HSPF hydrologic model for the USJRB were directly evaluated by the various environmental working groups (Chapters 7 through 13). The HSPF simulated flows from over 900 subwatersheds and multiple scenarios were aggregated as required to be used as input to the riverine EFDC hydrodynamic model for evaluation of effects on the middle and lower St. Johns River (see Chapter 5, River Hydrodynamics Calibration and Chapter 6, River Hydrodynamics Results).

Projected land use changes between 1995 and 2030 resulted in a district wide 10.6% increase in average discharge. The entire St. Johns River basin experienced tremendous urban development between 1995 and 2005 and the increase in impervious area associated with development projected to 2030 conditions explains the increased flows.

Twelve modeling scenarios were selected for detailed evaluation for WSIS. Of the 12 scenarios, nine were directly evaluated for the USJRB with results for the HSPF hydrologic modeling (Table 3–80). The most useful comparison is between the 1995 land use or Base scenario (Base1995P) and the projected 2030 land use and USJRB restoration project conditions with the Full St. Johns River withdrawal scenario (Full2030P). This comparison resulted in a 0.18 ft increase in average stage and 1.1% increase in average flow at the Cocoa gauge (USGS 02232400 SJR at SR 520) and a 0.18ft increase in average stage and 2.2% increase in average flow at the Christmas gauge (USGS 02232500 SJR at SR 50). There are temporal variations in the data generated by these scenario simulations, and additional evaluation of the hydrologic results by the environmental working groups are presented in Chapters 7 through 13.

REFERENCES

Adamus, Christine, David Clapp, and Stephen Brown. *Technical Publication SJ97-1: Surface Water Drainage Basin Boundaries [of the] St. Johns River Water Management District: A Reference Guide.* Palatka, FL: St. Johns River Water Management District, 1997.

BEBR. *FPS: Detailed Population Projections by Age, Sex, Race, and Hispanic Origin, 2008-2030: ALL CATEGORIES.* Gainesville, Florida: University of Florida, 2009.

Bergman, Martinus J. *Volume 2 of the Lower St. Johns River Basin Reconnaissance Report: Surface Water Hydrology: Technical publication SJ 92-1.* Palatka, Florida: St. Johns River Water Management District, 1992.

Bicknell, Brian R., John C. Imhoff, Jr., John L. Kittle, Thomas H. Jobes, and Jr., Anthony S. Donigian. *HYDROLOGICAL SIMULATION PROGRAM - FORTRAN, HSPF, Version 12, User's Manual.* Athens, GA: U.S. Environmental Protection Agency - National Exposure Research Laboratory, 2001.

Brooks, H. K. *Guide to the physiographic divisions of Florida.* Gainesvilel, FL: University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service, 1982.

Camp, Dresser, and McKee Inc. *City of Jacksonville Master Storm Water Management Plan. Intracoastal Waterway Basin Final Report.* Jacksonville, FL: Camp, Dresser, and McKee Inc., 1992.

Camp, Dresser, and McKee Inc. *Master Stormwater Management Plan, City of Jacksonville, Florida.* Jacksonville, FL: Camp, Dresser, and McKee Inc., 1989.

Canfield, D. E. *Final Report: Chemical and trophic state characteristics of Florida lakes in relation to regional geology.* Gainesville, FL: Cooperative Fish and Wildlife Research Unit, 1981.

Clapp, David A., C. Price Robison, and Richard B. Hupalo. *Surface Water Modeling and Environmental Validation Study: Wekiva River System Minimum Flows and Levels [DRAFT].* Paltaka, FL: St. Johns River Water Management District, 1999.

Doherty, John. *PEST, Model-Independent Parameter Estimation, User Manual: 5th Edition.* Watermark Numerical Computing, 2004.

Doolittle, James A., and Gregg Schellentrager. *Soil Survey of Orange County, Florida.* Soil Conservation Service, United States Department of Agriculture, 1989.

Dymond, J. R., and R. Christian. "Accuracy of discharge determined from a rating curve." *Hydrological Sciences Journal, 27(4)*, 1982: 493-504.

EPA. *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF.* EPA, July 2000.

Florida Department of Environmental Protection. *Basin Status Report: Middle St. Johns.* Tallahassee, FL: Florida Department of Environmental Protection, 2003.

Friends of Lake Apopka. "Lake Apopka Timeline." August 2011. http://www.fola.org/PDFs/LakeApopkaTimeLineAug2011.pdf (accessed January 12, 2012).

German, Edward R. *Analysis of the relation between discharge from the Apopka Spring and lake and ground-water levels.* Special Publication SJ2006-SP12, Palatka, FL: St. Johns River Water Management District, 2006.

GIS Associates, Inc. *SJ2009-SP7: The Small Area Population and Distribution Methodology of the St. Johns River Water Management District for the 2008 District 'Water Supply Assessment' and the 2010 District 'Water Supply Plan'.* Palatka, FL: St. Johns River Water Management District, 2009.

Hall, Greeneville (Editor). *Ocklawaha River Water Allocation Study, Technical Publication SJ2005-1.* Palatka: St. Johns River Water Management District, 2005.

Hargreaves, George H., and Richard G. Allen. "History and Evaluation of Hargreaves Evapotranspiratioin Equation." *Journal of Irrigation and Drainage Engineering*, 2003: 53-63.

Keesecker, D. H. *Lake Jesup restoration diagnostic evaluation, water budget and nutrient budget.* Palatka, Florida: St. Johns River Water Management District. File 91-5057, 1992.

Kennedy, E. J. "Computation of Continuous Records of Streamflow." In *Techniques of Water Resource Investigactions, Book 3, Chapter A13*. U.S. Geological Survey, 1983.

Lumb, A. M., R. F. Carsel, and J. L, Jr Kittle. "Data management for water-quality modeling development and use." *Proceedings of the International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology.* 1988.

Miller, Steven J, Mary Ann Lee, Edgar F Lowe, and Apurbah K Borah. *Environmental Water Management Plan for the Blue Cypress Water Management Area; Upper St. Johns River Basin Project.* Technical Memorandum No. 13, Palatka: St. Johns River Water Management District, 1996.

Miller, Steven J, Terry Tremwell, and Marc C Minno. *2003 Interim Environmental Water Management Plan for the Upper St. Johns River Basin Project.* Technical Memorandum 48, Palatka: St. Johns River Water Management District, 2003.

Moriasi, D. N., J. G. Arnold, M. W. Van Liew, R. L. Bigner, R. D. Harmel, and T. L. Veith. "Model evaluation guidelines for systematic quantification of accuracy in watershed simulations." *Transactions of ASABE, American Society of Agricultural and Biological Engineers*, 2007: vol 50, #3, pp 885-900.

Moriasi, D. N., J. G. Arnold, M. W. Van Liew, R. L. Bigner, R. D. Harmel, and T. L. Veith. "Model evaluation guidelines for systematic quantification of accuracy in watershed simulations." *Transactions of ASABE, American Society of Agricultural and Biological Engineers*, 2007: vol 50, #3, 885-900.

Rao, D. V., and C. C. Tai. *An evaluation of Lake Washington temporary weir for surface water management. Phase I: Hydraulic/hydrologic analyses: Technical Publication SJ 87-4.* Palatka, Florida: St. Johns River Water Management District, 1987.

Rao, Donthamsetti V., and David A. Clapp. *Preliminary Evaluation of the Impacts of Spring Discharge Reductions on the Flows of Receiving Water Bodies and Natural Systems, Central Florida.* Palatka, FL: St. Johns River Water Management District, 1996.

Robinson, C. Price. *Middle St. Johns River Minimum Flows and Levels Hydrologic Methods Report, Technical Publication SJ2004-2.* Palatka, FL: St. Johns River Water Management District, 2004.

Schellentrager, G., and G. W. Hurt. *Soil Survey of Seminole County, Florida.* U.S. Department of Agriculture, Soil Conservation Service, 1990.

Schelske, C. L., W. F. Kenney, and T. J. Whitmore. *Sediment and nutrient deposition in Harris Chain of Lakes.* Palatka, FL: St. Johns River Water Management District, 2001.

Shofner, J. *History of Apopka and Northeast Orange County, Florida.* Tallahassee, FL: Roe Printing Company, Inc, 1982.

SJRWMD. *District Water Supply Plan, 2005, Technical Publication SJ2006-2.* Palatka, Florida: St. Johns River Water Management District, 2006.

State of Florida. *Florida Land Use, Cover and Forms Classfication System.* Geographic Mapping Section, Surveying and Mapping, Department of Transportation, 1999.

Stem, Leon T., Hershel D. Dollar, David A. Howell, Douglas L. Lewis, Carol A. Wettstein, and Howard Yamataki. *Soil Survey of City of Jacksonville; Duval County, Florida.* United Stated Department of Agriculture; Soil Conservation Service; University of Florida; Institute of Food and Agricultural Sciences; Agricultural Experiment Station; Soil Science Department, 1978.

U.S. Census Bureau, Population Division. *Table 8: Population Estimates for the 100 Fastest Growing U.S. Counties with 10,000 or More Population in 2006: April 1, 2000 to July 1, 2006 (CO-EST2006-08).* March 20, 2007.

United States Geological Survey. *HSPF.* January 15, 2010. http://water.usgs.gov/software/HSPF (accessed January 18, 2012).

USACE. *Central and South Florida Project for Flood Control and other Purposes, Part III.* Jacsonville, FL: United States Army Corps of Engineers, 1963.

USACE. *Master Water Control Manual, Four River Basins Project, Ocklawaha River Basin.* Jacksonville, FL: Department of the Army, Corps of Engineers, Jacksonville District, 1993.

APPENDIX DESCRIPTIONS (LINKS TO SEPARATE DOCUMENTS)

APPENDIX 3.A. LAND USE CLASSIFICATION/GROUPING

The grouping of detailed land use to hydrologically similar groups for input into the HSPF model is documented.

APPENDIX 3.B. HSPF COMMON LOGIC FOR SJRWMD

SJRWMD modelers developed a common logic for use with all HSPF watershed hydrology models. The common logic defines parameter ranges based on knowledge of Florida hydrology and model experience.

APPENDIX 3.C. USJR POST-PROCESSING OF SIMULATED FLOWS AND STAGES

This appendix illustrates the process by which the USJR flows and stage were post-processed.

APPENDIX 3.D. EVALUATION OF MODEL UNCERTAINTY

The models in each river segment were given an uncertainty based on the performance of the calibrated models within that river segment.

APPENDIX 3.E. CALIBRATION AND SIMULATION FOR WATER QUALITY: CASE STUDY

The National Academy of Sciences review committee asked about water quality issues between the Base1995 and Base2030 scenarios and whether there was a difference in results due to implicit or explicit implementation of BMPs within the models. The SJRWMD could not answer this question in terms of the entire SJR watershed so late in the process since the WSIS intent was to evaluate water supply withdrawals, not the connection between land use and water quality. For a different project, SJRWMD had in hand a watershed modeling effort that answers these questions, but only covers the Little Econlockhatchee River in the Middle Basin.

APPENDIX 3.F. CLIMATE CHANGE EVALUATION

The initial evaluation of climate change determined that at SJRWMD's water supply planning horizon (2030) the expected shifts in precipitation and evaporation would be minimal and the only climate change issue to evaluate was sea level rise (see Chapters 5 and 6). The National Academy of Sciences review committee asked for an evaluation of climate change out to 2100 and the results of that effort are described in this appendix.

APPENDIX 3.G. ST. JOHNS RIVER WATERSHED WATER SUPPLY IMPACT STUDY MODEL REVIEW BY INTERA

This is the external review of the initial calibrated models.

APPENDIX 3.H. EXPLANATION OF PLOTS AND TABLES

This appendix describes the plots and tables in Appendix 3.J through 3.N

APPENDIX 3.I. 06-UPPER ST. JOHNS RIVER BASIN

Report for each calibrated subwatershed(s) for in the Upper St. Johns River Basin

APPENDIX 3.J. 04-MIDDLE ST. JOHNS RIVER BASIN

Report for each calibrated subwatershed(s) for in the Middle St. Johns River Basin

APPENDIX 3.K. 05-LAKE GEORGE BASIN

Report for each calibrated subwatershed(s) for in the Lake George Basin

APPENDIX 3.L. 07-OCKLAWAHA RIVER BASIN

Report for each calibrated subwatershed(s) for in the Ocklawaha River Basin

APPENDIX 3.M. 03-LOWER ST. JOHNS RIVER BASIN

Report for each calibrated subwatershed(s) for in the Lower St. Johns River Basin