

CHAPTER 3: WATERSHED HYDROLOGY

by

Tim Cera, P.E.
Dale Smith, P.E.
Michael G. Cullum, P.E.
Marc Adkins, P.E.
Joseph Amoah, Ph.D., P.E.
David Clapp
Robert Freeman, P.E.
Matt Hafner
Xiaoqing (Shaw) Huang, Ph.D.
Yanbing Jia, Ph.D., P.E.
Tom Jobes
Liang-Tsi Maria Mao, Ph.D., P.E.

St. Johns River Water Management District
Palatka, Florida

2012

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WATERSHED HYDROLOGY WORKING GROUP

SJRWMD Staff	Role
Timothy B. Cera, P.E. Florida Professional Engineer license: 52592	Editor, author, technical reviewer and manager; computer programming, lead for communication with National Academy of Sciences Review Committee, coordinated model development, and implemented training for HSPF, HSPF common logic, and PEST
Dale R. Smith, P.E. Florida Professional Engineer license: 32054	Working group leader, editor, author, technical reviewer and manager
Michael G. Cullum, P.E. Florida Professional Engineer license: 41869	Editor, project review and coordination
Marc Adkins, P.E. Florida Professional Engineer license: 42447	Author, hydrologic simulation of Black Creek, Deep Creek, Ortega, Trout, Little Wekiva; Helped to implement and use PEST with HSPF
Joseph Amoah, Ph.D., P.E. Florida Professional Engineer license: 73043	Author, hydrologic simulation of Crescent Lake and lower Orange Creek watersheds
David Clapp	Data management lead, author, hydrologic simulation of Orange Creek and Lake George watersheds
Robert Freeman, P.E. Florida Professional Engineer license: 17282	Author, hydrologic simulation of Etonia Creek watershed
Matt Hafner	Data management, author, hydrologic simulation of Lake George watersheds
Xiaoqing (Shaw) Huang, Ph.D.	Author, hydrologic simulation of Ocklawaha watersheds.
Yanbing Jia, Ph.D., P.E. Florida Professional Engineer license: 68422	Author, hydrologic simulation of Econlockatchee, Lake Monroe, and Lake Jesup watersheds; Water quality simulation of explicit modeling of BMP application to future land use
Tom Jobes	Author, computer programming, establishment of overall hydrologic framework, development of non-riparian/riparian methodology, hydrologic simulation of Upper Basin
Liang-Tsi (Maria) Mao, Ph.D., P.E. Florida Professional Engineer license: 46733	Author, hydrologic simulation of Six Mile, Big Davis, Pablo Creek watersheds and the north and south watersheds adjacent to the Lower St. Johns River

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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 – HSPF 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.

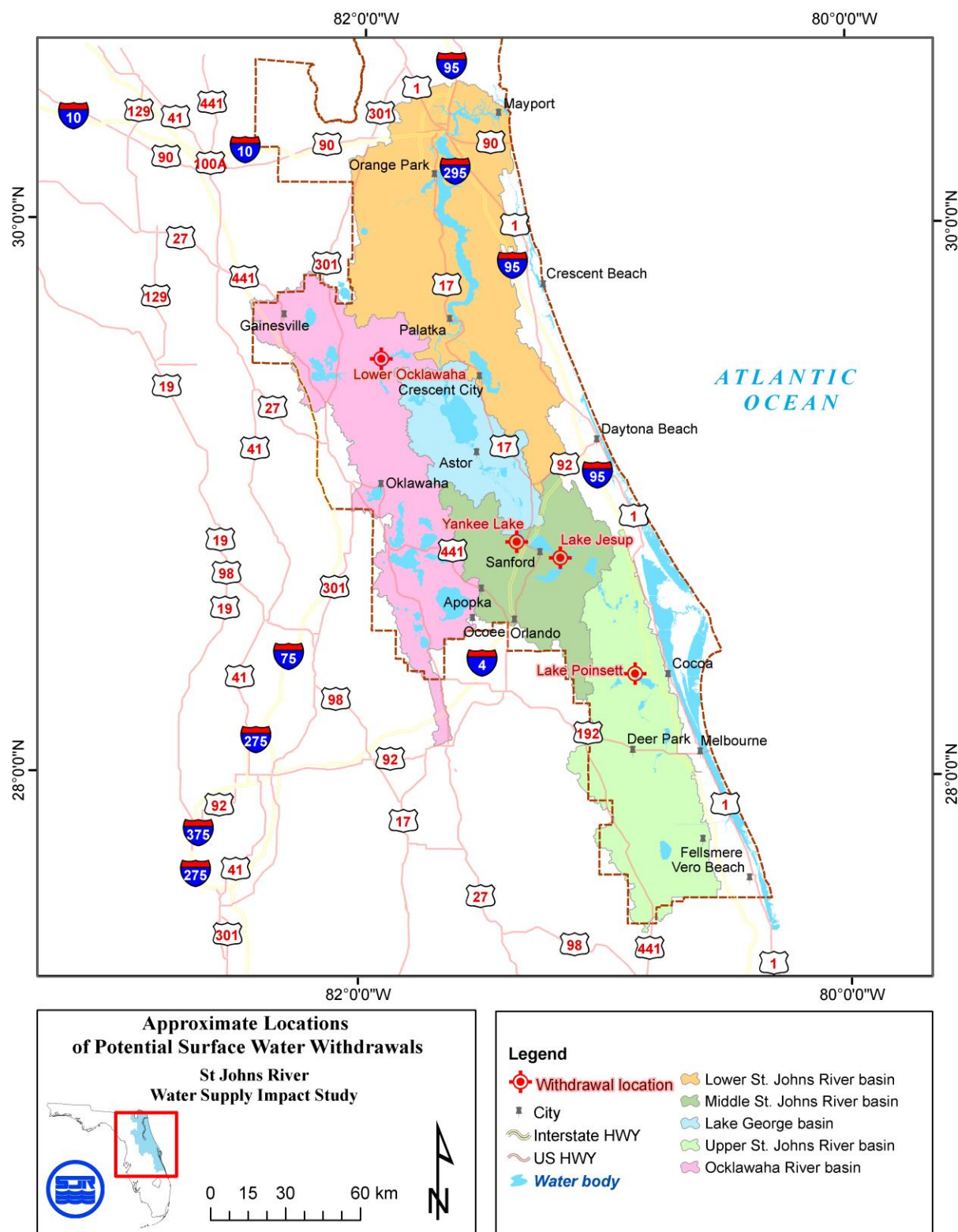


Figure 3–1. Approximate locations of potential surface water withdrawals.

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 USJRB 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 analogous 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 mi². 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.

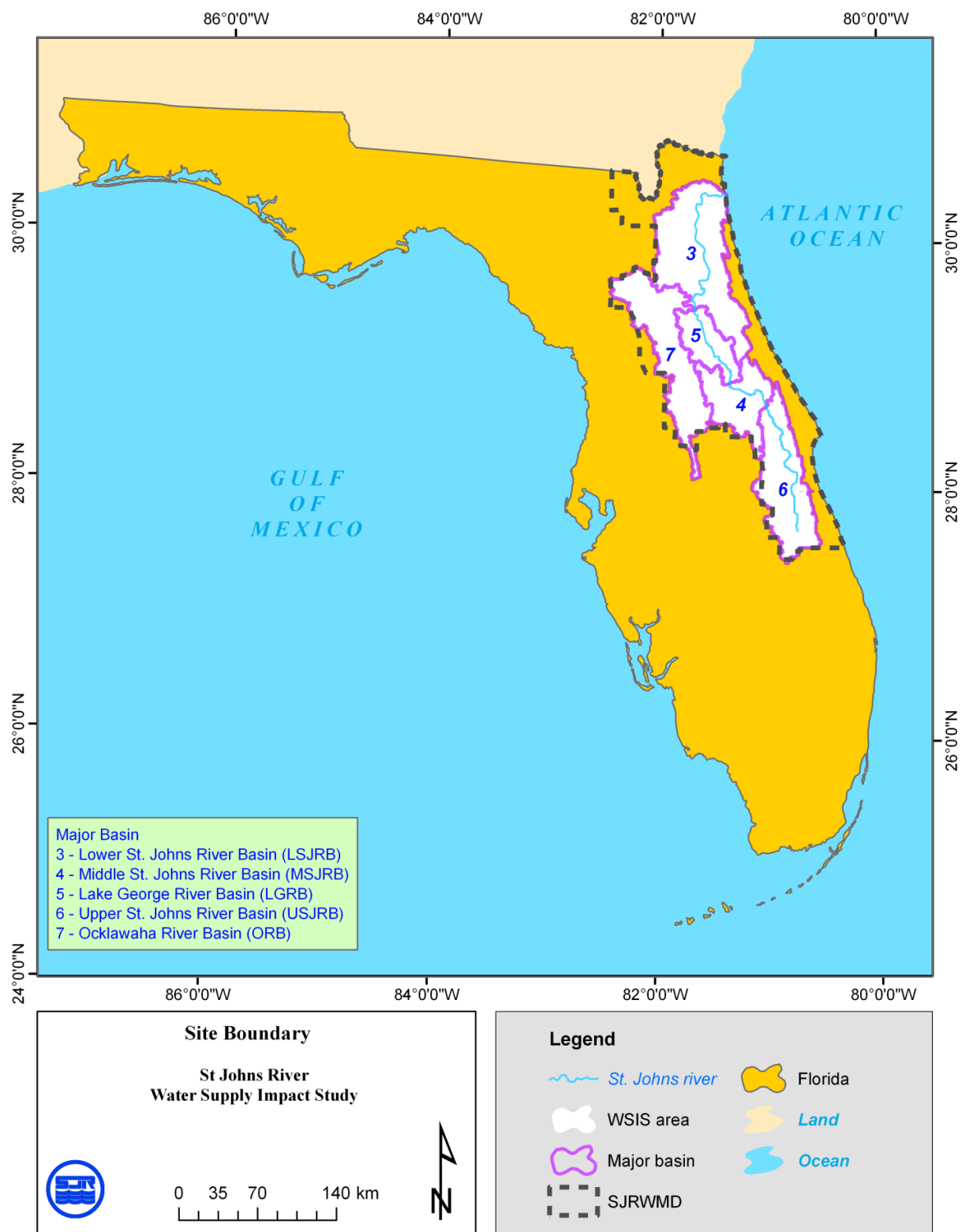


Figure 3–2. Water Supply Impact Study (WSIS) project boundary

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-mi² 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 mi². 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 mi². 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.

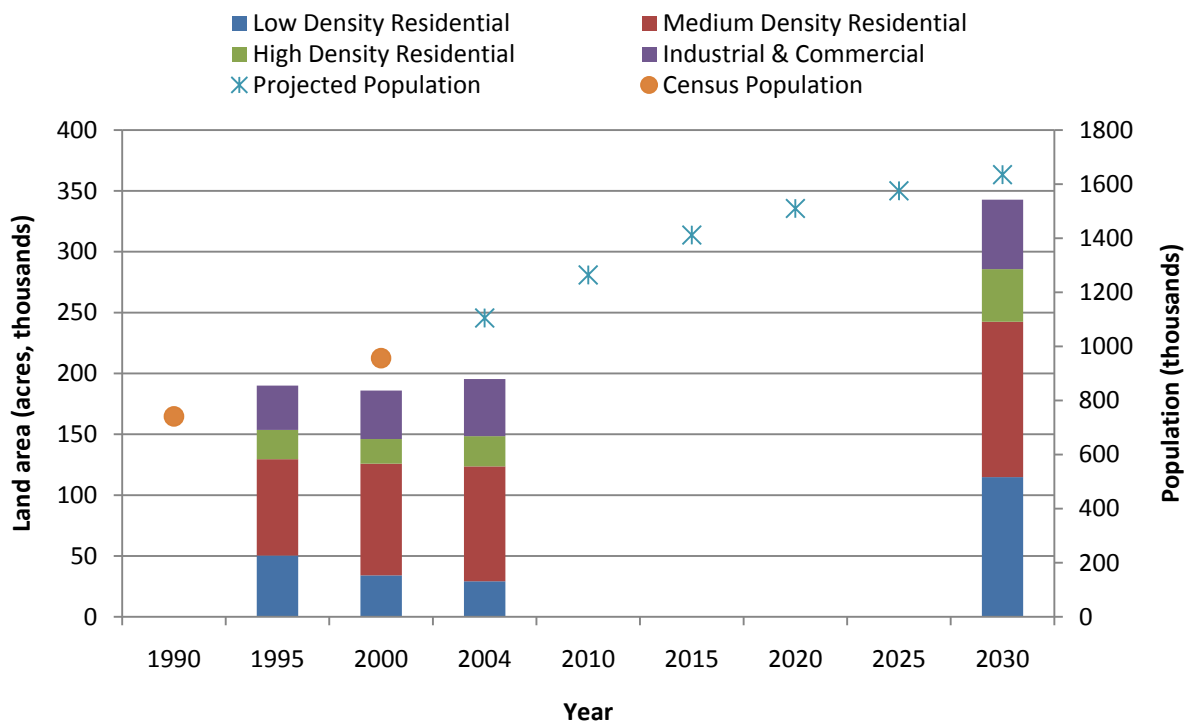


Figure 3–3. Comparison of observed and predicted population and land use for the middle St. Johns River basin (MSJRB).

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.

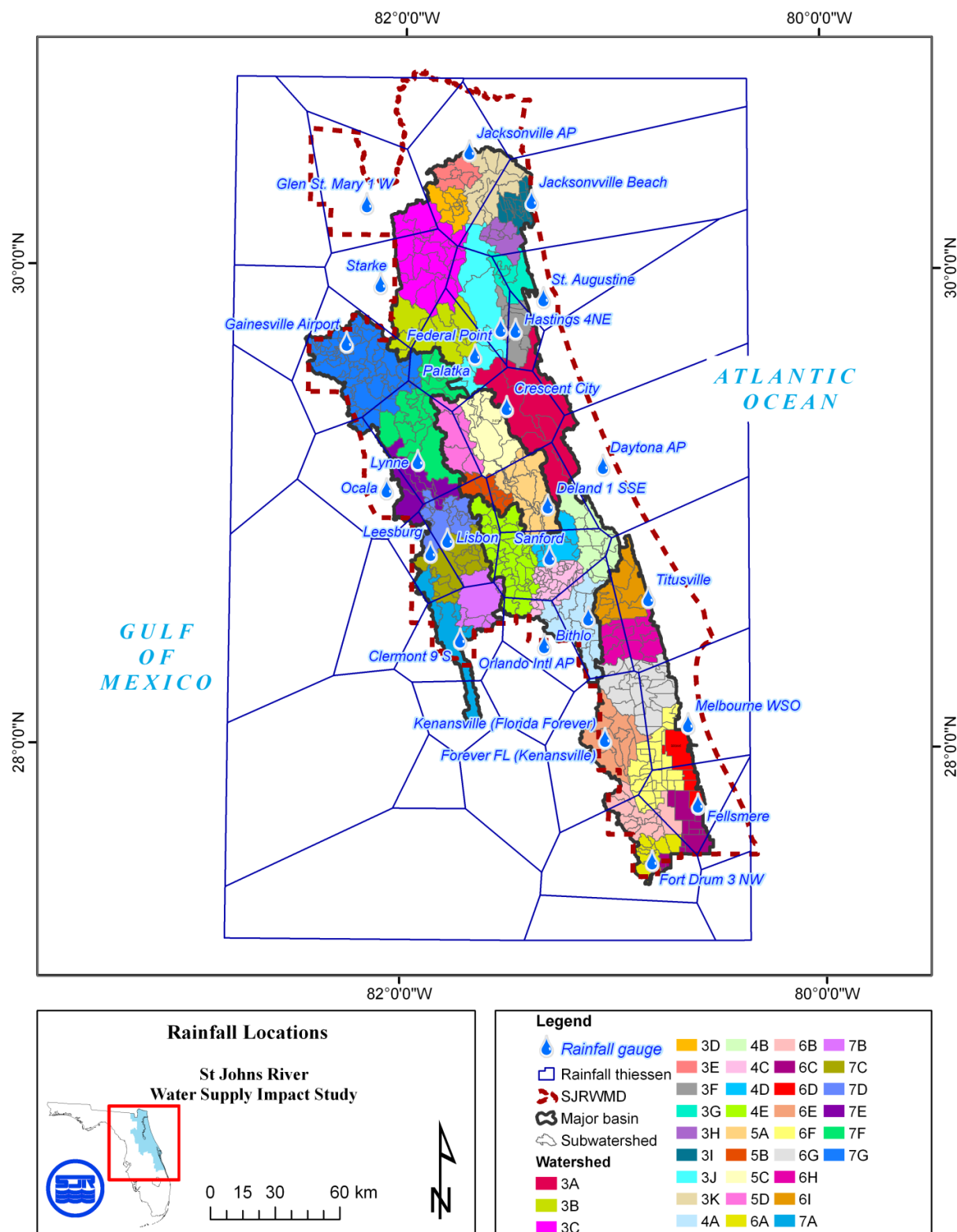


Figure 3-4. Rain gauge station locations and Thiessen polygons indicating area of influence.

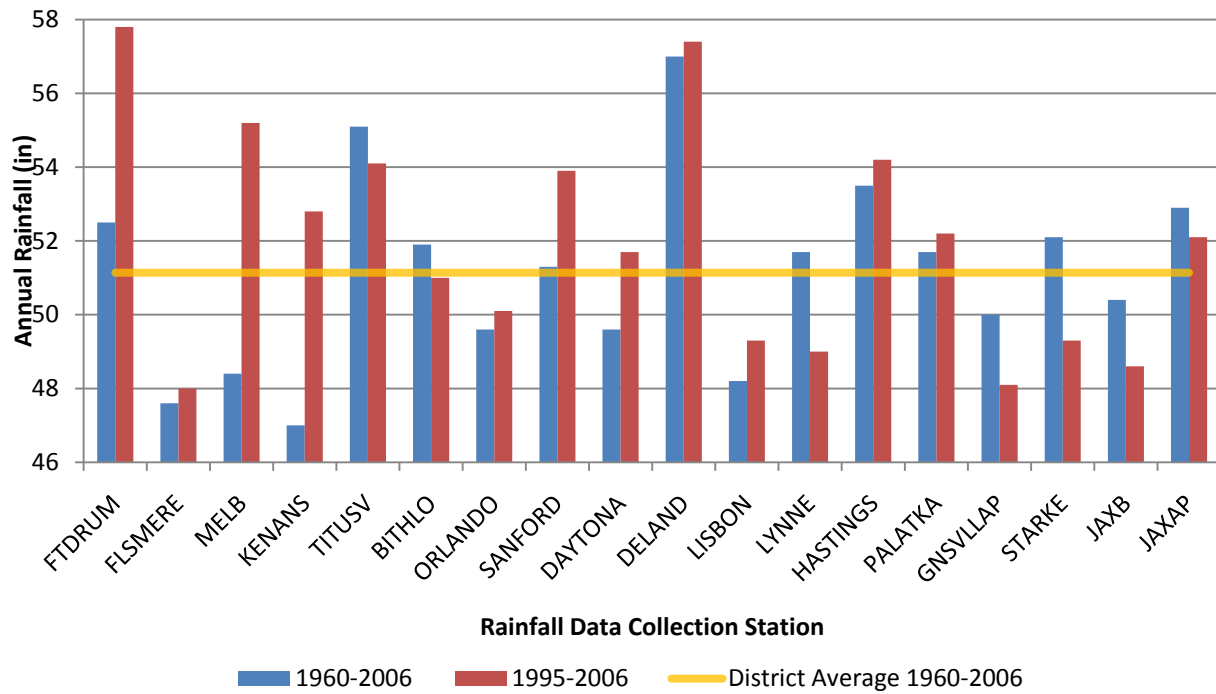


Figure 3-5. Average annual precipitation at rainfall gauge stations, arranged approximately south to north.

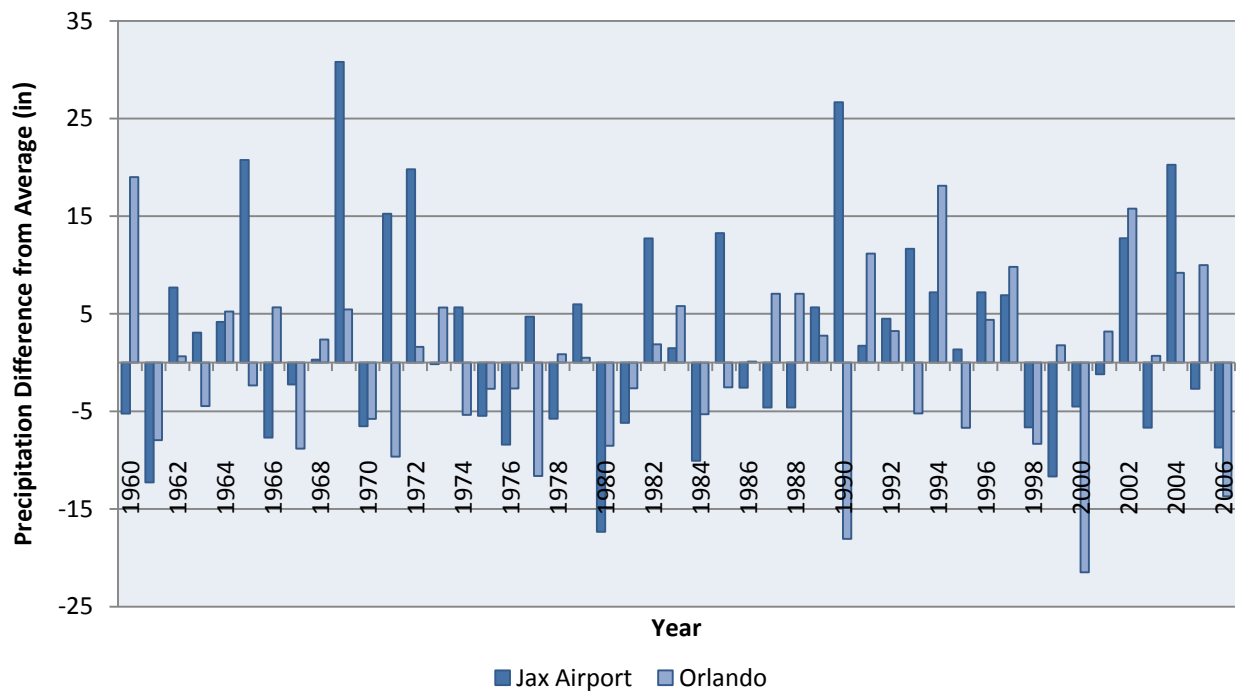


Figure 3-6. Yearly difference from station average in precipitation at Jacksonville International Airport and Orlando rain gauges.

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.

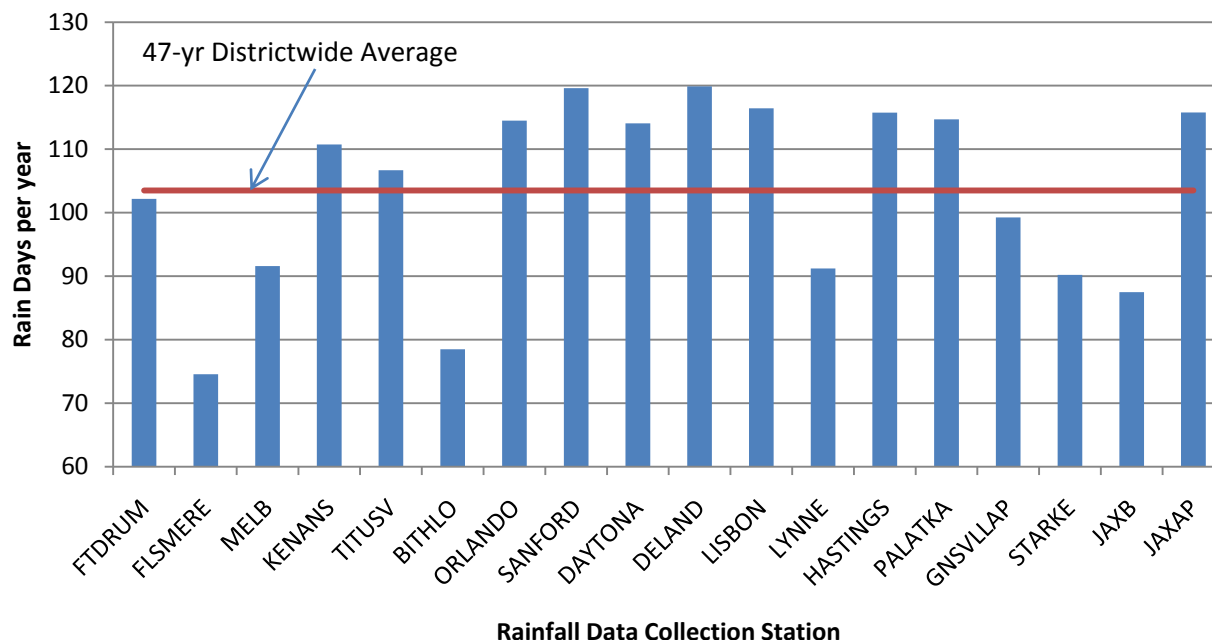


Figure 3–7. Days per year with precipitation at rainfall gauge stations, arranged approximately south to north

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.

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

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

$$lrad = latitude \frac{\pi}{180} \quad [\text{Eq. 3-2}]$$

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

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

where

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

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.

$$\begin{aligned} \text{potential evaporation} \\ = K \{ 0.408 * 0.0023 * R_a * (T_{mean} + 17.8) * \sqrt{T_{max} - T_{min}} \} \end{aligned} \quad [\text{Eq. 3-4}]$$

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.

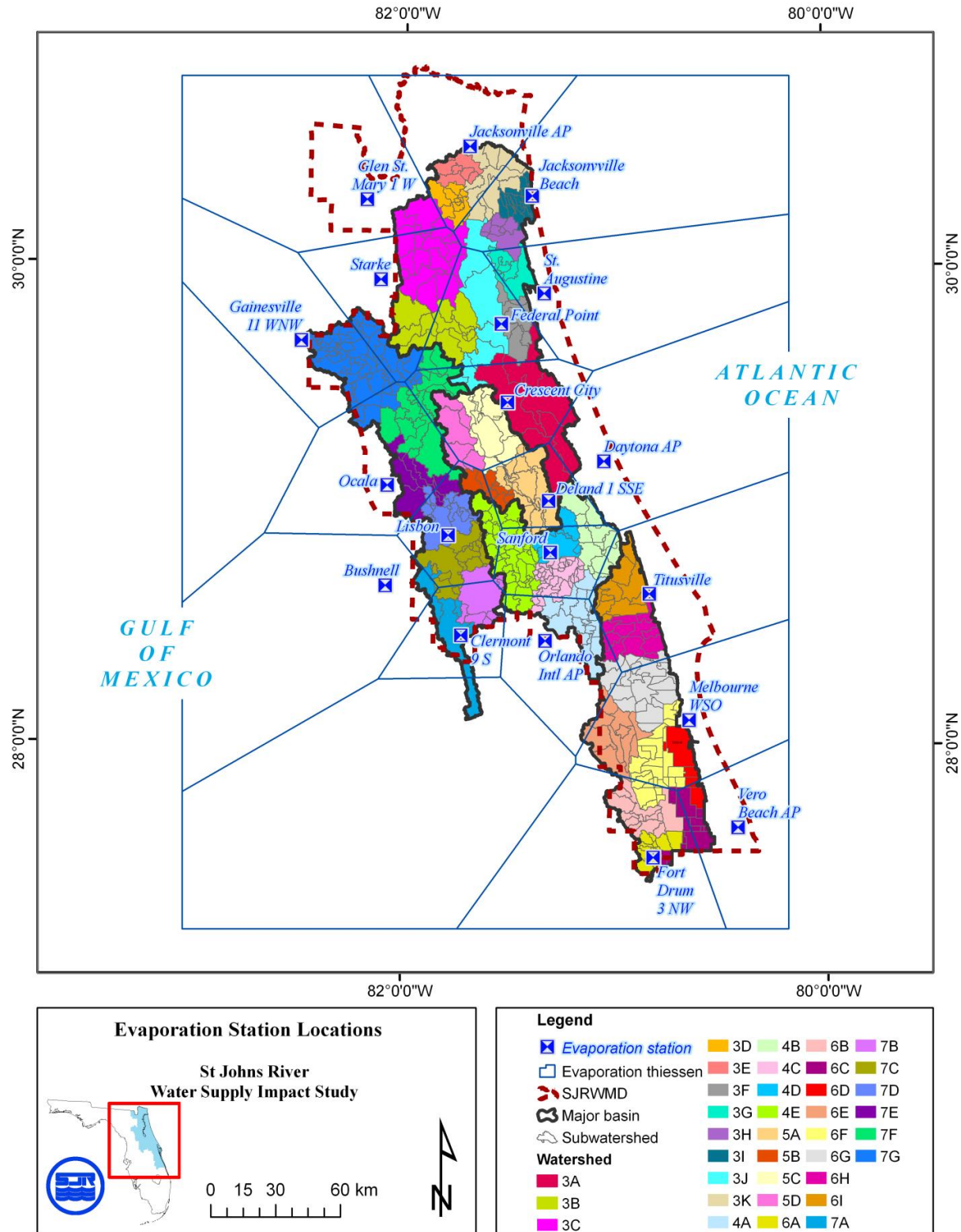


Figure 3–8. Evaporation station locations, where potential evaporation is computed, and Thiessen polygons defining each area of influence.

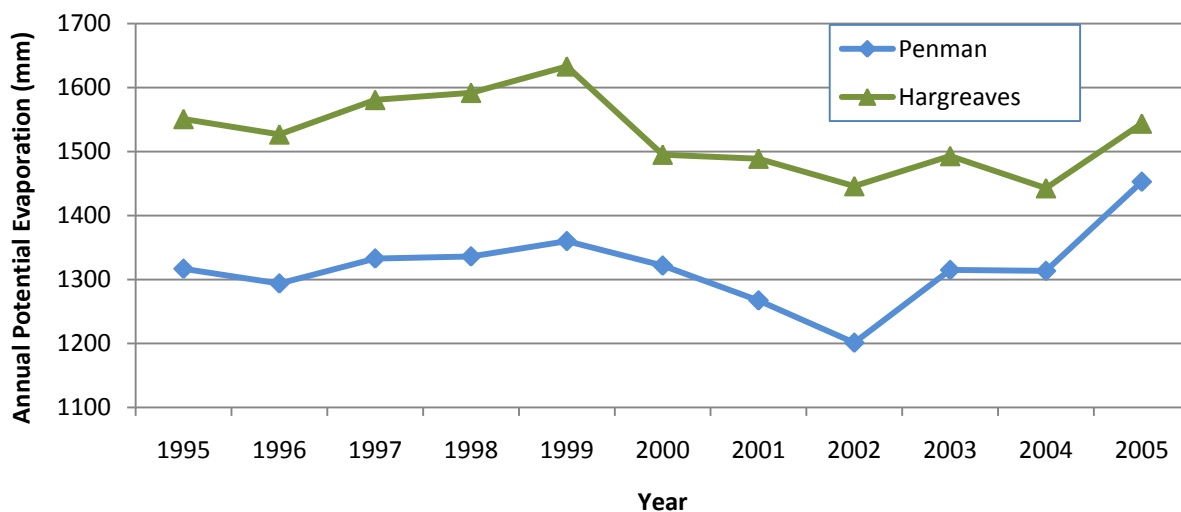


Figure 3–9. Annual potential evaporation comparison between Priestly-Taylor (with satellite radiation measurements) and Hargreaves for Gainesville.

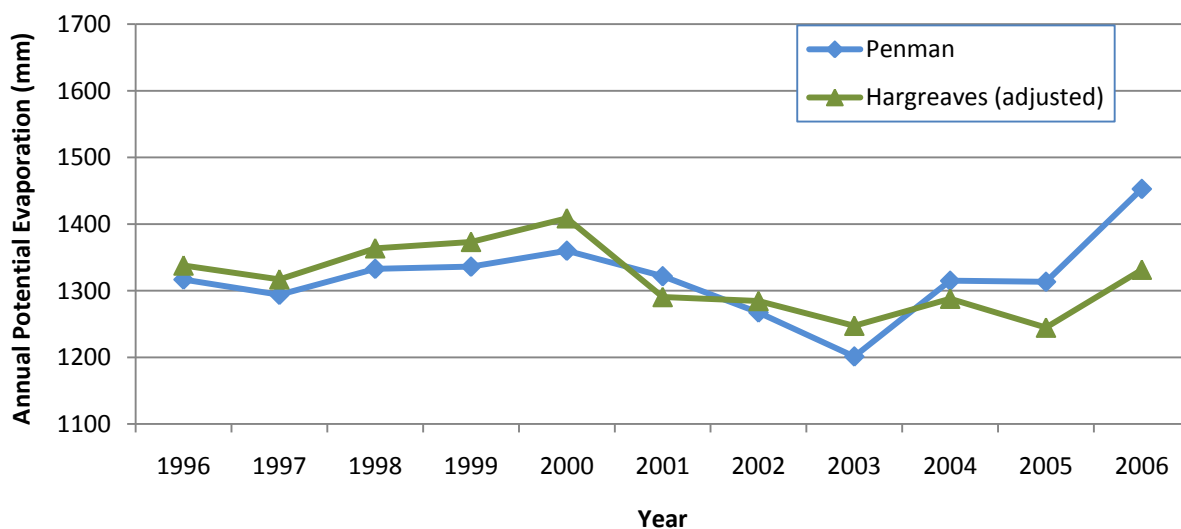


Figure 3–10. Annual potential evaporation comparison after Hargreaves method was adjusted for Gainesville.

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.

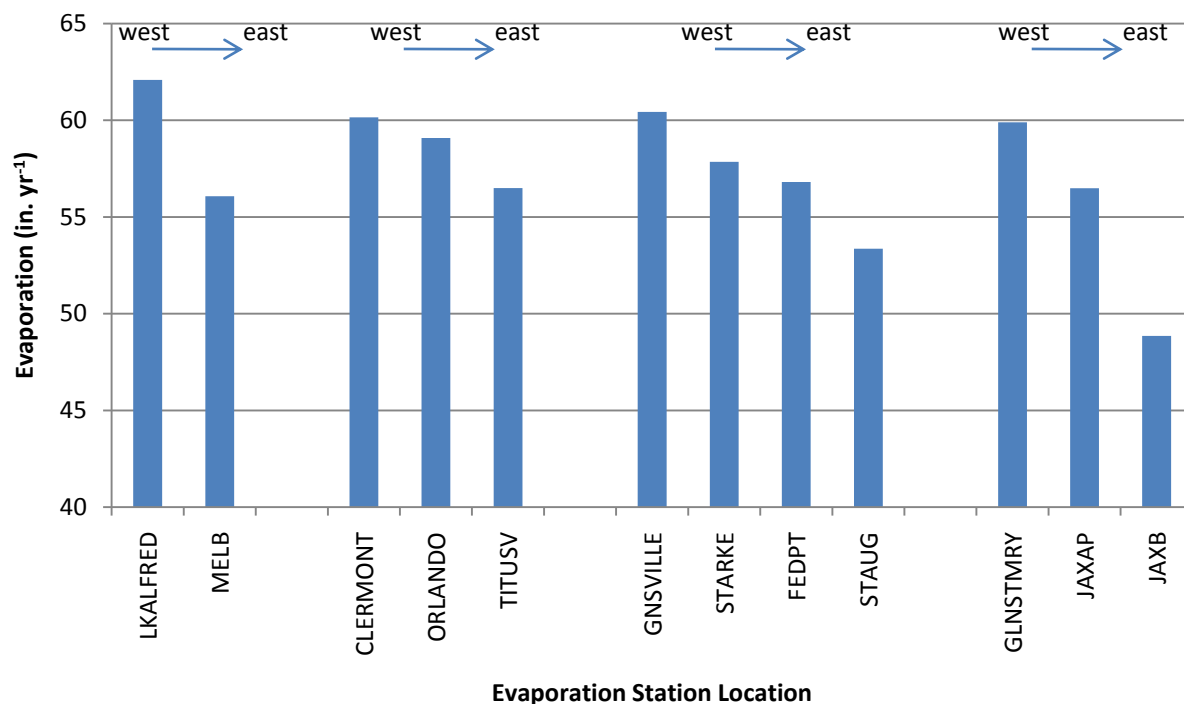


Figure 3–11. Average annual potential evaporation arranged in four approximate west to east cross-sections, with cross-sections arranged from south to north.

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 mi² 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.

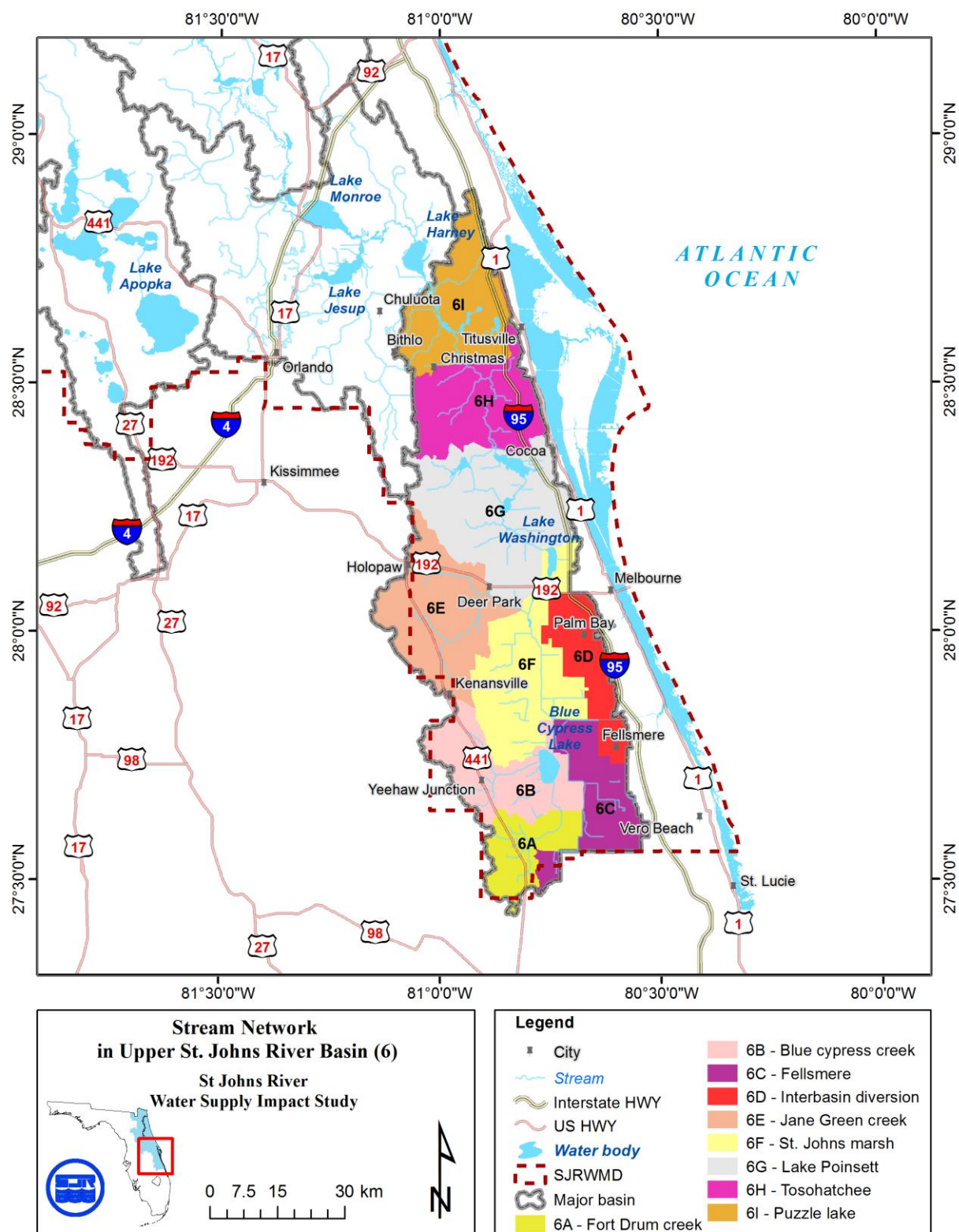


Figure 3–12. Stream network showing planning units 6A through 6I in the upper St. Johns River basin (6)

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 mi² (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 redirect 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.

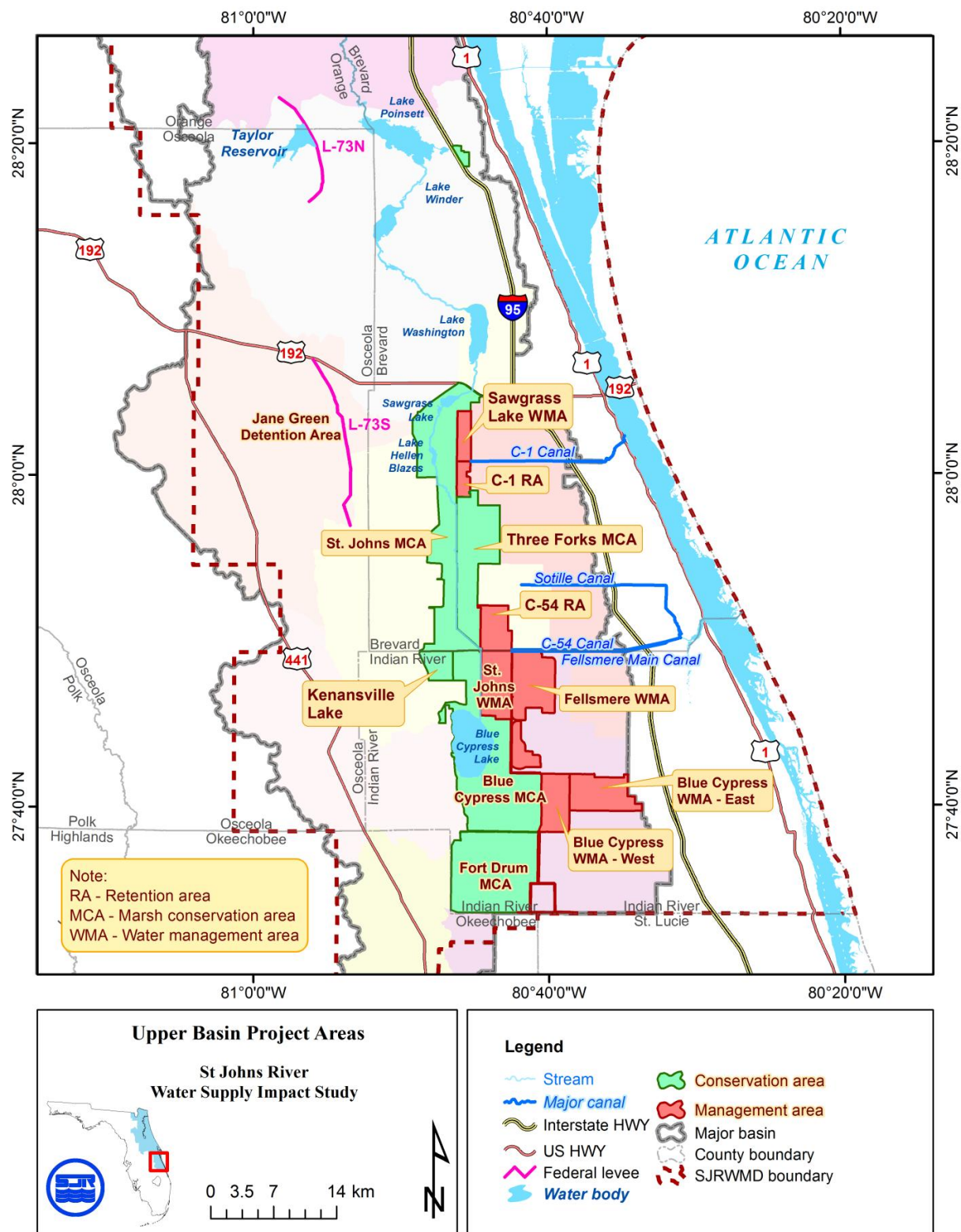


Figure 3–13. Upper basin project areas.

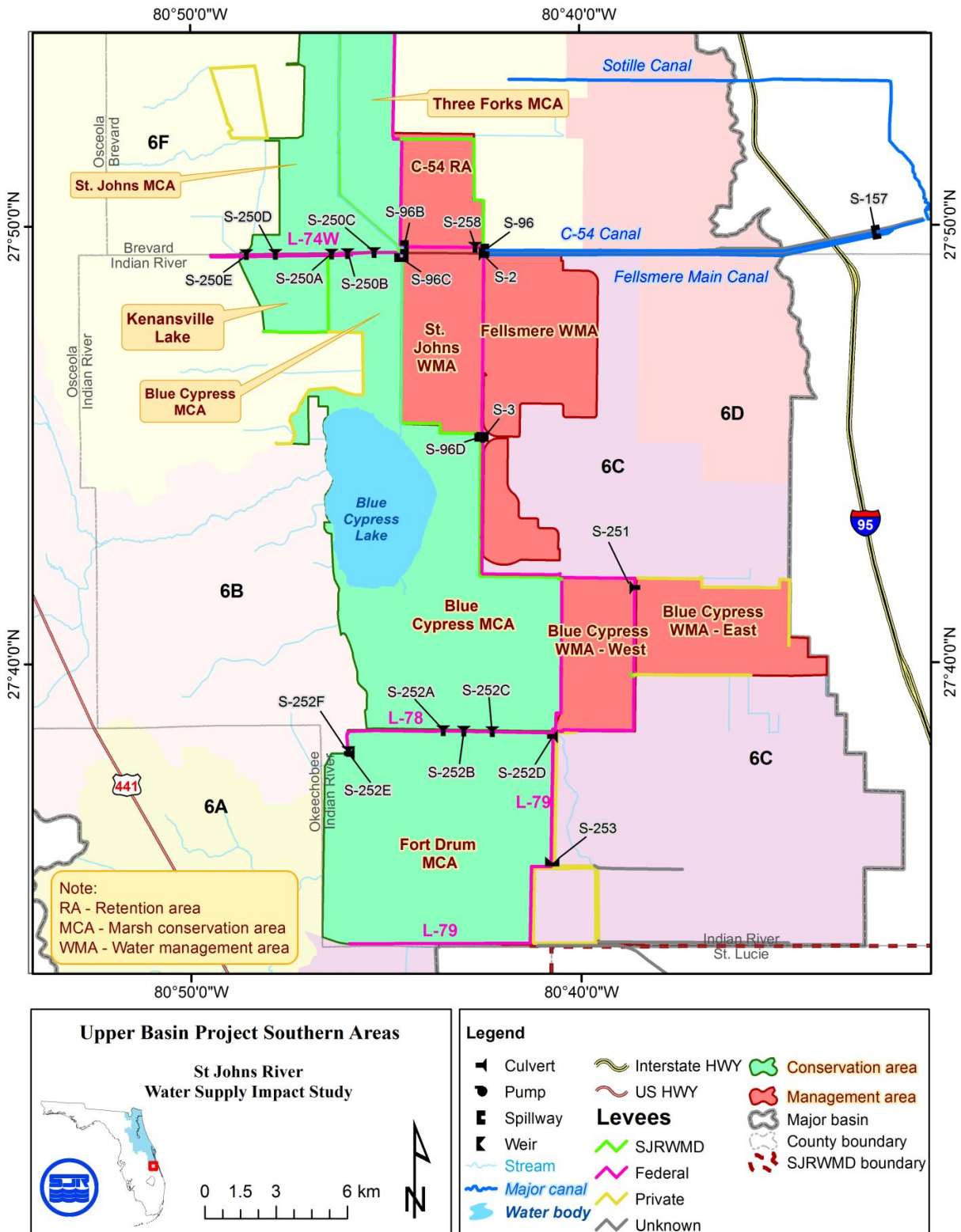


Figure 3–14. Southern upper basin project areas.

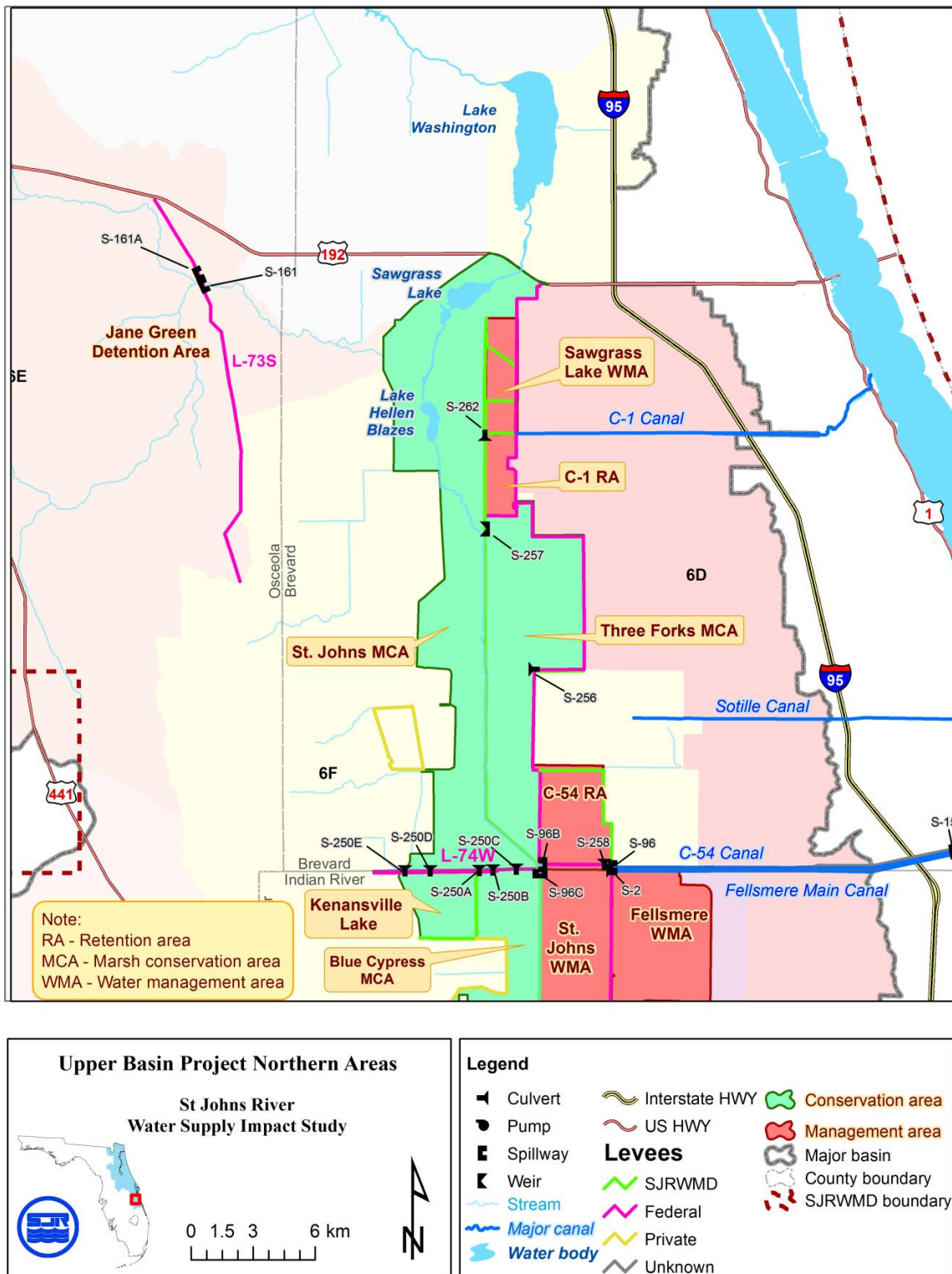


Figure 3–15. Northern upper basin project areas.

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.

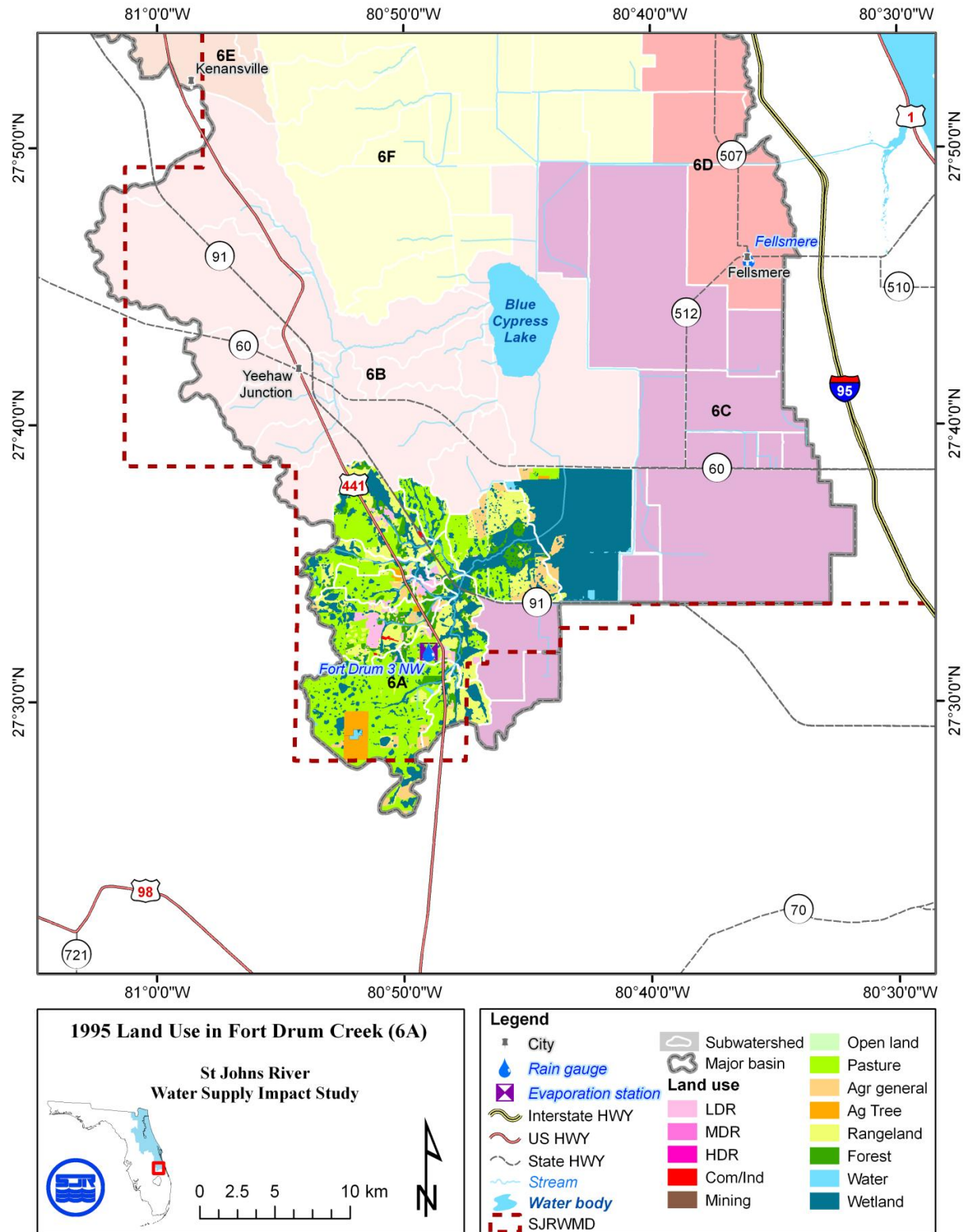


Figure 3–16. 1995 land use in Fort Drum Creek Planning Unit (6A).

The Fort Drum MCA, at the northeast corner of the planning unit, has an area of about 32 mi² (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.

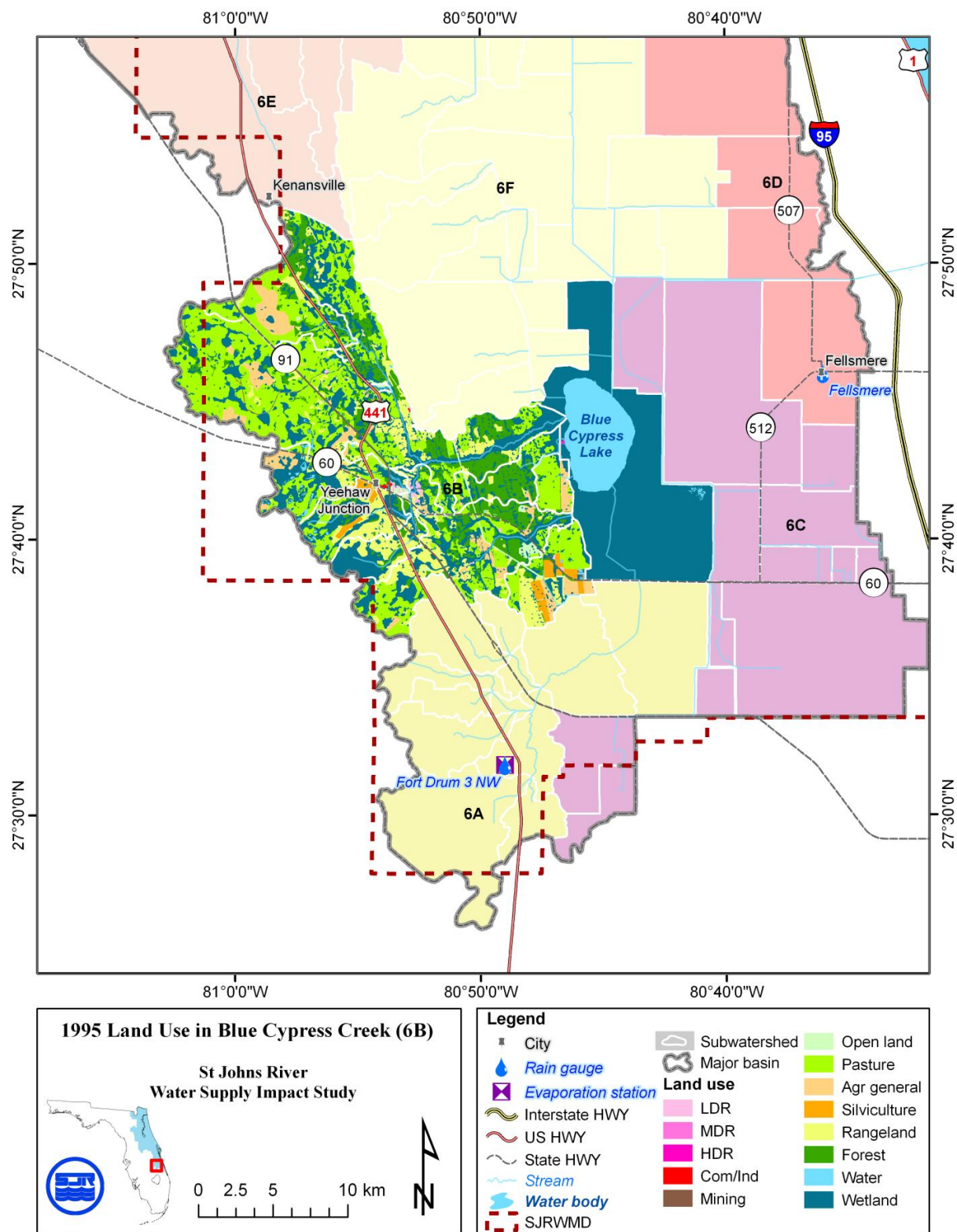


Figure 3–17. 1995 land use in Blue Cypress Creek Planning Unit (6B).

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.

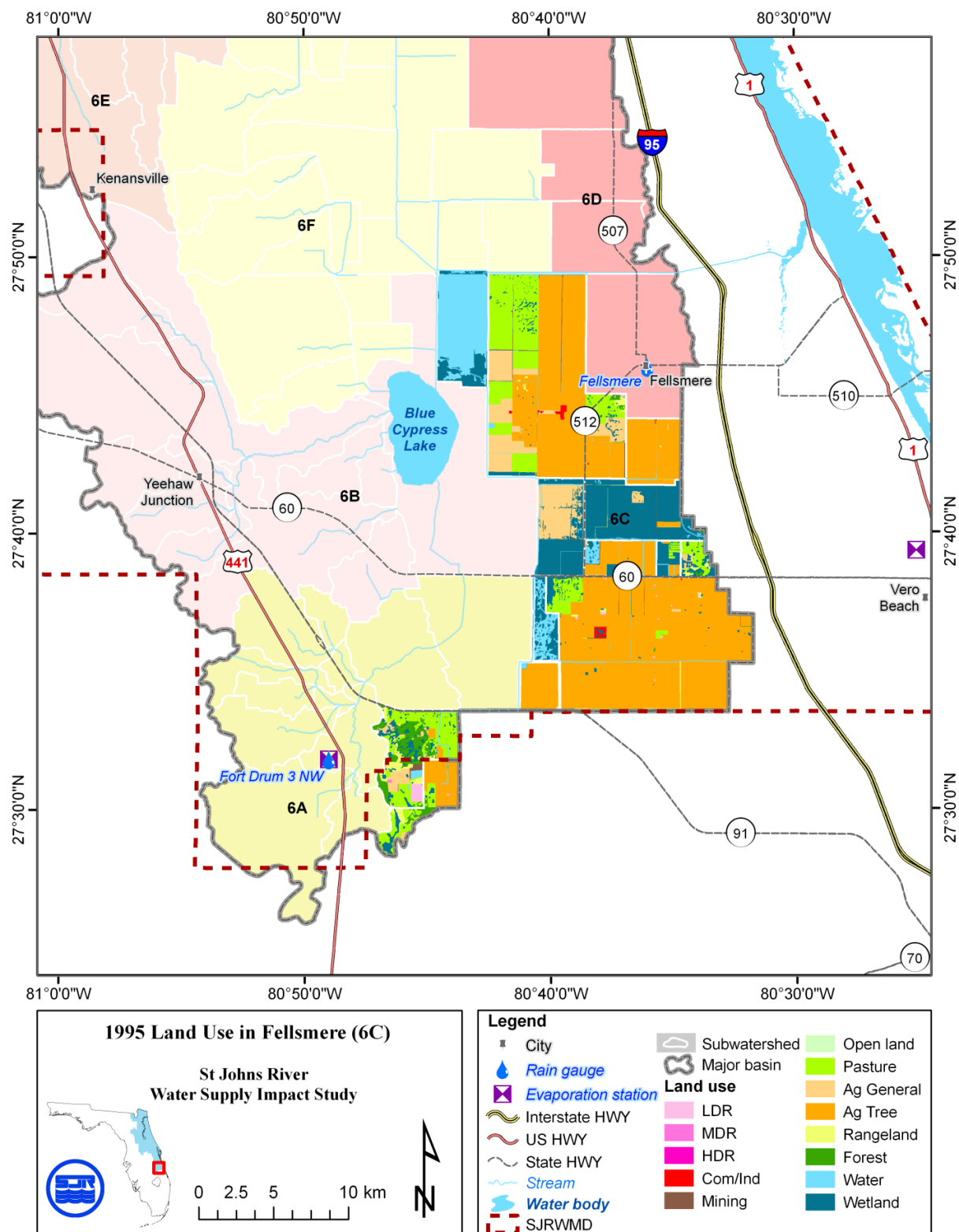


Figure 3–18. 1995 land use in Fellsmere Planning Unit (6C).

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 mi², 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 reddiverted 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 mi² 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.

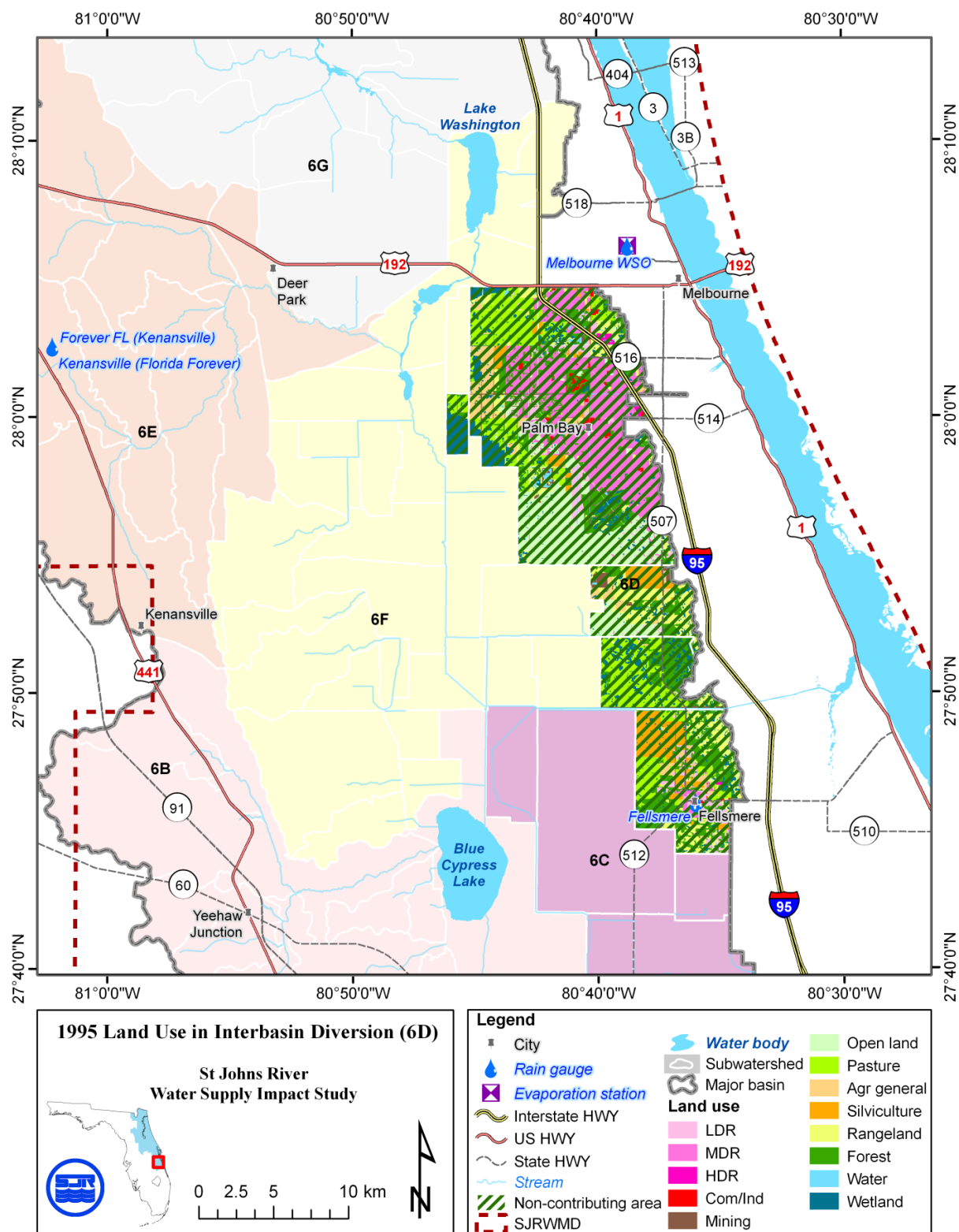


Figure 3–19. 1995 land use in Interbasin Diversion Planning Unit (6D).

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).

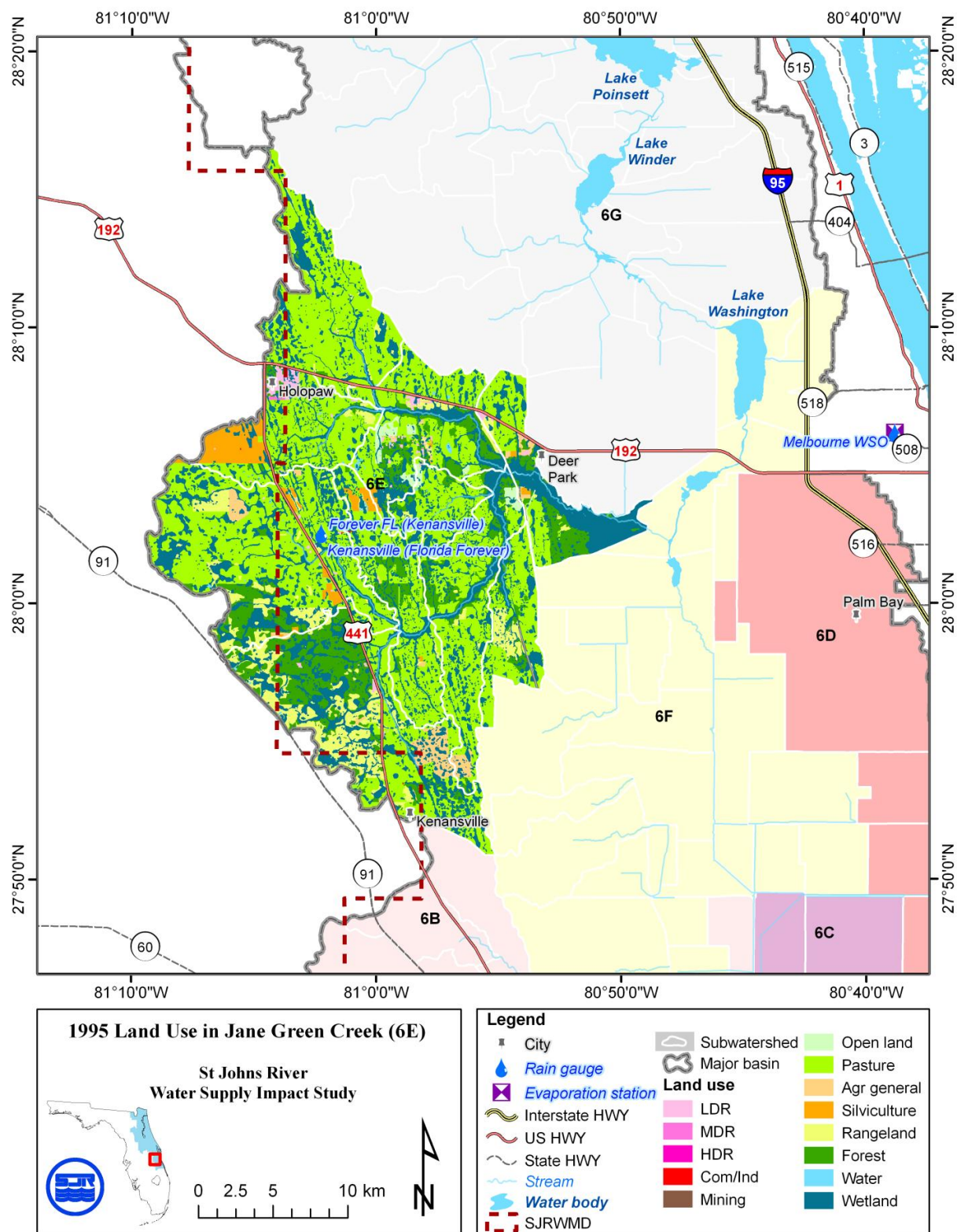


Figure 3–20. 1995 land use in Jane Green Creek Planning Unit (6E).

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.

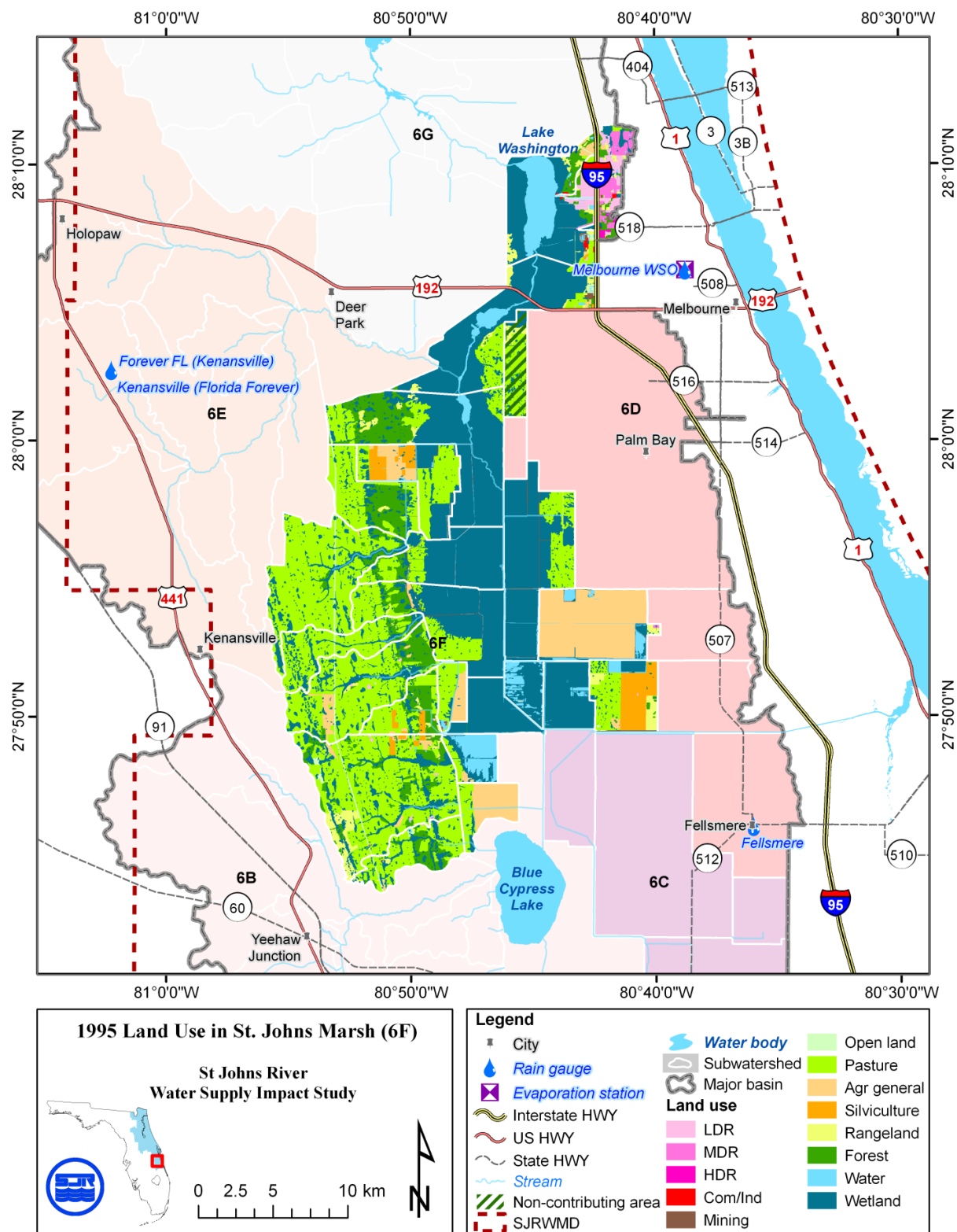


Figure 3–21. 1995 land use in St. Johns Marsh Planning Unit (6F).

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 NGVD29 thereby 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 mi² 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 mi², 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 redirection 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).

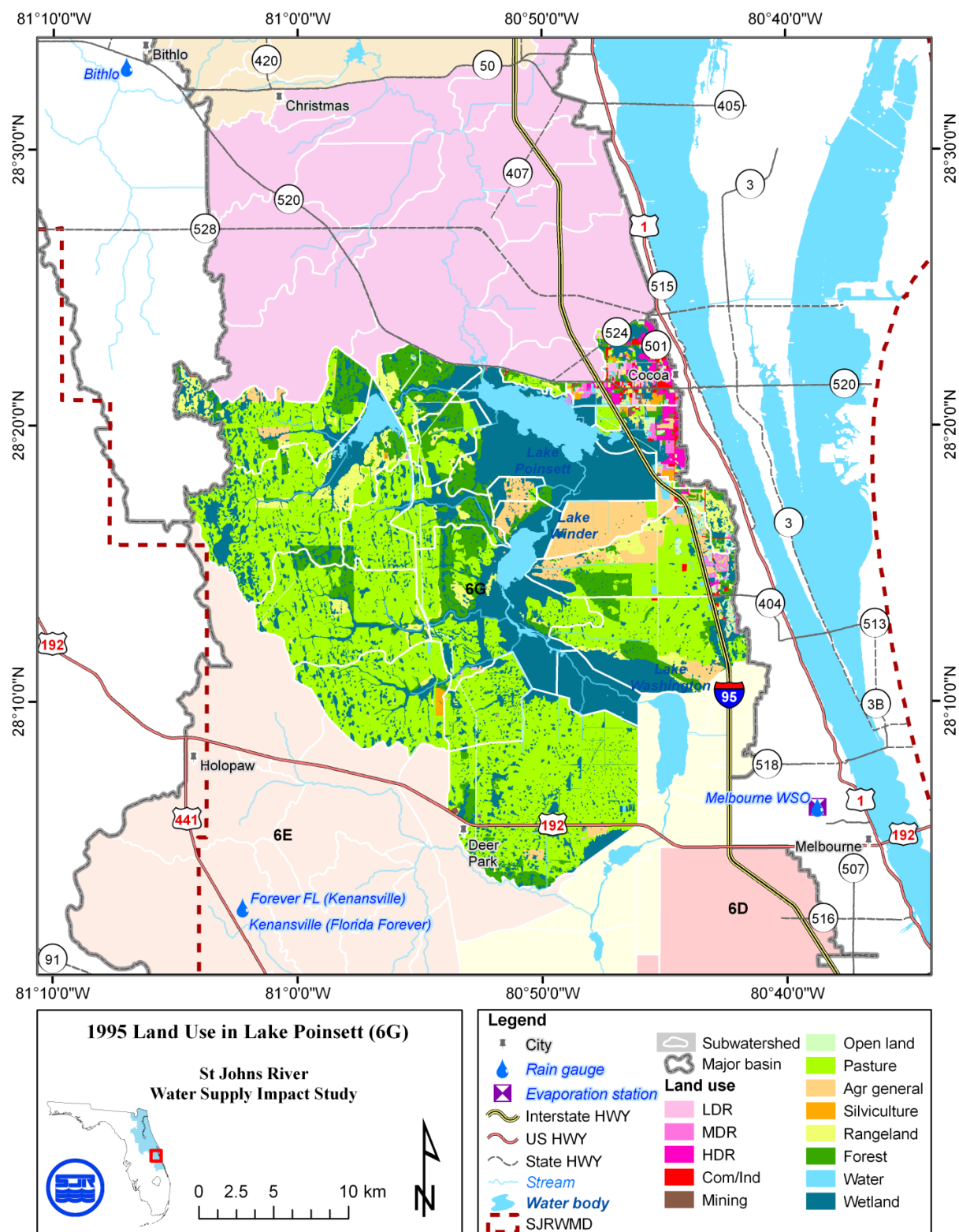


Figure 3–22. 1995 land use in Lake Poinsett Planning Unit (6G).

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).

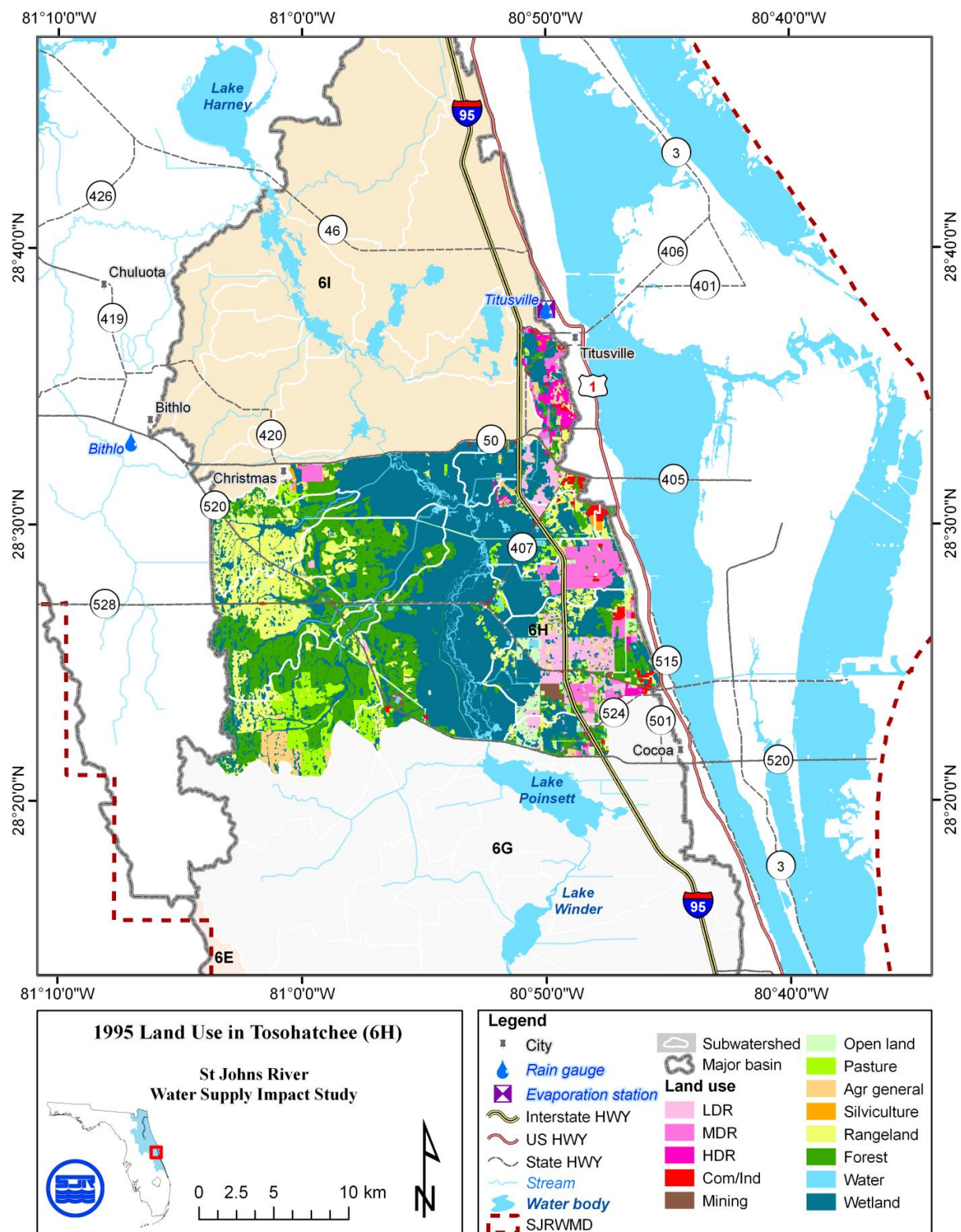


Figure 3–23. 1995 land use in Tosohatchee Planning Unit (6H).

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).

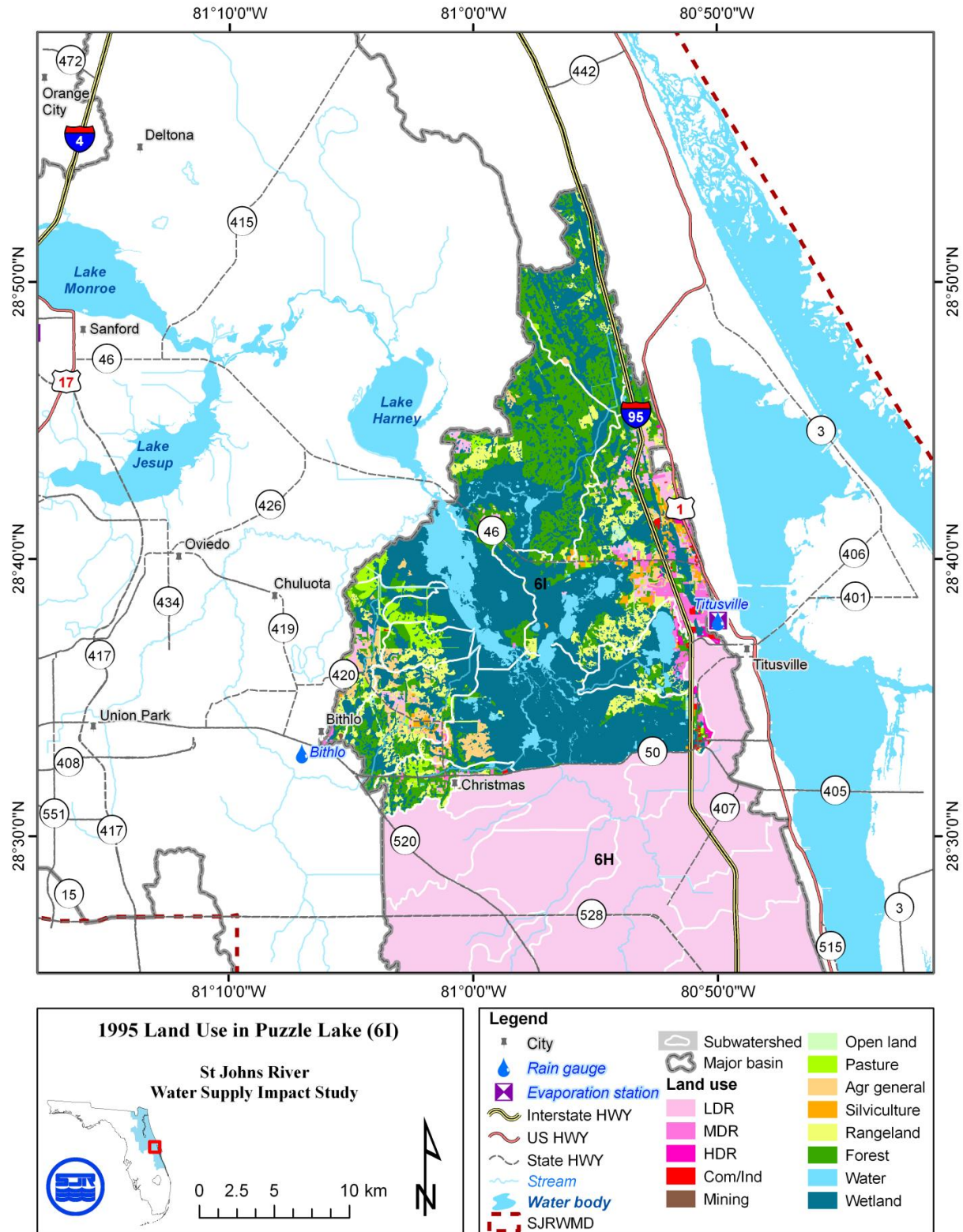


Figure 3–24. 1995 land use in Puzzle Lake Planning Unit (6I).

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 mi² 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.

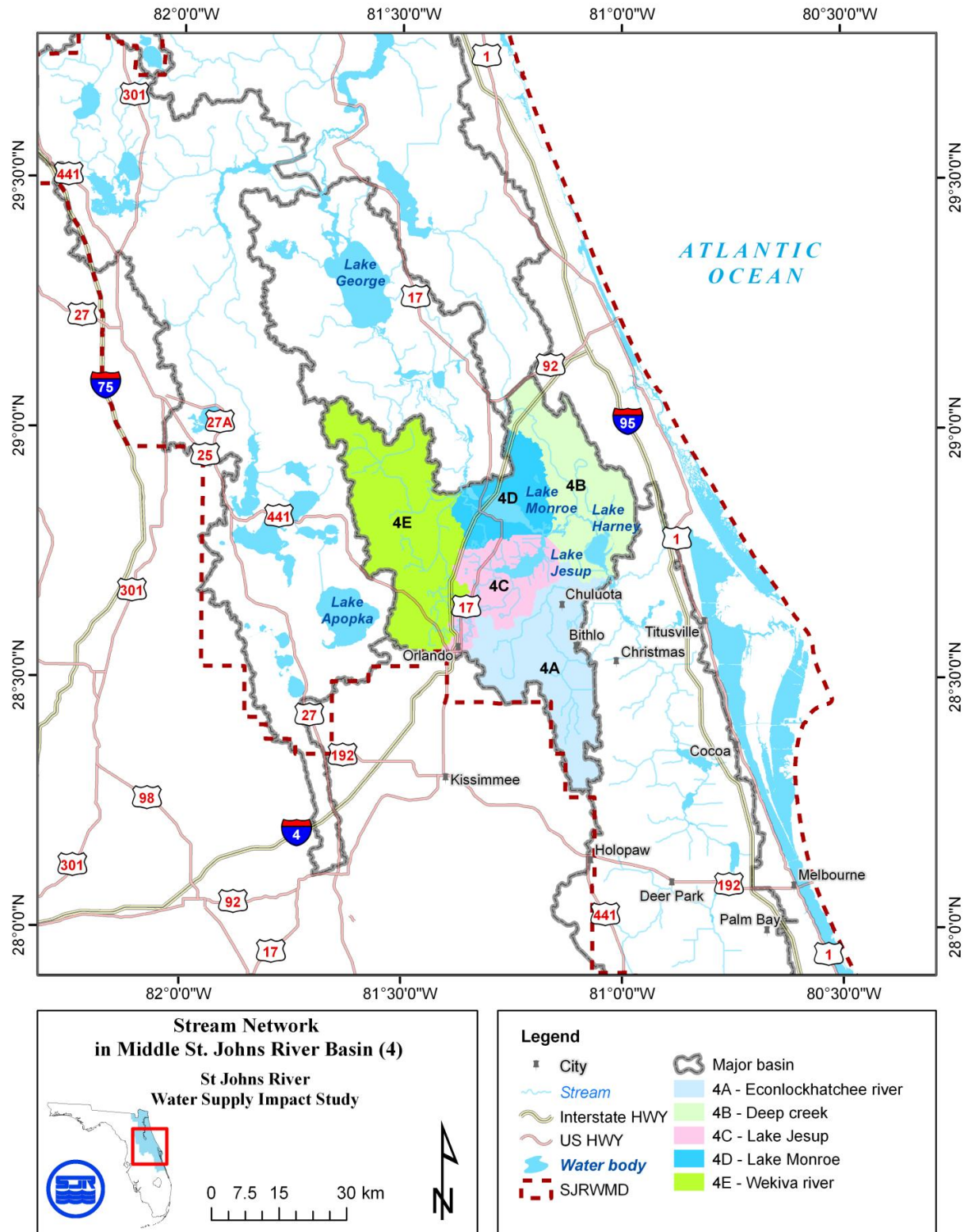


Figure 3–25. Stream network showing planning units 4A through 4E in the Middle St. Johns River Basin (4).

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 mi². 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 mi². 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.

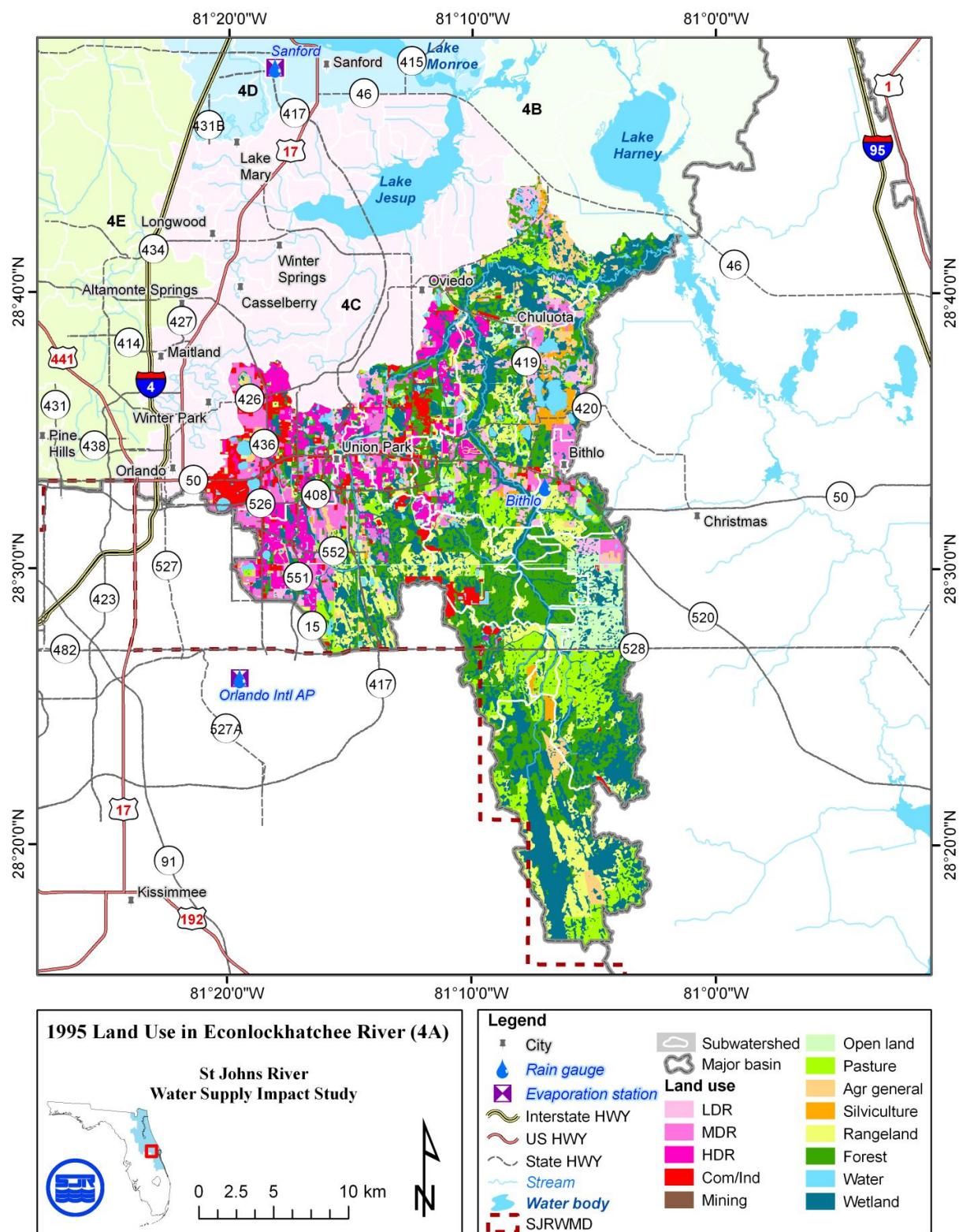


Figure 3–26. 1995 land use in Econlockhatchee River Planning Unit (4A).

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 mi², about 12 mi² 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 marshes (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 3–27 and 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.

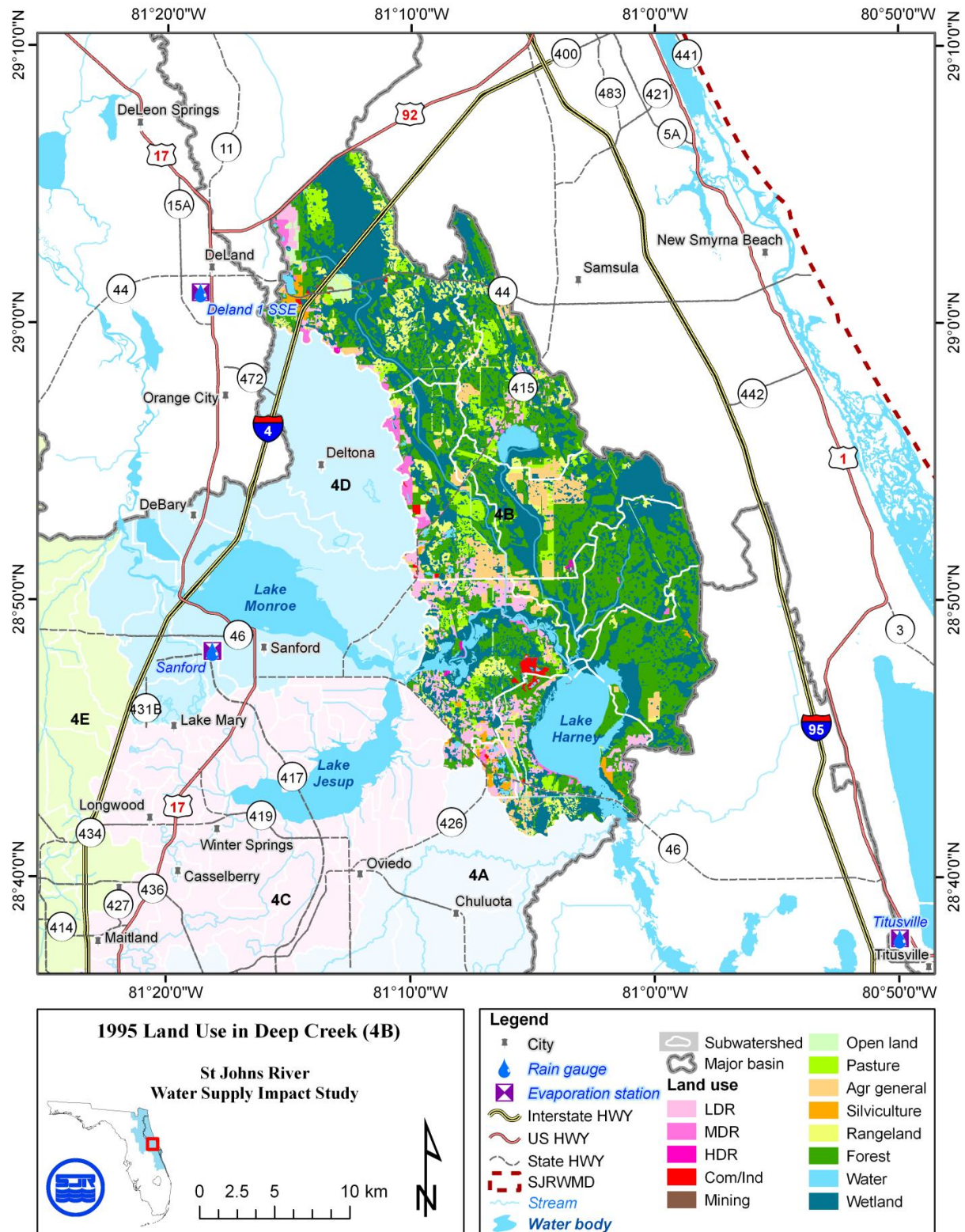


Figure 3–27. 1995 land use in Deep Creek Planning Unit (4B).

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 mi², of which about 17 mi² 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.

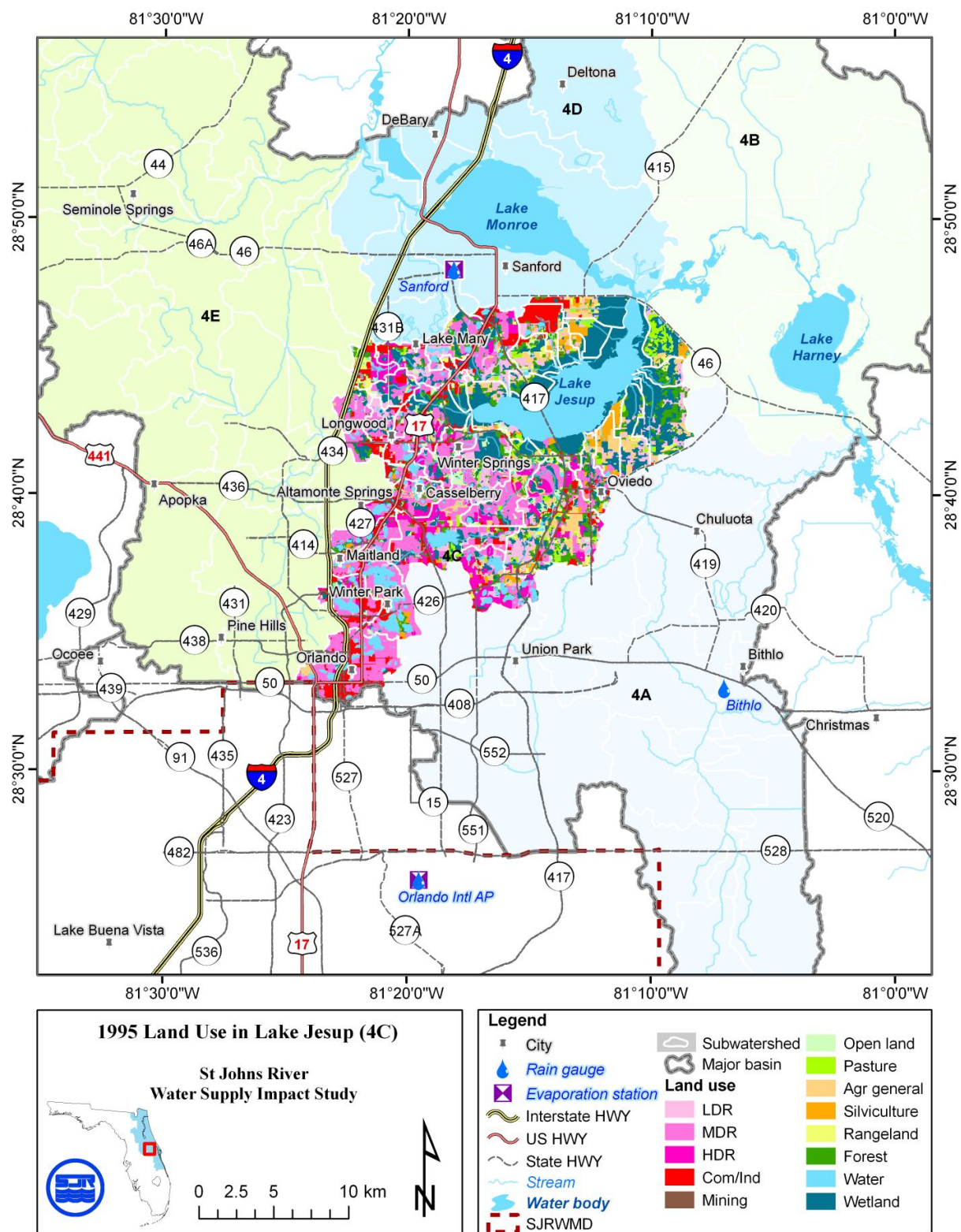


Figure 3–28. 1995 land use in Lake Jesup Planning Unit (4C).

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 mi². 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.

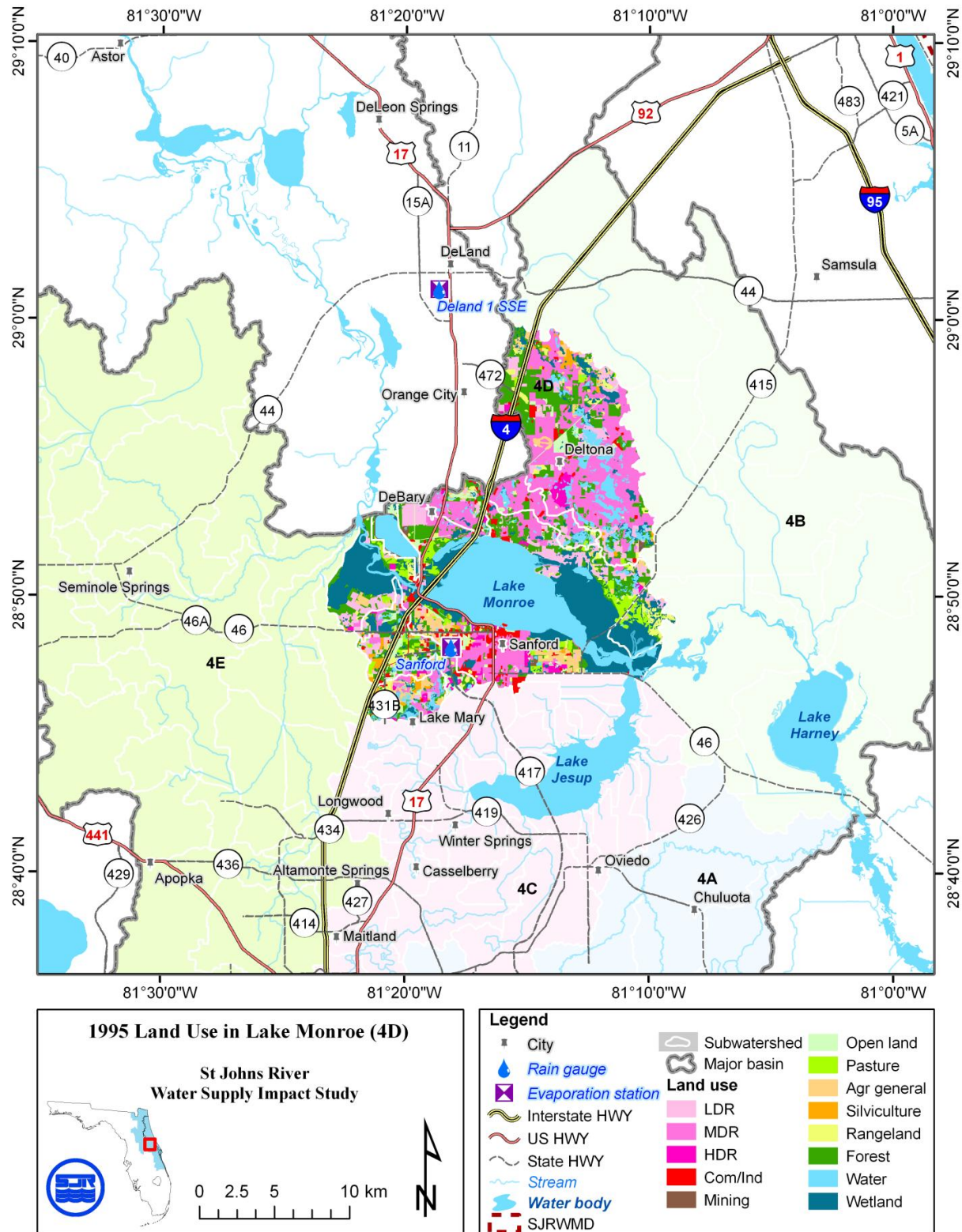


Figure 3–29. 1995 land use in Lake Monroe Planning Unit (4D).

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 mi² of watershed with three major watercourses: the Wekiva River, the Little Wekiva River, and Black Water Creek. Approximately 76.7 mi² 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 mi² of the northern portion of the watershed. The Little Wekiva River drains 55.9 mi² of the southeast portion of the watershed. The Wekiva River drains 78.6 mi² 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 streams 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.

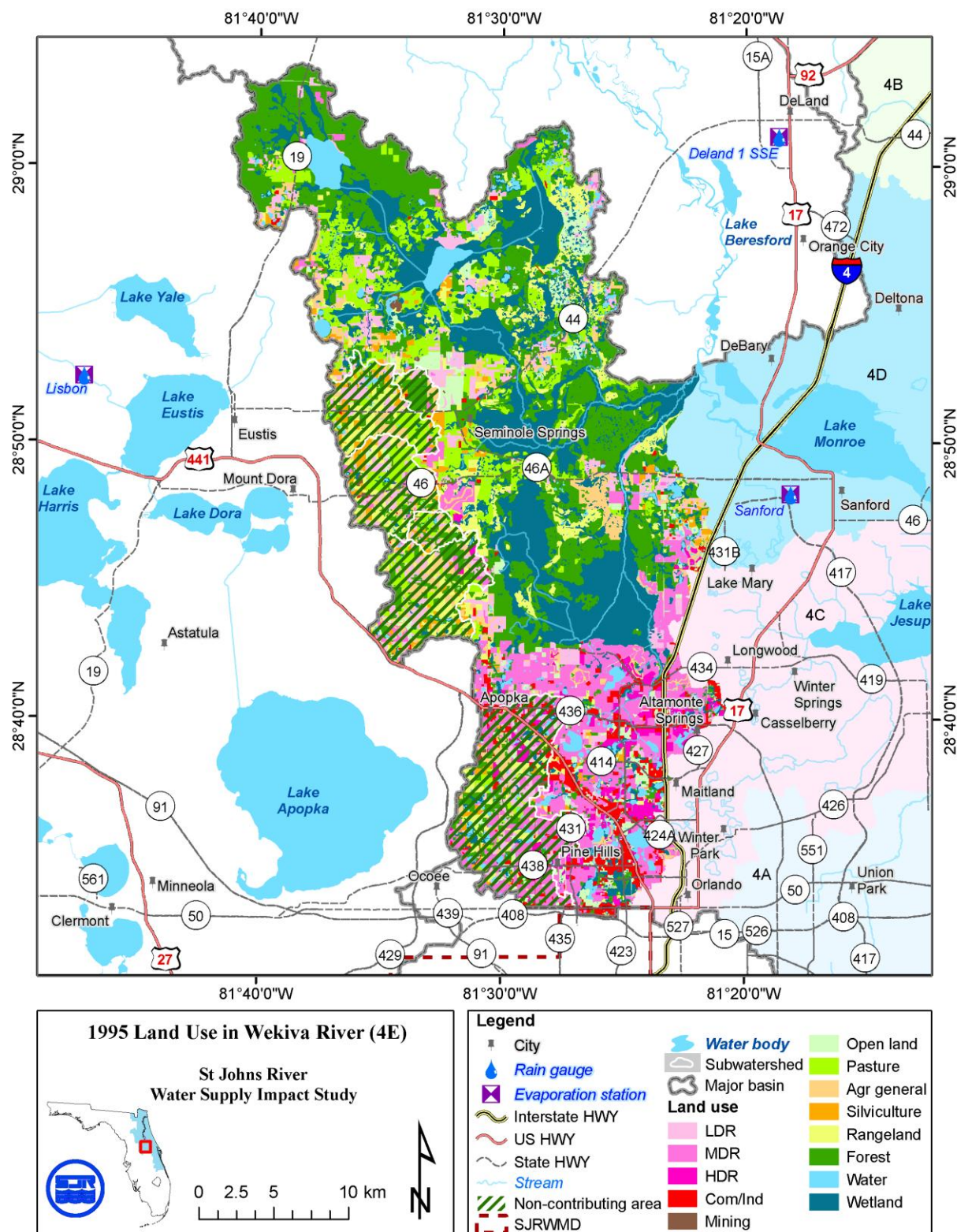


Figure 3–30. 1995 land use in Wekiva River Planning Unit (4E).

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 mi²) 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 mi². 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.

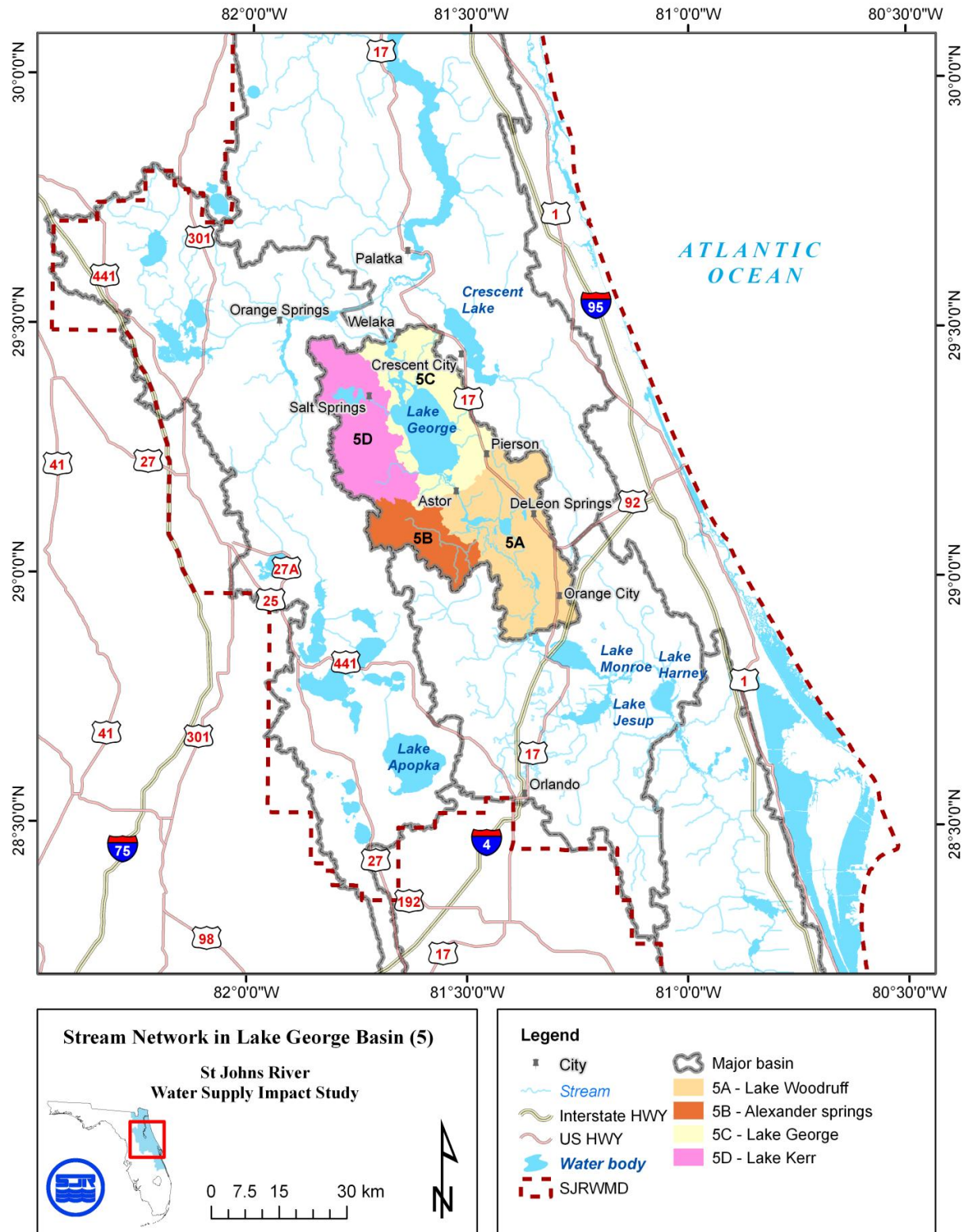


Figure 3–31. Stream network showing planning units 5A through 5D in the Lake George basin (5).

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).

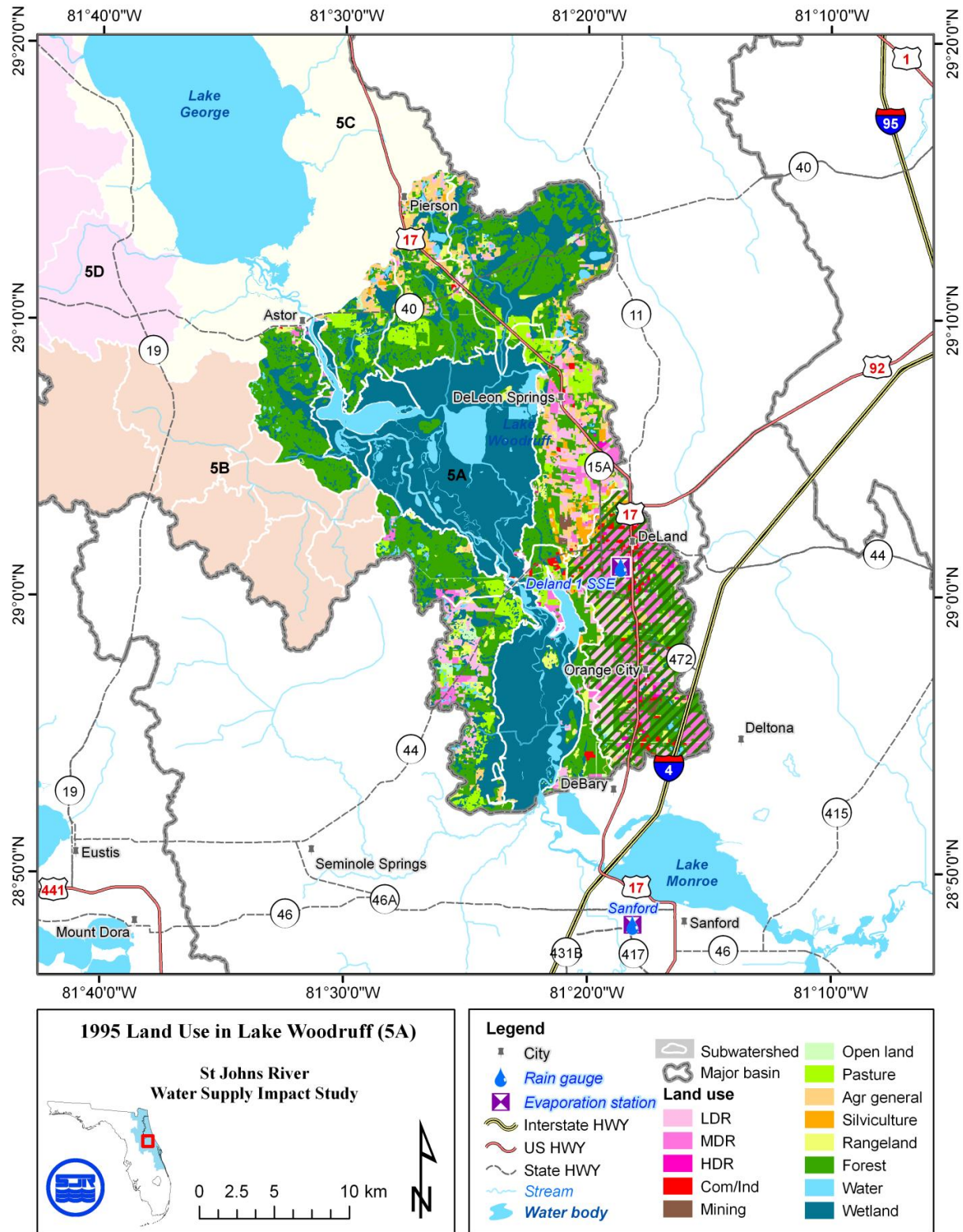


Figure 3–32. 1995 land use in Lake Woodruff Planning Unit (5A).

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.

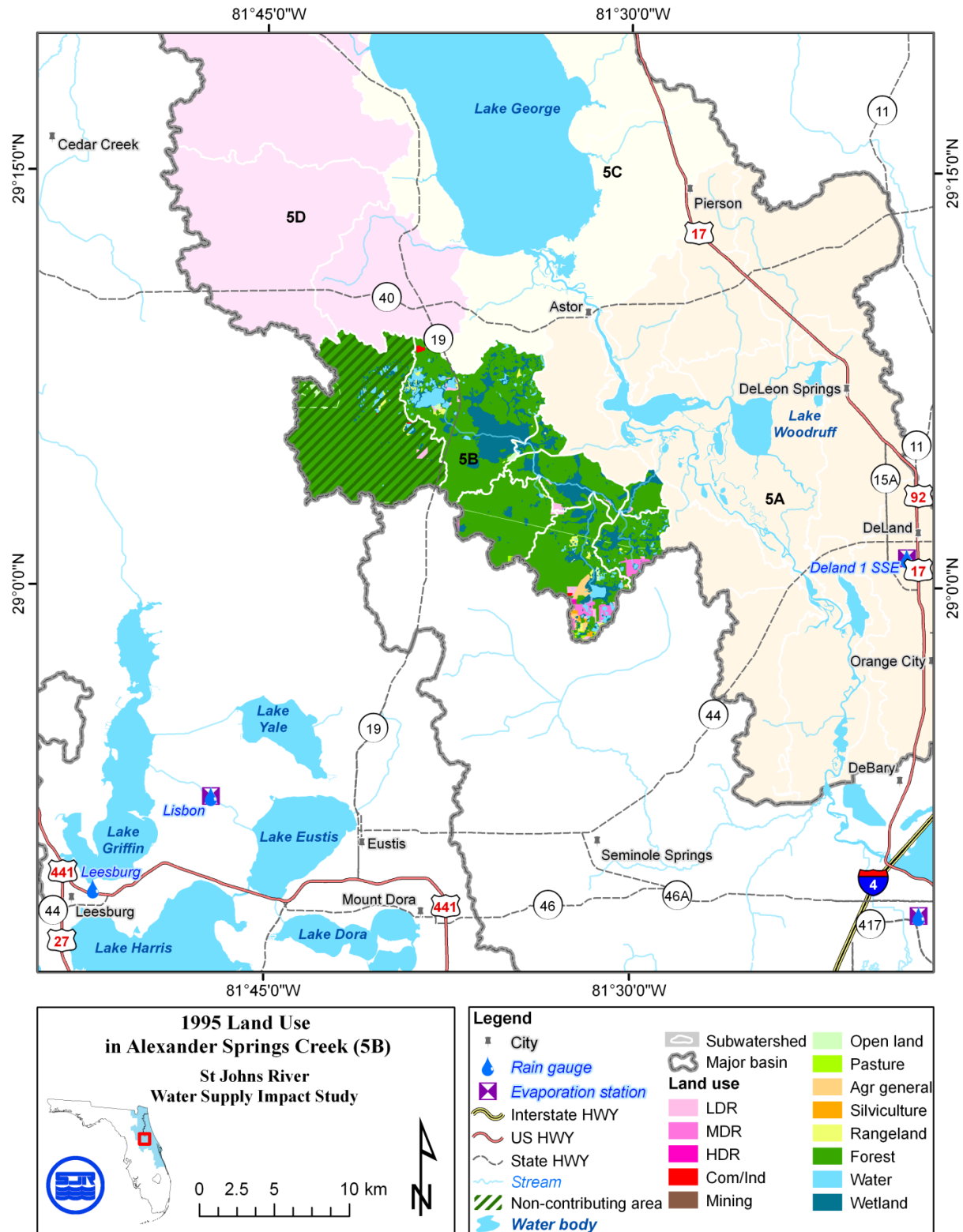


Figure 3–33. 1995 land use in Alexander Creek Planning Unit (5B).

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.

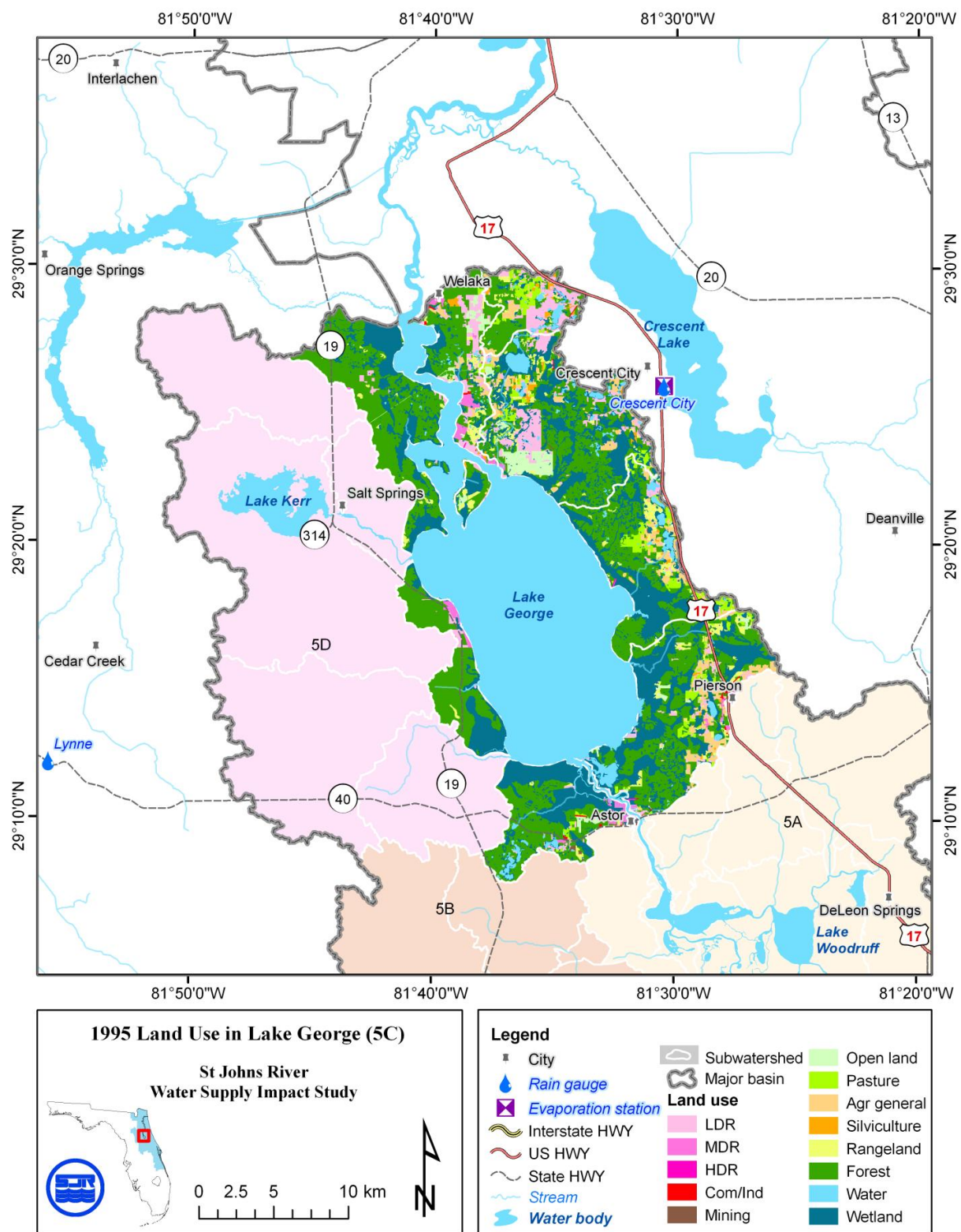


Figure 3–34. 1995 land use in Lake George Planning Unit (5C).