

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

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

4.1.4 OCKLAWAHA RIVER BASIN (7)

The Ocklawaha River basin is located in central Florida along the western edge of the St. Johns River watershed (Figure 3–36). It comprises about 2,116 mi² of watershed area draining into the Rodman Reservoir that then drains into the St. Johns River upstream of Palatka. The preexisting modeling in the Ocklawaha River basin had been accomplished in three sections for different purposes. Models were constructed in the upper Ocklawaha River Basin (UORB), lower Ocklawaha River Basin (LORB), and the upper portion of the Orange Creek Planning Unit (OC). The connection between the upper portion of Orange Creek and the LORB was developed as a new model. The UORB consists of planning units 7A through 7D. The LORB is represented by planning units 7E and 7F. The Orange Creek planning unit 7G, completes the Ocklawaha River basin (Table 3–40).

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

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

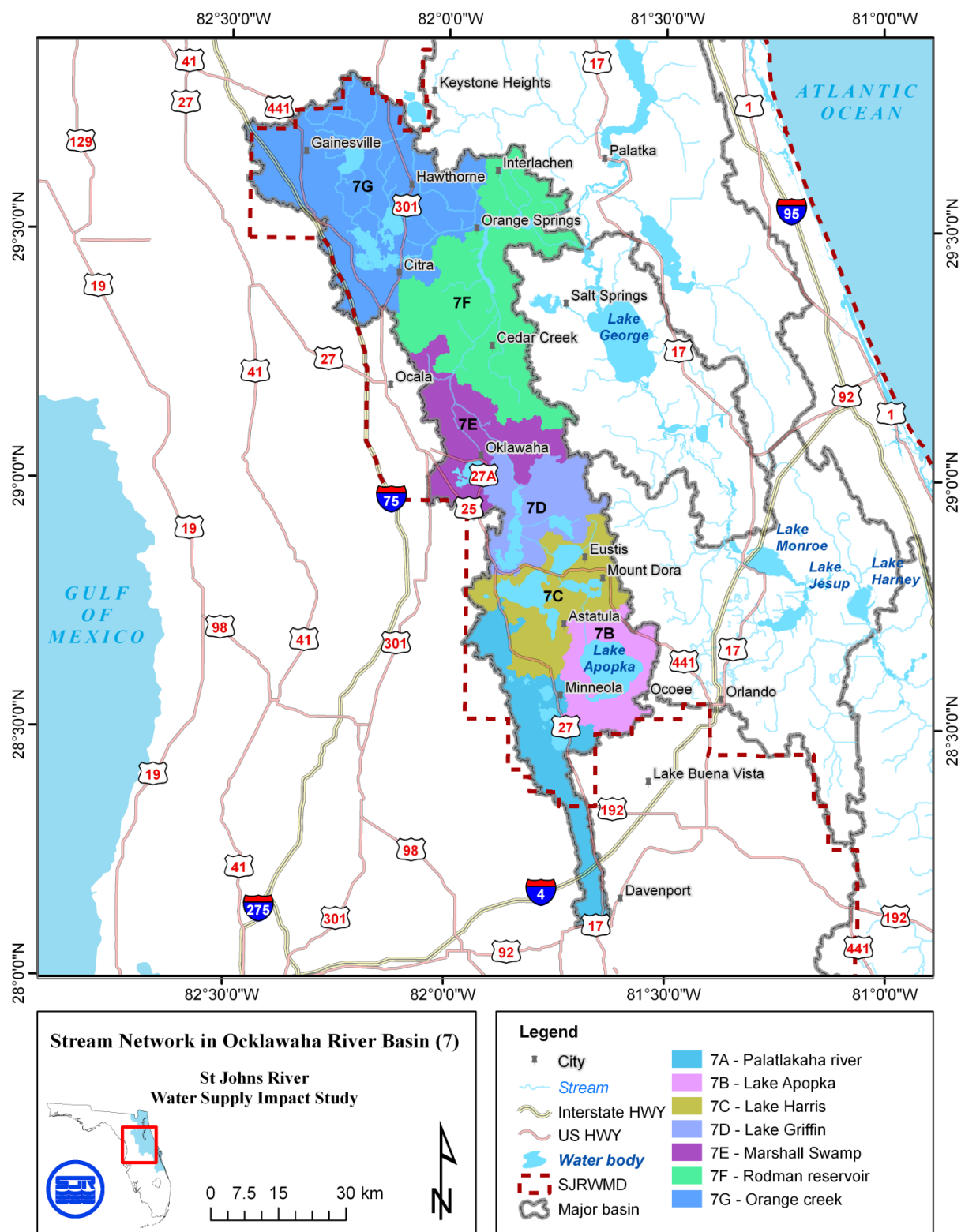


Figure 3–36. Stream network showing planning units 7A through 7G in the Ocklawaha River Basin (7).

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

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

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

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

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

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

The UORB is located in the central part of Florida just west of the MSJRB. It includes parts or all of Polk, Lake, Orange, and Marion counties. In accordance with SJRWMD's organizational

scheme, the basin includes Palatlakaha River, Lake Apopka, Lake Harris and Lake Griffin (Figure 3–36). Flow in the Palatlakaha River subwatersheds is regulated by a series of structures before entering Lake Harris at the M1 structure. The Lake Harris planning unit is divided into four subwatersheds: the Lake Beauclair, Lake Dora, Lake Harris with Little Lake Harris, and Lake Eustis. The Lake Griffin planning unit is divided into Lake Griffin and Lake Yale subwatersheds.

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

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

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

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

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

substantially increased surface water nutrient loads. Therefore, eutrophication has increased to detrimental levels and recreational, aesthetic, and commercial values have declined.

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

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

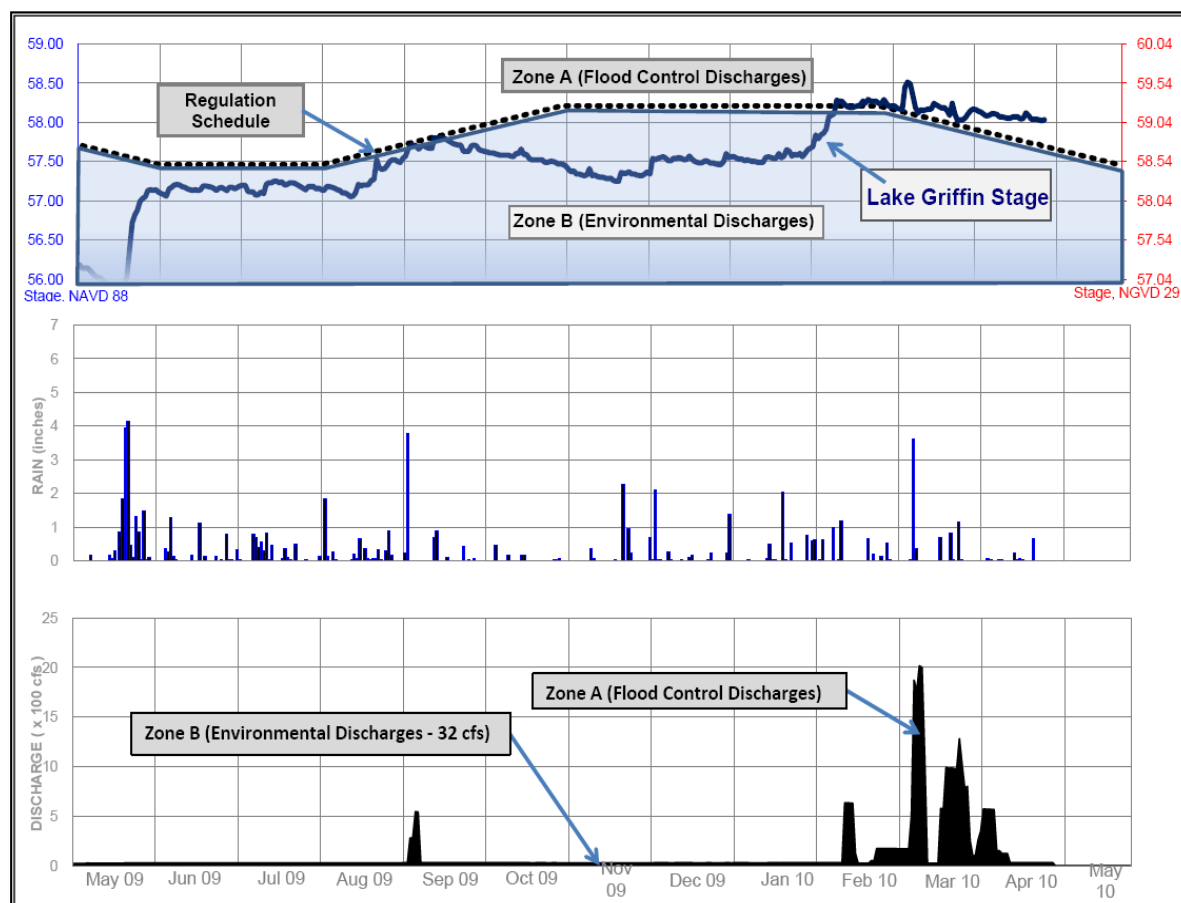


Figure 3–37. Lake Griffin regulation schedule illustrates seasonal regulation changes and Zones A and B discharges typical of upper Ocklawaha River basin (UORB) lakes.

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

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

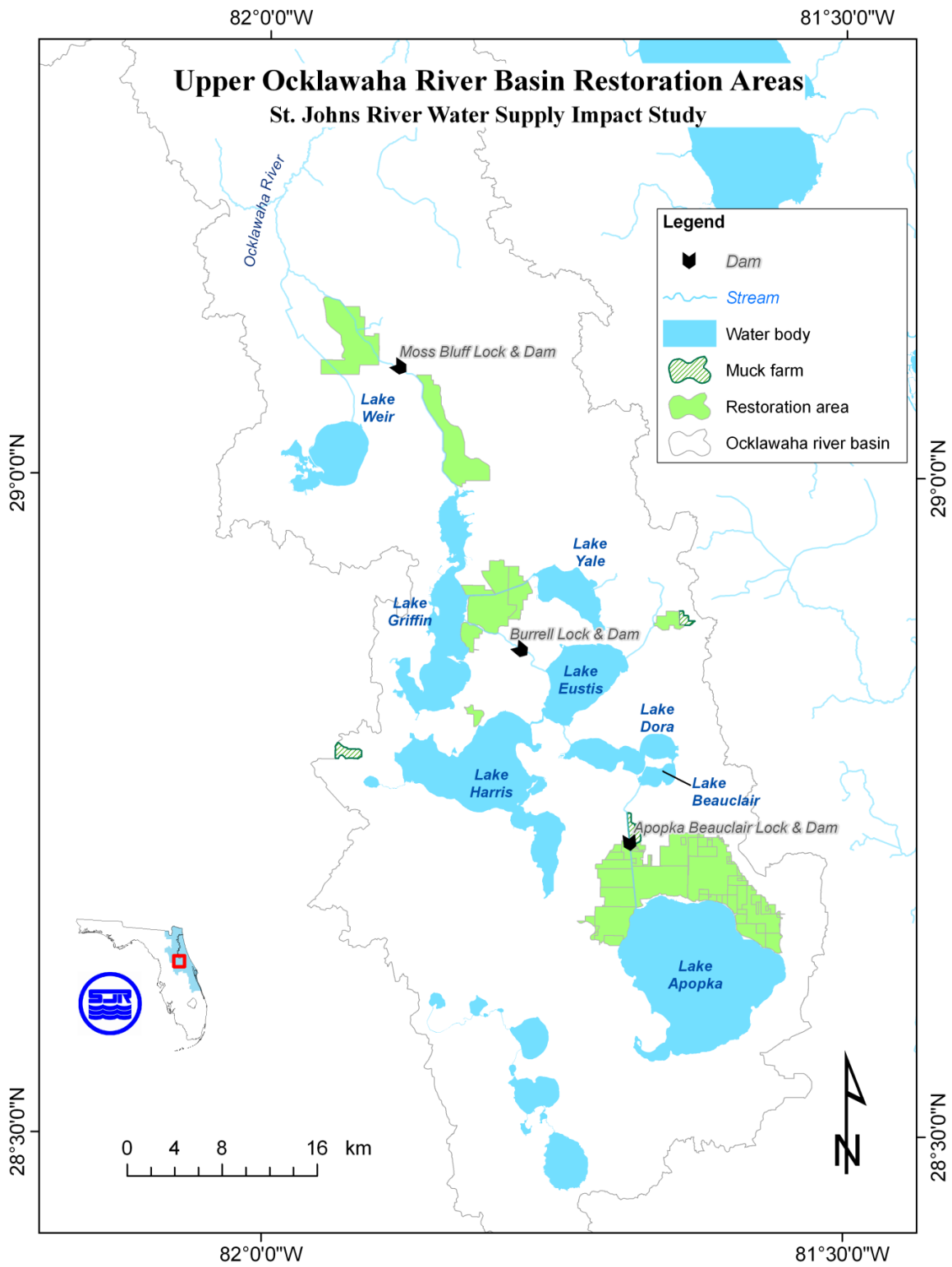


Figure 3–38. Upper Ocklawaha River restoration areas.

Palatlakaha River Planning Unit (7A)

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

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

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

1996	1997	1998	Overall
0.44	-11.36	-22.83	-5.60

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

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

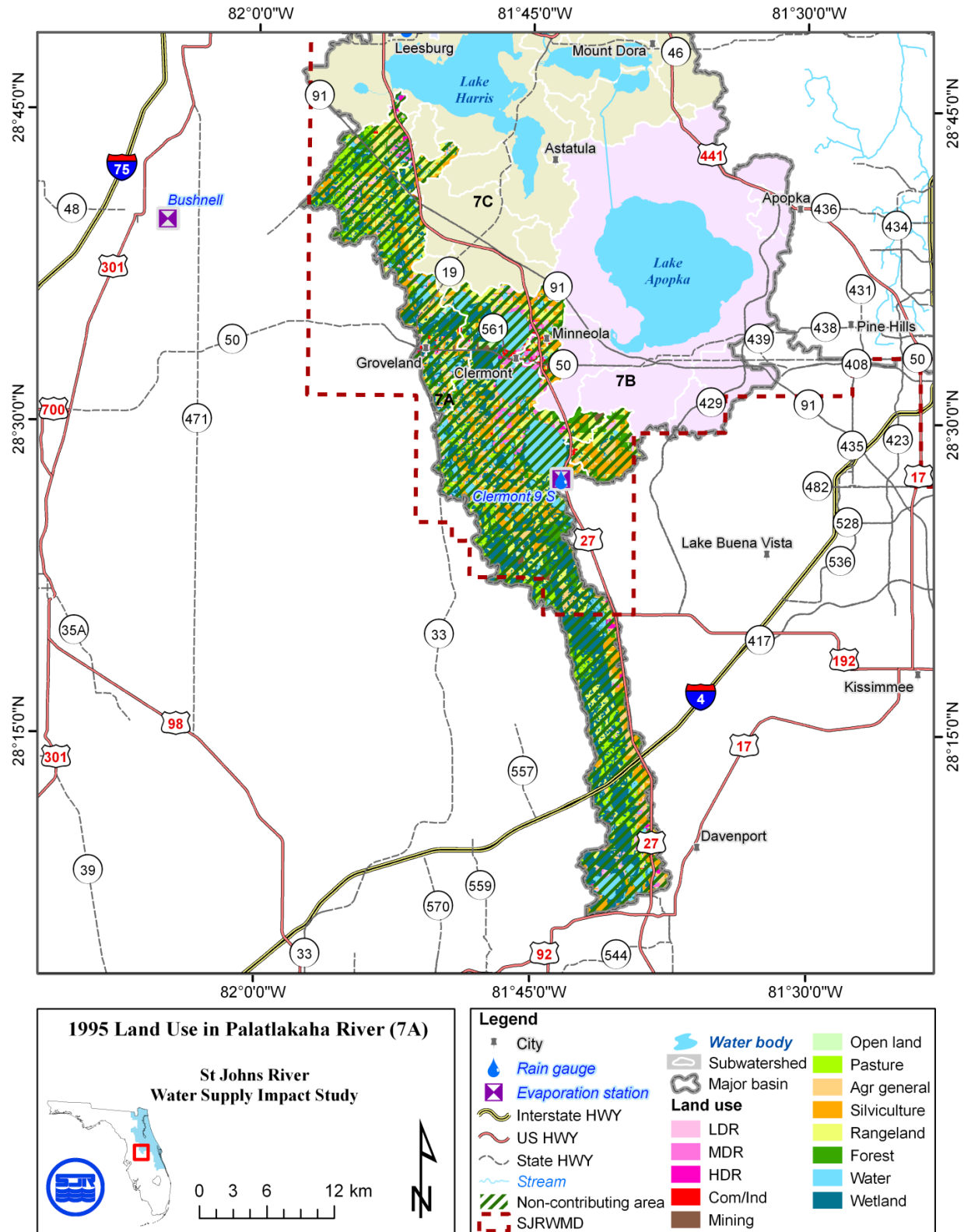


Figure 3–39. 1995 land use in Palatka River Planning Unit (7A).

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

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

Lake Apopka Planning Unit (7B)

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

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

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

satisfy downstream environmental requirements. Because of the regulation schedule the lake level fluctuates in a narrow range, varying from 62.6 ft to 68.7 ft NGVD with a mean of 66.5 ft NGVD from 1952 through 2011.

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

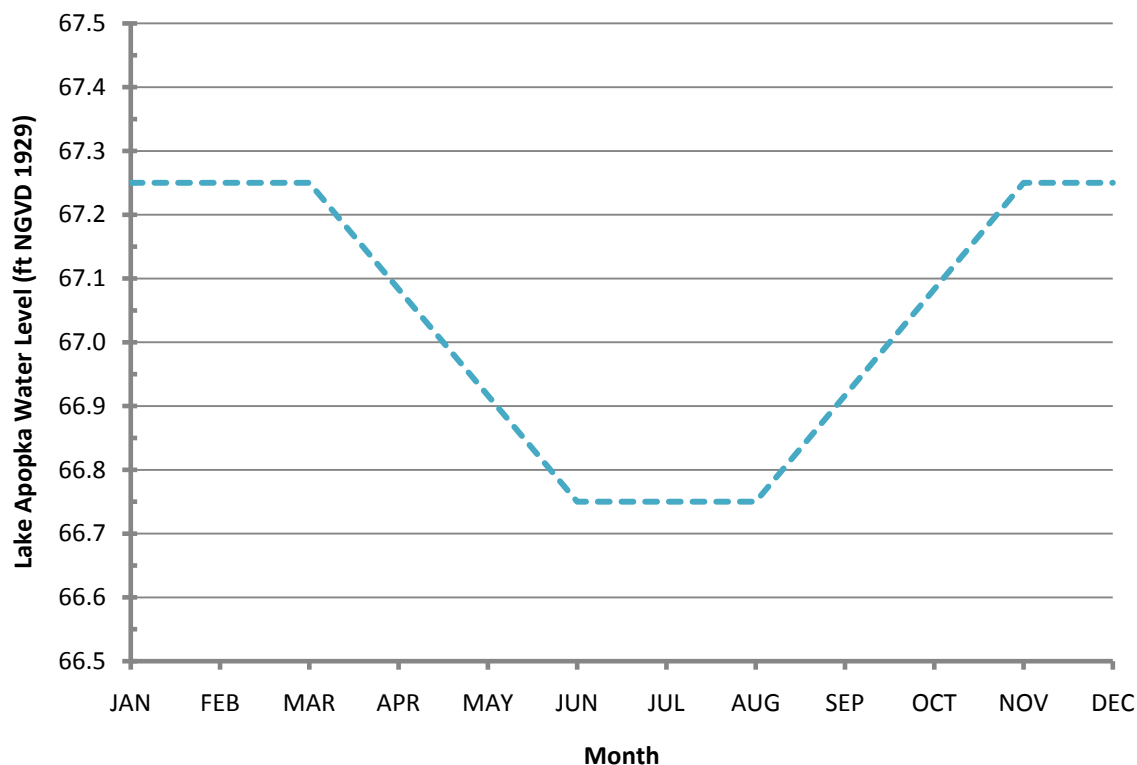


Figure 3–40. Lake Apopka regulation schedule.

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

Numerous activities in the nineteenth and twentieth centuries have contributed to the decline of the lake. Significant human impact affecting Lake Apopka probably began with the construction of the Apopka-Beauclair Canal, which altered the hydrology of the lake. In order to create a waterway for navigation and agricultural use, dredging of the Apopka-Beauclair Canal lowered the water surface of Lake Apopka by about 4 ft leaving approximately 20,000 ac of wetlands dry enough for farming (Shofner 1982). Crop production was mostly unsuccessful due to difficulty

in water table management and a series of freezes in the mid and late 1890s. A hurricane struck in 1926 and the entire north shore farm area reverted to marshland “under six to eight feet of water” (Shofner 1982). Due to improved technology, farming returned during World War II. In 1941, the Zellwood Drainage and Water Control District was created by a special act of the Florida Legislature and charged with facilitating agricultural production activities. In 1941, the mean elevation of the lake was approximately 67 ft (NGVD29), the same elevation as the muck and peat land along the northern shore at that time. These lands were inundated when the lake rose above the mean elevation and during lower lake stages, these lands drained into the lake or into the Apopka-Beauclair Canal. Under the management of Zellwood Drainage and Water Control District a levee was constructed along the north lakeshore, effectively separating the marshes from the lake and allowing drainage of the farm fields (Shofner 1982). Agricultural production peaked in the muck farms during the 1980s, with 18,000 ac of farmed land. With the final government purchase of the remaining muck farms on Aug. 20, 1999, Zellwood Drainage and Water Control District was dissolved in February 2000 by mandate of the 1999 Florida Legislature.

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

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

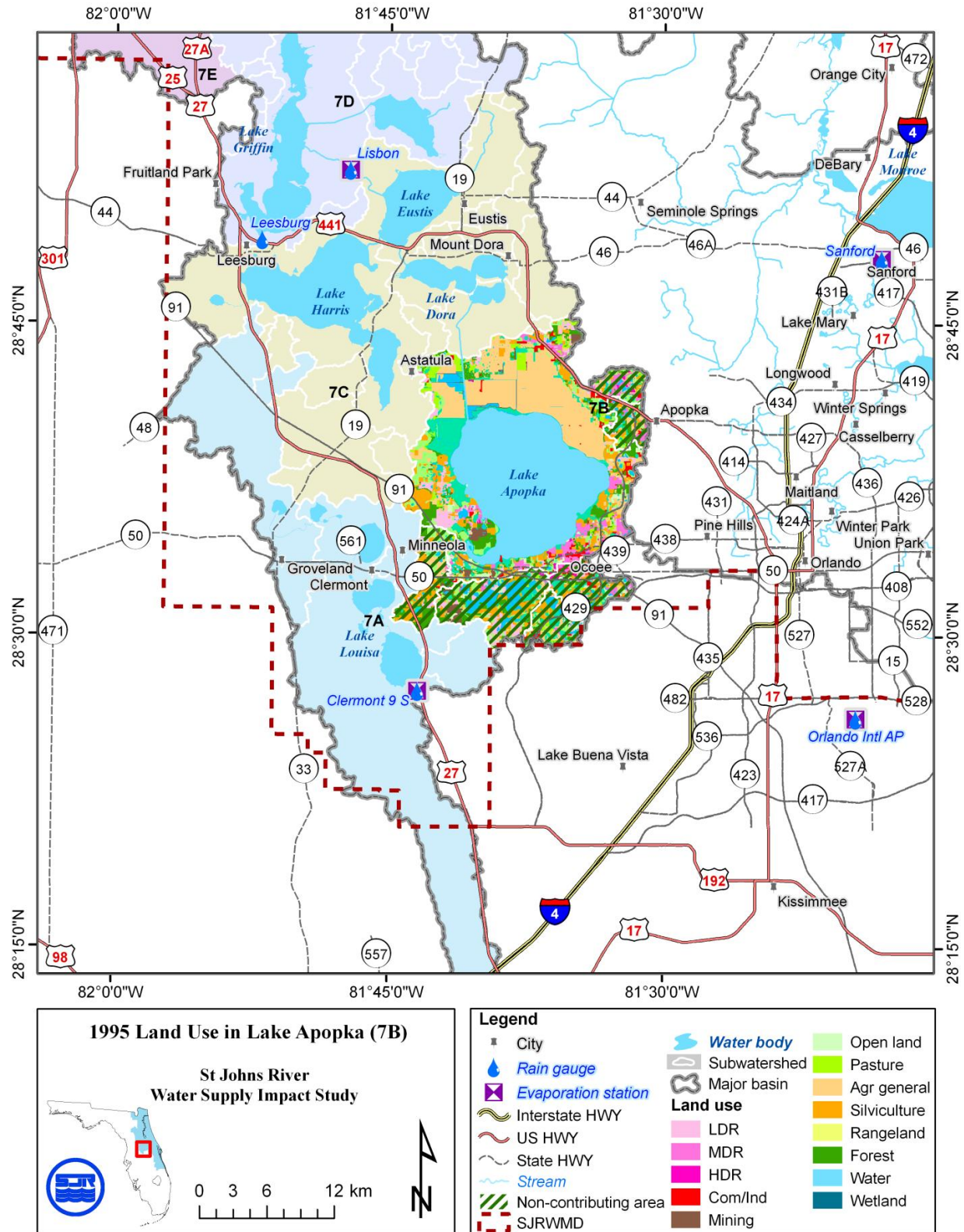


Figure 3–41. 1995 land use in Lake Apopka Planning Unit (7B).

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

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

Lake Harris Planning Unit (7C)

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

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

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

hydrological cycles may contribute to loss of habitat and deterioration in water quality in the basin.

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

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

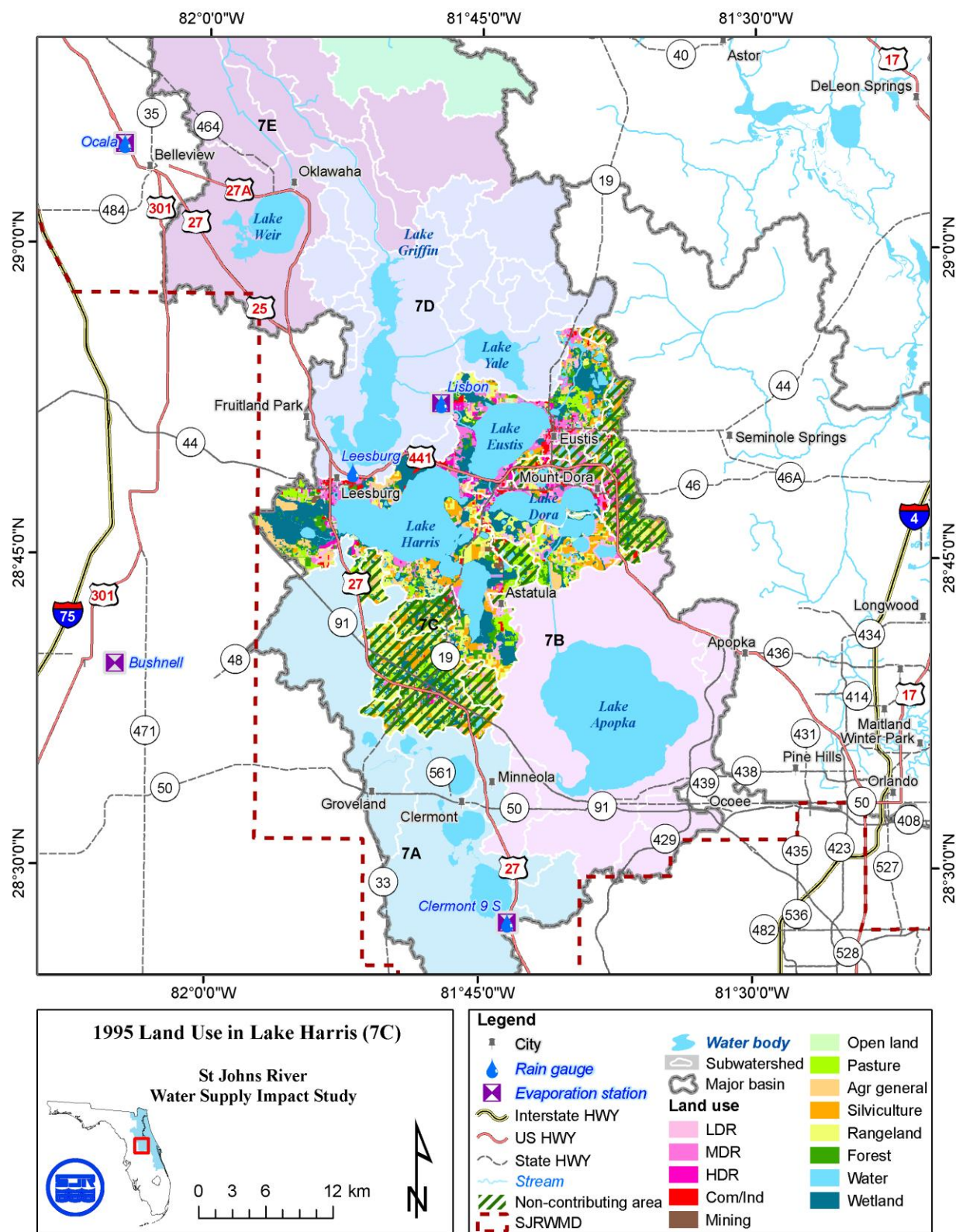


Figure 3–42. 1995 land use in Lake Harris Planning Unit (7C).

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

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

Lake Griffin Planning Unit (7D)

The total drainage area of Lake Griffin is approximately 97 mi² excluding the Lake Yale basin. Two major tributaries—Haines Creek and the Yale-Griffin Canal—discharge directly into Lake Griffin. Haines Creek receives discharge from upstream Harris Chain of Lakes and Apopka Basin at the Burrell Lock and Dam structure. The Yale-Griffin Canal connects the two lakes and delivers flow from Lake Yale into Lake Griffin. Most of the land surface areas around the lakes and the Ocklawaha River are low-lying wetlands and have been developed for agricultural production, predominantly muck farms. In most of these agricultural areas, drainage systems with perimeter levees and pump stations were constructed to provide flood protection. Most upland areas or ridges were used for citrus groves, with most contributing minimal runoff because they typically have high infiltration rates. There is urban or community development throughout the region, both in waterfront and ridge areas.

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

The water surface elevation of Lake Griffin is currently regulated to allow a narrow fluctuation of 0.75 ft from 58.50 to 59.25 ft NGVD29. However, levels regularly deviate from these control elevations due to rainfall and drought conditions. This fluctuation range is designed to facilitate navigation and to provide limited floodwater storage capacity. Because of the shallow nature of the lake, any minor change in water surface elevation beyond the specified operating range

would either flood waterfront properties or cause navigation problems: When the water level reaches or exceeds 60.00 ft NGVD29, some shoreline properties will be inundated; if the water level falls below 58.00 ft NGVD29, many areas become too shallow for normal boating activities.

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

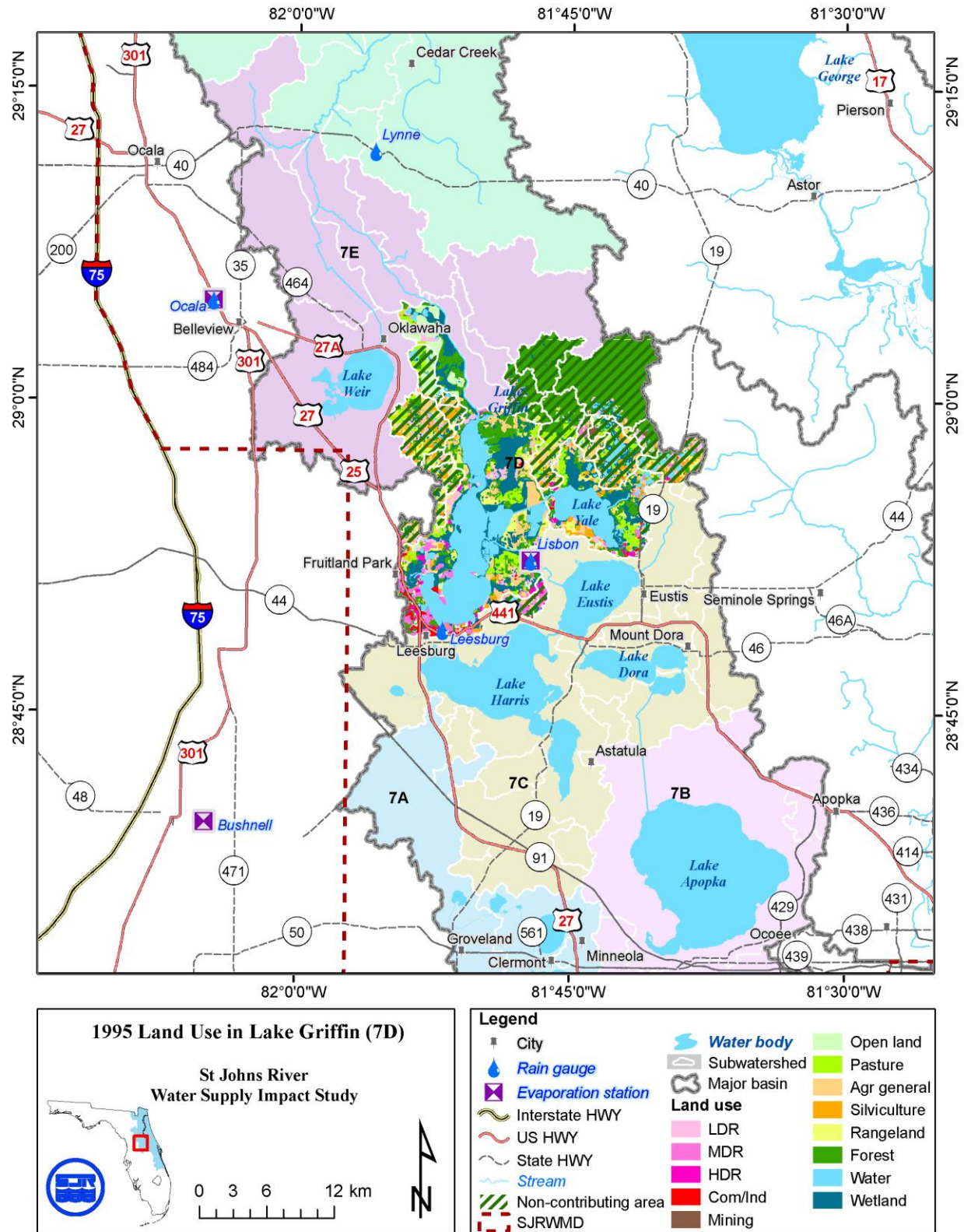


Figure 3–43. 1995 land use in Lake Griffin Planning Unit (7D).

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

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

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

The LORB starts at the Moss Bluff Lock and Dam and continues downstream to the Ocklawaha River's confluence with the St Johns River. The LORB includes drainage from Marshall Swamp and Lake Weir, Silver River, Orange Creek, the UORB, and other smaller tributaries. It encompasses an area of approximately 472 mi² in Putnam and Marion counties.

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

Silver River, the largest tributary of the Ocklawaha River, enters the Ocklawaha River near SR 40 east of Ocala. It receives its flow from several springs collectively known as Silver Springs. Its discharges originate from the Upper Floridan Aquifer system. According to SJRWMD's estimate, Silver Springs' groundwater contributing area is approximately 1,100 mi². Silver Springs accounts for approximately 80% of the base flow of the Ocklawaha River. Unlike selected spring and diffuse groundwater flows in the MSJRB and Lake George Basin, the springs in the Ocklawaha Basin are included in the hydrograph that forms the input into the EFDC hydrodynamic model. The Rodman Reservoir (Lake Ocklawaha) located near the mouth of the Ocklawaha River, is the main surface water body within the LORB. The reservoir was created in

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

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

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

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

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

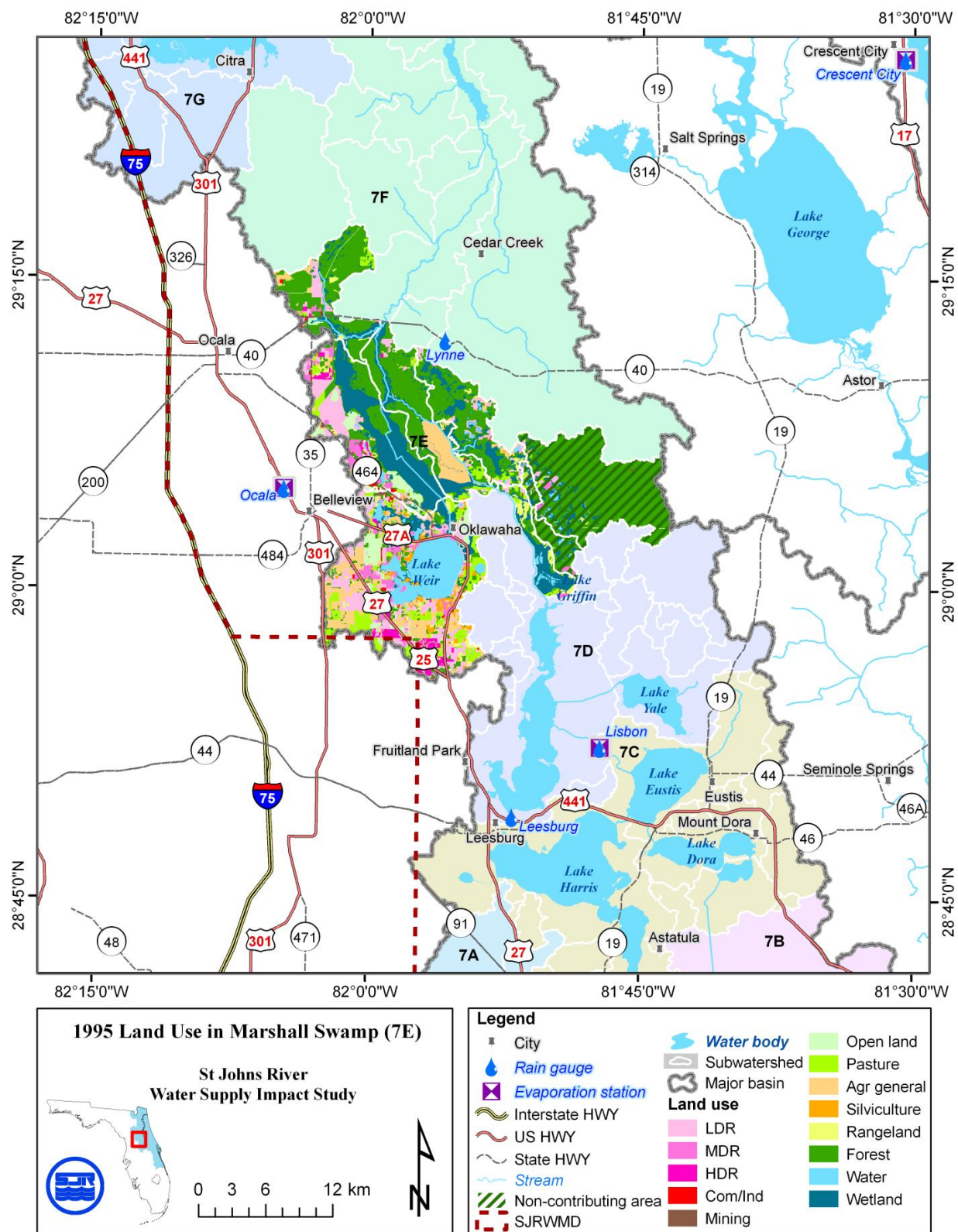


Figure 3–44. 1995 land use in Marshall Swamp Planning Unit (7E).

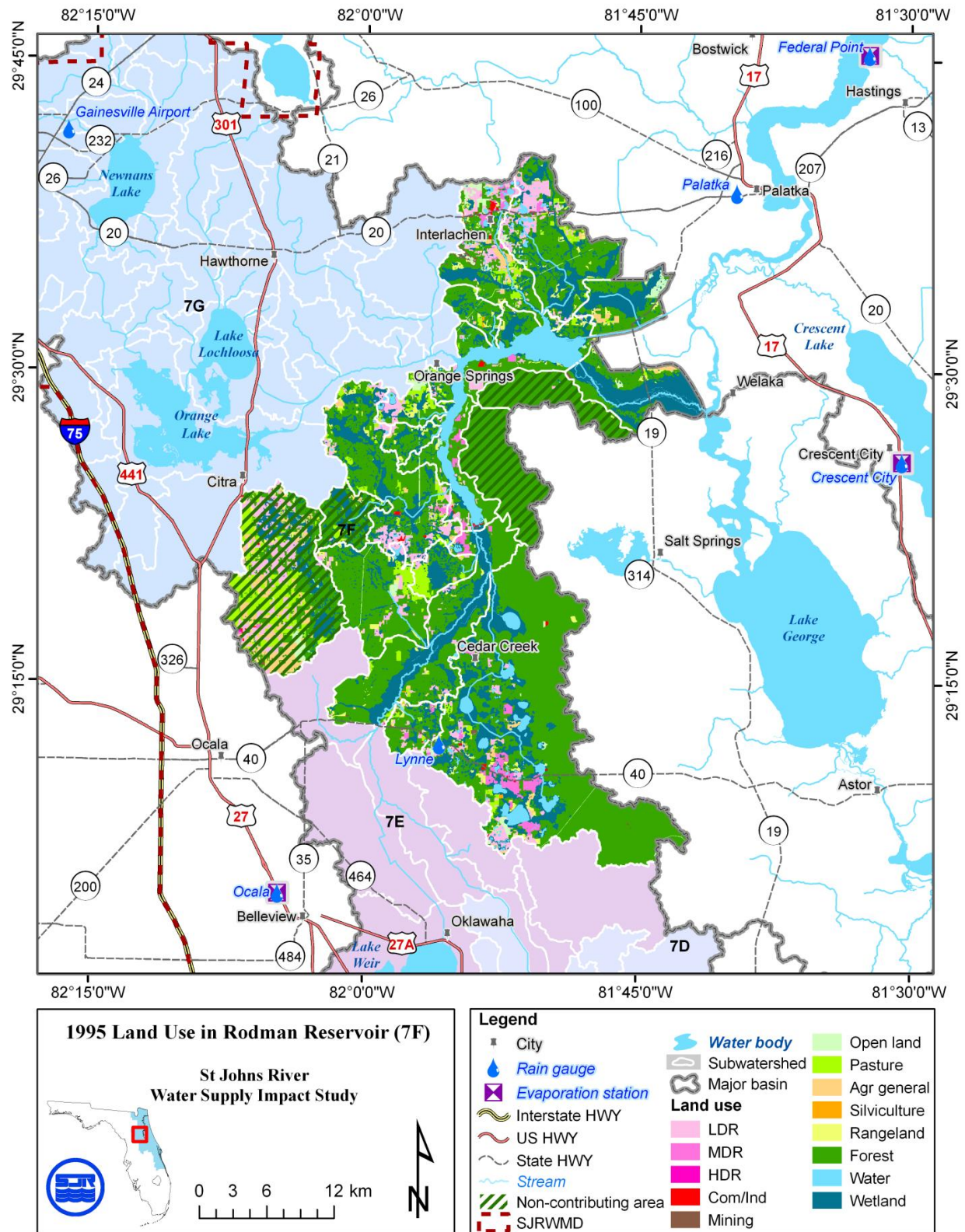


Figure 3–45. 1995 land use in Rodman Reservoir Planning Unit (7F).

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

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

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

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

Orange Creek Planning Unit 7G

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

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

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

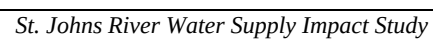


Table 3–49. Orange Creek Planning Unit (7G) 1995 and projected 2030 land use comparison.

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

Upper Portion of the Orange Creek Planning Unit

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

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

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

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

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

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

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

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

Lower Portion of the Orange Creek Planning Unit

Lower Orange Creek is the lower portion of the Orange Creek planning unit, which is a tributary of the lower Ocklawaha River. The 139-mi² (88,705-ac) area is delineated into 11 subwatersheds ranging from 907 ac to 19,121 ac. A significant portion of the lower Orange Creek subwatersheds falls within Putnam County with small portions in Alachua and Marion counties. Orange Creek is the major stream component in the watershed and it receives flow from tributaries that drain northern portions of the watershed. Cowpen Lake subwatershed is landlocked with water flow mostly occurring as groundwater discharge. Lower Orange Creek receives flow from Lochloosa Lake and Orange Lake through Orange Creek and Lochloosa

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

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

4.1.5 LOWER ST. JOHNS RIVER BASIN (3)

The LSJRB is comprised of 11 planning units encompassing 2,740 mi² (Figure 3–47 and Table 3–51). The basin is located in northeast Florida and represents 22% of the area within SJRWMD. The LSJRB extends from Lake George to the mouth of the river at the Atlantic Ocean near Jacksonville.

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

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

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

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

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

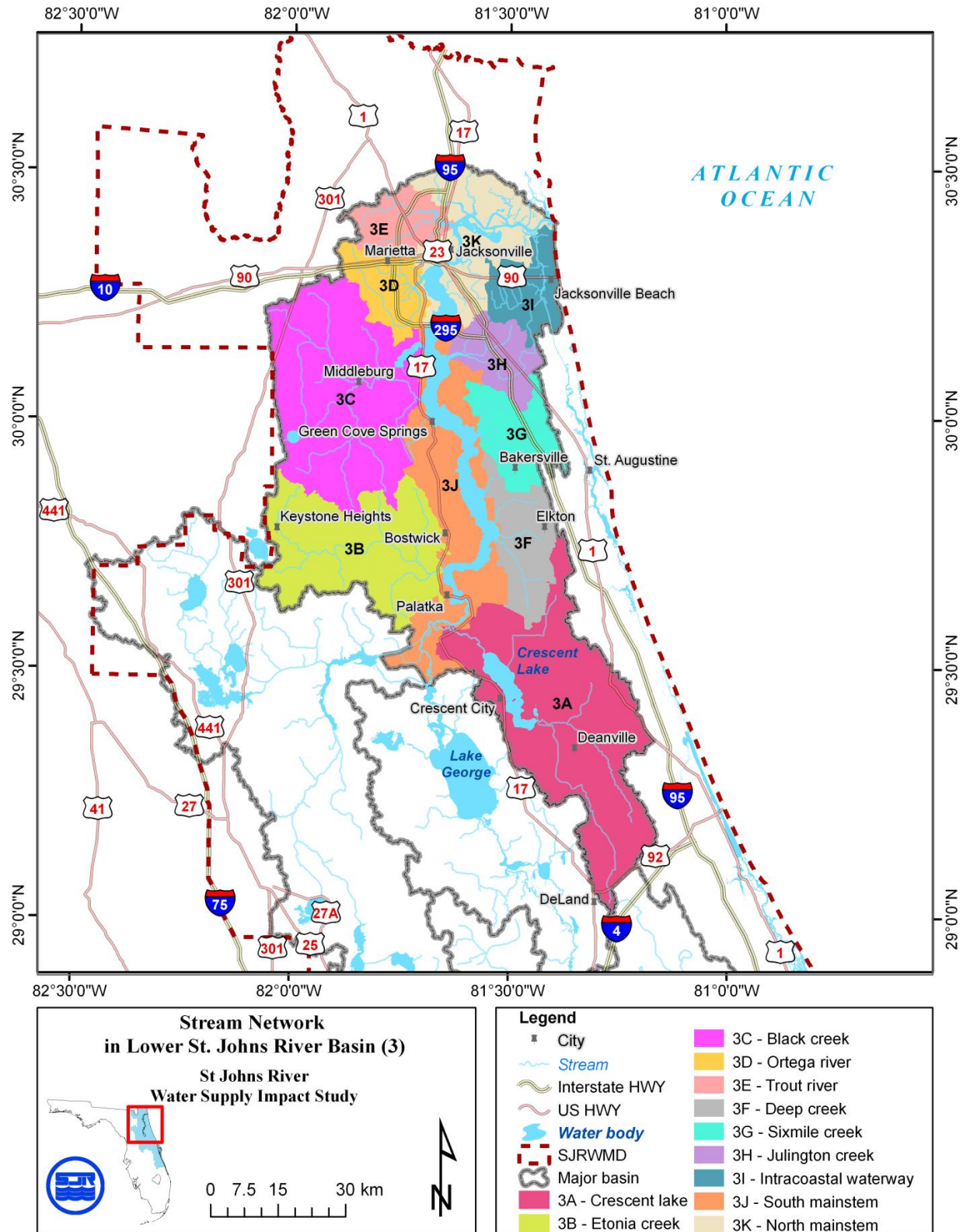


Figure 3–47. Stream network showing planning units 3A through 3K in the Lower St. Johns River Basin (3).

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

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

Crescent Lake Planning Unit (3A)

The Crescent Lake planning unit is located east of the St. Johns River and east of Lake George. Its discharge point into the St. Johns River is south of San Mateo, just downstream of Murphy Island. Crescent Lake encompasses an area of 595 mi² and extends over parts of Putnam, Flagler, and Volusia counties. The major components of the stream flow system are Dunns Creek, Crescent Lake, and Haw Creek. Important tributaries include Middle Haw Creek, Little Haw Creek, and Black Branch. The general direction of the flow is from southeast to northwest, and the planning unit discharges ultimately through Dunns Creek into the St. Johns River at RM 139.

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

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

In general, wetland (34%) and forest (43%) were the dominant land use in this area in 1995 (Figure 3–48). The planning unit was relatively undeveloped in 1995 (6% urban), but has and is

projected to continue to undergo significant development, resulting in approximately 25% urban land use by 2030 (Table 3–52).

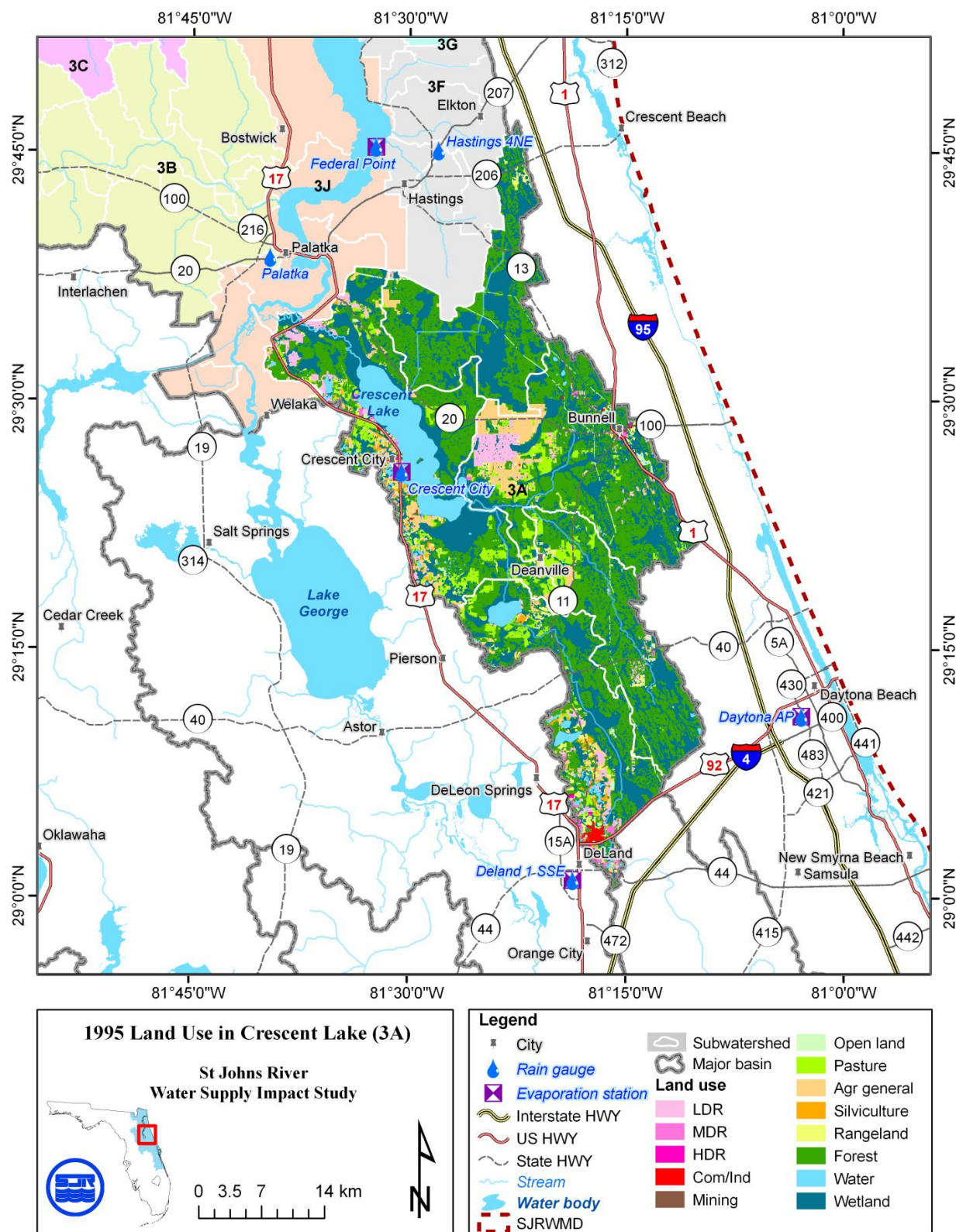


Figure 3–48. 1995 land use in Crescent Lake Planning Unit (3A).

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

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

Little Haw Subwatershed

Little Haw Creek begins as far south as the City of DeLand. On its way north, it crosses various swamps, so that the streambed is not always well defined. Little Haw (3a1) is a 106- mi² (67,599-ac) subwatershed located south of Crescent Lake planning unit. Little Haw Creek, a tributary of Crescent Lake, drains from south to north. Topography in the subwatershed is relatively flat (slope less than 3%) in eastern portions of the creek, but has steep surfaces with slopes up to 21% to the west as it nears Crescent Lake. Forest and wetlands are the predominant land uses. Soils in the area are composed of mainly poorly drained B/D (62%) and D (19%) soils, with excessively drained A (7%) soils in southwestern portions near municipalities of DeLand and DeLeon Springs. A B/D soil will respond as a B soil if a drainage system is in place, otherwise it responds as a D soil.

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

Middle Haw Subwatershed

The 83-ac Middle Haw Creek subwatershed discharges into Haw Creek. The stream flows from southeast to northwest towards Crescent Lake. Topography in the area is relatively flat with slopes averaging less than 1.5%. Forest and wetlands are the predominant land uses. The subwatershed did not have any high-density residential, industrial/commercial, or agriculture tree

crops land uses in 1995. Soils in the area are composed of mainly poorly drained B/D (60%) and D (18%) soils.

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

Etonia Creek Planning Unit (3B)

The Etonia Creek planning unit is 357 mi² in size and is located west of the St. Johns River just north of Palatka. The majority of the watershed is contained in Putnam County. The upstream portion is on the Trail Ridge, which is a subdivision of the Sea Island District formation. The downstream portion includes Rice Creek Swamp, which is a subdivision of the Eastern Flatwoods District formation (Brooks 1982). The final segment (2 mi) of the river is named Rice Creek, but because Etonia Creek makes up most of the watershed, the entire basin is identified as Etonia Creek Basin by SJRWMD. Elevations range from about 240.00 ft NGVD29 in the west to near sea level at the confluence with the St. Johns River.

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

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

Etonia Creek planning unit is divided into 13 subwatersheds. At its outlet into the St. Johns River, the watershed area is 356.9 mi². Of this total, the 172 ac in Gold Head State Park containing Sheeler Lake is considered noncontributing to surface runoff and is therefore not directly modeled. Likewise, the 1,024-ac water treatment reservoir owned by Georgia Pacific contributes no runoff and is not included in the HSPF hydrologic model.

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

The 1995 land use is predominantly forest (50%) and wetlands (20%) (Figure 3–49 and Table 3–53). A minor component is low-density residential (10%) but much of this is vacant lots on dirt

roads in rural areas left over from unsuccessful land development projects going back to the mid-1950s. Less than 3% of the watershed in 1995 was residential or industrial/commercial land. The amount of residential and industrial/commercial land use is expected to double by 2030, largely at the expense of forest.

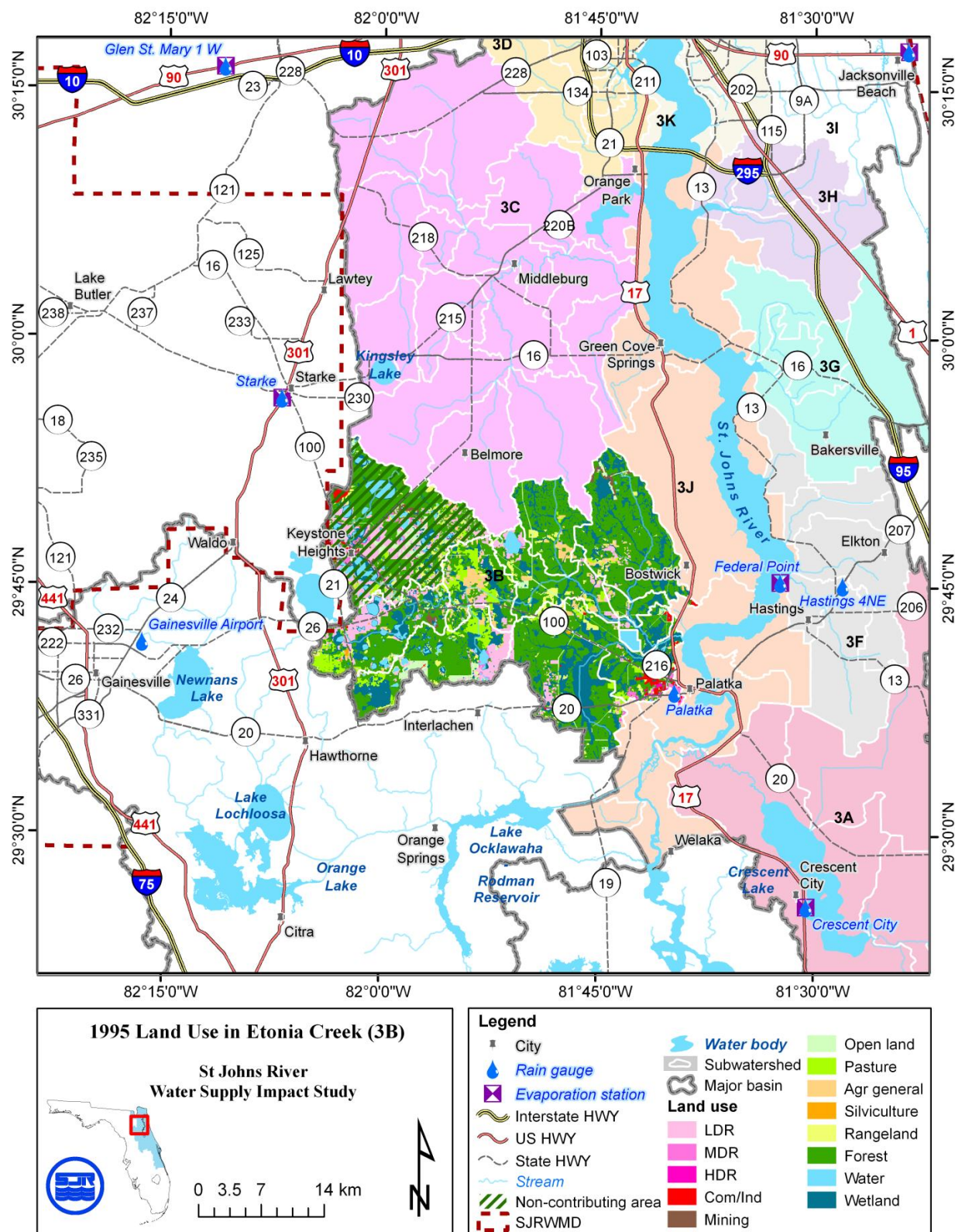


Figure 3–49. 1995 land use in Etonia Creek Planning Unit (3B).

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

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

The USGS Etonia Creek gauging station at Bardin has the largest drainage area of 219 mi². Annual mean discharge is 61.6 mgd (95.3 cfs); records are rated by the USGS as poor quality. The USGS Simms Creek gauging station near Bardin has a drainage area of 47.3 mi². Mean annual discharge is 31.7 mgd (49.0 cfs); records are rated as fair. The USGS Rice Creek gauging station near Springside has a drainage area of 43.2 mi². Annual mean discharge is 28.2 mgd (43.7 cfs); records are rated as fair.

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

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

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

Black Creek Planning Unit (3C)

The Black Creek planning unit is located west of the St. Johns River and discharges between Green Cove Springs and Doctors Lake. The total area is approximately 508 mi² with elevations ranging from 250 ft south of Kingsley Lake to sea level at the confluence with the St. Johns River. The basin drains nearly all of Clay County and portions of southwestern Duval County. The basin also drains very small portions of Baker, Bradford, and Putnam counties. Physiographically, it belongs to the Duval Upland formation. The headwaters of Black Creek originate on the Trail Ridge.

Major tributaries are the North and South forks of Black Creek and Little Black Creek. The contributing areas of both forks are almost equal in magnitude: 176 mi² for North Fork and 141 mi² for South Fork. The confluence of the North and South forks is near Middleburg. From this point, Black Creek runs an additional 13 mi to the St. Johns River. Tidal effects are evident in the lower 8 mi of the North Fork and South Fork, as well as in the lower 13 mi of Black Creek. Also included in the Black Creek planning unit are the subwatersheds surrounding and contributing to Doctors Lake. Due to its wide opening to the St. Johns River, the lake is actually a low-salinity estuary and, as such, is part of the EFDC hydrodynamic model.

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

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

with bank elevation ranging from 120.00 ft NGVD29 near Lake Varnes to 10.00 ft NGVD29 near Middleburg.

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

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

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

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

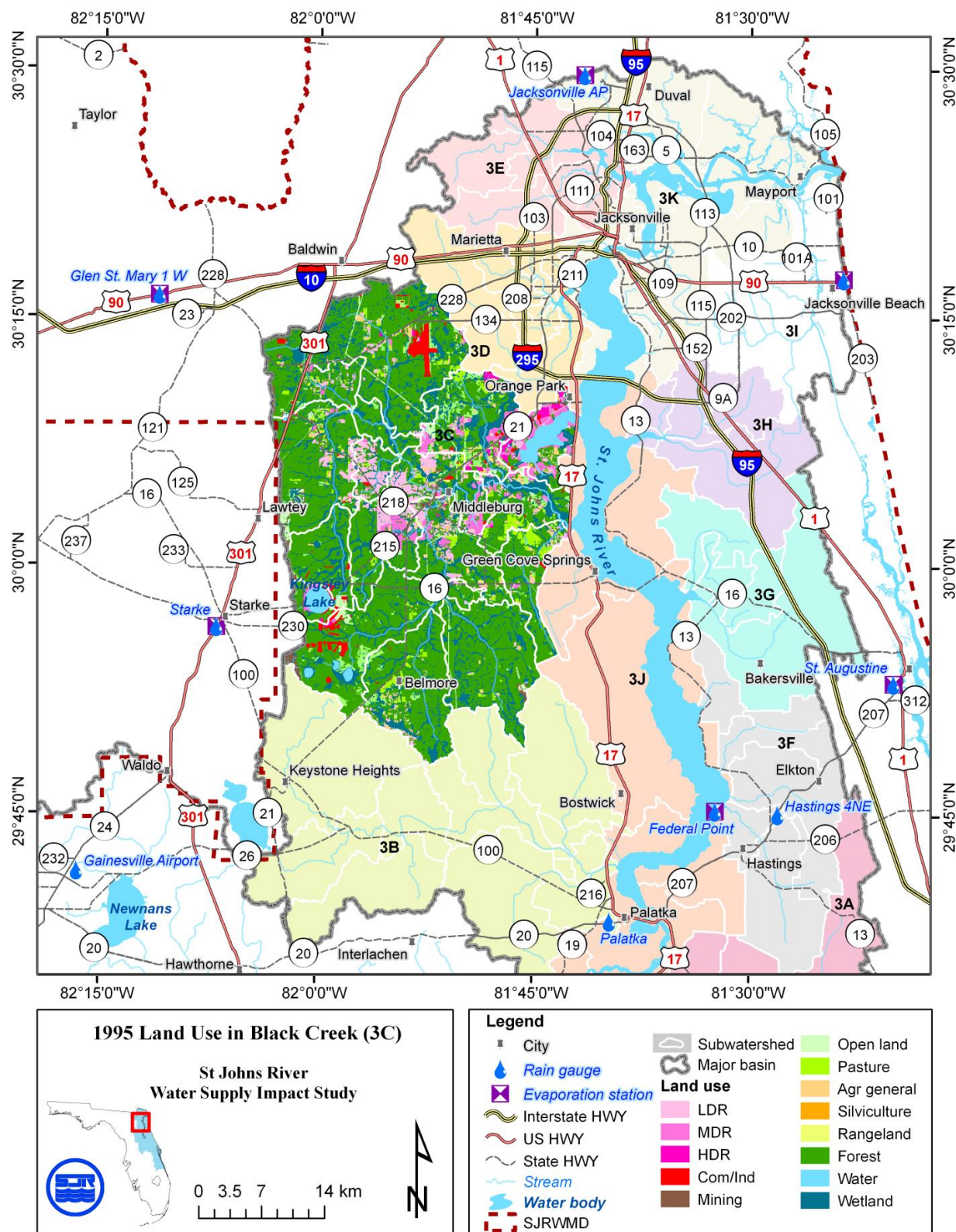


Figure 3–50. 1995 land use in Black Creek Planning Unit (3C).

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

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

Ortega River Planning Unit (3D)

The Ortega River planning unit is west of the St. Johns River and includes the southwest area of metropolitan Jacksonville and adjacent semirural areas, including a small part of Clay County. It encompasses approximately 104 mi². The Ortega River begins about 90 ft at its headwaters and runs a distance of 23.5 mi before discharging into the St. Johns River. The lower 10 mi of the river is almost flat. The upper 13 mi of the watershed is also flat, hovering around 85 ft, but the river channel cuts rather sharply through this area as it drops to the low-lying coastal area. The lower third of the watershed levels off at around 25.00 ft NGVD29 and tapers off to sea level along the tidal Ortega River estuary. The tidal interface for the Ortega River is at Collins Road (about 0.5 mi downstream of I-295), while the tidal interface for Cedar River is at Lane Avenue (just over 2 mi upstream of SR 21)(Camp, Dresser, and McKee Inc. 1989).

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

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

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

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

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

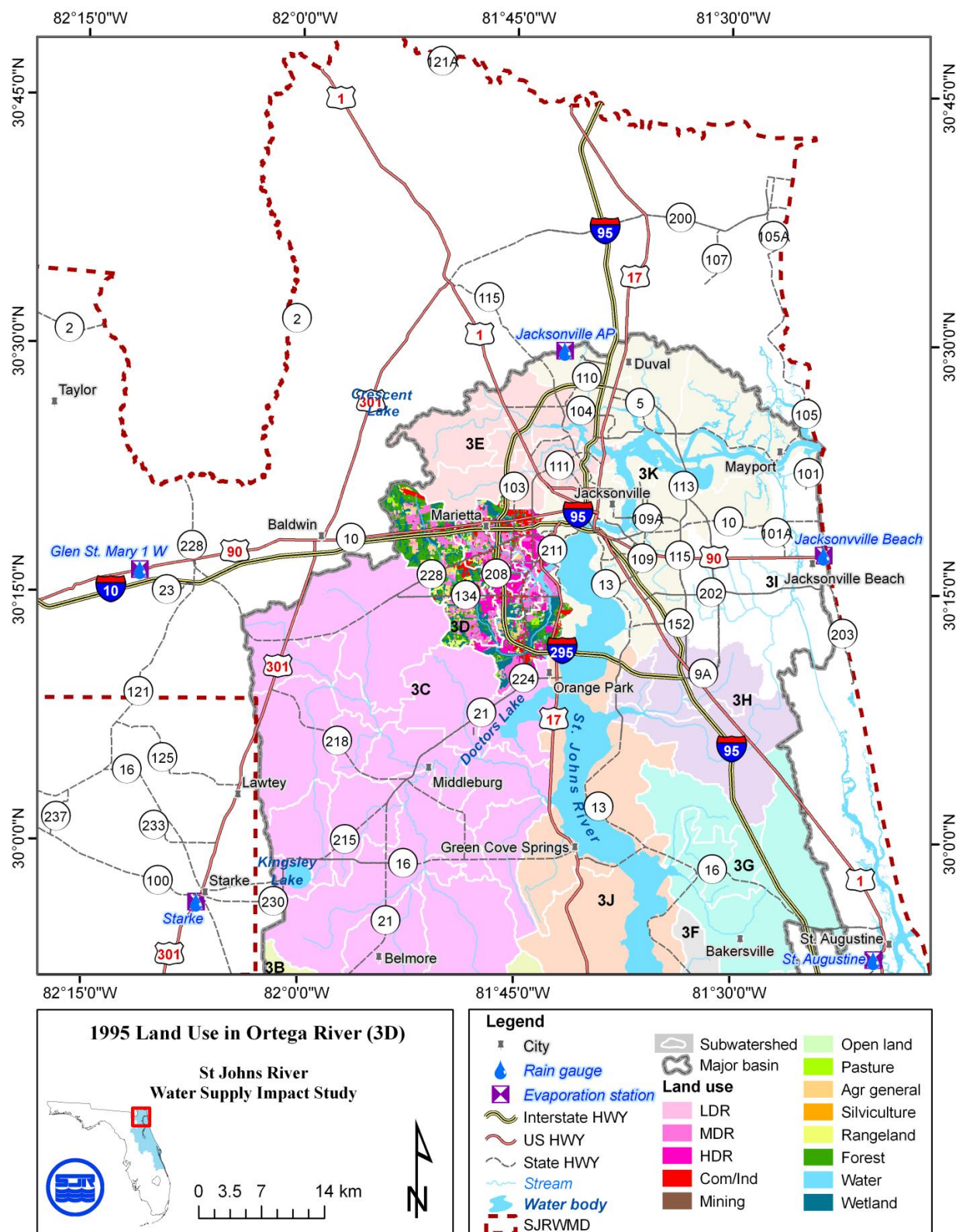


Figure 3–51. 1995 land use in Ortega River Planning Unit (3D).

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

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

Trout River Planning Unit (3E)

The Trout River lies west of the St. Johns River and flows in at the point where the St. Johns River turns east toward the Atlantic Ocean (Camp, Dresser, and McKee Inc. 1989). The total Trout River drainage area is approximately 94 mi². Elevations range from near sea level to about 100.00 ft NGVD29. The basin is heavily influenced by tidal fluctuations. It belongs to the Dinsmore Plain, which is a physiographic subdivision of the Northern Coastal Strip. Major tributaries are Little Trout River, Moncrief Creek, Ribault River, Sixmile Creek, Blockhouse Creek, West Branch, Half Creek, and Gulley Branch.

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

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

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

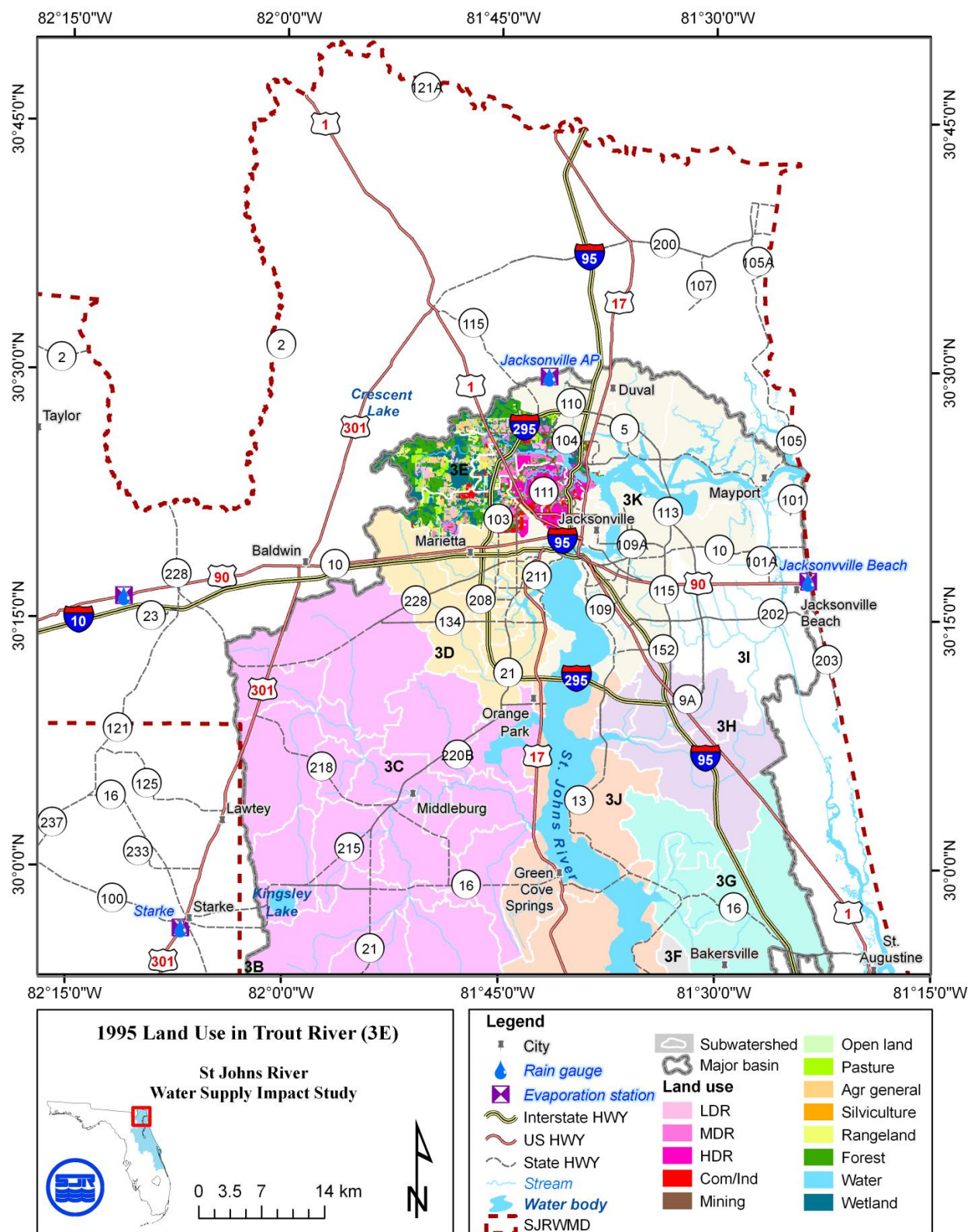


Figure 3–52. 1995 land use in Trout River Planning Unit (3E).

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

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

Deep Creek Planning Unit (3F)

The Deep Creek planning unit is located east of the St. Johns River and almost entirely in St. Johns County (Adamus, Clapp and Brown 1997). Elevations range from approximately 30.00 ft NGVD29 in the eastern part of the basin to near sea level at the mouth. The boundary delineation has been updated and is 88,380 ac (76 mi²). The watershed is separated into seven subwatershed basins. The Deep Creek watershed includes several independent drainage systems: Toco Creek, McCullough Creek, and Moccasin Branch. Each has its own outlet into the lower St. Johns River.

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

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

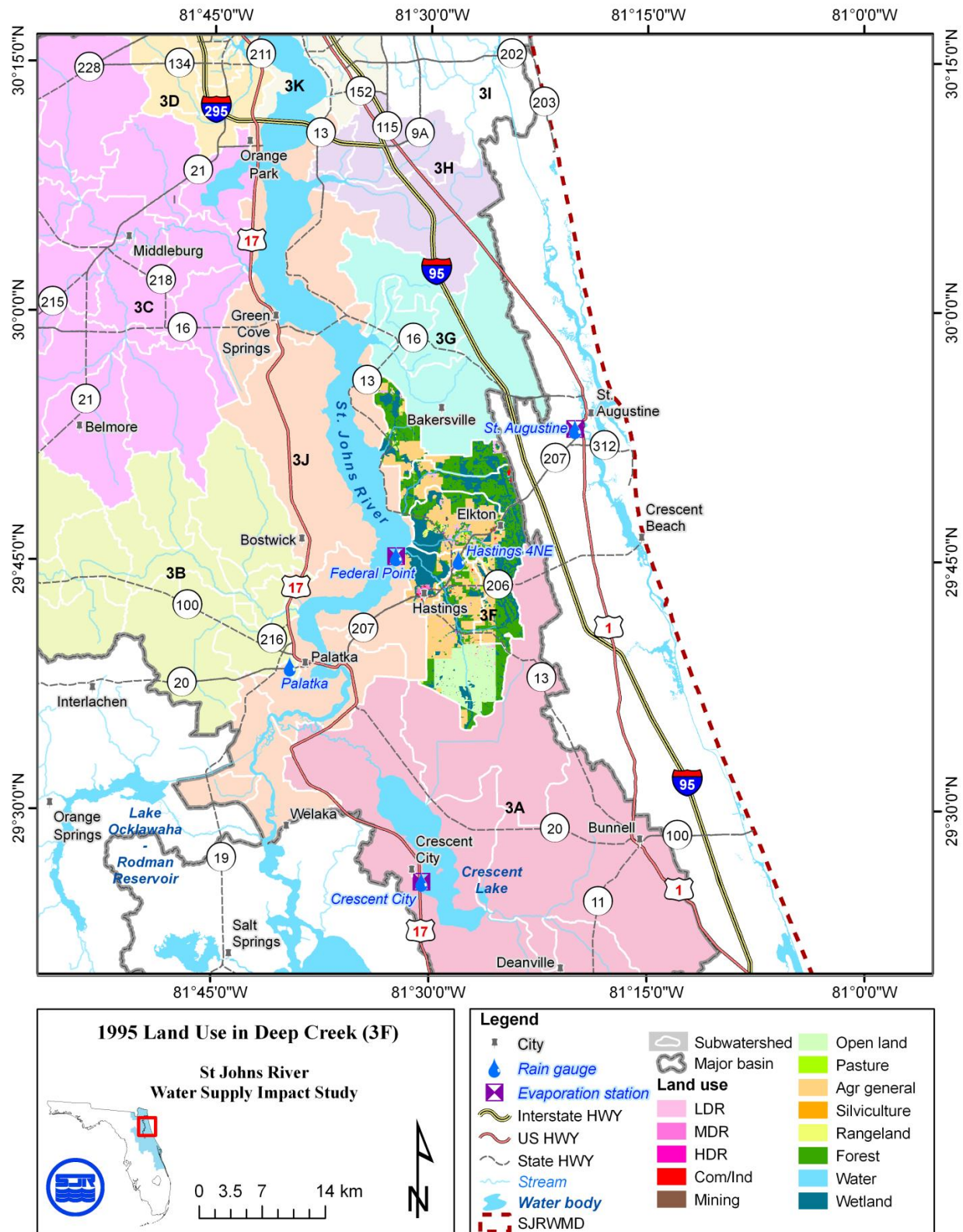


Figure 3–53. 1995 land use in Deep Creek Planning Unit (3F).

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

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

Sixmile Creek Basin Planning Unit (3G)

The Sixmile Creek planning unit is located in St. Johns County and has a total area of approximately 122 mi². It belongs to the Hastings Plain, which is a physiographic subdivision of the Palatka Anomalies.

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

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

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

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

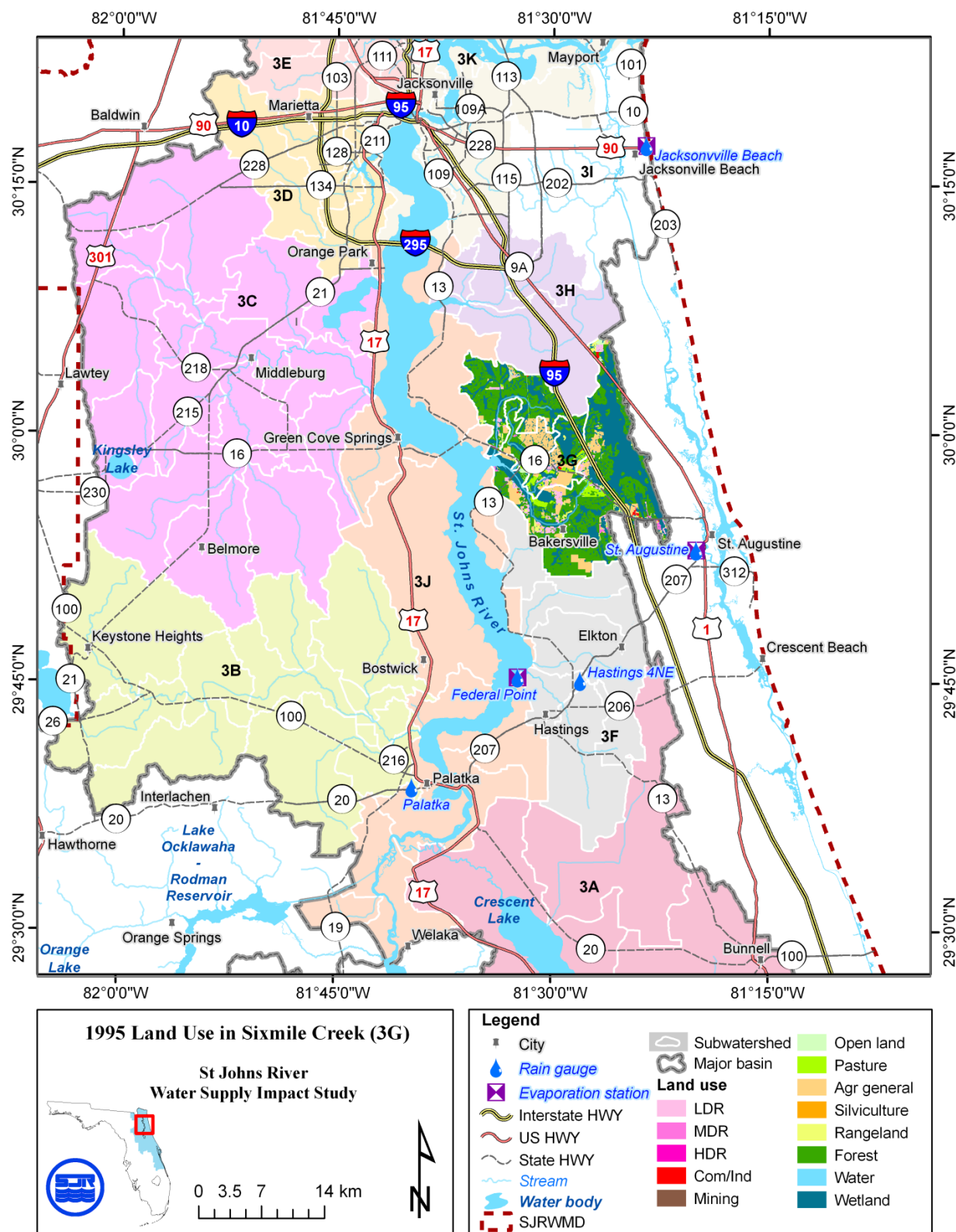


Figure 3–54. 1995 land use in Sixmile Creek Planning Unit (3G).

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

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

Julington Creek Planning Unit (3H)

The Julington Creek planning unit is located on the eastern side of the St. Johns River and extends over the southern part of Duval County and the northern part of St. Johns County. The drainage area is approximately 97 mi². Elevations are near sea level at the confluence with the St. Johns River and 30.00 ft NGVD29 to the east.

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

The Julington Creek HSPF hydrologic model was calibrated with 1995 to 2006 data from the USGS Big Davis Creek gauge station located at the downstream end of the culvert on US 1. Big Davis Creek begins in a wetland east of US 1 and extends to the west toward Julington Creek. The total contributory drainage area is 13.6 mi² at the gauge site, and the mean annual discharge from 1995 to 2006 is 7.4 mgd (11.4 cfs).

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

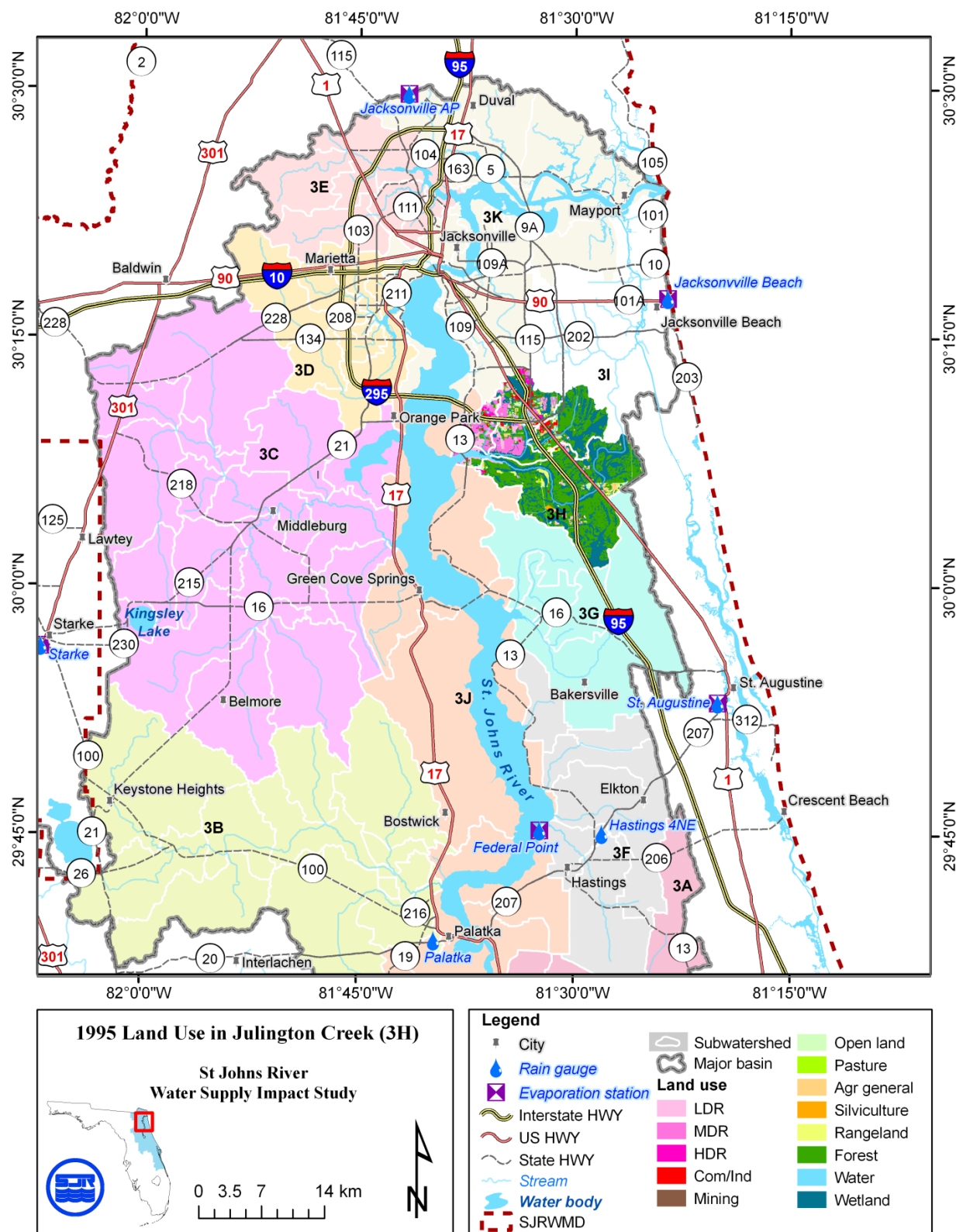


Figure 3–55. 1995 land use in Julington Creek Planning Unit (3H).

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

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

Intracoastal Waterway Planning Unit (3I)

The Intracoastal Waterway planning unit is located in eastern Duval County and south of the St. Johns River outlet at the Atlantic Ocean. The total acreage is 102 mi² excluding the EFDC estuary model area. According to the stream network and flow pattern, the basin is divided into two segments: the Pablo Creek subwatershed and the Intracoastal Waterway subwatershed, which are west and east of the Intracoastal Waterway, respectively.

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

Pablo Creek is a dendritic tributary basin. The Pablo Creek Basin is west of the Intracoastal Waterway with a total area of 49 mi². The USGS Pablo Creek gauge station is located 0.5 mi upstream of Cedar Swamp Creek, 4.8 mi upstream from the mouth, and 12.5 mi southeast of Main Street Bridge in Jacksonville. This gauge station measures the storm water from the 27 mi² drained by Puncheon Swamp Branch, Mill Dam Branch, Sawmill/Buckhead Branch, and Ryals Swamp subwatersheds. Box Branch and Cedar Swamp enter Pablo Creek downstream of the gauge station.

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

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

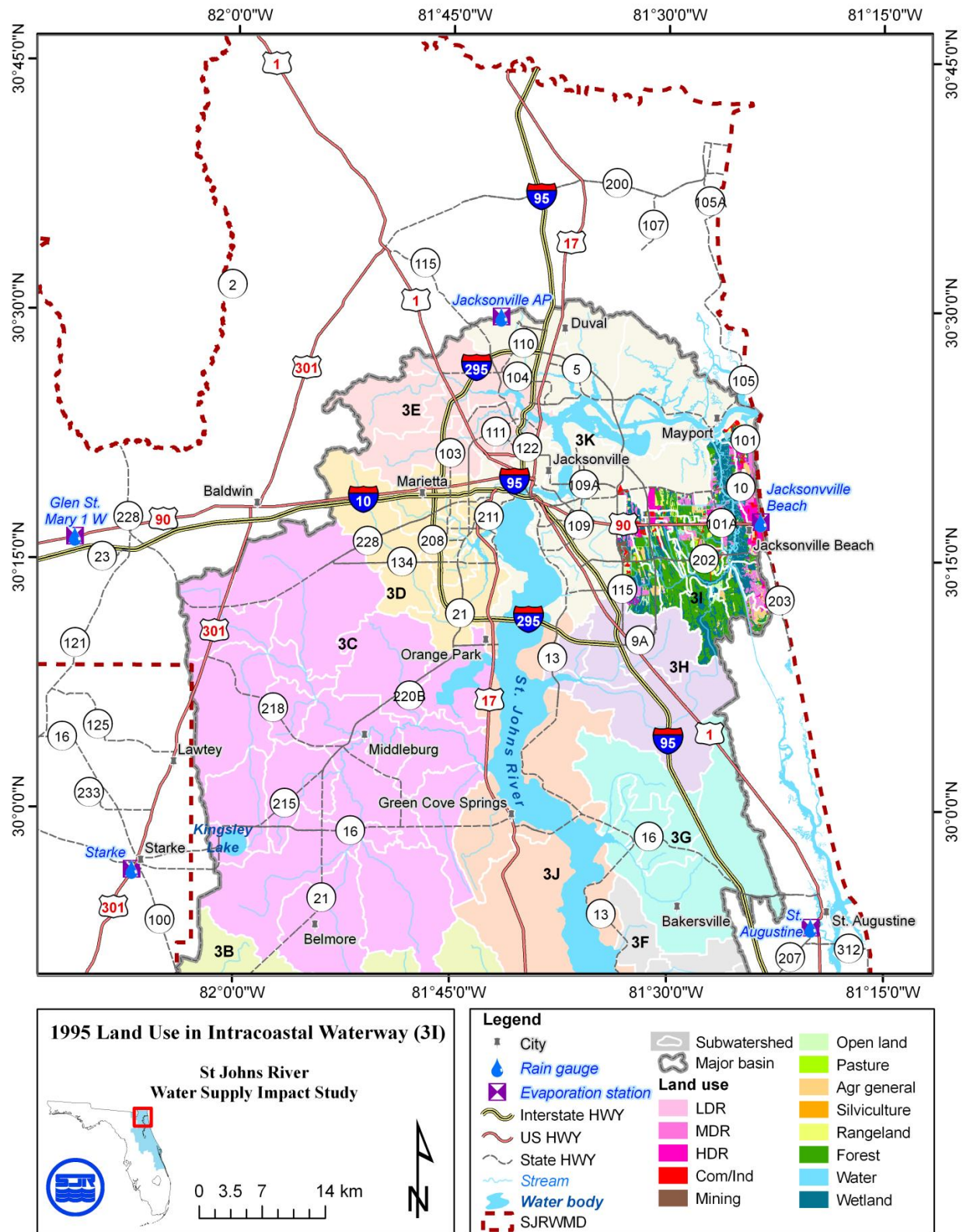


Figure 3–56. 1995 land use in Intracoastal Waterway Basin Planning Unit (3I)

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

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

South Main Stem Planning Unit (3J)

This planning unit is the collection of streams and creeks in the lower St. Johns River that are not included in other tributary basins and that drain directly into the St. Johns River up to I-295. The St. Johns River covers 25% of the total area (97 mi²), which is entirely modeled by the EFDC estuary model and is subtracted from the water land use category. The HSPF modeled area is 288 mi².

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

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

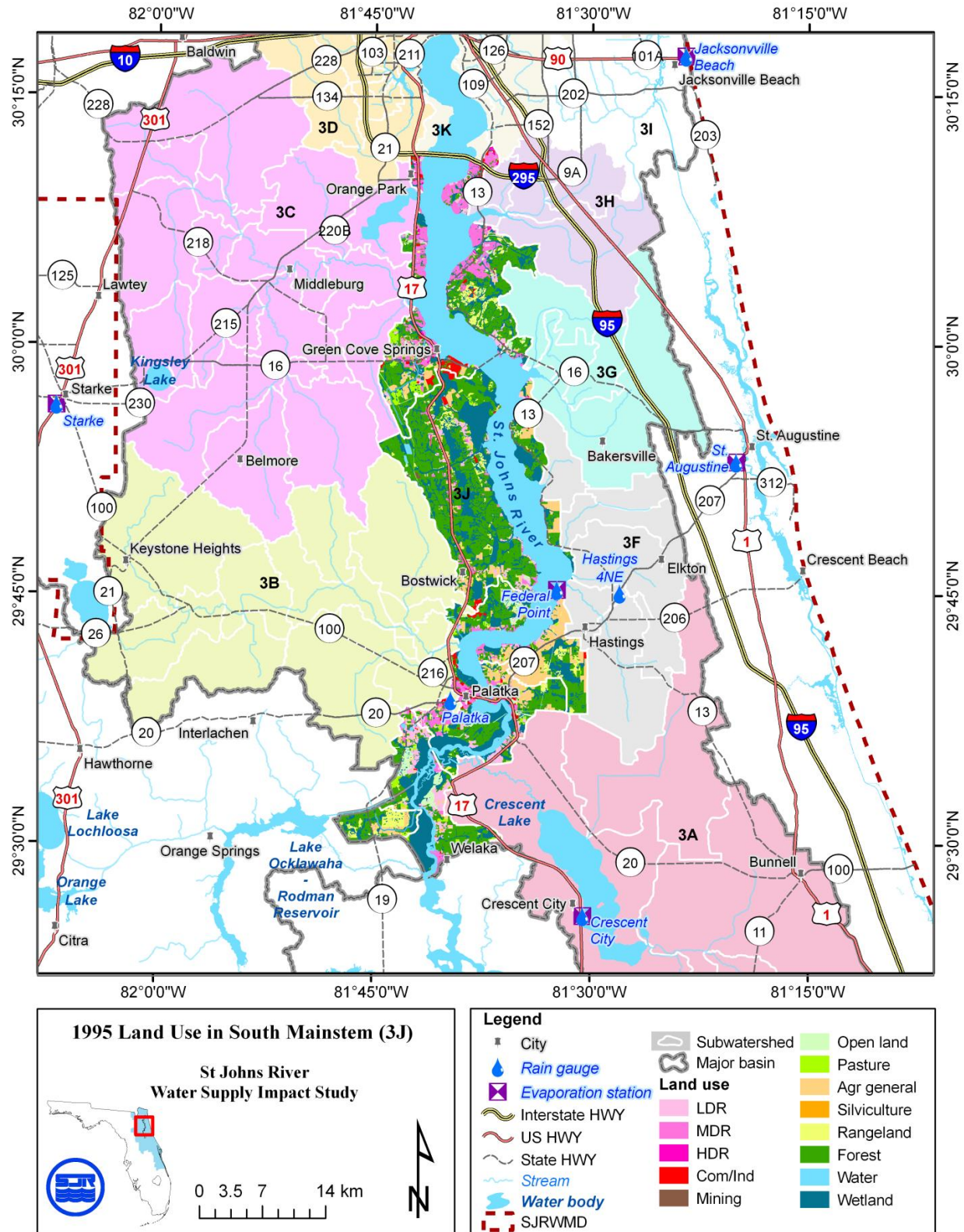


Figure 3–57. 1995 land use in South Main Stem Planning Unit (3J).

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

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

North Main Stem Planning Unit (3K)

The North Main Stem Planning Unit consists of 243 mi² and is grouped into eight segments according to the stream network and topography. Twenty percent of the area (51 mi²) is the St. Johns River itself, which is modeled by the EFDC hydrodynamic estuary model and subtracted from the areas contributing to the HSPF hydrologic model.

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

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

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

St. Johns River North Main Stem Subwatershed

This subwatershed includes the collection of streams and creeks that drain directly to the St. Johns River from I-295 to the Atlantic Ocean. The St. Johns River covers 46 of the 77 mi² of water land use acreage in the basin. Besides a higher industrial and commercial land use (13%),

the remaining area is rather evenly distributed among residential, agricultural, and other land uses.

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

Arlington River Subwatershed

The Arlington River subwatershed is located east of the St. Johns River in the City of Jacksonville. It covers approximately 36 mi² with elevations ranging from 70.00 ft NGVD29 to sea level (Camp, Dresser, and McKee Inc. 1989). Physiographically, it belongs to the Northern Coastal Strip. The Arlington River discharges into the St. Johns River at RM 21.5 and is more characteristic of an estuary than a river. Its tributary system consists of Pottsburg Creek Little Pottsburg Creek, Strawberry Creek, and Red Bay Branch. The tides affecting Pottsburg Creek extend as far as Beach Boulevard (US 90) in Jacksonville. The headwaters of Pottsburg Creek are hydraulically connected with the headwaters of Julington Creek via the Pottsburg Creek Swamp. Outside of some wetlands at the headwaters of Arlington River, this subwatershed is largely urbanized.

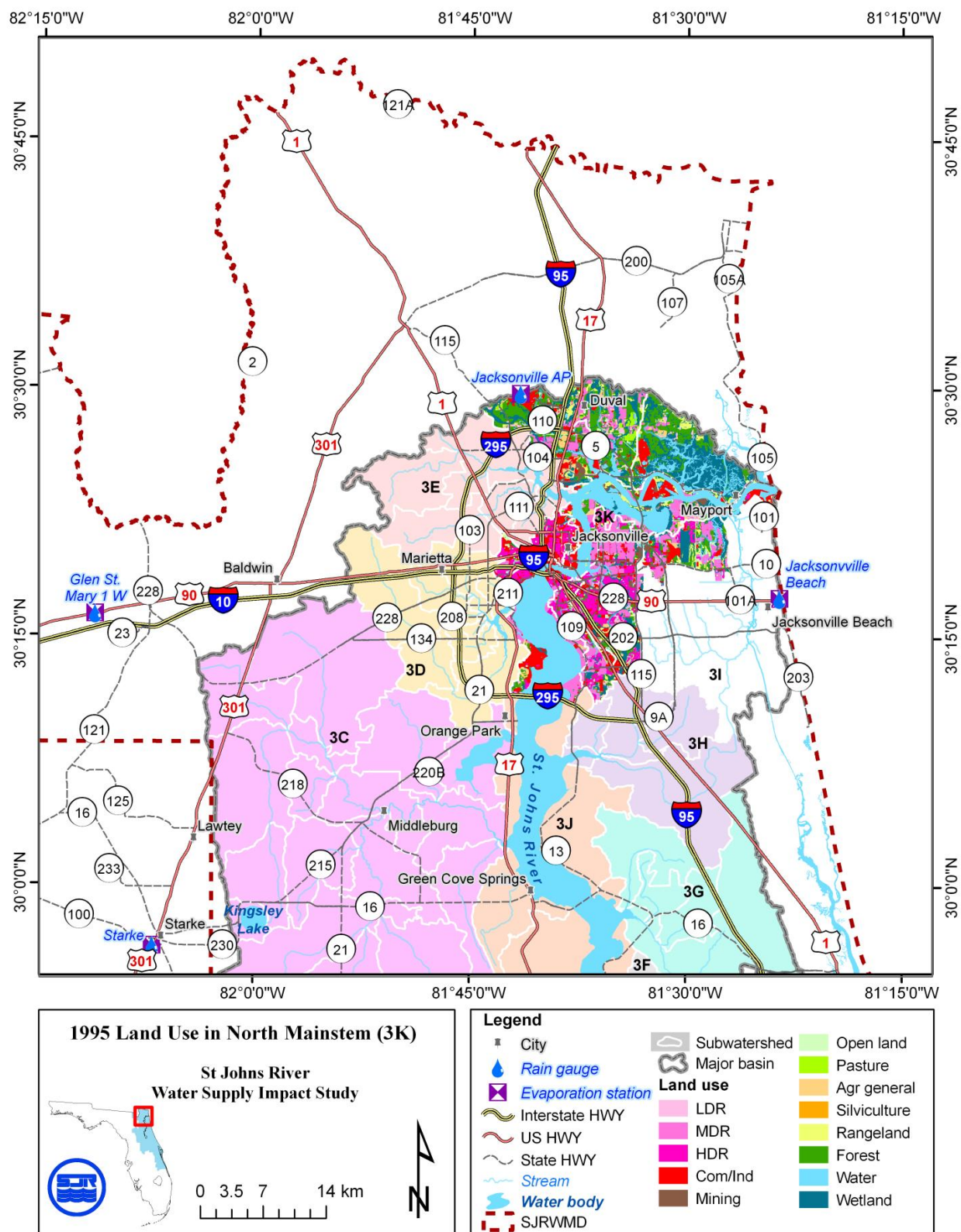


Figure 3–58. 1995 land use in North Main Stem Planning Unit (3K).

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

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

Tiger Pond Creek/Mt. Pleasant Creek Subwatershed

This basin has a contributing area of approximately 19 mi² with elevations ranging from sea level to 90.00 ft NGVD29 along Monument Road south of Fort Caroline and near the mouth of Mt. Pleasant Creek (Camp, Dresser, and McKee Inc. 1989). Physiographically, it belongs to the Northern Coastal Strip. Major tributaries within the basin are Newcastle Creek, Jones Creek, Ginhouse Creek, Tiger Pond Creek, Mt. Pleasant Creek, and Greenfield Creek.

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

Dunn Creek Subwatershed

The Dunn Creek tributary subwatershed is located in the northern part of Duval County, north of the St. Johns River and east of the Broward River drainage basin. The area is approximately 23 mi² and elevations range from near sea level to approximately 30.00 ft NGVD29. There is little topographic relief. Physiographically, the Dunn Creek tributary basin belongs to the Dinsmore Plain of the Northern Coastal Strip. The general flow direction is north to south. Delineation of the basin is rather difficult in areas where headwaters originate due to the flatness of the topography and the possible interconnection with the Nassau River basin (Camp, Dresser, and McKee Inc. 1989). Tributaries to Dunn Creek are Terrapin Creek and Rushing Creek; Caney Branch is a tributary to Rushing Creek. Tidal effects in the drainage basin extend to New Berlin

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

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

Broward River Subwatershed

The Broward River tributary subwatershed is located in the northern part of Duval County, flowing in a southeasterly direction from Jacksonville International Airport to its mouth at the St. Johns River between Drummond Point and Broward Point (Camp, Dresser, and McKee Inc. 1989). The drainage area is approximately 29 mi². Physiographically, it belongs to the Dinsmore Plan, which is a subdivision of the Northern Coast Strip. The topography of the basin is rather flat, although at some locations elevations of 80.00 ft NGVD29 occur. Major tributaries are Cedar Creek—the upstream extension of Broward River—and Little Cedar Creek, which joins Cedar Creek between I-95 and US 17.

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

Additional Subwatersheds

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

5 CALIBRATION FOR WATER QUANTITY

5.1 OBSERVED FLOW AND WATER LEVEL DATA

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

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

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

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

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

Table 3–64. USGS flow data quality categories.

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

Source: (Kennedy 1983)

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

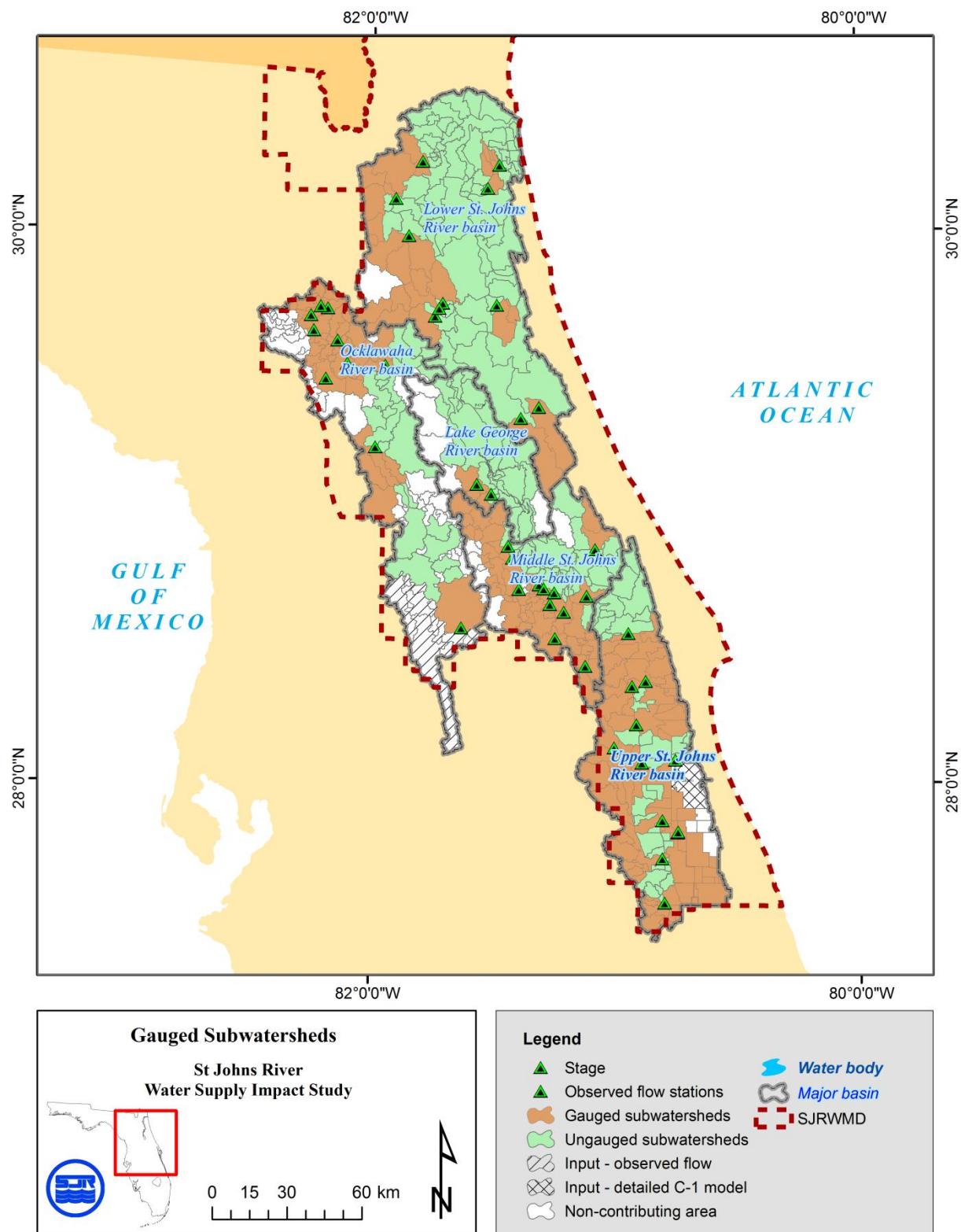


Figure 3–59. Map of flow and water level gauges, and gauged, ungauged, special input and noncontributing watersheds for St. Johns River watershed.

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

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

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

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

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

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

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

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

5.2 HYDROLOGICAL SIMULATION PROGRAM–FORTRAN (HSPF)

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

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

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

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

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

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

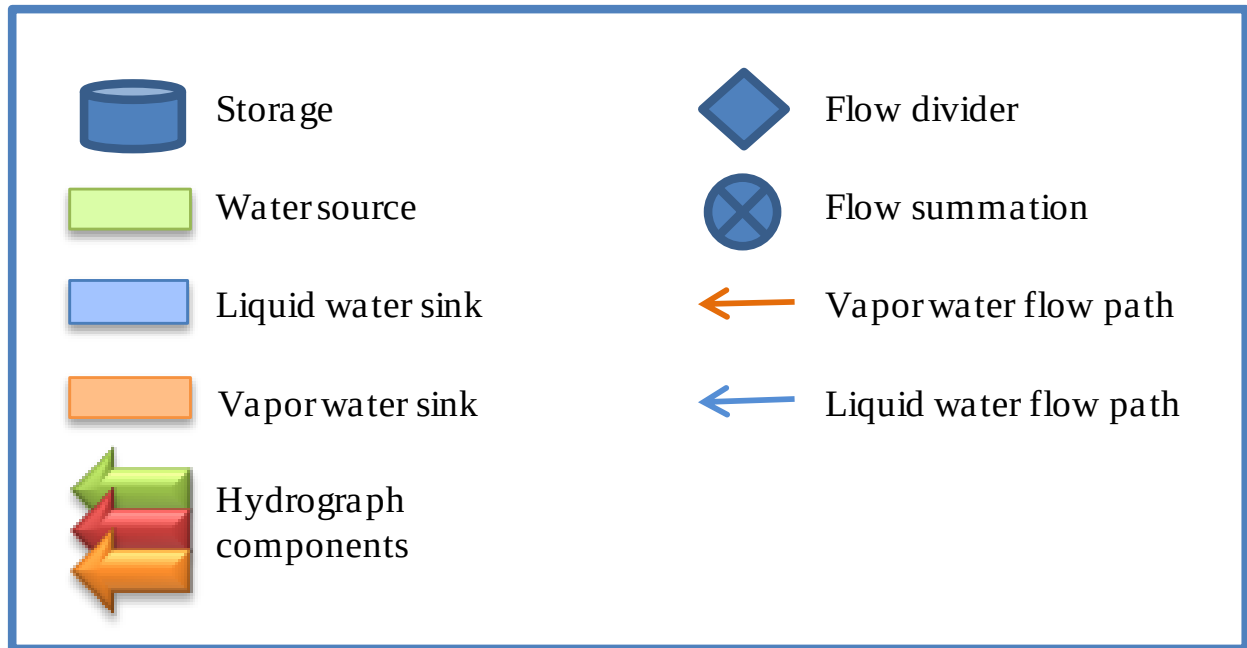


Figure 3–60. Legend for HSPF model simulation graphics in Figure 3–61, Figure 3–62, and Figure 3–63.

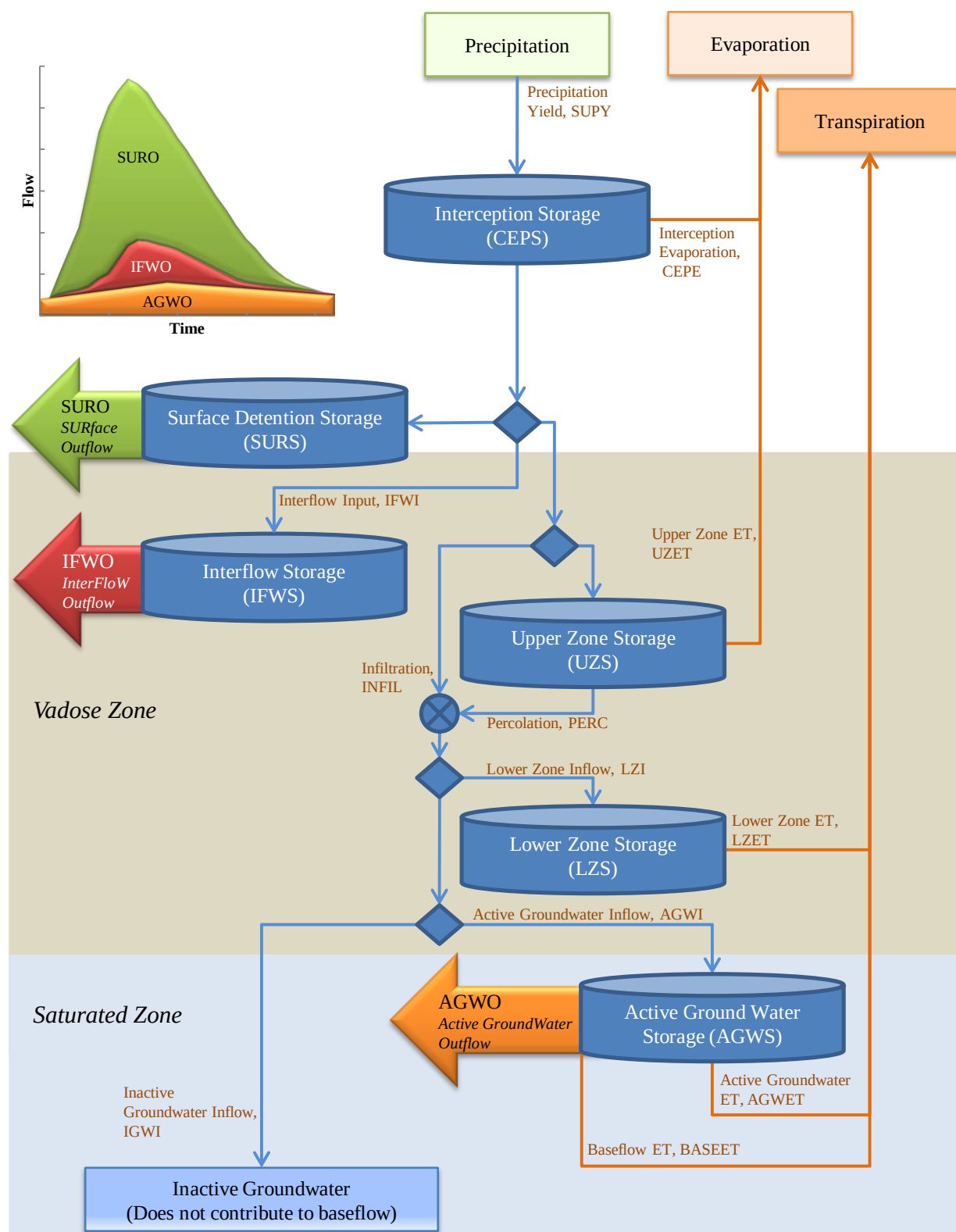


Figure 3–61. Illustration of water storage and movement in the HSPF model pervious land element (PERLND).

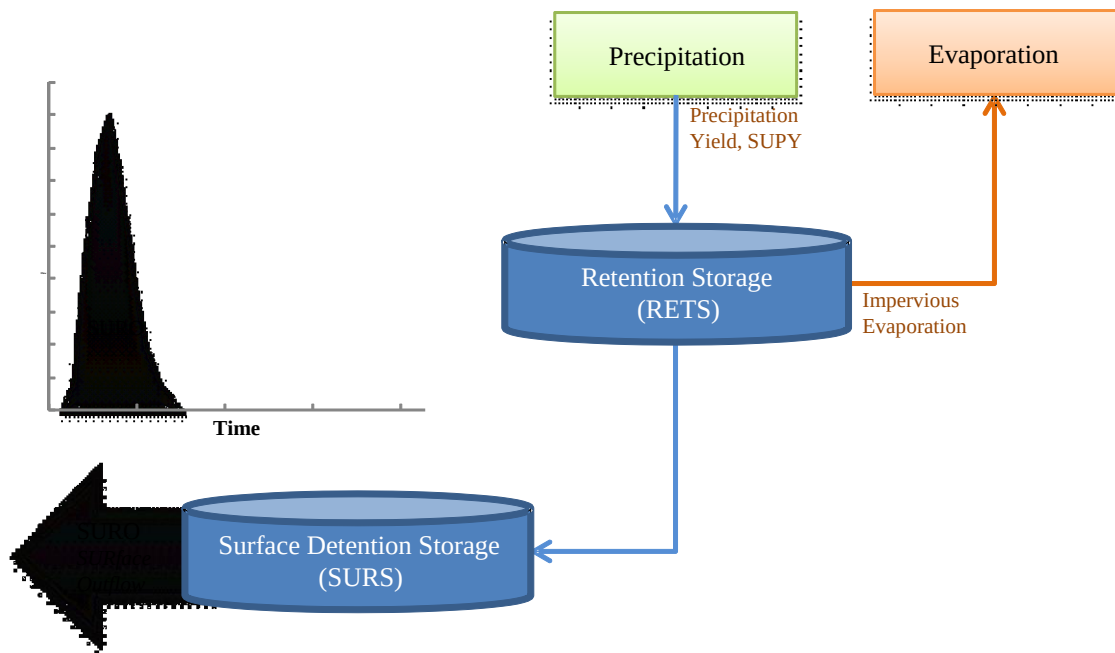


Figure 3–62. Illustration of water storage and movement in the HSPF model impervious land element (IMPLND).

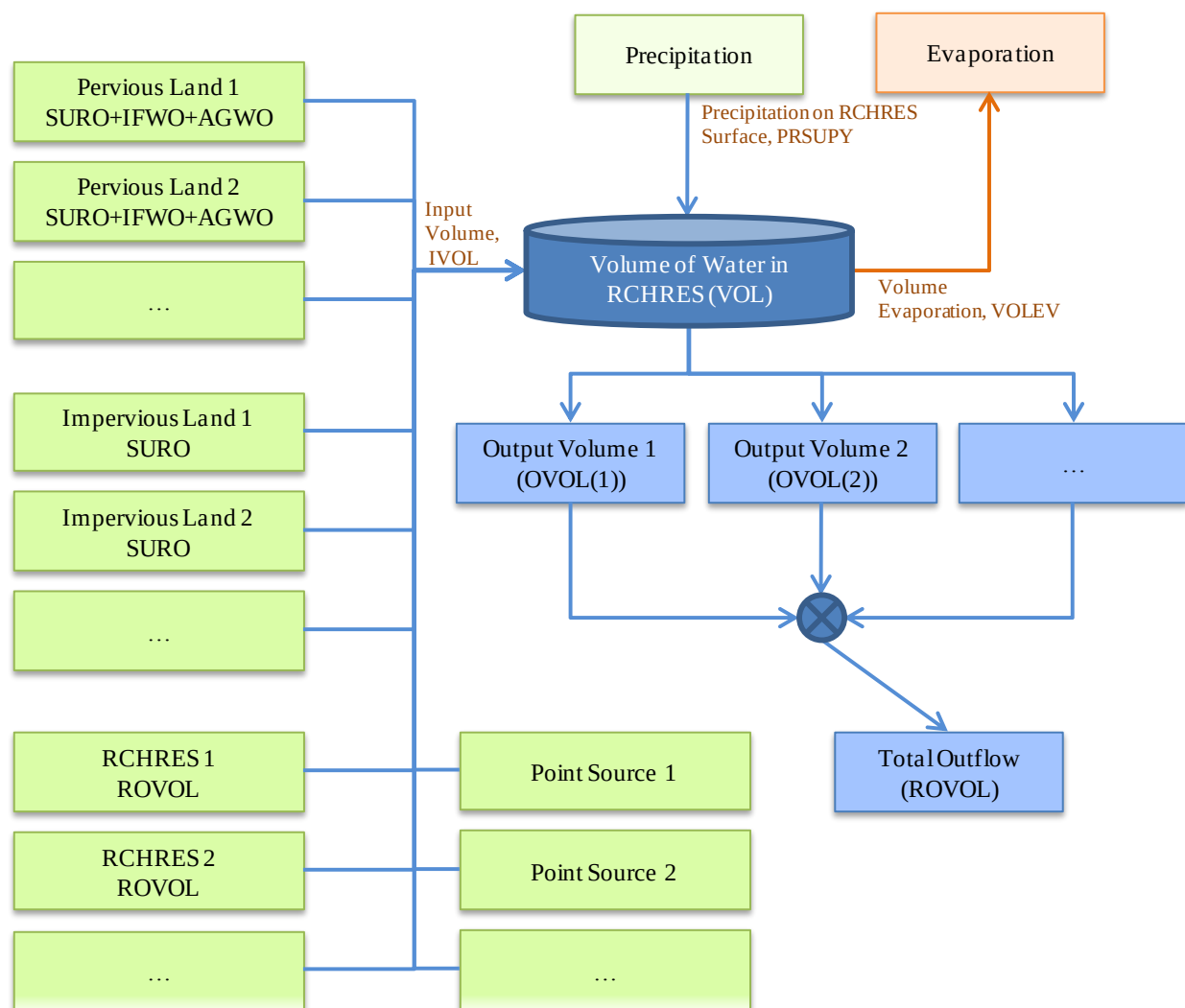


Figure 3–63. Illustration of water collection and movement in the HSPF model reach/reservoir element (RCHRES).

5.3 CALIBRATION PROCESS

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

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

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

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

5.3.1 MODEL INPUT PARAMETERS—COMMON LOGIC

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

5.3.2 LAND USE AND DIRECTLY CONNECTED IMPERVIOUS AREA (DCIA)

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

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

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

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

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

5.3.3 DEVELOPMENT OF FTABLES FOR STREAM NETWORKS

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

5.3.4 PARAMETER ESTIMATION MODEL OPTIMIZATION

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

PEST is a nonlinear parameter estimator that will adjust model parameters to minimize the discrepancies between model-generated numbers and corresponding real-world measurements. It does this by running the model as many times as is necessary to optimize multiple objective functions. The objective functions are usually some form of weighted, squared, model-to-

measurement differences. Because the problem of calibrating the HSPF hydrologic model is nonlinear, parameter estimation is an iterative process. PEST evaluates parameter changes based on the improvement to the objective functions and decides whether to undertake repeated optimization until no further improvement is achieved. The modeler must not only define the objective functions, but must also select pertinent parameters and set the permissible parameter's upper and lower bounds for adjustment.

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

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

5.3.5 HSPF HYDROLOGIC MODEL SPECIAL ACTIONS

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

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

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

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

5.3.6 PEER REVIEW

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

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

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

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

Examination of 1995 land use and 2030 predicted land use

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

Re-examination of Directly Connected Impervious Area values

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

Consideration of changes to retention storage capacities (RETSC) for IMPLND segments

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

Re-examination of active groundwater evapotranspiration (AGWET)

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

Implementation of storage attenuation for PERLND and IMPLND segments

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

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

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

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

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

$$Q = ay^m \quad [\text{Eq. 3-1}]$$

where

Q = fraction of storage that runs off per hour

y = normalized depth above the invert

a,m = general coefficient and exponent

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

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

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

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

* From 1995 land use geographic information system

† Calculated land use shifts based on percentages of each upland/riparian split in 1995 land use.

‡ From GIS Associates, Inc. population/land use model

5.4 CALIBRATION RESULTS

A review of the data for the tributary stream gauges can reveal differences in the hydrologic response of these streams. One simple measure of response is to represent the flow measurements as a flow rate per square mile of watershed. The discharge in cubic feet per second per square mile (cfs/mi²) allows a direct comparison of observed and simulated (calibrated) flows for the 50 gauged site locations used in the surface water models for the WSIS (Figure 3–64). These flows are averaged over the calibration period and reduced to cfs mi⁻². Most of the flows are less than 2.0 cfs mi⁻², with the exceptions being those discharges that contain spring flows. Note that the lower discharge per unit area watersheds typically had non-contributing surface area in the basin.

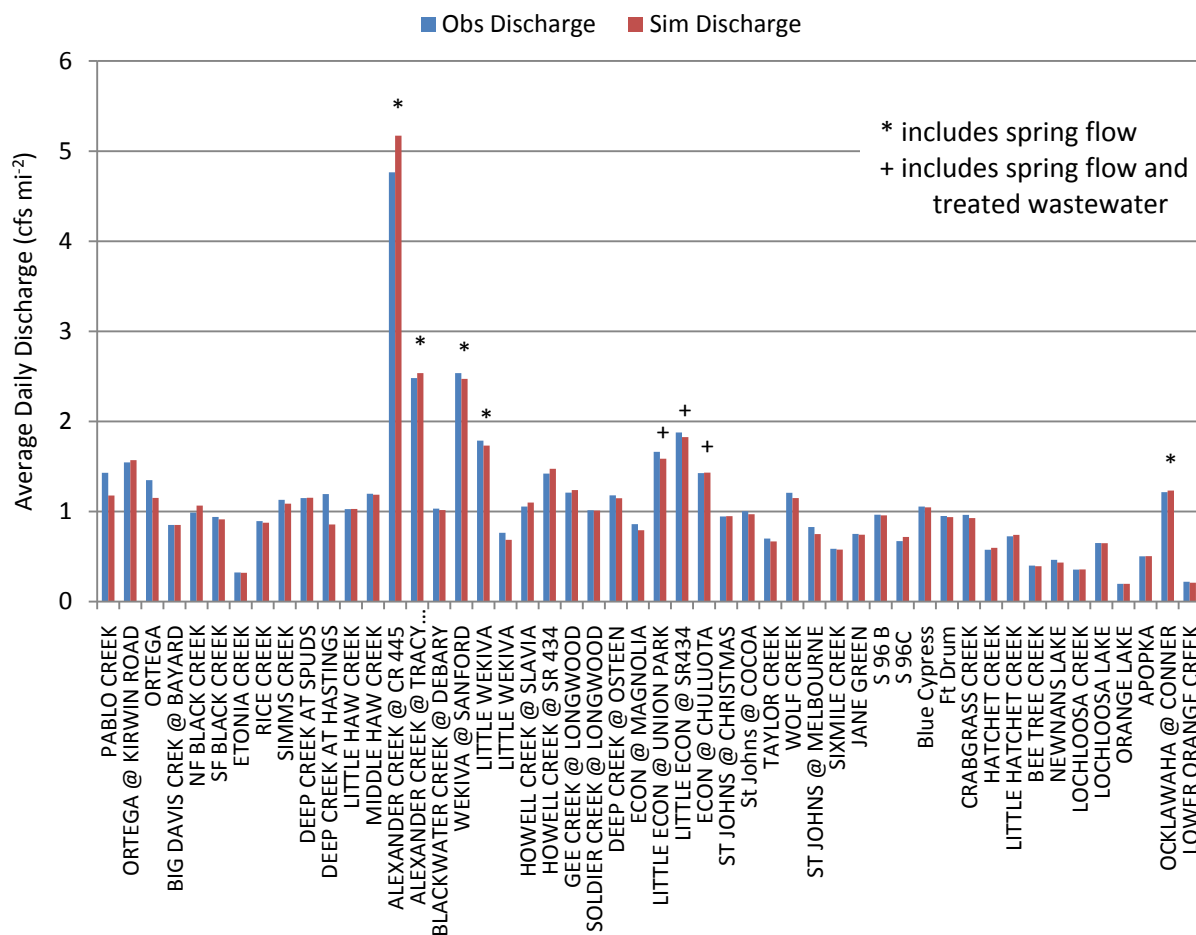


Figure 3–64. Comparison of observed (Obs) and simulated (Sim) discharge at calibration sites used in the WSIS watershed hydrology models.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6 SCENARIO SIMULATIONS AND RESULTS FOR WATER QUANTITY

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

6.1 SCENARIO DESCRIPTIONS

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

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

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

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

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

The 1995 scenario uses SJRWMD's 1995 land use conditions, permitted water withdrawals, and the 1995 status of the USJRB USACE Project. The 1995 condition models were modified to

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

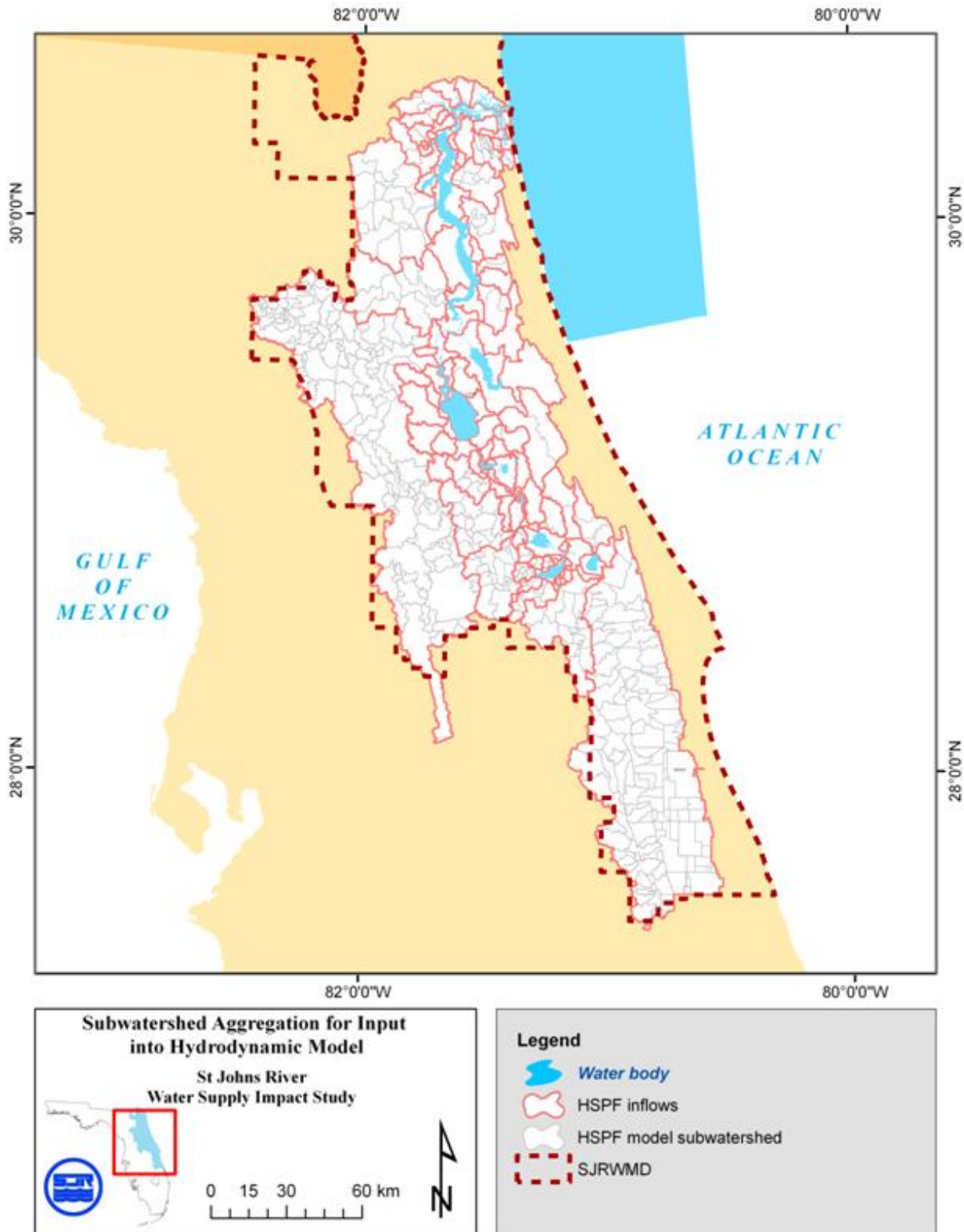


Figure 3–65. Subwatershed aggregation for input into the EFDC hydrodynamic model.

6.2 SCENARIO SIMULATION RESULTS

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

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

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

A higher average flow was generated in the projected 2030 land use scenario than in the 1995 scenario. This was expected due to increased impervious surfaces associated with urbanization,

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

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

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

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

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

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

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

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

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

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

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

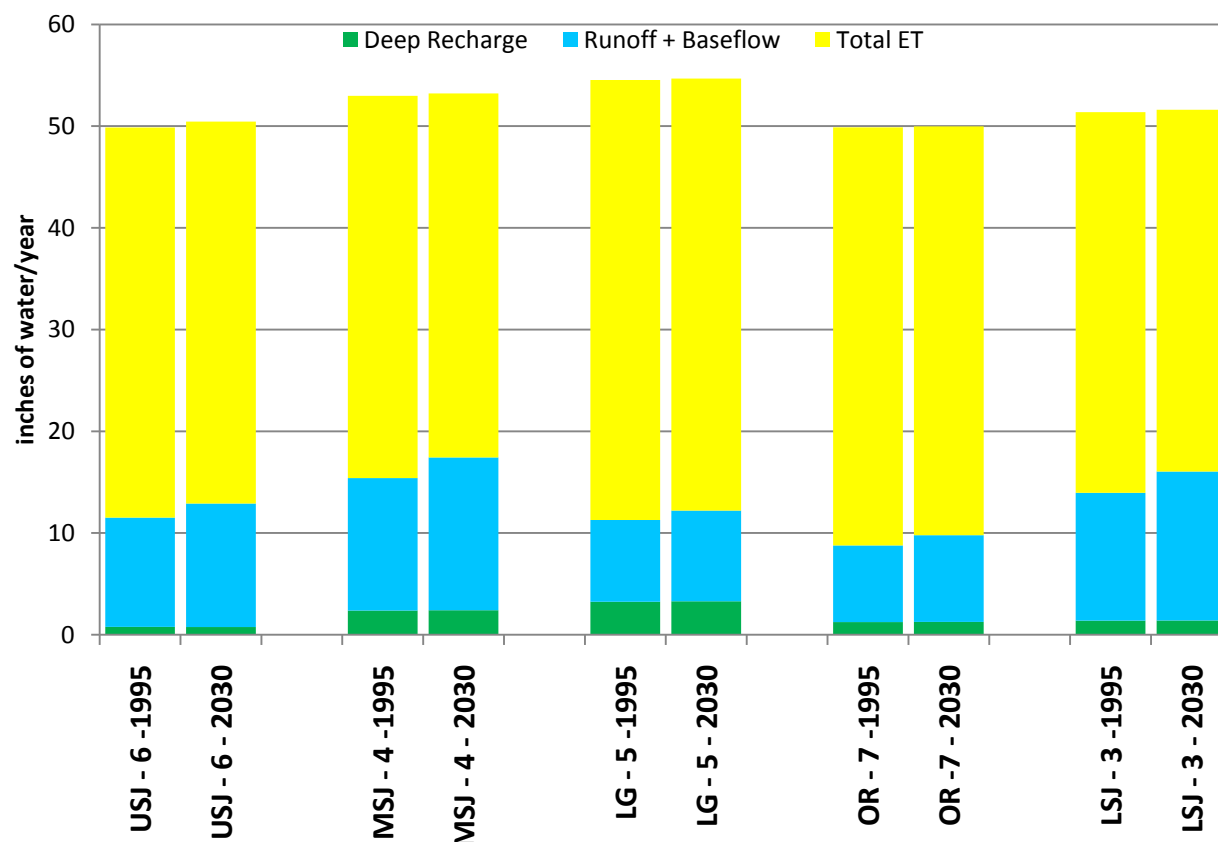


Figure 3–66. Water budget for surface processes (excludes open water and noncontributing areas) comparing Base1995P and Base2030P scenarios.

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

6.3 OCKLAWAHA RIVER BASIN (7)

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

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

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

NSRA = North Shore Restoration Area

6.4 OCKLAWAHA RIVER BASIN (7) RESULTS

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

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

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

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

6.5 UPPER ST. JOHNS RIVER BASIN (6)

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

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

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

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

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

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

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

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

* Changes seasonally

6.6 UPPER ST JOHNS RIVER BASIN (6) RESULTS

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

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

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

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

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

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

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

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

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

7 SUMMARY

The first step in the scientific foundation of WSIS was to evaluate surface water runoff of the St. Johns River watershed using the HSPF hydrologic model. Ninety-seven individual HSPF runoff models were developed, and 47 were directly calibrated to observed hydrologic data using 1995 land use conditions and 1995 through 2006 atmospheric data. This period was selected, in part, due to relatively constant physical conditions in the watershed. The calibration resulted in an acceptable fit for average daily discharges and a good fit for monthly and yearly results. Of the 47 calibrated watersheds, there were 21 very good, 22 good and satisfactory, and only four unsatisfactory values for the Nash–Sutcliffe statistic, which is a common rating of the

performance of hydrologic models. The parameters from the calibration models were then applied to the 50 watershed models that did not have gauges for calibration. This process allowed for development of a 1995 condition model for every subwatershed within the St. Johns River watershed. The subwatersheds were then aggregated as needed to develop flow input into the EFDC hydrodynamic model.

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

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

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

REFERENCES

- Adamus, Christine, David Clapp, and Stephen Brown. *Technical Publication SJ97-1: Surface Water Drainage Basin Boundaries [of the] St. Johns River Water Management District: A Reference Guide*. Palatka, FL: St. Johns River Water Management District, 1997.
- BEER. *FPS: Detailed Population Projections by Age, Sex, Race, and Hispanic Origin, 2008-2030: ALL CATEGORIES*. Gainesville, Florida: University of Florida, 2009.
- Bergman, Martinus J. *Volume 2 of the Lower St. Johns River Basin Reconnaissance Report: Surface Water Hydrology: Technical publication SJ 92-1*. Palatka, Florida: St. Johns River Water Management District, 1992.
- Bicknell, Brian R., John C. Imhoff, Jr., John L. Kittle, Thomas H. Jobes, and Jr., Anthony S. Donigian. *HYDROLOGICAL SIMULATION PROGRAM - FORTRAN, HSPF, Version 12, User's Manual*. Athens, GA: U.S. Environmental Protection Agency - National Exposure Research Laboratory, 2001.
- Brooks, H. K. *Guide to the physiographic divisions of Florida*. Gainesville, FL: University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service, 1982.
- Camp, Dresser, and McKee Inc. *City of Jacksonville Master Storm Water Management Plan. Intracoastal Waterway Basin Final Report*. Jacksonville, FL: Camp, Dresser, and McKee Inc., 1992.
- Camp, Dresser, and McKee Inc. *Master Stormwater Management Plan, City of Jacksonville, Florida*. Jacksonville, FL: Camp, Dresser, and McKee Inc., 1989.
- Canfield, D. E. *Final Report: Chemical and trophic state characteristics of Florida lakes in relation to regional geology*. Gainesville, FL: Cooperative Fish and Wildlife Research Unit, 1981.
- Clapp, David A., C. Price Robison, and Richard B. Hupalo. *Surface Water Modeling and Environmental Validation Study: Wekiva River System Minimum Flows and Levels [DRAFT]*. Palatka, FL: St. Johns River Water Management District, 1999.
- Doherty, John. *PEST, Model-Independent Parameter Estimation, User Manual: 5th Edition*. Watermark Numerical Computing, 2004.
- Doolittle, James A., and Gregg Schellentrager. *Soil Survey of Orange County, Florida*. Soil Conservation Service, United States Department of Agriculture, 1989.
- Dymond, J. R., and R. Christian. "Accuracy of discharge determined from a rating curve." *Hydrological Sciences Journal*, 27(4), 1982: 493-504.
- EPA. *BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF*. EPA, July 2000.
- Florida Department of Environmental Protection. *Basin Status Report: Middle St. Johns*. Tallahassee, FL: Florida Department of Environmental Protection, 2003.

Friends of Lake Apopka. "Lake Apopka Timeline." August 2011.

<http://www.foia.org/PDFs/LakeApopkaTimeLineAug2011.pdf> (accessed January 12, 2012).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

APPENDIX DESCRIPTIONS (LINKS TO SEPARATE DOCUMENTS)

APPENDIX 3.A. LAND USE CLASSIFICATION/GROUPING

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

APPENDIX 3.B. HSPF COMMON LOGIC FOR SJRWMD

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

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

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

APPENDIX 3.D. EVALUATION OF MODEL UNCERTAINTY

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

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

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

APPENDIX 3.F. CLIMATE CHANGE EVALUATION

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

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

This is the external review of the initial calibrated models.

APPENDIX 3.H. EXPLANATION OF PLOTS AND TABLES

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

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

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

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

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

APPENDIX 3.K. 05-LAKE GEORGE BASIN

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

APPENDIX 3.L. 07-OCKLAWAHA RIVER BASIN

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

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

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

