Appendix D. **Hydroperiod Tool Analysis of St. Johns River Segment 7**

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1 Introduction

1.1 Background

In Chapter 10, Wetlands Vegetation, the potential effects to wetlands of the St. Johns River floodplain from surface water withdrawals were analyzed using several approaches. One approach taken specifically for freshwater wetlands was use of a customized Geographic Information System (GIS) tool dubbed "the Hydroperiod Tool" (HT), based on its original intended use by the South Florida Water Management District for a wetland restoration project in which the maintenance of wetland-community-specific hydroperiods was critical. For the Water Supply Impact Study (WSIS) a modified version of the HT allowed wetland areas susceptible to reduced inundation from proposed water withdrawals to be identified and quantified. The HT study in Chapter 10 focused on the wetlands adjacent to and upstream of Lake Poinsett, up to the Lake Washington Weir, in WSIS segment 8 of the St. Johns River (Figure 1) floodplain. The Lake Poinsett area was chosen for the study primarily because hydrologic modeling indicated that this area would experience the greatest changes in stage (Figure 2).

The HT is a customized tool developed to work with ESRI's ArcMap. It functions primarily with raster (grid-based) representations of the environment. The basic GIS functions of the HT are shown in Figure 3. Elevation values from a digital elevation model (DEM or *land elevation*) are subtracted from the elevations of an interpolated water surface (*water elevation*) on a grid cell by grid cell basis, producing a new surface (raster) containing the elevation or depth of the water over the land for each grid cell (*ponded depth* raster). For reliable ponded depth calculations, both the water surface and land surface elevations must be as accurate as possible, within the limitations of available technology. Details about the interpolation method used in the GIS to achieve an appropriate water surface for the Lake Poinsett area are provided in Chapter 10. Additionally, extensive effort was undertaken to correct the most recent Lake Poinsett area LiDAR-derived DEM for the wetland vegetation that prevented the LiDAR pulse from reaching true ground. Wetland correction factors for the Lake Poinsett LiDAR-derived DEM ranged from 0.0 m for woody wetlands, 0.39 m for sparse herbaceous wetland habitats, 0.48 m for medium dense herbaceous wetlands and 0.76 m for the densest herbaceous wetlands.

Although the HT was originally designed to work with hydrologic data presented in time series, for the WSIS we used an exceedence approach in which the probability of a given stage being reached or exceeded is expressed for the entire period of record (Bedient and Huber, 2003).

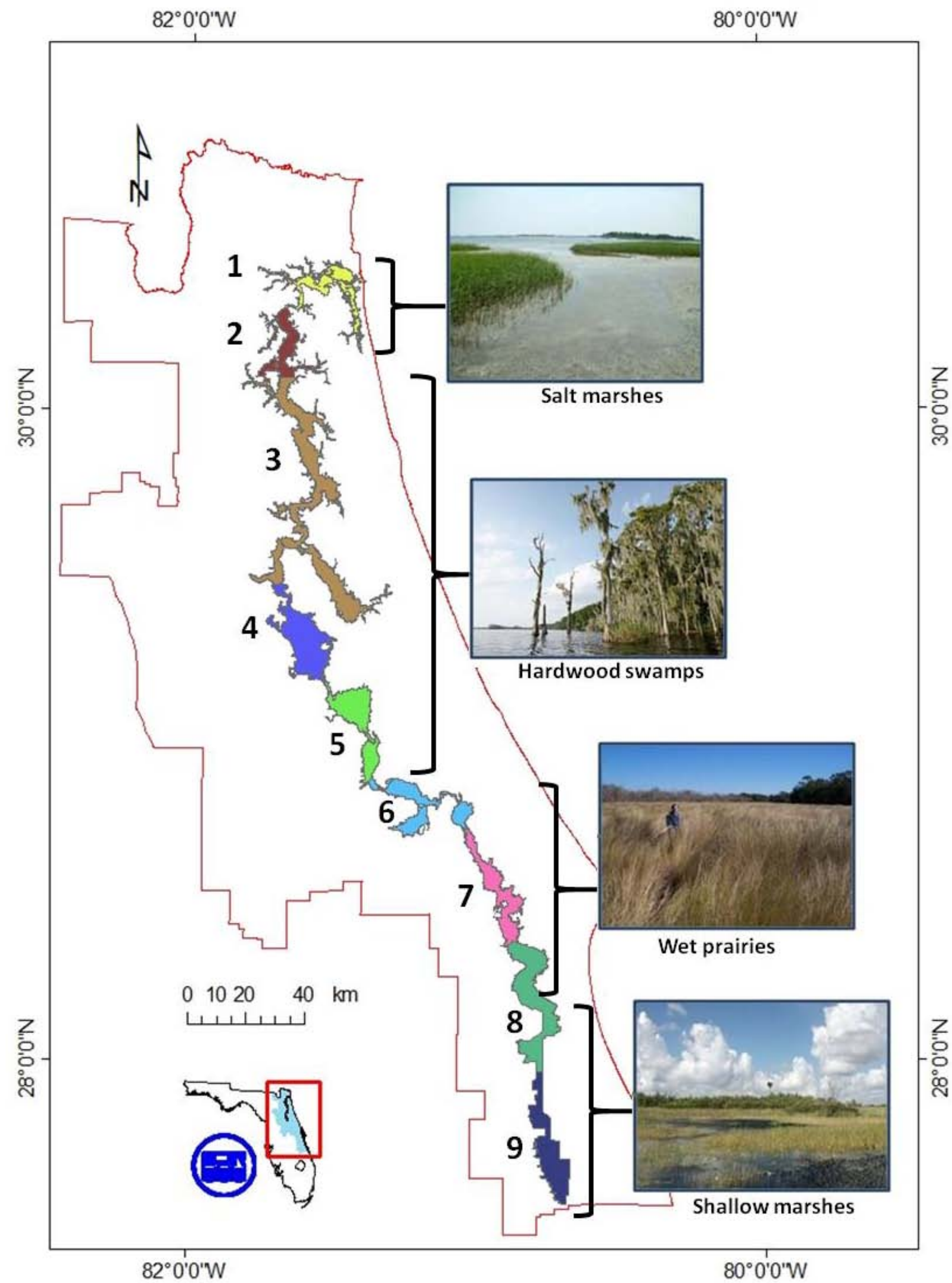


Figure 1. Regionalization of wetlands along the St. Johns River into segments for the Water Supply Impact Study. Lake Poinsett is located at the northern end of Segment 8, adjacent to Segment 7. Lake Poinsett in Segment 8 was chosen to be focus of HT analysis primarily because hydrologic modeling indicated that this area would experience the greatest changes in stage (Figure 2, the Cocoa station is at the outlet of Lake Poinsett).

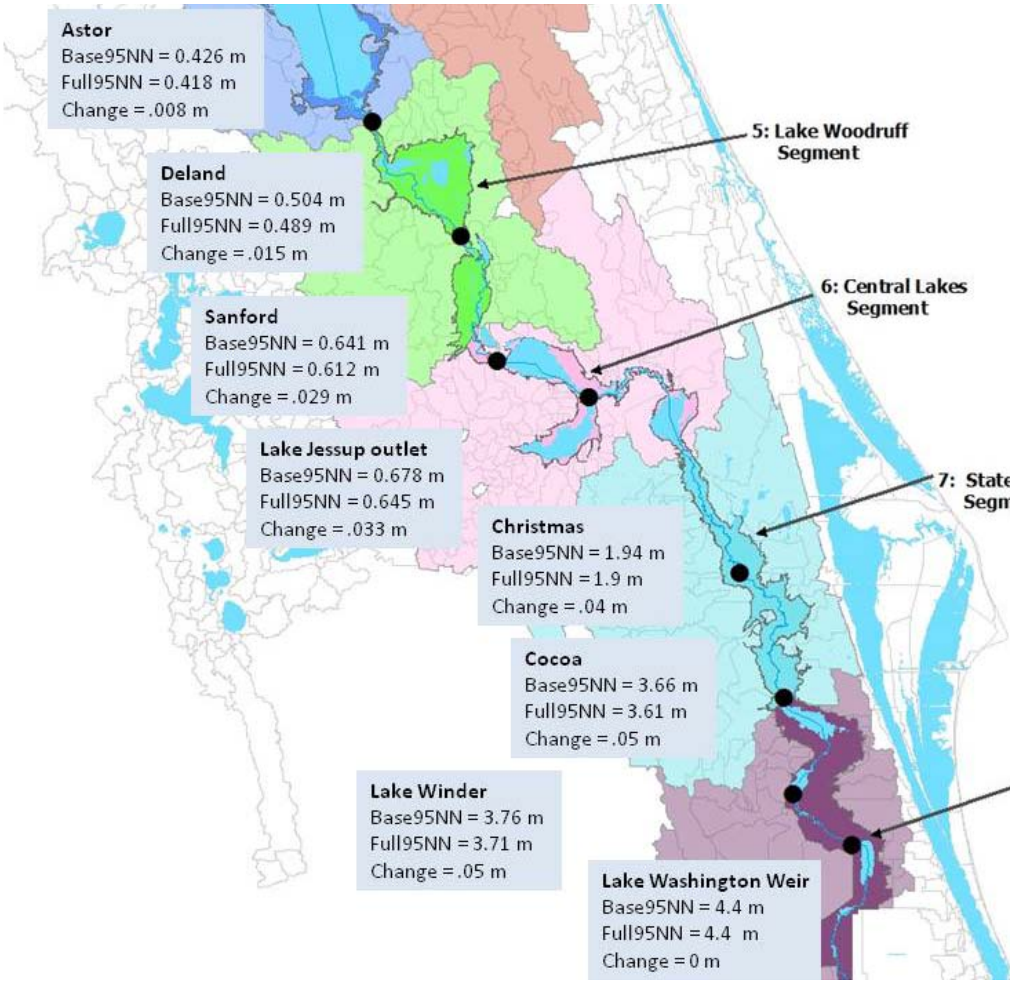


Figure 2. Modeled annual average water levels and change in water levels (m) at gauging stations under Base1995NN (historic conditions) and Full1995NN (withdrawal) scenarios. Scenarios described in Table 1. Note that the two stations in segment 8 (Cocoa and Lake Winder) have the greatest change in stage due to the proposed withdrawal scenario, both 0.05 m.

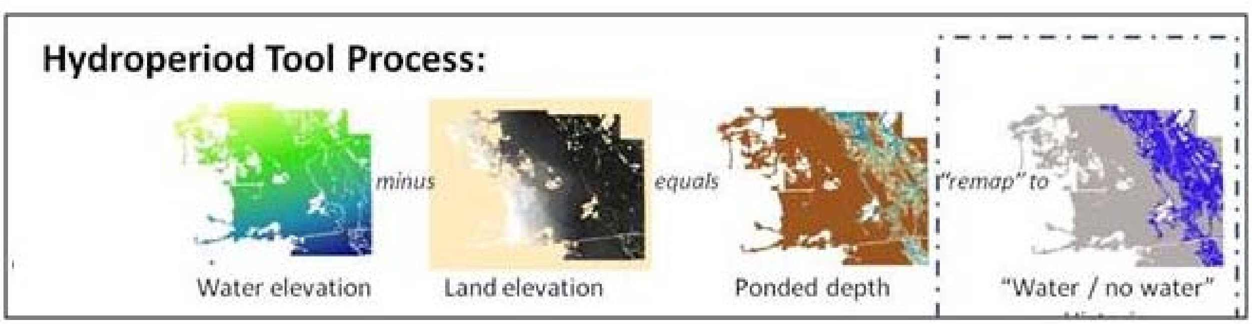


Figure 3. Basic Hydroperiod Tool function. Within the GIS a process commonly referred to as "Raster Math" executes a simple subtraction for each grid cell, subtracting the land elevation from the water elevation, to produce a new raster containing the water depth (ponded depth) for each grid cell.

Figure 4 displays the exceedence curves for both the historical record and a proposed withdrawal scenario. For the WSIS the study period was January 1, 2006 to December 31, 2005. The change in stage (the difference between the blue line and dashed red line in Figure 4) can be visualized as it manifests over wetlands (Figure 5). Figure 5 displays the area of inundation historically (the natural condition), the change in water depth (z) and resulting change in wetland inundation due to the proposed withdrawal scenario.

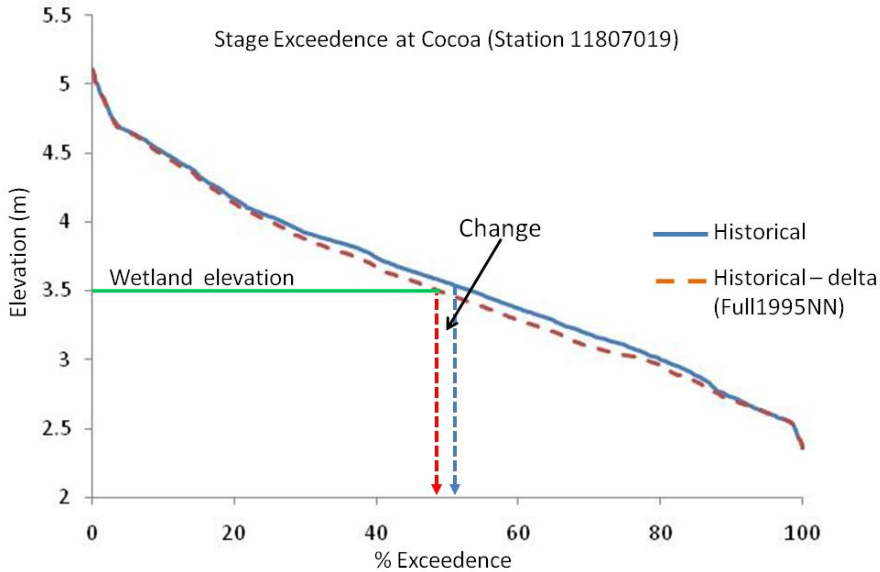


Figure 4. Exceedence curves for both the historical record and sample withdrawal scenarios.

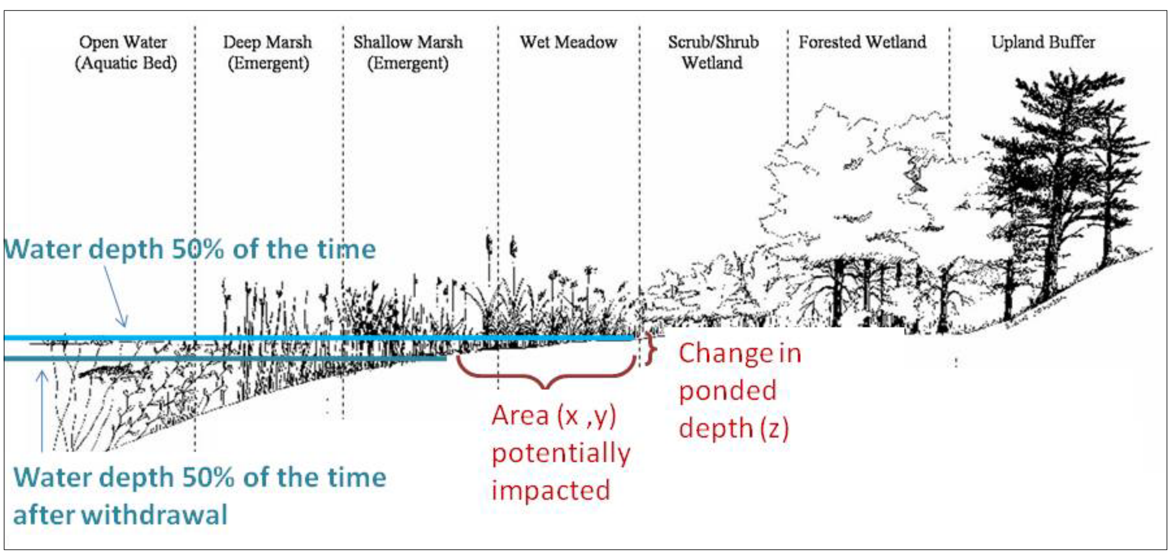


Figure 5. Cross sectional representation of the 50% exceedence water level and the resulting area of inundation for both the historical (natural) condition and a proposed withdrawal scenario. (Wetland cross section Figure from *http://www.newp.com/pdf/NEWP_WetlandCrossSection.pdf*)

For the Chapter 10 Wetlands Vegetation HT analysis, the number of scenarios that could be run was limited by both the amount of time required for HT data preparation and the HT processing time. Four model scenarios that varied by withdrawal amount, land use and USJRB project implementation were selected. The chosen scenarios were FULL1995NN, FULL1995PN, HALF1995PN and FULL2030PN, which are described in Table 1.

Table 1. Scenarios used in the assessment of effects to wetlands from water withdrawals.*

Scenario Name	Description	Application for Wetland Vegetation Analysis
Historical baseline	Empirical data on water surface elevation collected by USGS or SJRWMD, 1 January 1995 to 31 December 2005.	Used as the baseline for hydrologic change in the upper St. Johns River (segments 7 and 8)
Base1995NN	Modeled data, no water withdrawals, 1995 land use, no USJRB projects, and no sea level rise.	Used indirectly for developing a delta to be applied to the historical data set to capture change between scenarios in the upper St. Johns River and directly for assessment of salinity changes in the lower St. Johns River (segments 2, 7, and 8)
Base1995PN	Modeled data, no water withdrawals, 1995 land use, USJRB projects operational, and no sea level rise.	Used in the upper St. Johns River to isolate the effect of water management projects on hydrology (segments 7 and 8)
Full1995NN	Modeled data, full water withdrawal, 1995 land use, no USJRB projects, and no sea level rise.	Used to assess the effect of withdrawals on stage and salinity, without projects (segments 2, 7, and 8)
FwOR1995NN	Modeled data, full water withdrawal, Ocklawaha River withdrawal; no USJRB projects, and no sea level rise.	Used in the Lower St. Johns River to assess the effect of full withdrawals on salinity, without projects (segment 2)
Half1995PN	Modeled data, half water withdrawal, 1995 land use, USJRB projects operational, and no sea level rise.	Used in the Upper St. Johns River to assess effects of half withdrawals and projects on water levels (segments 7 and 8)
Full1995PN	Modeled data, full water withdrawal, 1995 land use, USJRB projects operational, and no sea level rise.	Used in the Upper St. Johns River to assess effects of full withdrawals and projects of water levels (segments 7 and 8)
Full2030PS	Modeled data, full water withdrawal, USJRB projects operational, 2030 land use, and +14 cm of sea level rise.	Used in the Lower St. Johns River to assess the effects of future conditions on salinity, with future sea level rise (segment 2)
Full2030PN	Modeled data, full water withdrawal, USJRB projects operational, 2030 land use, and no sea level rise.	Used in the Upper St. Johns River to assess the effects of future conditions on water levels (segments 7 and 8)

*See Chapter 6. River Hydrodynamics Results for a discussion of the scenarios.

The Lake Poinsett (Segment 8) HT results are provided in the GIS spatial analysis section in Chapter 10, 4.3 Areal Effects Analysis Results. Analysis of areal effects with the HT showed a range of results for the four scenarios. Potential effects are greatest under the Full1995NN scenario, but are progressively less for the Full1995PN and Half1995PN scenarios, and largely disappear in the Full2030PN scenario. The percent of the total study area (18,256 ha) negatively affected is 27.5% for Full1995NN, 10.04% for Full1995PN, 20.61% for Half1995PN, and 3.82% for Full2030PN. There is also variation in the change in water depth between the four scenarios. Average depth changes range up to 4 cm for the Full1995NN scenario but fall below 2 cm for the Full2030PN scenario. The dominant wetland category affected in all scenarios is freshwater marshes, although there is some effect to most communities. Additional Segment 8 HT results are included in the WSIS Chapter 13, Floodplain Wildlife. It is important to note that HT results provided in both chapters are from the same analyses. The Floodplain Wildlife chapter focused on changes to the area remaining inundated by the River following withdrawal, in both areal extent and ponded depth. Calculation of HT results and display (symbolization in GIS) for the Wetlands Vegetation chapter focused on identifying areas that would no longer be inundated at selected hydrologic exceedences following the withdrawal scenarios.

Although change in modeled annual stage (Figure 2) indicated that Segment 8 would experience the greatest changes in stage, change in modeled annual stage in Segment 7 (Christmas station = .04 m, Figure 2) was only slightly less than that modeled for Segment 8 (Cocoa and Winder stations, both = .05 m). Thus, Segment 7 also has high likelihood of effect due to changes in stage based on vegetation, soils, dominant hydrogeomorphology and change in water levels. Performing Hydroperiod Tool analysis in Segment 7, as requested by The National Research Council, was warranted. Comparing HT results for Segments 7 and 8 will facilitate predictions regarding the effects of withdrawals further downstream where the change in modeled annual stage is further reduced (Figure 2). Unfortunately, HT analysis in segments further downstream (i.e. Segments 5 and 6) are more difficult to perform due to the time and resources required to compile and correct the elevation data required for HT analysis (i.e. Segments 5 and 6 are covered by older DEMs that require more processing than the newer DEMs available for Segments 7 and 8).

Comparing HT results between segments is not as straight forward as simply comparing the change in modeled annual stage as shown in Figure 2. The values in Figure 2 suggest that impacts from alterations in stage will decrease downstream from Lake Poinsett, having negligible effect by Segment 5 (Lake Woodruff) due to the decreasing difference between the FULL1995NN and BASE1995NN scenarios downstream of Lake Winder. Terrain (geomorphology) pays a significant role in determining the effect of alteration in stage over a region. Regionalization of the St. Johns River into Segments in preparation for the screening level assessment was based on a wide set of physical criteria and is described in Chapter 2, Comprehensive Integrated Assessment, Appendix B, Description of River Segments Used in WSIS Study. The physical criteria included dominant vegetation, soils, and hydrogeomorphology (Table 2). Although screening level assessment of the River Segments for the Wetlands Vegetation chapter was based in part on the hydrological modeling results displayed in Figure 2 (Table 2), the other screening level criteria that influenced regionalization will likely influence HT results, especially those criteria that determine geomorphology, or the shape of the terrain. The River Segments are shown in Figures 1 and 6.

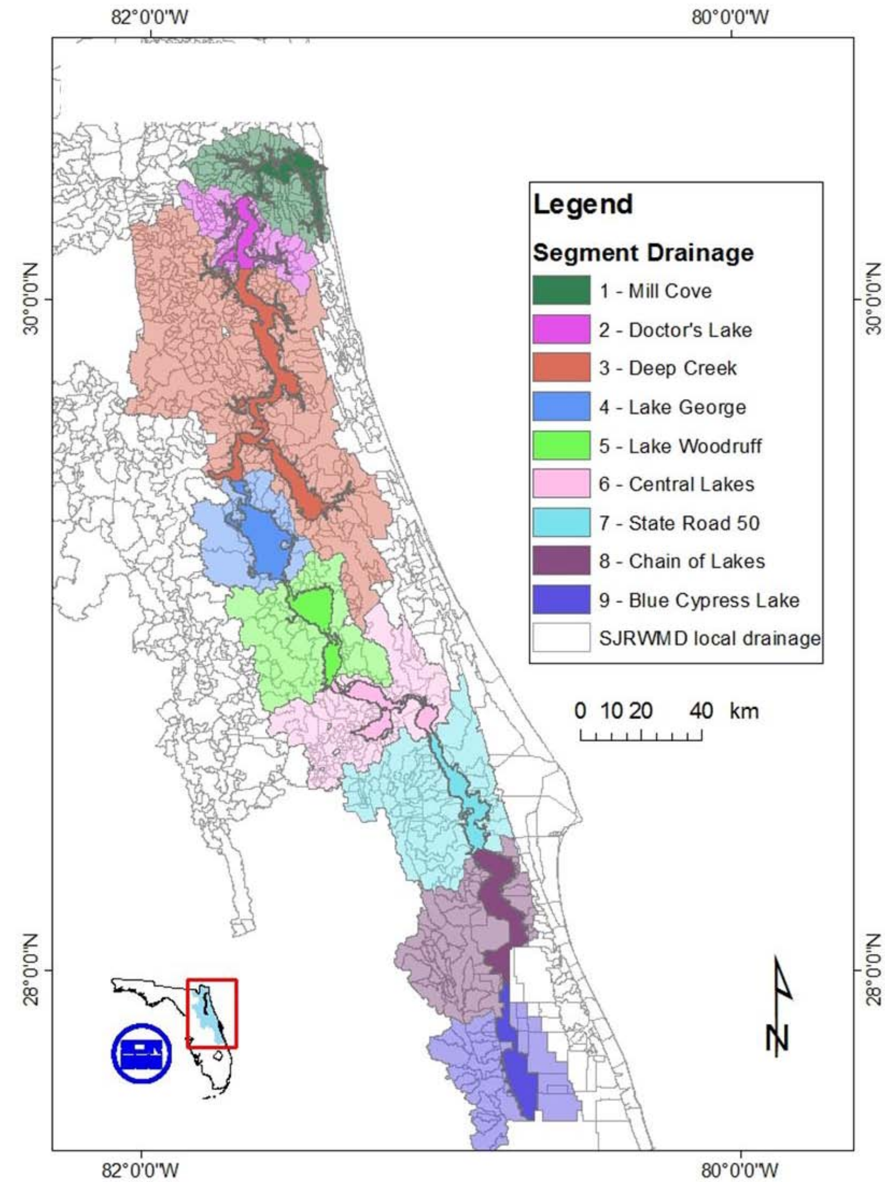


Figure 6. River Segments (darker hue) and segment drainage areas (lighter hue) for the St. Johns River Water Supply Impact Study produced during the screening level assessment.

Table 2. Data for WSIS screening level assessment. Vegetation, soils, and hydrogeomorphology by river segment with modeled deviations from the base condition in water levels and salinity for the Full1995NN scenario and the relative likelihood of effects for river segments (from Wetlands Vegetation chapter).

River Segment	Vegetation	Soils	Dominant Hydrogeomorphology	Change in levels (m)	Change in Salinity - Annual mean (highest monthly mean)	Likelihood of stage effects Full1995NN	Liklihood of salinity effects Full1995NN
1	Salt marsh	Mucky peat	Estuarine fringe	.003	0.32 (0.49)	Very low	Low
2	Hardwood swamp	Muck	Estuarine fringe	.003	0.12 (0.30)	Very low	High
3	Hardwood swamp	Muck	Estuarine fringe	.003	0.011(0.064)	Very low	Low
4	Hardwood swamp / hydric hammock	Muck; Misc. mineral	Lacustrine fringe	.006	None	Very low	None
5	Hardwood swamp / wet prairie	Muck, mucky peat; sandy clay loam	Riverine / Lacustrine fringe	0.008 – 0.015	None	Low	None
6	Wet Prairie; shallow marsh	Misc. mineral; sand, muck	Lacustrine fringe / Riverine	0.029 – 0.033	None	Moderate	None
7	Wet prairie / shallow marsh	Fine sand; muck	Riverine / mineral soil flats	0.04	None	High	None
8	Shallow marsh / shrub swamp	Mucky peat; muck, fine sand	Lacustrine fringe / Orgainc soil flats	0.05	None	High	None
9	Shallow marsh / shrub swamp	Muck, mucky peat	Organic soil flats / Lacustrine fringe	0.00	None	None	None

1.2 Objective

This appendix presents the data preparation and Hydroperiod Tool analysis of a 7,422-hectare area in Segment 7 and compares the results to those reported in Chapter 10, Wetland Vegetation.

2 Methods

2.1 Hydroperiod Tool Application to Segment 7

The Hydroperiod Tool (HT) is an extension for ESRI’s ArcMap and was developed for the South Florida Water Management District by a team that included Dr. David Maidment and students from the University of Texas, Austin and PBS&J (now Atkins) (Sorenson and Maidment, 2004; Sorenson et al., 2004; Carlson et al., 2005). It was designed to define depth and duration of flood inundation as a function of location in a portion of the restored Kissimmee River floodplain in order to predict whether restored wetlands would receive sufficient water to persist. The St. Johns River Water Management District (District) modified the HT to work with river stage statistics (rather than time series) and to enable change analysis to be performed based on the area of inundation at specific stage exceedence values, with and without withdrawals, and to determine the resulting change in ponded depth for areas that are negatively affected.

2.1.1 Description of Hydroperiod Tool Function

The basic goal of HT analysis for the WSIS is to identify the areal extent of wetlands affected by a withdrawal scenario, as illustrated in Figure 7. The HT accomplishes this through automation of a number of operations native to the ArcMap Spatial Analyst extension, commonly referred to as “raster math,” in which the value of coincident or corresponding grid cells from two or more rasters are treated to at least one mathematical operation (ESRI, 2011). The basic HT function is shown in Figure 3 and in the top row of graphics in Figure 8 (i.e. follow line 1 “Historical” @ X exceedence %). A GIS raster layer representing the **land elevation** (DEM) is subtracted from a raster layer representing the water surface or **water elevation**, producing a new raster layer of **ponded depth**. The ponded depth layer is converted (or reclassed) to a **“water/no water**” layer, “water” representing the area of inundation at the given scenario exceedence percentage.

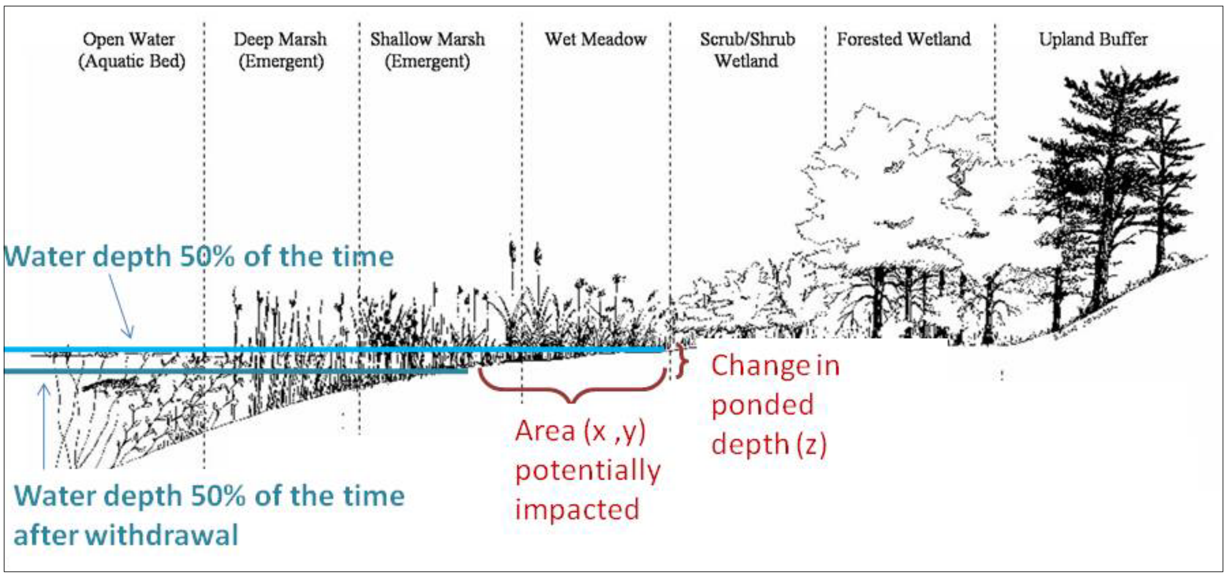


Figure 7. Areal effect of change in River stage (z) as seen in cross sectional representation of the 50% exceedence water level and the resulting area of inundation for both the historical (natural) condition and a proposed withdrawal scenario.
(Wetland cross section Figure from *http://www.newp.com/pdf/NEWP_WetlandCrossSection.pdf*)

HT change analysis to produce the **area affected at a given exceedence %** for a given scenario (vertical line 3 in Figure 8) identifies the wetlands that will receive fewer days of inundation as a results of the withdrawal scenarios. HT change analysis is performed using the raster math function of ArcMap Spatial Analyst, which is automated in the HT. The area of inundation (“water / no water”) layer produced from a model scenario (line 2 in Figure 8) is subtracted from the same exceedence percentage “water / no water” layer produced from the historical data (line 1 in Figure 8) resulting in the area affected (i.e. receiving fewer days of inundations) at that exceedence level.

HT change analysis may also be performed using the ponded depth rasters shown in Figure 8 to produce change in ponded depth layer (not illustrated). Results from ponded depth change analysis are more complex and will be discussed in detail in the Data Preparation section.

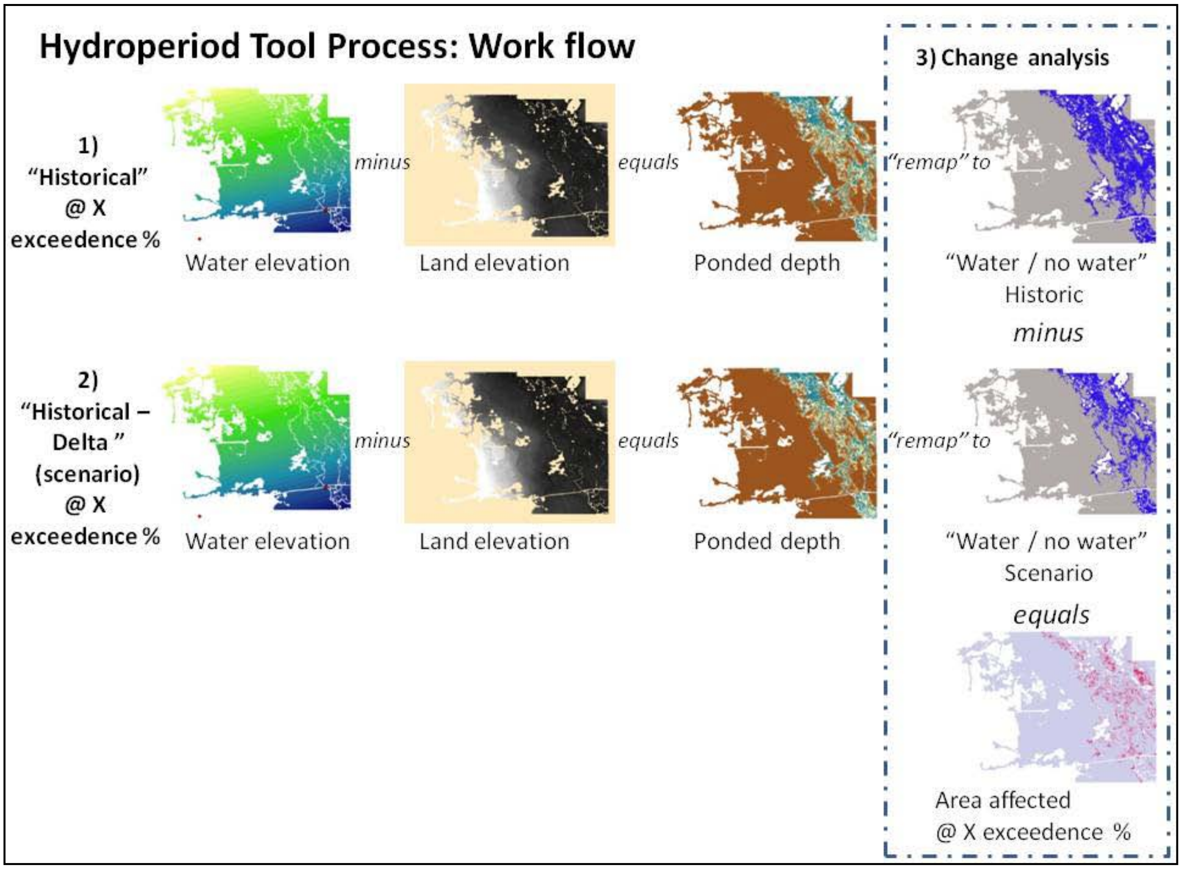


Figure 8. Summary of Hydroperiod Tool process. "Water elevation" in line 1 corresponds to the "water depth 50% of the time" in Figure 3. "Water elevation" in line 2 corresponds to the "water depth 50% of the time after withdrawal" in Figure 3. "Area affected @ X exceedence %" corresponds to "area (x,y) potentially impacted" in Figure 3.

2.1.2 Assumptions Employed With Use of the Hydroperiod Tool for the WSIS

Using the HT in GIS to model the effect of a change in hydrology necessitates the following simplifying assumptions:

- Consideration of only the riverine portion of wetland hydrology – all other sources of wetland hydrology are considered to remain consistent between scenarios
- Acceptance of the exceedence curve approach to statistically summarize stage data (historical and modeled) rather than the time series approach originally employed with the HT (Sorenson and Maidment, 2004; Sorenson et al., 2004; Carlson et al., 2005)
- Extension or continuation of River stage data out across the floodplain
- Modeling of the water surface as a sloping flat pool
- Disregarding the effect of friction from wetlands (to impede flow or hold water)

2.2 Hydroperiod Tool Data Preparation for Segment 7

As previously discussed, Hydroperiod Tool (HT) analysis requires a significant amount of data preparation, including:

- digital elevation model (DEM) correction for LiDAR-based bias in wetland areas (to achieve as close to a bare earth DEM as possible);
- stage data preparation for input to the HT from the historic record and modeled withdrawal scenarios, and determination of the appropriate water surface interpolation method for the stage data;
- data compilation into geodatabase format for HT operation;
- “raw” HT results preparation for the change analysis phase of HT function, including reclassification and calculation of affected areas from the GIS.

The two primary components of data preparation for Hydroperiod Tool (HT) analysis are digital elevation model (DEM) preparation, and hydrologic data preparation including determination of surface interpolation method. Additionally (but not described further here), vector data (River stage stations, interpolation accessory points, interpolation boundary, wetland community polygons) and tabular data (hydrologic data) are organized into a geodatabase for input to the HT. Finally, once the historic and scenario HT runs are complete, the ponded depth layers are reclassified and the change analysis is performed using the HT.

Due to WSIS project time constraints, a small subset (7,422 ha) of Segment 7 (located around Cone Lake) was selected for HT analysis, and the change analysis was performed for only the FULL1995NN scenario. HT analysis depends heavily on the nature and quality of the DEM used; therefore three DEM-based terrain analyses were performed in order to justify comparison of HT results from the two River Segments (see Final Corrected DEM, below). In other words, are the two DEMs comparable in quality to justify comparison of HT results generated from their use? (Note: a more detailed description of the HT methods, particularly DEM correction, data preparation and analysis of results, is provided here than was included in Chapter 10, Wetlands Vegetation.)

2.2.1 Digital Elevation Model (DEM)

2.2.1.1 Determination of Segment 7 Analysis Area

Although DEMs from a number of sources were available (i.e. USGS National Elevation Dataset, which is contour line-derived), only LiDAR-derived DEMs have the spatial resolution appropriate for HT analysis. LiDAR-derived DEMs are available for a large portion of River Segment 7 as shown in Figure 9. The USGS Upper St. Johns River Basin (USJRB) DEM (yellow boundary in Figure 9) covers portions of both Segments 7 and 8 (Dewberry, 2010). This was the source DEM for the Segment 8 Lake Poinsett HT work. Corrections to the USGS USJRB DEM (Segment 8) were based on surveyed elevations from the SJRWMD Minimum Flows and Levels (MFL) program (Mace, 2007a).

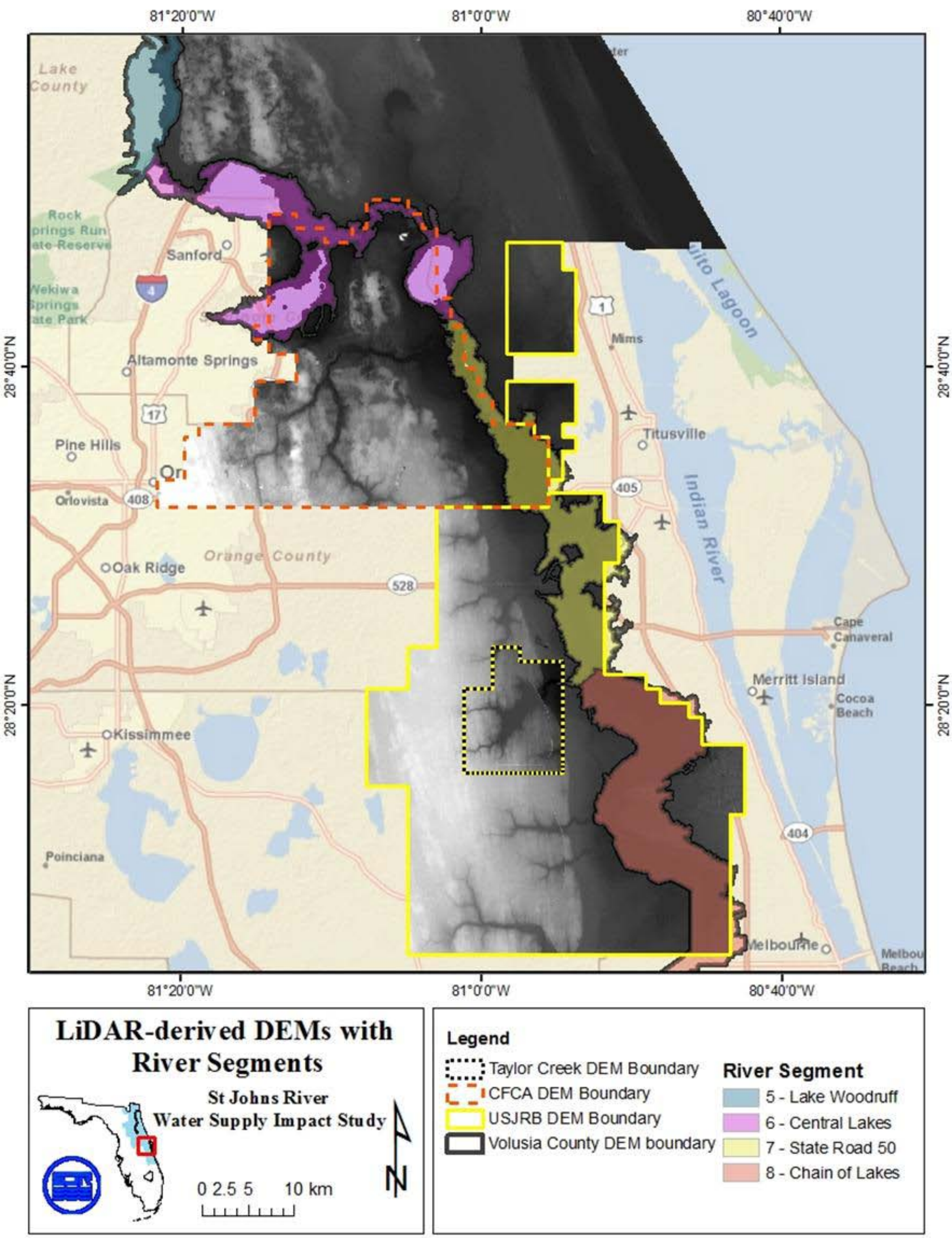


Figure 9. Area of LiDAR data coverage for WSIS project (from Wetlands Vegetation chapter).

Pilot HT work for the WSIS was performed using an area in Segment 7 using the Central Florida Coordination Area (CFCA – red dashed outline in Figure 9) LiDAR-derived DEM (Dewberry, 2009). The pilot work was conducted prior to the availability of the USGS USJRB DEM.

Although the newer USGS DEM used for Segment 8 also included areas within Segment 7 (Figure 9), and thus could have been spatially contiguous with the Segment 8 work, it was deemed most expedient for the WSIS to return to working with the pilot DEM (CFCA). Developing another area in Segment 7 using the USGS USJRB DEM would have entailed a considerable amount of work to correct the DEM for wetland vegetation. Additionally, the potential value of working with a different source DEM in order to develop a greater understanding of the nature of the LiDAR bias in wetlands, which necessitates DEM correction, was considered a worthwhile approach.

Determination of the specific area within the CFCA DEM to be used for HT analysis in Segment 7 is shown in Figure 10. The project area was dictated by the overlap of the CFCA DEM footprint (dashed red outline in Figure 9; grid array in Figure 10) with the wetlands contiguous with the St. Johns River within Segment 7 and the location of the SJRWMD Minimum Flows and Levels (MFL) elevation transects.

The resulting area was determined to be an appropriate representation of Segment 7 for HT analysis because the area is characterized by:

1. Central location or “geographic average” within Segment 7 (Figure 10),
2. Inclusion of the braided river channel nature of Segment 7 (partially visible in Figure 10), and
3. Inclusion of representative vegetation of Segment 7, with the exception of less Open Water and more Hardwood Swamp being present in the HT analysis area (Table 3).

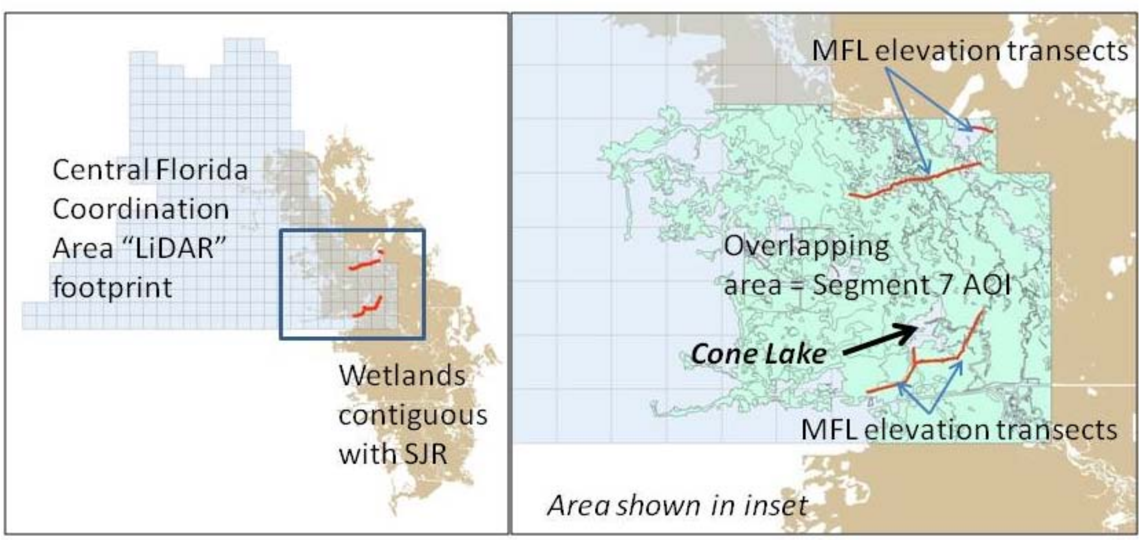


Figure 10. Determination of the area for Hydroperiod Tool analysis within River Segment 7

Table 3. Wetlands within Segment 7 (Wetlands Chapter 10, Appendix 1: Description of the River Floodplain) and within the Hydroperiod Tool study area.

Wetlands Group	% of area	
SJRWMD 24k Wetlands Layer	Segment 7	HT analysis area
Wet Prairie	38.37	32.96
Shallow Marsh	29.98	22.02
Water group	12.19	3.16
Transitional Shrub	6.76	5.18
Hydric Hammock Group	4.58	9.30
Hardwood Swamp	3.46	23.41
Floating Marshes	2.49	3.36
Upland	1.10	0.61
Other Wetlands	1.07	0.00

2.2.1.2 LiDAR Data Acquisition and DEM Production

LiDAR aerial acquisition for the CFCA was conducted in accordance with the Florida Division of Emergency Management Baseline Specifications (FDEM, 2006) between February 8 and 11, 2009 by Merrick & Company as subcontractor to Dewberry (Dewberry, 2009). The LiDAR data were acquired to meet 1-foot topographic contour accuracy, comparable to the USGS USJRB DEM used for Segment 8. Thirty-eight GPS ground control points were established and surveyed. The RMSE in bare-earth and low grass were within the target criteria of 0.30 ft (0.009 m) , and the Fundamental Vertical Accuracy tested 0.41 ft (0.12 m) at the 95% confidence level in open terrain (Dewberry, 2009). The LiDAR data was processed by the vendor with proprietary software to produce a DEM with a cell size of 5 feet (1.524 meter), using vertical datum NAVD 1988. Conversion to vertical datum NGVD 1929 (required for all WSIS work) was performed using Vertcon by SJRWMD staff in the Division of Information Technology. Vertcon, a software program that computes the orthometric height differential between NAVD 1988 and NGVD 1929 vertical datums was developed by the National Geodetic Survey and is considered to be accurate at the 2 cm level (USACE, 2004). Error introduced as a result of the conversion from NAVD 1988 to NGVD 1929 can be considered inconsequential for HT change analysis which is ultimately derived from changes in hydrology over a constant DEM source (Figure 8).

2.2.1.3 Determination of DEM Correction Factors

The purpose of DEM correction is to achieve, as close as possible, a true bare earth DEM for HT analysis. Dense wetland vegetation prevents the LiDAR pulse from reaching bare earth. Thus, the LiDAR last returns, which are considered to be from bare earth for DEM generation, are hitting the wetland vegetation as described in the WSIS Chapter 10, Wetlands Vegetation. Using an uncorrected DEM (elevations greatly above true bare earth) would produce unacceptable HT results. The process of DEM correction used for Segment 8 is described in Chapter 10; corrections were based on comparison to surveyed elevations from the SJRWMD Minimum Flows and Levels (MFL) program (Mace, 2007b). The Segment 8 approach to developing correction factors (using existing vector-based wetland habitat classification data) was: (1) to minimize the differences between the new (corrected) DEM and the surveyed elevation at each station, (2) to eliminate bias so that median error between the new DEM and survey elevations was zero, and (3) to be consistent with field knowledge. The same approach was used for the CFCA Segment 7 DEM.

The location and names of the four MFL transects in the HT Segment 7 study area are shown in Figure 11. Transect elevations were measured by survey by SJRWMD staff at multiple points along each transect (Mace, 2007b). Comparison of elevation between the points from the four MFL transects (originally in feet 1929 NGVD converted to meters 1929 NGVD) and the LiDAR-derived DEMs (originally in feet NAVD 1988, converted to meters 1929 NGVD) is shown in Figure 12, where a bias (i.e. LiDAR DEM elevation greater than MFL surveyed elevation) is evident.

- The bias appears to be greater in the Cone and M6 transects which are further upstream than Ruth and H1 (Figure 12).
- The bias is comparable to that seen in a sample transect (Buzzard's Roost) from the USGS USJRB DEM for Segment 8 before modification, shown in Figure 13.
- As with the DEM for Segment 8, correction for bias in wetland areas in the CFCA DEM was determined to be necessary for HT analysis for Segment 7.

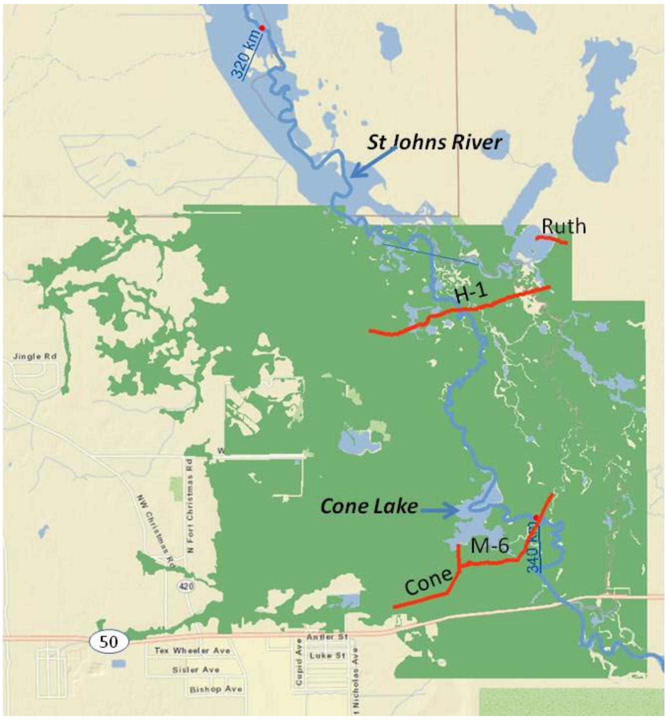


Figure 11. MFL transect locations. The transects are located between St. Johns River kilometers 320 and 340, north of State. Road 50.

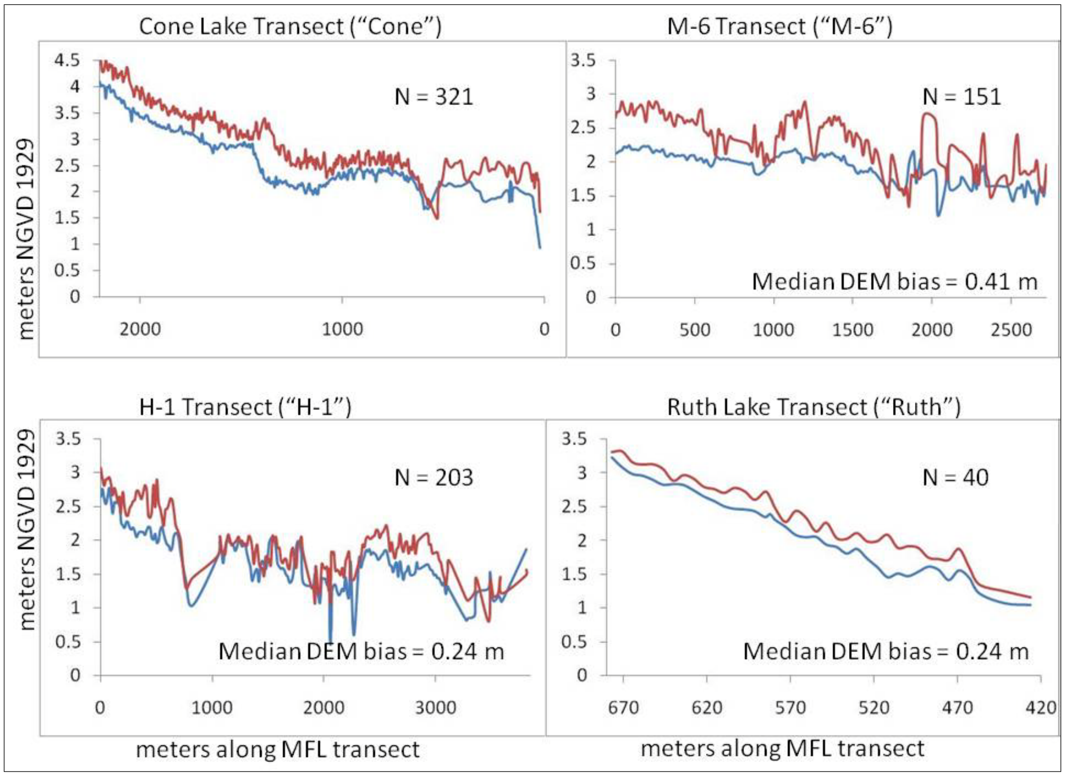


Figure 12. Comparison of LiDAR-derived DEM elevation to MFL survey elevation. Blue lines in all Figures represent the MFL surveyed elevation and the red lines are the LiDAR-derived DEM elevations.

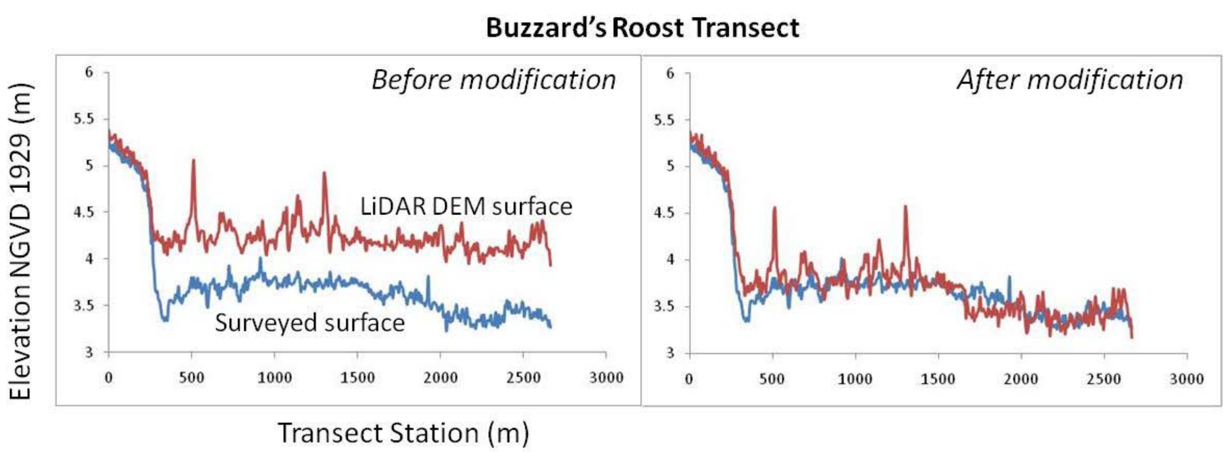


Figure 13. LiDAR surface before and after adjustment to fit surveyed transect, sample transect from Segment 8 (from Wetlands chapter).

Correction of the USGS USJRB DEM for Segment 8 employed four correction factors, based on the availability of polygons of defined wetland community groups that lined up well with the observed patterns of bias in the transect/DEM elevation data. For example, correction of the area around the Buzzard's Roost transect shown in Figure 13 employed 3 correction factors applied to defined wetland types available in the wetland polygon layers.

Figure 14 shows the vegetation polygon layers (SJRWMD Land Use Land Cover 2004 and USJRB vegetation mapping) available to create correction factor boundaries for Segment 7. These data are from the same larger datasets of wetland community polygons used to develop correction factors for the Segment 8 DEM. The wetland classes from the two polygon layers that overlap the MFL transects in Segment 7 are shown in Table 4. Elevation “data pairs” (one measurement by survey and one from LiDAR-derived DEM coincident with each survey point) were classified using both vegetation polygon classification schemes for statistical analysis in order to look for patterns supportive of developing wetland community specific correction factors (as was accomplished for the Segment 8 Lake Poinsett DEM). The LiDAR-bias (LiDAR elevation greater than survey elevation) was determined for each wetland community class and for the dataset as a whole.

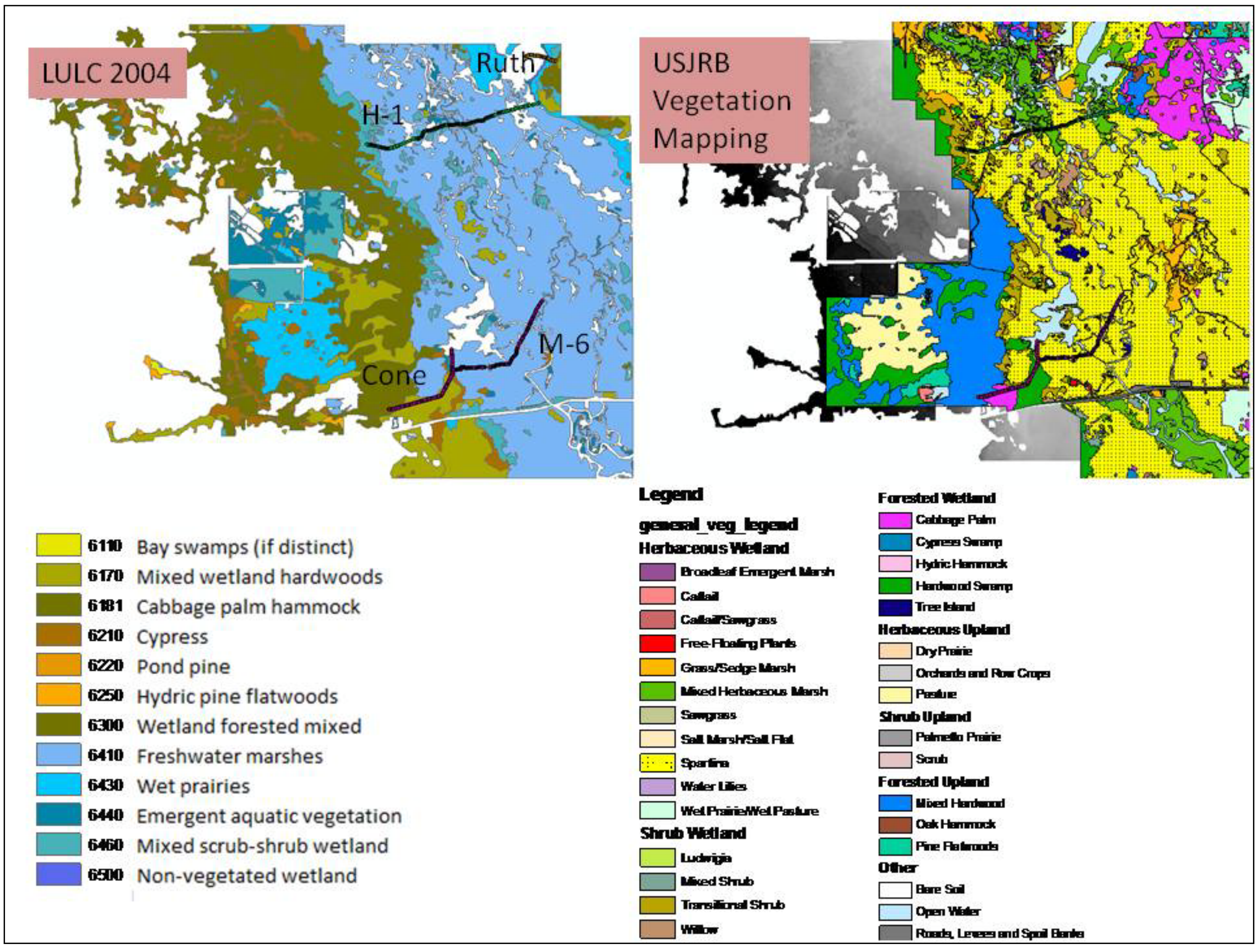


Figure 14. Vegetation polygon layers**.** Correction of the DEM is heavily dependent upon the availability of enough vegetation community polygons traversing the same areas as the elevation transects.

Table 4. Vegetation classes from the two SJRWMD polygon layers (USJRB vegetation mapping and Land Use Land Cover 2004) that overlap the MFL transects.

USJRB Vegetation Mapping
Cabbage Palms
Hardwood Swamps
Mixed Hardwoods
Mixed Herbacesous Marsh
Oak Hammock
Spartina Marsh
Transitional Shrub
Tree Island

LULC2004 Vegetation
Cabbage palm hammock
Cypress
Emergent aquatic vegetation
Freshwater marshes
Mixed scrub-shrub wetlands
Mixed wetland hardwoods
Non-vegetated wetland
Wet prairies

2.2.1.4 Final Corrected DEM

DEM correction was performed in ArcMap using the Spatial Analyst extension. The original 5 foot (1.524 meter) grid DEM was aggregated in ArcMap (by mean) to approximately 15 meter grid, which was previously determined to be the optimum grid cell size for HT analysis in Segment 8, maintaining terrain characteristics while allowing faster HT processing than with smaller grids. Once corrected and aggregated, the DEM was processed for several metrics in order to compare the Segment 7 DEM to the final processed DEM used for the Segment 8 HT work. The metrics were: (1) River floodplain area, or total wetland area (within study area) historically inundated by the river, (2) histogram or distribution of DEM elevation, and (3) histogram or distribution of slope. In order to compare HT results from different segments, the DEMs must be of comparable quality because the DEM is the foundation over which the hydrological changes are assessed (Figures 3 and 8). For example, if HT analysis is performed on two areas (two DEMs) using comparable hydrologic input, yet produces different areal results, the deviation is most likely due to the terrain, which is represented by the DEM. The elevation of maximum historical River stage was used to define the River floodplain and consequently to also identify the wetland area within the DEM that is not historically inundated by the River. The histogram or distribution of DEM elevation was also plotted as a simple geomorphologic assessment of terrain shape. The corrected and aggregated DEM was processed in Spatial Analyst for slope, the rate of maximum change in elevation for each grid cell. These metrics were used to compare the DEMs for Segments 7 and 8 in order to illustrate and define the effects of the DEM on HT results.

2.2.2 Hydrologic Data

2.2.2.1 Stage Data

The location of stage data recorders within the St. Johns River in relation to the Segment 7 study area is shown in Figure 15. Data from the stage data recorders is stored in the District's Hydstra (KISTERS) database. All modeled data for use with the HT was produced using HSPF as described in WSIS Chapter 4, Watershed Hydrology and Modeling of the St. Johns River, and is also stored in Hydstra. Preparation of hydrologic data (recorded historical and modeled) for interpolation of water surfaces with the HT is described in Chapter 10, Wetland Vegetation, Appendix A, Description of Method for Historical – Delta and simulated stages at ungauged river transect locations. Segment 7 stage data entered into the HT for water surface interpolation is shown in Table 5 where each station (Cocoa, Christmas and Harney) has both the historic (“HIST”) and modeled (“HIST-DELTA”) data values for 19 selected exceedence values based on 10 years of data (January 1, 1996 – December 31, 2005), as determined by statistical analysis (Bedient and Huber, 2003). The column “Delta” for each station indicates the change in stage occurring at each exceedence percentage for the historic minus the FULL1995NN scenario; “Delta” is provided here only for comparison between stations and between exceedences. The average “Delta” for the FULL1995NN scenario is 0.07 m for Cocoa, and 0.04 m for both Christmas and Harney.

Figure 15. Location of stage gages in the St. Johns River for Segment 7 Hydroperiod Tool analysis. Note that the Cocoa station was used for the Segment 8 HT work.

Table 5. Hydroperiod Tool input data (River stage) for three stations (in meters). Statistics based on 10 years of data (January 1, 1996, to December 31, 2005).

Exc	Cocoa			Christmas			Harney		
%	HIST	HIST-DELTA	Delta	HIST	HIST-DELTA	Delta	HIST	HIST-DELTA	Delta
5	4.66	4.62	0.04	3.10	3.08	0.02	2.61	2.54	0.07
10	4.51	4.46	0.05	2.91	2.89	0.02	2.24	2.20	0.05
15	4.34	4.29	0.05	2.78	2.76	0.03	2.05	1.99	0.05
20	4.17	4.11	0.06	2.62	2.58	0.04	1.86	1.80	0.06
25	4.04	3.98	0.06	2.53	2.49	0.04	1.65	1.59	0.06
30	3.92	3.85	0.07	2.42	2.38	0.04	1.46	1.39	0.06
35	3.85	3.76	0.09	2.33	2.28	0.05	1.25	1.21	0.05
40	3.74	3.65	0.09	2.23	2.17	0.05	1.11	1.06	0.05
45	3.65	3.55	0.09	2.12	2.05	0.06	1.00	0.95	0.04
50	3.56	3.46	0.10	2.01	1.94	0.07	0.86	0.83	0.03
55	3.47	3.37	0.11	1.89	1.83	0.07	0.78	0.74	0.04
60	3.38	3.27	0.11	1.80	1.72	0.07	0.70	0.66	0.04
65	3.29	3.19	0.10	1.67	1.61	0.05	0.62	0.58	0.04
70	3.19	3.08	0.11	1.52	1.44	0.08	0.54	0.51	0.03
75	3.12	3.02	0.10	1.40	1.34	0.05	0.46	0.45	0.02
80	3.01	2.95	0.07	1.30	1.25	0.05	0.41	0.39	0.02
85	2.90	2.83	0.06	1.16	1.12	0.04	0.36	0.34	0.02
90	2.74	2.70	0.04	1.01	1.00	0.01	0.30	0.28	0.02
95	2.63	2.61	0.02	0.86	0.89	-0.03	0.23	0.22	0.01

2.2.2.2 Interpolation of Water Elevation Surfaces

The HT automatically produces the water surfaces or water elevation layers (examples shown in Figures 3 and 8) from River stage data by interpolation (ESRI, 2011). Four water surface interpolation methods are built into the HT (inverse distance weighted, spline, Kriging, and “none”, which produces a uniform flat surface at a selected elevation). All except the “none” method require accessory points (Figure 16) within the GIS to extend River stage values out across the floodplain in the process of creating the interpolated water surface. During the data preparation stage, it is important to experiment with the available interpolation options as well as position and number of the accessory points in order to generate the desired water surface characteristic of a sloping flat pool, with River stage values extending approximately perpendicular to the River. Panel b in Figure 16 is an example of an interpolated water elevation surface processed for the area shown in panel a.

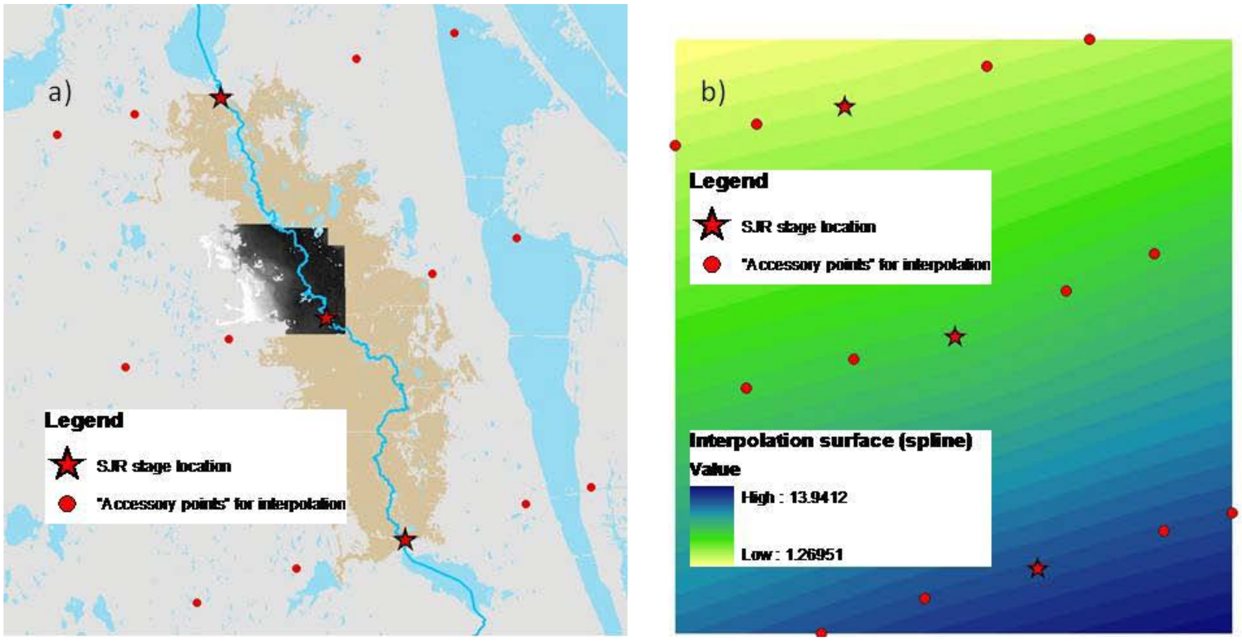


Figure 16. Interpolation of water surface for segment 7 study area. a) Distribution of “accessory” points across the floodplain necessary to generate surface in GIS; b) an interpolated surface. Note the diagonal distribution of elevations in figure b, extending River stage values perpendicular to the general direction of the River.

2.2.2.3 Ponded Depth Layers and Change Analysis

2.2.2.3.1 Hydroperiod Tool Output

For the WSIS project, the HT was programmed to produce sets of 19 ponded depth layers (or rasters), one set for the baseline or historic condition and one set for the withdrawal scenario. The 19 ponded depth layers correspond to the exceedence values shown in Table 5 (i.e. 5% exceedence through 95% exceedence). The modeled condition (scenario) for Segment 7 HT analysis was the FULL1995NN scenario (Table 1). All ponded depth rasters were converted to the simplified layer representing “water / no water” for change analysis (as illustrated in Figure 8).

2.2.2.3.2 Change Analysis

The HT change analysis process consists of the following two steps: (1) for each exceedence level, the “HIST-DELTA” (FULL1995NN) “water / no water” raster is subtracted from the “HIST” (historic condition) “water / no water” raster to produce a third, or new, raster representing change. The change raster is characterized by three states: (a) area of no change, (i.e. if the grid cell was inundated historically it is still inundated following the withdrawal scenario); (b) area that was inundated historically but is not inundated at this exceedence due to the withdrawal scenario; and (c) area receiving more water due to the scenario (not explored further for the WSIS); and (2) the areas (in hectares) classed as 2 (inundated historically, but not inundated due to withdrawal, at each exceedence) is totaled over all 19 exceedence levels as an index of the magnitude of the withdrawal effect from that withdrawal scenario.

2.2.2.3.3 Hectare-Days Calculation

An additional index of the magnitude of effect was arrived at by multiplying the area affected at each exceedence by the maximum reduction in days of inundation, referred to as hectare-days impact. Hectare-days is a measure of both the area identified by the HT as affected ("state 2," above) and the duration of effect.

The duration of the effect is found in the exceedence tables, which provide both the stage value and the days of inundation (expressed in the exceedence table as percentage of time over the period used to create the exceedence table). There are two exceedence tables (not included here), one for the historic record (table "A") and one for the withdrawal scenario (table "B"). The reduction in days of inundation (over the 10 year model period) is calculated for each exceedence percentage stage value from the historic days of inundation (from table "A") minus the days of inundation for that stage value located in the withdrawal scenario exceedence table (table "B"). For example (referring to Table 5), the Christmas station historic ("HIST") 50% exceedence stage value is 2.01 meters. This means that over the 10 years of data stage values reached up to 2.01 meters 50% of the time, or 1827 days. Using the withdrawal scenario exceedence table ("HIST-DELTA" in Table 5), the stage value of up to 2.01 meters occurs at approximately 47% of the time, meaning that stage is reached less frequently over the 10-year period, or about 1712 days. Thus, in this example, the reduction in days of inundation is 115 days (calculated for the 10-year period) specifically for the Christmas station at the 50% exceedence level for this scenario. The reduction in days of inundation is calculated for each exceedence level for each stage location used to create the interpolated water surface (Figure 15). The maximum reduction in days of inundation was determined by comparing the calculated reduction in days of inundation for each station (Figure 15) that was used to create the interpolated water surface and selecting the highest value among them.

2.2.2.3.4 Ponded Depth Change

Change analysis was also performed on the ponded depth layers, producing a complex change in ponded depth layer or raster. Figure 17 demonstrates the three different response areas from a ponded depth change analysis. Each grid cell in the resulting raster is characterized by either a zero or a positive value, in centimeters. A zero simply means that there was no inundation occurring at this exceedence either historically or following the scenario for a given grid cell. The positive values in the raster represent a reduction in ponded depth, which may seem counter-intuitive. To further complicate matters, some areas experiencing a reduction in ponded depth will still be inundated following the scenario, just at a lower water level. Other areas will be completely dewatered (i.e., inundated for fewer days) due to the scenario. Differentiating between these two areas is not immediately obvious, but it is possible by referencing the change in stage (at recorders) and the appropriate "water / no water" rasters. Development of a change specific symbolization method for the change in ponded depth raster would be useful but was not explored further for the WSIS. Note that Figure 17 also helps to define the different HT approaches used in Chapters 10 and 13. Chapter 10, Wetlands Vegetation HT results focused on the area that experienced dewatering (i.e. fewer days of inundation, change in ponded depth values < z in Figure 13.) Chapter 13, Floodplain Wildlife HT results focused more on the area that remained inundated following the withdrawal (i.e. change in ponded depth values = z in Figure 13.)

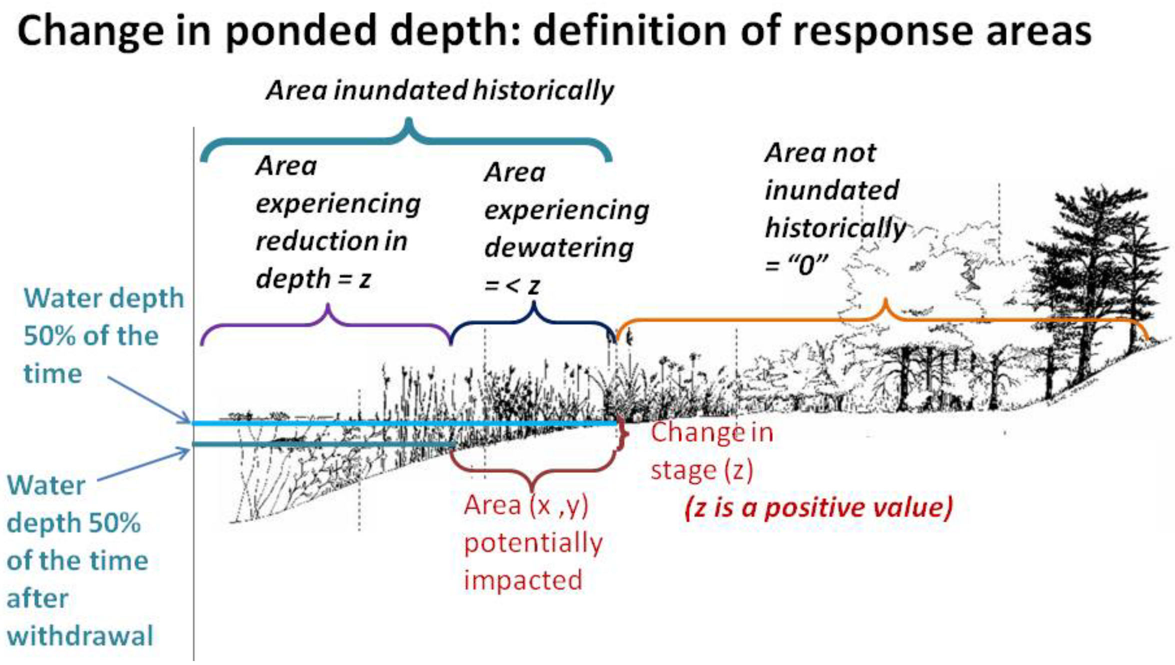


Figure 17. Summary of aerial results for change in ponded depth, HT results.
(Wetland cross section Figure from *http://www.newp.com/pdf/NEWP_WetlandCrossSection.pdf*)

3 Segment 7 Results

Results for Segment 7 are described in the following five sections:

- DEM correction factor determination
- Corrected DEM comparison to MFL transect elevation (or "success" of DEM correction)
- DEM as descriptor of segment terrain/geomorphology (for comparison to other segments)
- Hydroperiod Tool water surface interpolation method determination
- Hydroperiod Tool change analysis for the FULL1995NN scenario

The first two categories pertain to the preparation of the DEM for HT analysis, the results from which are critical to the integrity and value of the final HT results. They describe how closely a true bare earth DEM was achieved. The third category provides generalization of terrain elevation, or geomorphology-based measures, to facilitate comparison of Segment 7 HT results to the results provided for Segment 8 in the Chapter 10, Wetlands Vegetation and Chapter 13, Floodplain Wildlife. Results from the selection of water surface interpolation method, essential to representing the changing hydrological conditions, are provided in the fourth section. The last section is devoted to the effect of the FULL1995NN scenario, the HT change analysis, for Segment 7.

3.1 DEM Correction Factor Determination

Initially 728 pairs of elevation measurements from the four MFL transects (Figure 11) were evaluated statistically using the two vegetation polygon classification schemes (Figure 14). The results are provided in Table 6. Despite efforts to combine the two schemes and to form aggregates of wetlands community polygons that would provide a statistically supportable correction scheme involving more than one correction factor, no consistent pattern of bias could be determined based on the available wetland vegetation polygons from the two classification schemes.

Table 6. LiDAR bias statistics (in feet) for entire dataset using two wetland polygon schemas

	N	Mean	StDev	Median
All data points	728	1.0936	0.8871	1.086

USJRB Vegetation Mapping	N	Mean	StDev	Median
Cabbage Palms	78	1.6134	0.8775	1.4933
Hardwood Swamps	124	0.8941	0.7094	0.8933
Mixed Hardwoods	84	1.287	0.4452	1.3006
Mixed Herbacesous Marsh	54	0.696	1.274	0.742
Oak Hammock	10	0.5273	0.2044	0.5475
Spartina Marsh	358	1.0994	0.916	1.1305
Transitional Shrub	17	0.729	0.563	0.662
Tree Island	3	0.81	0.217	0.863
	728			

LULC2004 Vegetation	N	Mean	StDev	Median
Cabbage palm hammock	47	1.4606	0.439	1.43
Cypress	20	0.281	0.715	0.542
Emergent aquatic vegetation	29	0.487	1.474	0.838
Freshwater marshes	369	1.0994	0.941	1.1003
Mixed scrub-shrub wetlands	25	0.672	0.3292	0.5787
Mixed wetland hardwoods	215	1.2517	0.7161	1.1388
Non-vegetated wetland	3	0.466	0.1077	0.4346
Wet prairies	20	0.736	0.751	0.895
	728			

A single correction factor of 0.33 meter (1.09 feet), based on all of the elevation data (Table 7), was used for DEM correction. A total of 715 pairs were used for the final analysis because 13 points occurred in emergent aquatic vegetation and were determined to be picking up the water surface in the LiDAR-derived DEM instead of land. This reduction in data for calculating the correction factors appears not to have affected the value of the final correction factor's mean or median, likely due to the large sample size. Table 7 also provides the original DEM (uncorrected) median LiDAR bias (difference between the MFL survey and DEM elevation) for each of the individual transects. Both Ruth and H-1 (downstream, see Figure 11) had lower median wetland LiDAR bias (uncorrected, 0.21 and 0.24 m respectively) than the two upstream transects, M6 and Cone (0.41 and 0.38 meters, respectively).

Table 7. Median LiDAR-based bias for uncorrected DEM and error for corrected DEM

Transect	N	Feet UNCORRECTED	Meters UNCORRECTED	CORRECTED
ALL	**715**	1.09	0.33	-0.03
Ruth	40	0.68	0.21	-0.16
H1	203	0.79	0.24	-0.13
M6	151	1.33	0.41	0.04
Cone	321	1.23	0.38	0.12

3.2 Corrected DEM Comparison to MFL Transects Elevation

Following correction using 1.09 ft (0.33 m) over the entire DEM, the survey (MFL) and newly corrected DEM elevations were compared to determine the success of the correction process. Comparison of DEM elevation (both the original and corrected) and MFL transect elevation are shown in Figures 18 – 21 for the four Segment 7 transects. Median bias (before DEM correction) and error (after DEM correction) from Table 7 are also provided in the Figures. Distribution of the original LiDAR bias (due to the wetland vegetation) in the original DEM and the error following correction are shown in Figure 22. The median error of the corrected DEM (based on all transects) is -0.03 meters, indicating a nearly balanced error model (Figure 22). As noted above, both the Ruth and H-1 transects (downstream) had lower median wetland LiDAR bias in the original DEM than the two upstream transects, M6 and Cone. Use of a single correction factor based on all of the input data for the entire DEM resulted in “over correction” of Ruth and H-1 (median error -0.16 and-0.13, Table 7, Figures 20 and 121, respectively) and “under correction for Cone and M6 (median error 0.04 and 0.12, Table 7, Figure 18 and 19, respectively).

It is appropriate to note here that success of the DEM correction process for wetland bias depends heavily on the availability of GIS layers of wetlands classification from which to develop a statistically supported scheme of correction factors that is representative of the variation in evident bias. Better GIS-based wetland classification methods, possibly using remote sensing technology, may be helpful in the future.

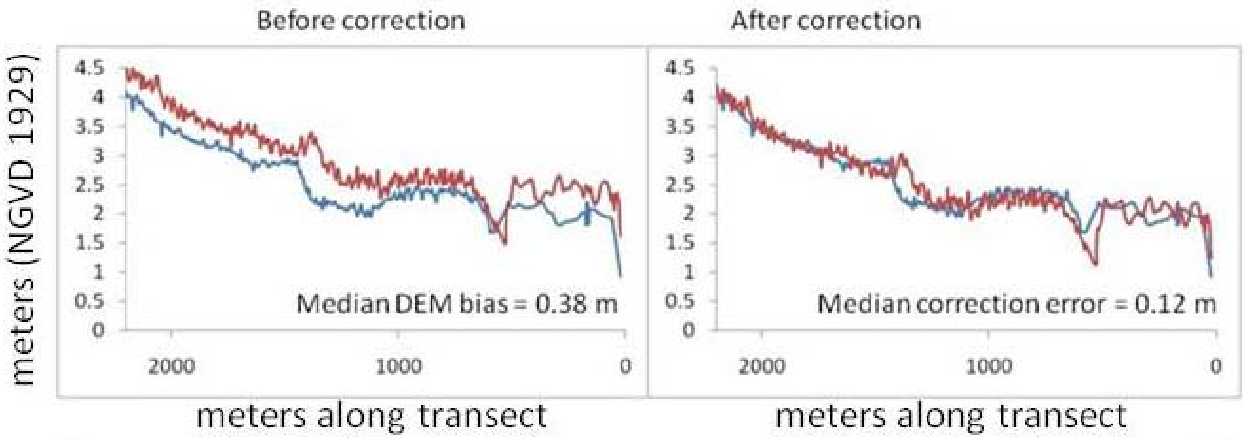


Figure 18. Cone transect comparison of DEM elevation to MFL elevation before and after DEM correction. N = 321, emergent aquatic vegetation removed. Blue lines in both Figures represent the MFL surveyed elevation and the red lines are the LiDAR-derived DEM elevations.

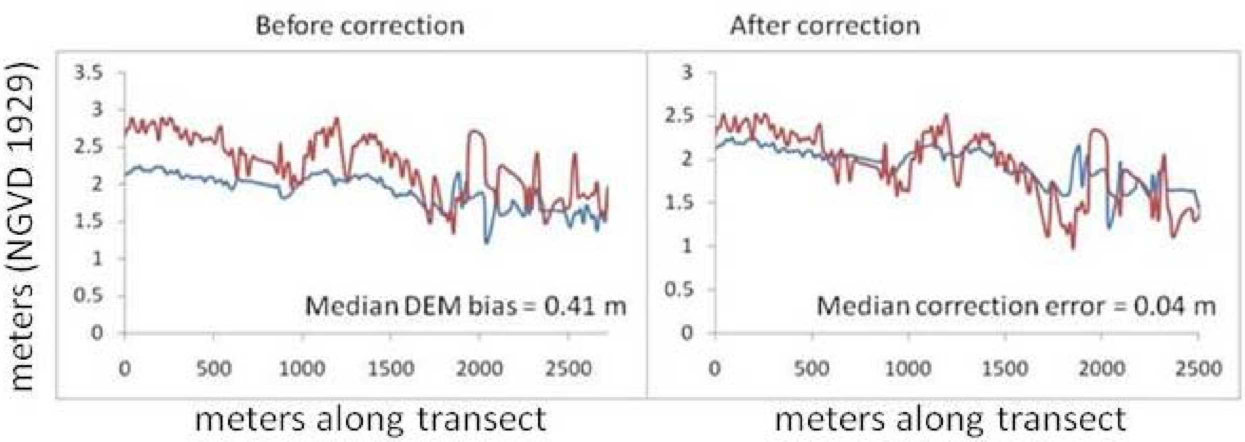


Figure 19. M-6 transect comparison of DEM elevation to MFL elevation before and after DEM correction. N = 151, emergent aquatic vegetation removed. Blue lines in both Figures represent the MFL surveyed elevation and the red lines are the LiDAR-derived DEM elevations.

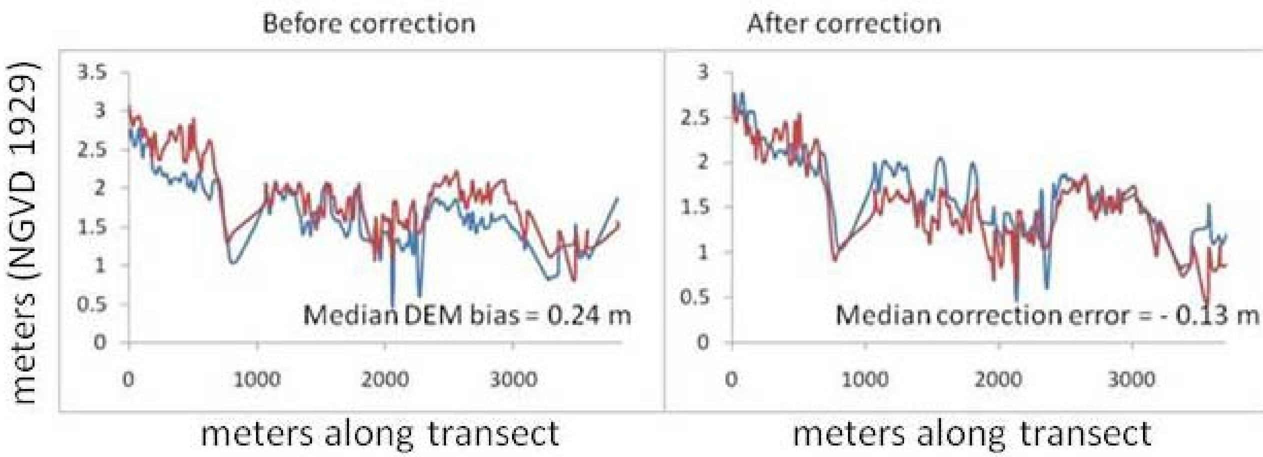


Figure 20. H-1 transect comparison of DEM elevation to MFL elevation before and after DEM correction. N = 203, emergent aquatic vegetation removed. Blue lines in both Figures represent the MFL surveyed elevation and the red lines are the LiDAR-derived DEM elevations.

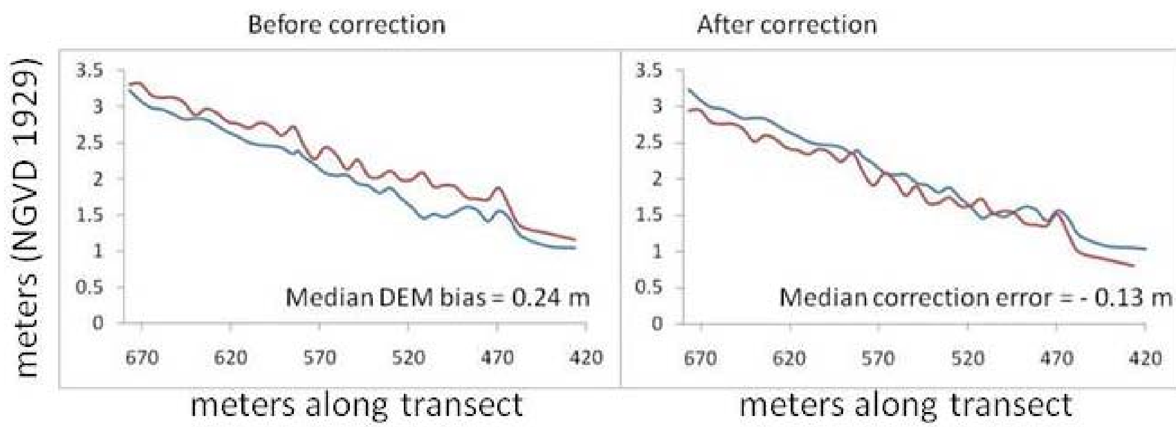


Figure 21. Ruth transect comparison of DEM elevation to MFL elevation before and after DEM correction. N = 40, emergent aquatic vegetation removed. Blue lines in both Figures represent the MFL surveyed elevation and the red lines are the LiDAR-derived DEM elevations.

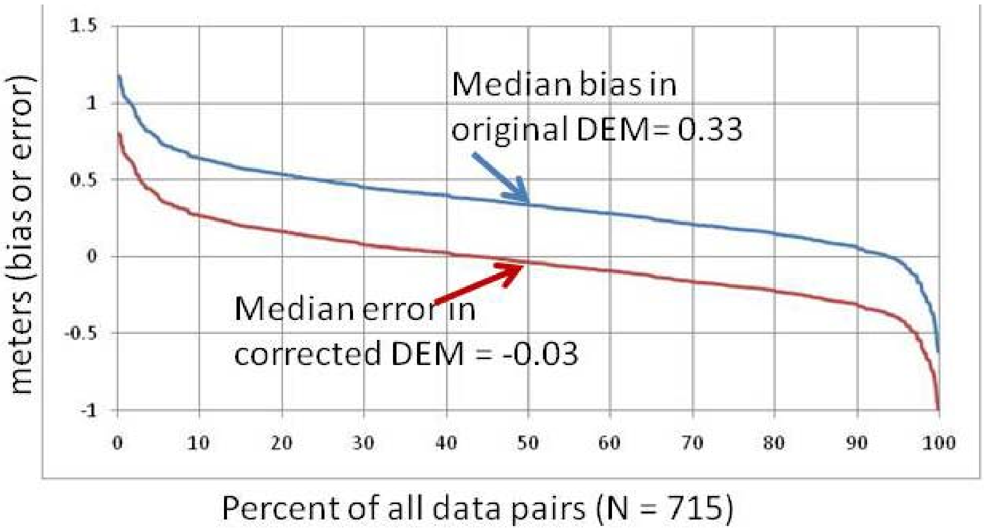


Figure 22. Summary of LiDAR bias and correction error.

3.3 Historical Inundation and DEM Metrics as Terrain Descriptors

The screening level assessment regionalized the St. Johns River wetlands into segments (Figures 1 and 6) based on descriptions of geomorphology, vegetation and soils, as well as on modeled changes in hydrology. Vegetation and soil differences between segments are provided in Appendix B, Description of River Segments Used in WSIS Study, of Chapter 2, Comprehensive Integrated Assessment. Vegetation and soils are not input to the HT, but geomorphology in the form of a DEM is a major input to the HT. Further, DEMs can be used to identify and quantify geomorphologic differences between segments, based on metrics such as (1) area of the River floodplain, (2) histogram of elevation and (3) histogram of slope. These DEM-based metrics are useful for comparing HT results between segments and for making predictions about the withdrawal effects in areas where HT analysis was not conducted.

3.3.1 River Floodplain

The River floodplain (Figure 23) is defined here as the area historically inundated by the River. It is determined with GIS using the highest stage values reported over the total period of record for the River stations shown in Figure 15 and interpolating a sloping flat pool (water surface) with the HT (HT process is shown in Figures 3 and 8; interpolation is shown in Figure 16). The area thus inundated defines the River floodplain. Once the River floodplain has been determined, the wetlands contiguous to the River are divided into two classes: River floodplain wetlands and the wetlands above the River floodplain. Wetlands above the River floodplain are displayed with hatches in Figure 23 for both segments. Wetlands above the River floodplain are a far greater proportion of Segment 7 than Segment 8. These areas have never been flooded by the River historically but are hydrated by other sources, such as precipitation, overland flow, seepage and groundwater.

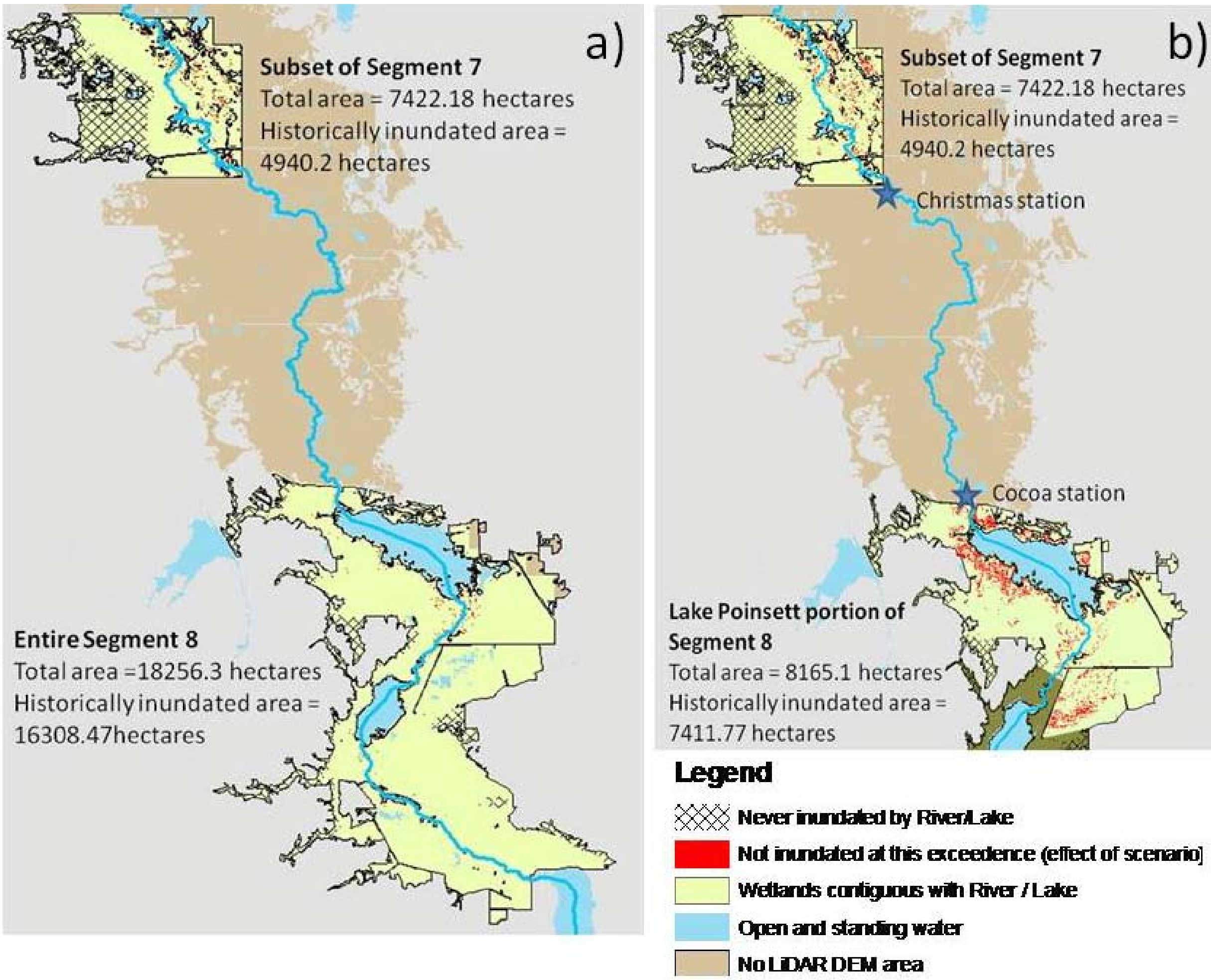


Figure 23. River floodplain. The area of contiguous wetlands historically inundated by the River, segments 7 and 8 are displayed in pale green. Panel a has the original Segment 8 area as reported in Chapters 10 and 13. Panel b displays a subset of Segment 8 which was created to facilitate comparison of results between the two Segments. The Segment 7 study area is 63% of the area of the Segment 8 study area shown in panel b.

3.3.2 Modification of Segment 8 Study Area

Terrain shape (geomorphology) contributes to the magnitude of the impact of a surface water withdrawal scenario. For example, if an area is characterized by a large plateau and/or shallow slope, a relatively small change in water elevation can result in a large areal extent of impact if that change in water elevation occurs at the elevation of the plateau/shallow slope. Terrain shape can be quantified by producing histograms of elevation and slope for the DEM (ESRI, 2011).

Unfortunately, the overall DEM (or study area) size was very different for the two segments confounding comparison of DEM-based results (Figure23, panel a). The total area of contiguous wetlands (DEM area) for HT analysis for segment 8 was more than 18,250 hectares while the area from Segment 7 was less than 7,500 hectares. In order to facilitate comparison of histograms of elevation and slope between the two segments, a subset DEM of Segment 8 was created (Figure 23, panel b) based on known drainage patterns around Lake Poinsett, resulting in a smaller Segment 8 DEM total area of just under 8,200 hectares.

Comparison of the areal extent of the two study areas shown in Figure 23b resulted in the Segment 7 study area being 63% the size of the Segment 8, providing a normalization factor for comparison of DEM metrics. Both the histograms of elevation (Figure 24) and slope (Figure 25) for Segment 8 were based on the smaller area shown in panel b of Figure 23.

This two-step process (area reduction and then normalization) was deemed more appropriate than a single process of normalization because the terrain in the Segment 8 DEM varied considerably while the terrain in the Segment 7 area was more uniform. Additionally, a number of management structures characterizes the southern portion (upstream of Lake Poinsett); comparable structures are not found in the Segment 7 area.

3.3.3 Histogram of Elevation

Figure 24 provides the distribution or histogram of elevation for corrected DEMs for both the Segment 7 and the Lake Poinsett portion (subset) of Segment 8. The Segment 8 DEM has a very high proportion of elevation between 3.5 and 4 meters, describing a very large flat plateau between the water's edge and uplands. The Segment 7 DEM is not characterized by such a large plateau area. An additional DEM feature to note is that the lowest land elevations (< 2.5 meters) in the Segment 8 DEM were essentially lost from LiDAR detection due to standing water on the wetlands at the time of LiDAR data acquisition for this area. The Segment 7 DEM does not appear to have been affected this way. This limitation of the Segment 8 DEM was determined to be inconsequential to HT results, because it represents a very small portion of the study area (< 5 %) and occurs at water levels determined to experience minimal change due to withdrawals based on modeling parameters.

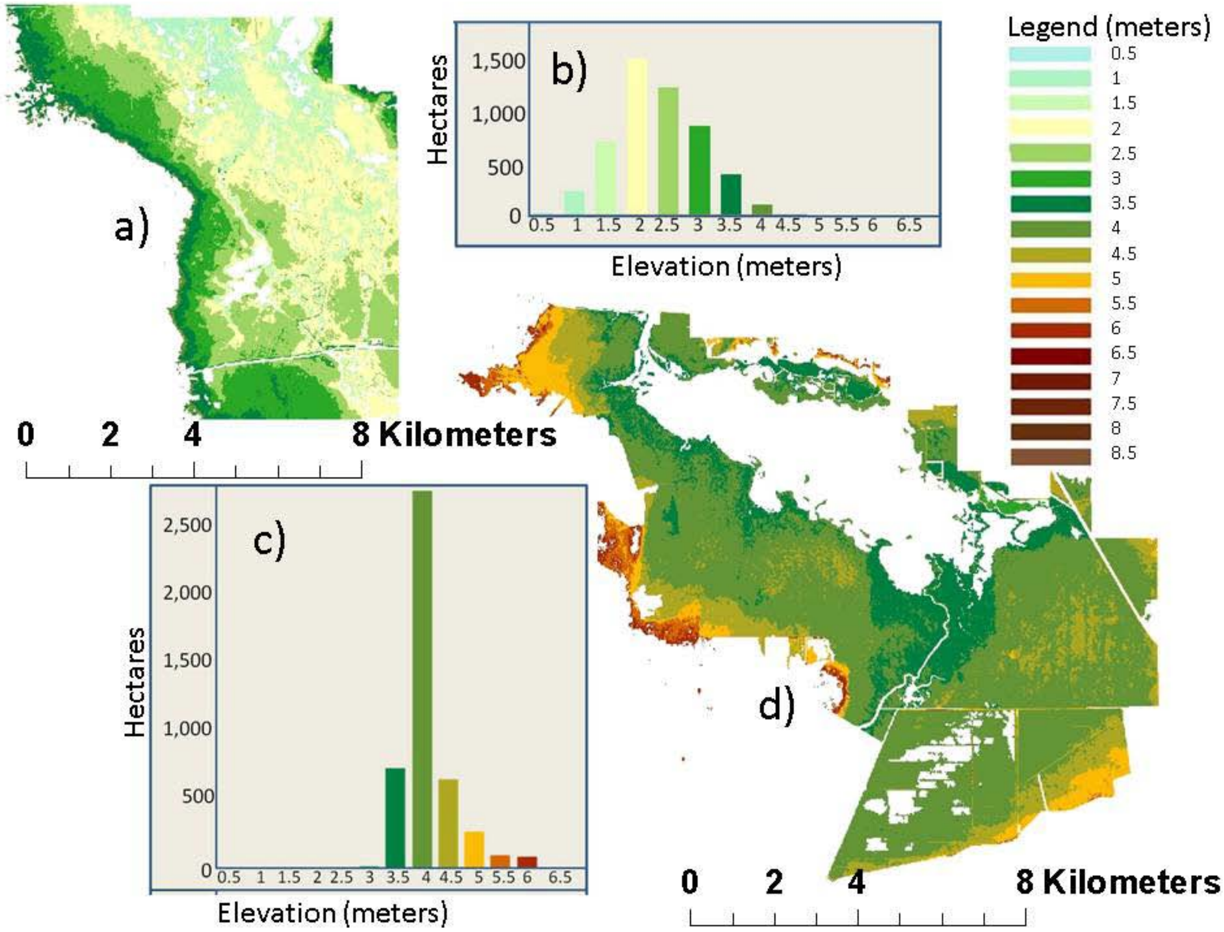


Figure 24. Distribution of DEM elevation within the St. Johns River floodplain. a) Segment 7 DEM. b) Histogram demonstrating the distribution of elevation in segment 7 DEM. c) Histogram demonstrating the distribution of elevation in segment 8 DEM. d) Segment 8 DEM. The legend is for both Figures and histograms. Note that Segment 8 is devoid of elevations less than 3.5 meters. This is due to standing water at the time the LiDAR data was flown, which partially covered the wetlands, obscuring the ground from the LiDAR signal in those areas. This can be most easily observed in the southern part of the DEM where there are “empty spaces” of no data. It was determined that less than 5% of the entire study area was affected by standing water.

3.3.4 Histogram of Slope

Grid cell slope or the rate of maximum change in z-value (elevation) for each cell, for the two DEMs, is shown in Figure 25. The Segment 8 DEM is dominated by the 0 to 0.17 degree slope class, likely due to the large plateau described in Figure 24.

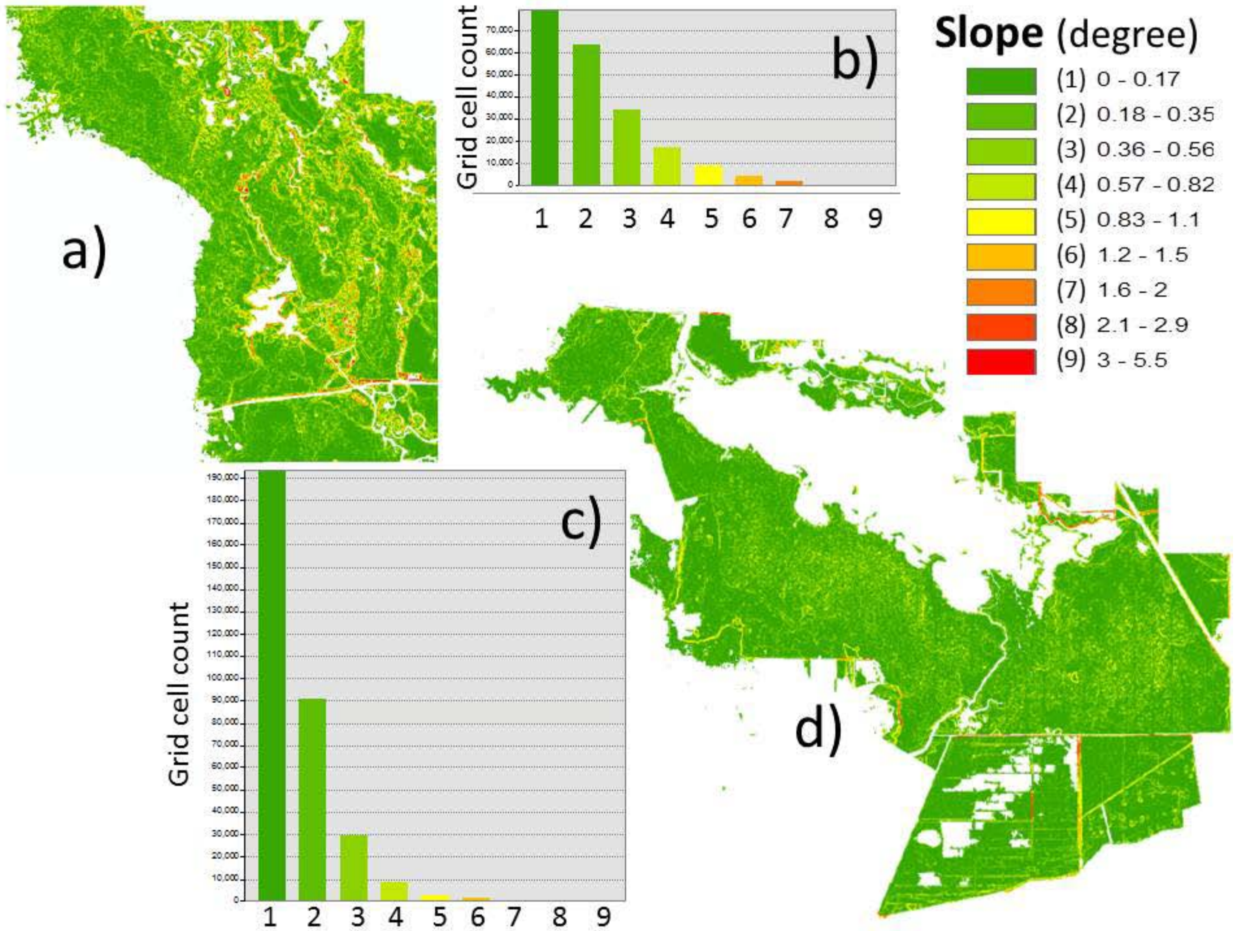


Figure 25. Distribution of DEM slope within St. Johns River floodplain. a) Segment 7 slope raster. b) Histogram demonstrating the distribution of slope in Segment 7 DEM, c), Histogram demonstrating the distribution of slope in Segment 8 DEM, d) Segment 8 slope raster. Legend is for both Figures and histograms. Segment 7 grid cell size = 15. 24 meters. Segment 8 grid cell size = 15 meters.

3.4 Water Surface Interpolation Method

Of the three main surface interpolation methods available with the HT (inverse distance weighted, spline and Kriging) the method that produced water surfaces most closely resembling a sloping flat pool for Segment 7, using relatively few accessory points, was the spline method (Figure 26). The inverse distance weighted method produced pronounced pits around the GIS points (the interpolation or accessory points shown in Figure 16), regardless of the number of points used and their placement. The Kriging method required many more accessory points and produced a surface less like a sloping flat pool than the spline method. The spline method resulted in a uniform reduction in elevation in keeping with the River stage measurements (stations shown in Figure 15) and the goal of producing a surface similar to a sloping flat pool. The banding appearance in Figure 26 is an artifact of the symbolization method in the GIS (classified, as opposed to stretched) but clearly demonstrates the even pattern of surface elevation change, suggesting a sloping flat pool. Once determined for an area (DEM), the interpolation method and its parameters remain constant over the course of HT analysis.

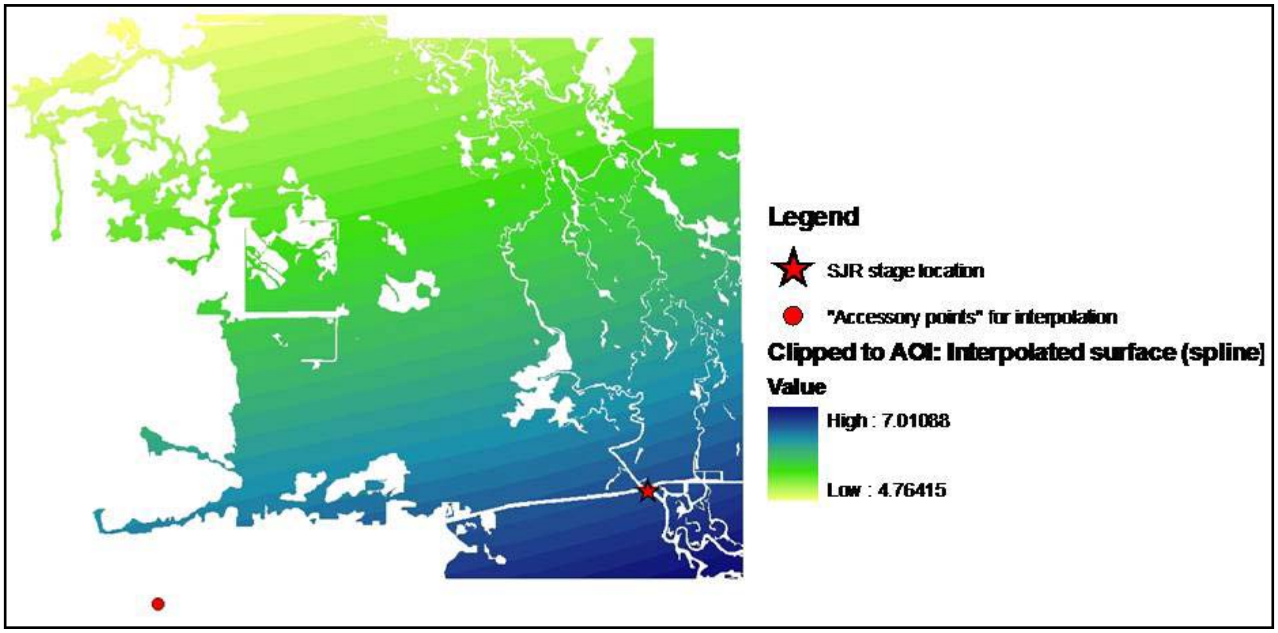


Figure 26. Interpolated surface for Segment 7 study area using the spline method. The banding pattern is an artifact of the classified symbolization (rather than stretched) in the GIS but more clearly shows that a surface described by a sloping flat pool was approximately achieved.

3.5 Change Analysis, FULL1995NN

Results for Segment 7 change analysis based on the FULL1995NN scenario fall in the following categories:

- Total area dewatered and hectare-days impact
- Wetland communities affected by withdrawal scenario, in dewatered areas
- Distribution of the change in ponded depth in dewatered areas
- Change in area of inundation
- Change in ponded depth in inundated areas

The first three categories represent the HT approach taken in Chapter 10, Wetlands Vegetation, focusing on the area that was inundated historically but is inundated for fewer days following the withdrawal scenario at a given exceedence (dewatered). The last two represent the HT approach taken in Chapter 13, Floodplain Wildlife, focusing on the area that remains inundated following the withdrawal scenario, its change in areal extent and ponded depth. Differentiation between the HT change analysis response areas is provided in Figure 17 (provided again below, with additional comments).

To facilitate comparison between segments, results of the Segment 7 HT change analysis are presented in the format and symbolization used for the Figures and Tables for HT results from Chapters 10 and 13, Wetland Vegetation and Floodplain Wildlife, respectively.

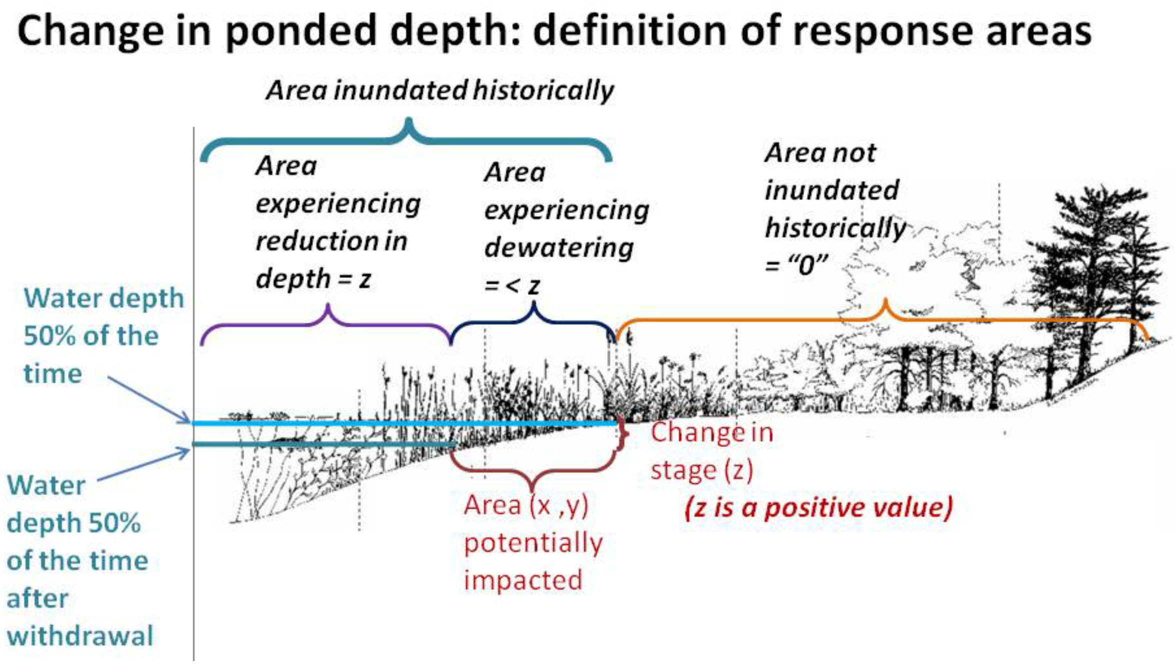


Figure 17. Summary of aerial results for change in ponded depth, HT results. The area of focus for the Wetland Vegetation study is the "Area experiencing dewatering". The areas of interest to the Floodplain Wildlife study are both the "Area experiencing dewatering" and the "Area experiencing reduction in depth". (Wetland cross section Figure from *http://www.newp.com/pdf/NEWP_WetlandCrossSection.pdf*)

3.5.1 Total Area Dewatered and Hectare-Days Impact

Dewatered is defined here as fewer days of inundation. Dewatered areas were inundated historically at a given exceedence % (time period), but are not inundated at that same exceedence % following the withdrawal scenario (Figure 17).

Figure 27 and Table 8 contain results of the total areal extent and the hectare-days calculation of the effect for the FULL1995NN withdrawal scenario on Segment 7. Figure 28 and Table 9 contain FULL1995NN results for Segment 8 from the Wetlands Vegetation chapter.

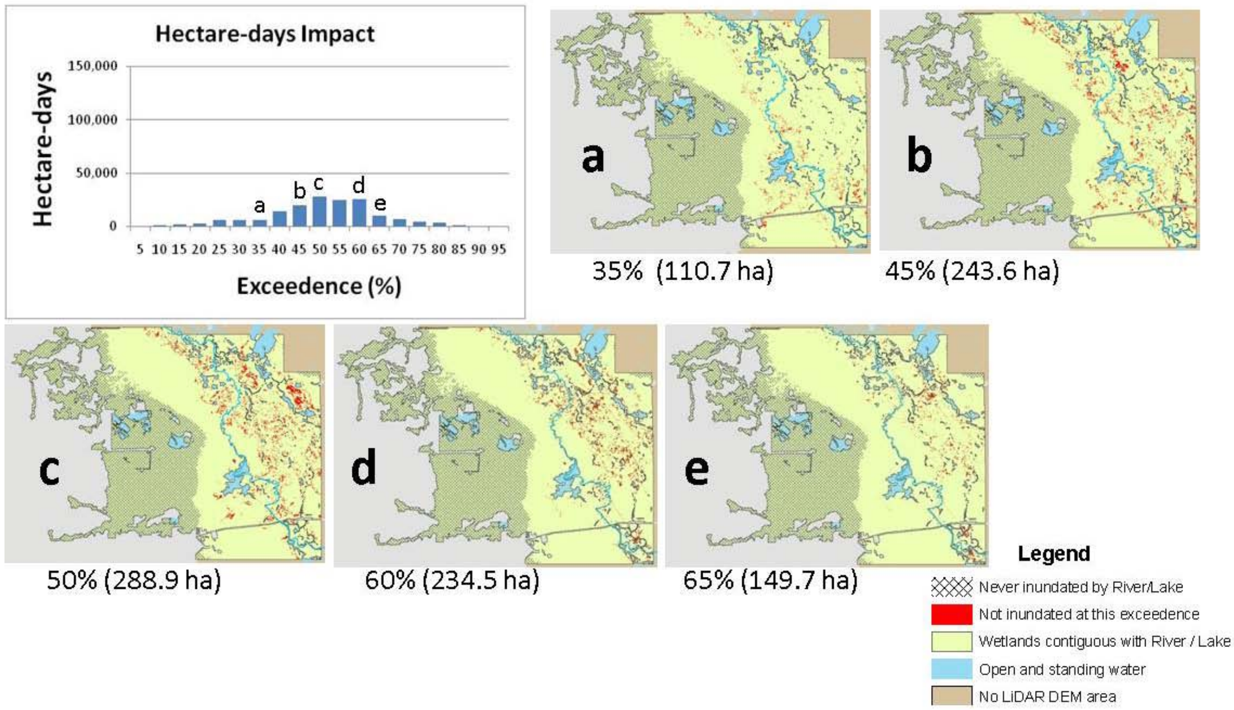


Figure 27. Areal extent and hectare-days effect of FULL1995NN scenario on Segment 7. Panels a through e are examples of dewatered areas experiencing fewer days of inundation at selected exceedences. Hectare-days effect at all exceedences shown in Figure in upper left corner.

A total of 2,042 hectares are affected in Segment 7 (over the entire exceedence range studied), which is just under 28% of the entire Segment 7 study area (Table 8). As with Segment 8 HT analysis, the greatest effect occurs at the 50% exceedence. 289 hectares that were inundated historically 50% of the time in this portion of Segment 7 are not inundated following the FULL1995NN scenario at this exceedence level.

A total of 5,014 hectares are affected in Segment 8, 27.5% of the total study area (Table 9). Direct comparison of percentage of hectares affected is confounded by the large area in the southern portion of Segment 8 that was not impacted at all by the water withdrawal (see Chapter 10). Most of the impact in Segment 8 occurred around Lake Poinsett.

Direct comparison of the matching hectare-days impact by exceedence charts between Figures 27 and 28 is difficult because of the much larger area of the Segment 8 DEM (HT analysis not redone with smaller area). However, the hectare-days impact for 50% exceedence (c) in the Segment 7 histogram (Figure 27) is only slightly greater than for the other exceedences, while the comparable hectare-days value is markedly higher for Segment 8 (Figure 28) at the 50% exceedence level. This indicates that, particularly at the 50% exceedence, the impact of the FULL1995NN withdrawal scenario on Segment 8 is greater than on Segment 7. Further, Table 10 compares hectare-days impact in Segments 7 with the subset of Segment 8 (the Lake Poinsett drainage) and the normalized area of Segment 8. Based on the results of area normalization, Segment 8 would experience more than 275,000 hectares-days impact, while Segment 7 would experience less than 200,000 hectare-days impact, due to the FULL1995NN scenario.

Table 8. Wetland area affected in River Segment 7, FULL1995NN Scenario. Percentage of total area calculated based on project area of 7,422 hectares.

FULL1995NN % exceedence	Area impacted (hectares)	Maximum # fewer days inundated (over 10 years)	Area impacted as % total area	Maximum hectare-days impact (over 10 years)
5	31.4	19	0.42	585
10	37.1	28	0.50	1,051
15	51.8	47	0.70	2,433
20	70.5	48	0.95	3,354
25	80.1	97	1.08	7,788
30	90.7	80	1.22	7,246
35	110.7	70	1.49	7,699
40	175.2	99	2.36	17,382
45	243.6	98	3.28	23,833
50	288.9	115	3.90	33,084
55	266.4	114	3.59	30,407
60	234.5	136	3.16	31,846
65	149.7	87	2.02	13,088
70	91.4	94	1.23	8,602
75	51.5	110	0.69	5,653
80	40.3	101	0.54	4,083
85	23.9	65	0.32	1,557
90	4.2	31	0.06	130
95	0.0		0.00	0
Total	2041.9		27.53	199,820

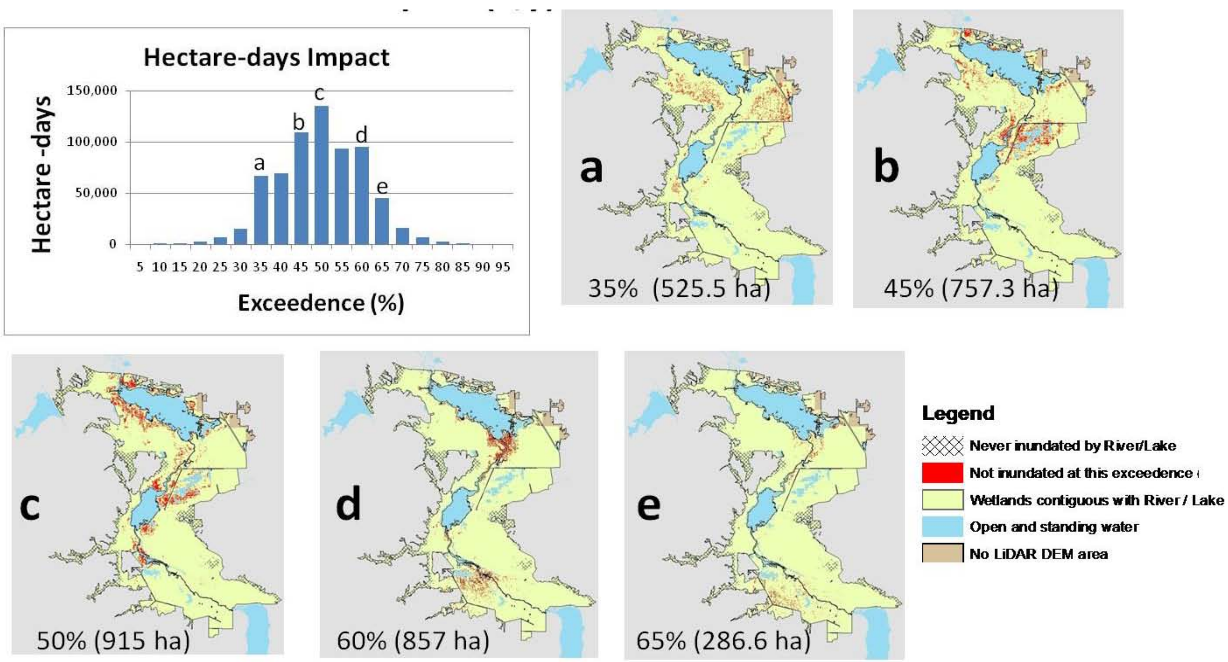


Figure 28. Areal extent and hectare-days effect of FULL1995NN scenario on Segment 8. Panels a through e are examples of dewatered areas experiencing fewer days of inundation at selected exceedences. Hectare-days effect at all exceedences shown in Figure in upper left corner. (Figure 4-26 in Wetlands chapter). Note the very small area in the northeastern portion not covered by LiDAR.

Table 9. Wetland area affected in River Segment 8, FULL1995NN Scenario. (Table 4-22 in Chapter 10, Wetlands Vegetation).

FULL1995NN % exceedence	Area impacted (hectares)	Maximum # fewer days inundated (over 10 years)	Area impacted as % total (ha)	Maximum hectare-days impact (over 10 years)
5	18.7	11	0.10	206
10	30.9	23	0.17	712
15	37.5	13	0.21	487
20	73.5	32	0.40	2,353
25	128.9	53	0.71	6,830
30	224.3	68	1.23	15,254
35	525.4	127	2.88	66,732
40	666.1	104	3.65	69,273
45	753.6	145	4.13	109,266
50	914.9	148	5.01	135,410
55	600.3	156	3.29	93,653
60	587.0	162	3.22	95,095
65	286.6	157	1.57	44,989
70	107.1	150	0.59	16,066
75	32.9	204	0.18	6,720
80	14.9	151	0.08	2,243
85	6.4	177	0.03	1,125
90	4.3	77	0.02	333
95	1.1	36	0.01	41
Total	5014.5		27.47	

Table 10. Comparison of hectare-days impact resulting from the FULL1995NN scenario for Segment 7 and the Lake Poinsett subarea of Segment 8.

	SEGMENT 7 (CONE LAKE)		POINSETT (SEG8)		0.63
% exc	fewer days of inundation	ha days (10 years)	fewer days of inundation	ha days (10 years)	normalized to Seg 7 (Cone)
5	19	585	11	63	40
10	28	1,051	23	267	168
15	47	2,433	12	186	117
20	48	3,354	32	1,389	875
25	97	7,788	53	4,724	2,976
30	80	7,246	68	13,047	8,219
35	70	7,699	127	59,589	37,541
40	99	17,382	101	60,864	38,344
45	98	23,833	145	88,691	55,875
50	115	33,084	148	91,495	57,642
55	114	30,407	136	43,646	27,497
60	136	31,846	162	48,960	30,845
65	87	13,088	157	16,460	10,370
70	94	8,602	148	5,376	3,387
75	110	5,653	204	2,028	1,278
80	101	4,083	77	151	95
85	65	1,557	70	153	97
90	31	130	40	32	20
95		-	6	-	-
		199,820		437,120	275,385

3.5.2 Wetland Communities Affected by Withdrawal Scenario

Table 11 provides the compiled results for all exceedences of vegetation communities experiencing fewer days of inundation due to the FULL1995NN scenario for Segment 7. Freshwater marshes are by far the most affected by this scenario, as is the case with Segment 8 (Table 12). The FULL1995NN scenario effects 22% of the wetlands in the Segment 7 study area, while 28% of the wetlands in Segment 8 study area are impacted by the FULL1995NN scenario.

Table 11. Effect of FULL1995NN by wetland community for Segment 7. Extent of area inundated for less time (dewatered) totaled over all exceedences. Wetland communities defined by SJRWMD Land Cover/Land Use 2004.

		Hectares	
			Inundated for less time by scenario
LULC code	LULC wetland class	Study area total	FULL1995NN
6110	Bay swamps (if distinct)	7.1	-
6170	Mixed wetland hardwoods	594.6	54.1
6181	Cabbage palm hammocik	1,683.7	76.2
6210	Cypress	293.6	27.4
6220	Pond pine	2.0	-
6250	Hydric pine flatwoods	24.6	-
6300	Wetland forested mixed	313.8	2.7
6410	Freshwater marshes	3,025.9	1,270.6
6430	Wet prairies	417.4	43.8
6440	Emergent aquatic vegetation	258.9	22.0
6460	Mixed scrub-shrub wetland	486.7	70.7
6500	Non-vegetated wetland	3.4	0.8
	Water	195.0	63.8
	Other (uplands)	109.7	-
	total (hectares)	7,416.3	1,632.1
	total (hectares) wetlands only	7,111.6	1,568.3
	% total wetlands impacted		22%

Note that the reported total percentage of wetlands affected in Segment 7 (22%, Table 11) in this section differs from that that reported in the previous section (27.5%, Table 8). A disparity occurs for Segment 8 in Tables 12 and 9. This is due to two inadvertent effects of data management within GIS:

1. The incorporation of non-wetland areas into the final DEM area. This occurred in the process of DEM aggregation, which essentially enlarged the study area beyond the original contiguous wetland boundary (increase of about 300 hectares), thereby including a small amount of both upland and open water areas in the final study area (7,422 hectares in DEM compared to 7,112 hectares of true wetlands within same boundary).
2. The areal generalization that occurred when raster data is summarized using vector data. Of the two data management issues, this could be avoided by modifying the processing step in which the results from the change analysis are converted to polygons.

To account for these issues, corrections were made in the process of summarizing the results, specifically for the wetland classes affected, resulting in a total of 7,112 hectares in the Segment 7 study area and 17,942 hectares in the Segment 8 study area. Segment 8 was not affected by the GIS issues as much as Segment 7 primarily due to the inadvertent incorporation of more water in Segment 7 than in Segment 8 (195 hectares of water in Segment 7 equals nearly 3% of the total area, 93 hectares of water in Segment 8 is 0.5% of the total area). Note that when comparing results between segments, consistent management of the results across analysis step was maintained. In other words, Table 8 and 9 used the same method to calculate change overall (including uplands and open water) and Tables 11 and 12 used the same methods to calculate change specifically for the wetland communities polygons from the LULC dataset.

Table 12. Effect of FULL1995NN by wetland community for Segment 8 (all). Extent of area inundated for less time (dewatered) totaled over all exceedences (excerpted from Table 4-21 in Wetlands chapter). Wetland communities defined by SJRWMD Land Cover/Land Use 2004.

		Hectares	
			Inundated for less time by scenario
LULC code	LULC wetland class	Study area total	FULL1995NN
6170	Mixed wetland hardwoods	1,500.9	25.4
6181	Cabbage palm hammocik	798.2	12.5
6210	Cypress	321.73	63.7
6250	Hydric pine flatwoods	41.36	-
6300	Wetland forested mixed	336.51	3.3
6410	Freshwater marshes	5,794.76	2,713.2
6430	Wet prairies	3,103.27	767.0
6440	Emergent aquatic vegetation	205.61	105.9
6460	Mixed scrub-shrub wetland	3,243.16	1,063.0
9999	USJRB restoration areas	2,596.3	180.3
	Water	92.6675	-
	Other (uplands)	221.9	-
	total (hectares)	18,256.3	4,934.3
	total (hectares) wetlands only	17,941.7	
	% total wetlands impacted		28%

3.5.3 Distribution in the Change in Ponded Depth in Dewatered Areas

Change in ponded depth for the areas experiencing dewatering in Segment 7 is shown in Figure 29 for the same selected exceedences shown in Figure 27. For Segment 7, these areas experienced a ponded depth ranging from 1 to 9 cm historically but are not inundated at this exceedence % following the withdrawal scenario. Compare to Figure 30 for the Segment 8 FULL1995NN distribution of change in ponded depth (based on the original Segment 8 DEM area, shown in Figure 19, panel a). Direct comparison of the matching exceedence histograms between Figures 29 and 30 is difficult because of the much larger area of the Segment 8 DEM, resulting in larger bars representing more area in hectares. Scale of both x and y axes are consistent between figures 29 and 30. The distribution of the change in ponded depth in dewatered areas is most useful for comparing the effect between exceedences and/or between scenarios within the same area, as was performed for Segment 8 in Chapter 10.

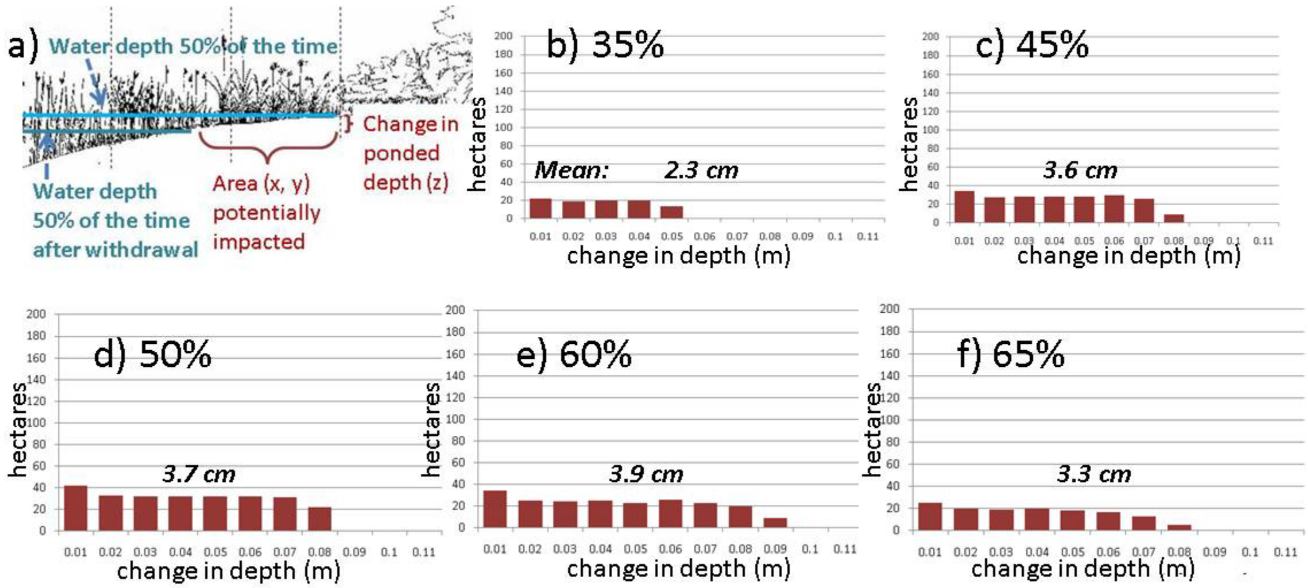


Figure 29. Distribution of change in ponded depth for areas experiencing fewer days of inundation following FULL1995NN scenario in Segment 7. Selected exceedences are the same as those shown in Figure 27.

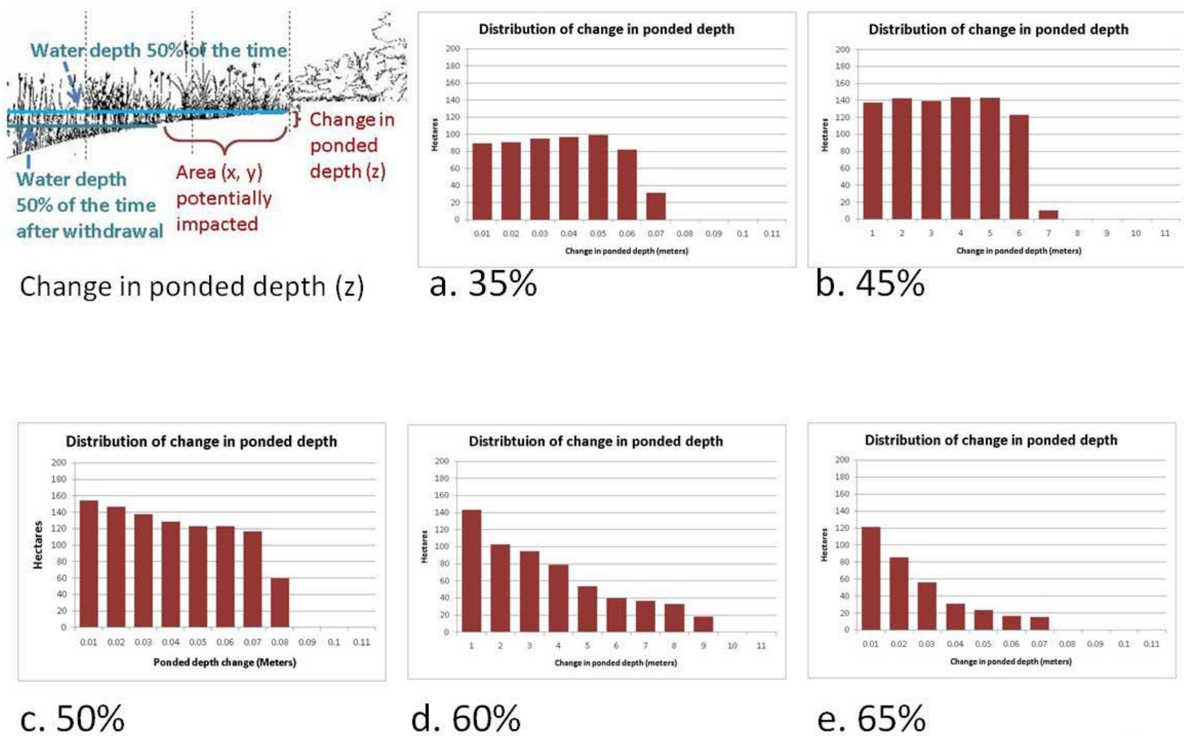


Figure 30. Distribution of change in ponded depth for areas experiencing fewer days of inundation following FULL1995NN scenario in Segment 8. Selected exceedences are the same as those shown in Figure 28.

3.5.4 Change in Area of Inundation

A different approach to analyzing and symbolizing HT results was taken for Chapter 13, Floodplain Wildlife, by focusing on the area that remains inundated following the withdrawal scenario (Figure 17). Figure 31 compares the area in Segment 7 that is inundated at the 50% exceedence for the historic condition and following the FULL1995NN scenario. Approximately 1,908 hectares of wetlands were inundated historically while approximately 1,619 hectares are inundated following the withdrawal scenario, a 15% reduction. Compare to Figure 32, which shows the area inundated at 50% exceedence under the FULL1995NN scenario for Segment 8. Approximately 6,193 hectares were inundated historically at 50% in Segment 8, but only approximately 5,278 hectares are inundated following the withdrawal scenario, also a 15% reduction. Note that most of the effect occurs around Lake Poinsett, with little change occurred in the southern portion of the Segment 8 area (Figure 28, panel c) a consequence of the modeling parameters. The change to the areal extent of inundation due to the FULL1995NN scenario is much easier to see in the inset in Figure 32 for Segment 8 than in the inset in Figure 31 for Segment 7. Map scale is comparable in both figures.

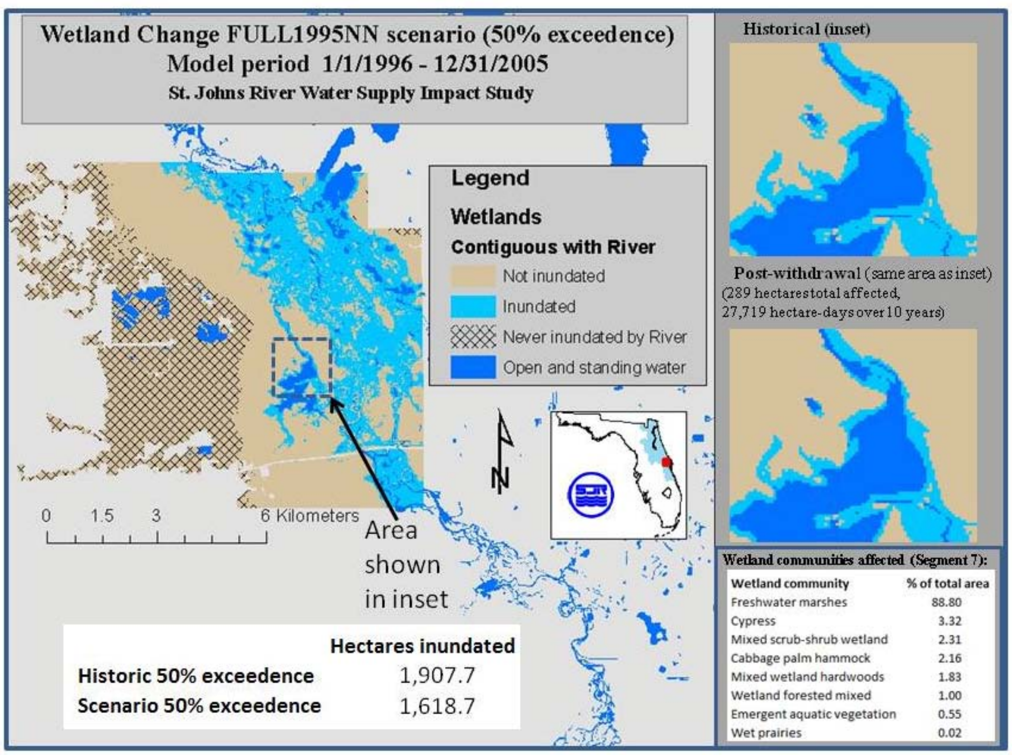


Figure 31. Wetland changes in the Cone Lake area of Segment 7 under the FULL1995NN scenario (see inset maps)

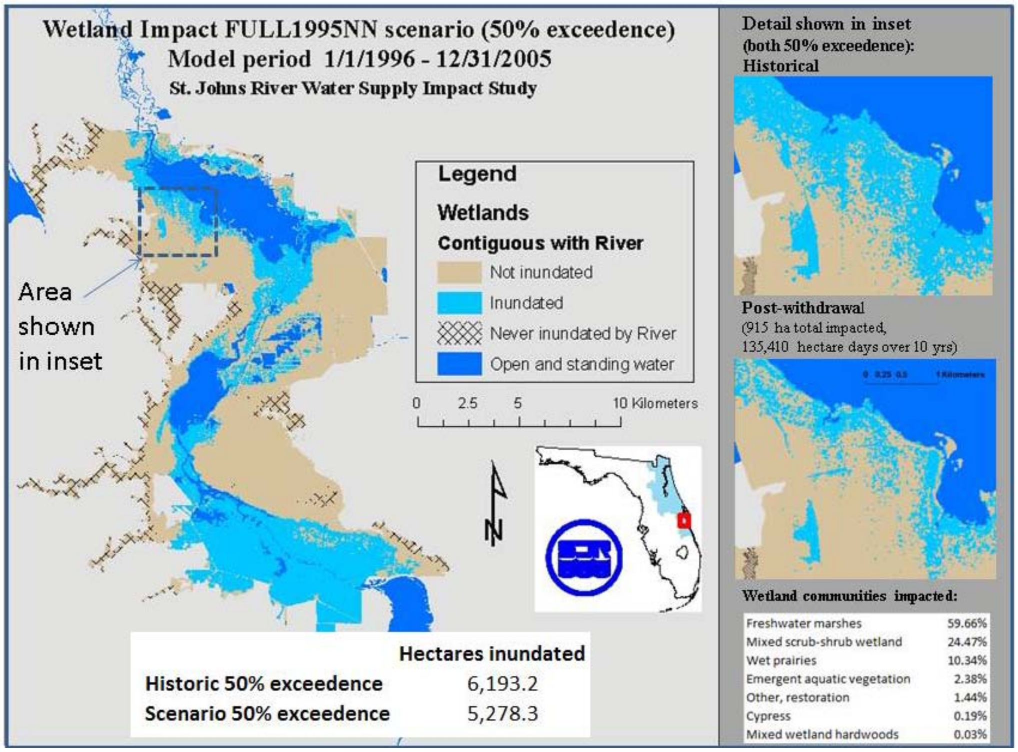
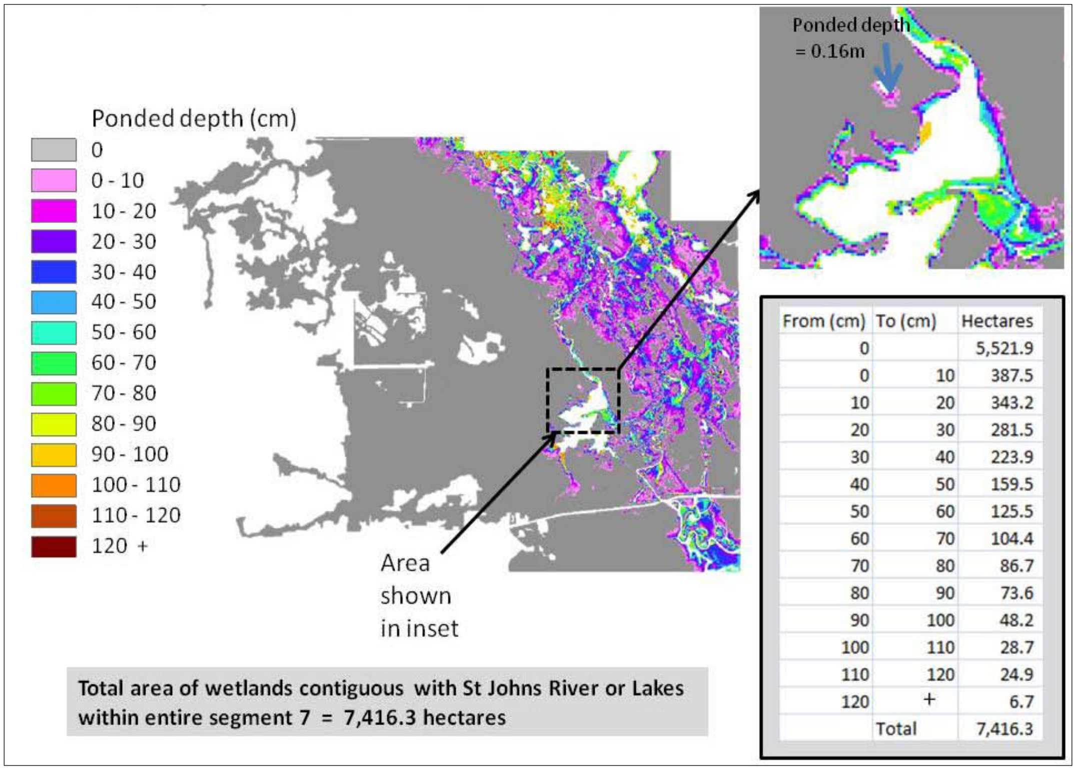


Figure 32. Wetland changes in the Lake Poinsett area of Segment 8 under the FULL1995NN scenario (see inset maps; Figure 16 in Floodplain Wildlife Chapter)

3.5.5 Change in Ponded Depth in Inundated Areas

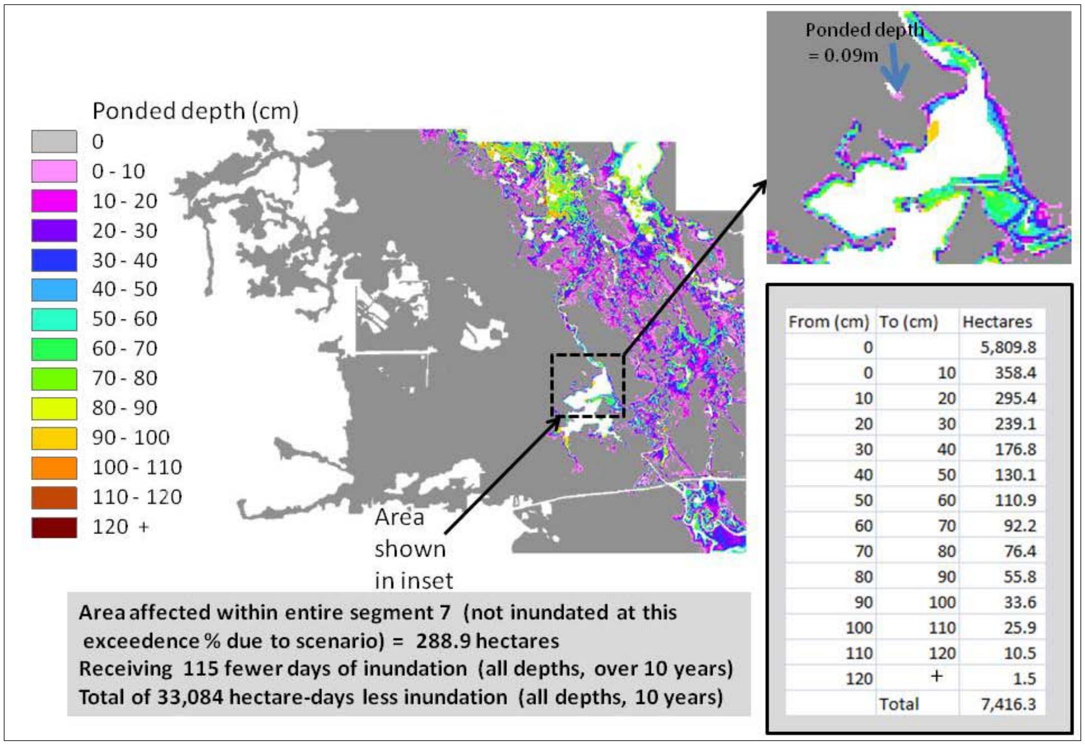
Along with the change in area of inundation depicted in Figures 31 and 32, the Floodplain Wildlife chapter focused on ponded depth in the area that remains inundated following withdrawal. Ponded depth results for Segment 7 are provided in Figures 33 through 35. Figure 33 is the ponded depth at the 50% exceedence for the historic condition, Figure 34 is ponded depth for 50% exceedence under FULL1995NN and Figure 35 is the difference between Figures 33 and 34 calculated using the ArcMap raster math function in the HT. The results in Figure 35 thus represent the change in ponded depth for Segment 7, including a histogram of the distribution of the change in centimeters, indicating that most of the area experienced a reduction in ponded depth between 7 and 8 centimeters at the 50% exceedence. To aid comprehension of the ponded depth change analysis process, each figure (Figures 33 through 35) identifies the ponded depth value of a specific grid cell in the inset. From the historic condition (Figure 33) the grid cell ponded depth value is 0.16 m, following the withdrawal scenario the ponded depth is 0.09 m (Figure 34) resulting in a change of 0.08 m (Figure 35).

Figures 36 through 38 display the comparable ponded depth analysis for Segment 8. The insets in the upper right hand corner of all the ponded depth figures (Figures 33–38) display at least one enlargement of a sample area adjacent to the water’s edge. The intent of providing a close up of an area is to highlight the effects of the withdrawal scenario visually because it is very difficult to discern from the full area view. Additionally, different areas within a given study area respond differently based on local terrain so the overall picture of impact for the entire area can be misleading. In the sample areas chosen for the two segments, change in ponded depth in the chosen sample area is more easily observed in the Segment 8 insets (Figures 36–38), than it is in the Segment 7 insets (Figures 33–35). Overall, it was difficult to find any area within Segment 7 that demonstrated as pronounced an effect of change in ponded depth as observed in the Segment 8 area, especially around Lake Poinsett.



From (cm)	To (cm)	Hectares
0		5,521.9
0	10	387.5
10	20	343.2
20	30	281.5
30	40	223.9
40	50	159.5
50	60	125.5
60	70	104.4
70	80	86.7
80	90	73.6
90	100	48.2
100	110	28.7
110	120	24.9
120	+	6.7
	Total	7,416.3

Figure 33. Segment 7 historic (baseline) ponded depths in area remaining inundated at the 50% exceedence.



From (cm)	To (cm)	Hectares
0		5,809.8
0	10	358.4
10	20	295.4
20	30	239.1
30	40	176.8
40	50	130.1
50	60	110.9
60	70	92.2
70	80	76.4
80	90	55.8
90	100	33.6
100	110	25.9
110	120	10.5
120	+	1.5
	Total	7,416.3

Figure 34. Segment 7 ponded depths for the FULL1995NN scenario at 50 percent exceedence.

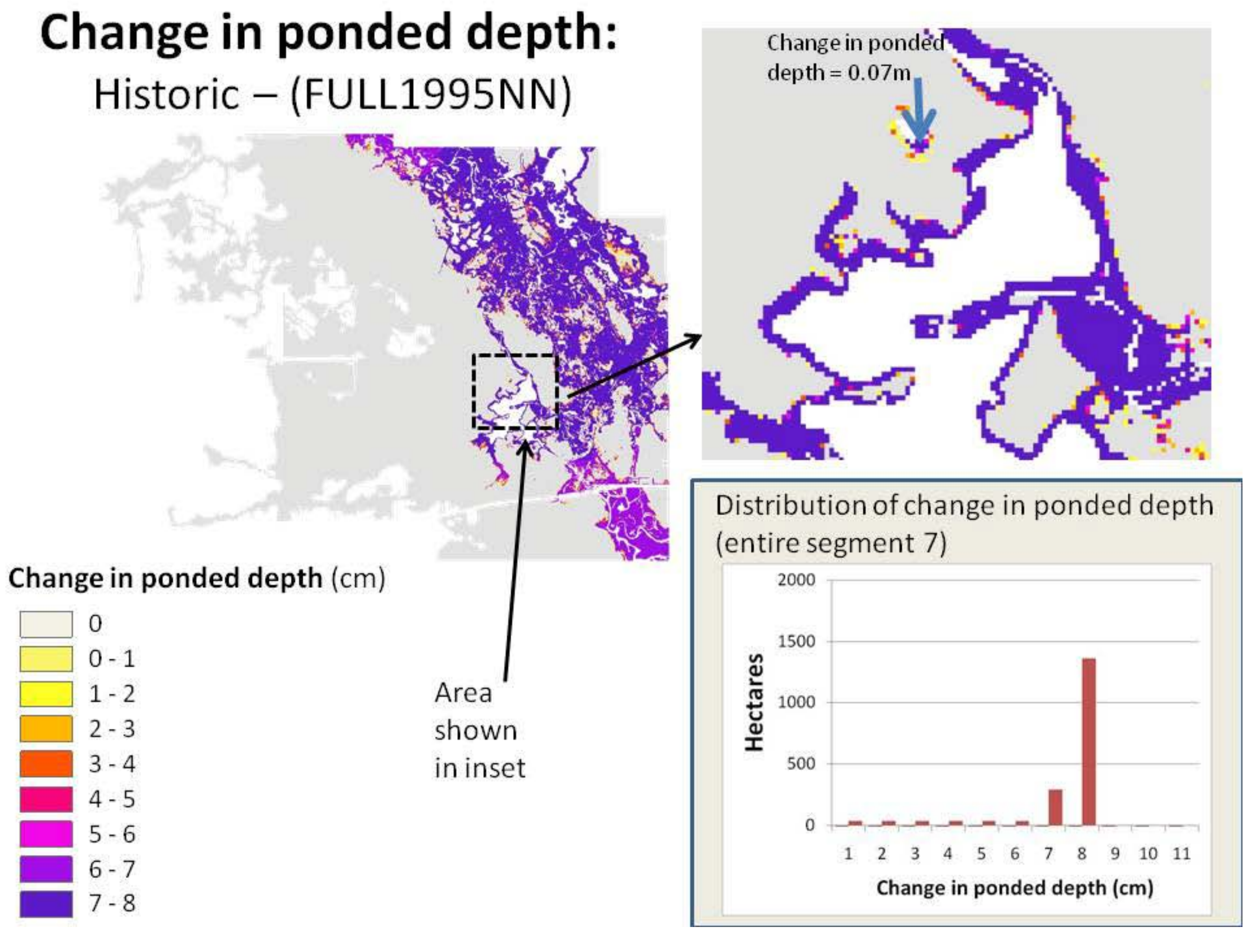


Figure 35. Change in ponded depth in areas remaining inundated resulting from FULL1995NN scenario for Segment 7 at 50 % exceedence. Refer to Figures 33 and 34, historic, and Full1995NN ponded depth respectively. Figure 35 is the result when the ponded depth in Figure 34 is subtracted from that in Figure 33. Area indicated by the arrow has ponded depth of 0.16 m historically at the 50% exceedence, 0.09 m following the FULL1995NN scenario, resulting in a change of 0.07 m (7 cm). Inset Figure, “Distribution of change in ponded depth” x-axis classes are in increments of 0–1, 1–2, 2–3, etc. Thus, class 8 represents change of 7–8 cm.

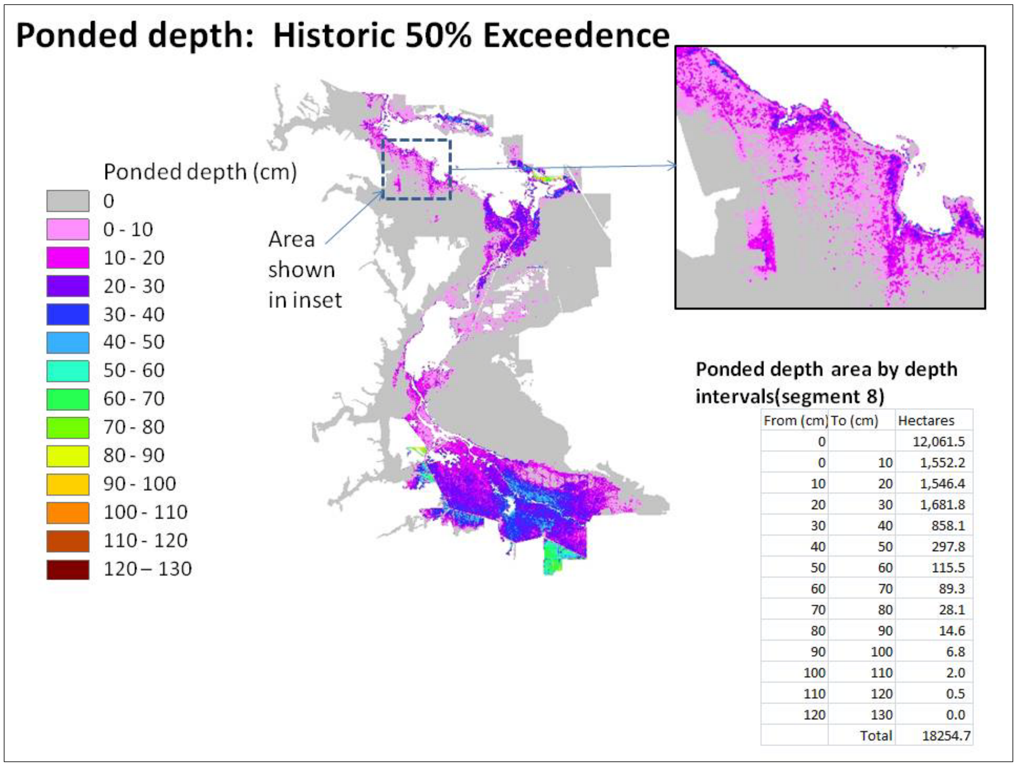


Figure 36. Segment 8 historic (baseline) ponded depths in area remaining inundated at the 50% exceedence. (From Chapter 13, Floodplain Wildlife)

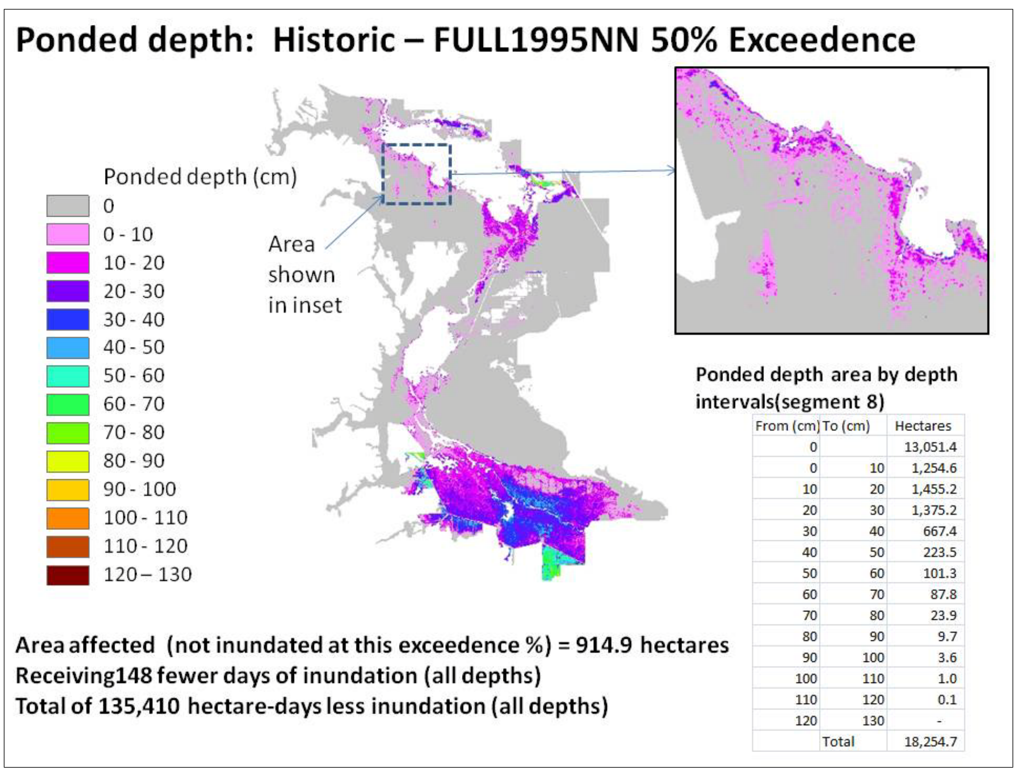


Figure 37. Segment 8 ponded depths for the FULL1995NN scenario at 50 percent exceedence. (From Chapter 13, Floodplain Wildlife)

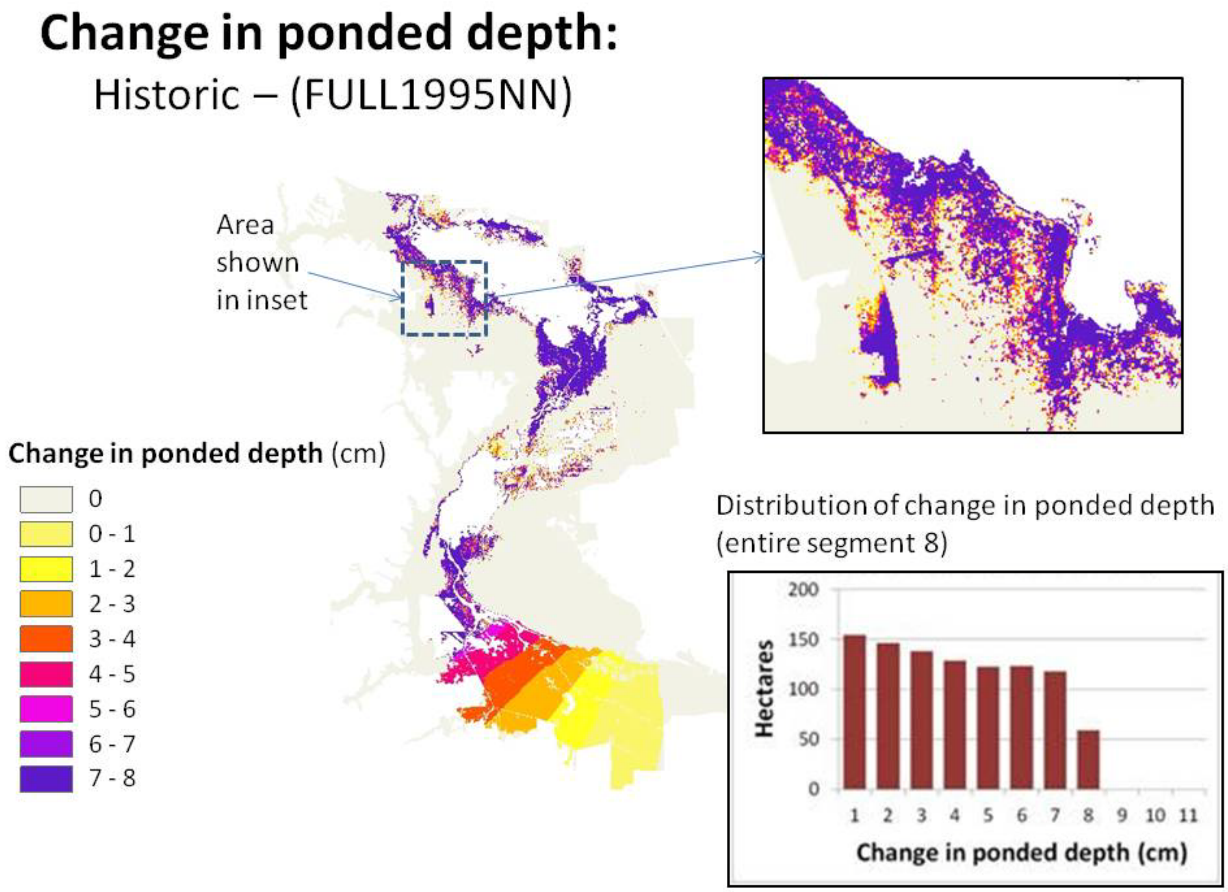


Figure 38. Change in ponded depth in areas remaining inundated at the 50% exceedence level for segment 8. Prepared for Floodplain Wildlife chapter, by subtracting results shown in Figure 37 from Figure 36. Note that most of the change is the result of areas that were historically being inundated no longer being inundated at this exceedence.

4 Discussion

Screening level assessment indicated that both Segments 7 and 8 had high likelihood of effects due to changes in stage based on vegetation, soils, dominant hydrogeomorphology and change in water levels (Table 2). Hydroperiod Tool (HT) analysis uses geographic information systems (GIS) to identify wetland areas potentially affected by change in water levels, quantifying the magnitude of the areal effect by both depth and duration. The results from HT analysis were used to compare the magnitude of effects from withdrawals based on the FULL1995NN scenario between Segments 7 and 8. HT analysis for Segment 8 covered four withdrawal scenarios for the area extending from the outlet of Lake Washington to the outlet of Lake Poinsett and is presented in detail in Chapter 10, Wetland Vegetation. WSIS project time constraints limited HT analysis for Segment 7 to a smaller geographic area and to only one withdrawal scenario.

The discussion of the results provided in this appendix cover four topics:

- Summary of the HT results for Segment 7
- Discussion of factors that confound comparison of HT results between segments
- Comparison of HT results for Segments 7 and 8, identifying the factors that determine the difference between their responses to the FULL1995NN scenario,
- Conclusions relevant to Chapter 10, Wetlands Vegetation.

4.1 Segment 7 Hydroperiod Tool Results

HT analysis of the FULL1995NN scenario effect on Segment 7 demonstrated that 2,042 (28%) of the total 7,422 hectares are affected over the nineteen exceedence levels studied (Table 8). The exceedence value at which Segment 7 experienced the greatest effect was 50% (289 hectares). The greatest effect as measured by hectare-days also occurred at the 50% exceedence. The distribution of the change in ponded depth for areas no longer inundated by the River following withdrawal ranged from 1 to 9 cm, with means ranging from 2.3 cm to 3.9 cm (Figure 29). The wetland community (based on SJRWMD Land Cover / Land Use 2004) most affected by the withdrawal scenario (over all exceedences) is Freshwater marshes (Table11). No other wetland community is heavily affected by this scenario. Areas remaining inundated at 50% exceedence level following withdrawal experienced a change in ponded depth mostly in the 6–8 cm range, with very little area experiencing changes less than this (Figure 35).

4.2 Factors Confounding Comparison of Hydroperiod Tool Results Between River Segments

A number of factors pertaining to the nature of the data used for HT analysis, as well as the study area terrain itself, can confound comparison of HT results between River Segments. A description of several of these factors and how they were dealt with for the WSIS follows: These are:

- Study area size and floodplain coverage
- Characteristics of the Digital Elevation Models
- Water surface interpolation methods
- Terrain characteristics

4.2.1 Study Area

In addressing the potential effects of study area on comparing HT results from different areas, two components must be addressed, study area size and floodplain coverage.

The original (and maximum) intended study area size was determined by the maximum upslope boundary of wetlands contiguous with the St. Johns River. Wetlands contiguous with the River, and/or the Lakes comprising the St. Johns River main stem, were defined by the SJRWMD 2004 Land Cover / Land Use layer, and are shown in Figure 23. Within this boundary, the study area is limited by the available LiDAR-derived DEMs' footprint, the area where LiDAR was flown based on project specifications. The resulting total study area of contiguous wetlands contained within the DEM for Segment 8 is 18,256 hectares and for Segment 7 is 7,422 hectares (Figure 23, panel a). In order to facilitate the comparison between the two segments, a subset (8,165 hectares) of Segment 8 (Figure 19, panel b) was created and partially analyzed for this appendix study. Additionally, HT results for Segment 8 were normalized to the area of Segment 7 (based on the ratio of their areas, Table 10).

Due to the limitation of available LiDAR data, floodplain coverage differed between the two segments. The Segment 8 DEM nearly extended "from upland to upland," missing only a very small portion of wetlands along the northeastern corner not covered by the LiDAR mission (Figure 28). In contrast, the Segment 7 study area was considerably more limited by the CFCA LiDAR footprint (Figure 10, partially displayed below). The resulting study area for Segment 7 includes the center and western portion of the floodplain, and extends to the uplands, but does not extend to the eastern portion of the floodplain. It was determined that a large enough portion of the floodplain wetlands are present within the Segment 7 study area, sufficient to consider the HT results to be representative of the segment and therefore sufficient to compare to the HT results for Segment 8.

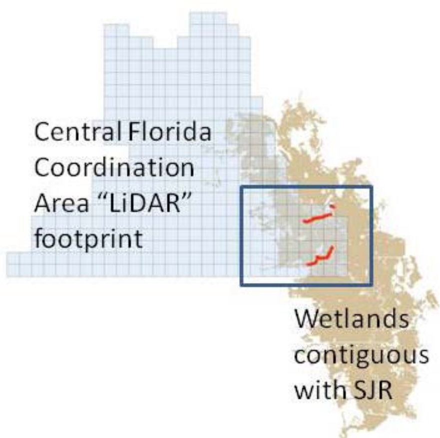


Figure 10 (portion). Incomplete coverage of wetlands by CFCA LiDAR footprint, Segment 7.

4.2.2 Digital Elevation Models

Based on the project specifications contained in the LiDAR survey reports for both Segments, the LiDAR input to and processing of the DEMs are comparable (Dewberry, 2009; 2010). Significantly, the same company (Dewberry) was the primary contractor for both projects. Both

DEMs were converted from NAVD 1988 to NGVD 1929 by the SJRWMD Information Technology Division using Vertcon (USACE, 2004).

The USGS USJRB DEM (Segment 8) was slightly diminished in value due to the loss of the lowest elevation areas from the DEM because of standing water on wetlands at the time of LiDAR acquisition (see **Histogram of elevation**, figure 24). This impairment of the Segment 8 DEM is considered minimal (loss of less than 5% of the total wetlands historically inundated by the River or Lakes), because most of the withdrawal effects occurred at mid-elevations (Figure 28, Table 9), well upslope of the River or Lake edge. This was the case with all four scenarios (see Chapter 10, Wetlands Vegetation). The CFCA (Segment 7) DEM did not appear to have standing water on any wetland area since the LiDAR was flown during low River stages.

Both DEMs were corrected using factors derived from surveyed elevation data provided by the SJRWMD Minimum Flows and Levels program. Four correction factors were arrived at based on wetland community aggregates for the USGS USJRB (Segment 8) DEM while only one correction factor could be justified for the CFCA (Segment 7) DEM. The different corrections for LiDAR bias in wetland vegetation could have an impact on making a comparison of results for the two Segments. Although a near zero (-0.03 m) median error was achieved for the Segment 7 DEM based on all transects, error calculated for each individual transect was somewhat greater (Table 7). Thus, the Segment 8 DEM might be considered to be a better representation of true bare earth than the Segment 7 DEM. There did not appear to be a spatial pattern to the correction error for the Segment 8 DEM. That is likely not the case for the Segment 7 DEM because of the range in individual transect error (Table 7). The northern area (near the Ruth and H-1 transects) is likely to have experienced a least some over-correction, while the southern area (near M-6 and Cone) is likely to have experienced some under-correction. However, both correction methods arrived at median errors of zero or near-zero, indicating balanced error models. In other words, for every over-correction there was an equivalent under-correction. The resulting corrected DEMs can be considered to be the best available representation of terrain for the two Segments and thus are comparable for purpose of HT analysis.

Both DEMs were aggregated to approximately 15 m grid cell size to optimize HT processing time.

4.2.3 Water Surface Interpolation Method

Different interpolation methods were employed to create the water surfaces for HT analysis for the two Segments (Figure12). Water surface interpolation for Segment 7 employed the spline method with relatively few accessory points, while the best results for Segment 8 were achieved with the Kriging method employing a very large number of accessory points. The selection or determination of different interpolation methods for the two segment areas can be attributed to the position of the stage recorders within the River (Figure 15) in relation to the study areas and to the general shape or bending of the River within each Segment (Figures 1 and 6). Each interpolation methods achieved the “sloping flat pool” effect that was desired for the analysis for its respective segment. The interpolation methods were employed consistently throughout the respective HT runs.

4.2.4 Terrain Characteristics

The two Segments are described in detail in Appendix B, Description of the St. Johns River Floodplain, Chapter 2, Comprehensive Integrated Assessment. Segment 7 is referred to as the State Road 50 segment and is characterized by multiple braided river channels, a terrain very distinct from that of Segment 8 ("Chain of Lakes") which is dominated by Lakes Poinsett and Winder.

Three DEM-based correlates of geomorphology were used to compare the segment study areas; (1) historical inundation patterns (River floodplain), (2) histogram of elevation and (3) histogram of slope. The River floodplain (light green, not hatched in Figure 23) is proportionally much greater in Segment 8, compared to Segment 7. Segment 7 has a larger area that historically never receives inundation by the River (light green, hatched area in Figure 23). Comparison of the elevation histograms in Figure 24 illustrates the elevation patterns that determined the shape of the River floodplain. Segment 8 is characterized by a large area (nearly 2,800 hectares, approximately 40% of the River floodplain) between 3.5 and 4 meters in elevation (panel c, Figure 24). This is an extensive almost plateau-like region that is inundated historically approximately 50% of the time (Table 5, Cocoa station). Changes in hydrology occurring at this elevation will have a far greater effect than at other elevations in this segment simply due to the broad expanse of wetlands occurring at this elevation. The Segment 7 histogram of elevation (panel b, Figure 24) suggests a more normally distributed pattern of elevation, with only a slightly larger proportion of the total area occurring between 1.5 to 2 meters of elevation, which is historically inundated approximately 65% of the time (Table 5, Christmas station).

4.2.5 Summary of Factors Confounding Comparison Between Segments

Of the factors considered to potentially confound comparison between HT results for Segments 7 and 8, only the different terrain characteristics are significant enough to influence HT results. Concerning study area size, reduction and normalization of the Segment 8 study area allowed comparison of hectare-days impact for the two Segments. The Segment 7 study area is centrally located within the Segment, and contains the pertinent geographic features (braided channels) of the segment. Enough of the representative wetlands ("central" River area and western wetlands "slope") are present in the Segment 7 study area to be considered representative of the entire Segment and thus to be compared to the Segment 8 study area. The DEMs as delivered by the contractors were nearly identical in specifications. The same process of calculating correction factors was used for both segments' DEMs and both corrected DEMs had a zero or near-zero median error. Both surface interpolation methods achieved the desired "sloping flat pool" and were consistently applied throughout the analyses.

Terrain differences (as measured by River inundation patterns, distribution of elevation and slope) between the two Segments are considerable. The areas are very distinct in geomorphologic character; the Segment 7 area is characterized by braided River channels and a uniform change in elevation from River edge to upland area, while the Segment 8 area is characterized by lakes and a large flat area. These terrain differences most likely play an equal or greater role in determining the magnitude of the results from HT change analysis than changes in River stage.

4.3 Comparison of Hydroperiod Tool Results for Segments 7 and 8

Subject to the caveats discussed above, we believe it is appropriate to compare HT results for Segments 7 and 8, which may suggest a guide for assessing the effects from surface water withdrawals for areas not studied using the Hydroperiod Tool.

Direct comparison of the size of the areas affected across exceedence values between the two segments is difficult due to the difference in size of the study areas. However, the normalization of Segment 8 area (Figure 23, panel b) allows the use of hectare-days as a measure to compare the magnitude of impact between segments (Table 10). Table 10 also provides the maximum number of fewer days of inundation for both Segments (second and fourth columns), which is higher in Segment 8 than in Segment 7. The exceptions occur at low exceedences or high stage values that, by definition, do not occur frequently. Even with the normalization of Segment 8 study area size, the hectare-days impact of the FULL1995NN scenario is greater on Segment 8 than that on Segment 7. This is due in large part to the greater reduction in days of inundation experienced in segment 8 (i.e. 148 days over 10 years for Segment 8 @ 50% exceedence and 115 days for Segment 7 @50% exceedence), which is a direct consequence of change in hydrology as expressed in the exceedence curves/tables.

Tables 11 and 12 provide the areal extent of the wetland communities affected by the FULL1995NN scenario in the two segments based on the Wetlands Vegetation chapter focus on dewatered areas (total hectares reported represent all exceedences combined). Freshwater marshes are the communities most affected in both Segments. From this point, the two Segments diverge. The community that is the next most affected in Segment 8 is Mixed scrub-shrub wetlands. However, in Segment 7, this scenario greatly effects no other community. The difference in wetlands affected can be attributed to the difference in wetland communities present in the floodplain of the two segments, which is likely due to the differences in terrain as described above. The Segment 7 study area is dominated by Freshwater marshes (3,026 hectares, more than 42% of the total wetland area) within the River floodplain; the next most common wetland community is Cabbage palm hammock (1,684 hectares, almost 24% of the total wetland area), which occupies areas primarily upslope of the River's highest stages. The Segment 8 study area is characterized by 5,795 hectares of Freshwater marshes (32%), and 3,243 hectares of Mixed scrub-shrub wetlands (18%) occurring within the River floodplain and 3,103 hectares of Wet prairies (17%) which mostly occur upslope of the River's highest stages.

Rasters depicting ponded depth can be difficult to interpret because the values increase with decreasing elevation, which initially seems counter-intuitive. Thus, the highest values are immediately adjacent to areas of open water. Change to ponded depth is even harder to follow because in some areas the change results in dewatering (or fewer days of inundation at a specific exceedence value) and in other areas the change is merely a reduction in depth (i.e. the area remains inundated at that exceedence value). Figure 17 (provided again here) defined the wetland response areas following withdrawal. A number of figures were produced to demonstrate the changes in ponded depth (Figures 29 and 30 for dewatered areas; Figures 33 through 38 for areas remaining inundated). Change resulting in dewatering can be considered to be a greater impact to an area than reduction in depth. Comparing the insets in Figures 35 and 38 demonstrates that the areal impact is greater in Segment 8, where more of the area experiences

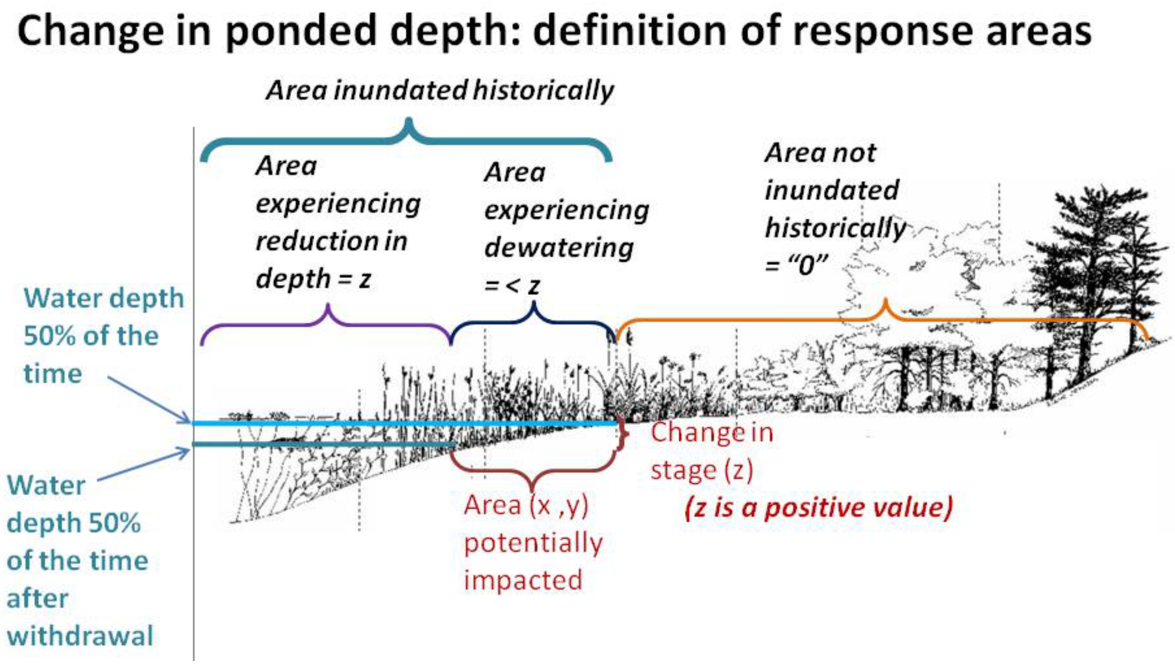


Figure 17. Summary of aerial results for change in ponded depth, HT results. The area of focus for the Wetland Vegetation study is the "Area experiencing dewatering". The areas of interest to the Floodplain Wildlife study are both the "Area experiencing dewatering" and the "Area experiencing reduction in depth". (Wetland cross section Figure from *http://www.newp.com/pdf/NEWP_WetlandCrossSection.pdf*)

complete dewatering than in Segment 7. The insets in these figures provide the distribution in the change in ponded depth for the area remaining inundated following the withdrawal (FULL1995NN) scenario for Segment 7 (Figure 35) and Segment 8 (Figure 35). The distribution of change in ponded depth for the area remaining inundated for Segment 7 is concentrated between 7 and 8 cm, suggesting that the area experiences a simple reduction in ponded depth, but is still inundated following withdrawal. The distribution of the change in ponded depth for Segment 8 ranges from 1 to 8 cm, which suggests that the change in stage resulted in a larger area experiencing fewer days of inundation (dewatering) due to the scenario (changes in ponded depth < than 8). This difference is more likely attributed to the difference in terrain between the two Segments than to just the difference in the magnitude of the change in River stage resulting from water withdrawals.

4.4 Conclusions

The difference in the magnitude of withdrawal effect experienced by two River Segments due to a common withdrawal scenario can be attributed to two factors. The first is the actual change in stage created by the withdrawal scenario (Figures 2 and 3, Table 5) with the concomitant duration of that change (Tables 9 and 10) determined from the exceedence tables or curves. Both change in stage and duration of the change decrease with distance from withdrawal site (Figure 2). The second factor is the nature of the terrain, shown in Figures 23–25. The nature of the terrain (vegetation, soils and dominant hydrogeomorphology), evident from the DEMs and described in Table 2, is very different in these two Segments.

Based on hydrology alone, if the terrain in the Segment 7 study area were identical to that in the Segment 8 study area, the effect would be less in Segment 7 simply due to the lesser reduction in stage and duration change experienced in Segment 7 (Figure 2, Table 10). However, the reduced effect from the FULL1995NN scenario on Segment 7 is even less than can be attributed to hydrology alone because of the difference in the terrain between the two segments. The effect of the change in stage in Segment 8 is exacerbated by the wide expanse or plateau of wetlands occurring between 3.5 and 4 meters of elevation, resulting in a very large area affected around the 50% exceedence level. Segment 7 is not characterized by this feature, having a more normally distributed pattern of elevation.

Although the wetland communities affected are comparable, Segment 8 experiences a greater effect than Segment 7 from the FULL1995NN scenario:

- The total area impacted is greater (as a percent of the total study area)
- The duration of the impact is longer
- A larger area experiences complete dewatering rather than just reduction in ponded depth
- The effect is due to both the changes in hydrology (greater in Segment 8) and the nature of the terrain (more susceptible in Segment 8).

4.5 Conclusions Relevant to Chapter 10, Wetlands Vegetation and Summary, Corresponding to Table 4-1, Wetlands Vegetation Chapter

The intent here is to extend the results from the FULL1995NN withdrawal scenario for the two areas studied with the Hydroperiod Tool to the other River Segments, represented by abbreviated analyses in Table 5-2, Chapter 10 Wetlands Vegetation (Table 13). Based on the comparison of FULL1995NN effect on the two areas studied with the HT, wetlands in Segment 7, between the two study areas (north of Segment 8 and south of the Segment 7 study area), are likely to have a pattern of impact similar to that of the Segment 7 study area. This is because the terrain in that area is very similar to that in the Segment 7 study area (braided River channels). This area does not have a broad plateau-like expanse of wetlands, as seen around Lake Poinsett in Segment 8. Further downstream of the Segment 7 study area the hydrologic component of the effect will continue to decrease (Figure 2) and only areas characterized by large flat expanses of wetlands (perhaps around Lake Woodruff) would be susceptible to effects due to withdrawals, if the change in hydrology occurred at the appropriate elevation and was of sufficient magnitude. However, the change in stage occurring in the Lake Woodruff area (Segment 5) is considered to be negligible (Figure 2; Table 2). These results support the conclusions shown in Table 5-2 of the Wetlands Vegetation chapter, Summary of Effects – FULL199NN; overall, the effect of FULL1995NN would be moderate on Segment 7 and minor on Segments 5 and 6.

Other model scenarios: Four scenarios were run for Segment 8 (FULL1995NN, FULL1995PN, HALF1995PN and FULL2030PN) and the withdrawal effect was observed to decrease respectively. Further, it was concluded in the Wetlands Vegetation chapter that the effect from the FULL2030PN scenario was negligible in Segment 8. Although only the FULL1995NN scenario was run using the HT for Segment 7 it is reasonable to conclude that the pattern of decreasing effects demonstrated in the Segment 8 HT analysis would be experienced in Segment 7 as well, because HT results between scenarios are driven by the hydrologic data input (i.e. the DEM component remains constant). Thus, as in Segment 8, the FULL2030PN scenario would have virtually no negative impact on Segment 7 and the effects from the other two scenarios would correspond to the effects seen in Segment 8, but be smaller in magnitude.

Table 13. Wetlands Chapter Table 5-2. Summary of effects for the Full1995NN scenario.

River Region	Change in Upper And Lower Wetland Boundaries	Boundaries Between Wetland Types	Wetlands Hydrologic Seasonality	Boundaries Between Freshwater and Saltwater Communities	Overall
1	*1,1,1	* 1,1,1	*1,1,1	*1,1,1	*
2	*1,1,1	* 2,3,2	*1,1,1	*2,3,2	*
3	* 1,1,1	* 1,1,1	*1,1,1	* 1,1,1	*
4	* 1,1,1	*1,1,1	*1,1,1	* 1,1,1	*
5	* 1,1,1	***1,3,1	*1,1,1	* 1,1,1	***
6	* *1,1,1	***1,3,1	*1,1,1	* 1,1,1	***
7	* *1,1,1	***2,3,2	*1,1,1	*1,1,1	***
8	* *1,3,1	** 2,3,3	*1,1,1	*1,1,1	**

Level of Effect	Uncertainty	
Negligible	*	Very low
Minor	**	Low
Moderate	***	Medium
Major	****	High
Extreme	*****	Very High

5 Acknowledgements

Dr. Lawrence Spencer, South Florida Water Management District, essentially made the Hydroperiod Tool analysis possible for the Wetlands Working Group of the Water Supply Impact Study. Dr. Spencer provided the program code for the Hydroperiod Tool, Citrix access to the SFWMD version of the tool and training for SJRWMD staff at the SFWMD facility. He continues to be a valuable asset to the development of the Hydroperiod Tool at SJRWMD.

Chun Chen, SJRWMD, Division of Information Technology, reprogrammed the Hydroperiod Tool for use with the SJRWMD system.

Fay Baird, SJRWMD, Bureau of Engineering, prepared the hydrologic data for Hydroperiod Tool input (Appendix A).

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