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June 2005

TECHNICAL MEMORANDUM

A Preliminary Evaluation of Available Surface Water in Boggy and Shingle Creeks

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EXECUTIVE SUMMARY

Analyses performed as part of the 2000 Kissimmee Basin Water Supply Plan (KB Plan) identified possible risks that may result from future groundwater withdrawals in central Florida. The KB Plan recommended developing alternative water sources that would reduce future dependence on the Floridan Aquifer in areas of greatest projected drawdown. Surface water, reclaimed water, storm water and brackish groundwater were identified as possible alternative sources. Recommendation 3.1 of the KB Plan suggested performing research to evaluate the surface water systems in the Upper Kissimmee Basin.

The South Florida Water Management District (SFWMD or District) has conducted studies of East Lake Tohopekaliga (East Lake Toho), Lake Tohopekaliga (Lake Toho) and the major tributaries including Boggy and Shingle creeks, to evaluate surface water availability within the Upper Kissimmee Basin. This technical memorandum summarizes the purpose, analysis and results of the Boggy and Shingle creeks study and should be reviewed with the companion report, *A Preliminary Evaluation of Available Surface Water in Lake Tohopekaliga and East Lake Tohopekaliga* (Cai 2005).

Much of the storm water generated in southern Orange County and northern Osceola County drains towards one of three surface basins: Boggy Creek, Shingle Creek and Reedy Creek basins. This study represents a planning-level evaluation of the surface water resources from Boggy Creek and Shingle Creek basins to identify potential water supply availability. This investigation does not include an evaluation of the Reedy Creek Basin, as sufficient environmental information in this basin was not available at the time of the study.

This study also identifies environmental concerns to address in developing these two surface water resources and characterizes the technical issues associated with potential withdrawal. The study does not try to identify withdrawal scenarios to maximize the quantity of water available from the system. Instead, the study evaluates system availability under historic flow conditions and the impacts these withdrawals may have on matters, such as storage, supply dependability and ecosystem restoration.

This study involved the collection of climatic and hydrologic data, identification of environmental issues, field reconnaissance of local wetland systems, tool development and identification of engineering issues needed to improve withdrawals. To conduct this evaluation, the SFWMD made assumptions about the manner in which withdrawals might occur and the way environmental issues might be addressed.

Evaluating water availability in these creeks was done using statistical methods and a preexisting model, originally developed to evaluate management alternatives for the Kissimmee Chain of Lakes as part of the Kissimmee River Restoration. These tools were used to simulate 32 years of historic climatic and operational conditions. Two separate calculations evaluated environmental impacts, one for in-basin concerns and the other addressing downstream lake levels and restoration efforts. The results of this evaluation, while preliminary, suggest that significant volumes of water might be withdrawn from Boggy and Shingle creeks, while causing minor changes to the environmental health. This suggests the need for further investigation of these surface water resources.

Available surface water for withdrawal from Boggy and Shingle creeks is estimated at 2 and 6 million gallons per day (MGD) respectively. The evaluation also demonstrated however, that the withdrawal reliability was in question. The evaluation showed that over the 32-year demonstration period, the reliability of the withdrawals was at best 85 percent during the wet season and was reduced to 50 percent or less during the dry season. Restoring hydrologic conditions within the Boggy Creek and Shingle Creek basin wetlands may lead to improved water availability in the creeks. Water availability in Boggy and Shingle creeks during the dry season is limited by ecosystem health concerns in the downstream environment. Incorporating elements of storage is expected to improve system reliability. Evaluating alternative withdrawal options for the Kissimmee Chain of Lakes withdrawals may improve dry season reliability.

The results of this evaluation should be considered in combination with the sister study, *A Preliminary Evaluation of Surface Water Availability in East Lake Tohopekaliga and Lake Tohopekaliga* (Cai 2005). Withdrawals that might occur from these lakes may have an impact on the availability of supplies within Boggy and Shingle creeks.

The concerns identified in this study are not the only limiting resource matters to consider in making a final determination of water availability. Any system devised for withdrawing water from these surface water sources will need to review environmental, economic, navigational and water quality concerns within and downstream of the basin.

The water for Boggy and Shingle creeks, the Kissimmee Chain of Lakes, the Kissimmee River and their connection with Lake Okeechobee is a complex hydrologic system. Its management is a balance of many objectives. The SFWMD is developing a long-term management plan for the Kissimmee Chain of Lakes and its tributaries to arrive at a strategy to address these varied concerns. Recommended is a full evaluation of the surface water supply potential for the Upper Kissimmee Basin in union with efforts of the *Kissimmee Chain of Lakes Long-Term Management Plan*, currently under development.

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INTRODUCTION

Analyses performed as part of the 2000 Kissimmee Basin Water Supply Plan (KB Plan) identified possible risks that may result from future groundwater withdrawals in central Florida. The KB Plan recommended developing alternative water sources that would reduce future dependence on the Floridan Aquifer in areas of greatest projected drawdown. Surface water, reclaimed water, storm water and brackish groundwater were identified as possible alternative sources. Recommendation 3.1 of the KB Plan suggested performing research to evaluate the surface water systems in the Upper Kissimmee Basin.

The SFWMD conducted two studies. The first study was an evaluation of the Upper Kissimmee Chain of Lakes and the second was this study of two tributaries to the chain of lakes – Boggy and Shingle creeks. The lakes evaluation report is available separately.

Much of the storm water generated in southern Orange County and northern Osceola County makes its way to one of three surface basins: Boggy Creek, Shingle Creek and Reedy Creek basins. This study represents a planning-level evaluation of the surface water resources from Boggy Creek and Shingle Creek basins to identify potential water supply availability. This investigation does not include an evaluation of the Reedy Creek Basin, as sufficient information for this basin was unavailable at the time of the evaluation.

This study also identifies environmental concerns to address in developing these two surface water resources and characterizes the technical issues associated with potential withdrawal. The study does not try to identify withdrawal scenarios to maximize the quantity of water available from the system. Instead, the study evaluates system availability under historic flow conditions and the impacts these withdrawals may have on matters, such as storage, supply dependability and ecosystem restoration.

The steps in this study included collection of climatic and hydrologic data, identification of environmental issues, field reconnaissance of local wetland systems, tool development and identification of engineering issues needed to improve withdrawals.

Basin Description

Figure 1 shows the locations of the Boggy Creek and Shingle Creek basins. These two basins span Orange and Osceola counties and are primarily located within SFWMD's jurisdiction. Portions of the Boggy Creek Basin are located in the St. John River Water Management District's (SJRWMD's) jurisdiction.

The Boggy Creek Basin has a drainage area of 86.8 square miles and encompasses portions of both Orange and Osceola counties. The main watercourse of Boggy Creek, known as the East Branch, is 12 miles in length (Guardo 1992). The western branch of Boggy Creek, a secondary canal channelized in certain sections, extends east to the Boggy Creek Swamp. The upper portion of the basin is within the general urban area of Orlando. The lower portion of the basin contains several wetland areas. Two large wetland systems, which have hydrologic connections with the main stream, are the Boggy Creek Swamp-Mud Lake complex and the creek's delta wetlands found near the inflow to East Lake Tohopekaliga (East Lake Toho). The Boggy Creek Swamp is the largest wetland in the basin. The portion of Boggy Creek upstream of Boggy Creek Swamp, from Lake Warren to the Orlando International Airport, is channelized (Guardo 1992). Boggy Creek discharges into the northwestern shore of East Lake Toho and is the largest inflow contributing an estimated 55 percent of the total inflow into East Lake Toho during average rainfall conditions.

The U.S. Geological Survey (USGS) maintains two flow/stage monitoring stations within the Boggy Creek Basin. These stations include the BOGGY.TA (flow and stage) station. **Figure 2** shows the locations of these stations. Water level and stage information for the creek is available from the early 1970s.

The Shingle Creek Basin has a drainage area of 111.4 square miles covering portions of Orange and Osceola counties (Guardo 1992). Inflow from Shingle Creek represents a major part of the total inflow to Lake Tohopekaliga (Lake Toho), contributing on average about 60 percent of the total flow into the lake. The southern one-third of the basin, south of the Orange-Osceola County line, consists of limited citrus and pastureland use. There are two large wetland systems along Shingle Creek, the Shingle Creek Swamp and an area of cypress swamp found south of the Kissimmee Airport.

The northern 13-mile portion of the creek, located in Orange County, is channelized. Creek channelization started in the 1920s with the northern most portions and continued in the 1960s, constructing the main channel north of the Florida Turnpike. In the 1970s, wastewater treatment plants began discharges into Shingle Creek. An estimated 11 million gallons per day were released before the practice of direct discharges was discontinued in 1987. Orange County currently maintains reclaimed water infiltration basins near the creek. The lower 10-mile portion of the creek flows through Osceola County and is considered to be in a more natural state. Around 2.5 miles north of Lake Toho the creek joins with Browns Farm Canal, which drains portions of the City of Kissimmee.

The USGS maintains four flow/stage monitoring stations within the Shingle Creek Basin. These stations include the SHING.CA (flow and stage) and SHING.AP (flow and stage) stations. **Figure 2** shows the locations of these stations. Water level and stage information for the creek is available from the early 1970s.

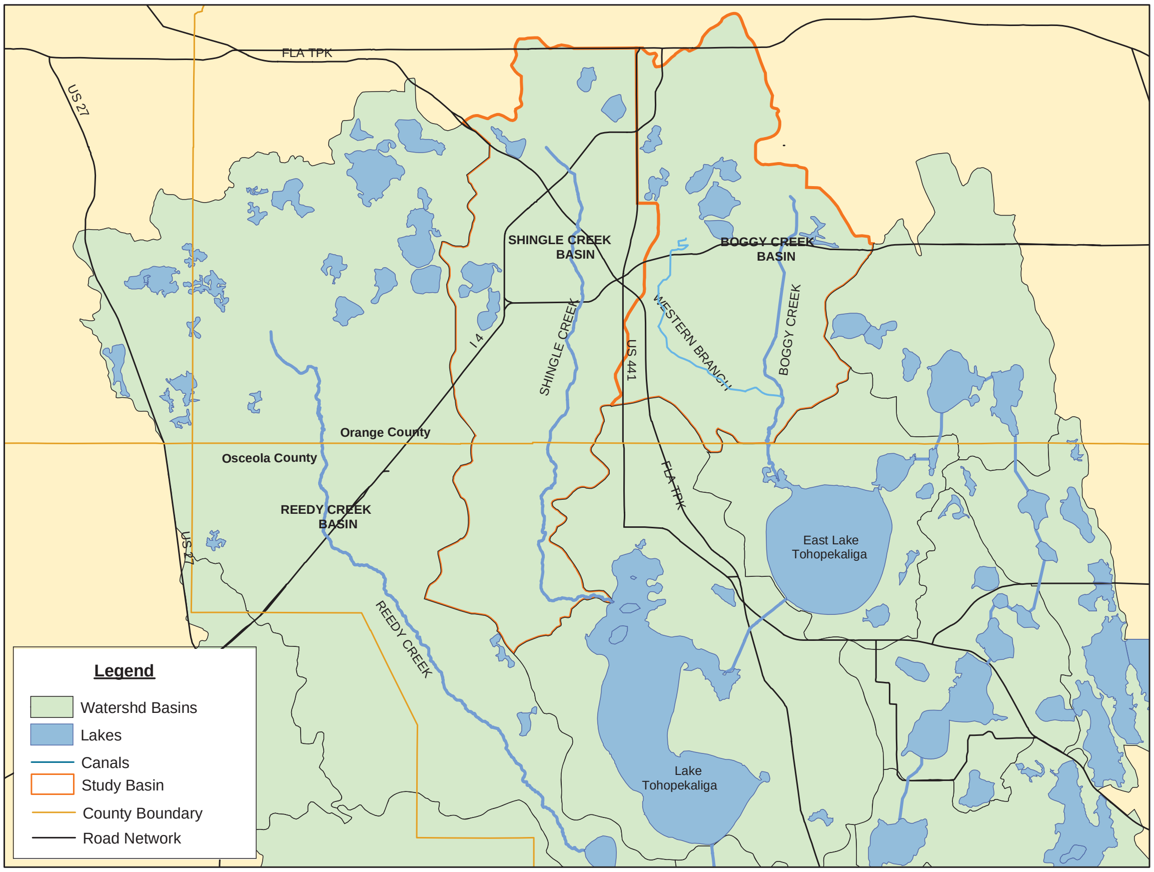

Figure 1. Basins Location Map.

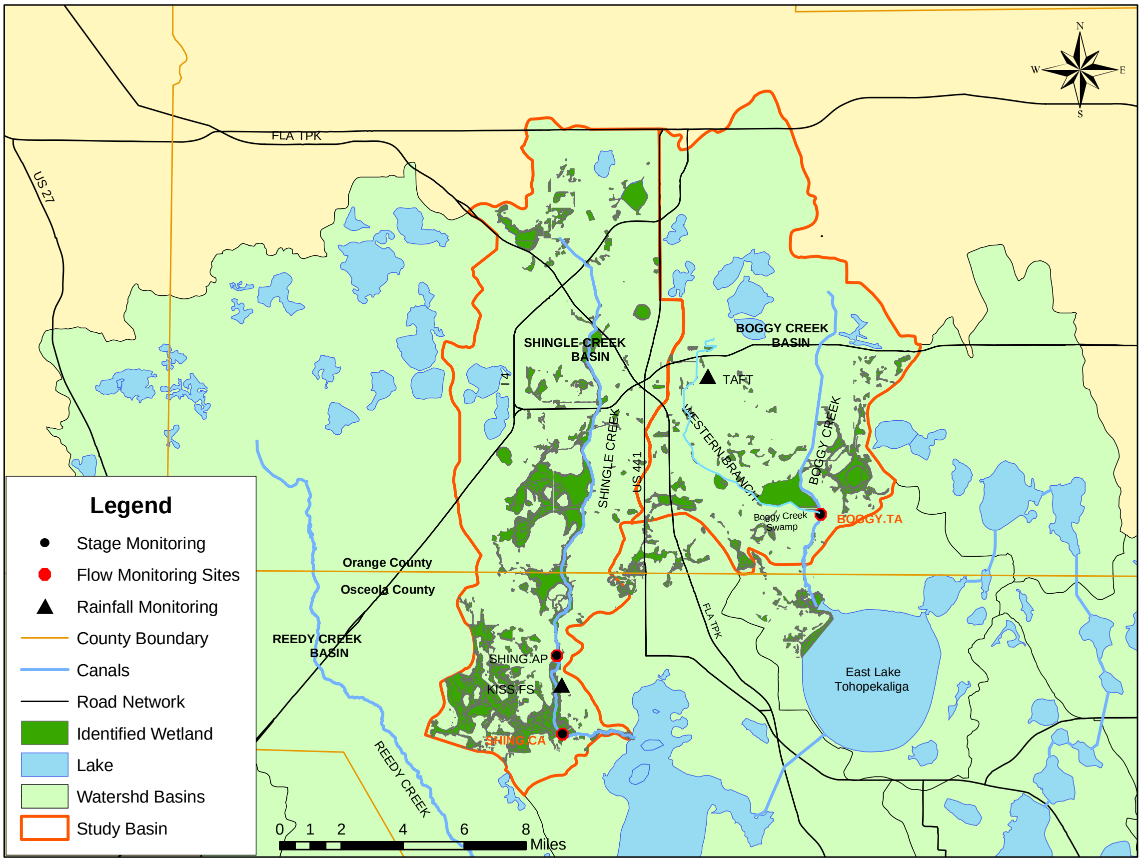

Figure 2. Monitoring Stations and Identified Wetlands.

METHODOLOGY

The use of water from the Kissimmee Chain of Lakes tributaries may be constrained by ecological, flood control and economic concerns relative to individual lakes, as well as potential impacts on in-basin environmental systems. This surface water evaluation considers the in-basin and downstream concerns.

The evaluation approach addressed the in-basin and downstream concerns as separate issues and then combined these results to address the cumulative impacts. In both evaluations, the approach assumed that in-basin and downstream needs were met before allowing withdrawals from the creeks. This method is discussed in the following sections.

In this feasibility assessment, concerns for in-basins environmental systems are addressed by protecting wetlands in direct hydrologic contact with the creek. Downstream environmental considerations are more complex. The District's effort to restore large portions of the Kissimmee River is dependent on the water discharged from upstream tributaries including Boggy Creek, Shingle Creek, Reedy Creek and the Kissimmee Chain of Lakes (**Figure 3**). In addition, these headwaters are an important contributor to Lake Okeechobee and coastal ecosystems. The success of this restoration project is dependent on five primary hydrologic criteria that must be simultaneously satisfied. These five criteria include:

1. Continuous flow via S-65.
2. Interannual monthly mean flows will reflect historic (1934–1960) seasonal patterns and have interannual variability less than 1.0.
3. Mean channel velocities will range between 0.8 to 1.8 feet per second at 85 percentile.
4. Reestablished floodplain inundation depth and duration similar to the historic pattern.
5. Stage recession rates typically less than 1.3 feet per 30 days.

The Upper Kissimmee Chain of Lakes Routing Model (UKISS Model), developed for the Kissimmee River Restoration Project, was available to estimate the impacts of altered flows on the downstream systems. The use of this model enabled the evaluation of impacts related to lake stage changes in the Kissimmee Chain of Lakes, changes in flow rates and the number days of non-continuous flow simulated for the S-65 Structure, located at the south end of Lake Kissimmee. Results of this study are summarized in *A Preliminary Evaluation of Available Surface Water in Lake Tohopekaliga and Lake Tohopekaliga* (Cai 2005).

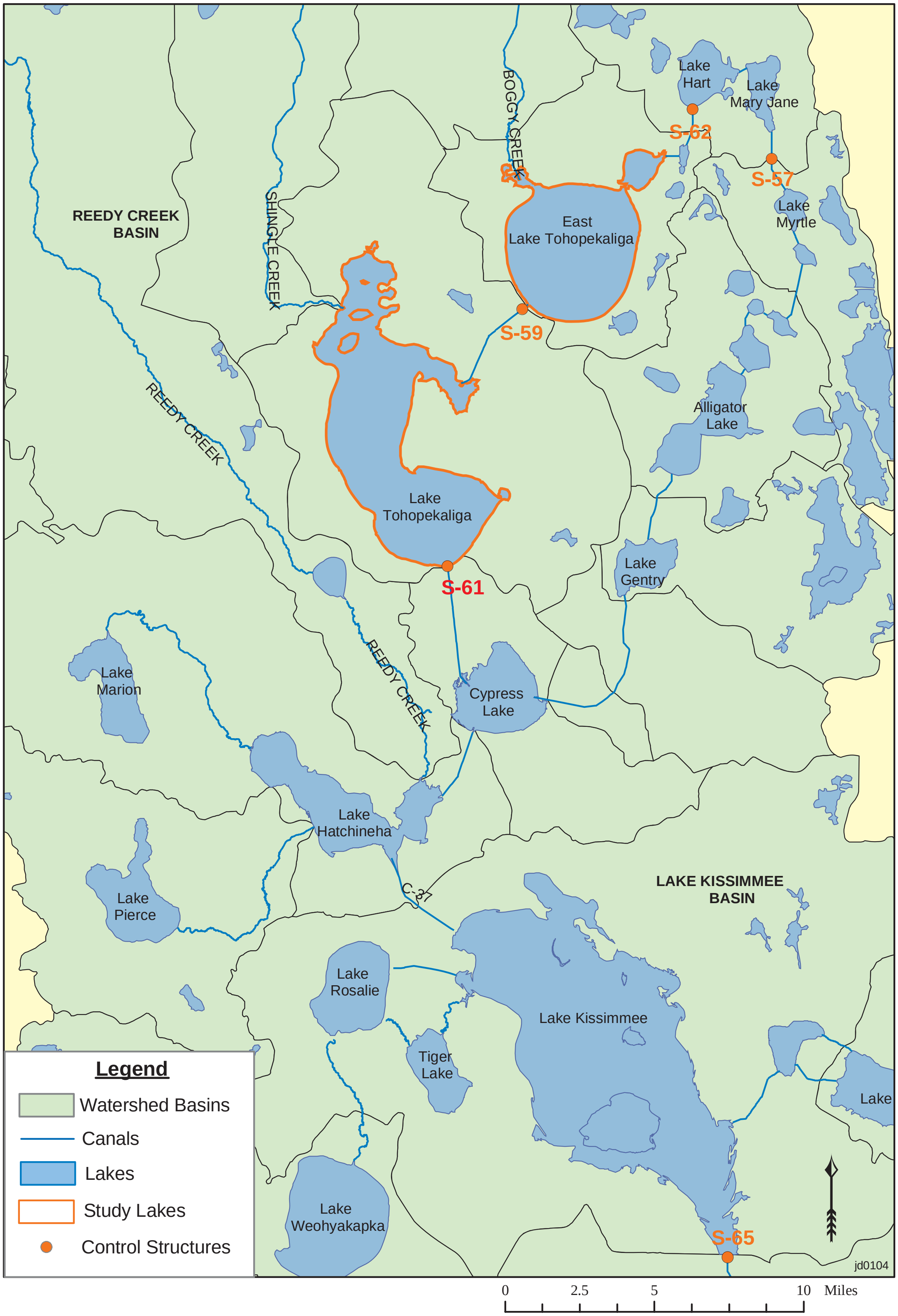

Figure 3. Lake Location Map.

This assessment identified certain environmental concerns. The Kissimmee Chain of Lakes and Kissimmee River water system is complex, may involve other resource protection constraints, and requires additional studies to determine water availability.

Estimating the Required Flow for the Ecosystem within the Region

To determine the potential for influencing in-basin ecosystems, a preliminary assessment of the existing wetland systems was performed as part of this project. The purpose of the assessment was to establish baseline conditions of the current ecosystems and to determine if the systems appeared to be healthy or under stress. The results of this assessment were compared to measure water levels (from SFWMD/USGS monitoring stations) along Boggy and Shingle creeks to determine if water levels in the creeks were consistent with water levels in identified stressed wetland systems. This review was limited to wetlands having a direct hydrologic connection to the creeks. The wetland assessment field report is attached as **Appendix A**: *Determination of Water Levels and Hydrologic Needs of the Natural Areas along Boggy and Shingle Creeks.*

The historical water stage data collected at the closest station to the identified wetlands was analyzed to determine whether the water level in the creeks might have affected the existing wetland. This creek stage information was compared to the range of typical surface water levels and hydroperiods found in major vegetation community types in central Florida in order to estimate the stage deficiency in maintaining an appropriate monthly water level for a healthy wetland system. Each of the identified wetlands is believed to be hydraulically connected to the respective creek. The typical wetland hydroperiod is presumed to be maintained if the observed wetland is healthy. If a wetland appears to be under stress, it is presumed the creek’s hydroperiod has altered the wetland. In this case, more water may need to be preserved for this wetland. Although the stresses the wetland system experienced may have resulted in the current condition of the hydrologic system, an evaluation of other causes was not performed. It is presumed that water for restoring the system will be derived from the creek. Development of an alternative restoration plan could free more water from the creek than otherwise might be needed for potential restoration.

The results of this field reconnaissance indicate the Boggy Creek Swamp close to the BOGGY.TA station and the wetland associated with the closest recorder station (SHING.CA, DBKey 00132) in the Shingle Creek Basin are overdrained and under stress (Appendix A). Based on the historical stage and preferred stages in the creeks associated with these wetland types, the required flow (Q_b) for wetland restoration in a basin could be estimated with **Equation 1**:

$$Q_b = D*A \qquad [1]$$

where,

Q_b = the required water within the basin during the wet season, acre-feet

D = the average depth of stage deficiency, feet

A = the total area of the wetland, acre

The results of the wetland assessment show the average monthly stage deficiency in these two wetland areas is continuous and spans the entire year. However, it is noted that these wetlands are normally dry during portions of the year and may not be adversely influenced by the low dry season water levels. To maintain a healthy wetland, the stage deficiency during the wet season, when the wetland is normally flooded, should be addressed. For the purpose of this evaluation, the amount of water needed to restore the wetlands is calculated as the water deficiency from the stage deficiency over the wetland area during the wet season.

Estimating the Required Flow for the Downstream Ecosystem

Boggy Creek and Shingle Creek average 60 percent and 55 percent, respectively, of the total annual inflow into East Lake Toho and Lake Toho for the period of record. The excessive removal of water from these creeks for supply may contribute to downstream impacts. The resource concerns are downstream lake water levels and downstream discharge rates through Structure S-65 on Lake Kissimmee. The modeling tools and downstream resource protection thresholds were identified as part of the Headwaters Revitalization project.

Modeling completed for the Kissimmee Chain of Lakes showed the dependability of water supply from the lakes is predictably more limited during the dry season. During these periods, inflows to the Kissimmee Chain of Lakes from Boggy and Shingle creeks become a significantly larger portion of the total lake budget. Therefore, a base flow condition for the creeks was established equivalent to the dry season flow during periods of no pumping in the lake's modeling.

The baseline flow condition for the downstream ecosystem needs was estimated as the average daily flow during the dry season (November 1 to May 31) for a 32-year period from 1970 to 2001. When conducting the analysis to estimate the average daily flow, the Box-and-Whisker Plot method was used. This method was selected because the distribution of the flow data is not normal. The data distribution is skewed to the right, which means the lower 50 percent of the data are spread over a smaller range than the upper 50 percent of the data. As an example, in Boggy Creek, the median flow (50% exceedance) is 22 cubic feet per second (cfs). However, the maximum flow recorded in Boggy Creek is 1070 cfs. The data range in the lower 50 percent bound (from 0 to 22 cfs) is smaller than that in the upper 50 percent bound (from 22 to 1070 cfs). This distribution of the recorded data is best suited for evaluation by the Box-and-Whisker Plot method. To apply this method, the data bounds were developed with **Equation 2** (Prem 1995):

$$[Q_1 - 1.5*IQR, Q_3 + 1.5*IQR] \quad [2]$$

where,

Q_1 = the flow at 25 percentile

Q_3 = the flow at 75 percentile

$IQR = Q_3 - Q_1$

Data outside the bounds were not used when the dry season average daily flow was calculated.

Estimating the Available Flow for Water Supply

Quantifying available flow (Q_a) in million gallons per day (MGD) was estimated as two components depending on seasonal limitations. During the dry season, the available flow equals the historical recorded flow (Q, cfs) minus the required flow for downstream needs (Q_d, cfs) in the dry season. **Equation 3**:

$$Q_a = \text{Sum}\ (Q - Q_d)K_1 \quad [3]$$

where,

K_1 is the factor to convert flow in cubic feet per second to million gallons per day. The available flow (Q_a) in the equation is obtained by subtracting the Q_d from the daily recorded flow (Q). Each residual (positive value) is summed and converted to a daily flow in million gallons per day.

During the wet season, the available flow (Q_a) in MGD equals the recorded flow (Q, cfs) minus the required flow for downstream needs (Q_d, cfs) in the dry season, and the required flow for wetland restoration within the basin (Q_b, acre-feet), **Equation 4**:

$$Q_a = (\text{Sum}\ (Q - Q_d) * K_2 - Q_b)K_3 \quad [4]$$

where,

K_2 is the factor to convert flow in cubic feet per second to acre-feet for the wet season. K_3 is a factor to convert flow in acre-feet to MGD.

Total available flow is the total of the wet season and dry season availability estimations. This amount however, needs to be compared for consistency with surface water availability determined in the East Lake Toho and Lake Toho companion study. Examples of this comparison are discussed in the results section.

Rainfall Return Period and Data Processing

Availability of storm water is driven by variations in rainfall. The rainfall data collected from each of the two basins was analyzed to determine the 1-in-10 year drought, 1-in-5 year drought and 1-in-2 year average rainfall condition. A 1-in-10 year drought event is defined as rainfall with a probability of exceedance of 90 percent for a 12-month period. A 1-in-10 year drought is a drought of such intensity, that it is expected to have a return frequency of once in 10 years. The rainfall data is available for a period of 32 years from January 1970 to December 2001 for both basins. By conducting statistical analysis of the yearly (January to December) rainfall data in the Boggy Creek and the Shingle Creek basins, the drought condition for the three different situations was determined and summarized in **Table 1**. **Appendix B** shows details of the rainfall analysis.

Table 1. Summary of Annual Rainfall Analysis.

Basin	1-in-10 Year Drought	1-in-5 Year Drought	1-in-2 Year Average Rainfall Condition
Boggy Creek (DBkey:06042)	2000	1982	1979
Shingle Creek (DBkey:06305)	1971	1978	1995

The database key (DBKey) numbers for the two rainfall stations selected are 06042 and 06305 for Boggy Creek and Shingle Creek, respectively. **Figure 1** shows the locations of these rainfall stations.

RESULTS

Required Flow for the Ecosystem within the Basin

The in-basin wetland reconnaissance found that a wetland area identified as the Boggy Creek Wetlands (**Appendix A**), appeared to be stressed. The wetland is adjacent to the Boggy Creek stage gauging station BOGGY.TA. In the Shingle Creek Basin, a wetland area near the confluence of Shingle Creek and Browns Canal appeared to be under stress (**Appendix A**). The wetland is adjacent to the Shingle Creek stage gauging station SHINGLE.CA. As described earlier, the recorded stage measurements from these two stations were used to show the difference between actual and target levels in the adjacent wetlands. **Table 2** provides the results of the wetland evaluation for the wet season in these two areas.

Table 2. Analysis Results for BOGGY.TA and SHINGLE.CA Stations.

BOGGY.TA	Annual Mean Stage (ft)	Reference Wetland Mean Stage (ft)	Stage Difference (ft)
June	59.5	64.4	4.9
July	62.2	64.7	4.5
August	60.4	65.2	4.8
September	60.6	65.5	4.9
October	59.9	64.7	4.8
Average Deficiency			**4.78**
SHINGLE.CA	**Annual Mean Stage (ft)**	**Reference Wetland Mean Stage (ft)**	**Stage Difference (ft)**
June	52.6	57.1	4.5
July	53.3	57.2	3.9
August	53.8	57.5	3.7
September	54.3	57.2	2.9
October	54.3	57.0	2.7
Average Deficiency			**3.54**

Parameter values of **Equation 1** and the estimated wet season flow for maintaining the hydroperiod of the wetland were summarized in **Table 3**. With **Equation 1**, loss through seepage and evapotranspiration was also considered. It is assumed the average evapotranspiration through a wetland equals the average rainfall during the wet season. The estimated wet season flows to maintain five months inundation at a depth of 4.78 feet are 3,755-acre-feet for Boggy Creek and 11,885 acre-feet at a depth of 3.54 feet for Shingle Creek.

Table 3. Parameter Values and Required Wet Season Flows Estimated Using Equation 1 for Boggy Creek and Shingle Creek.

Parameters	Boggy Creek	Shingle Creek
1. Average depth of deficiency to maintain a desired hydroperiod, D (ft)	4.78	3.54
2. Total area of the Wetland, A (acre)	785.5	3357.4
Required flow, Q_b (acre-feet)	**3,755**	**11,885**

Note: Parameter D on wetland hydroperiod is based on the GIS analysis of the existing wetland as shown in Table 2 (Appendix A).

Required Flow for Downstream Ecosystem

Table 4 is a summary of the data boundary defined by **Equation 2** and the required flow during the dry season for the downstream ecosystem estimated as an average flow during the dry season (January 1 through May 31 and November 1 through December 31). The flow data spans from 1970 through 2001. To avoid overcounting the downstream average flow during the dry season, the wastewater flow being discharged into Shingle Creek in the 1970s and the early 1980s was subtracted from the recorded flow in DBHYDRO, the District's corporate environmental database. With 32 years of data, the estimated wet season flow for the downstream ecosystem was 26 cfs for Boggy Creek Basin and 85 cfs for Shingle Creek Basin.

Table 4. Data Bounds and Estimated Dry Season Daily Flow for the Downstream Ecosystem of Boggy Creek and Shingle Creek Basins.

Period	Q_1, (cfs)	Q_3, (cfs)	IQR (cfs)	Q_1 - 1.5*IQR (cfs)	Q_3 + 1.5*IQR (cfs)	Average Flow (cfs)
Boggy Creek 1970–2001	12	45	33	-38*	95	26
Shingle Creek 1970–2001	50	137	87	-81	268	85

* = A negative number here means the data bands start from zero.

Available Flow for Water Supply

The available flows for the two basins were estimated for the 1-in-10 and 1-in-5 year drought conditions and 1-in-2 year average rainfall condition. **Table 5** summarizes the results of the evaluation. The results are expressed in million gallons per day (MGD).

Table 5. Available Stormwater in the Boggy Creek Basin and East Lake Toho; the Shingle Creek Basin and Lake Toho.

	Jan	Feb	Mar	Apr	May	Wet Season	Nov	Dec
Boggy Creek, MGD								
1-in-10 (2000)	**0.9**	**0.5**	**0.0**	**0.0**	**0.0**	**0.7**	**0.0**	**0.0**
Creek Flow	0.9	0.5	0.0	0.0	0.0	0.7	0.0	0.0
East Toho Flow	31.0	23.0	10.0	19.0	10.0	12.0	0.0	0.0
1-in-5 (1982)	**0.0**	**0.0**	**0.55**	**17.6**	**5.1**	**16.5**	**0.9**	**0.0**
Creek Flow	7.4	0.3	3.6	38.7	5.1	45.1	0.9	0.0
East Toho Flow	0.0	0.0	1.0	32.0	30.0	30.0	22.0	10.0
1-in-2 (1979)	**0.0**	**2.1**	**15.4**	**0.0**	**6.6**	**13.2**	**0.1**	**0.0**
Creek Flow	21.0	2.1	15.4	0.0	6.6	28.1	0.1	0.0
East Toho Flow	0.0	8.0	29	33.0	24.0	24.0	4.0	4.0
Shingle Creek, MGD								
1-in-10 (1971)	**0.0**	**0.0**	**0.0**	**0.0**	**2.0**	**0.0**	**0.0**	**0.0**
Creek Flow	0.0	6.8	0.0	0.0	2.0	0.0	0.0	0.0
Toho Flow	0.0	0.0	0.0	3.0	42.0	0.0	0.0	0.0
1-in-5 (1978)	**22.2**	**28.8**	**28.8**	**0.0**	**0.0**	**10.8**	**0.0**	**0**
Creek Flow	24.1	92.4	68.6	0.0	0.0	23.5	0.0	1.3
Toho Flow	37.0	48.0	48.0	42.0	47.0	18.0	0.0	0.0
1-in-2 (1995)	**25.2**	**21.6**	**23.4**	**1.8**	**0.0**	**19.2**	**21.6**	**11.4**
Creek Flow	92.9	35.6	27.4	1.8	0.0	193.2	44.1	11.4
Toho Flow	42.0	36.0	39.0	50.0	50.0	32.0	36.0	27.0

Since the Boggy Creek and Shingle Creek basins are the major tributaries to East Lake Toho and Lake Toho, the water availability in the creeks should be consistent with that in the lakes. Therefore, the available flow in the creek was obtained by adjusting the creek flow based on the available flow in the lake. This flow adjustment was based on the following criteria:

1. If the creek flow equals zero, there is no water available in the creek.
2. If the lake flow equals zero, there is no water available in the creek.
3. If the lake flow and the creek flow are greater than zero and the Boggy Creek flow is less than 55 percent of the East Lake Toho flow, the available water in the Boggy Creek Basin equals the Boggy Creek flow. Otherwise, the available water in the Boggy Creek Basin equals 55 percent of the East Lake Toho flow.
4. If the lake flow and the creek flow are greater than zero and the Shingle Creek flow is less than 60 percent of the Lake Toho flow, the available water in the Shingle Creek Basin equals the Shingle Creek flow. Otherwise, the available water in the Shingle Creek Basin equals 60 percent of the Lake Toho flow.

For example, the flow in Boggy Creek was 7.4 MGD during the 1-in-5 year drought condition in January. However, the water availability analysis for East Lake Toho shows there is no water available under the same drought condition (same year) in the same month. Based on this result, **Table 5** shows that under the 1-in-5 year drought condition in January, there is no water available in Boggy Creek. Under the 1-in-2 year average rainfall condition, the available flow was 28.1 MGD in the wet season in Boggy Creek. However, the available flow in East Lake Toho is only 23.8 MGD under the same weather condition at the same time. Since Boggy Creek contributes 55 percent of the total inflow to East Lake Toho, the available flow in Boggy Creek under the 1-in-2 average rainfall condition in the wet season could be 55 percent of 24 MGD, which is 13.2 MGD. **Table 5** shows the available flow in Boggy Creek under the 1-in-2 average rainfall condition in the wet season is 13.2 MGD instead of 28.1 MGD. **Appendix C** provides available flows in both East Lake Toho and Lake Toho.

The results presented in **Table 5** indicate the available water under the 1-in-10 year drought condition in the Boggy Creek Basin is at times limited and not reliable. Therefore, no water is considered available for this condition. In the 1-in-5 year drought condition, and the 1-in-2 year average rainfall condition there is water available in the Boggy Creek Basin. In comparing the available water shown in **Table 5**, it was noted that in the 1-in-2 average rainfall condition, the available water in Boggy Creek is less than that in the 1-in-5 year drought condition. The available water in the 1-in-5 year drought condition was focused on April, May, June, July, August, September and October. This is due to the rainfall in the year when the 1-in-5 year drought condition was selected and focused on April through October. However, in the year in which the 1-in-2 year average rainfall condition was selected, the rainfall was distributed throughout the year.

Under the defined limitations for Shingle Creek, there is no water available for most of the time in the 1-in-10 year drought condition. Even though **Table 5** shows 2 MGD in May during the 1-in-10 year drought condition, it is considered not reliable, especially in May, which is the end of the dry season. The available flow range in the 1-in-2 year average rainfall condition is between 1.8 MGD and 25.2 MGD throughout the year, except in May.

The distribution of available flow exceedance throughout of the year was also analyzed. **Table 6** and **Table 7** present the results. **Appendix D** of this technical memorandum includes the graphs.

Table 6. Available Flow Exceedance in Boggy Creek.

Jan	Feb	Mar	Apr	May	Wet Season	Nov	Dec
Available flow equal to or greater than 2 MGD							
40%	50%	55%	40%	25%	80%	30%	35%
Available flow equal to or greater than 1 MGD							
40%	50%	60%	50%	35%	85%	40%	35%

Table 6 indicates that 2 MGD of water can be diverted from Boggy Creek 80 percent of the time or less during the wet season for 32 years of record. This 2 MGD diversion is estimated to limit adverse impacts to downstream lakes and the natural system within the creek basin. The reliabilities of 2 MGD diversion in February and March are greater than that in the other months during the dry season.

Table 7. Available Flow Exceedance in Shingle Creek.

Jan	Feb	Mar	Apr	May	Wet Season	Nov	Dec
Available flow equal to or greater than 6 MGD							
50%	50%	50%	40%	15%	80%	30%	40%
Available flow equal to or greater than 4 MGD							
50%	50%	50%	45%	20%	85%	35%	40%

Based on the water diversion scenario outlined above, **Table 7** shows that chances of diverting 4 MGD or 6 MGD from Shingle Creek are relatively the same during the January, February and March. Diverting 6 MGD can be achieved 80 percent of the time or less for the 32-year period of record. Withdrawal dependability can be observed closer to 85 percent of the time during the wet season for 32 years of records if the flow of 4 MGD is diverted.

The results presented in this section are based on the results of available water analysis for the creeks and the analysis conducted for East Lake Toho and Lake Toho. The results derived from the lake analysis were further evaluated by using the UKISS Model, which was developed to simulate lake operations in the Upper Kissimmee River Basin. The lake analyses and results are presented in *A Preliminary Evaluation of Surface*

Water Availability in East Lake Tohopekaliga and Lake Tohopekaliga (Cai 2005).

SUMMARY AND CONCLUSIONS

To conduct this evaluation, the SFWMD made presumptions about the manner in which withdrawals might occur and the way environmental issues might be addressed. The water availability in these creeks was evaluated by statistical methods and by using the preexisting UKISS Model, originally developed to evaluate management alternatives for the Kissimmee Chain of Lakes. Evaluations of the creek basins were made by simulating 32 years of historic climatic and operational conditions using these tools. Two separate calculations were used to evaluate environmental impacts, one for in-basin concerns and the other addressing downstream lake levels and Kissimmee River restoration efforts. The following is a summary of the findings:

1. The availability of surface water for withdrawals from Boggy and Shingle creeks is estimated at 2 MGD and 6 MGD respectively. The evaluation over the 32-year demonstration period showed that reliability of the withdrawals was at best 85 percent during the wet season and was reduced to 50 percent or less during the dry season.
2. While reliability of the creek withdrawals was poor, combining elements of storage will improve system reliability. This storage might take the form of surface water reservoirs or groundwater storage through aquifer storage and recovery.
3. A field reconnaissance of wetlands in each creek basin found that a large wetland system in each showed signs of stress and restoration efforts might be appropriate. Restoring hydrologic conditions in these wetland systems may also lead to improved water availability in the creeks during the wet season.
4. Water availability in Boggy and Shingle creeks is limited during the dry season by ecosystem health concerns in the downstream environment. These limitations are, in part, a function of the withdrawal scenarios used in the Kissimmee Chain of Lakes study. Evaluating alternative withdrawal options for the lake withdrawals may improve dry season reliability.
5. Although certain environmental concerns were identified in this study to allow an estimation of water available from Boggy and Shingle creeks for withdrawal, these limits, as described are not intended to represent the final limiting constraints in determining actual water availability. The concerns identified in this study are not the only limiting resource matters to consider in making a final determination of water availability. Any system devised for withdrawing water from these surface water sources will need to review environmental, economic, navigational and water quality concerns within and downstream of the basin.

6. The results of this evaluation, while preliminary, suggest that significant volumes of water might be withdrawn from Boggy and Shingle creeks, while causing minimal environmental concerns. Results suggest the need for further investigation of these surface water resources.
7. The results of this evaluation should be considered with *A Preliminary Evaluation of Surface Water Availability in East Lake Tohopekaliga and Lake Tohopekaliga* (Cai 2005). Withdrawals that might occur from these lakes may have an impact on the availability of supplies within Boggy and Shingle creeks.
8. The water system for Boggy and Shingle creeks, the Kissimmee Chain of Lakes, the Kissimmee River and their connection with Lake Okeechobee is a complex hydrologic system. Its management is a balance of many objectives. The SFWMD began efforts to develop a long-term management plan for the Kissimmee Chain of Lakes and its tributaries to arrive at a strategy to address these varied concerns. A full evaluation of the surface water supply potential for the Upper Kissimmee Basin in union with efforts of the *Kissimmee Chain of Lake Long-Term Management Plan* is recommended.

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APPENDIX A

Determination of Water Levels and Hydrologic Needs of the Natural Areas along Boggy and Shingle Creeks

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ACKNOWLEDGEMENTS

This appendix was produced by the Environmental Evaluation Section of the Planning Division, Water Supply Department. The analysis was completed with assistance from the following District staff: Joel VanArman provided oversight of the method and analysis, April Huffman assisted in obtaining and analyzing water level data and Rachelle Grein provided important GIS support and produced most of the maps in this report.

INTRODUCTION

Boggy and Shingle creeks are the main tributaries to East Lake Tohopekaliga and Lake Tohopekaliga, respectively, in central Florida. The water requirements of natural systems along Boggy and Shingle creeks are currently unknown and this analysis was conducted to examine this question. This work was undertaken in support of the Upper Kissimmee Basin Water Supply Plan.

A method was developed to determine monthly water levels in representative wetlands along these creeks by relating existing stage data to ground elevations in adjacent plant communities. This analysis was used to determine the average monthly water levels along Boggy and Shingle creeks, which was then used to identify wetlands that have been impacted by lowered water levels.

Examination of field sites and data analysis identified one site along Boggy Creek and two sites along Shingle Creek that had water level depths and flooding durations below the range reported for these wetland types. The remaining sites have sufficient water to support the surrounding wetlands, and thus may have some extra water available for redistribution. Possible methods for providing sufficient water to those wetlands that have been impacted by lowered water levels include an increase in tributary, creek or surface water flows, construction of berms or levees and improved groundwater management.

ANALYTICAL METHODS

The analysis was conducted in three steps. In the first step, the type and extent of major wetland systems along Boggy and Shingle creeks were determined using the 1995 FLUCCS geographical information system (GIS) data layer. A second GIS data layer containing the locations of SFWMD/USGS water level gauging stations was used to identify wetlands near existing water level gauging stations; these wetlands were used in our analysis as “reference wetlands.” The reference wetland types identified from the FLUCCS land use codes were verified with field observations.

In the second step, water level data from gauging stations adjacent to the reference wetlands were obtained from the SFWMD’s DBHYDRO database. **Table A-1** shows the stations and period of record used in the analysis. These data were reviewed for correctness and analyzed to provide mean monthly average water levels.

Table A-1. Water Level Gauging Stations used in the Hydrologic Analysis

Station	Description	Period of Record
SHING.PE	On Shingle Creek just south of the Osceola Parkway	1992–1997
SHING.AP	On Shingle Creek just west of the Kissimmee Airport	1958–2002
SHING.CA	On Shingle Creek at S.R. 531	1968–2002
BOGGY.530	On Boggy Creek just north of Boggy Creek Swamp	1985–2001
BOGGY.TA	On Boggy Creek at S.R. 417 (Florida Greenway)	1959–2000
S59	On East Lake Tohopekaliga's southwest shore at the S-59 Structure	1963–2003

In the third step, ground elevations within the reference wetlands were obtained from available data sources. Two types of elevation data were available, each originating from different methods and sources. Where available, one-foot elevation contours obtained by Light Detection and Ranging (LIDAR) methods were used. At one site where LIDAR data was not available (the Boggy Creek inflow to East Lake Tohopekaliga), a five-foot contour data layer was used.

The range of surface water levels and hydroperiods found in major wetland types in central Florida were obtained from several sources (**Table A-2**). These reported hydroperiod values were used to evaluate historical hydroperiods within reference wetlands to determine if water levels were within the natural range expected for the wetland type.

Table A-2. Average Hydroperiod and Inundation Depths for Selected Wetland Types.

Wetland Type (Reference)	Mean Annual Low Water Depth	Hydroperiod (months)
Marsh-Shallow		
CH2M Hill 1996	Subsurface	3–7
ESE 1992	Subsurface	4
Marsh		
Duever 2003	0.5–3.8 ft*	6–10
Ewel 1990	Subsurface	6–9
CH2M Hill 1996	Subsurface	6–10
Marsh-Deep		
Brown & Starnes 1983	Subsurface	12
ESE 1992	Subsurface	10
CH2M Hill 1996	Subsurface	10–12
Lake Marsh		
ESE 1992 (littoral)	Subsurface	6
ESE 1992 (pelagic)	Subsurface	12
Swamp- Mixed, Shallow		
ESE 1992	Subsurface	3
Swamp- Mixed		
Brown & Starnes 1983	Subsurface	6–8
CH2M Hill 1996	Subsurface	3–6
Duever 2003	0.5–3.0 ft*	8–10
ESE 1992	Subsurface	5
Ewel 1990	Subsurface	6–9
Swamp- Mixed, Deep		
CH2M Hill 1996	Subsurface	5–9
ESE 1992	Subsurface	6
Swamp- Cypress, Shallow		
CH2M Hill 1996	Subsurface	3–7
Swamp- Cypress		
CH2M Hill 1996	Subsurface	6–9
Duever 2003	1.3–3.8 ft*	6–8
ESE 1992	Subsurface	7

* = Maximum range indicates depth expected during a 1-in-10 year drought.

A helicopter flight was conducted on October 22, 2003 to 1) verify the location of gauging stations and reference wetlands; 2) verify a hydrologic connection between the reference wetland, gauging station and creek surface water; 3) examine the "health" of the reference wetland (did it have obvious signs of stress or impact?); and to 4) verify the wetland type as described by the FLUCCS data.

ANALYSIS RESULTS

Boggy Creek Wetlands

Boggy Creek is a main tributary to East Lake Tohopekaliga. Two large wetland systems are found along Boggy Creek, the Boggy Creek Swamp-Mud Lake complex and the creek's delta wetlands at the point of inflow to East Lake Tohopekaliga (**Figure A-1**). Boggy Creek has been channelized upstream of Boggy Creek Swamp.

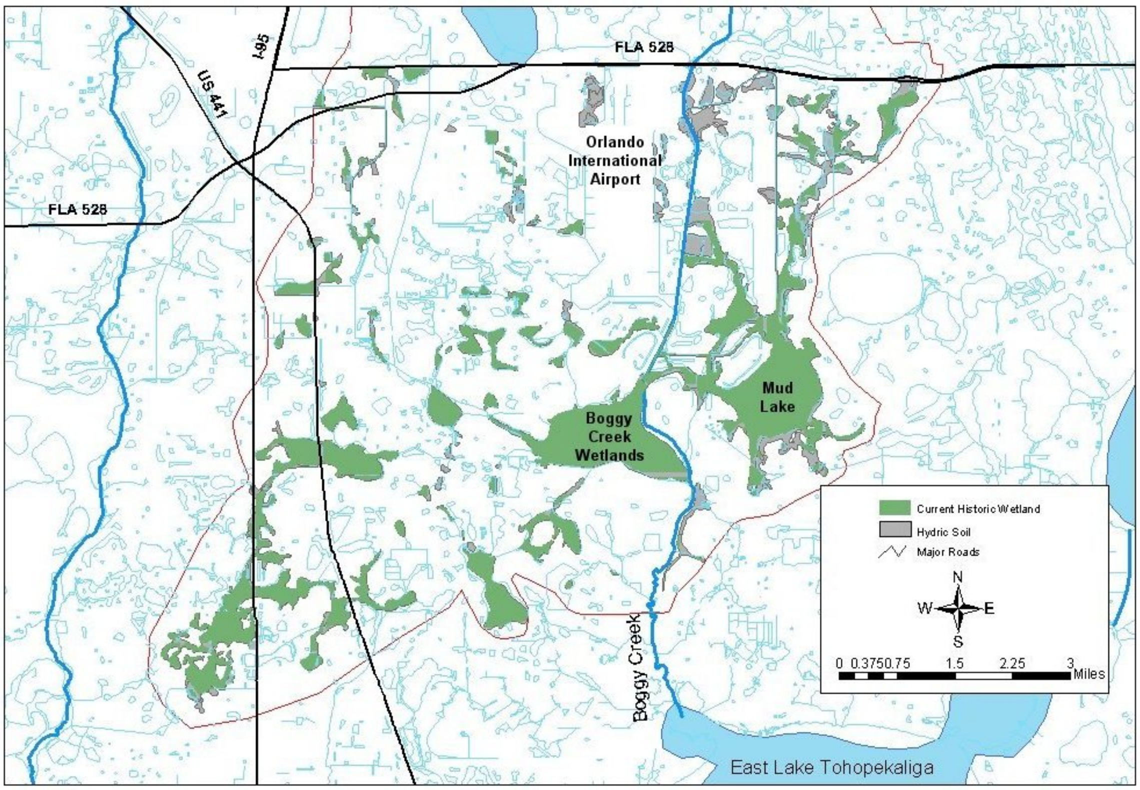

Figure A-1. Boggy Creek Map Showing Watershed Boundary.

The Boggy Creek Swamp-Mud Lake complex lies approximately halfway between East Lake Tohopekaliga and Orlando International Airport (McCoy Field). Boggy Creek Swamp lies west of the creek's channel and there is a perennial surface water connection to Mud Lake, which lies east of Boggy Creek, through a cypress strand. Two gauging stations are located adjacent to the Boggy Creek Swamp, one in the creek's channel on the downstream side of the swamp and the second within the connection with Mud Lake wetlands on the north side of Boggy Creek Swamp (**Figure A-2**). An additional gauging station along the southwestern shore of East Lake Tohopekaliga at the S-59 Structure (not shown on map) was used to measure water levels at reference wetlands at the delta Boggy Creek (**Figure A-3**).

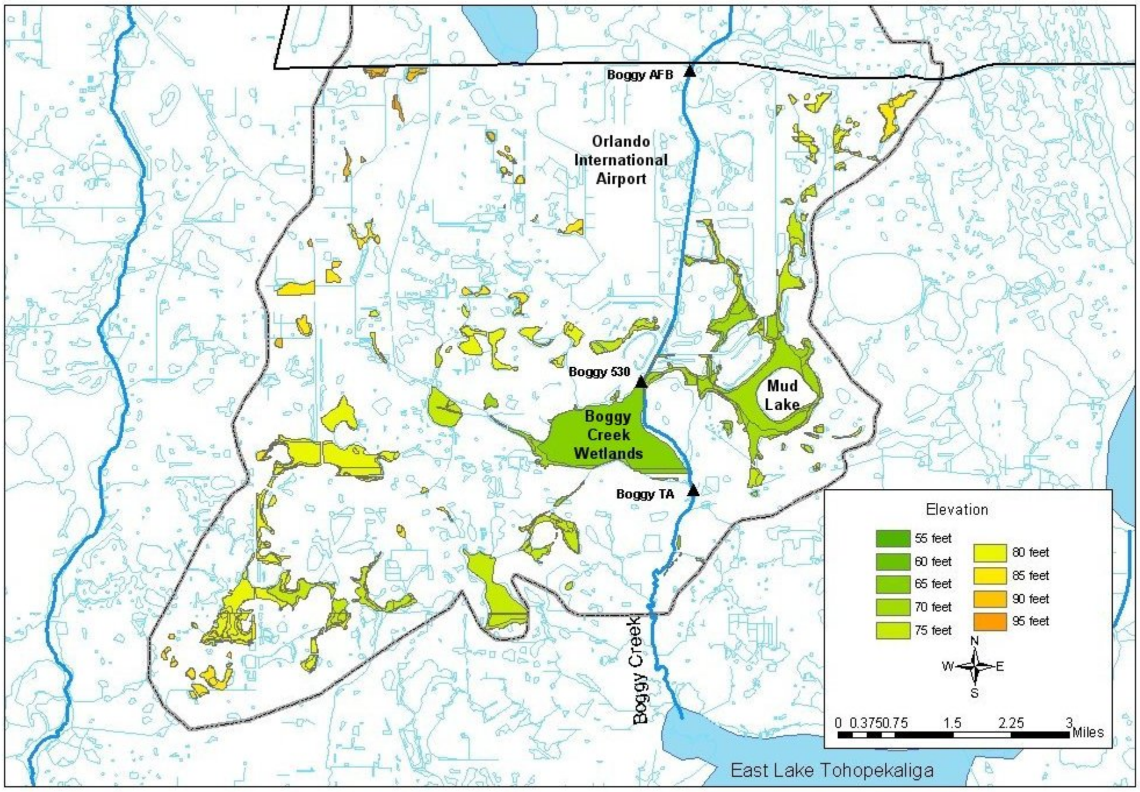

Figure A-2. Boggy Creek Wetlands and Gauging Stations.

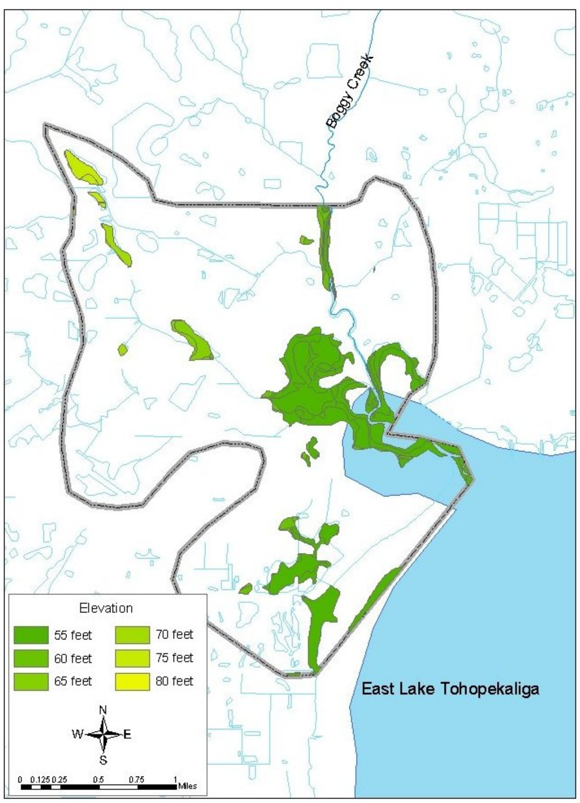

Figure A-3. Wetlands at the Boggy Creek inflow to East Lake Tohopekaliga.

BOGGY.530 Station

Hydrologic conditions within the reference wetlands at the BOGGY.530 gauging station are shown in **Figure A-4**. These results show that at this site, the average hydroperiod is approximately 11 months in duration and water levels varied from at or below the soil surface to one foot above the soil surface. These values are within the range of hydrologic conditions found within cypress and swamp forest (**Table A-2**); however, water levels tend to fluctuate more in natural systems. Field examination of the wetland around the gauging station site indicated the cypress swamp was in relatively good health and surface water was present. However, some woody or shrubby species were found in the understory, which may indicate some hydrologic disturbance (such as water levels stabilization).

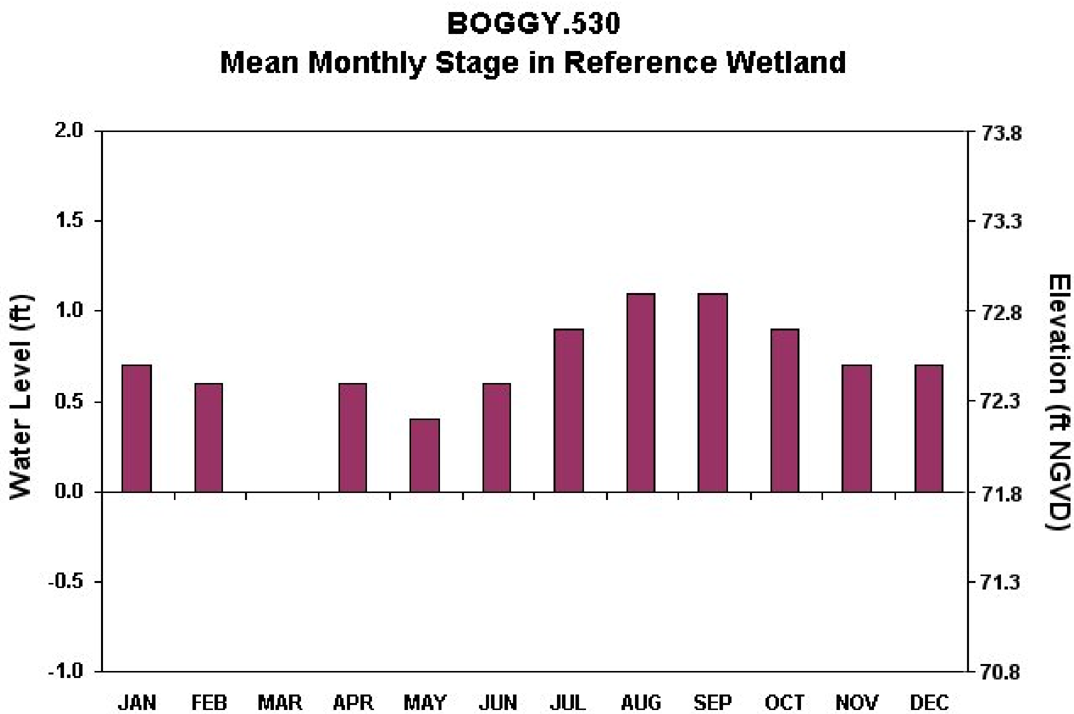

Figure A-4. Mean Monthly Stage in the Reference Wetland at the BOGGY.530 Gauging Stage Site (1985–2001); Soil Surface Elevation is at 71.8 ft NGVD.

BOGGY.TA Station

Estimated hydrologic conditions within the reference wetlands at the BOGGY.TA gauging station are shown in **Figure A-5**. These results show that at this site, mean monthly surface water levels (at the gauging station) range from two to five feet below the wetland soil surface. Actual water table levels in the wetland may be somewhat closer to the surface, as groundwater tends to be higher in soils than in surrounding water bodies due to capillary action of soil particles. The hydroperiod at this site is well below values reported for cypress swamps and swamp forest (**Table A-2**). Field examination of the wetland around the gauging station site indicated that this wetland has been impacted by lowered water levels. Surface water was not visible and an invasion of woody and shrubby species into the cypress swamp was visible.

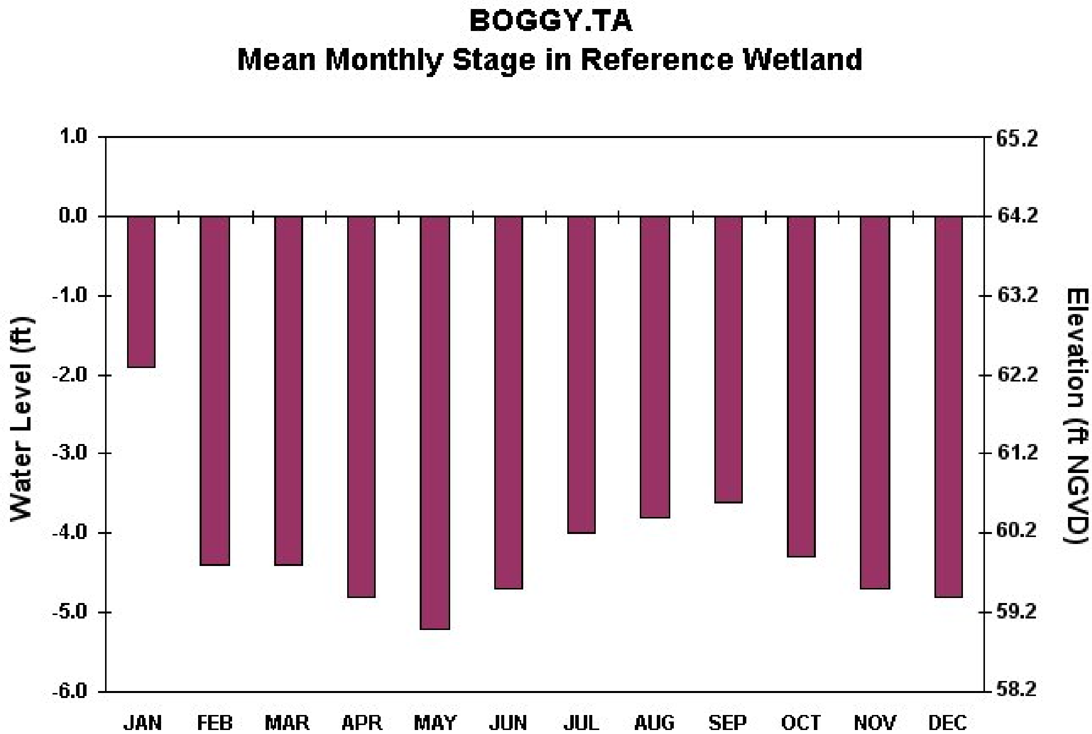

Figure A-5. Mean Monthly Stage in the Reference Wetland at the BOGGY.TA Gauging Stage Site (1959–2000); Soil Surface Elevation is at 64.2 ft NGVD.

Boggy Creek Inflow to East Lake Tohopekaliga (BOGGY.MOUTH)

Estimated hydrologic conditions within the reference wetlands at Boggy Creek delta are shown in **Figure A-6**. The water level gauging station was located along the southwest side of East Lake Tohopekaliga at the S-59 Structure (not shown on map), south of the wetlands. These results show the average hydroperiod is approximately 11 months in duration and water levels varied from at or below the soil surface to 1.7 feet above the soil surface. These values compare well with those reported for marshes (**Table A-2**). Field examination of the wetland at the site indicated that this wetland was in relatively good health. Surface water was visible throughout and the species present were typical of marsh habitats (e.g. cattail, pickerelweed and flag).

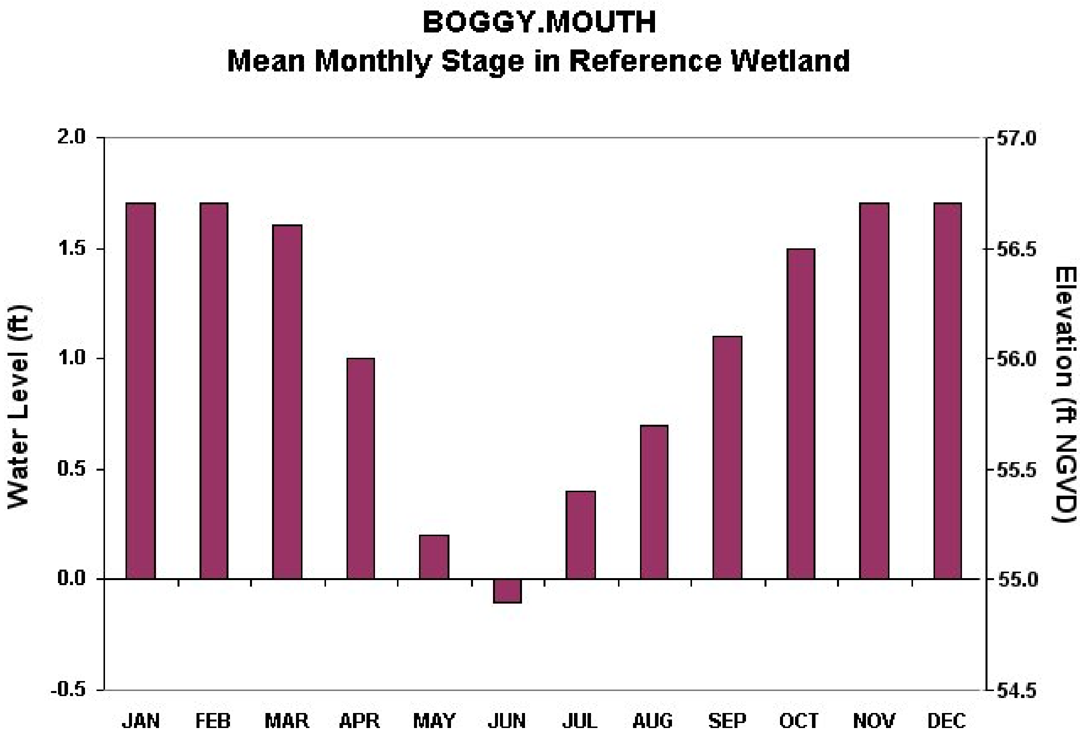

Figure A-6. Mean Monthly Stage in the Reference Wetland at the BOGGY.MOUTH Gauging Stage Site (1963–2003); Soil Surface Elevation is at 55.0ft NGVD.

Shingle Creek Wetlands

Shingle Creek is the main tributary to Lake Tohopekaliga. As with Boggy Creek, several major roads cross the waterbody: the Beeline Expressway (State Road 528) along its northern extension, the Florida Greenway (S.R. 417) along the southern end of a large unnamed cypress swamp, the Osceola Parkway and the Orange Blossom Trail (U.S. 17 and U.S. 92) near the creek's inflow into Lake Tohopekaliga. These large-scale road projects have the potential to affect the hydrologic characteristics of the area, especially if the Shingle Creek is the receiving water body for stormwater runoff. Two large wetland systems are found along Shingle Creek, an unnamed cypress swamp north of the Florida Greenway and an area of cypress swamp south of the Kissimmee Airport that extends to the Reedy Creek Swamp (**Figure A-7**). Much of the creek is fringed with cypress swamp from Lake Tohopekaliga to the Florida Greenway. The creek has been channelized in the most upstream segment.

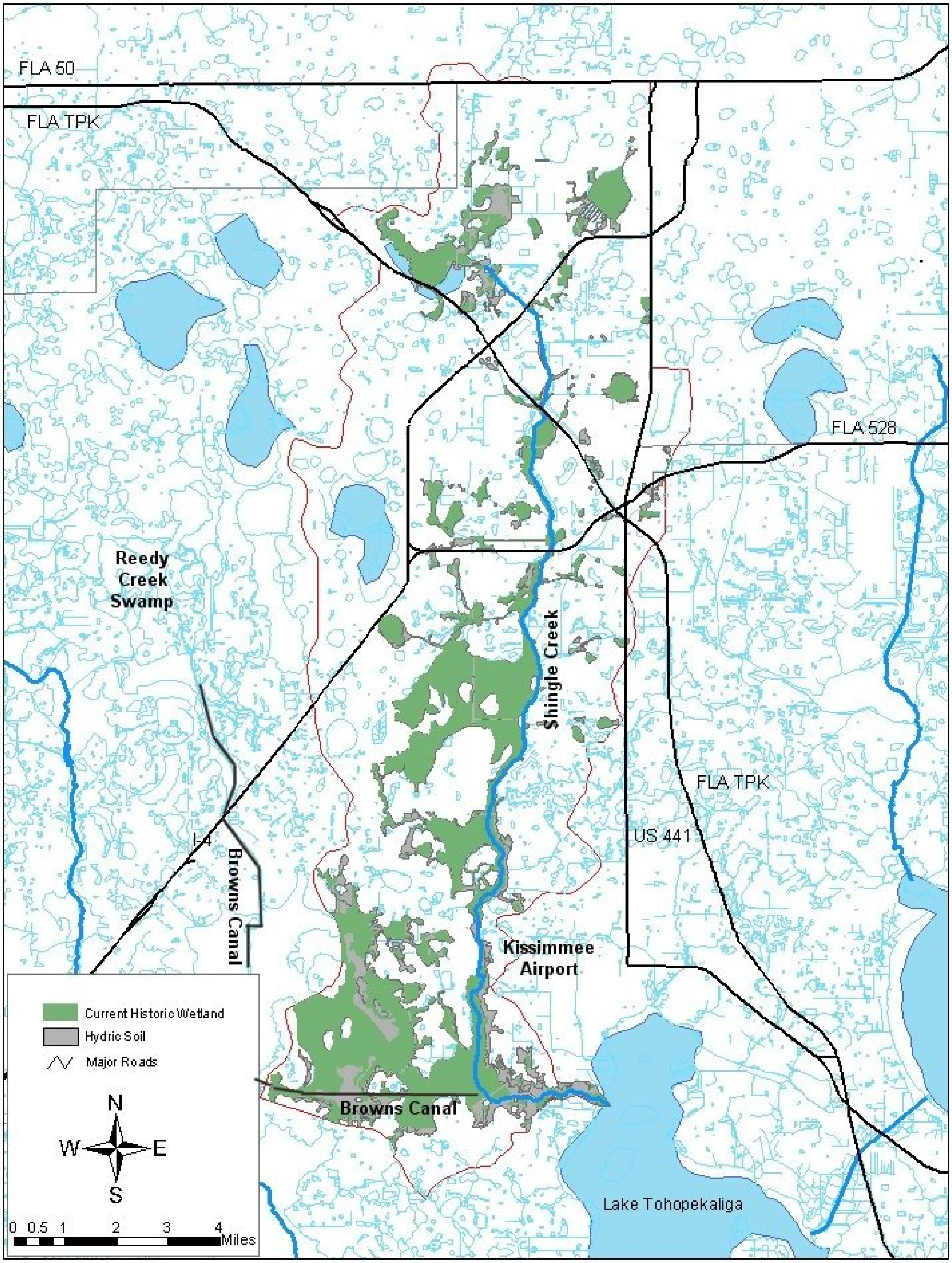

Figure A-7. Shingle Creek Map Showing Basin Boundary.

Three gauging stations are located within Shingle Creek and cypress wetlands are adjacent to these sites. These wetlands were used as "reference wetlands" in our analysis.

SHING.PE Station

At SHING.PE site (**Figure A-8**), measured water-level depths and hydroperiod were below the range typically found in bald cypress swamps (**Figure A-9**). Field observations of this wetland indicated that some broadleaf species were present (e.g., bays), which are often found in wetlands that have shorter hydroperiods. The physical characteristics of this site are different from other points along the creek (e.g., SHING.AP) as it lies within a section of the waterway where the creek empties into and overflows across the broad, flat expanse of wetland. This expanse of wetland provides a large storage area for rising floodwaters from the creek and as a result, it takes a much larger volume of water to raise the surface water elevation than would be required in a more constricted portion of the creek. Even so, the water levels measured at the SHING.PE monitoring station indicate the hydroperiod in the surrounding wetland is sub-optimum.

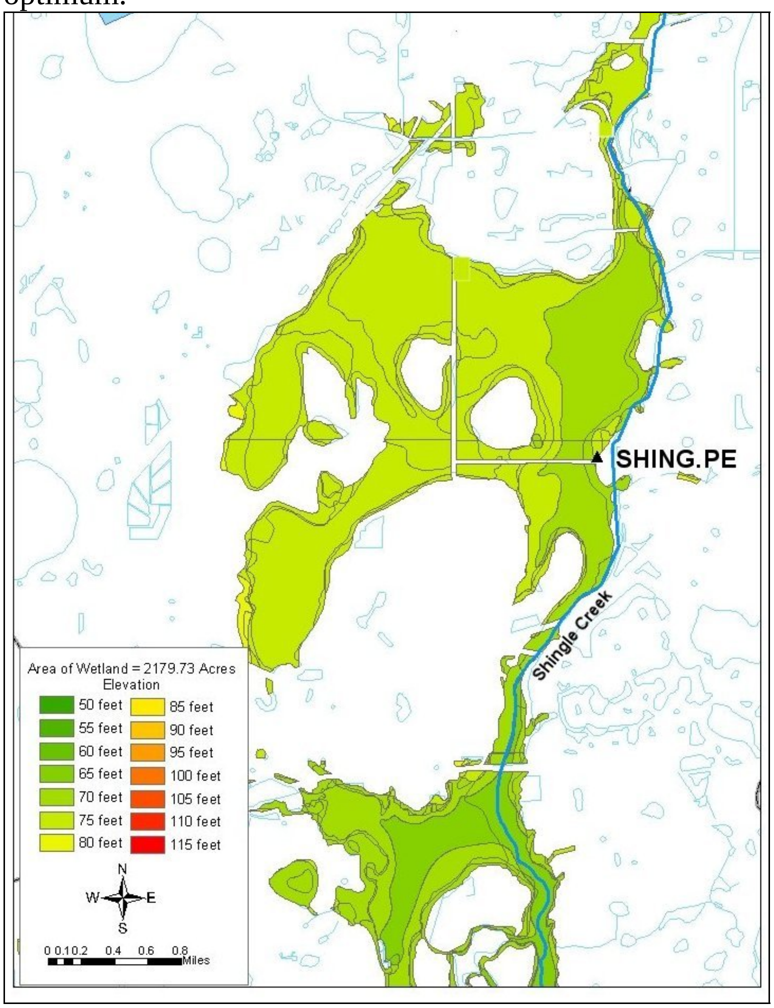

Figure A-8. Location of SHING.PE Water Level Gauging Station.

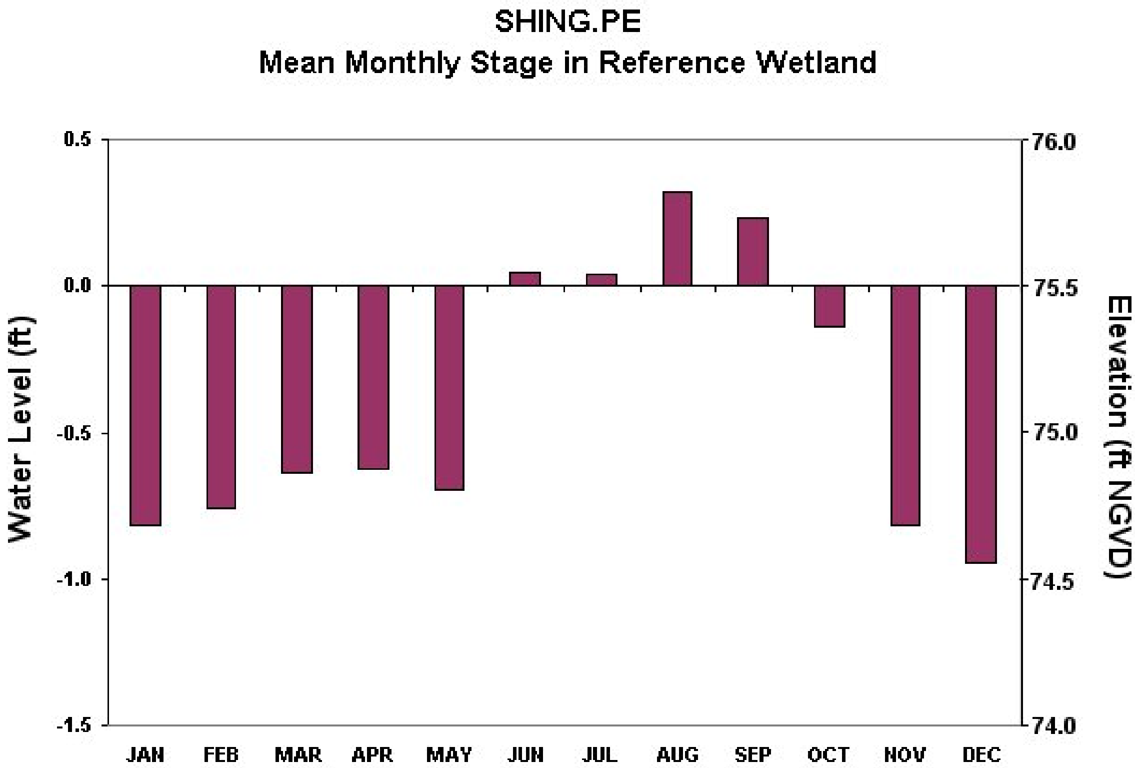

Figure A-9. Mean Monthly Stage in the Reference Wetland at the SHING.PE Gauging Stage Site (1992–1997); Soil Surface Elevation is at 75.5ft NGVD.

SHING.AP

At site SHING.AP (**Figure A-10**) measured water levels were within the range for bald cypress swamps (**Figure A-9**); however the hydroperiod was longer than is typically found (**Table A-2**). Usually, there is a seasonal dry down period (water levels at the soil surface or below) and this does not occur at this site. Prolonged inundation can interrupt successful reproduction of the swamp by preventing germination and growth of seedlings that require dry periods for establishment. Inspection of the site revealed a healthy bald cypress swamp and the water level values at the monitoring station are within those found within "deep" cypress swamps (CH2M Hill 1996). Characterization of this site as "deep cypress" is probably appropriate since it lies in a narrow floodplain downstream of a large wetland system and water levels may be naturally higher in this constriction of the watercourse.

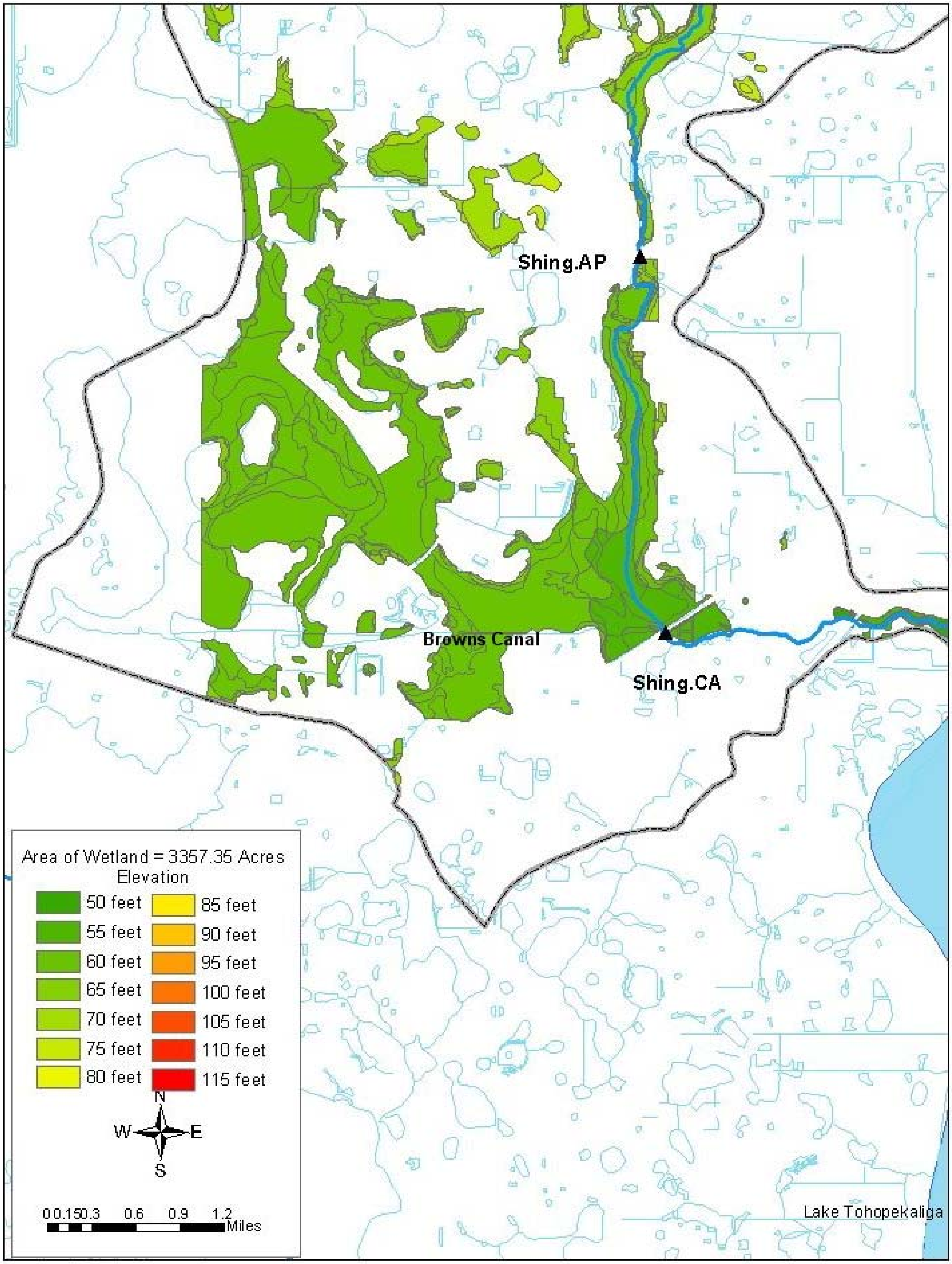

Figure A-10. Location of SHING.AP and SHING.CA Gauging Stations and Wetlands.

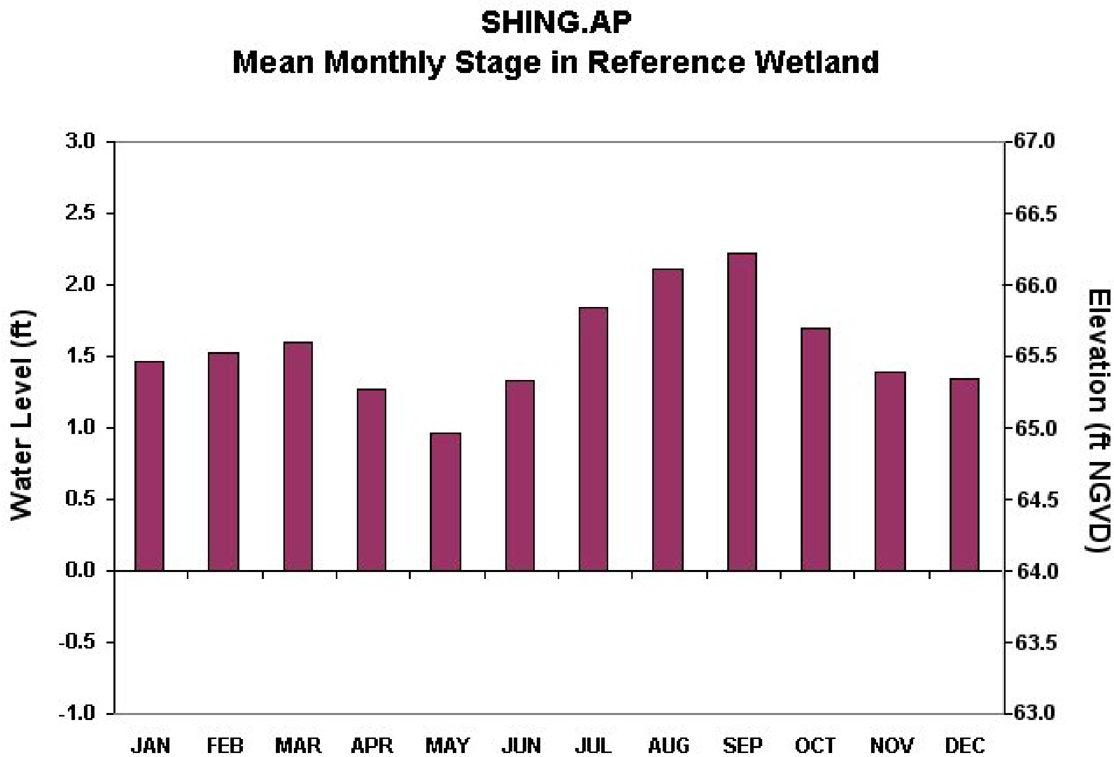

Figure A-11. Mean Monthly Stage in the Reference Wetland at the SHING.AP Gauging Stage Site (1958–2002); Soil Surface Elevation is at 64.0ft NGVD.

SHING.CA

At site SHING.CA (**Figure A-10**), there is a large difference between the measured stage and typical stages for the reference wetland type (**Figure A-12**). Water levels at the monitoring station ranged from 2.7 to 4.5 feet below the soil surface in the reference wetland. This suggests the wetland adjacent to this monitoring station has been overdrained. The wetland is characterized by numerous woody and shrubby species (associated with reduced hydroperiod). Browns Canal (**Figure A-10**), which cuts through floodplain wetlands from the Shingle Creek channel to the west and north to Reedy Creek Swamp, contributes to overdraining by providing an efficient means for surface water to be channeled into Lake Tohopekaliga rather than retained on the site as surface water or slowly moved by sheet flow.

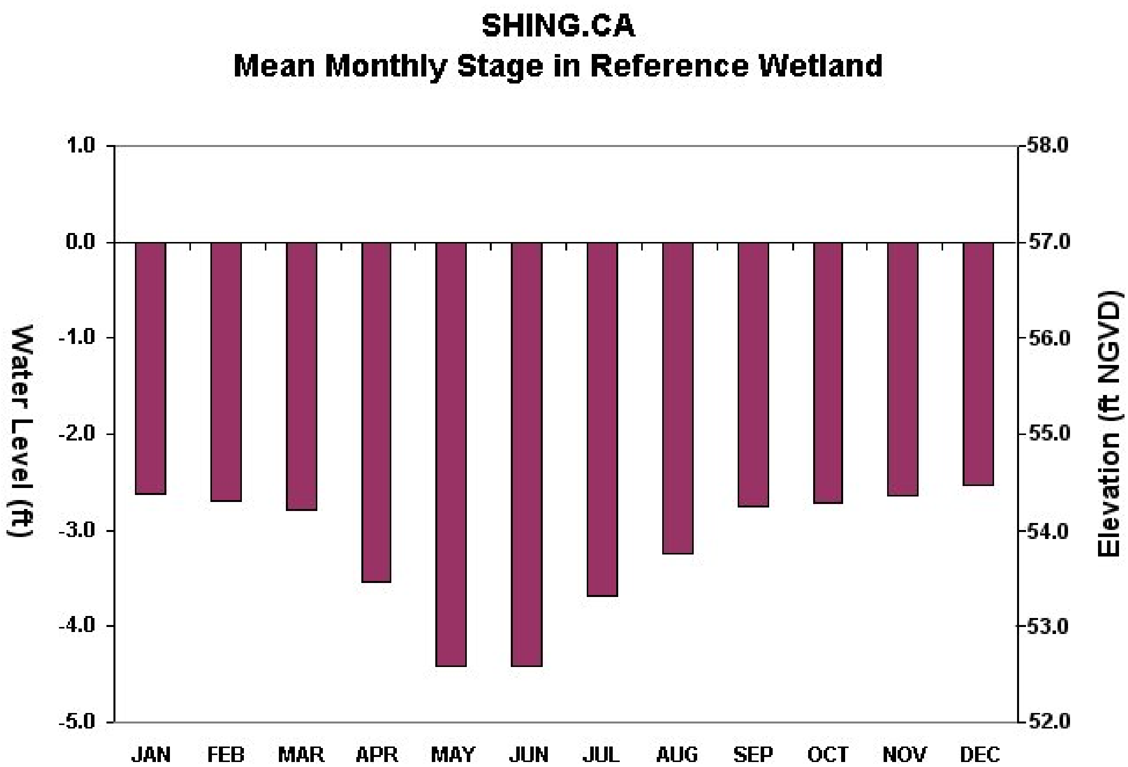

Figure A-12. Mean Monthly Stage in the Reference Wetland at the SHING.CA Gauging Stage Site (1968–2002); Soil Surface Elevation is at 57.0ft NGVD.

CONCLUSIONS

The results of this analysis indicate that wetlands adjacent to the BOGGY.TA and SHING.PE gauging stations have been affected by reduced water levels and hydroperiods. At the BOGGY.TA site, which lies at the downstream end of the Boggy Creek Swamp, water levels from historical stage data are well below those that would be required to sustain a healthy bald cypress community. Field observations verified the cypress-dominated wetland was invaded by shrubby vegetation and hardwoods, indicating a shortened hydroperiod. The reason for the reduction in water levels is not apparent; however, a reduction of inflows or altered flow patterns within Boggy Creek Swamp may be significant factors. At the SHING.PE site, water levels within the reference wetland were also below those expected for a bald cypress swamp and invasion of woody and shrubby species into the cypress swamp were noted in field inspections. A primary factor contributing to the observed reduction in hydroperiod may be impacts from Browns Canal, which drains surface water from the site.

These results suggest that no additional surface water should be withdrawn from areas upstream of the impacted sites (BOGGY.TA and SHING.PE) that would result in further reduction of water levels at these reference wetlands. Since BOGGY.TA is located on the downstream end of the creek, this suggests that further withdrawals should not occur for this creek. It may be possible to withdraw additional surface water from areas downstream of SHING.PE without impairing wetland function. Site-specific analysis should be performed to determine how much water might be available.

In order to further understand the factors affecting hydrologic conditions within these wetlands, consultation with field biologists in the area would be most helpful. An examination of the historical inputs (surface water and groundwater), either through analysis of field data (e.g., flow or stage) or through modeling, can help determine impacts of diverted flows and development in the watershed. Besides identifying specific factors that contribute to lower water levels at specific sites, other possible methods for providing sufficient water to impacted wetlands include an increase in tributary, creek or surface water flows, construction of berms or levees and improved groundwater management.

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APPENDIX B
Rainfall Data Analysis

Boggy Creek Basin

The rainfall data spanning from January 1, 1970 to December 31, 2001 was analyzed to determine the probability of reoccurring interval for the situations of 1-in-10 and 1-in-5 year drought conditions and 1-in-2 year average conditions. The following table was developed for this analysis.

Table B-1. Summary of Rainfall Data Analysis – Shingle Creek Rainfall Station.

Year	Recorded Rainfall (in)		Station Value	Exceedence Probability*
1970	23.68		23.68	97
1971	47.63		28.05	94
1972	34.91		28.12	91
1973	45.28		30.51	88
1974	41.53		34.91	85
1975	40.13		35.14	82
1976	42.76		36.73	79
1977	39.46		36.85	76
1978	38.55		38.55	73
1979	43.03		39.46	70
1980	36.85		40.13	67
1981	48.33		41.53	64
1982	36.73		41.62	61
1983	46.38		42.76	58
1984	35.14		42.90	55
1985	43.87		43.03	52
1986	45.46		43.87	48
1987	42.90		45.28	45
1988	50.30		45.46	42
1989	28.05		46.38	39
1990	30.51		47.63	36
1991	63.59		48.33	33
1992	58.79		50.20	30
1993	41.62		50.30	27
1994	71.97		51.13	24
1995	51.13		52.80	21
1996	59.00		54.00	18
1997	54.00		55.68	15
1998	50.20		58.79	12
1999	52.80		59.00	09
2000	28.12		63.59	06
2001	55.68		71.97	03

Note: The Weibull formula is applied here to obtain the exceedance probability (P).
P = m/ (n+1) *100%, where m = rank, n = number of years of record.

As shown in the above table, the total rainfall of 28.12 inches in 1984 has a probability of exceedance of about 91 percent. It is considered to meet 1-in-10 year drought condition. Due to the limitation of available data, the exact probability of 80 percent (1-in-5 year drought) was not achieved. The estimated 1-in-5 year drought occurs in the year of 1982 with a probability of exceedance of 79 percent. The estimated 1-in-2 year average condition occurs in the year of 1979.

Shingle Creek Basin

The rainfall data spanning from January 1, 1970 to December 31, 2001 was analyzed to determine the probability of reoccurring interval for the situations of 1-in-10 and 1-in-5 year drought conditions and 1-in-2 year average conditions. **Table B-2** was developed for this analysis.

As shown in **Table B-2**, the total annual rainfall of 40.54 inches in 1974 has a probability of exceedance at about 91 percent. And the total rainfall of 40.87 inches in 1971 has a probability of exceedance at about 88 percent. However, the flow in 1974 is much more than that in 1971. The rainfall in 1971 is considered to meet 1-in-10 year drought condition. Due to the limitation of available data, the exact probability of 80 percent (1-in-5 year drought) was not achieved. The estimated 1-in-5 year drought occurs in the year of 1978 with a probability of exceedance of 79 percent. The estimated 1-in-2 year average condition occurs in the year of 1995.

Table B-2. Summary of Rainfall Data Analysis – Shingle Creek Rainfall Station.

Year	Recorded Rainfall (in)
1970	48.82
1971	40.87
1972	49.19
1973	56.60
1974	40.54
1975	54.07
1976	44.65
1977	51.73
1978	41.71
1979	53.82
1980	34.23
1981	43.70
1982	52.56
1983	67.78
1984	47.64
1985	44.33
1986	41.22
1987	59.79
1988	57.69
1989	51.15
1990	41.57
1991	53.30
1992	51.16
1993	46.67
1994	70.82
1995	49.37
1996	57.22
1997	62.22
1998	55.64
1999	46.84
2000	38.59
2001	51.89

Sort	Exceedance Probability
34.23	97
38.59	94
40.54	91
40.87	88
41.22	85
41.57	82
41.71	79
43.70	76
44.33	73
44.65	70
46.67	67
46.84	64
47.64	61
48.82	58
49.19	55
49.37	52
51.15	48
51.16	45
51.73	42
51.89	39
52.56	36
53.30	33
53.82	30
54.07	27
55.64	24
56.60	21
57.22	18
57.69	15
59.79	12
62.22	09
67.78	06
70.82	03

APPENDIX C

Summarized Results from the Kissimmee Chain of Lakes Analysis for Lake Tohopekaliga and East Lake Tohopekaliga

Table C-1. Available Water from East LakeTohopekaliga.

Year	Jan	Feb	March	April	May	Wet Season (Jun–Oct)	Nov	Dec
1970	45	44	46	39	27	7	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	13	0	0
1973	0	30	39	36	12	19	5	2
1974	5	4	0	2	4	34	0	0
1975	0	0	0	0	0	22	4	0
1976	0	0	0	6	18	27	0	0
1977	0	3	6	11	4	8	0	0
1978	0	23	46	39	28	17	0	0
1979	0	8	29	33	24	24	4	4
1980	9	12	30	37	36	0	0	0
1981	0	0	0	0	0	6	0	0
1982	0	0	1	32	30	30	22	10
1983	13	40	48	50	26	27	2	13
1984	48	43	32	47	39	23	0	0
1985	0	0	0	0	0	23	1	6
1986	34	20	7	10	8	15	0	0
1987	4	4	10	46	32	12	35	47
1988	36	42	42	43	28	24	4	33
1989	33	31	25	33	23	18	0	0
1990	4	14	35	38	30	14	0	0
1991	0	0	0	29	46	41	10	7
1992	5	7	9	38	38	40	9	11
1993	32	45	21	4	28	15	3	0
1994	5	33	39	39	43	45	44	48
1995	43	28	32	42	30	35	31	25
1996	46	47	47	49	42	29	5	5
1997	5	5	6	22	45	28	6	47
1998	50	50	50	43	35	11	0	0
1999	0	0	0	1	17	33	47	34
2000	31	23	10	19	10	12	0	0
2001	0	0	0	0	0	25	0	0

Table C-2. Available Water from Lake Tohopekaliga.

Year	Jan	Feb	March	April	May	Wet Season (Jun–Oct.)	Nov	Dec
1970	49	49	48	48	44	12	0	0
1971	0	0	0	3	42	0	0	0
1972	0	6	15	45	43	21	0	0
1973	3	39	48	48	48	24	5	5
1974	14	6	8	39	46	33	0	0
1975	0	0	0	34	47	25	23	16
1976	12	10	33	43	43	32	0	3
1977	15	32	36	41	50	12	2	17
1978	37	48	48	42	47	18	0	0
1979	1	6	39	50	49	19	5	16
1980	37	40	41	46	47	0	0	0
1981	0	0	0	0	9	9	11	20
1982	34	32	38	46	49	41	10	10
1983	9	45	48	50	50	34	26	35
1984	50	43	39	50	50	24	0	0
1985	0	0	2	36	49	26	8	13
1986	42	45	40	49	48	19	0	2
1987	3	0	1	50	48	14	43	47
1988	40	41	47	49	49	20	5	45
1989	39	29	42	46	49	14	0	11
1990	25	44	46	47	43	17	0	0
1991	1	2	17	48	49	42	9	5
1992	5	10	24	50	50	35	23	38
1993	50	44	46	49	49	12	5	4
1994	10	36	47	50	50	42	50	50
1995	42	36	39	50	50	32	36	27
1996	44	48	50	49	50	36	5	14
1997	20	25	34	49	50	24	13	47
1998	50	50	50	50	50	6	7	8
1999	17	25	26	47	47	37	47	37
2000	34	26	28	48	47	17	0	0
2001	0	0	0	17	50	30	7	5

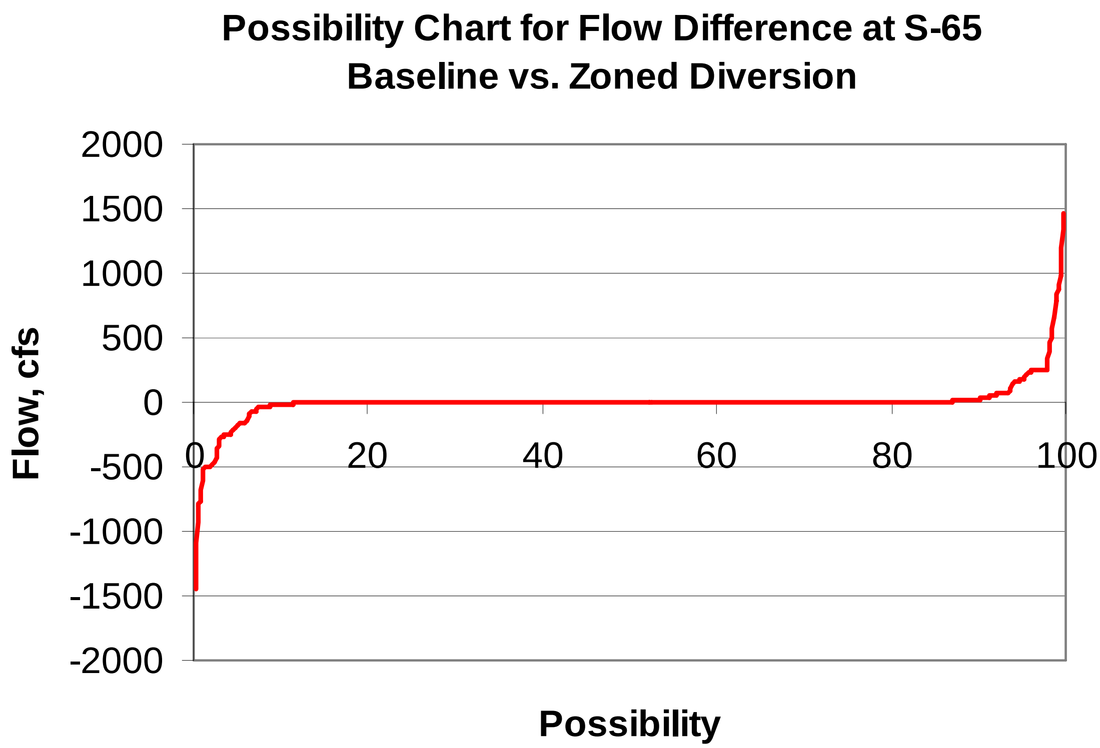

Figure C-1. Discharge Flow Changes at S-65 after Diverting Water from Lake Tohopekaliga.

This chart was prepared to demonstrate the discharge flow changes at S-65 after diverting the maximum amount of 50 MGD water from East Lake Tohopekaliga and Lake Tohopekaliga independently. In the lake analysis, the condition with no flow diversion from the system is defined as the baseline condition. Water diverted in the lakes was based on the regulation schedules and zones. This chart indicates that there are less than 8 percent chances that the flow at S-65 is less by 50 cfs or more than the baseline flow in the 32-year period of record. Theoretically, with the diversion zones set up in both East Lake Tohopekaliga and Lake Tohopekaliga the flow at S-65 should be less than the baseline flow. Thus there are less than 10 percent chances that the flow at S-65 is greater by 50 cfs or more than the baseline flow. The source data of this chart shows that the positive and negative flow differences occur at the consequent months. In other words, if the flow diverted in a month was too much, there maybe no water available for diversion in the next month based on the set diversion zones. Thus, the flow going downstream is greater than that in baseline analysis in the next month. Whether the impact is significant or not, the definition of significant impact on the flow at S-65 should be defined before a further evaluation of the impact resulted from the diversion is conducted.

APPENDIX D

Monthly Graphical Depiction of Potentially Available Flow Exceedance

Boggy Creek

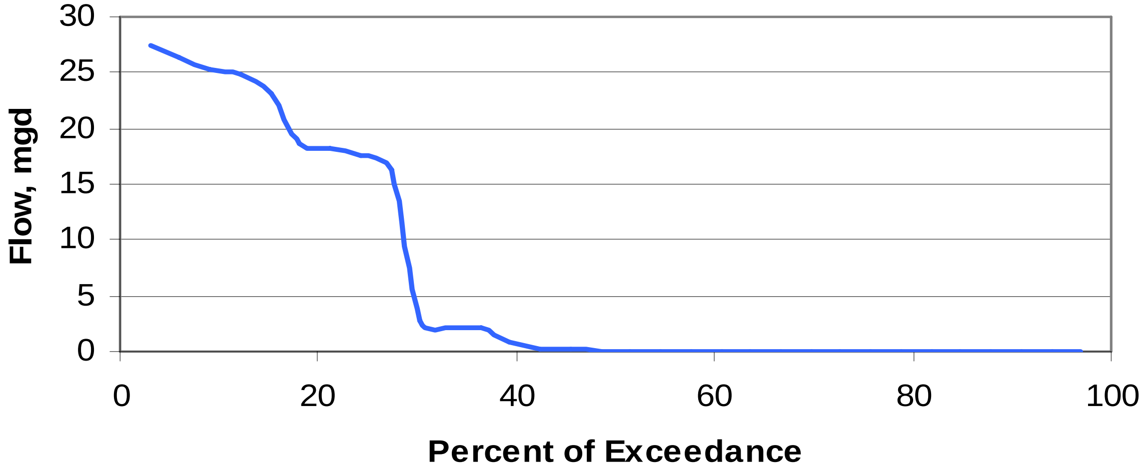

Figure D-1. January Available Flow Exceedance in Boggy Creek.

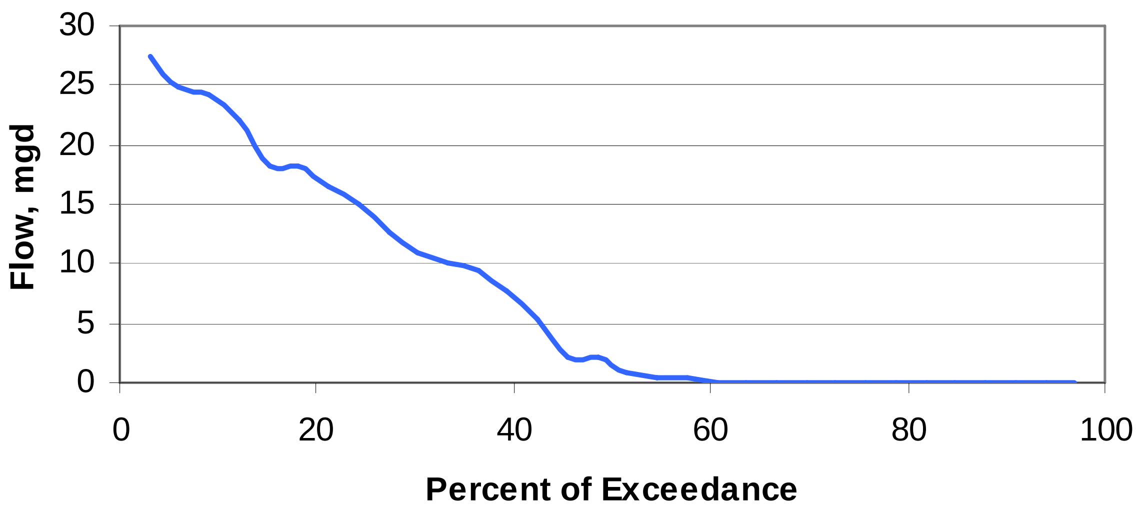

Figure D-2. February Available Flow Exceedance in Boggy Creek.

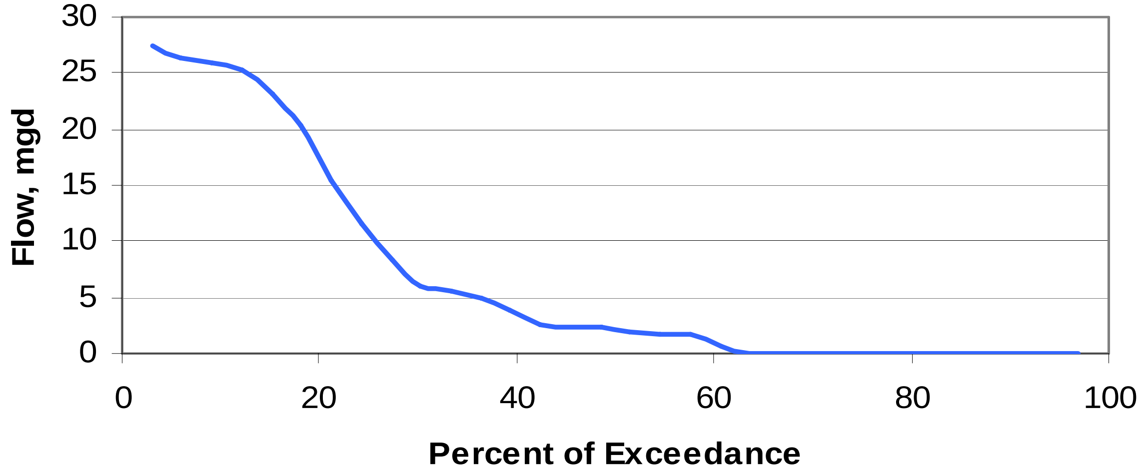

Figure D-3. March Available Flow Exceedance in Boggy Creek.

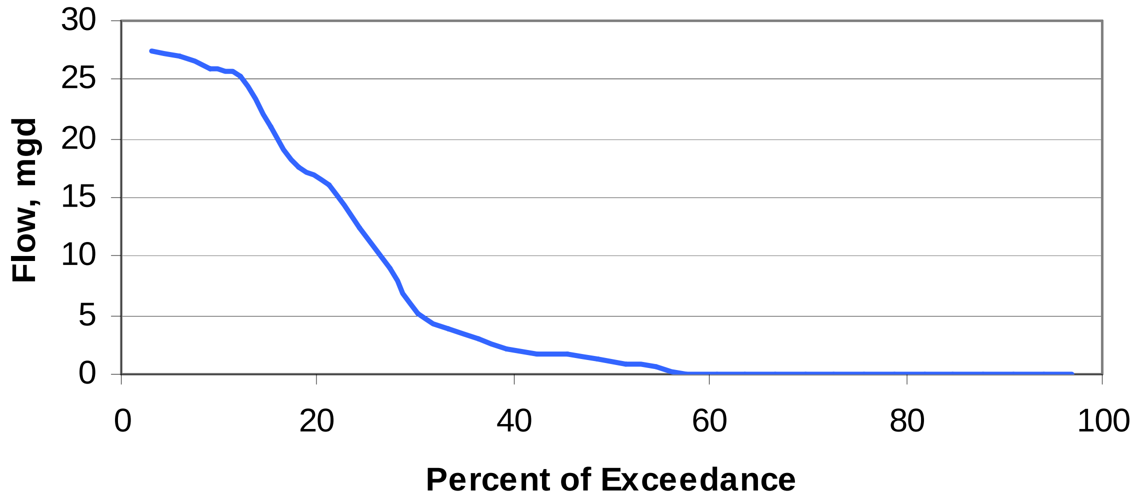

Figure D-4. April Available Flow Exceedance in Boggy Creek.

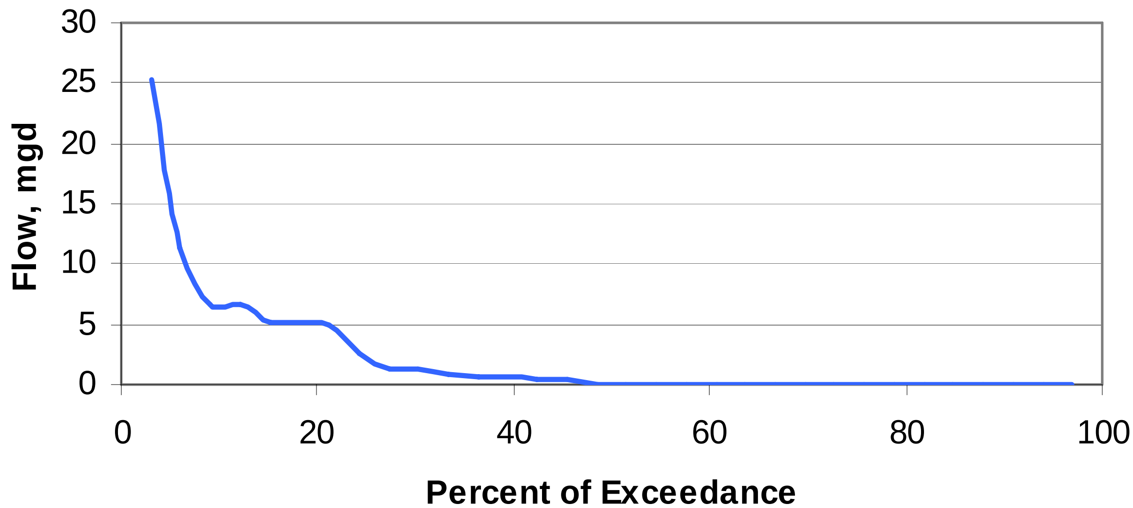

Figure D-5. May April Available Flow Exceedance in Boggy Creek.

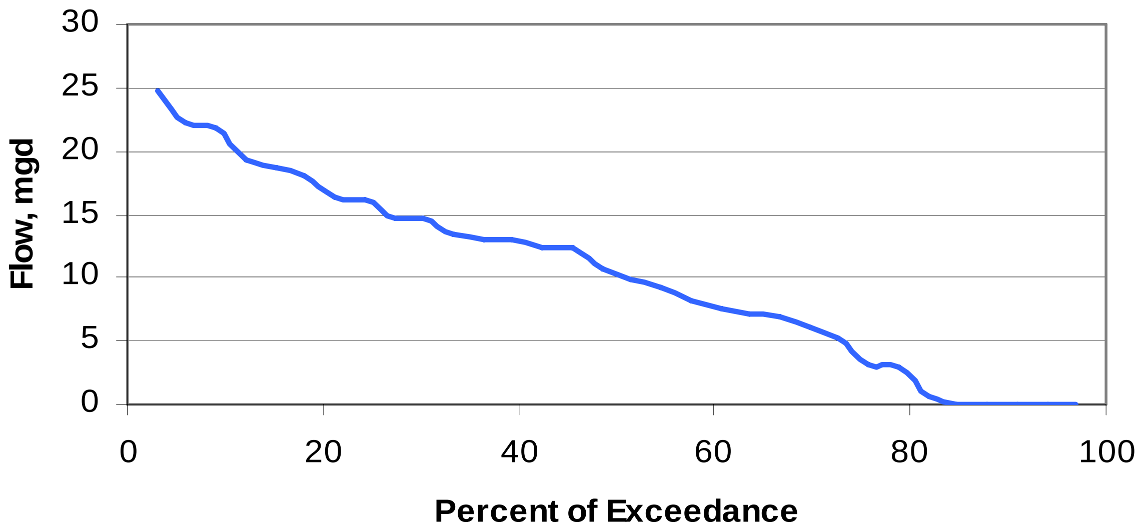

Figure D-6. Wet Season Available Flow Exceedance in Boggy Creek.

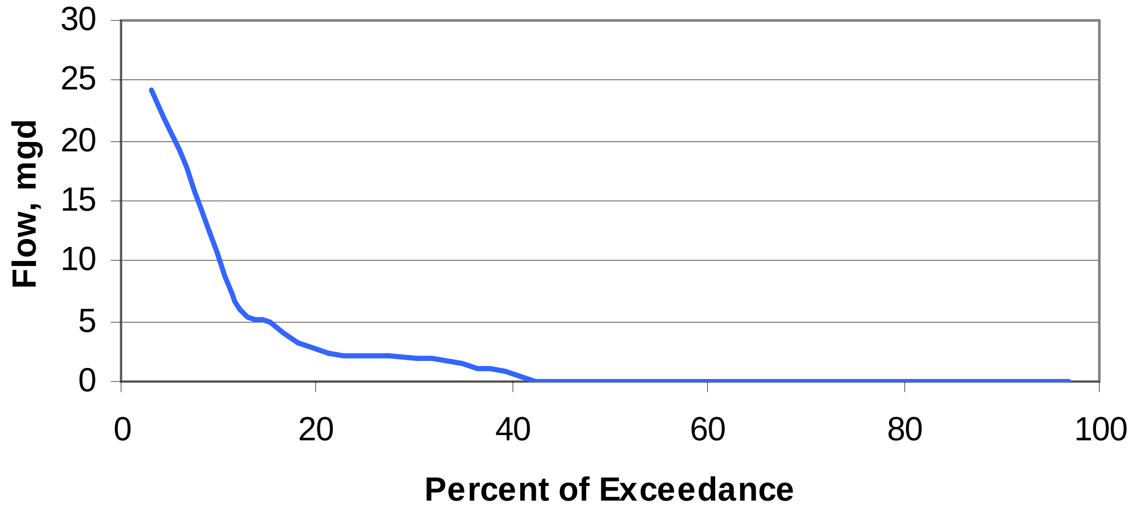

Figure D-7. November Available Flow Exceedance in Boggy Creek.

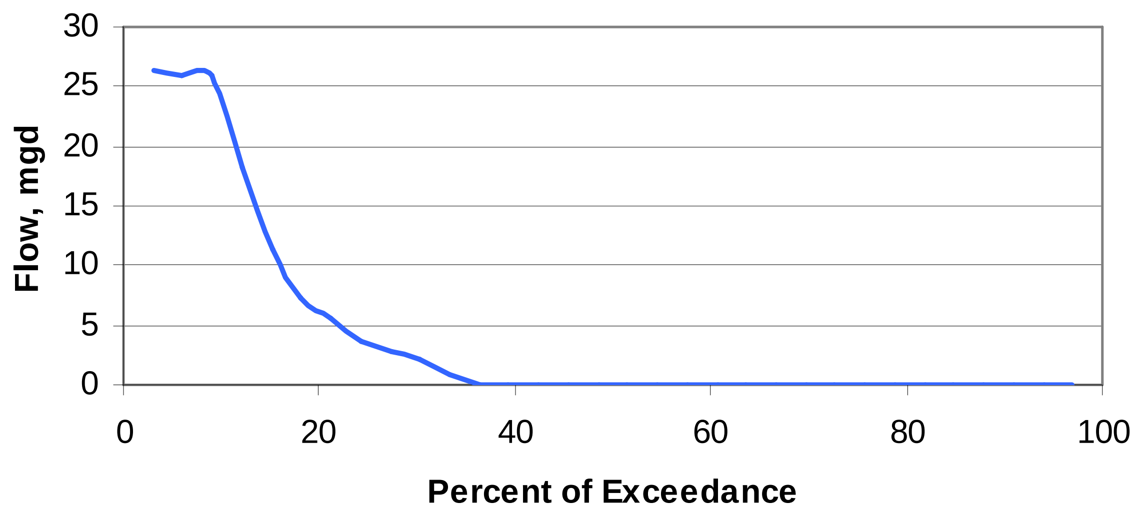

Figure D-8. December Available Flow Exceedance in Boggy Creek.

Shingle Creek

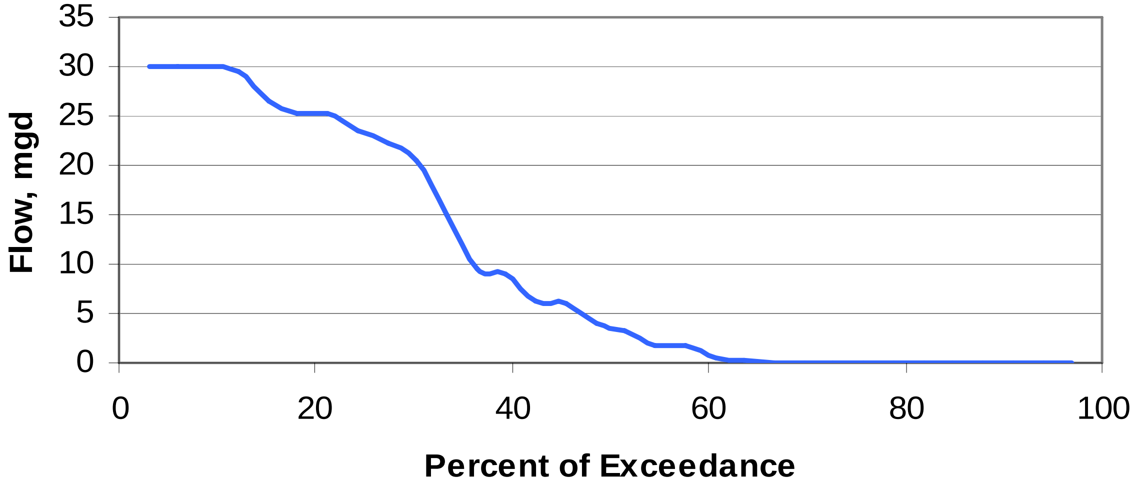

Figure D-9. January Available Flow Exceedance in Shingle Creek.

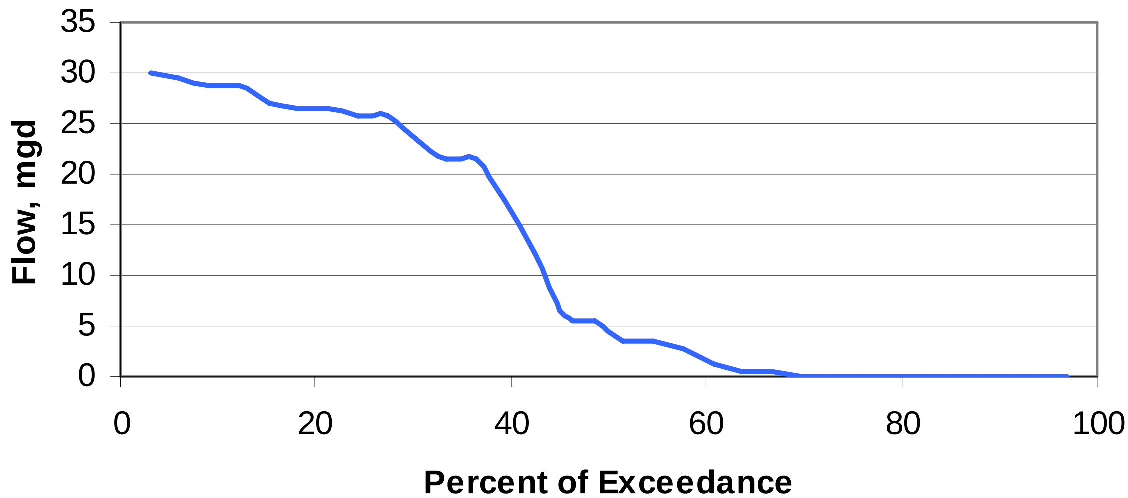

Figure D-10. February Available Flow Exceedance in Shingle Creek.

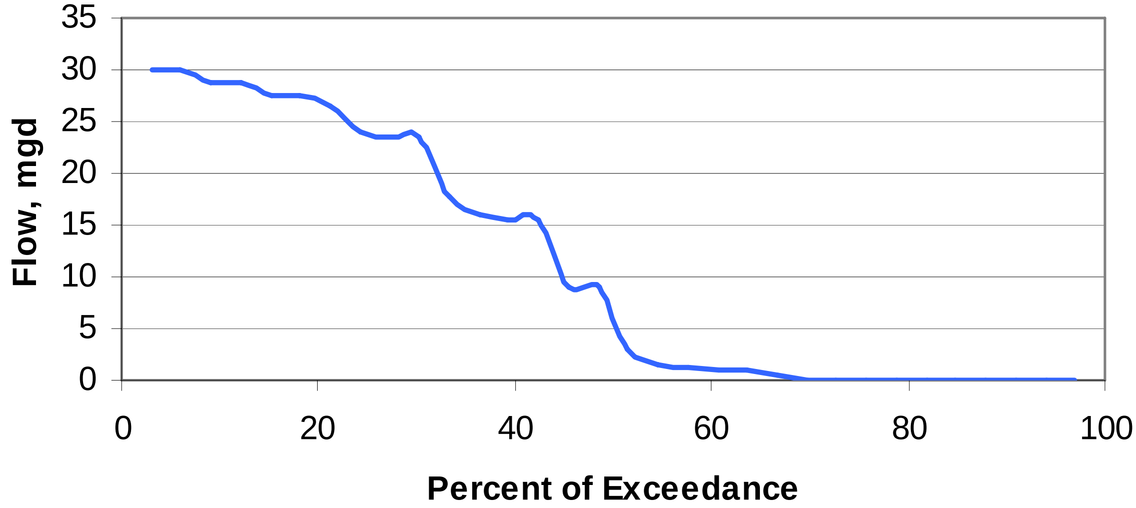

Figure D-11. March Available Flow Exceedance in Shingle Creek.

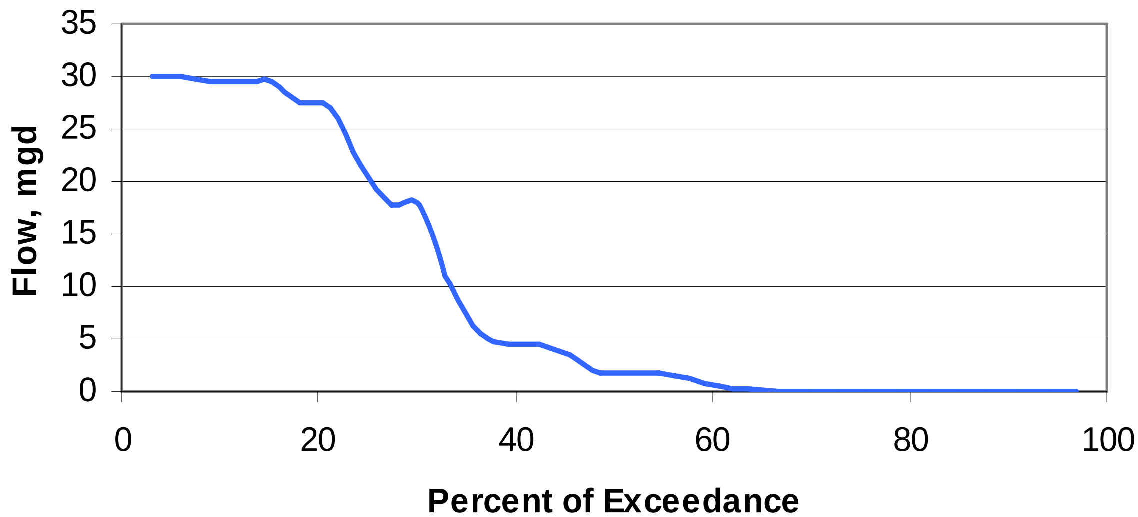

Figure D-12. April Available Flow Exceedance in Shingle Creek.

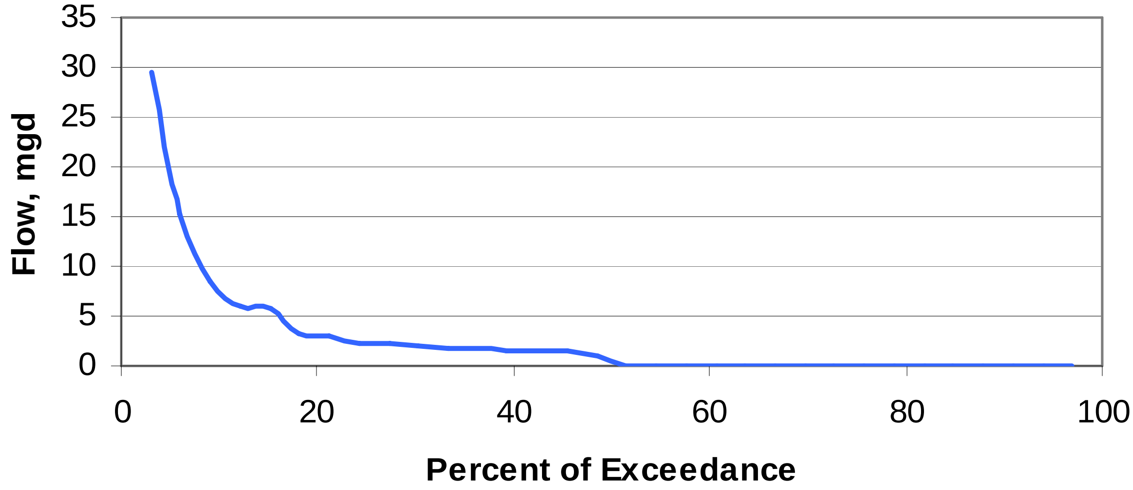

Figure D-13. May Available Flow Exceedance in Shingle Creek.

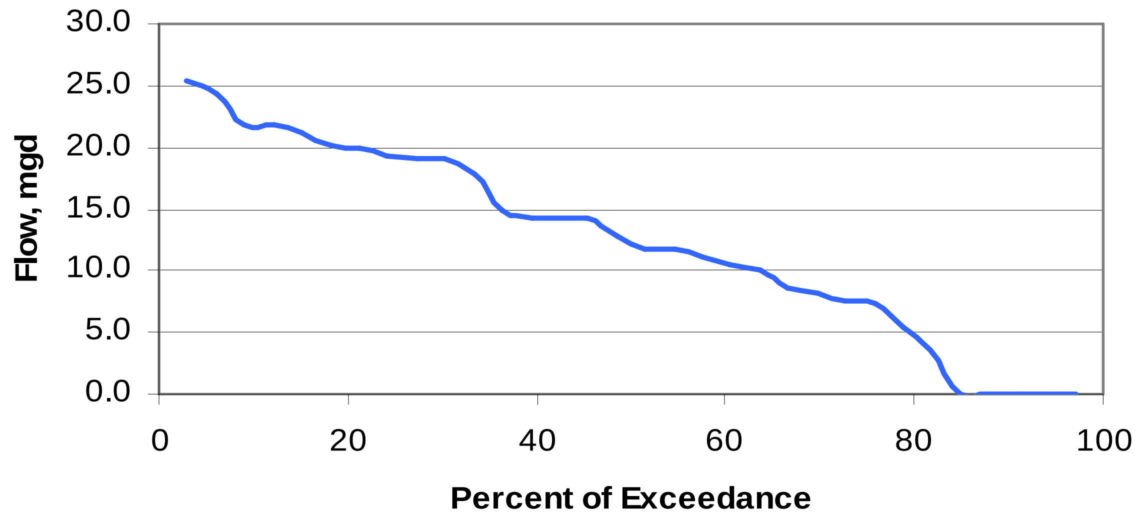

Figure D-14. Wet Season Available Flow Exceedance in Shingle Creek.

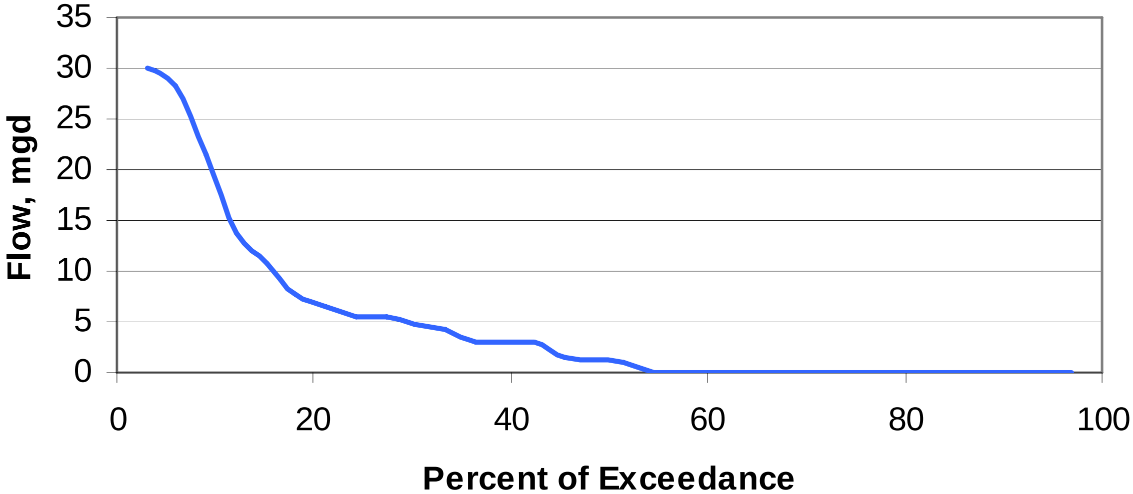

Figure D-15. November Available Flow Exceedance in Shingle Creek.

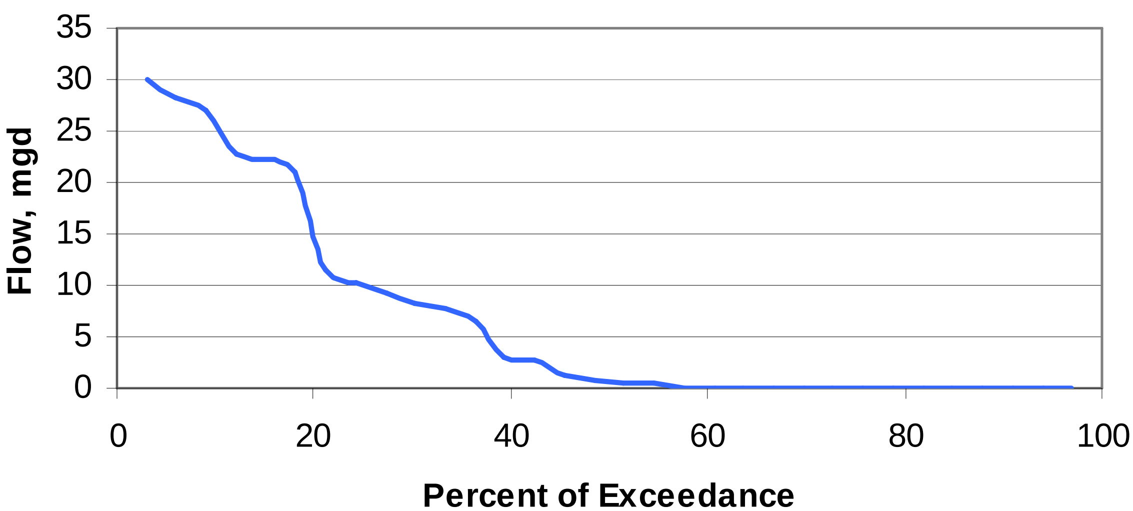

Figure D-16. December Available Flow Exceedance in Shingle Creek.