TECHNICAL PUBLICATION SJ2008-2

MINIMUM LEVELS REEVALUATION:
THREE ISLAND LAKES
VOLUSIA COUNTY, FLORIDA

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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THREE ISLAND LAKES
VOLUSIA COUNTY, FLORIDA

by

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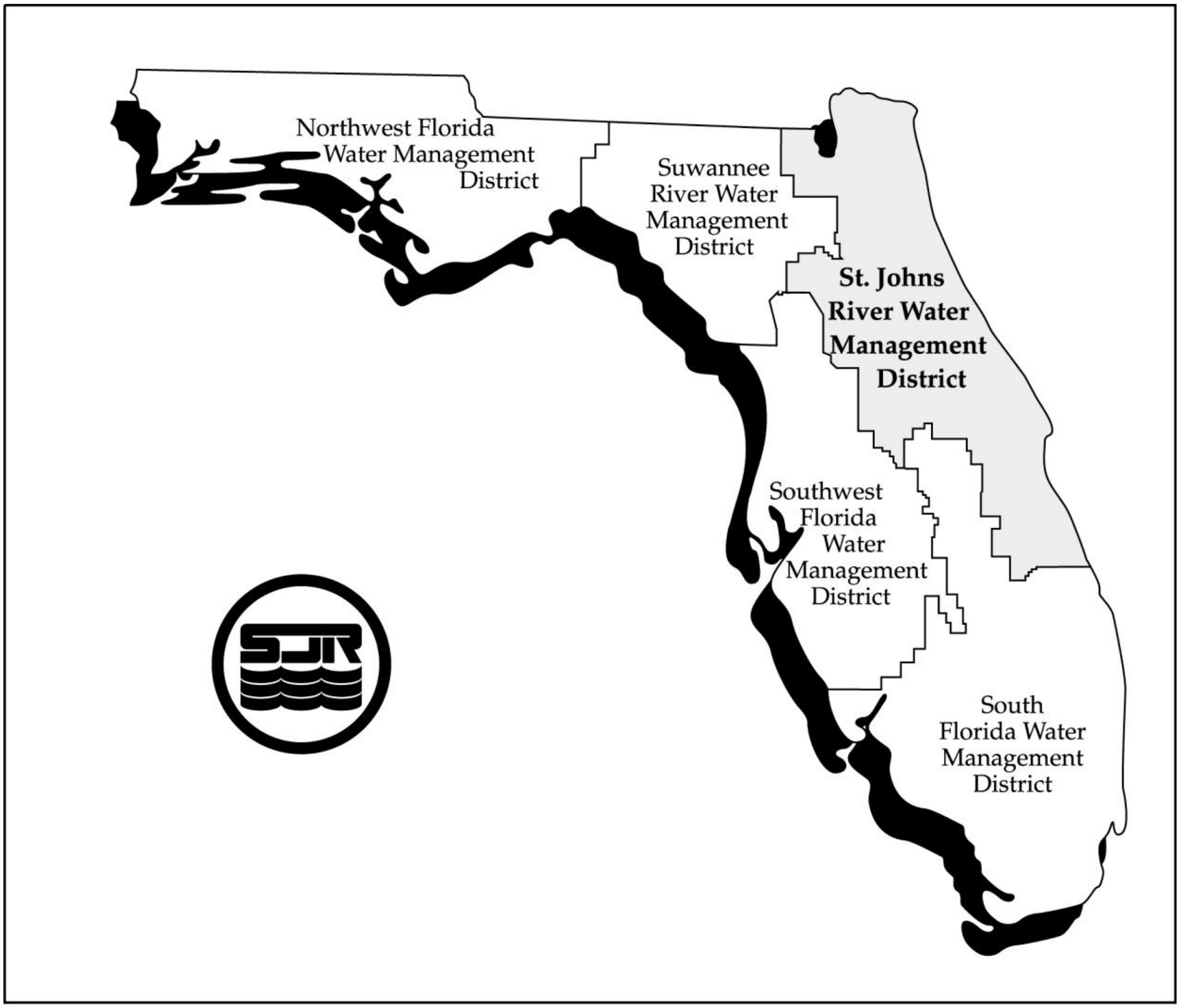

The St. Johns River Water Management District (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 18 counties in northeast Florida. The mission of SJRWMD is to ensure the sustainable use and protection of water resources for the benefit of the people of the District and the state of Florida. SJRWMD accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

This report presents the St. Johns River Water Management District (SJRWMD) minimum flows and levels (MFLs) reevaluation for Three Island Lakes, Volusia County, Florida. This system is on the MFLs Priority Water Body List and Schedule (SJRWMD 2006a), which includes a schedule for the establishment and reevaluation of MFLs pursuant to Section 373.042(2), *Florida Statutes* (F.S.). MFLs for Three Island Lakes were determined in 1997 based upon the best information and methods available at that time (Mace 1997, Appendix A). The SJRWMD Governing Board adopted minimum levels for Three Island Lakes by SJRWMD rule in 1997 (40C-8.021, *Florida Administrative Code* [*F.A.C.*]). However, no hydrologic model was available in 1997 to assess the protection of the proposed MFLs. Recent development of a hydrologic model indicates that adopted minimum frequent high and minimum average levels for Three Island Lakes are not protected under existing 2003 modeled hydrologic conditions (Robison 2006). As a result, additional fieldwork was completed to reevaluate the MFLs. This reevaluation has resulted in the recommendation to modify the existing MFLs for Three Island Lakes (Table ES-1) based on current SJRWMD MFLs methodology.

Table ES-1. Adopted (Mace 1997) and recommended minimum surface water levels for Three Island Lakes, Volusia County, Florida

Minimum Levels	Adopted Elevation (ft NGVD) 1929 Datum	Adopted Hydroperiod Categories	Recommended Elevation (ft NGVD) 1929 Datum	Recommended Duration	Recommended Return Interval
Minimum frequent high (FH) level	23.4	Seasonally flooded	23.7	30 days	5 years
Minimum average (MA) level	21.8	Typically saturated	none	none	none
Minimum frequent low (FL) level	18.8	Semi-permanently flooded	19.4	120 days	10 years

ft NGVD = feet National Geodetic Vertical Datum

The minimum lake levels presented here were determined with SJRWMD's multiple MFLs methodology (SJRWMD 2006b). MFLs determinations are based on evaluations of topographic, soils and vegetation data collected within plant communities associated with the water body, along with information collected from other aquatic ecosystems and from the scientific literature.

The recommended minimum frequent high elevation component for Three Island Lakes, 23.7 feet (ft) National Geodetic Vertical Datum (NGVD), is 0.3 ft higher than the adopted minimum frequent high elevation component, 23.4 ft NGVD. The same criterion, mean elevation of transitional shrub/shoreline communities, was utilized for the determination of the adopted and recommended minimum frequent high elevation components. The difference arises from the incorporation of data from two additional transects in the determination of the recommended minimum frequent high elevation component. In addition to a recommended change in the minimum frequent high elevation, it is also recommended that the temporal components be modified. The change in temporal components results in a 30-day flood event occurring less frequently, i.e., once every 5 years, on average, rather than once every 3 years, on average. This modification is recommended because it is supported by current surface water inundation/dewatering signatures (SWIDS) (Neubauer et al. 2006).

The minimum frequent high level allows the mean elevation of the transitional shrub communities to be flooded, on average, 30 continuous days once every 5 years, which is slightly wetter than the driest hydrologic signature for transitional shrub communities based on current SWIDS analysis (Neubauer et al. 2006). Since the minimum frequent high level maintains a hydrologic signature within the range observed for transitional shrubs, this minimum level is intended to maintain the location, structure, and function of this community. This minimum level allows for some change, which will likely be expressed in a change in species abundance, species composition, and potentially some shift in the extent of the community at its extreme (maximum/minimum) elevations. Further hydrologic shifts caused by withdrawals that exceed MFLs will likely result in significant harm via conversion of the upper portion of the transitional shrub to a drier plant community and alteration of the community’s structure and function at its extreme elevations.

The adopted minimum average elevation component is 21.8 ft NGVD and is equivalent to the median stage elevation for the period January 4, 1990, to October 8, 1997 (Mace 1997). No minimum average level is recommended for Three Island Lakes. This is because Three Island Lakes is a sandhill lake. Based on the conceptual model of sandhill lakes developed by CH2M HILL (2003), sandhill upland lakes are astatic and lack a mean around which the system is organized. CH2M HILL (2003) also suggests that critical system behaviors of sandhill lakes may be related most strongly to high- and low water levels corresponding to drought cycles and multidecadal climate cycles and that both high- and low water levels are necessary to maintain expected ecosystem structure and function. Therefore, only minimum frequent high and minimum frequent low levels are recommended for Three Island Lakes.

The recommended minimum frequent low elevation component for Three Island Lakes (19.4 ft NGVD) is 0.6 ft higher than the adopted minimum frequent low elevation component (18.8 ft NGVD). The same criterion, mean elevation of deep marsh (aquatic bed) communities, was utilized for the determination of the adopted and recommended minimum frequent low elevation components. The difference arises from the incorporation of data from two additional transects in the determination of the recommended minimum frequent low elevation component. Upon review of the original MFLs determination, it was evident that the aquatic bed on Transect 2 likely skewed the mean deep marsh/aquatic bed elevation toward a low value. This bias was substantially reduced via incorporation of the two additional transects completed during the reevaluation process. In addition to a recommended change in the minimum frequent low level elevation, it is also recommended that the temporal components be modified. The change in temporal components results in a 120-day dewatering event occurring less frequently, i.e., once every 10 years, on average, rather than once every 5 years, on average. This modification is supported by current SWIDS for deep marsh plant communities (Neubauer et al. 2006).

The minimum frequent low level allows the mean elevation of the deep marshes at Three Island Lakes to be dewatered, on average, for 120 continuous days once every 10 years. This dewatering signature is slightly wetter than the driest deep marsh based on current SWIDS analysis of 20 deep marsh plant communities (Neubauer et al. 2006), and is drier than approximately 75% of the deep marshes analyzed. The minimum frequent low level is intended to maintain the location, structure, and functions of this community. This minimum level allows for some change, which will likely be expressed via a change in species abundance, species composition, and potentially some shift in the extent of the community at its extreme (maximum/minimum) elevations. A further hydrologic shift caused by withdrawals that exceed the recommended MFLs will likely result in significant harm via conversion of the upper portion of the deep marsh to a drier plant community and alteration of the structure and functions at the extreme elevations within this community.

Additional information is included in the preliminary minimum levels reevaluation section regarding the criteria and supporting data used to recommend the MFLs described here. Additional information regarding the adopted MFLs can be obtained from Mace (1997, Appendix A).

The adopted MFLs with associated hydroperiod categories and the recommended MFLs with associated durations and return intervals are presented in Table ES-1. The hydroperiod categories and definitions are adapted from water regime modifiers developed by Cowardin et al. (1979). Results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule.

The hydrologic model for Three Island Lakes (Robison 2006) was calibrated for 2003 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2003 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Three Island Lakes are protected under 2003 conditions. To determine if changes in groundwater use allocations subsequent to 2003 would cause lake levels to fall below the recommended MFLs for Three Island Lakes, the existing Three Island Lakes hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.

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MFLS PROGRAM OVERVIEW

The St. Johns River Water Management District (SJRWMD) minimum flows and levels (MFLs) program is based on the requirements of Section 373.042 and Section 373.0421, *Florida Statutes* (F.S.), and establishes MFLs for lakes, streams and rivers, wetlands, springs, and aquifers. Furthermore, the MFLs program is subject to the provisions of Chapter 40C-8, *Florida Administrative Code (F.A.C.*), and provides technical support for the SJRWMD regional water supply planning process (Section 373.0361, F.S.) and the consumptive use permitting program (Chapter 40C-2, *F.A.C.*). Based on the provisions of Rule 40C-8.011(3), *F.A.C.*, "… the Governing Board shall use the best information and methods available to establish limits which prevent significant harm to the water resources or ecology." Significant harm, or the environmental effects resulting from the reduction of long-term water levels and/or flows below MFLs, is prohibited by Section 373.042(1a)(1b), F.S. In addition, MFLs should be expressed as multiple flows or levels defining a minimum hydrologic regime to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area (Rule 62-40.473(2), *F.A.C.*).

Factors to Be Considered When Determining MFLs

According to Rule 62-40.473, *F.A.C.*, in establishing MFLs pursuant to Section 373.042 and Section 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including the following:

- Recreation in and on the water (Rule 62.40.473(1)(a), *F.A.C.*)
- Fish and wildlife habitats and the passage of fish (Rule 62.40.473(1)(b), *F.A.C.*)
- Estuarine resources (Rule 62.40.473(1)(c), *F.A.C.*)
- Transfer of detrital material (Rule 62.40.473(1)(d), *F.A.C.*)
- Maintenance of freshwater storage and supply (Rule 62.40.473(1)(e), *F.A.C.*)
- Aesthetic and scenic attributes (Rule 62.40.473(1)(f), *F.A.C.*)
- Filtration and absorption of nutrients and other pollutants (Rule 62.40.473(1)(g), *F.A.C.*)
- Sediment loads (Rule 62.40.473(1)(h), *F.A.C.*)

- Water quality (Rule 62.40.473(1)(i), *F.A.C.*)
- Navigation (Rule 62.40.473(1)(j), *F.A.C.*)

In addition to these factors, based on Section 373.0421(1), F.S., the following considerations are also required.

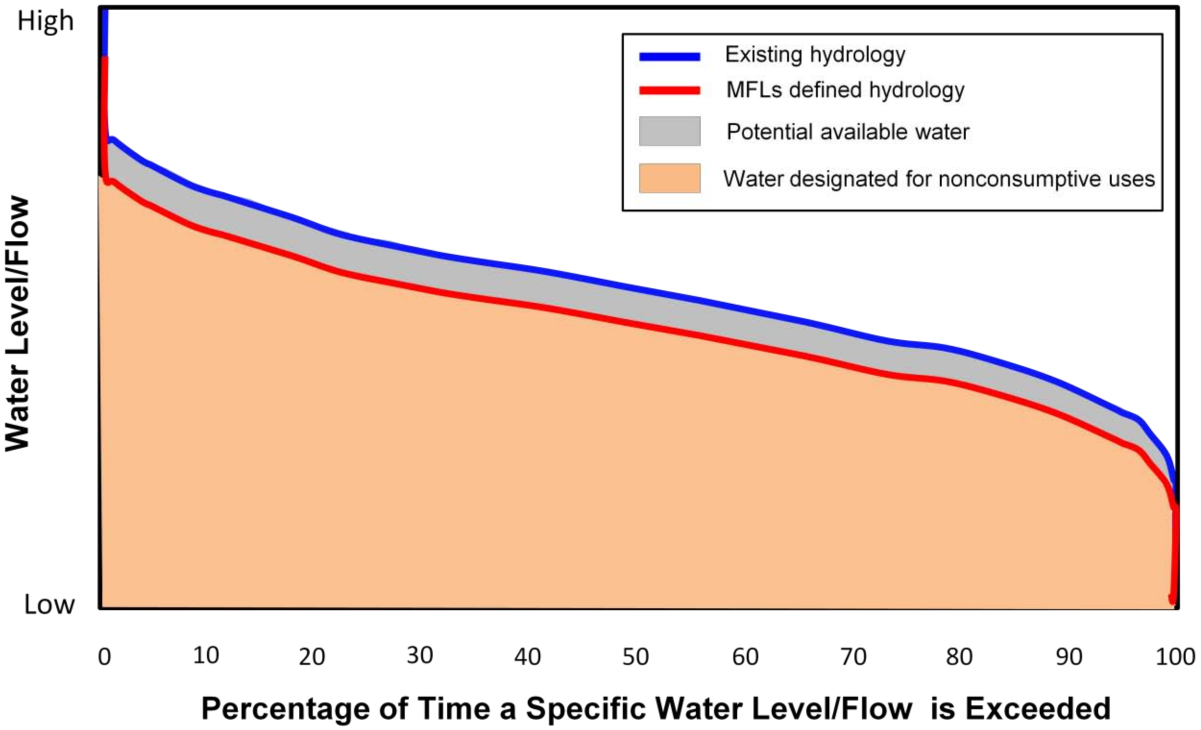
"When establishing minimum flows and levels pursuant to Section 373.042, the department or Governing Board shall consider changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of an affected watershed, surface water, or aquifer, provided that nothing in this paragraph shall allow significant harm as provided by Section 373.042(1) caused by withdrawals."

Hydrology

The MFLs designate an environmentally protective hydrologic regime (i.e., hydrologic conditions that prevent significant ecological harm) and identify levels and/or flows above which water may be available for use. MFLs define the frequency and duration of high- and low water events necessary to protect relevant water resource values, criteria, and indicators that prevent significant harm to aquatic and wetland habitats. Three MFLs are usually defined for each system—minimum frequent high, minimum average, and minimum frequent low—flows and/or water levels. If deemed necessary, minimum infrequent high and/or minimum infrequent low flows and/or water levels are also defined. The MFLs represent hydrologic statistics composed of three components: a magnitude (a water level and/or flow), duration (days), and a frequency or return interval (years). Historically, SJRWMD staff synthesized the continuous duration and frequency components of the MFLs into seven discrete hydroperiod categories to facilitate MFLs determinations for lakes and wetlands. However, for MFLs associated with reevaluations of established MFLs and MFLs for water bodies for which MFLs have not been previously established, these hydroperiod categories are now being replaced with specific duration and return interval values.

MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in hydrologic conditions. Therefore, MFLs allow for an acceptable level of change to occur relative to the existing hydrologic conditions (gray-shaded area, Figure 1). However, when use of water resources shifts the hydrologic conditions below that defined by the MFLs, significant ecological harm occurs. As it applies to wetland and aquatic communities, significant harm is a function of changes in the frequencies and durations of water level and/or flow events, causing unacceptable changes to ecological structures and/or functions.

MFLs apply to decisions affecting consumptive use permit applications, declarations of water shortages, and assessments of water supply sources. Surface water and groundwater computer simulation models are used to evaluate existing and/or proposed consumptive uses and the likelihood they might cause significant harm. Actual or projected instances where water levels fall below established MFLs require the SJRWMD Governing Board to develop recovery or prevention strategies (Section 373.0421(2), F.S.). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), F.S.).



The existing hydrology curve represents the current river stage or flow regime.
The MFLs-defined hydrology curve represents the new river stage or flow regime, which provides for the potentially available water (gray-shaded area).

Figure 1. Hypothetical percentage exceedence curves for existing and MFLs-defined hydrologic conditions

MFLS METHODOLOGY

MFLs determinations incorporate biologic and topographic information collected in the field with stage data, wetland, and soils data from geographical information system (GIS) coverages, aerial photography, the scientific literature, and hydrologic and hydraulic models to generate an MFLs regime. MFLs methodology provides a process for incorporating these factors. This section describes the MFLs methodology and assumptions used in the MFLs determination process, including field procedures such as site selection, field data collection, and data analyses. Additional MFLs methodology descriptions are located in the (draft) Minimum Flows and Levels Methods Manual (SJRWMD 2006b).

FIELD SITE SELECTION

Many factors are considered in the selection of field transect sites. Transects, or fixed sample lines, are established across a river, lake or wetland floodplain and usually extend from open water to uplands. Elevation, soils and vegetation are sampled along each transect to characterize the influence of surface water flooding on the distribution of soils and plant communities.

Field site selection begins with the implementation of a site history survey and data search. The team collates all pertinent existing information and conducts data searches of SJRWMD library documents, project record files, the hydrologic database, and SJRWMD Division of Surveying Services files. The types of information may include the following:

- On-site and regional vegetation surveys and maps
- Aerial photography (existing and historical)
- Remote sensing (vegetation, land use, etc.) and topographic maps
- Soil surveys, maps, and soil descriptions
- Hydrologic data (hydrographs and stage duration curves)
- Environmental, engineering, or hydrologic reports
- Topographic survey profiles
- Occurrence records of rare and endangered flora and fauna

Data sources are reviewed to familiarize the investigator with site characteristics, locate important basin features that need to be evaluated, and assess prospective sampling locations. Copies of this information are organized and placed in permanent files for future reference (SJRWMD 2006b).

Potential transect locations are identified from maps of wetlands, soils, topography, and landownership. Specific transect site selection goals include:

- Establishing transects at sites where multiple wetland communities of the most commonly occurring types are traversed.
- Selecting multiple transect locations with common wetland communities among them.
- Establishing transects that traverse unique wetland communities.
- Avoiding humanly altered or impacted areas.

Transect characteristics are subsequently field-verified to ensure the particular locations contain representative wetland communities, hydric soils, and reasonable upland access. These goals help to ensure ecosystem protection of commonly occurring and unique wetland ecosystems. Individual transect site selection criteria for Three Island Lakes are described in the Results and Discussion section of this document.

FIELD DATA COLLECTION

The field data collection procedure for determining MFLs involves collecting elevation, soils, and vegetation data along fixed lines, or transects, across a hydrologic gradient. Transects are established in areas where there are changes in vegetation and soil, and the hydrologic gradient is marked (SJRWMD 2006b). The main purpose in using transects in these situations, where the change in vegetation and soils is clearly directional, is to describe maximum variations over the shortest distance in the minimum time (Martin and Coker 1992).

Site Survey

Upon selection of a transect site, conventional survey methods are used to establish and record elevation data at each site. The elevation data enable similar features on a single system to be quantitatively compared.

Transect site vegetation is trimmed to allow a line-of-sight along the transect length. A measuring tape is laid down on the ground along the length of the transect. Elevation measurements are recorded at various length intervals (5 feet [ft], 10 ft, 20 ft) to adequately characterize the topography and transect features. Additional elevations are generally measured at obvious elevation changes, vegetation community changes, soil changes, and within river channels (where applicable).

Latitude and longitude data are also collected, using a global positioning system (GPS) along the length of each transect. These GPS data accurately locate specific features along each transect and facilitate recovery of transect locations in the future.

Soil Sampling Procedures

Detailed soil profiles are described along each transect to gain an understanding of past and present hydrologic, geologic, and anthropogenic processes that have occurred, resulting in the observed transect soil features. Soil profiles are described following standard Natural Resources Conservation Service (NRCS) procedures (USDA–NRCS 2002). Each soil horizon (unique layer) is generally described with respect to texture, thickness, Munsell color (Kollmorgen Corp. 1992), structure, consistency, boundary, and presence of roots.

The primary soil criteria considered in the determination of MFLs is the presence and depth of organic soils, as well as the extent of hydric soils and the location of sandhill lake soil indicators (where applicable) observed along the field transects (SJRWMD 2006b). The procedure to document hydric soils includes:

- Removing all loose leaf-matter, needles, bark, and other easily identified plant parts to expose the soil surface; digging a hole and describing the soil profile to a depth of at least 20 inches (in.) and, with the use of the completed soil description, specifying which hydric soil indicators have been matched.
- Performing deeper examination of soil where field indicators are not easily seen within 20 in. of the surface. (It is always recommended that soils be excavated and described as deep as necessary to make reliable interpretations and classification.)
- Paying particular attention to changes in microtopography over short distances, since small elevation changes may result in repetitive sequences of hydric/nonhydric soils and the delineation of individual areas of hydric and nonhydric soils may be difficult (USDA–NRCS 1998).

Additional soil sampling procedures are documented in the (draft) Minimum Flows and Levels Methods Manual (SJRWMD 2006b).

Vegetation Sampling Procedures

SJRWMD has wetland maps developed from aerial photography utilizing a unique wetland vegetation classification system. SJRWMD’s Wetland Vegetation Classification System (Kinser 1996) was used to standardize the names of wetland plant communities sampled in MFLs fieldwork and in developing reports documenting the MFLs determination.

The spatial extent of plant communities or transition zones (i.e., ecotones) among plant communities was determined using reasonable scientific judgment. Reasonable scientific judgment involves the ability to collect and analyze information using technical knowledge, personal skills, and experience to serve as a basis for decision making (Gilbert et al. 1995). In this case, such judgment was based upon field observations of relative abundance of dominant plant species, occurrence and distribution of soils and hydric soil indicators, and changes in land slope or elevation along the hydrologic gradient. Plant communities and transition zones were delineated along a specialized line transect called a belt transect. A belt transect is a line with width (belt width). It is essentially a widening of the line transect to form a long, thin, rectangular plot divided into smaller sampling areas called quadrats that correspond to the spatial extent of plant communities or transitions between plant communities (Figure 2). The transect belt width will vary depending upon the type of plant community to be sampled (SJRWMD 2006b). For example, a belt width of 10 ft (5 ft on each side of the transect line) may suffice for sampling herbaceous plant communities of a floodplain marsh. However, a belt width of 50 ft (25 ft on each side of the line) may be required to adequately represent a forested community (e.g., hardwood swamp) (Figure 2).

Plants were identified and the percent cover of plant species was estimated if they occurred within the established belt width for the plant community under evaluation (quadrat). Percent cover is defined as the vertical projection of the crown or shoot area of a plant to the ground surface, expressed as a percentage of the quadrat area. Percent cover as a measure of plant distribution is often considered as being of greater ecological significance than density, largely because percent cover gives a better measure of plant biomass than the number of individuals. The canopies of the plants inside the quadrat will often overlap each other, so the total percent cover of plants in a single quadrat will frequently sum to more than 100% (SJRWMD 2006b). Percent cover was estimated visually using cover classes (ranges of percent cover). The cover class and percent cover ranges (Table 1) are a variant of the Daubenmire method (Mueller-Dombois and Ellenberg 1974) and summarized in SJRWMD's draft Minimum Flows and Levels Methods Manual (SJRWMD 2006b). Plant species, plant communities and percent cover data were recorded on field vegetation data sheets. The data sheets are formatted to facilitate data collection in the field and, also, computer transcription.

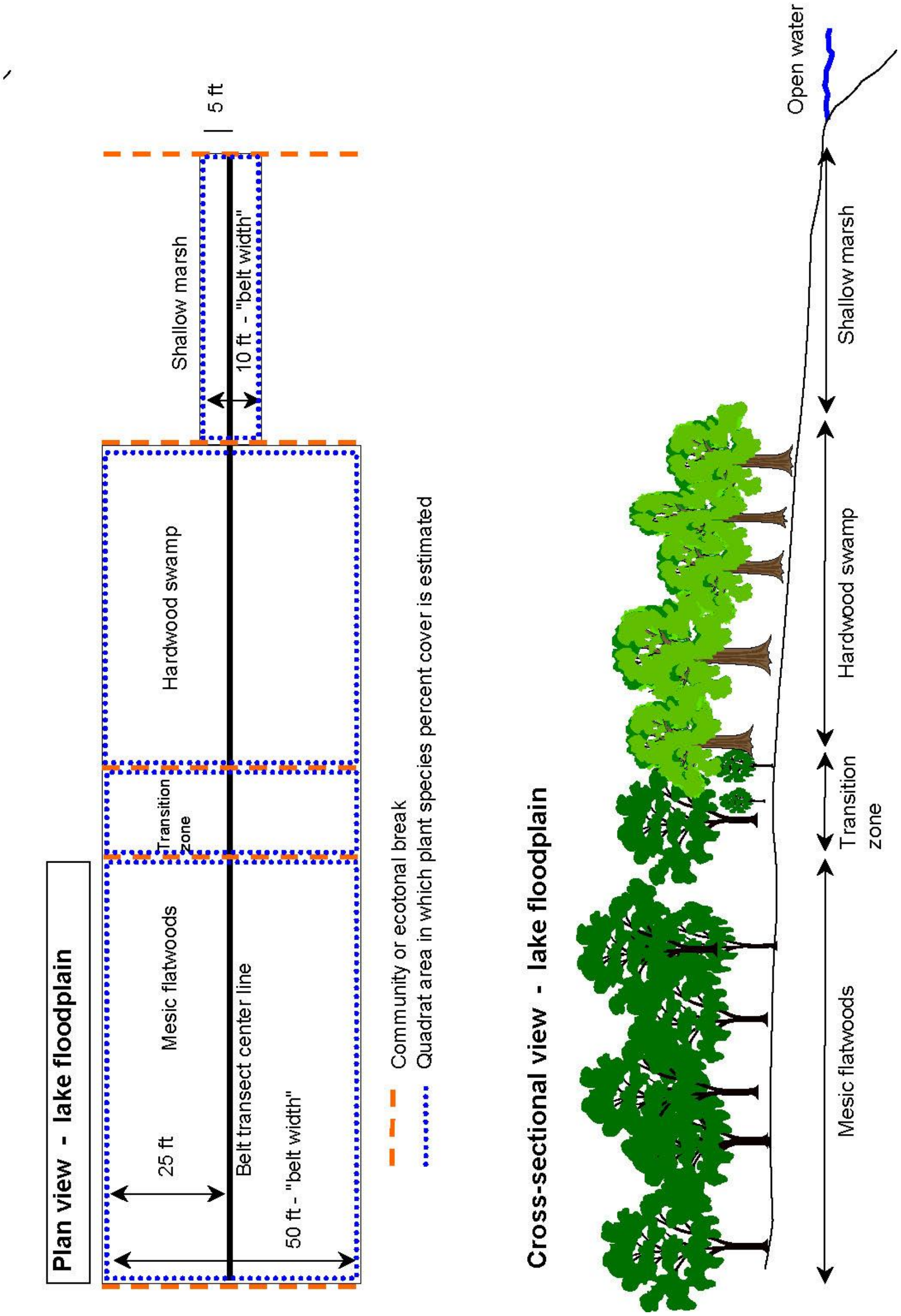


Figure 2. Example of belt transect through forested and herbaceous plant communities

Table 1. Summary of cover classes and percent cover ranges

Cover Class	Percentage Cover Range	Descriptor
0	< 1 %	Rare
1	1–10 %	Scattered
2	11–25 %	Numerous
3	26–50 %	Abundant
4	51–75 %	Co-dominant
5	> 75 %	Dominant

It is important that the same person or team estimate plant cover in each quadrat or community along the transect because the estimation is likely to vary from person to person or team to team. Plant species, plant communities and percent cover data are recorded on field vegetation data sheets (Appendix B). The data sheets are formatted to facilitate data collection in the field and computer transcription. A detailed explanation of the field vegetation sheet is located in the (draft) Minimum Flows and Levels Methods Manual (SJRWMD 2006b).

The wetlands diagnostic classification system (Kinser 1996) is used to standardize wetlands plant community names recorded in the field. SJRWMD has wetlands maps developed from aerial photography utilizing the characteristics of this classification system.

DATA ANALYSIS

The primary data analysis for information collected in the MFLs determination process generally consists of using a computer spreadsheet file to perform basic statistical analyses on the surveyed elevation data. Vegetation and soils information collected along the transects are incorporated with the elevation data. Descriptive statistics are calculated for the elevations of the vegetation communities, specific hydric soil indicators, sandhill lake soil indicators (where applicable) and other relevant site characteristics.

Transect elevation data are also graphed to illustrate the elevation profile between the open water and upland community. The locations of vegetation communities along the transect, with a list of dominant species, statistical results, and soils information, are typically labeled on the graph. Specific transect elevation data from Three Island Lakes are illustrated in the Results and Discussion section of this document.

CONSIDERATION OF ENVIRONMENTAL VALUES IDENTIFIED IN RULE 62-40.473, *F.A.C.*

In establishing MFLs for water bodies pursuant to Section 373.042 and Section 373.0421, F.S., SJRWMD identifies the environmental value or values most sensitive to long-term changes in the hydrology of each water body or watercourse. SJRWMD then typically defines the minimum number of flood events and maximum number of dewatering events that would still protect the most sensitive environmental value or values. For example, for water bodies or watercourses for which the most sensitive environmental values may be wetlands and organic substrates, recommended MFLs would reflect the number of flooding or dewatering events that allow for no net loss of wetlands and organic substrates. By protecting the most sensitive environmental value or values for each water body or watercourse, the 10 environmental values identified in Rule 62-40.473, *F.A.C.*, are considered to be protected.

SJRWMD uses the following working definitions when considering these 10 environmental values:

1. Recreation in and on the water—The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include, but are not limited to swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. Fish and wildlife habitat and the passage of fish—Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species; to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies, and durations sufficient to support the life cycles of wetland and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.
5. Maintenance of freshwater storage and supply—The protection of an amount of freshwater supply for permitted users at the time of MFLs determinations.
6. Aesthetic and scenic attributes—Those features of a natural or modified waterscape usually associated with passive uses, such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of

relaxation, that usually result in human emotional responses of well-being and contentment.

7. Filtration and absorption of nutrients and other pollutants—The reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.
8. Sediment loads—The transport of inorganic material, suspended in water, which may settle or rise. These processes are often dependent upon the volume and velocity of surface water moving through the system.
9. Water quality—The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in definition number 7 (i.e., nutrients and other pollutants).
10. Navigation—The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and width.

CONSIDERATION OF BASIN ALTERATIONS IN ESTABLISHING MFLS

Based on the provisions of Section 373.0421(1)(a), F.S., SJRWMD, when establishing MFLs, considers changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes and alterations have placed, on the hydrology of an affected watershed, surface water, or aquifer. However, when considering such changes and alterations, SJRWMD cannot allow harm caused by withdrawals. To accomplish this, SJRWMD reviews and evaluates available information and makes site visits to ascertain the following information concerning the subject watershed, surface water body, or aquifer:

- The nature of changes and structural alterations that have occurred.
- The effects the identified changes and alterations have had.
- The constraints the changes and alterations have placed on the hydrology.

SJRWMD develops hydrologic models, which address existing structural features, and uses these models to consider the effects these changes have had on the long-term hydrology of water bodies for which recommended MFLs are being developed.

SJRWMD considers that the existing hydrologic condition, which is used to calibrate and verify the models, reflects the changes and structural alterations that have occurred in addition to changes that are the result of groundwater and surface water withdrawals that existed at the time of model development. This consideration may also apply to vegetation and soils conditions if the changes, structural alterations, and water withdrawals have been sufficiently large to affect vegetation and soils and have been in place for a sufficiently long enough period to allow vegetation and soils to respond to the altered hydrology. However, the condition of vegetation and soils may not reflect the long-term, existing hydrologic condition if the changes, structural alterations, and water withdrawals are relatively recent. This is because vegetation and soil conditions do not respond to all hydrologic changes nor respond instantaneously to changes in hydrology that are sufficiently large enough to cause such change. SJRWMD typically develops recommended MFLs based on the vegetation and soils conditions that exist at the time fieldwork is being performed to support the development of these recommended MFLs.

SJRWMD also provides for the collection and evaluation of additional data subsequent to the establishment of MFLs. SJRWMD uses this data collection and evaluation as the basis of determining if the MFLs are protecting the water resources or if the MFLs are appropriately set. If SJRWMD determines, based on modeling and this data collection and evaluation process, that MFLs have not been appropriately set, SJRWMD can establish revised MFLs.

If SJRWMD determines that recommended MFLs cannot be met under post-change hydrologic conditions due to existing structural alterations, SJRWMD may consider whether feasible structural or nonstructural changes, such as changes in the operating schedules of water control structures, can be accomplished such that the recommended MFLs can be met. In such cases, SJRWMD may identify a recovery strategy that includes feasible structural or nonstructural changes.

MFLS COMPLIANCE ASSESSMENT

A hydrologic model for Three Island Lakes was developed to provide a means of assessing whether compliance with MFLs is achieved under specific water use and land use conditions (Robison 2006). This hydrologic model was calibrated for 2003 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2003 regional water use. An explanation of the use of this hydrologic model and the applicable SJRWMD regional groundwater flow model to assess whether water levels are likely to fall below MFLs under specific water uses and land use conditions is presented in Appendix D. This appendix also includes an introduction to the use of hydrologic statistics in the SJRWMD MFLs program.

THREE ISLAND LAKES GENERAL INFORMATION

Three Island Lakes is located approximately 5 miles east of Orange City and is within the city of Deltona in Volusia County (Figure 3), Florida. The lake has an open water area of about 116 acres at a water level of 23 ft NGVD (U.S. Geological Survey Lake Helen quadrangle map, scale 1:24,000). Three Island Lakes has naturally occurring intermittent surface water connections to Sand Lakes to the northwest, Wood Lake to the northeast, and Dupont Lake to the south. Three Island Lakes is in the Crescent City–DeLand Ridge physiographic subdivision of the Central Lakes District, which consists of sand hills with summits generally between 80 ft and 100 ft in elevation (Brooks 1982). The Central Lakes District serves as a principle recharge area for the Floridan aquifer. This region is composed of sand hills (underlain by karst topography) that serve as solution basins favorable for sinkhole development.

THREE ISLAND LAKES WATER QUANTITY MANAGEMENT CONCERNS

Three Island Lakes was selected for reevaluation because recent development of a water budget model and frequency analysis of the modeled stage data show that the hydrologic conditions defined by the adopted minimum frequent high level and the minimum average level are not being achieved (Figures 4, 5, and 6). Frequency analysis of the modeled stage data also shows that the minimum frequent low level is met under 2003 hydrologic conditions and would allow for additional consumptive use if other levels were being protected (Figure 7). This reassessment is necessary to ensure that the minimum levels are based on robust criteria before any remedial action (i.e., development of a recovery strategy, permit denial, etc.). According to hydrologic model projections for 1995–2005 using the Volusia regional groundwater flow model, the surficial aquifer may currently be affected by a drawdown of approximately 0.5–0.7 ft and the Floridan aquifer may currently be affected by a drawdown of approximately 0.8 ft in the direct vicinity of Three Island Lakes (SJRWMD groundwater model projections 2005). Recorded stage data, precipitation, and nearby groundwater data, as well as other data sources, were utilized to simulate the lake stage from 2003 to 1961 (Robison 2006).

THREE ISLAND LAKES HYDROLOGY

Three Island Lakes intermittently has surface water connection with Sand Lakes and Wood Lake and discharges to Dupont Lake. Groundwater inflows originate from sand ridges surrounding the lake. Recharge to the Floridan aquifer is estimated at 0–4 in. per year, with nearby areas estimated at 4–8 in. per year and greater than 12 in. per year (Boniol et al. 1993).

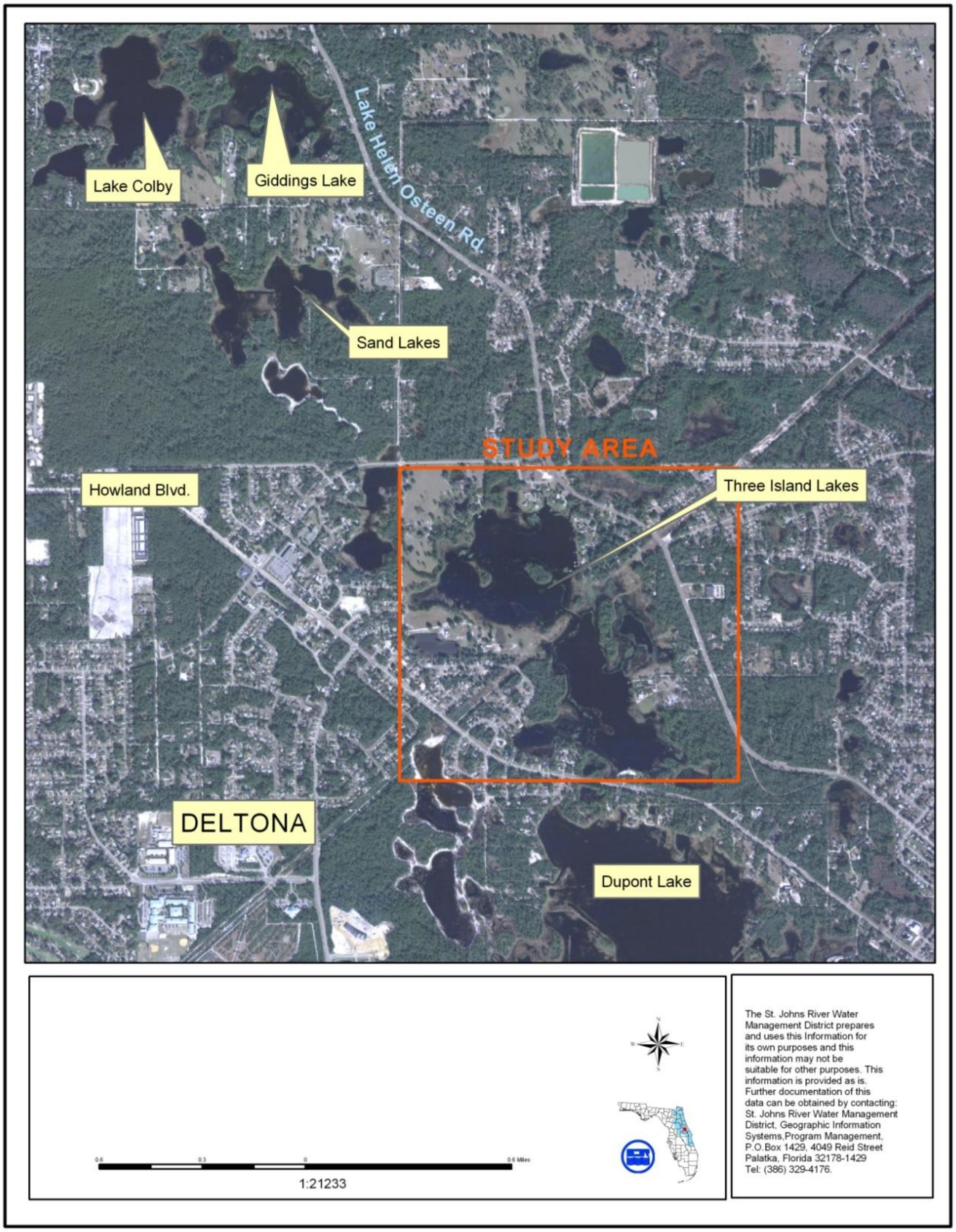


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Figure 3. General location of Three Island Lakes, Volusia County, and nearby water bodies

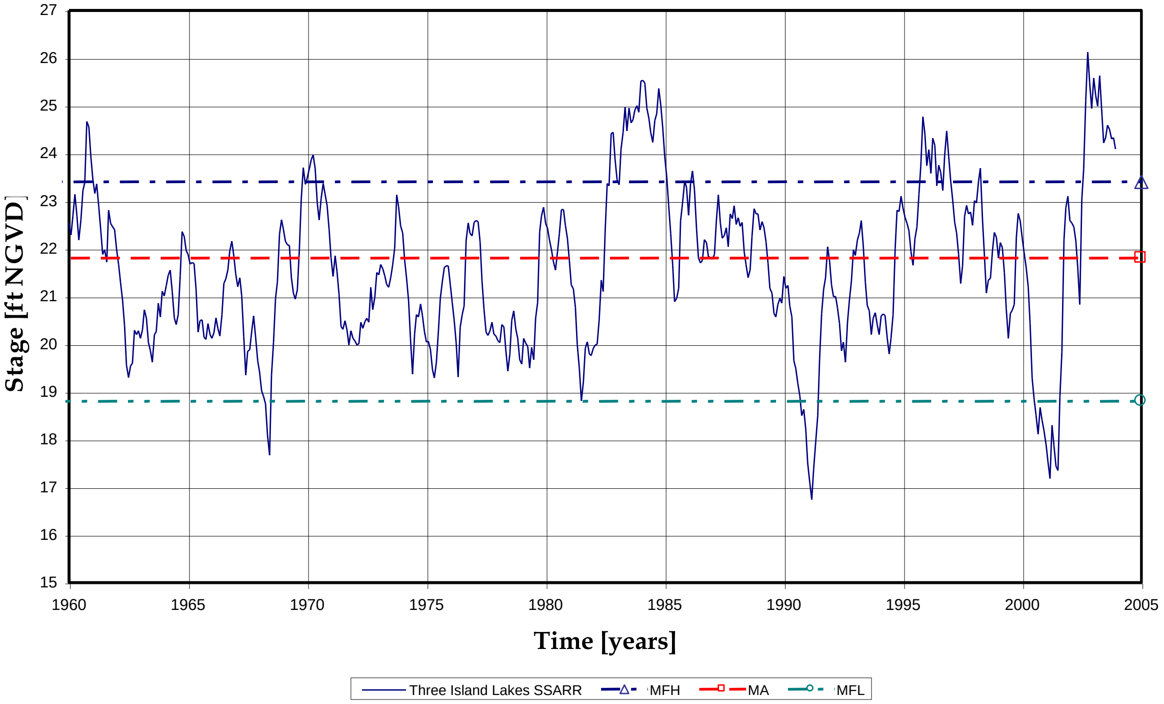


Figure 4. Hydrograph of modeled data (1961–2003) with adopted minimum levels, Three Island Lakes, Volusia County

Stage data for Three Island Lakes exists from January 1990 to the present (Figure 8). The lake stage was recorded daily until September 1996 and at least weekly thereafter. Several short gaps (2 to 3 weeks) exist in the data set, with one data gap of seven weeks. Weekly stage data were analyzed to give equal weight to the entire period of record.

During this period, the lake fluctuated 10.4 ft, with a mean stage of 21.6 ft NGVD, as determined from 783 observations. The maximum and minimum elevations for the period of record are 26.0 ft NGVD (March 26, 2003) and 15.5 ft NGVD (March 15, 1991), respectively. A stage duration curve was generated to show the average amount of time that a given elevation was exceeded during the period of record (Figure 9).

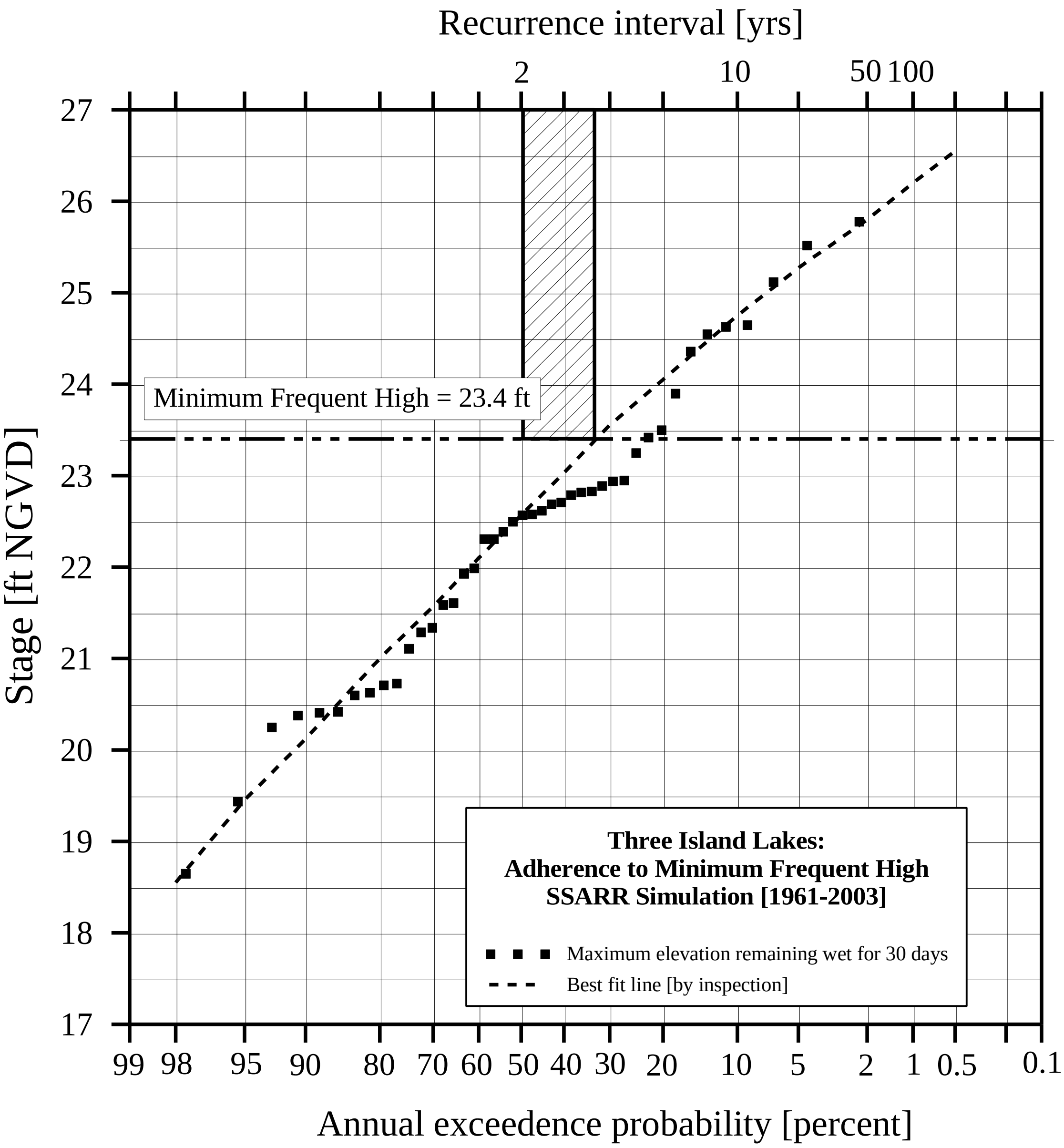


Figure 5. Frequency analysis of modeled data (1961–2003) for 30-day continuously exceeded elevations, Three Island Lakes, Volusia County

*Note: The adopted minimum frequent high level does not meet criteria for seasonally flooded under 2003 modeled conditions. The adopted minimum frequent high level would be flooded for 30 continuous days approximately once every 3.1 years, under 2003 modeled conditions, rather than once every 3 years as recommended by the hydroperiod category, seasonally flooded.

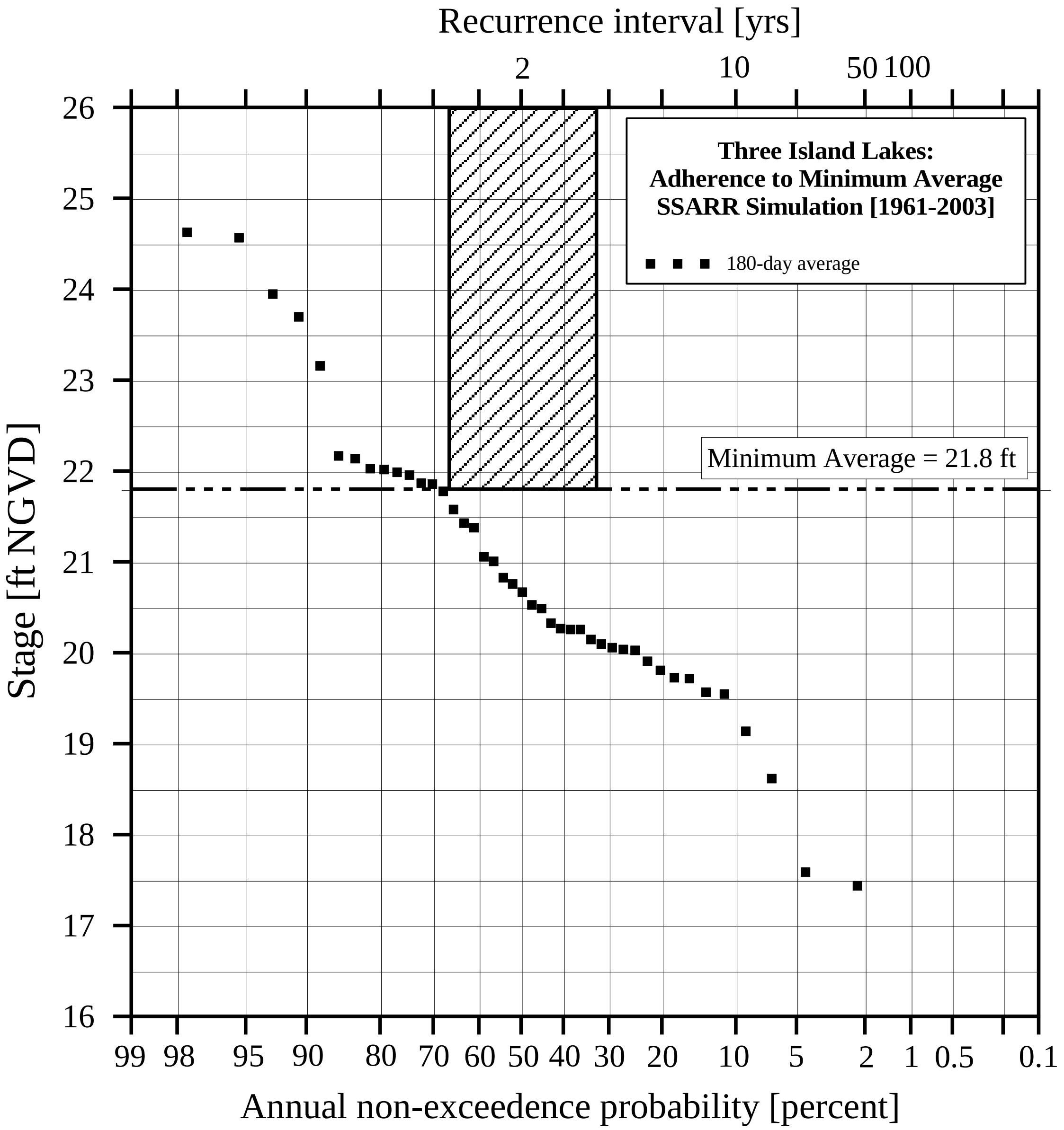


Figure 6. Frequency analysis of modeled data (1961–2003) for 180-day average non-exceeded elevations, Three Island Lakes, Volusia County

*Note: The adopted minimum average level does not meet criteria for typically saturated under 2003 modeled conditions. The adopted minimum average level would be dewatered for an average of 180-days approximately once every 1.47 years, under 2003 modeled conditions, rather than once every 1.5 years as recommended by the hydroperiod category, typically saturated.

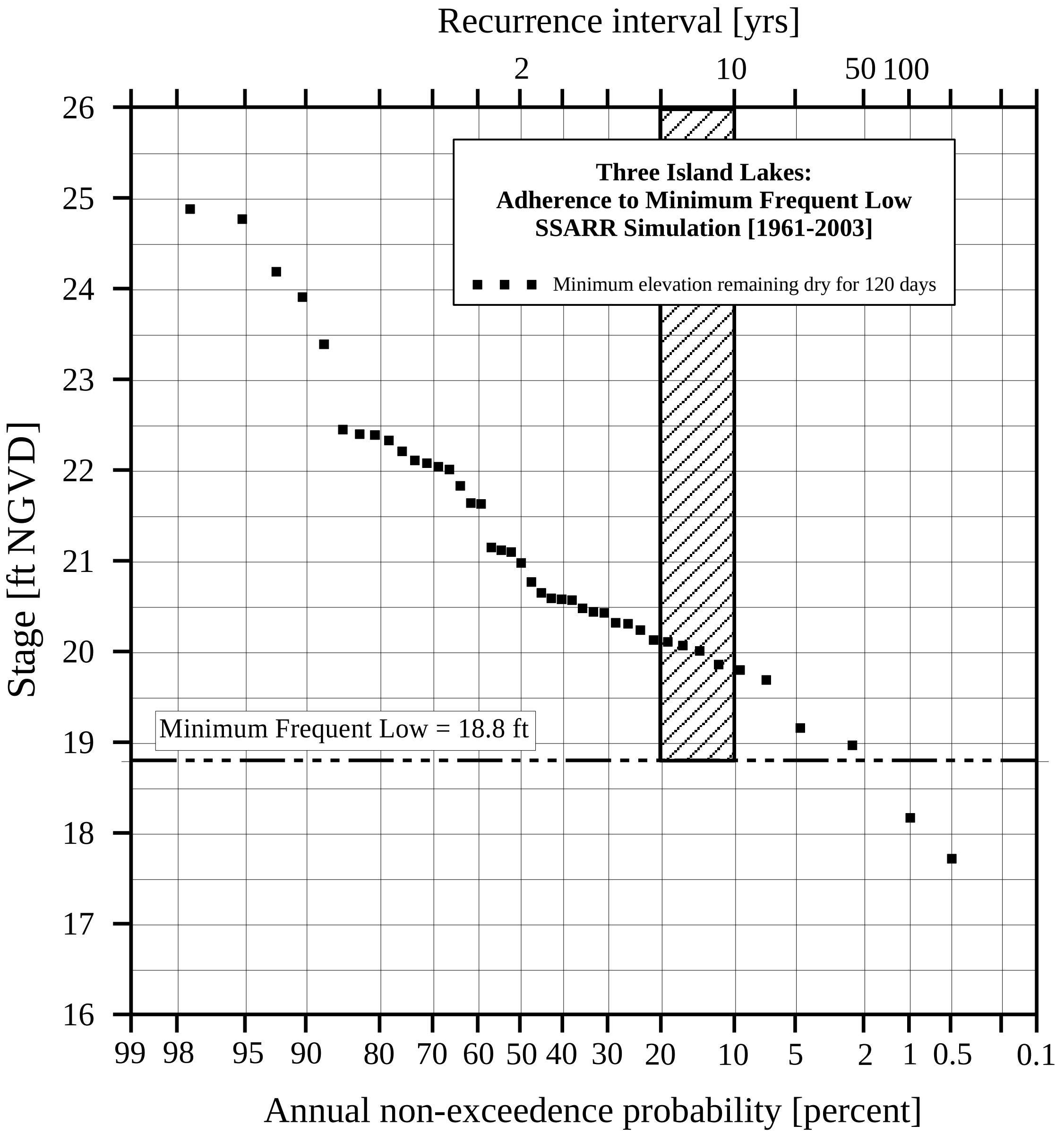


Figure 7. Frequency analysis of modeled data (1961–2003) for 120-day continuously non-exceeded elevations, Three Island Lakes, Volusia County

*Note: The adopted minimum frequent low level meets criteria for the semipermanently flooded hydroperiod category under 2003 modeled conditions.

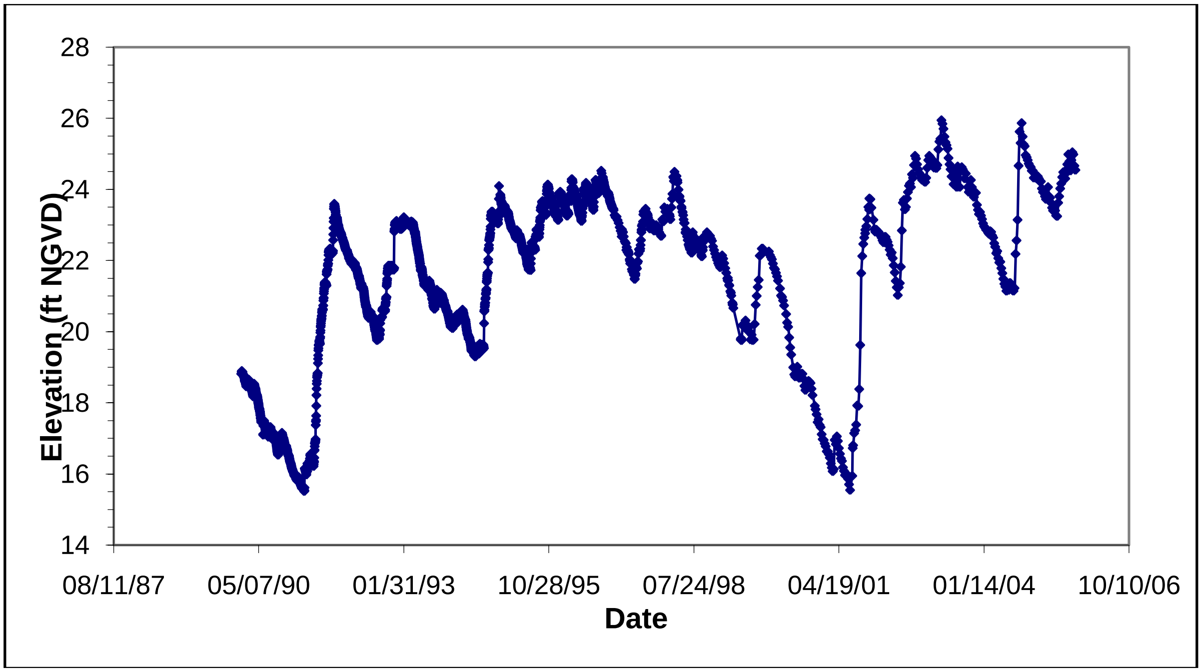


Figure 8. Three Island Lakes stage data from January 1990–April 2005

THREE ISLAND LAKES MAPPED WETLANDS

Wetland communities mapped near Three Island Lakes consist of shallow marshes and deep marshes as classified by the SJRWMD wetlands classification system (Kinser 1996, Figure 10). Shallow marshes are herbaceous or graminoid communities that occur most often on organic soils and are subject to lengthy seasonal inundation. Deep marshes are wetlands dominated by a mixture of water lilies and deepwater emergent species and are semipermanently flooded to permanently flooded (Kinser 1996).

THREE ISLAND LAKES MAPPED SOILS

Soils are considered hydric or nonhydric based on the presence/absence of hydric soil indicators resulting from flooding, ponding, or saturation. Flooding is a condition in which the soil surface is covered with flowing water from any source, such as a water body overflowing its banks, runoff from surrounding slopes, inflow from high tides or any combination of sources (FAESS 2000). Ponding is considered the temporary accumulation of standing water in a closed depression and removed only by percolation, evaporation, or transpiration (FAESS 2000). Saturation is characterized by zero- or positive pressure in the soil water and can generally be determined by observing water in an unlined auger hole (FAESS 2000). Ponding and saturation are strongly influenced by the soil properties and the surrounding physiography.

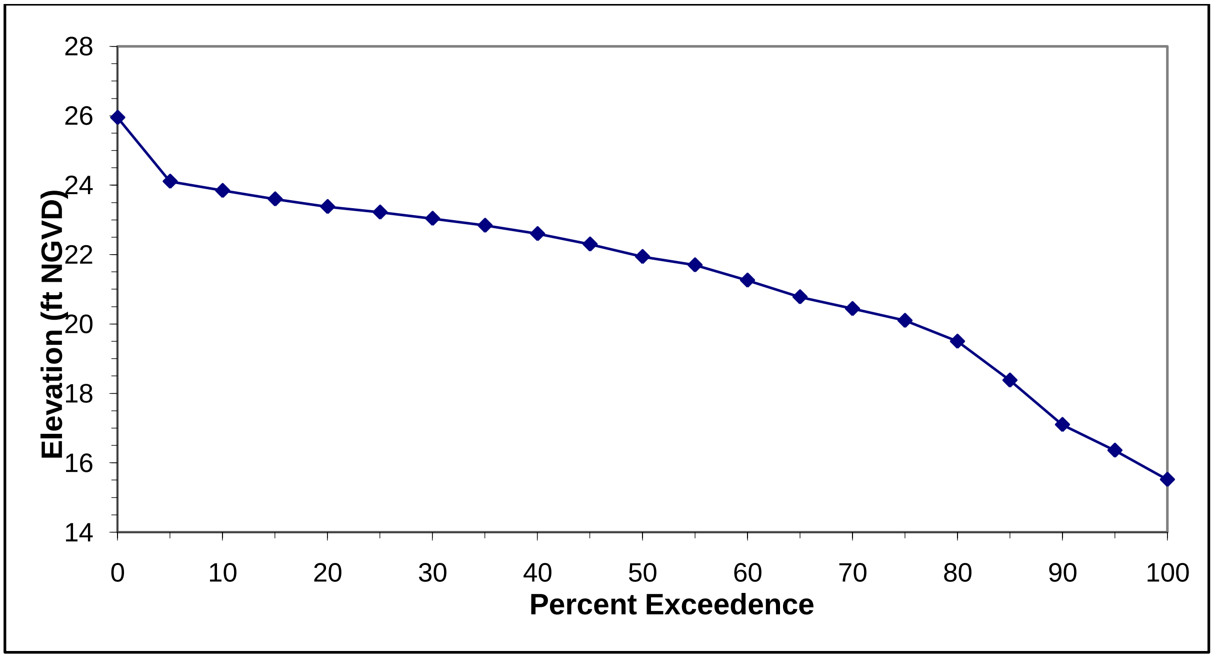
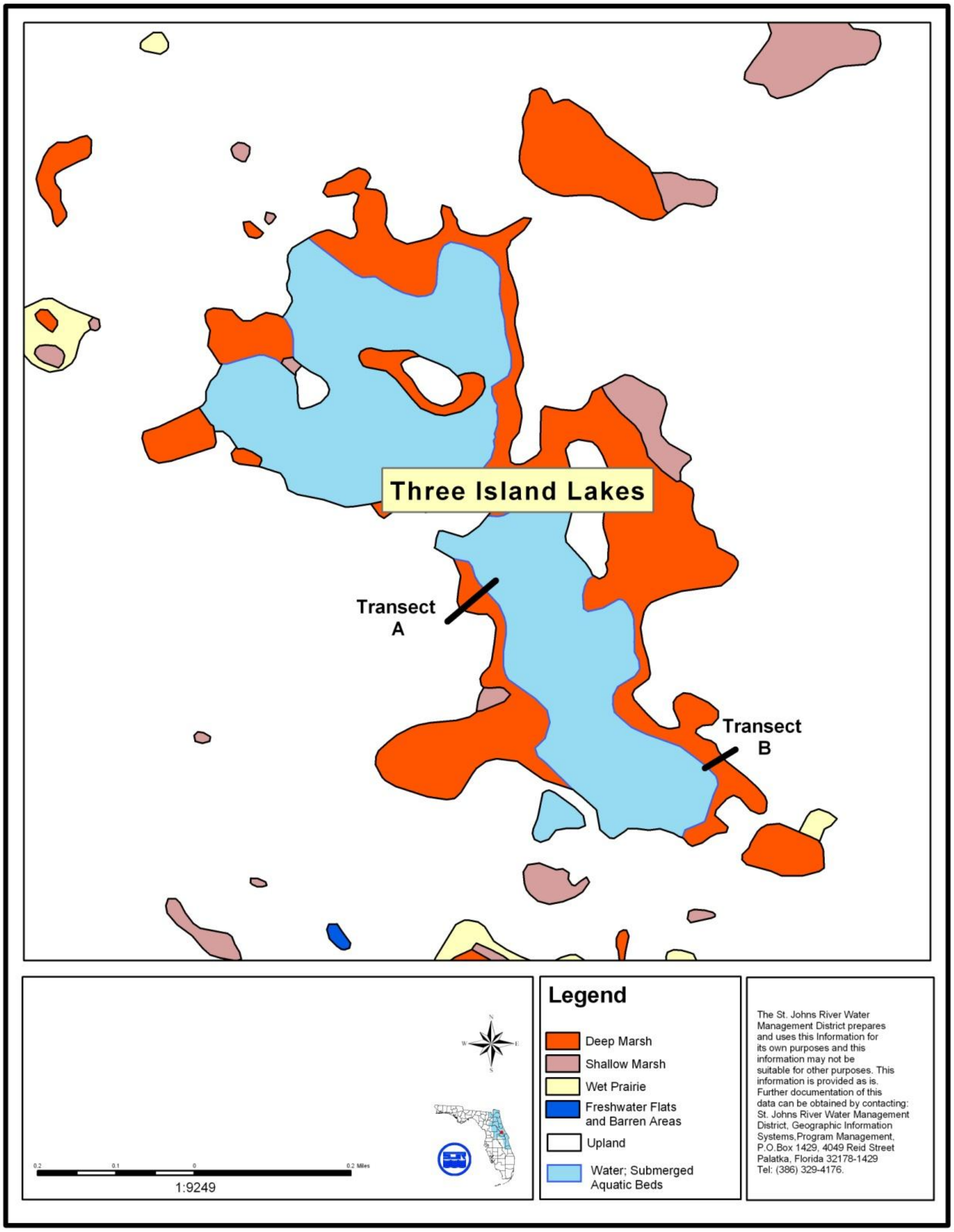


Figure 9. Stage duration curve for Three Island Lakes, Volusia County, Fla.

Five soil series are mapped adjacent to Three Island Lakes: (1) Astatula fine sand; (2) Daytona sand; (3) Myakka fine sand; (4) Paola fine sand, and (5) Tavares fine sand (USDA–SCS 1980, Figure 11). Of the mapped soil series, only Myakka fine sand is considered hydric, and meets criteria for saturation (FAESS 2000). Depressional areas of Myakka fine sand, though not mapped, are likely present around the perimeter of Three Island Lakes. Myakka fine sand-depressional differs from Myakka fine sand in that it is slightly lower in the landscape and meets hydric soils criteria for saturation and ponding (FAESS 2000). Descriptions of these two hydric soil series follow.

Myakka fine sand. Myakka fine sand consists of nearly level, poorly drained soil and is common in flatwoods throughout Volusia County. The permeability is rapid to moderately rapid but is often impeded by a high water table. The water table in these areas is within 12 in. of the surface from June through November and commonly within 40 in. of the surface the remainder of the year except during extended droughts (USDA–SCS 1980).



The St. Johns River Water Management District prepares and uses this Information for its own purposes and this information may not be suitable for other purposes. This information is provided as is. Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems,Program Management, P.O.Box 1429, 4049 Reid Street Palatka, Florida 32178-1429 Tel: (386) 329-4176.

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Figure 10. Mapped vegetation communities adjacent to Three Island Lakes, Volusia County

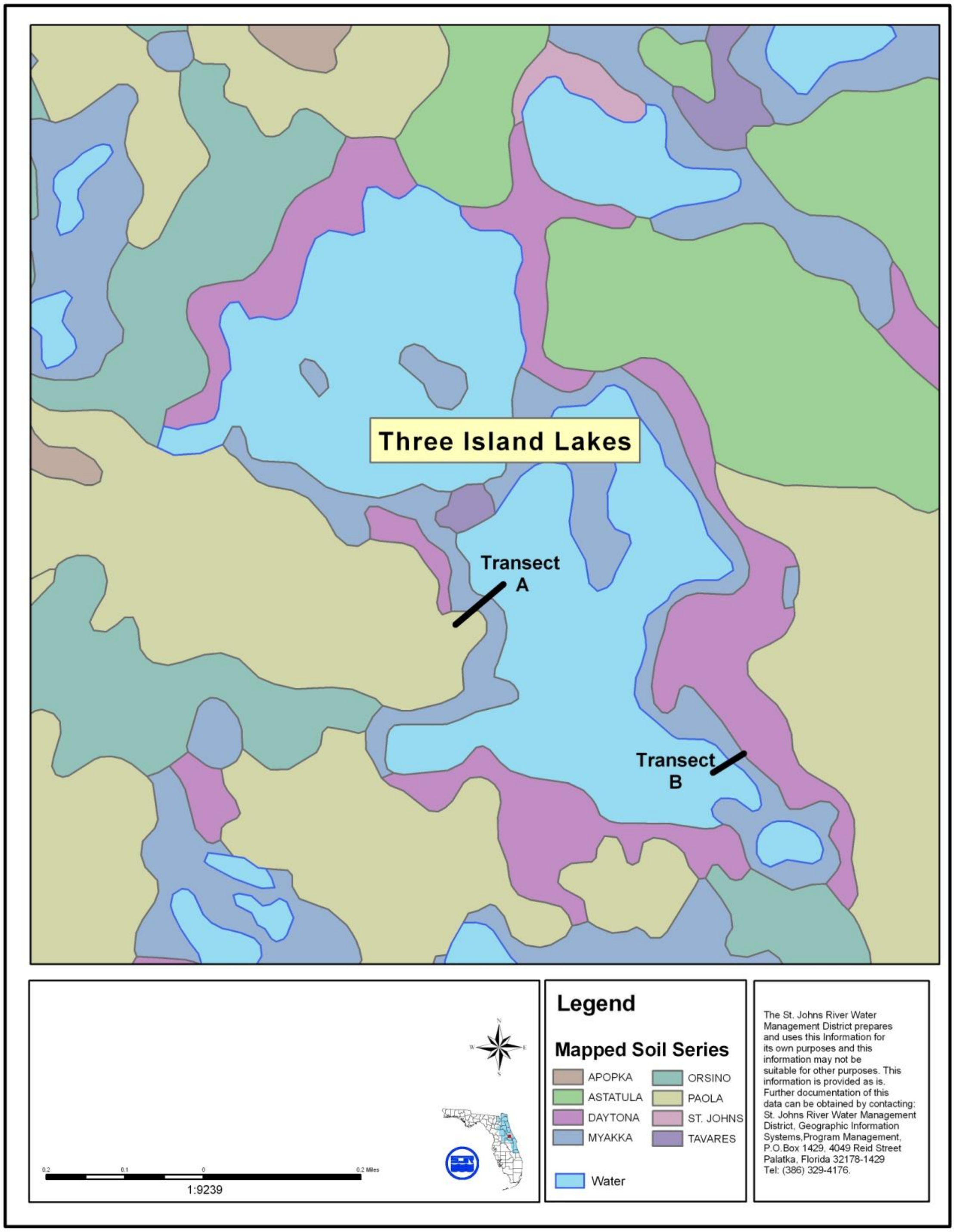

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Figure 11. Mapped soil series adjacent to Three Island Lakes, Volusia County

Myakka fine sand–depressional. Myakka fine sand–depressional consists of nearly level, poorly drained soil and is common in depressions within flatwoods throughout Volusia County. The permeability is rapid to moderately rapid but is often impeded by a high water table. These areas are ponded for 6 to 9 months in most years; the water table is within 10 in. of the soil surface for 3 to 6 months in most years; and during prolonged dry periods, the water table can drop to a depth of 2–3 ft (USDA–SCS 1980).

Field soil sampling at Three Island Lakes was performed by Jones, Edmunds and Associates Inc. (JEA Inc.), under contract to SJRWMD. Hydric soil indicators, sandhill lake soil indicators, and soil series were identified at each transect. Transect-specific field soil sample descriptions are presented in the Results and Discussion section of this document and in Appendix C.

RESULTS AND DISCUSSION

To reevaluate and determine minimum levels for Three Island Lakes, elevation, soils, and vegetation field data were obtained at two transect locations. This section describes the transect site selection criteria, the data collected at each transect location, the primary level determination criteria, and concludes with a description of the minimum level determinations for Three Island Lakes.

FIELD DATA COLLECTION

Data collection was performed on July 6, July 18, and October 7, 2005. The recommended minimum levels are derived from topographic data related to the occurrence of vegetation communities, hydric soil indicators, and sandhill lake soil indicators observed on transects A and B, and data from transects 1 and 2 from the original minimum levels determination (Appendix A). Field data collection was completed to provide additional support for or refine the adopted minimum levels.

SJRWMD staff, BCI engineers and scientists, and JEA Inc. staff collected vegetation and soils data, and SJRWMD's Division of Surveying Services staff collected elevation data. Elevations on transects A and B were determined via a water elevation transfer, based on SJRWMD benchmark identification (ID) 04-08-610-0 (23.463 ft NGVD), reference mark ID 04-08-610-1 (23.616 ft NGVD), and reference mark ID 04-08-610-2 (23.492 ft NGVD). The water level elevation on July 18, 2005, was 24.45 ft NGVD.

FIELD DATA TRANSECT A

The wetland communities adjacent to Three Island Lakes are dominated by shallow and deep marshes with a narrow transitional shrub community between the marshes and drier communities. Transect A was established on the northwest shore of the southern lobe of Three Island Lakes, because this location reached upland rapidly and had broad shallow marsh and transitional shrub communities. Transect A extended northeast (~52°) 365 ft from uplands to open water (Table 2 and Figures 10 and 12). Figure 12 depicts sandhill lake soil indicators, the extent of hydric soils, elevation ranges, and dominant plant species for each delineated vegetation community.

Table 2. Transect A location and fieldwork dates, Three Island Lakes

Latitude–Longitude (Station 0; upland)	Latitude–Longitude (Station 365; open water)	Transect A—Location and Dates of Fieldwork
285623.38 – 811244.43	285625.90 – 811241.02	NW shore, southern lobe of Three Island Lakes; July 6, 18, and Oct. 7, 2005

Vegetation at Transect A

Six vegetation communities were observed along transect A—uplands; pine fringe; transitional shrub; shallow marsh; deep marsh; and open water (Figures 12 and 13 and Table 3). The plant species and cover found in each community and *The Florida Wetlands Delineation Manual* (FWDM, Gilbert et al. 1995) wetland indicator status are listed in Table 4.

Table 3. Transect A vegetation community elevation statistics, Three Island Lakes

Vegetation Community	Stations Distance (ft)	Mean (ft NGVD)	Median (ft NGVD)	Min (ft NGVD)	Max (ft NGVD)	N
Upland	0–22	-	-	25.6	-	6
Pine fringe	22–30	25.4	25.4	25.1	25.6	3
Transitional shrub	30–70	23.8	23.5	22.7	25.1	9
Shallow marsh	70–185	21.9	22.0	21.2	22.7	24
Deep marsh	185–320	20.1	20.1	18.4	21.2	28
Open water	320–365	-	-	-	18.4	10

ft NGVD = National Geodetic Vertical Datum
N = the number of elevations surveyed

The upland community was located between stations 0 ft and 22 ft (27.7 ft and 25.6 ft NGVD, respectively) and had abundant sand live oak and numerous laurel oak and slash pine. The pine fringe was located between stations 22 ft and 30 ft (25.6 and 25.1 ft NGVD, respectively) and had abundant slash pine. The transitional shrub was located between stations 30 ft and 70 ft (25.1 and 22.7 ft NGVD, respectively) and had numerous wax myrtle, maidencane, buttonbush, beggar-ticks, and American cupscale grass. The shallow marsh community was located between stations 70 ft and 185 ft (22.7 ft and 21.2 ft NGVD, respectively) and had abundant maidencane, buttonbush, and American cupscale grass and numerous water spangles and

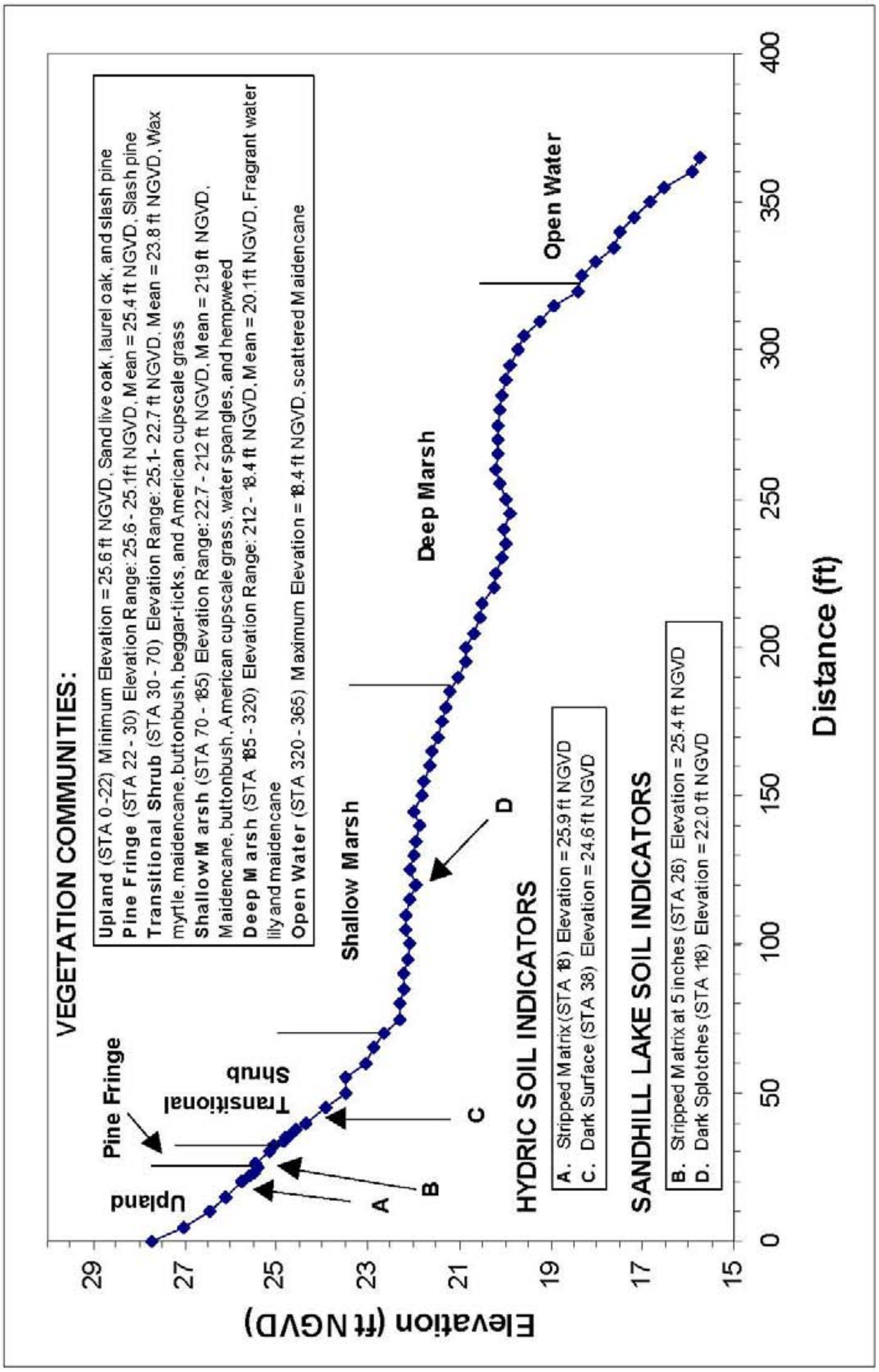


Figure 12. Transect A, Three Island Lakes—topography, vegetation communities, hydric soil indicators, and sandhill lake soil indicators
(*Note: water level = 24.44 ft NGVD on July 18, 2005)

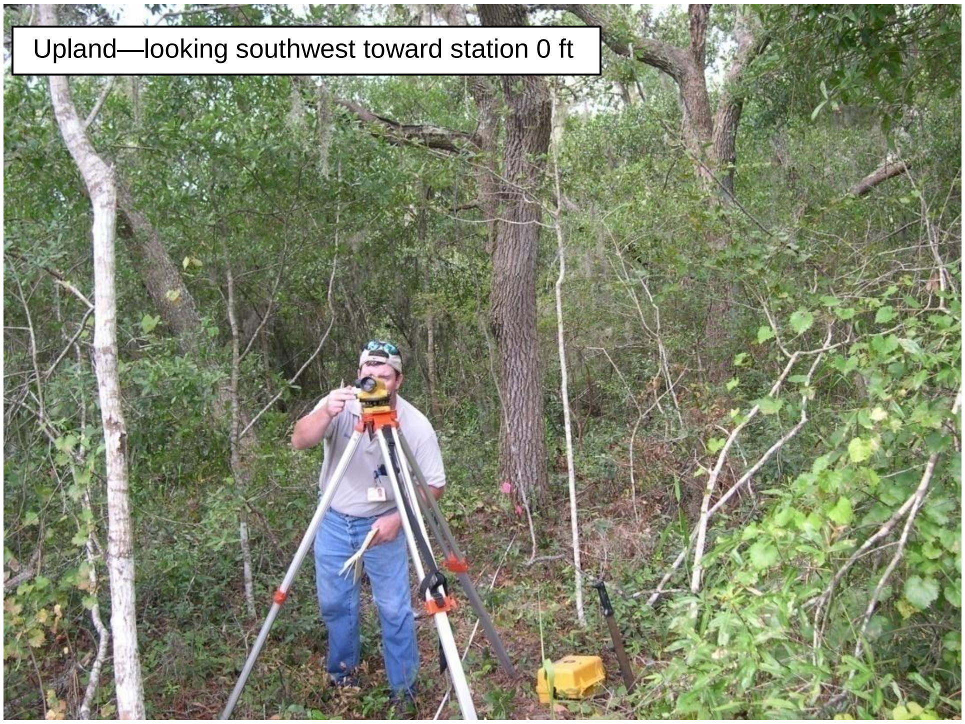
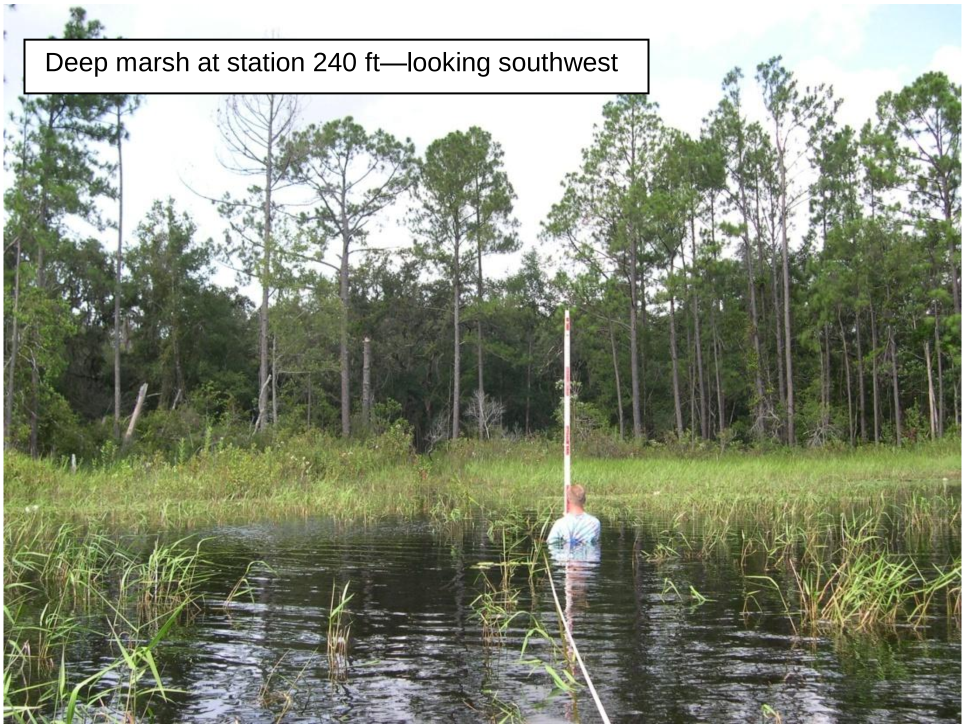


Figure 13. Transect A photographs, Three Island Lakes

Shallow marsh at station 180 ft—looking southwest



Deep marsh at station 240 ft—looking southwest

Figure 13—*Continued*

Table 4. Transect A vegetation species list, Three Island Lakes

Species	Common Name	FWDM Code[1,2]	Plant Communities With Plant Species Cover Estimates[3]					
			Upland (0–22 ft)	Pine Fringe (22–30 ft)	Transitional Shrub (30–70 ft)	Shallow Marsh (70–185 ft)	Deep Marsh (185–320 ft)	Open Water (320–365 ft)
Bidens mitis	Beggar-ticks	OBL		0	2	0		
Centella asiatica	Coinwort	FACW		0	1			
Cephalanthus occidentalis	Buttonbush	OBL			2	3	1	
Dichanthelium dichotomum	Cypress witchgrass	FACW	0					
Eleocharis sp.	Spikerush	OBL		0	1			
Erechtites hieracifolia	Fireweed	FAC		0				
Galactia elliottii	Milkpea	UPL	1	1	0			
Ilex cassine	Dahoon holly	OBL			1			
Ilex opaca	American holly	FAC	1					
Ludwigia peruviana	Primrose willow	OBL		0	1			
Luziola fluitans	Watergrass	OBL				1	1	
Mikania scandens	Hempweed	UPL		0	1	2		
Myrica cerifera	Wax myrtle	FAC		1	2			
Nuphar luteum	Spatterdock	OBL				0		
Nymphaea odorata	Fragrant waterlily	OBL				0	2	
Nymphoides aquatica	Water bananas	OBL					0	
Panicum hemitomon	Maidencane	OBL	1	1	2	3	2	1
Pinus elliottii	Slash pine	UPL	2	3	1			
Polygonum hirsutum	Jointweed	OBL			1	1		
Pontederia cordata	Pickerelweed	OBL				0		
Ptilimnium capillaceum	Mock bishop's weed	FACW		0	1			
Quercus geminata	Sand live oak	UPL	3					
Quercus laurifolia	Laurel oak	FACW	2					
Quercus myrtifolia	Myrtle oak	UPL	1					
Sabal palmetto	Cabbage palm	FAC	1					
Sacciolepis striata	American cupscale	OBL			2	3	1	
Salvinia minima	Water spangles	OBL			1	2	1	
Smilax sp.	Catbriar	UPL	1	1	0			
Vaccinium corymbosum	Highbush blueberry	FACW	1					
Vaccinium elliotii	Mayberry	FAC	1					
Vaccinium myrsinites	Shiny blueberry	UPL	1					
Vitis rotundifolia	Muscadine grape	UPL	1	1				

[1] Species and hydric designations are taken from Ch. 62-340.450, *F.A.C.* Species not in the rule are assumed upland (UPL) unless they are obvious aquatics; unlisted aquatic species are designated as obligates (OBL).

[2] *The Florida Wetlands Delineation Manual* (FWDM) wetland indicator status (Gilbert et al. 1995)—UPL = Upland plants that rarely occur in wetlands, but almost always occur in uplands; FAC = Facultative plants with similar likelihood of occurring in both wetlands and uplands; FACW = Facultative wet plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation, but may also occur in uplands; OBL = Obligate plants that are found or achieve their greatest abundance in an area that is subject to surface water flooding and/or soil saturation; rarely in uplands

[3] Species Occurrence: Aerial extent of vegetation species along each transect within each community where,0 = <1% (rare);
1 = 1–10% (scattered); 2 = 11–25% (numerous); 3 = 25–50% (abundant); 4 = 51–75% (co-dominant); 5 = >75% (dominant)

hempweed. The deep marsh community was located between stations 185 ft and 320 ft (21.2 ft and 18.4 ft NGVD, respectively) and had numerous fragrant water lilies and maidencane. The open water was located between stations 320 ft and 365 ft (18.4 ft and 15.7 ft NGVD, respectively) and had scattered maidencane.

Soils at Transect A

Flooding and dewatering of soils can result in unique soil morphologies, which can be indicators of past hydrology. Hydric soil indicators and sandhill lake soil indicators were identified at transect A (Table 5). In addition, soil descriptions were made to a depth sufficient to identify the soil series at stations 5 ft and 30 ft along transect A. Soil series were not identified at further stations because the soils were too wet to enable descriptions to a sufficient depth.

Table 5. Transect A soil feature elevations (ft NGVD), Three Island Lakes

Location	Station	Feature	Elevation (ft NGVD)
Hydric Soil Indicators			
Transect A	Station 18 ft	Stripped matrix	25.9
Transect A	Station 38 ft	Dark surface	24.6
Sandhill Lake Soil Indicators			
Transect A	Station 26	Stripped matrix at 5 in.	25.4
Transect A	Station 118	Dark splotches	22.0

ft NGVD = National Geodetic Vertical Datum

One soil series, Pomona, was identified along transect A at stations 5 and 30 ft (JEA Inc. 2006, Appendix C). The mapped soils series differed from those classified, based on characteristics observed in the field, likely due to the mapping scale associated with the Volusia County Soil Survey, which did not account for soil changes in the narrow wetland transition between the upland and the lake (JEA Inc. 2006, Appendix C). Pomona soils are spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and aluminum and/or iron oxides. These soils have an aquic moisture regime, indicating that they are saturated with water and virtually free of gaseous oxygen for sufficient periods to induce anaerobic conditions (Brady and Weil 1996). This soil series also contains an argillic horizon, a diagnostic illuvial subsurface horizon characterized by an accumulation of silicate clays, starting below 40 in. of the ground surface (USDA–NRCS 2005). The Pomona soil series is poorly drained to very poorly drained, with a water table within 6–8 in. for 1 to 3 months during most years. The water table is at a depth of 10–40 in. for 6 months or more during most years. Depressional areas of Pomona soils are typically ponded for 6 to 9 months a year (USDA–NRCS 2005).

Sandhill lake soil indicators were identified at stations 26 ft and 118 ft at transect A (JEA Inc. 2006, Appendix C). The sandhill lake soil indicator, Stripped matrix, indicates an elevation that is exceeded by the lake stage approximately 20% of the time over the long-term (Richardson et al. 2006) and was identified at station 26 ft (25.4 ft NGVD). A Stripped matrix is a layer in which iron/manganese oxides and/or organic matter have been stripped from the matrix exposing the primary base color of the soil materials and forming a diffuse splotchy pattern of two or more colors. The Stripped matrix sandhill lake soil indicator is identified at its waterward-most extent where the stripping begins 5 in. beneath the soil surface (Richardson et al. 2006). The sandhill lake soil indicator, Dark splotches, indicates an elevation that is exceeded by the lake stage approximately 80% of the time over the long term (Richardson et al. 2006) and was identified at station 118 ft (22.0 ft NGVD). This indicator was identified at its landward extent, where there was just less than 3 in. of sand over a layer at least 3 in. thick, with 20% or more of the soil having a Munsell color 10YR 3/1 or darker.

Hydric soil indicators were identified at station 18 ft through station 38 ft at transect A (JEA Inc. 2006, Appendix C). Station 18 ft demarcates the hydric/nonhydric soil boundary. A hydric soil indicator consisting of Stripped matrix (S6, USDA–NRCS 2002) was recorded at station 18 ft (25.9 ft NGVD). The hydric soil indicator, Stripped matrix, is a layer starting within 6 in. of the surface, in which, iron/manganese oxides and/or organic matter have been stripped from the matrix, thereby exposing the primary base color of the soil materials and forming a diffuse splotchy pattern of two or more colors. The hydric soil indicator, Stripped matrix, where it begins 6 in. beneath the soil surface (i.e. station 18 ft), is routinely used to delineate hydric soils throughout Florida (FAESS 2000) and, therefore, is generally near the wetland-upland interface. A hydric soil indicator consisting of Dark surface (S7, USDA–NRCS 2002) was recorded at station 38 ft (24.6 ft NGVD). The hydric soil indicator, Dark surface, is a layer 4 in. or thicker starting within the upper 6 in. of the soil surface that is predominately black. The matrix color value is three or less and chroma is one or less. At least 70% of the visible soil particles must be covered, coated, or similarly masked with organic material. The matrix color of the layer below the dark layer has a chroma of two or less (USDA–NRCS 2002). The occurrence of Stripped matrix and Dark surface indicate a seasonal high saturation within 6 in. of the soil surface (FAESS 2000).

FIELD DATA TRANSECT B

Transect B was established on the southeast shore of the southern lobe of Three Island Lakes because this location had a well-defined deep marsh, as well as the other dominant communities observed. Transect B extended southwest (~240°) 210 ft from upland to open water (Table 6 and Figures 10 and 14). Figure 14 depicts the extent of hydric soils, elevation ranges and dominant plant species for each vegetation community.

Vegetation at Transect B

Six vegetation communities were observed along transect B— uplands; forested depression-pine; transitional shrub; shallow marsh; deep marsh; and open water (Figures 14 and 15 and Table 7). The plant species and cover found in each community, and the FWDM (Gilbert et al. 1995) wetland indicator status are listed in Table 8. The upland community was located between stations 0 ft and 50 ft (27.8 ft and 25.4 ft NGVD, respectively) and had numerous sand live oak, slash pine, gallberry, and mayberry. The forested depression-pine was located between stations 50 ft and 65 ft (25.4 ft and 24.7 ft NGVD, respectively) and had abundant slash pine and numerous gallberry and catbriar. The transitional shrub community was located between stations 65 ft and 78 ft (24.7 ft and 23.5 ft NGVD, respectively) and had numerous slash pine, catbriar, water oak, maidencane, wax myrtle, water spangles,

Table 6. Transect B location and fieldwork dates, Three Island Lakes

Latitude–Longitude (Station 0; upland)	Latitude–Longitude (Station 210; open water)	Transect B—Location and Dates of Fieldwork
285614.68 – 811222.81	285613.61 – 811224.81	SE shore, southern lobe of Three Island Lakes; July 6, 18, and Oct. 7, 2005

Table 7. Transect B vegetation community elevation statistics, Three Island Lakes

Vegetation Community	Stations Distance (ft)	Mean (ft NGVD)	Median (ft NGVD)	Min (ft NGVD)	Max (ft NGVD)	N
Upland	0–50	-	-	25.4	-	11
Pine fringe	50–65	25.0	25.0	24.7	25.4	4
Transitional shrub	65–78	24.1	24.2	23.5	24.7	4
Shallow marsh	78–105	22.3	22.2	21.2	23.5	7
Deep marsh	105–185	19.7	19.9	17.9	21.2	17
Open water	185–210	-	-	-	17.9	6

ft NGVD = National Geodetic Vertical Datum
N = the number of elevations surveyed

and milkpea. The shallow marsh was located between stations 78 ft and 105 ft (23.5 ft and 21.2 ft NGVD, respectively) and had co-dominant maidencane. The deep marsh community was located between stations 105 ft and 185 ft (21.2 ft and 17.9 ft NGVD, respectively) and had abundant fragrant water lilies and numerous maidencane. The open water was located between stations 185 ft and 210 ft (17.9 ft and 16.6 ft NGVD, respectively) and had scattered maidencane.

Soils at Transect B

Hydric soil indicators and sandhill lake soil indicators were identified at transect B (Table 9). In addition, soil descriptions were made to a depth sufficient to identify the soil series at stations 15 ft and 61 ft along transect B. Soil series were not identified at further stations because the soils were too wet to enable descriptions to a sufficient depth.

The Pomona and Myakka soil series were identified along transect B at stations 15 ft and 61 ft, respectively (JEA Inc. 2006, Appendix C). The mapped soil series differ from those classified based on characteristics observed in the field, likely due to the mapping scale associated with the Soil Survey of Volusia County, which did not account for soil changes in the narrow wetland transition between the upland and the lake (JEA Inc. 2006, Appendix C). Pomona soils are spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and aluminum and/or iron oxides. This soil series has an aquic moisture regime, indicating that the soil is saturated with water and virtually free of gaseous oxygen for sufficient periods to induce anaerobic conditions (Brady and Weil 1996). This soil series also contains an argillic horizon, a diagnostic illuvial subsurface horizon characterized by an accumulation of silicate clays, starting below 40 in. of the ground surface (USDA–NRCS 2005). The Pomona soil series is poorly drained or very poorly drained, with a water table within 6–18 in. for 1 to 3 months, during most years. The water table is at a depth of 10–40 in. for 6 months or more during most years. Depressional areas of Pomona soils are typically ponded for 6 to 9 months a year (USDA–NRCS 2005).

Myakka soils are spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and oxides of aluminum and/or iron. This soil series has an aquic moisture regime indicating that these soils are saturated with water and virtually free of gaseous oxygen for sufficient periods to induce anaerobic conditions (Brady and Weil 1996). Myakka soils are poorly drained to very poorly drained with a water table at depths of less than 18 in. for a duration of 1 to 4 months during most years, receding to depths of more than 40 in. during very dry seasons. Depressional areas of Myakka soils are covered with standing water for periods of 6 to 9 months or more in most years (USDA–NRCS 2005).

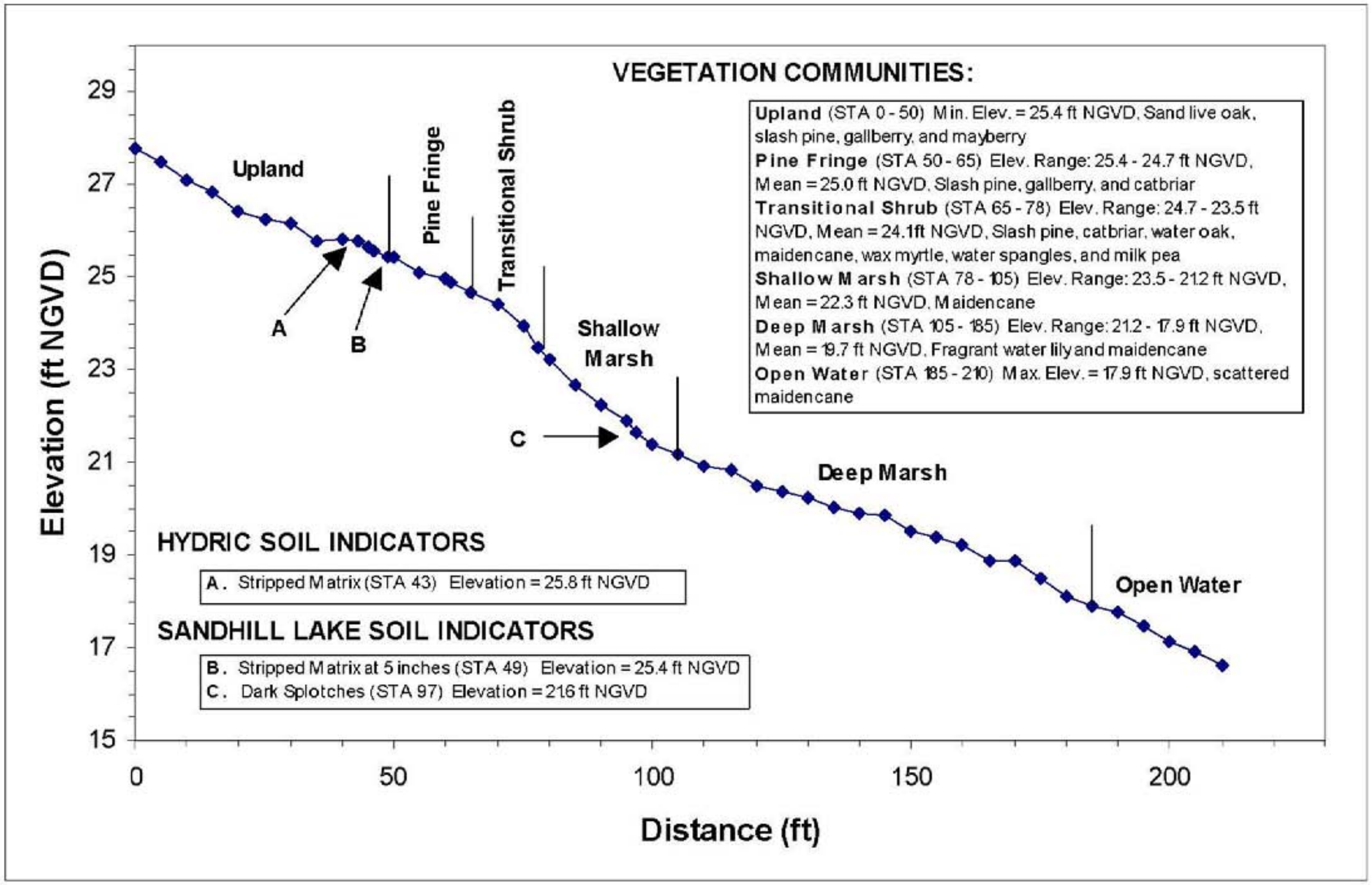
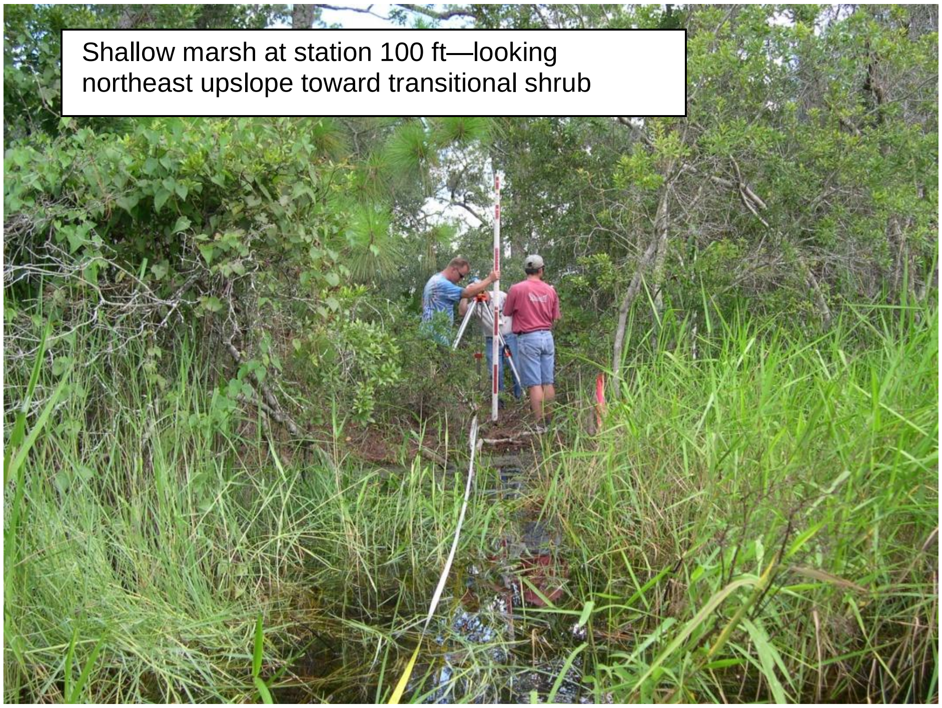


Figure 14. Transect B, Three Island Lakes—topography, vegetation communities, hydric soil indicators, and sandhill lake soil indicators
(*Note: water level = 24.44 ft NGVD on July 18, 2005)

Upland at station 15 ft—looking northeast upslope toward station 0 ft

Upland—looking southwest toward the pine fringe and Three Island Lakes

Figure 15. Transect B photographs, Three Island Lake



Shallow marsh at station 100 ft—looking northeast upslope toward transitional shrub

Transition between shallow marsh and deep marsh—looking southeast

Figure 15—*Continued*

Table 8. Transect B vegetation species list, Three Island Lakes

Species	Common Name	FWDM Code[1,2]	Plant Communities With Plant Species Cover Estimates[3]					
			Upland (0–50 ft)	Pine Fringe (50–65 ft)	Transitional Shrub (65–78 ft)	Shallow Marsh (78–105 ft)	Deep Marsh (105–185 ft)	Aquatic Bed (185–210 ft)
Amphicarpum muhlenbergianum	Blue maidencane	FACW	1	1				
Cephalanthus occidentalis	Buttonbush	OBL				1		
Cladonia sp.	Deer moss	UPL	1					
Cuphea carthagenensis	Columbia waxweed	FAC			0			
Dichanthelium dichotomum	Cypress witchgrass	FACW	1					
Eupatorium capillifolium	Dog fennel	FAC			1	0		
Galactia elliottii	Milkpea	UPL	1	1	2			
Gratiola hispida	Rough hedge hyssop	FAC	1					
Hypericum fasciculatum	St. John’s wort	OBL				1	0	
Ilex glabra	Gallberry	UPL	2	2	1			
Ipomoea sagittata	Morning glory	UPL			1			
Ludwigia peruviana	Primrose willow	OBL			1			
Myrica cerifera	Wax myrtle	FAC			2	0		
Nymphaea odorata	Fragrant waterlily	OBL				0	3	
Panicum hemitomon	Maidencane	OBL	0		2	4	2	1
Panicum repens	Torpedo grass	FACW			1	1	1	
Pinus clausa	Sand pine	UPL	1	1				
Pinus elliottii	Slash pine	UPL	2	3	2			
Pityopsis graminifolia	Grass-leaved aster	UPL	1					
Quercus geminata	Sand live oak	UPL	2	1				
Quercus myrtifolia	Myrtle oak	UPL	1	1				
Quercus nigra	Water oak	FACW	1		2			
Rhynchospora megalocarpa	Beakrush	UPL	1					
Salvinia minima	Water spangles	OBL			2	1	1	
Serenoa repens	Saw palmetto	UPL	1					
Smilax sp.	Catbriar	UPL	1	2	2			
Vaccinium elliotii	Mayberry	FAC	2	1				
Vaccinium myrsinites	Shiny blueberry	UPL	1					

[1] Species and hydric designations are taken from Ch. 62-340.450, *F.A.C.* Species not in the rule are assumed upland (UPL) unless they are obvious aquatics; unlisted aquatic species are designated as obligates (OBL).

[2] *The Florida Wetlands Delineation Manual* (FWDM) wetland indicator status (Gilbert et al. 1995)—UPL = Upland plants that rarely occur in wetlands, but almost always occur in uplands; FAC = Facultative plants with similar likelihood of occurring in both wetlands and uplands; FACW = Facultative wet plants that typically exhibit their maximum cover in areas subject to surface water flooding and/or soil saturation, but may also occur in uplands; OBL = Obligate plants that are found or achieve their greatest abundance in an area that is subject to surface water flooding and/or soil saturation; rarely in uplands

[3] Species Occurrence: Aerial extent of vegetation species along each transect within each community where, 0 = <1% (rare); 1 = 1–10% (scattered); 2 = 11–25% (numerous); 3 = 25–50% (abundant); 4 = 51–75% (co-dominant); 5 = >75% (dominant)

Table 9. Transect B soil feature elevations (ft NGVD), Three Island Lakes

Location	Station	Feature	Elevation (ft NGVD)
Hydric Soil Indicators			
Transect B	Station 43 ft	Stripped matrix	25.8
Sandhill Lake Soil Indicators			
Transect B	Station 49 ft	Stripped matrix at 5 in.	25.4
Transect B	Station 97 ft	Dark splotches	21.6

ft NGVD = National Geodetic Vertical Datum

Sandhill lake soil indicators were identified at stations 49 ft and 97 ft at transect B (JEA Inc. 2006, Appendix C). The sandhill lake soil indicator, Stripped matrix, indicates an elevation that is exceeded by the lake stage approximately 20% of the time over the long term (Richardson et al. 2006) and was identified at station 49 ft (25.4 ft NGVD). A Stripped matrix is a layer in which iron/manganese oxides and/or organic matter have been stripped from the matrix, exposing the primary base color of the soil materials and forming a diffuse splotchy pattern of two or more colors. The Stripped matrix sandhill lake soil indicator is identified at its waterward-most extent, where the stripping begins 5 in. beneath the soil surface (Richardson et al. 2006). The sandhill lake soil indicator, Dark splotches, indicates an elevation that is exceeded by the lake stage approximately 80% of the time over the long-term (Richardson et al. 2006), and this was identified at station 97 ft (21.6 ft NGVD). This indicator was identified at its landward extent, where there was just less than 3 in. of sand over a layer at least 3 in. thick, with 20% or more of the soil material having a Munsell color of 10YR 3/1 or darker.

The hydric soil indicator, Stripped matrix, was identified at station 43 ft (25.8 ft NGVD) at transect B (JEA Inc. 2006, Appendix C). The hydric soil indicator, Stripped matrix, is a layer starting within 6 in. of the surface, in which, iron/manganese oxides and/or organic matter have been stripped from the matrix, exposing the primary base color of the soil materials and forming a diffuse splotchy pattern of two or more colors. The hydric soil indicator, Stripped matrix, where it begins 6 in. beneath the soil surface (i.e. station 43 ft), is routinely used to delineate hydric soils throughout Florida (FAESS 2000) and, therefore, is generally near the wetland-upland interface. The occurrence of Stripped matrix indicates a seasonal high saturation within 6 in. of the soil surface (FAESS 2000).

STRUCTURAL ALTERATIONS AND OTHER CHANGES

The Three Island Lakes drainage basin has undergone significant urbanization since 1960. The lake's drainage basin area is approximately 826 acres. Based upon 2004 land use (SJRWMD 2004), the watershed contains approximately 479 acres (58%) low- and medium-density residential development with impervious surfaces associated with residences, such as driveways and roadbeds. Additionally, the naturally occurring interconnections of Three Island Lakes with upstream and downstream lakes have been improved, although the precise timing of these improvements is unknown. The increased residential development and drainage improvements between the lake basins has likely caused water levels in the lake to rise more rapidly during rainfall events compared with predevelopment conditions.

Despite the changes in the lake basin, the conditions of soils and vegetation, observed at the time fieldwork that was performed to support the development of recommended MFLs, did not appear to be in transition because of anthropogenic changes. Further, the water budget model developed for Three Island Lakes shows that MFLs were protected under existing conditions, long-term hydrology.

MINIMUM LEVELS DETERMINATION CRITERIA

Two minimum levels with associated durations and return intervals are recommended. A short description of the criteria applied to determine these minimum levels is presented. Important ecological structures and functions protected by the minimum levels are also discussed.

Soils and vegetation community field-collected data are the principle components of each MFLs determination. Standardized procedures for setting each level using the best available information are described in the (draft) Minimum Flows and Levels Methods Manual (SJRWMD 2006b). Criteria vary depending upon the level being determined and the on-site wetland community characteristics. For example, the primary criterion for a level may be the average or extreme (high or low) elevation associated with a vegetation community or soil indicator, based on the scientific literature and hydrologic data.

Vegetation data and associated elevation statistics were the primary criteria applied to determine the recommended minimum levels for Three Island Lakes. Vegetation communities lie along a continuum, from dry (upland) to very wet (deep marsh) and were used together with published literature concerning the hydrology and functions of individual communities to determine the recommended minimum levels. Sandhill lake soil indicators and hydric soil indicators identified at each transect and surface water inundation/dewatering signatures (SWIDS, Neubauer et al. 2006) were used as supporting information.

Sandhill lake soil indicators are being developed to provide consistent hydrologic indicators to aid in the determination of MFLs at sandhill lakes. Vegetation at sandhill lakes may be an unreliable indicator of hydrology since the extent and composition of herbaceous vegetation may change in response to water level fluctuations. However, where sandhill lakes have stable vegetation communities, such as at Three Island Lakes, then hydrologic interpretations based on vegetation are reasonable. Soil characteristics within a lake's fluctuation range develop as a result of long-term hydrologic conditions and persist through wet and dry cycles (FAESS 2000) and can be used as reliable indicators of historic hydrology (Richardson et al. 2006).

The minimum frequent high level and minimum frequent low level, based on existing conditions at systems throughout SJRWMD, have consistently been determined at elevations with approximate stage exceedences of 20% and 80%, respectively. Unique soil morphologies were identified at sandhill lakes within SJRWMD, near the 20% and 80% stage exceedences and were termed frequent high and frequent low sandhill lake soil indicators, respectively (Richardson et al. 2006). The frequent high sandhill lake soil indicator, Stripped matrix, beginning 5 in. beneath the soil surface, was found to be the most reliable indicator of 20% stage exceedence (Richardson et al. 2006). The frequent low sandhill lake soil indicator, Dark splotches, was found to be the most reliable indicator of 80% stage exceedence (Richardson et al. 2006).

A Stripped matrix is a soil layer in which iron/manganese oxides and/or organic matter have been stripped from the soil matrix, exposing the primary base color of the soil material (USDA–NRCS 2002). The stripped areas are generally rounded and result in splotchy coated and uncoated soil areas (USDA–NRCS 2002). Dark splotches is identified by the accumulation of organic coatings on the mineral soil particles into a darker layer within the soil matrix. The thickness, color, and depth to this dark layer are key to its identification. For specific details regarding identification of sandhill lake soil indicators, see Richardson et al. (2006).

The frequent high and frequent low sandhill lake soil indicators, Stripped matrix, Dark splotches, and the other unique soil morphologies identified by Richardson et al. (2006), represent historic hydrology and, thus, cannot directly be applied as minimum levels. Minimum flows and levels must consider existing changes and structural alterations to watersheds, surface waters, and aquifers (sections 373.042(1)(a) and (b), F.S.), and nonconsumptive uses, including navigation, recreation, fish and wildlife habitat, and other natural resource values (Rule 62-40.473, *F.A.C.*). Therefore, an offset is required to convert the elevations identified via sandhill lake soil indicators to minimum levels. The offsets for the sandhill lake soil indicators are currently being developed in cooperation with the University of Florida, Soil and Water Science Department, and JEA Inc. Sandhill lake soil indicators can only be used to support a minimum levels determination until the offsets have been developed and thoroughly reviewed.

The MFLs are also supported by current SWIDS analysis. Frequency analysis of long-term stage data or modeled stage data is utilized to provide probabilities of flooding/dewatering events of a set duration (i.e., SWIDS). The probabilities are interpreted as return intervals (Gordon et al. 1992). For example, if a 30-day flooding event of an elevation of interest (e.g., maximum elevation of shallow marsh) had a probability of exceedence of 33%, then the event is interpreted as occurring approximately 33 in 100 years or a 1:3 year return interval, on average. This approach enables like communities from systems at different elevations to be compared, and results in quantitative hydrologic signatures of specific elevations (e.g., mean, minimum, and maximum elevation of a vegetation community, Neubauer et al. 2006). Quantitatively defining the hydrologic signatures of vegetation communities provides a hydrologic range for each vegetation community, with a transition to a drier community on one side of the range and a transition to a wetter community on the other side. These hydrologic signatures provide a target for MFLs determinations that are based on vegetation communities and provide an estimate of how much the return interval of a flooding or dewatering event can be shifted, while maintaining a vegetation community within its observed hydrologic range.

MINIMUM LEVELS REEVALUATION FOR THREE ISLAND LAKES

Minimum Frequent High Level (23.7 ft NGVD)

The recommended minimum frequent high level for Three Island Lakes is 23.7 ft NGVD with an associated duration of 30 days and return interval of once in 5 years, on average. The minimum frequent high level is defined as "… a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetlands functions" (Rule 40C-8.021(7), *F.A.C.*). Frequency analysis of modeled stage data (Figure 5) shows that the recommended minimum frequent high level with an associated duration of 30 days and return interval of once in 5 years, on average, is met under existing 2003 modeled hydrologic conditions and allows for a small amount of additional consumptive use (Robison 2006).

The recommended minimum frequent high level elevation component is equal to the grand mean of the mean elevations of the transitional shrub/shoreline communities on transects A, B, 1, and 2 (23.7 ft NGVD, Table 11). The grand mean gives equal weight to each transect. Transitional shrub communities are typically found between uplands and wetter community types and can develop on wet prairies that have been protected from fire (Kinser 1996). Flooding of the transitional shrub community is necessary to prevent permanent encroachment of upland plant species into this community.

The adopted minimum frequent high level elevation component (23.4 ft NGVD) was derived from the mean elevation of the shoreline communities traversed at transects 1 and 2 from the original MFLs determination (23.4 ft and 23.5 ft NGVD, respectively, Appendix A). These shoreline communities were recovered in the reevaluation process to verify that the vegetation and location along the original transects remained unchanged and to verify that the shoreline communities were equivalent to the transitional shrub communities identified during the reevaluation process. No changes from the original descriptions were evident in the composition, location, or extent of the shoreline communities on transects 1 and 2, and they were equivalent to the transitional shrub communities on transects A and B; therefore, no additional data collection was necessary on these transects. It is important to note that numerous pines, such as slash pines, around the perimeter of the lake and much of the wax myrtle within the transitional shrub/shoreline communities have died or are showing stress, presumably from recent high water levels.

Table 10. Combined transect summary statistics, Three Island Lake

Transects	Feature	Mean (ft NGVD)	Median (ft NGVD)	N
A, B, 1, and 2	Upland[1] (minimum elevations)	25.4	–	4
A, B, 1, and 2	Pine fringe/flatwoods	25.0	24.9	4
A, B, 1, and 2	Transitional shrub/shoreline	23.7	23.6	4
A, B, 1, and 2	Shallow marsh	21.9	21.8	4
A, B, 1, and 2	Deep marsh	19.4	19.5	4
A and B	Open water (max elevations)	18.2	–	2
A and B	Frequent high sandhill lake soil indicator	25.4	–	2
A and B	Frequent low sandhill lake soil indicator	21.8	–	2

[1] Minimum upland elevation on Transect 2 was taken as the maximum elevation of the Pine Flatwoods
ft NGVD = National Geodetic Vertical Datum
N = the number of elevations surveyed

The mean elevation of transitional shrub communities has commonly been used as the criterion for minimum frequent high determinations at other MFLs water bodies. Recent hydrologic analyses, SWIDS (Neubauer et al. 2006), provide additional support for the use of the mean elevation of the transitional shrub community for a minimum frequent high level.

SWIDS analysis of 16 transitional shrub communities showed that the median hydrologic signature for the mean elevation of transitional shrubs will flood, on average, for 30 continuous days, with an approximate return interval of 1:2.2 years, with a range of 1:1.1 to 1:7.4 years (Neubauer et al. 2006). The return interval associated with the recommended minimum frequent high level (1:5 years, on average) is slightly wetter than the driest hydrologic signature observed for transitional shrub communities at other systems and drier than approximately 75% of the transitional shrub communities observed. This return interval allows for some shift in hydrology, but maintains a natural hydrologic signature for the transitional shrub communities, which should maintain the location, structure, and functions of this community.

Frequency analysis of the modeled stage data shows that the recommended minimum frequent high level will be exceeded for 30 continuous days, on average, with an approximate return interval of 1:3.6 years, under 2003 modeled conditions (Figure 5). This duration and return interval shows that the hydrologic requirements of the recommended minimum frequent high level are being met under 2003 modeled conditions and that this minimum level would allow for some additional consumptive use.

The minimum frequent high elevation component as it relates to the vegetation communities observed at Three Island Lakes inundates the shallow marsh communities observed on transects A, B, 1 and 2 (maximum elevations 22.7 ft, 23.5 ft, 22.5 ft and 23.0 ft NGVD, respectively); provides 4.3 ft of water over the combined mean elevation of the deep marsh communities on transects A, B, 1 and 2 (19.4 ft NGVD, Table 10); and provides 4.5 ft of water at the hydraulic control elevation between the north and south lobes of Three Island Lakes (19.2 ft NGVD).

Although the frequent high sandhill lake soil indicator (25.4 ft NGVD, Table 11) generally provides a good estimate of the minimum frequent high level elevation on sandhill lakes, it may be a poor indicator of existing hydrologic conditions at Three Island Lakes. This is further evidenced by the observation of the upper boundary of hydric soils at 25.9 ft and 25.8 ft NGVD on transects A and B, respectively. The sandhill lake soil indicators and upper boundary of hydric soil indicators were identified in the upland or pine fringe vegetation communities, which have not been flooded frequently or for long durations in the observed period of stage record (Figure

8). These indicators are either relict features, typical of past hydrology before alterations within the basin, or are maintained by seepage.

The recommended minimum frequent high elevation component (23.7 ft NGVD) provides inundation or saturation within the transitional shrub communities at Three Island Lakes for a frequency and duration that is intended to prevent permanent encroachment of upland species and sufficient to maintain the spatial extent of this community. Longer duration and more-frequent inundation, as compared to the recommended minimum frequent high level, occur in the marsh communities downslope from the transitional shrub communities. The longer duration and more frequent inundation in the marsh communities are sufficient to support the obligate and facultative wetland plant species within as well as the spatial extent and functions of the marsh communities. This level also allows sufficient water depths for fish and other aquatic organisms to feed and spawn on the lake floodplain. In addition to providing aquatic habitat, the floodplain marshes may improve water quality by functioning as filters and sinks for dissolved and suspended constituents, as found with river floodplains (Wharton et al. 1982).

Additional benefits from the recommended minimum frequent high level include the greatly expanded aquatic habitat when Three Island Lakes inundates the marshes and transitional shrub communities traversed at transects A, B, 1, and 2. Connecting lakes to floodplain swamps has been found to be extremely important to animal productivity in the lower coastal plain (Bain 1990; Poff, et. al. 1997). Similar benefits likely result from flooding the marsh and transitional shrub communities at Three Island Lakes. When the floodplains are flooded, many fish likely migrate from the lake to the inundated areas for spawning and feeding. As water levels continue to rise, the amount of vegetative structure available to aquatic organisms increases greatly as large areas of floodplains are inundated (Light, et al. 1998).

Minimum Frequent Low Level (19.4 ft NGVD)

The recommended minimum frequent low level for Three Island Lakes is 19.4 ft NGVD, with an associated duration of 120 days and a return interval of once every 10 years, on average. The minimum frequent low level is defined as "… a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of the floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs" (Rule 40C-8.021 (10); *F.A.C.*). Relative to the deep marsh community surveyed, the minimum frequent low level should not be dewatered for more than 120 consecutive days, more often than once every 10 years, on average (i.e., 10 events in 100 years). When surface water is absent during moderate droughts, the water table is near the surface. Hydrologic model results (Figure 7) support the minimum frequent low level recommended, with a duration of 120 consecutive days and return interval of 10 years, on average (Robison 2006).

The recommended minimum frequent low elevation component is equivalent to the grand mean of the mean elevations of the deep marshes observed on transects A and B and the aquatic beds observed on transects 1 and 2 (19.4 ft NGVD, Table 10). The grand mean gives equal emphasis to each transect. The aquatic beds observed on transects 1 and 2 were recovered during the reevaluation process and are equivalent to the deep marshes observed on transects A and B and will be referred to as deep marshes herein. The deep marshes on all transects have water lilies and/or spatterdock interspersed with maidencane and are located on mineral soils. Extreme low water levels in 2001 and extreme high water levels in 2003 and 2004 have likely resulted in the mix of maidencane and fragrant water lilies at Three Island Lakes. This mix of emergent and floating-leaved vegetation results in less confidence in the vegetation community break between shallow marsh and deep marsh; hence, the use of the more stable mean deep marsh elevation as criteria for the determination of the minimum frequent low level.

Water lilies require inundation to complete their life cycle (Ware 2002), while maidencane can tolerate a wide range of hydrologic conditions. It has also been observed that the bulk of water lily populations occur below an inundation frequency of 88% (Hagenbuck et al. 1974). Water lilies are intolerant of severe drought because the horizontal rhizomes quickly dry and rot (Conti and Gunther 1984), though recovery via the seed bank can occur, as the seeds can persist for more than 2.5 years if kept wet.

The recommended minimum frequent low level will likely allow some mortality of rooted, floating-leafed vegetation near the maximum elevation of the deep marsh, but these areas will recover during higher water levels. This water level limits the aquatic habitat to the main lake bodies while maintaining diverse aquatic flora and fauna and providing foraging habitats for a variety of animals that utilize the dry portions of the lake, floodplain, or basin. Shallow ponding is maintained within the deep marsh communities, which provides ideal conditions for wading birds to forage. Great Egrets need water depths of less than 10 in., and the small herons need water depths of less than 6 in. to effectively forage (Bancroft et al. 1990).

The recommended minimum frequent low elevation component is supported by water table drawdowns for vegetation communities reported in the literature and by vegetation communities observed at Three Island Lakes. The recommended minimum frequent low elevation component (19.4 ft NGVD) results in a 30-in. drawdown from the grand mean elevation of the shallow marshes observed on transects A, B, 1, and 2 (21.9 ft NGVD, Table 10). This drawdown is within the range reported by ESE Inc. (1991), calculating an average minimum dry-season water table depth of 53 cm ±

13.5 cm (range of 13–100 cm) below the soil surface, based upon field data reported from the scientific literature for 29 seasonally flooded freshwater marshes. The minimum frequent low level should sufficiently protect the shallow marshes observed at Three Island Lakes since the drawdown within the shallow marsh enabled by this level is within the range observed for numerous systems.

Dewatering the shallow marsh is a natural consequence of drought and has ecological benefits. Drawdown conditions enable seeds of emergent wetland plants to germinate from the seed banks of the floodplain. Seeds of many wetland plant species require exposed soils to germinate (Van der Valk 1981). Exposing the floodplain of Three Island Lakes for suitable durations should maintain healthy and diverse floodplain communities.

The frequent low sandhill lake soil indicator, Dark splotches, was identified at transects A and B (22.0 ft and 21.6 ft NGVD, respectively, Tables 5 and 9) and is similar to the maximum elevations of the deep marsh communities on transects A, B, 1 and 2 (21.2 ft, 21.2 ft, 20.8 ft and 20.6 ft NGVD, respectively). Development and application of an offset will likely reduce these differences. The elevation identified with the frequent low sandhill lake soil indicator and the maximum elevation of the deep marsh community often correspond, but have longer duration and more frequent dewatering than would be typical of the mean elevation of deep marsh; thus, the frequent low sandhill lake soil indicator cannot directly support the recommended minimum frequent low level in this case.

The temporal components associated with the recommended minimum frequent low level are supported by current SWIDS analysis for the mean elevation of deep marshes. SWIDS analysis of 20 deep marsh communities shows that the median signature for the mean elevation of deep marshes is dewatered, on average, for 120 continuous days approximately 1:14.0 years, with a range of 1:2.8 to less frequent than 1:100 years (Neubauer et al. 2006). The return interval associated with the minimum frequent low level is wetter than the driest hydrologic signature observed for the mean elevation of deep marshes and is a drier hydrologic signature than approximately 75% of the deep marshes observed. This return interval allows for some shift in hydrology, but maintains a natural hydrologic signature for the deep marsh communities, which should maintain the location, structure, and functions of this community.

Frequency analysis of the modeled stage data at Three Island Lakes shows that the recommended minimum frequent low level will be dewatered, on average, for 120 continuous days, with an approximate return interval of 1:20 years under 2003 modeled conditions. This duration and return interval show that the hydrologic requirements of the recommended minimum frequent low level are met under 2003 modeled conditions and some additional water is available for consumptive use.

CONCLUSIONS AND RECOMMENDATIONS

The intent of the establishment of minimum levels for Three Island Lakes in Volusia County, Florida, is to protect aquatic ecosystems from significant ecological harm caused by the consumptive use of water. Additionally, minimum flows and levels (MFLs) provide technical support to St. Johns River Water Management District's (SJRWMD's) regional water supply planning process and the consumptive use permitting program (Chapter 40C-2, *F.A.C.*). Recent completion of a hydrologic model for Three Island Lakes indicates that the adopted minimum frequent high and minimum average levels for Three Island Lakes (Mace 1997) are not being met under 2003 modeled hydrologic conditions. Consequently, a reevaluation of the adopted levels was performed. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Three Island Lakes (Table 11) based on current SJRWMD MFLs methodology (SJRWMD 2006b).

Table 11. Adopted (Mace 1997) and recommended minimum surface water levels for Three Island Lakes, Volusia County

Minimum Levels	Adopted Elevation (ft NGVD) 1929 Datum	Adopted Hydroperiod Categories	Recommended Elevation (ft NGVD) 1929 Datum	Recommended Duration	Recommended Return Interval
Minimum frequent high (FH) level	23.4	Seasonally flooded	23.7	30 days	5 years
Minimum average (MA) level	21.8	Typically saturated	none	none	none
Minimum frequent low (FL) level	18.8	Semi-permanently flooded	19.4	120 days	10 years

ft NGVD = feet National Geodetic Vertical Datum

SJRWMD's multiple MFLs methodology (SJRWMD 2006b) was applied to determine the minimum lake levels presented within this report. MFLs determinations are based on evaluations of topographic, soils and vegetation data collected within plant communities associated with the water body, together with information collected from other aquatic ecosystems and from the scientific literature.

The recommended minimum frequent high elevation component for Three Island Lakes, 23.7 ft NGVD, is 0.3 ft higher than the adopted minimum frequent high elevation component, 23.4 ft NGVD. The same criterion, mean elevation of transitional shrub communities, was utilized for the determination of the adopted and recommended minimum frequent high elevation components. The difference arises from the incorporation of data from two additional transects in the recommended minimum frequent high level. In addition to a recommended change in the minimum frequent high elevation, it is also recommended that the temporal components be modified. The change in temporal components results in a 30-day flood event occurring less frequently, i.e., once every 5 years, on average, rather than once every 3 years, on average. This modification is recommended because it is supported by current surface water inundation/dewatering signatures (SWIDS) determined for transitional shrub communities (Neubauer et al. 2006). In addition, Three Island Lakes is a sandhill lake, which lacks an accumulation of organic material, suggesting that the system is dewatered frequently, and this enables organic material deposited on the soil surface to oxidize rather than accumulate.

The minimum frequent high level allows the mean elevation of the transitional shrub communities to be flooded, on average, 30 continuous days, once every 5 years, which is slightly wetter than the driest hydrologic signature for transitional shrub communities based on current SWIDS analysis (Neubauer et al. 2006). Since the minimum frequent high level maintains a hydrologic signature within the range observed for transitional shrubs, this minimum level is intended to maintain the location, structure, and function of this community. This minimum level allows for some change from historic hydrology, which will likely be expressed in a change in species abundance, species composition, and potentially some shift in the extent of the community at its extreme (maximum and minimum) elevations. A further hydrologic shift caused by withdrawals that exceed the recommended MFLs will likely result in significant harm via conversion of the upper portion of the transitional shrub to a drier plant community and alteration of the community’s structure and function at its extreme elevations.

The adopted minimum average elevation component is 21.8 ft NGVD and is equivalent to the median stage elevation for the period January 4, 1990, to October 8, 1997 (Mace 1997). No minimum average level is recommended for Three Island Lakes. This is because Three Island Lakes is a sandhill lake. Based on the conceptual model of sandhill lakes developed by CH2M HILL (2003), sandhill upland lakes are astatic and lack a mean around which the system is organized. CH2M HILL (2003) also suggests that critical system behaviors of sandhill lakes may be related most strongly to high and low water levels corresponding to drought cycles and multidecadal climate cycles and that both high and low water levels are necessary to maintain expected ecosystem structure and functions. Therefore, only minimum frequent high and minimum frequent low levels are recommended for Three Island Lakes.

The recommended minimum frequent low elevation component for Three Island Lakes (19.4 ft NGVD) is 0.6 ft higher than the adopted minimum frequent low elevation component (18.8 ft NGVD). The same criterion, mean elevation of deep marsh (aquatic bed) communities, was applied for the determination of the adopted and recommended minimum frequent low elevation components. The difference arises from the incorporation of data from two additional transects in the determination of the recommended minimum frequent low elevation component. Upon review of the original MFLs determination, it was evident that the aquatic bed on Transect 2 likely skewed the mean deep marsh/aquatic bed elevation toward a low value. This bias was substantially reduced via incorporation of the two additional transects completed during the reevaluation process. In addition to a recommended change in the minimum frequent low level elevation, it is also recommended that the temporal components be modified. The change in temporal components results in a 120-day dewatering event occurring less frequently, i.e., once every 10 years, on average, rather than once every 5 years, on average. This modification is recommended because it is supported by current surface water inundation/dewatering signatures (SWIDS) determined for deep marsh communities (Neubauer et al. 2006).

The minimum frequent low level allows the mean elevation of the deep marshes at Three Island Lakes to be dewatered, on average, for 120 continuous days, once every 10 years. This dewatering signature is slightly wetter than the driest deep marsh, based on current SWIDS analysis of 20 deep marshes (Neubauer et al. 2006), and is drier than approximately 75% of the deep marshes analyzed. The minimum frequent low level is intended to maintain the location, structure, and function of this community. This minimum level allows for some change, which will likely be expressed via a change in species abundance, species composition, and potentially some shift in the extent of the community at its extreme (maximum/minimum) elevations. A further hydrologic shift caused by withdrawals that exceed the recommended MFLs will likely result in significant harm via conversion of the upper portion of the deep marsh to a drier plant community and alteration of the structure and functions at the extreme elevations within this community.

SJRWMD concludes that the recommended minimum frequent high and minimum frequent low levels for Three Island Lakes are protected under 2003 conditions, based on long-term hydrologic model simulations. The adopted MFLs and associated hydroperiod categories, and the recommended MFLs and associated durations and return intervals are presented in Table 11. The hydroperiod categories and definitions are adapted from water regime modifiers developed by Cowardin et al. (1979). Results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule.

The hydrologic model for Three Island Lakes (Robison 2006) was calibrated for 2003 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2003 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Three Island Lakes are protected under 2003 conditions. To determine if changes in groundwater use allocation subsequent to 2003 would cause lake levels to fall below the recommended MFLs for Three Island Lakes, the existing Three Island Lakes hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation. Information included in Appendix D concerning uses of the hydrologic model and applicable SJRWMD regional groundwater flow model should be utilized to assess whether water levels are likely to fall below MFLs under specific water use and land conditions.

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APPENDIX A—MINIMUM SURFACE WATER LEVELS FOR THREE ISLAND LAKES, AS DETERMINED IN 1997

MEMORANDUM F.O.R. 94-1514

DATE: November 11, 1997

TO: Jeff Elledge, Director
Resource Management Department

THROUGH: Charles A. Padera, Director
Water Resources Department

Edgar F. Lowe, Ph.D, Director
Environmental Sciences Division

Greeneville B. (Sonny) Hall, Ph.D, Technical Program Manager
Environmental Sciences Division

Clifford P. Neubauer, Ph.D, Supervising Environmental Specialist
Environmental Sciences Division

FROM: Jane Mace, Environmental Specialist III
Environmental Sciences Division

RE: Minimum Surface Water Levels determined for Three Island Lakes,
Volusia County (Project # 01-43-5140-DIST-10900)

The purpose of this memorandum is to forward recommended minimum lake levels (Table 1) determined for Three Island Lakes to the Department of Resource Management. Three Island Lakes was identified as a priority system due to the projected groundwater drawdown between 1 and 2.5 feet (ft) by the year 2010 in the vicinity of Three Island Lakes. Fieldwork was done at Three Island Lakes on October 8, 1997.

Table 1. Recommended minimum surface water levels for Three Island Lakes. Terminology is defined in Ch. 40C-8.021, *F.A.C.*

Minimum Level	Elevation (ft. NGVD)	Hydroperiod Category
Minimum frequent high level	23.4	Seasonally flooded
Minimum average level	21.8	Typically saturated
Minimum frequent low level	18.8	Semipermanently flooded

ft NGVD = feet National Geodetic Vertical Datum

Three Island Lakes is located within the city of Deltona in Volusia County (Figure 1). It is located within the Crescent City–DeLand Ridge physiographic division (Brooks 1982). The Crescent City–DeLand Ridge Division consists of sand hills with summits generally between 80 and 100 ft in elevation. Plio-Pleistocene sand and shell rest directly upon the Floridan aquifer (Brooks 1982). Floridan aquifer recharge may equal 0–4 in. per year at Three Island Lakes (Boniol et al., 1993).

Hydrology and Basin Features

Three Island Lakes is a 116-acre (when stage equals 23.0 ft. NGVD) sand hill lake connected via a culvert under Lake Helen–Osteen Road to a small (approximately 10 acres) water body to the northeast (Figure 1). On October 8, 1997, water was flowing rapidly into Three Island Lakes via this culvert. The hydrologic control elevation of this culvert is unknown. Additionally, water may exit Three Island Lakes to Dupont Lake to the south. No culvert was observed between Three Island Lakes and Dupont Lake, but based on the USGS topographical Lake Helen quadrangle map and the USBS National Wetland Inventory (NWI) map, drainage into Dupont Lake may occur.

Stage data recorded daily exists from January 4, 1990, to the present (Figure 2). Three Island Lakes has fluctuated 9.01 ft during the 7.8-year period of record with the maximum and minimum recorded stage equal to 24.57 and 15.56 ft. NGVD, respectively. The mean and median stage for the period of record equals 21.21 and 21.84 ft. NGVD, respectively. Figure 2 illustrates the low water levels that occurred during the drought of 1990–91. Drought recovery began in July of 1991 at Three Island Lakes. Between July 4, 1991, and October 8, 1997, the water level in Three Island Lakes fluctuated 5.23 ft.

Water depths were measured in the channel connecting the north and south lake lobes (Figure 1). The average elevation in this channel equaled 18.7 ft. NGVD with the shallowest point measured equaling 19.2 ft. NGVD. Water depths were also measured at seven locations near the center of the north lobe where the average depth equaled 11.0 ft. (12.1 ft. NGVD). The average water depth in the south lobe, calculated from five measurements taken near the lobe center equaled 12.7 ft. (10.4 ft. NGVD).

Consumptive Use

There is one consumptive use permit (CUP) for surface water withdrawals from Three Island Lakes. This permit also allocates water use from an 8-in. well with a combined maximum allocation of 7.1 million gallons per year (mgy) and a frost and freeze protection allocation of 4.0 mgy.

There are three additional approved permits for groundwater withdrawals within approximately a one-mile radius of the lake. The majority of the water allocation from these three permits is from the Deltona Utilities permit. This permit provides for a maximum allocation of 6,040 mgy from

33 existing or proposed wells. However, of the 33 existing or proposed wells, only four existing 10–12-in. wells and two proposed 12-in. wells occur within one mile of Three Island Lakes. A breakdown of the water withdrawals from the wells adjacent to Three Island Lakes is not available for the Deltona Utilities permit. The remaining two permits allow for a total maximum allocation of 152.38 mgy, with a frost and freeze protection allocation of 1.9 mgy from an existing 8-in., 10-in. and proposed 12 -in. well (Mary McKinney, Resource Management, personal communication, November 5, 1997).

Soils

The soils adjacent to Three Island Lakes were mapped as nonhydric sands by the Soil Conservation Service (Figure 3, SCS, 1980). Soil samples taken along the vegetation transects matched the soil descriptions in the soil survey. Additionally, the lake bottom consisted of a firmly packed sand.

Wetland Vegetation

Five different wetland communities were classified by the USBS National Wetland Inventory (NWI) using 1983 CIR photography (Figure 4) at Three Island Lakes. Table 2 lists these wetland communities.

Table 2. National Wetland Inventory Map codes at Three Island Lakes

NWI Code	Vegetation Description	Hydroperiod Description
PFO1A	Forested, broad-leaved deciduous	Temporarily flooded
PEM1C	Emergent, permanent	Seasonally flooded
PEM1F	Emergent, permanent	Semipermanently flooded
L2AB3G	Lacustrine, littoral, aquatic bed, rooted vascular	Intermittently exposed
L1UBH	Lacustrine, limnetic, unconsolidated bottom	Permanently flooded

The littoral zone at Three Island Lakes included maidencane, pickerelweed, rush fuirena, cutgrass, and waterlily. Maidencane and waterlily were co-dominant between the elevation of 18.5 and 20.8 ft. NGVD at Transect 1. At Transect 2, maidencane and waterlily were also abundant at a similar elevation (Figure 5). The mean waterward elevation of maidencane equaled 15.8 ft. NGVD (Table 3).

Transect 1 (Figure 6) traversed an area identified as PFO1A and L2AB3G on the northwest shore of the small island in the north lobe (Figure 1). The vegetation at the origin of Transect 1 consisted of live oaks and sand pines, grading into slash pines and swamp bays at a slightly lower elevation (Figure 6). A shoreline zone consisting primarily of wax myrtle was followed by a marsh grading from a zone of maidencane, lemon bacopa, and buttonbush, to a zone of cutgrass, pickerelweed, and waterlily. Waterward of the emergent marsh was located an aquatic bed of waterlily, rush fuirena, and maidencane.

Transect 2 (Figure 5) began in pine flatwoods on the north lakeshore and traversed an area identified as L2AB3G. Below the pine flatwoods, this transect traversed a shoreline zone consisting of wax myrtles, a marsh grading from a zone of rush fuirena, marsh St. John's wort, bladderwort, and bristle leaved beakrush, to a zone of pickerelweed, rush fuirena, and waterlily. An aquatic bed located waterward of the marsh contained primarily maidencane and waterlily.

The wetland communities delineated on the NWI map (Figure 4) as emergent marsh (PEM1C and PEM1F) appeared disturbed. The PEM1C marshes contained fill and were overgrown with willows. The PEM1F marsh was disconnected from the lake by an earthen berm. Consequently, vegetation transects were not performed in these communities.

Minimum Levels

The minimum levels for Three Island Lakes are based upon data from two elevation/vegetation transects, information contained in the (SCS) Soil Survey of Volusia County, the NWI map, and stage data. Transect elevation data were collected by Environmental Sciences and Surveying Services staff (Jane Mace, Patty Valentine-Darby, Ric Hupalo, and Tim King) on October 8, 1997, by using the benchmark 892-20 (elev. 30.025 ft. NGVD; FB 90-97, p. 54) as the datum. Table 3 describes important elevations that were key factors to consider when determining the minimum lake levels. Table 4 (p. 6) lists common and scientific names of the plant species found at Three Island Lakes. A surface water budget model to predict lake levels with and without out-of-lake withdrawals (CUPs) is not available for Three Island Lakes. Minimum levels are based on biological features associated with the long-term fluctuation of water levels. Three levels with corresponding hydroperiod categories are recommended. A short description of the functions of each minimum level and some of the related data used in the determination are presented below.

Table 3. Key elevations at Three Island Lakes

Location	Mean Elevation (ft. NGVD)	Elevation Range	N
Oak Uplands (Transect 1)	spot	>25.1	1
Pine flatwoods (Transect 1)	24.8	24.4 - 25.1	8
Pine flatwoods (Transect 2)	24.7	24.1 - 25.5	12
Top of dock deck	spot	23.8	1
Shoreline (Transect 2)	23.5	23.3 - 23.7	2
Shoreline (Transect 1)	23.4	22.8 - 24.2	4
Upper marsh (Transect 1)	22.2	22.1 - 22.5	3
Upper marsh (Transect 2)	22.2	21.5 - 23.0	14
Stage (Jan. 4, 1990–Oct. 8, 1997)	21.8 (median)	15.56 - 24.57	2580
Lower marsh (Transect 1)	21.3	20.8 - 21.8	4
Lower marsh (Transect 2)	21.0	20.7 - 21.4	6
Aquatic bed (Transect 1)	19.4	18.5 - 20.8	11

Location	Mean Elevation (ft. NGVD)	Elevation Range	N
Aquatic bed, east shore, south of power line	18.9	18.7 - 19.3	17
Channel between north and south lake lobes	18.7	18.3 - 19.2	21
Aquatic bed (Transect 2)	18.4	16.1 - 20.6	17
Channel between lg island and east shore in north lobe	17.8	17.0 - 18.0	10
Waterward maidencane	15.8	15.5 - 16.1	6

ft NGVD = feet National Geodetic Vertical Datum

MINIMUM FREQUENT HIGH LEVEL

The recommended minimum frequent high level (23.4 ft. NGVD) with the assigned hydroperiod category of seasonally flooded corresponds to the average elevation of the shoreline zone at Transect 1 and is similar to the average elevation of the shoreline zone at Transect 2 (23.5 ft. NGVD). This level maintains the spatial extent and functions of the marsh and aquatic bed communities and allows sufficient water depths for aquatic fauna to feed and spawn in the upper marshes.

Additionally, the recommended minimum frequent high level is between the 20th and 25th percent exceedence on the stage duration curve (Figure 7). The stage duration curve was created (based on recommendations from Price Robison, engineer, SJRWMD) from stage data collected between July 4, 1991, and October 8, 1997. This time period was chosen to exclude the extreme low lake levels which occurred during the 1990–91 drought which skew the analyses when there is a short (<10 years) period of record.

Other indicators which are more related to an infrequent high level are the oak upland elevation (>25.1 ft. NGVD) at Transect 1, the pine flatwood mean elevations at transects 1 and 2 (24.8 and 24.7 ft. NGVD, respectively) and the record high stage (24.57 ft. NGVD).

The recommended minimum frequent high level inundates the upper marshes at transects 1 and 2 with an average water depth of 1.2 ft. Average water depths in the lower marshes at transects 1 and 2 would equal 2.1 and 2.3 ft, respectively. Water depths would range from 2.6 to 7.3 ft in the three aquatic beds measured. Additionally, the minimum water depth measured in the channel connecting the north and south lobe would equal 4.2 ft.

The recommended minimum frequent high level is 0.4 ft below the one dock deck height measured. Presumably due to the wide range of water level fluctuation at Three Island Lakes, all but two of the docks were floating. The other non-floating dock was not measured because it was under several feet of water.

MINIMUM AVERAGE LEVEL

The recommended minimum average level (21.8 ft. NGVD) with the assigned hydroperiod category of typically saturated equals the average elevation of the emergent marshes at transects 1 and 2 (Figures 5 and 6). This level and hydroperiod category approximates a “typical” level that is slightly less than the long-term median water level while still protecting the wetland resources.

The recommended minimum average level provides for soil saturation and inundation in the upper emergent marshes at transects 1 and 2 with water depths ranging from 0–0.3 ft. Water depths ranging from 0–1.1 ft will occur in the lower emergent marshes. The recommended level will provide ideal water depths in the upper and lower emergent marshes for refugia and foraging habitat for aquatic fauna. Great Egrets need water depths less than 0.8 ft. and the small herons need water depths less than 0.5 ft. to forage efficiently when water levels are receding (Bancroft et al., 1990).

Inundation of the intermittently exposed aquatic beds at transects 1 and 2 with water depths averaging 2.4 ft and 3.4 ft, respectively, would occur at the recommended minimum average level. Additionally, this level provides unrestrained boat passage between the north and south lake lobes with a water depth of 2.6 ft at the shallowest point measured in the connecting channel.

The recommended minimum average level equals the median water level (21.8 ft. NGVD) for the period of record. This level also equals the 65th percent exceedence on the stage duration curve (Figure 7), derived from the abbreviated stage data set, discussed in the previous section.

MINIMUM FREQUENT LOW LEVEL

The recommended minimum frequent low level (18.8 ft. NGVD) with the assigned hydroperiod category of semipermanently flooded equals the average of the aquatic bed elevations at transects 1, 2, and on the east shore, south of the powerline (Figures 5 and 6). The NWI map describes the hydrologic regime of these aquatic beds as intermittently exposed, indicating that surface water is present throughout the year except during extreme droughts. Consequently, soil saturation and shallow inundation of the aquatic bed communities is appropriate to provide aquatic fauna habitat, and to protect these communities from the invasion of marsh and upland species. Additionally, the recommended minimum frequent low level will encourage organic matter decomposition in the marshes and aquatic beds, as well as, wetland plant germination. Water depths would range from 0–0.3 ft in the aquatic bed at Transect 1, between 0.1 ft and 2.7 ft in the aquatic bed at Transect 2, and between 0–0.1 ft in the aquatic bed on the east shore, south of the power line.

Surface water connectivity would not occur between the north and south lake lobes at the recommended minimum frequent low level. Both lake lobes are large and ecologically diverse with negative impacts unlikely to occur from the temporary separation. The recommended minimum frequent low level is 5.0 ft below the top of the one dock deck measured and provides a water depth of 1.6 ft at the waterward end of the dock.

Please call me (ext. 4389), Ric Hupalo (ext. 4338) or Patty Valentine-Darby (ext. 2309), if you wish to discuss these minimum levels or hydroperiod categories.

Table 4. Vegetation list, Three Island Lakes

Scientific Name	**Common Name**
Bacopa caroliniana	Lemon bacopa
Brasenia schreberi	Water shield
Cephalanthus occidentalis	Buttonbush
Eupatorium leptophyllum	Dog fennel
Fuirena scirpoidea	Rush fuirena
Hypericum fasciculatum	Marsh St. John’s wort
Ilex cassine	Dahoon holly
Ilex glabra	Gallberry
Lachnanthes caroliniana	Bloodroot
Leersia hexandra	Southern cutgrass
Lyonia mariana	Staggerbush
Magnolia grandiflora	Southern magnolia
Myrica cerifera	Wax myrtle
Nymphaea odorata	Water lily
Nymphoides aquatica	Floating hearts
Osmunda cinnamomea	Cinnamon fern
Panicum hemitomon.	Maidencane
Panicum repens	Torpedo grass
Persea palustris	Swamp bay
Pinus clausa	Sand pine
Pinus elliottii	Slash pine
Pluchea foetida	Camphor weed
Pontedaria cordata	Pickerelweed
Quercus virginiana	Live oak
Rhynchospora filifolia	Bristle leaved beakrush
Serenoa repens	Saw palmetto
Utricularia sp.	Bladderwort
Vitus rotundifolia	Muscadine grape
Xyris sp.	Yellow-eyed grass

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Attachments

JM:bs

cc: Kathryn Mennella
Larry Battoe
Larry Fayard
Chris Ware
Tommy Walters
David Clapp
Bob Freeman
Donna Curtis
Hal Wilkening
Ric Hupalo
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Patty Valentine-Darby
Sandy McGee
Dwight Jenkins
MFL REG

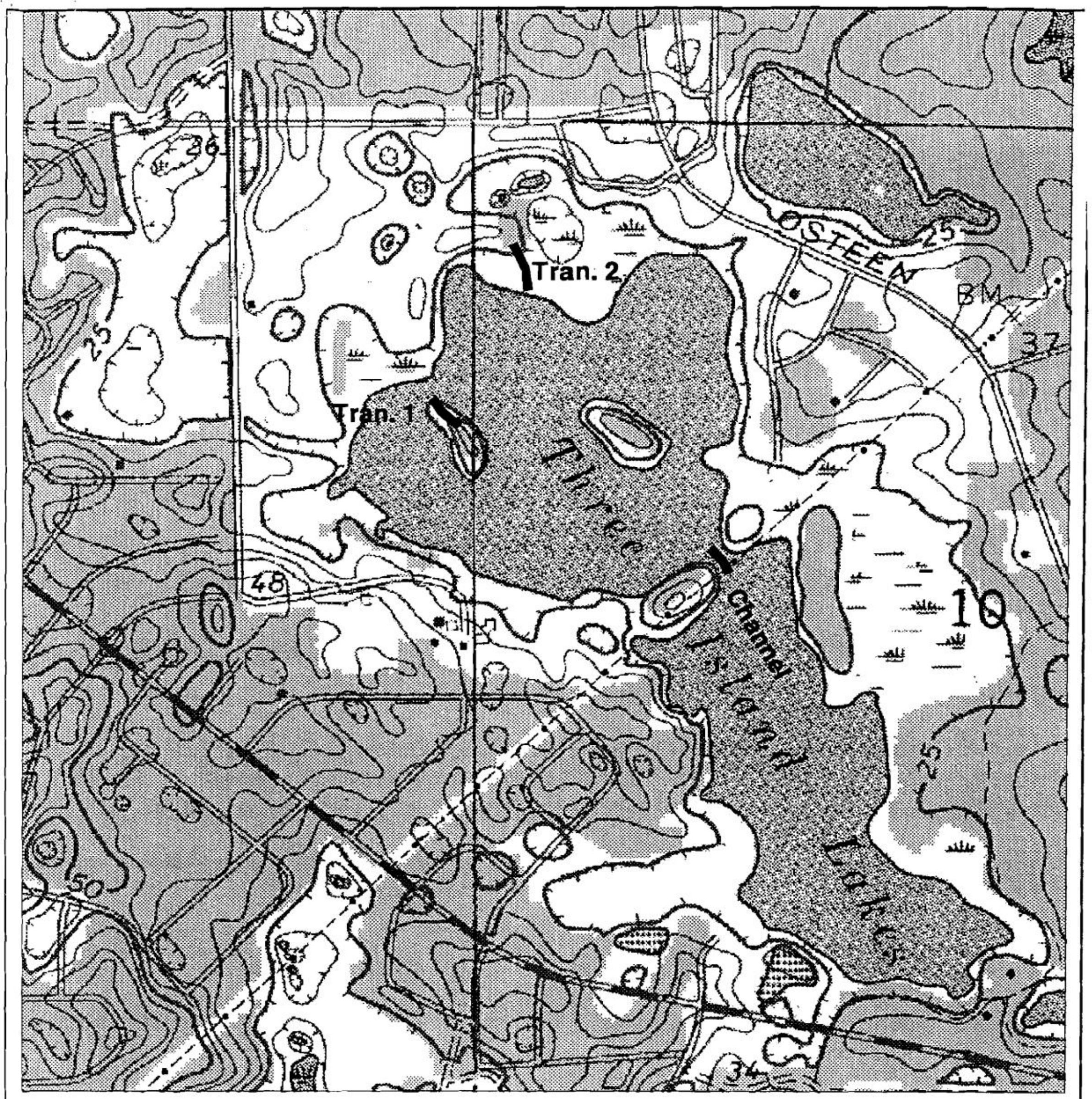

Figure 1. Three Island Lakes
Deltona, Volusia County

0.1 0 0.1 Miles
Scale 1:8401

Figure 2

THREE ISLAND LAKE STAGE

Period of Record January 4, 1990 - October 8, 1997

Average stage = 21.21; Median stage = 21.84

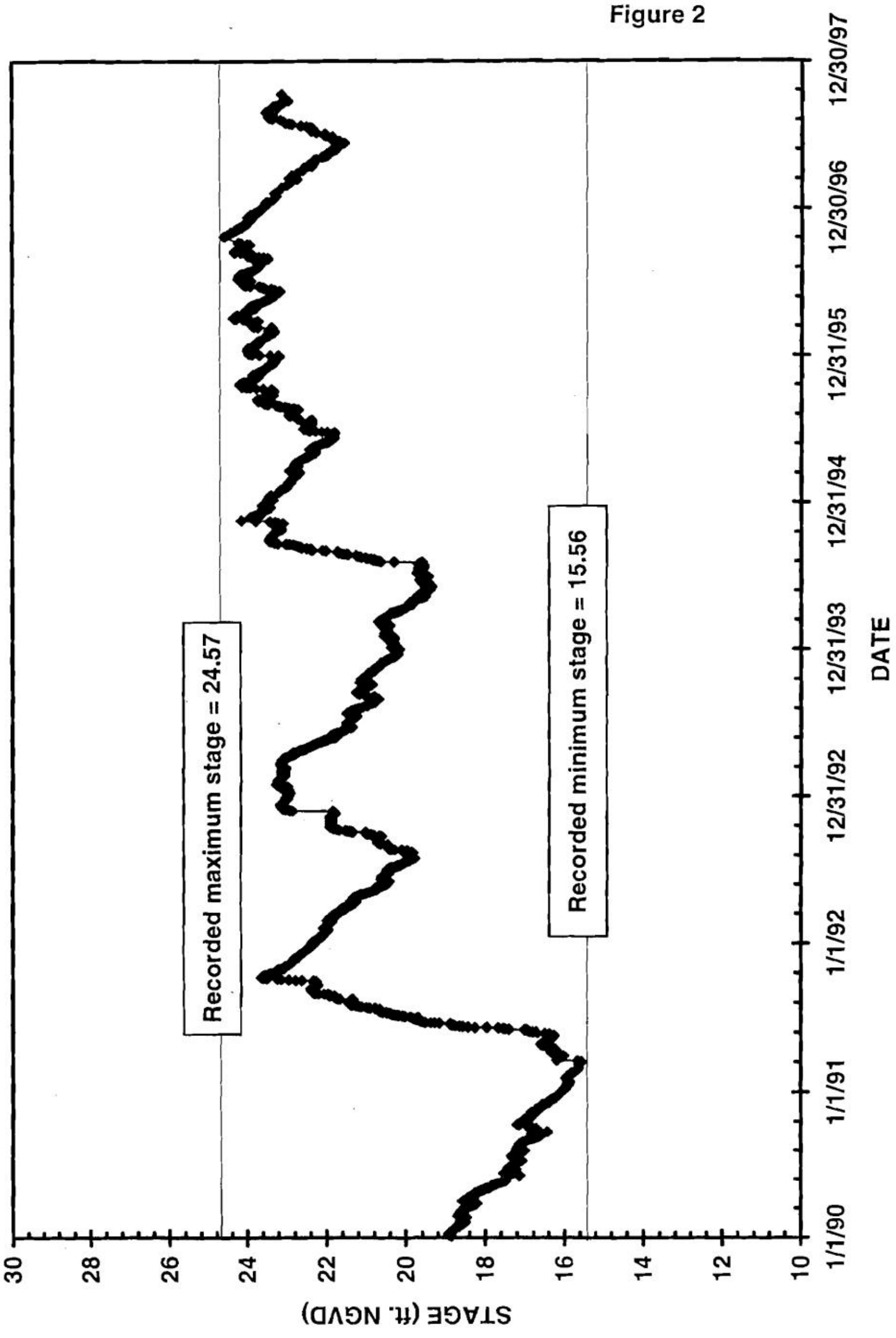

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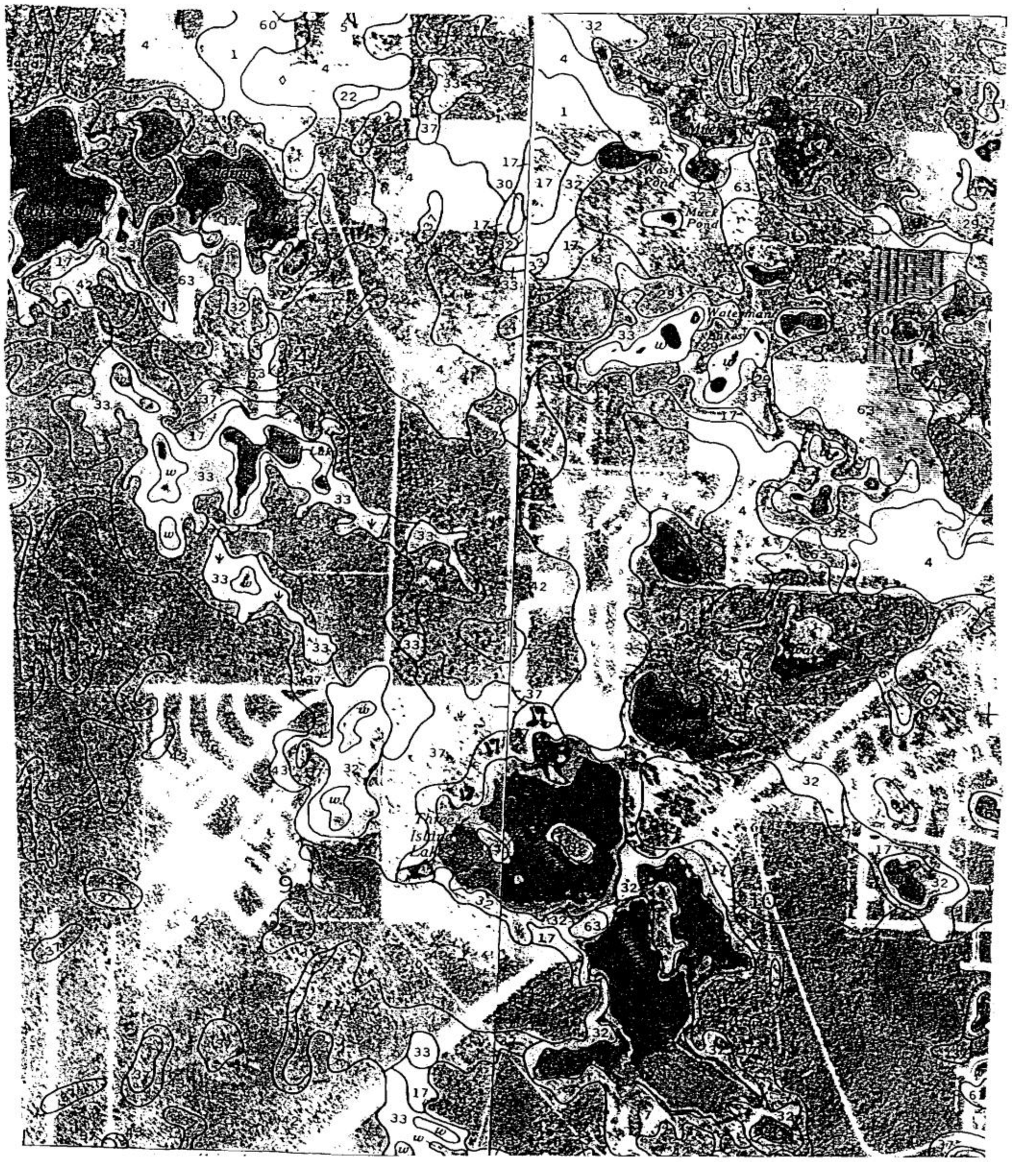
Figure 3



Volusia County Soils Id

Map No.	Soil Name	Description
4	Astatula fine sand	Excessively drained with H2O table >80" below surface
17	Daytona sand	Moderately well drained with H2O table 40-50" below surface
32	Myakka fine sand	Nearly level, poorly drained, H2O table 12" below for 3 months
42	Paola fine sand	Excessively well drained with H2O table > 72" below surface
63	Tavares fine sand	Moderately well drained with H2O table 40-60" below surface

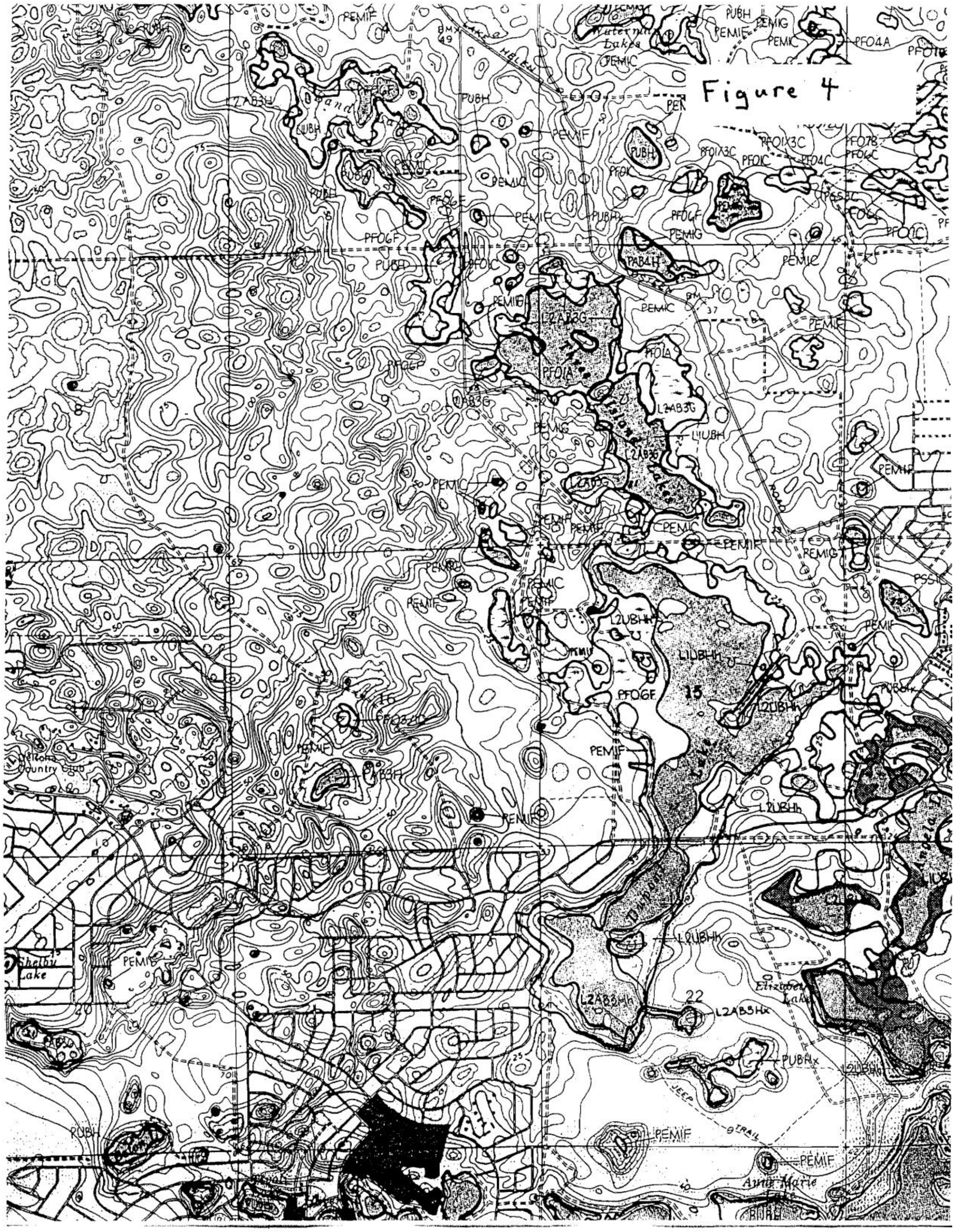


Figure 4
Watermelon Lakes
Sand Lake
Three Island Lakes
Deltona Country Club
Shelby Lake
Elizabeth Lake
Anna Marie Lake
Jeep Trail
PEMIF
PEMIC
PEMIG
PUBH
PFO1A
PFO4C
PFO6F
PAB4H
L2AB3G
L1UBH
L2UBHh
L1UBHh
L2AB3Hh
L2AB3Hx
PUBHx
15
16
22

Figure 5

THREE ISLAND LAKE VEGETATION TRANSECT #2

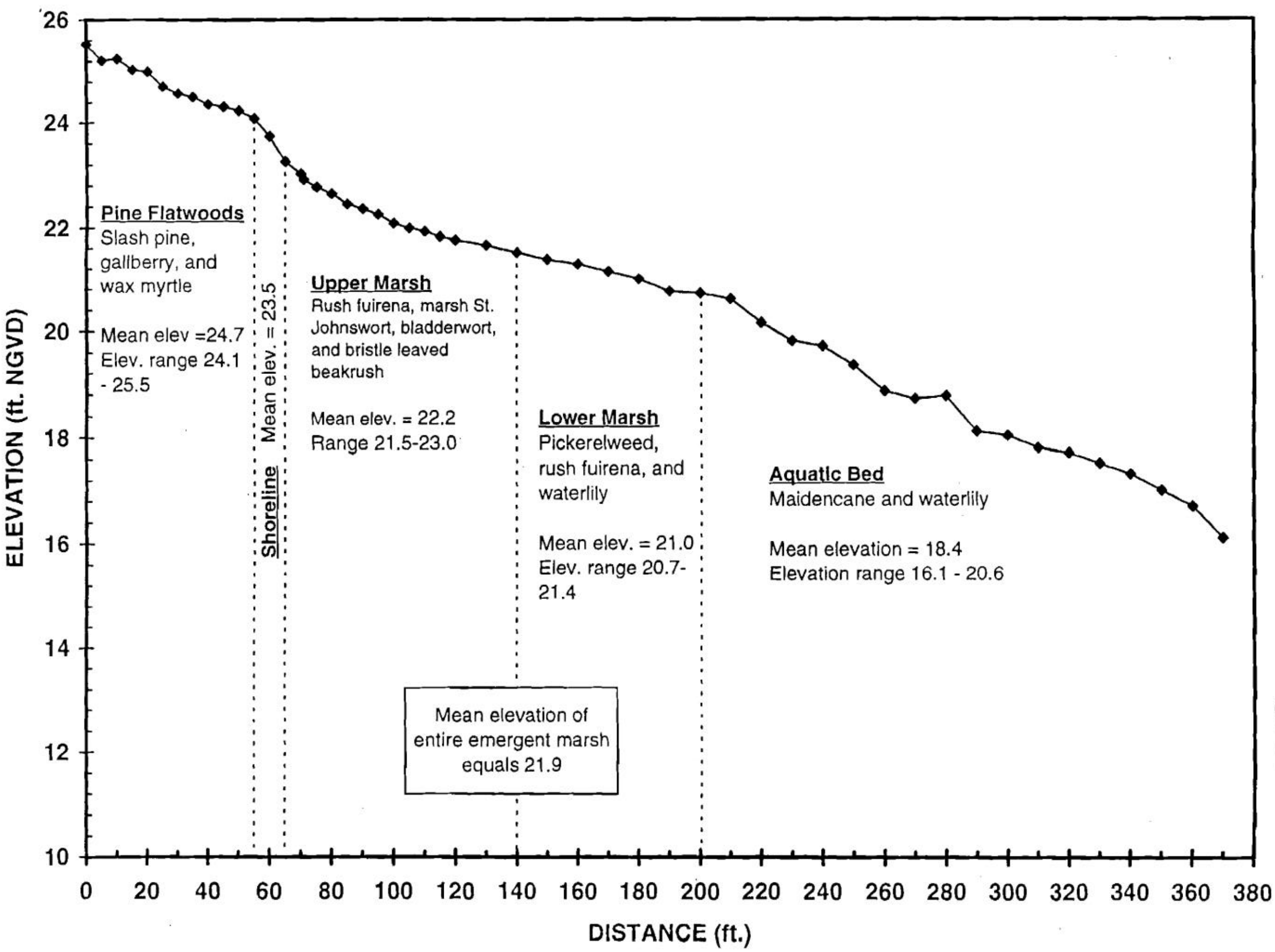


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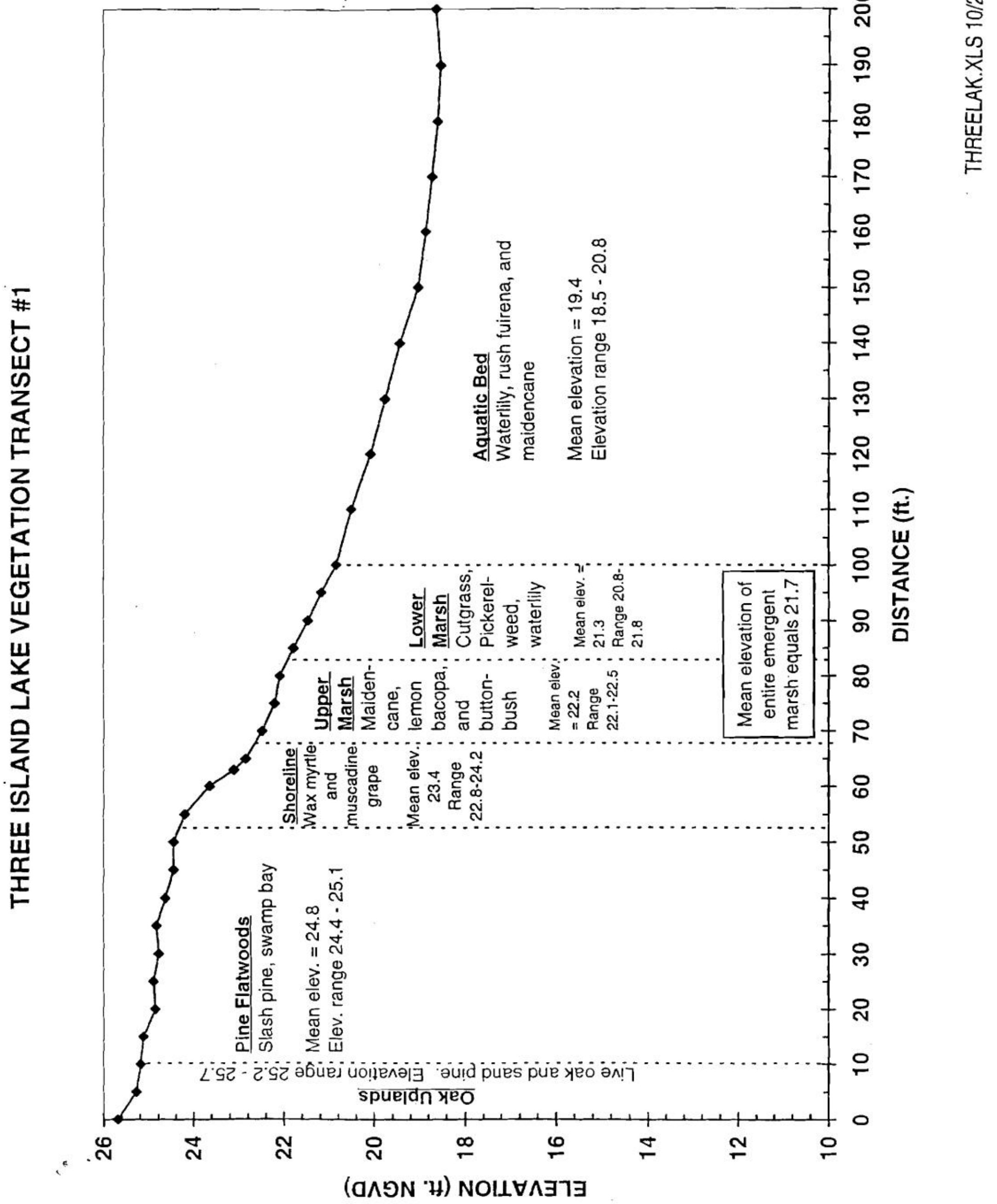
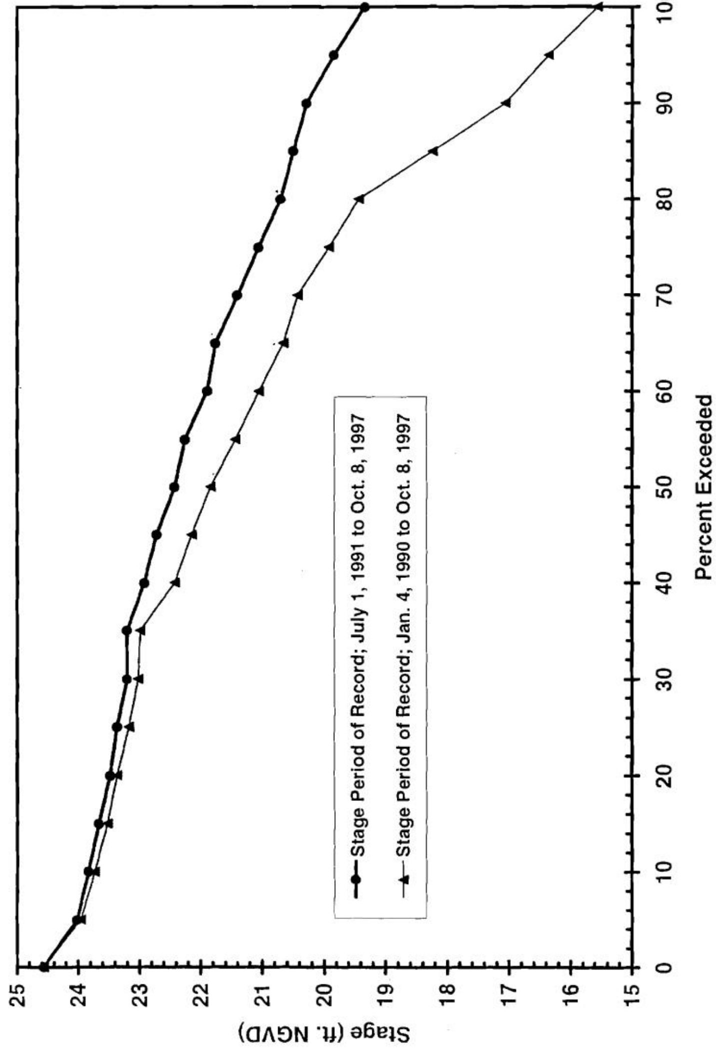
Figure 6



THREELAK.XLS 10/29/97

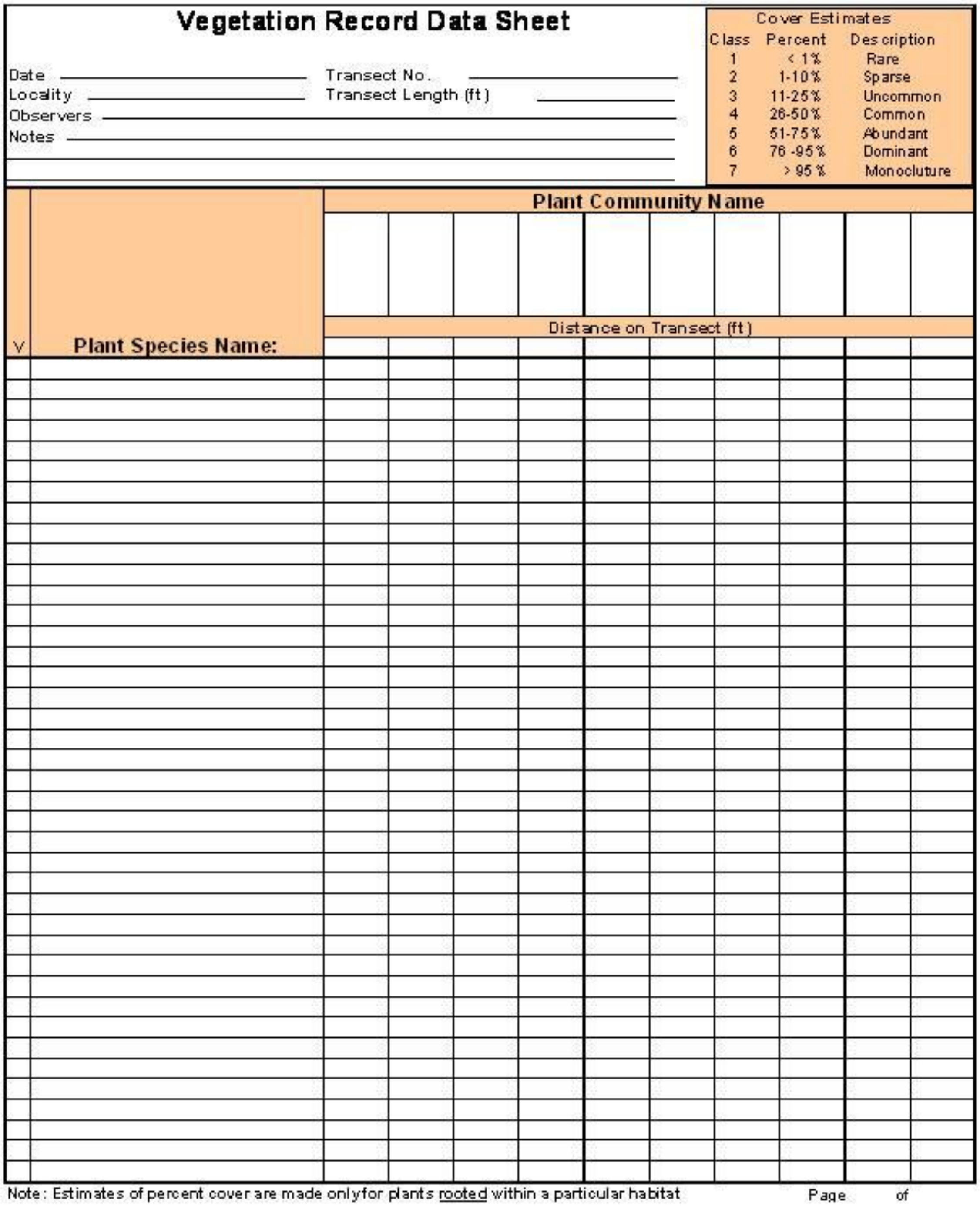
Figure 7

Three Island Lakes Stage Duration Curve



THREELAK.XLS

APPENDIX B—FIELD VEGETATION DATA SHEET



Vegetation Record Data Sheet

Date ____________ Transect No. ____________

Locality ____________ Transect Length (ft) ____________

Observers ____________

Notes ____________

Cover Estimates

Class	Percent	Description
1	< 1%	Rare
2	1-10%	Sparse
3	11-25%	Uncommon
4	26-50%	Common
5	51-75%	Abundant
6	76 -95%	Dominant
7	> 95%	Monocluture

V	Plant Species Name:	Plant Community Name									
		Distance on Transect (ft)									

Note: Estimates of percent cover are made only for plants rooted within a particular habitat

Page of

APPENDIX C—SOILS INVESTIGATION AT THREE ISLAND LAKES

SOILS INVESTIGATION AT THREE ISLAND LAKES, VOLUSIA COUNTY, IN SUPPORT OF MINIMUM FLOWS AND LEVELS

Jones Edmunds, Inc.

April 2006

SOILS INVESTIGATION AT THREE ISLAND LAKES, VOLUSIA COUNTY IN SUPPORT OF MINIMUM FLOWS AND LEVELS

Prepared for:

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P.O. Box 1429
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Prepared by:

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730 NE Waldo Road
Gainesville, Florida 32641

Certificate of Authorization #1841

Project No. 19750-030-03

April 2006

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1.0 THREE ISLAND LAKES SOIL REPORT

Minimum Flows and Levels (MFLs) were recently reevaluated at Three Island Lakes, Volusia County by St. Johns River Water Management District (District) to verify that the adopted MFLs are preventing significant harm from occurring to the water resources. Soils, vegetation, and hydrologic data were collected to reevaluate the adopted MFLs. This report addresses the soils investigation that was conducted at Three Island Lakes in support of the revised MFLs.

Soils were characterized along two transects at Three Island Lakes on July 15, 2005 by examining and describing soil horizons, soil colors, soil textures, profile depths, sandhill lake soil indicators, and hydric soil indicators (Figure 1). The Volusia County Soil Survey (Baldwin et al 1980) was consulted to determine commonly mapped soil series adjacent to Three Island Lakes. The mapped soil series differ from those classified based on characteristics observed in the field. This is likely due to the mapping scale associated with the Volusia County Soil Survey, which did not account for soil changes in the narrow wetland transition between the upland and the lake. The U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) official soil descriptions were then reviewed to determine if there was consistency between the official description and soil characteristics observed in the field. The official descriptions were found on the Soils Survey Staff website at (soils.usda.gov/soils/technical/classification/osd/).

2.0 TRANSECT A

Transect A is located on the northwest shore of the south lobe of Three Island Lakes. Transect A began in an upland vegetative community (Station 0-22), and traversed a pine fringe (Stations 22-30), transitional shrub (Stations 30-70), shallow marsh (Stations 70-185), deep marsh (Stations 185-320), and ended in open water (Station 320-365). Steep elevation changes are present at the upper (western) end of the transect (Figure 2). Six soil stations were characterized to identify hydric soil indicators (Table 2). Two of the six soil stations were characterized to a sufficient depth to determine the soil series along this transect. Stripped matrix (S6) and Dark surface (S7) hydric soil indicators were noted along Transect A at stations 18 feet and 38 feet, respectively (Table 1) (Figure 2). Special emphasis was also placed on identifying the location of frequent high and frequent low sandhill lake soil indicators. The frequent high sandhill lake soil indicator Stripped matrix, beginning 5 in. below the soil surface (SJRWMD 2005), was identified at Station 26. The frequent low sandhill lake soil indicator Dark splotches (SJRWMD 2005) was identified at Station 118. These hydric soil and sandhill lake soil indicators are described in greater detail towards the end of this report. One soil series, Pomona, was identified on Transect A (Table 2).

Pomona soils were identified at Stations 5 and 30 in the upland and at the break between the pine fringe and transitional shrub vegetative communities, respectively. The taxonomic classification subgroup for Pomona soil is an **Ultic Alaquod** (interpreted from right to left). Ultic Alaquods are Spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and aluminum and/or iron oxides. An aquic moisture regime indicates that soils are saturated with water and virtually free of gaseous oxygen for sufficient periods to induce anaerobic conditions (Brady and Weil 1996). Ultic Alaquods contain a light-colored albic horizon above a spodic horizon, which starts within 30 in. of the ground surface (ultic). It also contains an argillic horizon starting below 40 in. of the ground surface (USDA 2005). The Pomona soil series are poorly drained or very poorly drained with a water table within 6 to 18 in. for 1 to 3 months during most years. The water table is at a depth of 10 to 40 in. for 6 months or more during most years. Depressional areas of Pomona soils are typically ponded for 6 to 9 months a year (USDA–NRCS 2005).

3.0 TRANSECT B

Transect B is located on the southeastern shore of the south lobe of Three Island Lakes and began in an upland vegetative community (Station 0-50), and traversed a pine fringe (Stations 50-65), transitional shrub (Stations 65-78), shallow marsh (Stations 78-105), deep marsh (Stations 105-185), and ended in open water (Station 185-210). Seven soil stations were characterized to identify hydric soil indicators (Table 2). Additionally, 2 of the 7 soil stations were characterized to a sufficient depth to determine the soil series along this transect. The hydric soil indicator, Stripped matrix (S6) was noted along Transect B at station 43 (Table 1) (Figure 3). Special emphasis was also placed on identifying the location of Frequent high (FH) and Frequent low (FL) sandhill lake soil indicators. Thefrequent high sandhill lake soil indicator, Stripped Matrix beginning 5 in. below the soil surface (SJRWMD 2005), was identified at Station 49. Thefrequent low sandhill lake soil indicator Dark Splotches (SJRWMD 2005) was identified at Station 97. These hydric soil and sandhill lake soil indicators are described in greater detail towards the end of this report. Two soil series, Pomona and Myakka, were identified on transect B (Table 2).

Pomona soil was identified at Stations 15 in the upland vegetative community. The taxonomic classification subgroup for Pomona soil is an ultic alaquod**,** described in the Transect A soil details. Pomona soils are poorly drained or very poorly drained with a water table within 6 to 18 in. for 1 to 3 months during most years. The water table is at a depth of 10 to 40 in. for 6 months or more during most years. Depressional areas of Pomona soils are typically ponded for 6 to 9 months a year (USDA–NRCS 2005).

Myakka soils were observed at Station 61 in the pine fringe. Myakka soils are in the taxonomic classification subgroup Aeric Alaquods. Aeric Alaquods are Spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and oxides of aluminum and/or iron. An aquic moisture regime indicates that soils are saturated with water and virtually free of gaseous oxygen for sufficient periods to induce anaerobic conditions (Brady and Weil 1996). Aeric Alaquods contain a light-colored albic horizon above a spodic horizon. Aeric Alaquods are alaquods that have an ochric epipedon. The ochric epipedon fails to meet the definitions for any of the other seven epipedons because it is too thin or too dry, has too high a color value or chroma, contains too little organic carbon, or is both massive and hard when dry (USDA 2005).

Myakka soils are poorly drained to very poorly drained with a water table at depths of less than 18 in. for 1 to 4 months duration during most years and recedes to depths of more than 40 in. during very dry seasons. Depressional areas of Myakka soils are covered with standing water for periods of 6 to 9 months or more in most years (USDA–NRCS 2005).

4.0 HYDRIC SOIL INDICATORS

A hydric soil is a soil that has formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper horizons (FAESS 2000). Hydric soil indicators result from repeated periods of saturation and/or inundation for more than a few days. Such wetness essentially eliminates oxygen. Anaerobic microbiological activity in soils promotes the accumulation of organic matter, and the reduction of iron, manganese, and sulfur. This results in characteristics that persist in the soil during both wet and dry periods. Hydric soils can be used to estimate the seasonal high saturation which, is the highest expected annual elevation of saturation in a soil and is usually confirmed by observation of water in an unlined bore hole or the correlation of redoximorphic features with probable saturation (FAESS 2000). Hydric soil indicators that were identified along the Three Island Lakes transects are described in more detail below in the order from driest to wettest.

S6. Stripped Matrix—A layer starting within 6 in. of the surface in which iron/manganese oxides and/or organic matter have been stripped from the matrix exposing the primary base color of the soil materials. The stripped areas and translocated oxides and/or organic matter form a diffuse splotchy pattern of two or more colors. Stripped matrix has seasonal high saturation within 6 in. of the soil surface and is routinely used to delineated hydric soils throughout Florida (FAESS 2000).

S7. Dark Surface—A layer 4 in. or thicker starting within the upper 6 in. of the soil surface that is predominately black. The matrix color value is three or less and chroma is one or less. At least 70% of the visible soil particles must be covered, coated, or similarly masked with organic material. The matrix color of the layer below the dark layer has a chroma of two or less (USDA 2003). Dark surface has a seasonal high saturation within 6 in. of the soil surface (FAESS 2000).

5.0 SANDHILL LAKE SOIL INDICATORS

Sandhill lake soil indicators were developed to provide consistent hydrologic indicators to aid in the determination of MFLs at sandhill lakes. Vegetation at sandhill lakes may be an unreliable indicator of hydrology since the extent and composition of herbaceous vegetation may change in response to water level fluctuations. Soil characteristics, on the other hand, develop as a result of long-term hydrologic conditions and can be used as reliable indicators of historic hydrology (SJRWMD 2005).

The Minimum Frequent high Level and Minimum Frequent low Level, based on existing conditions at systems throughout SJRWMD, have consistently been determined at elevations with approximate stage exceedences of 20% and 80%, respectively. Unique soil morphologies were identified at sandhill lakes within SJRWMD, near the 20% and 80% stage exceedences and were termed frequent high (FH) and frequent low (FL) sandhill lake soil indicators, respectively. Thefrequent high sandhill lake soil indicator, Stripped matrix beginning 5 in. beneath the soil surface, was found to be the most reliable indicator of 20% stage exceedence. Thefrequent low sandhill lake soil indicator, Dark Splotches, was found to be the most reliable indicator of 80% stage exceedence. Additionalfrequent high andfrequent low sandhill lake soil indicators were identified (i.e., Degrading Spodic), but were thought to be less reliable indicators of hydrology than Stripped matrix or Dark Splotches (SJRWMD 2005).

Stripped Matrix (beginning 5 in. below the soil surface)—A layer starting 5 in. beneath the mineral soil surface in which the stripped (uncoated areas) are 10% or more of the volume, are rounded, and approximately 0.5- to 1-in., in diameter. Commonly the splotches of color have a Munsell value of 5 or more, and chroma of one and/or two (stripped), and chroma three and/or four (unstripped). The matrix may lack the three and/or four chroma material. Mobilization and translocation of oxides and /or organic matter are important processes and should result in splotchy coated and uncoated areas (SJRWMD 2005).

Dark Splotches—A layer starting within 3 in. of the soil surface that is at least 3 in. thick and has at least 20% of the soil material that is 10YR 3/1 or darker and a matrix color of 10YR 4/1 or lighter. Where surface soil layer(s) are uniformly 10YR 3/1 or darker (muck, mucky mineral, and/or mineral) or hemic material, thefrequent low occurs where the Dark splotches layer starts within 3 in. of the uniformly 10YR 3/1 or darker soil material or hemic material (SJRWMD 2005).

6.0 DISCUSSION

Soil profiles along transects A and B of the Three Island Lakes soil evaluation included an argillic horizon as well as a spodic horizon. An argillic horizon is an accumulation of silicate clays and is indicated in Table 2 as the Bt horizon. The argillic horizon will act like the spodic (Bh) horizon and allow water to travel laterally above its upper extent because of its slower percolation rate. With both of these soil horizons present in the same profile, seepage will likely elevate the hydric/nonhydric boundary andfrequent high indicator.

7.0 LITERATURE REVIEW

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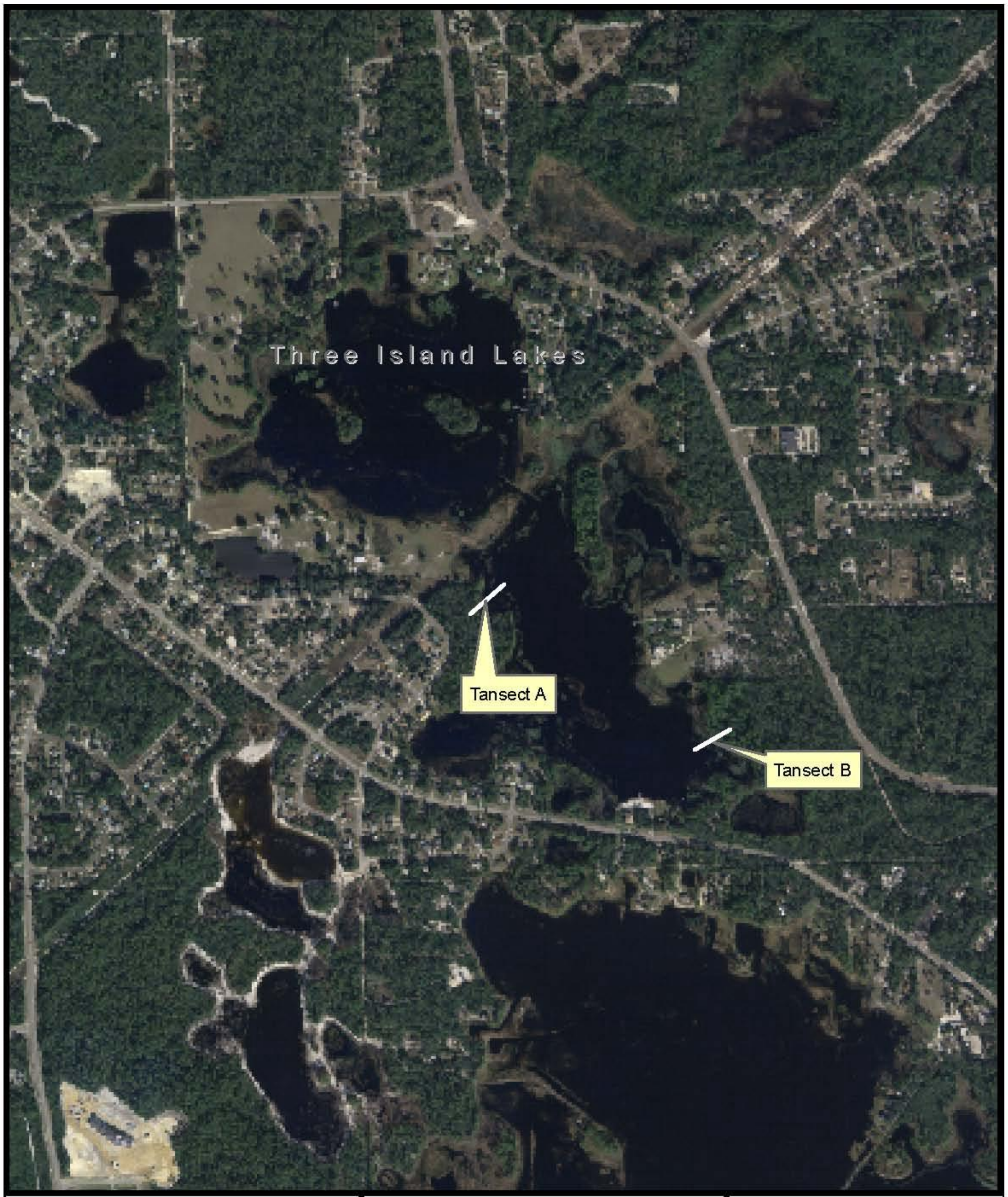

JONES EDMUNDS

Figure 1

Three Island Lakes

For Informational Purposes Only

Figure 2. Transect A - Relating Soils and Vegetation to Topograhy

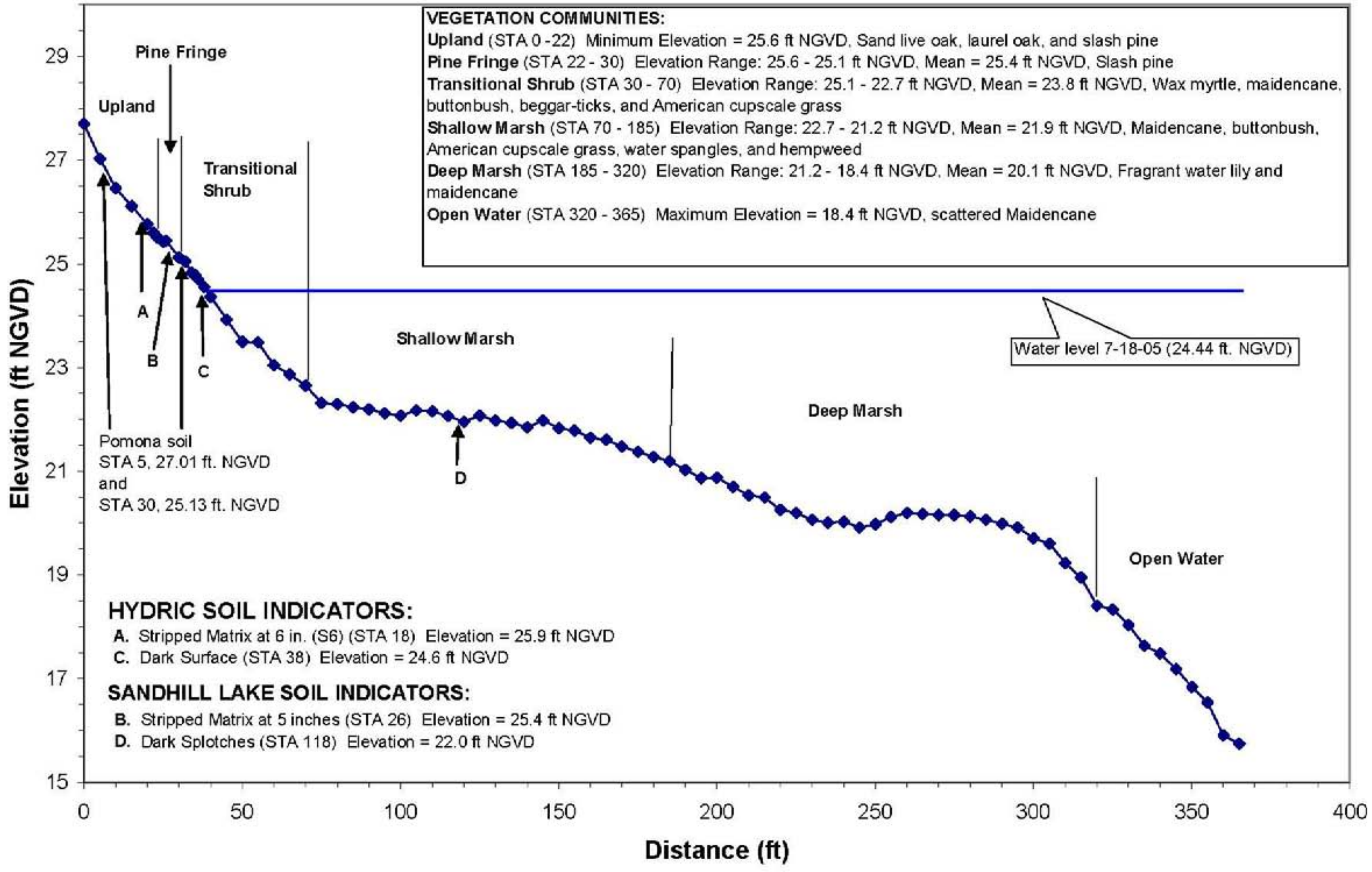

Figure 3. Transect B - Relating Soils and Vegetation to Topograhy

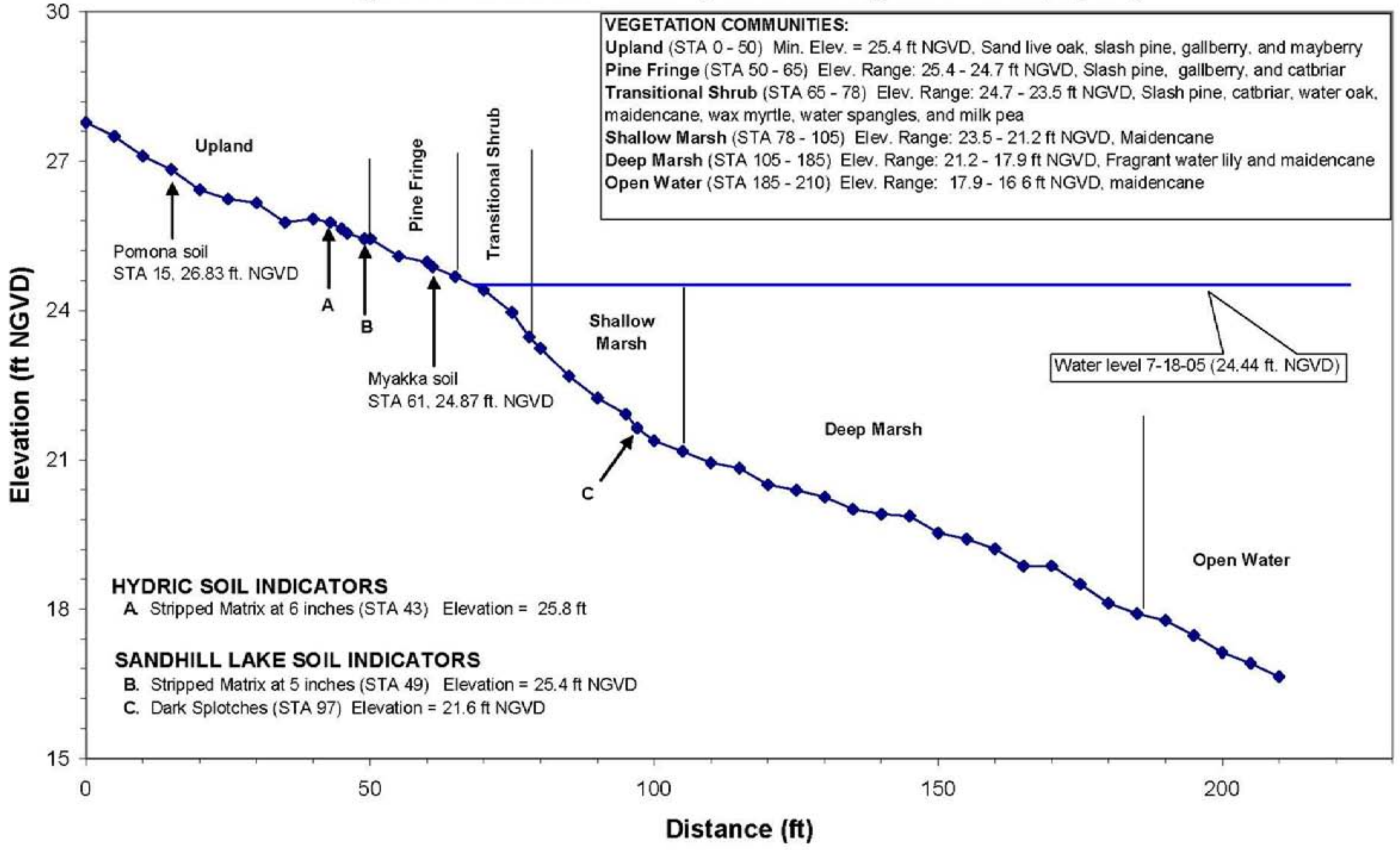

Table 1. Soil Indicators Identified at Three Island Lakes

Location	Hydric Soil Indicators		Sandhill Lake Indicators	
	Stripped Matrix at 6 inches (S6)	Dark Surface (S7)	Stripped Matrix at 5 inches (FH)	Dark Splotches (FL)
Transect A Ft. NGVD (Station)	25.9 (Station 18)	24.6 (Station 38)	25.4 (Station 26)	22.0 (Station 118)
Transect B Ft. NGVD (Station)	25.8 (Station 43)	N/A	25.4 (Station 49)	21.6 (Station 97)

Table 2 Soil Descriptions for Three Island Lakes

Station Name:	Transect A
Field User:	T. Richardson, J. Sullivan
Sample Date:	7/15/05

Station	Hydric Soil Indicator Description
5	Mapped upland soil
18	Stripped matrix at 6"
23	Stripped matrix at 5"
30	Mapped transitional soil, stripped matrix at 4"
38	Dark surface
118	Dark splotches at 3"

Station Point	5
Soil Classification	Pomona
Hydric Soil Indicator	none

Horizon	Depth	Color	Soil Texture	Soil Description
A	0–7	10YR 3/1 - Very dark gray	Fine Sand	
E1	7–14	10YR 6/2 - Light brownish gray	Fine Sand	~20% 10YR 7/1 @ 7 inches
E2	14–37	10YR 7/1 - Light gray	Fine Sand	
Bh1	37–41	10YR 3/2 - Very dark grayish brown	Fine Sand	~10% 10YR 7/1
Bh2	41–43	10YR 3/2 - Very dark grayish brown	Loamy Sand	~30% 10YR 4/4
Bt1	43–56	10YR 6/4 - Light yellowish brown	Sandy Clay Loam	~20% 10YR 2/1+10YR 3/2
Bt2	56 - 72+	5GY 7/1 - Light greenish gray	Sandy Clay	~10% 7.5YR 5/8

Station Point	30
Soil Classification	Pomona
Hydric Soil Indicator	S7. Dark Surface

Horizon	Depth	Color	Soil Texture	Soil Description
A1	0–4	10YR 2/1 - Black	Fine Sand	Dark surface
A2	4–7	10YR 3/1 - Very dark gray	Fine Sand	~10% 10YR 6/1
E	7–22	10YR 5/1 - Gray	Fine Sand	
Bh1	22–41	10YR 3/2 - Very dark grayish brown	Fine Sand	
Bh2	41–54	10YR 3/2 - Very dark grayish brown	Loamy Sand	~30% 10YR 4/4
Bt	54–72+	5GY 7/1 - Light greenish gray	Sandy Clay	

Station Name:	Transect B
Field User:	T. Richardson, J. Sullivan
Sample Date:	38548

Station	Hydric Soil Indicator Description
15	Mapped upland soil
43	Stripped matrix at 6"
46	Stripped matrix at 5" starts (landward extent)
49	Stripped matrix at 5" starts (waterward extent)
61	Mapped transitonal soil, stripped matrix at 4"
65	Stripped matrix at 3"
97	Dark splotches at 3"

Station Point	15
Soil Classification	Pomona
Hydric Soil Indicator	None

Horizon	Depth	Color	Soil Texture	Soil Description
Ap	0–4	10YR 5/1 - Gray	Fine Sand	
A	4–9	10YR 4/1 - Dark gray	Fine Sand	
Eg1	9–14	10YR 6/1 - Light brownish gray	Fine Sand	~20% 10YR 7/1
Eg2	14–39	10YR 7/1 - Light gray	Fine Sand	Saturated at 24"
Bh1	39–50	10YR 3/2 - Very dark grayish brown	Fine Sand	
Bh2	50–62	10YR 3/3 - Dark brown	Fine Sand	

Bt1	62–73	5GY 7/1 - Light greenish gray	Sandy Clay Loam	~5% 7.5YR 5/8
Bt2	73–75+	5GY 7/1 - Light greenish gray	Sandy Clay	~5% 7.5YR 5/8
Station Point	61			
Soil Classification	Myakka			
Hydric Soil Indicator	S6. Stripped Matrix			
Horizon	Depth	Color	Soil Texture	Soil Description
A1	0–4	10YR 2/1 - Black	Fine sand	Salt and pepper
A2	4–6	10YR 4/1 - Dark gray	Fine sand	Stripped matrix
E	6–27	10YR 5/1 - Gray	Fine sand	~20% 10YR 6/1
Bh1	27–33	10YR 2/1 - Black	Fine Sand	
Bh2	33–59	10YR 3/2 - Very dark grayish brown	Fine Sand	
Bh3	59–68+	10YR 4/6 - Dark yellowish brown	Fine Sand	

APPENDIX D—IMPLEMENTATION OF MFLS FOR THREE ISLAND LAKES

Prepared by
C. Price Robison, P.E., St. Johns River Water Management District (2007)

The objective of minimum flows and levels (MFLs) is to establish limits to allowable hydrologic change in a water body or watercourse, to prevent significant harm to the water resources or ecology of an area. Hydrologic changes within a water body or watercourse may result from an increase in the consumptive use of water or the alteration of basin characteristics, such as down-cutting outlet channels or constructing outflow structures.

MFLs define a series of minimum high and low water levels and/or flows of differing frequencies and durations required to protect and maintain aquatic and wetland resources. MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in hydrologic conditions. MFLs allow for an acceptable level of change to occur relative to existing hydrologic conditions, without incurring significant ecological harm to the aquatic system.

Before MFLs can be applied, the minimum hydrologic regime must be defined or characterized statistically. Resource management decisions can then be made predicated on maintaining at least these minimum hydrologic conditions as defined by the appropriate statistics.

One way to understand how changes within a watershed alter a hydrologic regime and, therefore, how the aquatic and wetland resources might be affected, is by simulating the system with a hydrologic model. Significant harm can be avoided by regulating hydrologic changes based on the comparison of statistics of the system with and without changes.

MFLs determinations are based on a concept of maintaining the duration and return periods of selected, ecologically based stages and/or flows. Thus, a water body can fall below the selected stage and/or flow, but if it does so too often and/or for too long, then the MFLs would no longer be met.

Statistical analysis of model output provides a framework to summarize the hydrologic characteristics of a water body. The St. Johns River Water Management District (SJRWMD) MFLs program relies on a type of statistical analysis referred to as frequency analysis.

Frequency analysis

As discussed previously, aquatic resources are sustained by a certain hydrologic regime. Depending on the resource in question, a selected ground elevation, for example, might need to:

- Remain wet for a certain period of time with a certain frequency.
- Remain dry for a certain period of time with a certain frequency.
- Be under a given minimum depth of water for a certain period of time with a certain frequency.

Frequency analysis is used to estimate how often, on average, a given event will occur. If annual series data are used to generate the statistics, frequency analysis is used to estimate the probability of a given hydrologic event happening in any given year.

A simple example illustrates some of the concepts basic to frequency analysis. A frequently used statistic with respect to water level is the yearly peak stage of a water body. If a gauge has been monitored for 10 years, then there will be 10 yearly peaks $S_1, S_2, \cdots, S_{10}$. Once sorted and ranked, these events can be written as $\hat{S}_1, \hat{S}_2, \cdots, \hat{S}_{10}$, with $\hat{S}_1$ being the highest peak. Based on this limited sample, the estimated probability of the yearly peak being greater than or equal to $\hat{S}_1$ would be

$$P(S \geq \hat{S}_1) = \frac{1}{n} = \frac{1}{10} = 0.1 \quad ; \qquad \text{(D1)}$$

the probability of the 1-day peak stage in any year being greater than $\hat{S}_2$

$$P(S \geq \hat{S}_2) = \frac{2}{10} = 0.2 \quad ; \qquad \text{(D2)}$$

and so on. The probability the stage equaling or exceeding $\hat{S}_{10}$ would be

$$P(S \geq \hat{S}_{10}) = \frac{10}{10} = 1.0 \quad . \qquad \text{(D3)}$$

Because this system of analysis precludes any peak stage from being lower than $\hat{S}_{10}$, the usual convention is to divide the stage continuum into 11 parts: nine between each of the 10 peaks, one above the highest peak, and one below the lowest peak (n – 1 + 2 = n + 1=11). This suggests what is known as the Weibull plotting position formula:

$$P(S \geq \hat{S}_m) = \frac{m}{n+1} \qquad \text{(D4)}$$

where,

$P(S \geq \hat{S}_m) =$ probability of S equaling or exceeding $\hat{S}_m$

$m =$ rank of the event.

Thus, in the example, the probability of the peak in any year equaling or exceeding $\hat{S}_1$ would be

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{11} = 0.0909\ ; \qquad \text{(D5)}$$

the probability of the 1-day peak stage in any year being greater than $\hat{S}_{10}$

$$P(S \geq \hat{S}_{10}) = \frac{10}{11} = 0.9091\ ; \qquad \text{(D6)}$$

and so on. The probability the stage in any year is smaller than $\hat{S}_{10}$ would be

$$P(S < \hat{S}_{10}) = 1 - P(S \geq \hat{S}_{10}) = 1 - \frac{10}{11} = 1 - 0.9091 = 0.0909\ . \qquad \text{(D7)}$$

The return period (in years) of an event, T, is defined as

$$T = \frac{1}{P} \qquad \text{(D8)}$$

so the return period for $\hat{S}_1$ would be

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = \frac{1}{\frac{1}{11}} = 11 \quad . \qquad \text{(D9)}$$

Said another way, $\hat{S}_1$ would be expected to be equaled or exceeded, on average, once every 11 years.

As the size of the sample increases, the probability of $\hat{S}_1$ being exceeded decreases. Thus, with $n = 20$,

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{21} = 0.048 \qquad \text{(D10)}$$

and

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = 21 \quad . \qquad \text{(D11)}$$

The stage or flow characteristics of a water body can be summarized using the Weibull plotting position formula and a frequency plot. For example, Figure D1 shows a flood frequency plot generated from annual peak flow data collected at the U.S. Geological Survey (USGS) gauge on the Wekiva River.

Minimum events are treated in much the same way as maximum events, except with minimums the events are ranked from smallest to largest. Thus $\hat{S}_1$ is the smallest or lowest event in a sampling. The minimum stage or flow characteristics of a gauge or water body can be summarized using the Weibull plotting position formula and a frequency plot. For example, Figure D2 shows a drought frequency plot generated from a hydrologic simulation of the middle St. Johns River.

One of the purposes of performing this process of sorting, ranking, and plotting events is to estimate probabilities and return periods for events larger than $\hat{S}_1$, smaller than $\hat{S}_n$, or any event between sample points. There are two methods of obtaining these probabilities and return periods. The first method is to use standard statistical methods to mathematically calculate these probabilities and return periods (Figure D3). This method is beyond the scope of this appendix; the reader is referred to a standard hydrology text (Ponce 1989, Linsley et al. 1982) or the standard flood frequency analysis text, Bulletin 17B (USGS 1982).

With the second method, interpolated or extrapolated frequencies and return periods can also be obtained by the graphical method. Once the period-of-record or period-of-simulation events have been sorted and ranked, they are plotted on probability paper. Probabilities and return periods for events outside of the sampled events can be estimated by drawing a line through the points on the graph to obtain an estimated best fit (Figure D4).

Frequency analysis is also used to characterize hydrologic events of durations longer than 1 day. Frequency analysis encompasses four types of events: (1) maximum average stages or flows; (2) minimum average stages or flows; (3) maximum stages or flows continuously exceeded; and (4) minimum stages or flows continuously not exceeded.

Maximum average stages or flows. In this case, an event is defined as the maximum value for a mean stage or flow over a given number of days. For example, if the maximum yearly values for a 30-day average are of interest, the daily-value hydrograph is analyzed by using a moving 30-day average. Therefore, a 365-day hydrograph would have 336 (365 – 30 + 1 = 336) different values for a 30-day average. These 336 values are searched and the highest is saved. After performing this analysis for each year of the period of record or period of simulation, the events are sorted and ranked. The analytical process is then the same as for the 1-day peaks.

Minimum average stages or flows. In this case, an event is defined as the minimum value for a mean stage or flow over a given number of days. For example, if the minimum yearly values for a 30-day average are of interest, the daily-value hydrograph is analyzed by using a moving 30-day average. Therefore, a 365-day hydrograph would have 336 (365 – 30 + 1 = 336) different values for a 30-day average. These 336 values are searched and the lowest is saved. After performing this analysis for each year of the period of record or period of simulation, the events are sorted and ranked. The process is then the same as for the 1-day low stages.

Maximum stage or flow continuously exceeded. In this case, an event is defined as the stage or flow that is exceeded continuously for a set number of days. For example, if the maximum yearly ground elevation that continuously remains under water for 60 days is of interest, the stage hydrograph of each year is analyzed by taking successive 60-day periods and determining the stage that is continuously exceeded for that period. This is repeated for 306 (365 – 60 + 1 = 306) periods of 60 days. The maximum stage in those 306 values is saved. Once that operation is performed for all years of record or of simulation, the results are sorted and ranked as for the 1-day peaks.

Minimum stage or flow continuously not exceeded. In this case, an event is defined as the stage or flow that is not exceeded continuously for a set number of days. For example, if the minimum yearly ground elevation that continuously remains dry for 60 days is of interest, the stage hydrograph of each year is analyzed by taking successive 60-day periods and determining the stage that is continuously not exceeded for that period. This is repeated for 306 (365 – 60 + 1 = 306) periods of 60 days. The minimum stage in those 306 values is saved. Once that operation is performed for all years of record or of simulation, the results are sorted and ranked as for the 1-day low stages.

In frequency analysis, it is important to identify the most extreme events occurring in any given series of years. Because high surface water levels (stages) in Florida generally occur in summer and early fall, maximum value analysis is based on a year that runs from June 1 to May 31. Conversely, because low stages tend to occur in late spring, the year for minimum events runs from October 1 to September 30.

Hydrologic statistics and their relationships to the Three Island Lakes MFLs

This section describes the process used to relate long-term hydrologic statistics to the establishment of MFLs. SJRWMD has determined two recommended MFLs for Three Island Lakes: (1) a minimum frequent high (FH) level; and (2) a minimum frequent low (FL) level. The FH level for this lake is used here to illustrate how long-term hydrologic statistics of a lake relate to MFLs.

Each of the two MFLs is tied to characteristic stage durations and return frequencies. For example, the ground elevation represented by the FH level is expected to remain wet continuously for a period of at least 30 days. This event is expected to occur, on average, at least once every 5 years.

The standard stage frequency analysis described previously in this appendix was performed on stage data from lake model simulations of Three Island Lakes (Robison 2007). In particular, stages continuously exceeded (ground elevations remaining wet) for 30 days were determined, sorted, ranked, and plotted (Figure D5). These stages were obtained assuming that long-term groundwater withdrawals occurred in the same manner in which they occurred in 2003. The ground elevation of the FH level can be superimposed on the plot (Figure D6) to demonstrate how the level is related to the pertinent hydrologic statistics. Finally, a box bounded by: (1) the FH level on the bottom; (2) a vertical line corresponding to a frequency of occurrence of once in every 5 years on the right; and (3) a vertical line corresponding to a frequency of occurrence of once in every 3 years on the left, is superimposed on the plot (Figure D7). Given the irregularity of the plotted points in this case, a best-fit line is added to determine compliance with the FH level (Figure D8). Similar analyses were performed for the MFL level (Figure D9). Both levels are being met under these conditions.

A summary of the recommended MFLs for Three Island Lakes is shown in Table D1. Values in this table will be used as benchmarks for modeling outputs to determine if groundwater withdrawals in the vicinity of Three Island Lakes will cause water levels to fall below MFLs.

Evaluation of the potential impacts of proposed increased withdrawals of water from the Floridan aquifer

This section describes the process used by SJRWMD to determine if proposed or projected increased withdrawals of water from the Floridan aquifer in the vicinity of Three Island Lakes would cause water levels in the lake to fall below established MFLs. SJRWMD uses two modeling tools in this process: a regional groundwater flow model and the lake model described above. The following steps are included in the process:

1. Estimation of Floridan aquifer water level drawdown (1995 through the last year of model simulation).
2. Estimation of Floridan aquifer freeboard in the year of calibration of the lake model.
3. Estimation of Floridan aquifer water level decline from 1995 to the year of calibration of the lake model.
4. Estimation of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation.
5. Comparison of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of simulation (step 4) to the year of calibration freeboard (step 2).

Step 1. Estimation of Floridan aquifer water level drawdown (1995 through the last year of model simulation)

When evaluating consumptive use permit applications for increased withdrawals of groundwater from the Floridan aquifer or when performing water supply planning evaluations, SJRWMD estimates the projected drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of lakes with established MFLs. The analysis includes all existing permitted uses in addition to the proposed increased withdrawals. SJRWMD uses the appropriate regional groundwater flow model to produce these estimates. In the case of Three Island Lakes, at the time of preparation of this document, SJRWMD was using the Volusia Regional Groundwater Flow Model (Williams 2006) for this purpose. This steady-state model is calibrated to 1995 conditions; therefore, the projected drawdown in the potentiometric surface represents the estimated drawdown that would occur from 1995 to the last year of simulation. In association with consumptive use permit evaluations, the last year of simulation represents the year through which issuance of the permit is contemplated. In

SJRWMD's water supply assessment and planning processes, the last year of simulation represents the planning horizon year and/or other intermediate years that may represent significant water use targets.

Step 2. Estimation of Floridan aquifer freeboard in year of calibration of lake model

As stated previously, the model simulation results depicted in Figures D8 and D9 assume long-term Floridan aquifer withdrawals at 2003 levels. Any withdrawal increases beyond 2003 would tend to lower potentiometric levels in the area and, therefore, would tend to lower lake levels in Three Island Lakes. In order to determine the freeboard present at Three Island Lakes from the point of view of Floridan aquifer water level drawdowns, a trial-and-error process was undertaken assuming incrementally increasing drawdowns. Drawdowns are represented by subtracting a set amount from the well hydrograph used in simulation of Three Island Lakes. In the case of Three Island Lakes, for a Floridan aquifer water level drawdown of 0.5 ft, the FH level would still be met (Figure D10). However, any drawdowns greater than 0.5 ft would cause water levels to fall below the established FH level. At a drawdown of 0.5 ft, the MFL level would still be met (Figure D11). Therefore, future Floridan aquifer water level drawdowns beyond 2003 conditions will be limited to 0.5 ft in the Three Island Lakes area.

Step 3. Estimation of Floridan aquifer water level decline from 1995 to the year of calibration of the lake model

Because the calibration years of lake models and the applicable regional groundwater flow models do not coincide, an adjustment of projected drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of the lake of interest must be made for purposes of comparison to the previously described Floridan aquifer freeboard value. The adjusted value should represent the projected drawdown from the calibration year of the lake model to the final year of simulation of the applicable regional groundwater flow model.

In order to determine this adjusted value, drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of a lake of interest from 1995 through the calibration year of the lake model is estimated. This estimated value is subtracted from the projected drawdown from 1995 to the final year of simulation of the applicable regional groundwater flow model to determine the adjusted value.

Estimated drawdown in the potentiometric surface of the Floridan aquifer in the vicinity of a lake of interest from 1995 through the calibration year of the lake model is calculated using one of the following approaches.

- A water use data set for the calibration year of the lake model is prepared and used in the applicable regional groundwater flow model. The resulting drawdowns represent drawdowns from 1995 to the calibration year of the lake model. Based on drawdowns projected for 2003 conditions by the Volusia Regional Groundwater Flow Model, drawdown in the vicinity of Three Island Lakes between 1995 and 2003 was approximately 0.3 ft.

- Estimated drawdowns in the potentiometric surface from 1995 to the calibration year of the lake model are interpolated based on estimates of drawdowns projected to occur from 1995 to some simulation year beyond the lake calibration year. This approach requires assuming a straight-line increase of the projected drawdown from 1995 to the final year of simulation and selecting the appropriate interpolated value for the period 1995 to the year of calibration for the lake model.

Step 4. Estimation of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation

The Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation is estimated by subtracting the drawdown from 1995 through the year of calibration of the lake model (step 3) from the total drawdown (step 1).

Step 5. Comparison of Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of model simulation (step 4), to the freeboard in the year of calibration of the lake model (step 2)

If the Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of groundwater model simulation (step 4) is greater than the year of calibration of the lake model freeboard (step 2), then proposed or projected increased withdrawals through the last year of groundwater model simulation would cause water levels to fall below MFLs. If the Floridan aquifer water level drawdown from the year of calibration of the lake model through the last year of groundwater model simulation (step 4) is less than the year of calibration of the lake model freeboard (step 2), then proposed or projected increased withdrawals through the last year of groundwater model simulation would not cause water levels to fall below established MFLs.

Because the estimated 2003 freeboard for Three Island Lakes is 0.5 ft and the drawdown in the vicinity of Three Island Lakes between 1995 and 2003 was approximately 0.3 ft, then the allowable drawdown from 1995 to some future year would be limited to 0.8 ft.

Table D1. Summary of recommended MFLs for Three Island Lakes

MFLs	Level (ft NGVD)	Duration	Series	Water Year	Statistical Type	Minimum Return Period	Maximum Return Period
Minimum frequent high (FH)	23.7	30 days	Annual	June 1–May 31	Maximum, continuously exceeded	NA	5 yrs
Minimum frequent low (FL)	19.4	120 days	Annual	Oct. 1–Sept. 30	Minimum, continuously not exceeded	10 yrs	NA

ft NGVD = feet National Geodetic Vertical Datum

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Williams, S.A., 2006. *Simulation of the Effects of Groundwater Withdrawals From the Floridan Aquifer System in Volusia County and Vicinity*. Technical Pub. SJ2006-4. Palatka, Fla.: St. Johns River Water Management District.

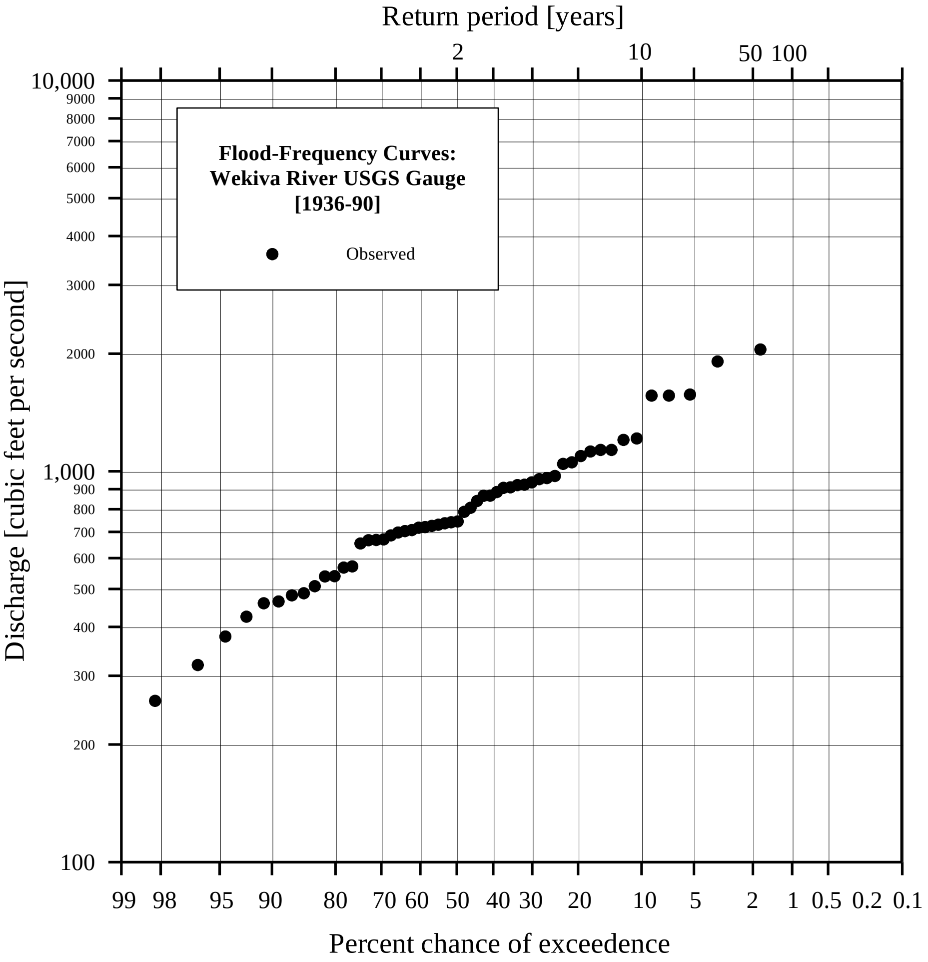

Figure D1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla. (the 1-day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula)

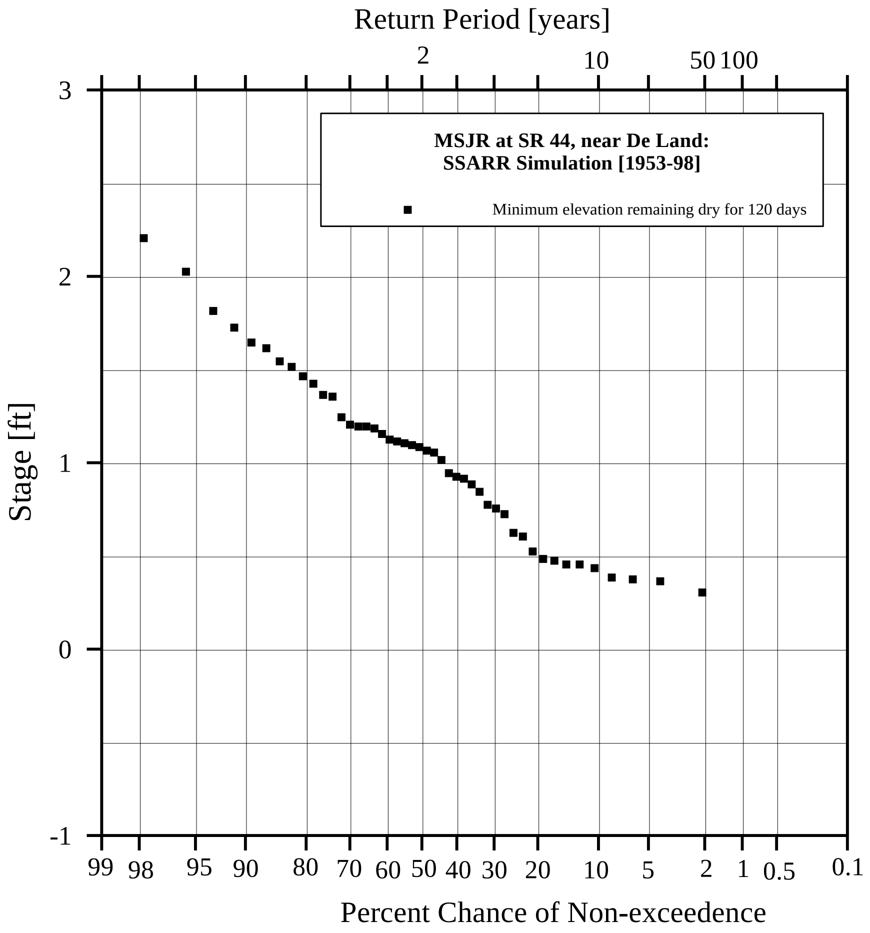

Figure D2. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand (the minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula)

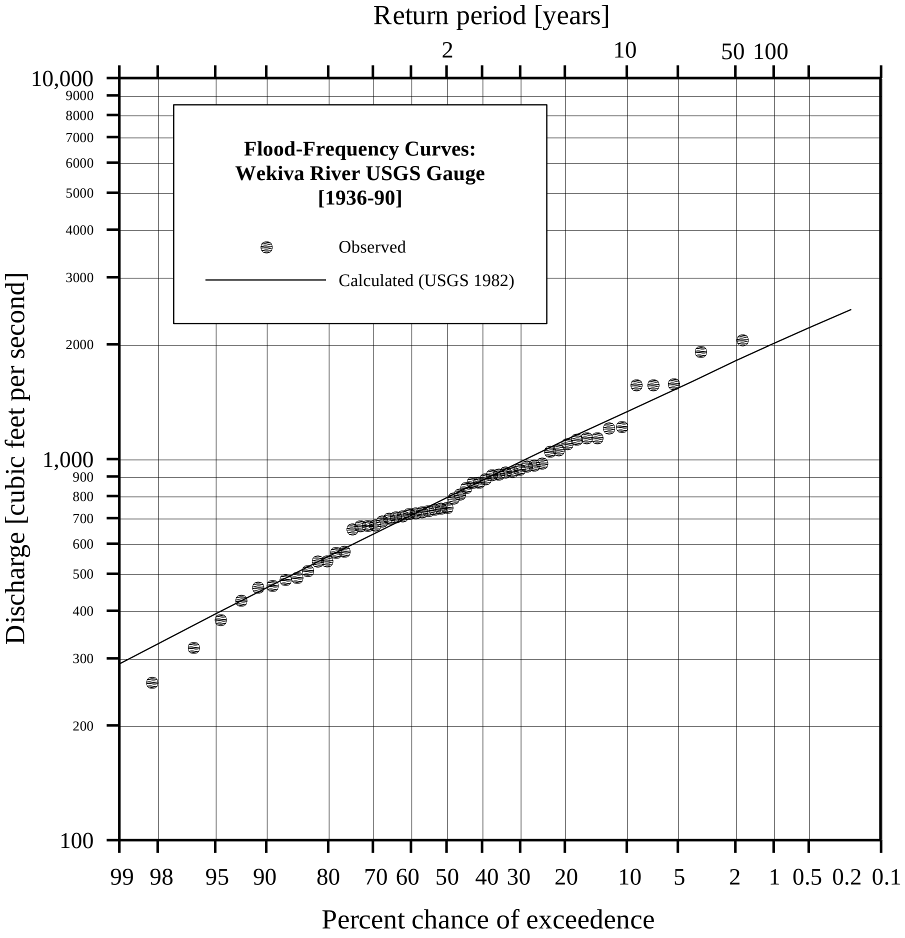

Figure D3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla. (fitted by standard mathematical procedure)

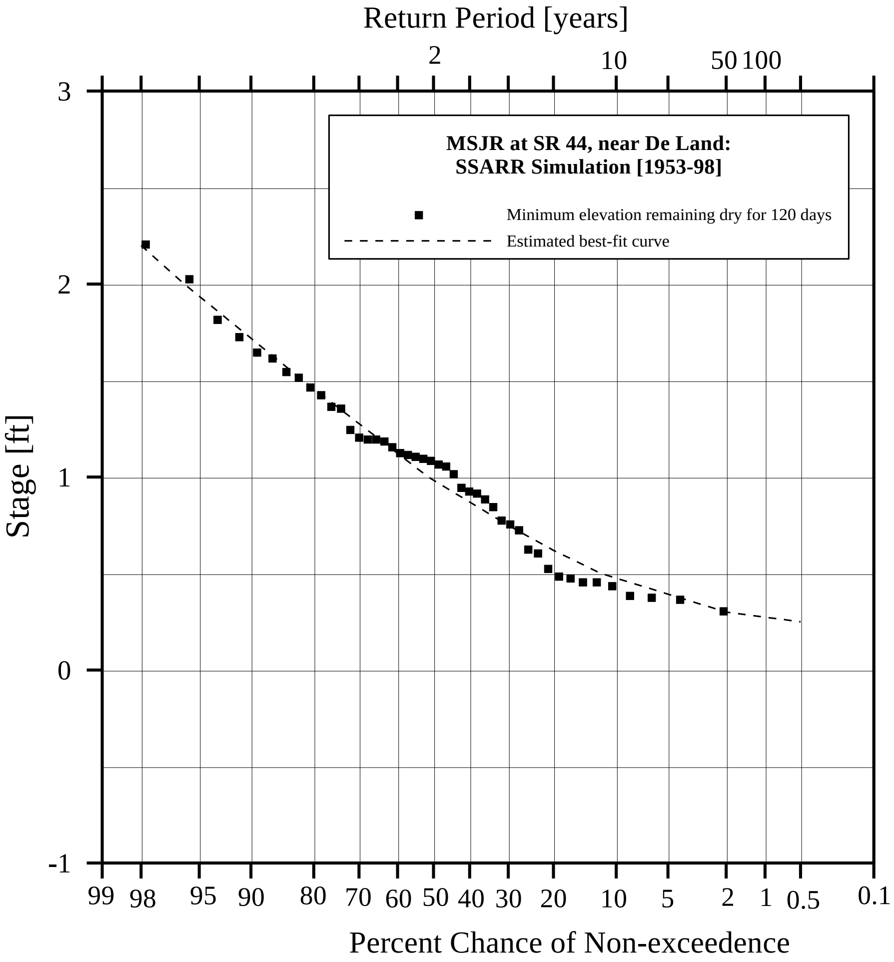

Figure D4. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand (fitted by the graphical method)

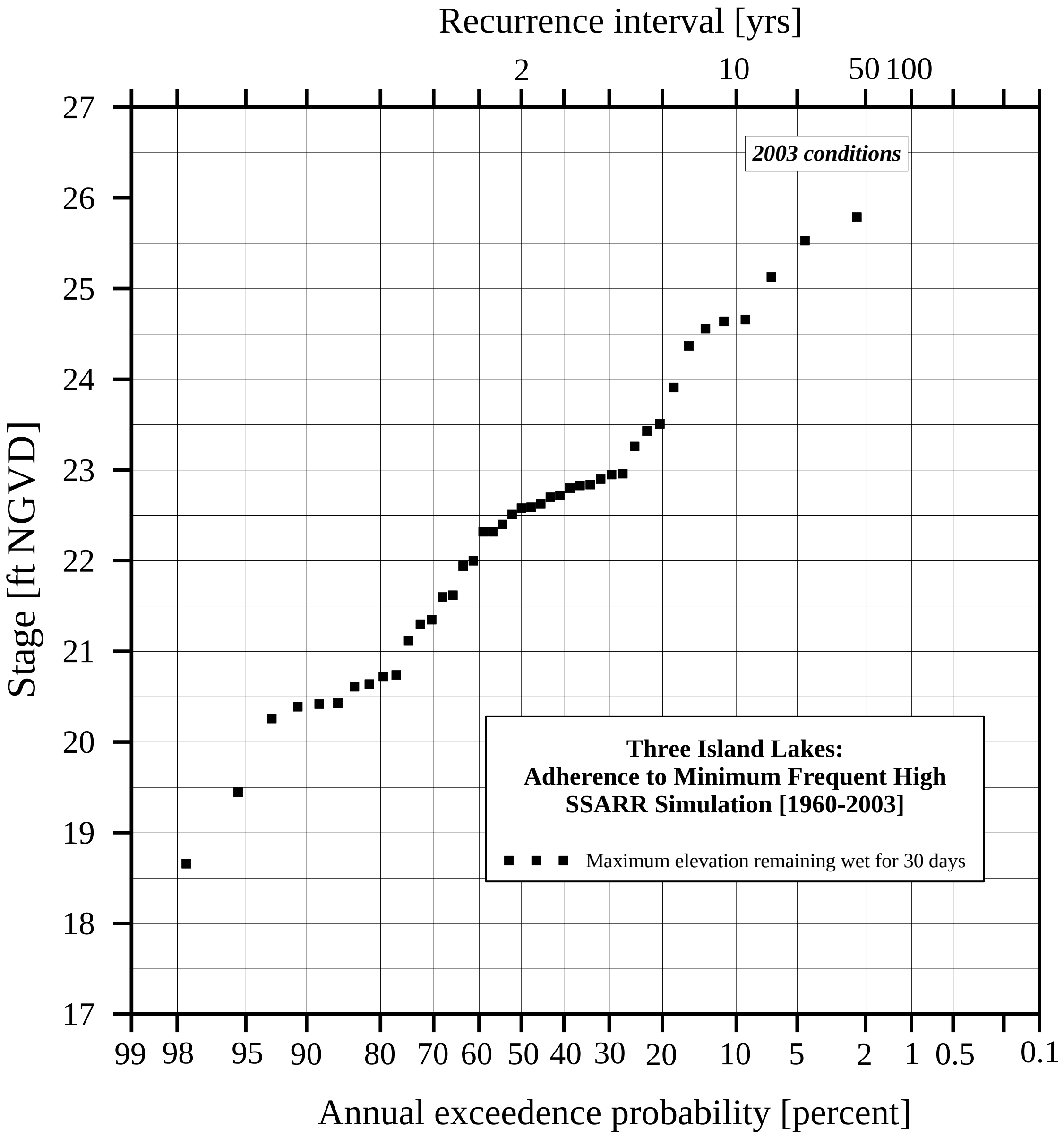

Figure D5. Flood frequencies computed using daily stages from model simulations of Three Island Lakes (for elevations continuously wet for 30 days and 2003 conditions)

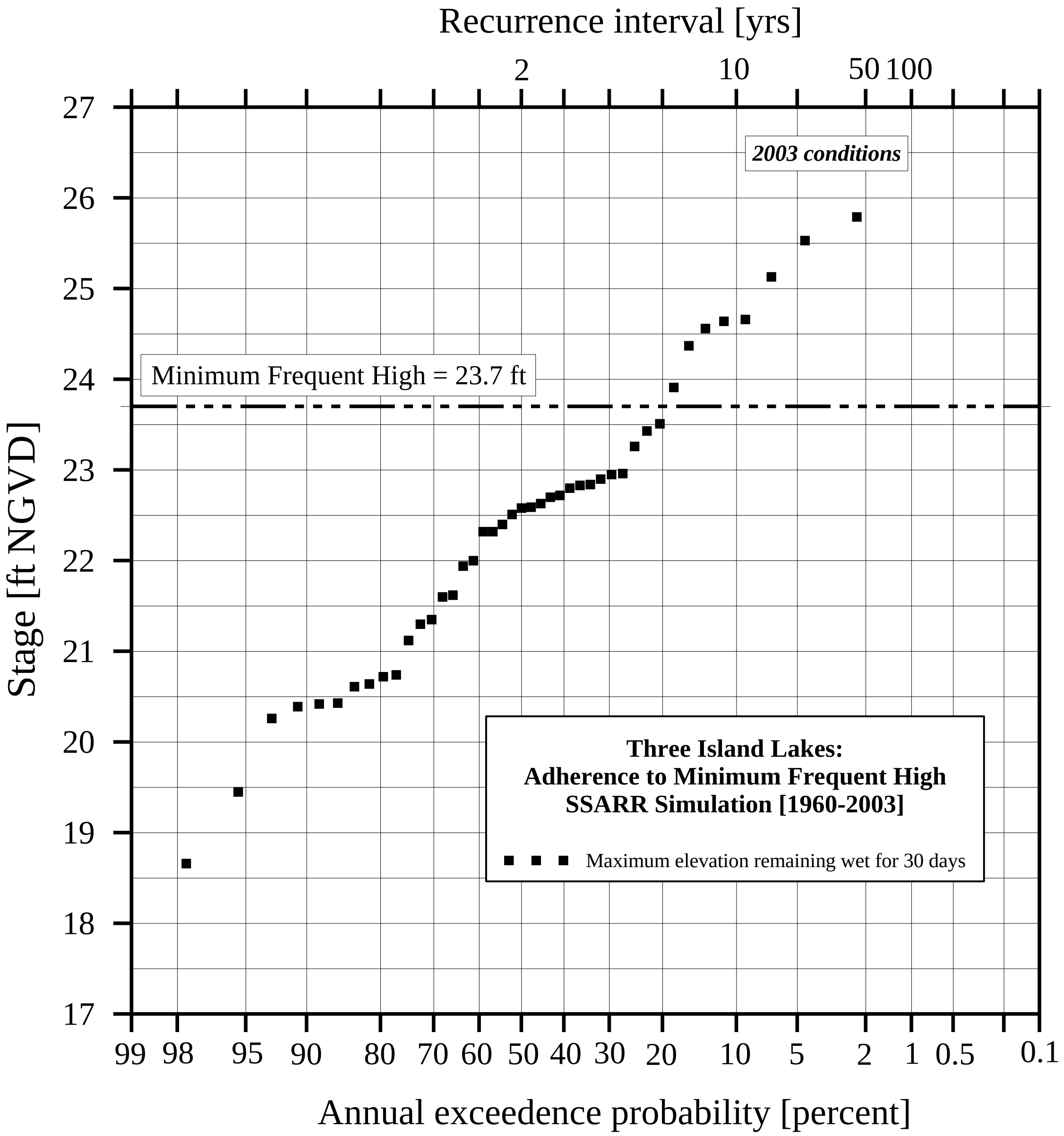

Figure D6. Flood frequencies computed using daily stages from model simulations of Three Island Lakes (for elevations continuously wet for 30 days and 2003 conditions with the FH of 23.7 ft NGVD superimposed)

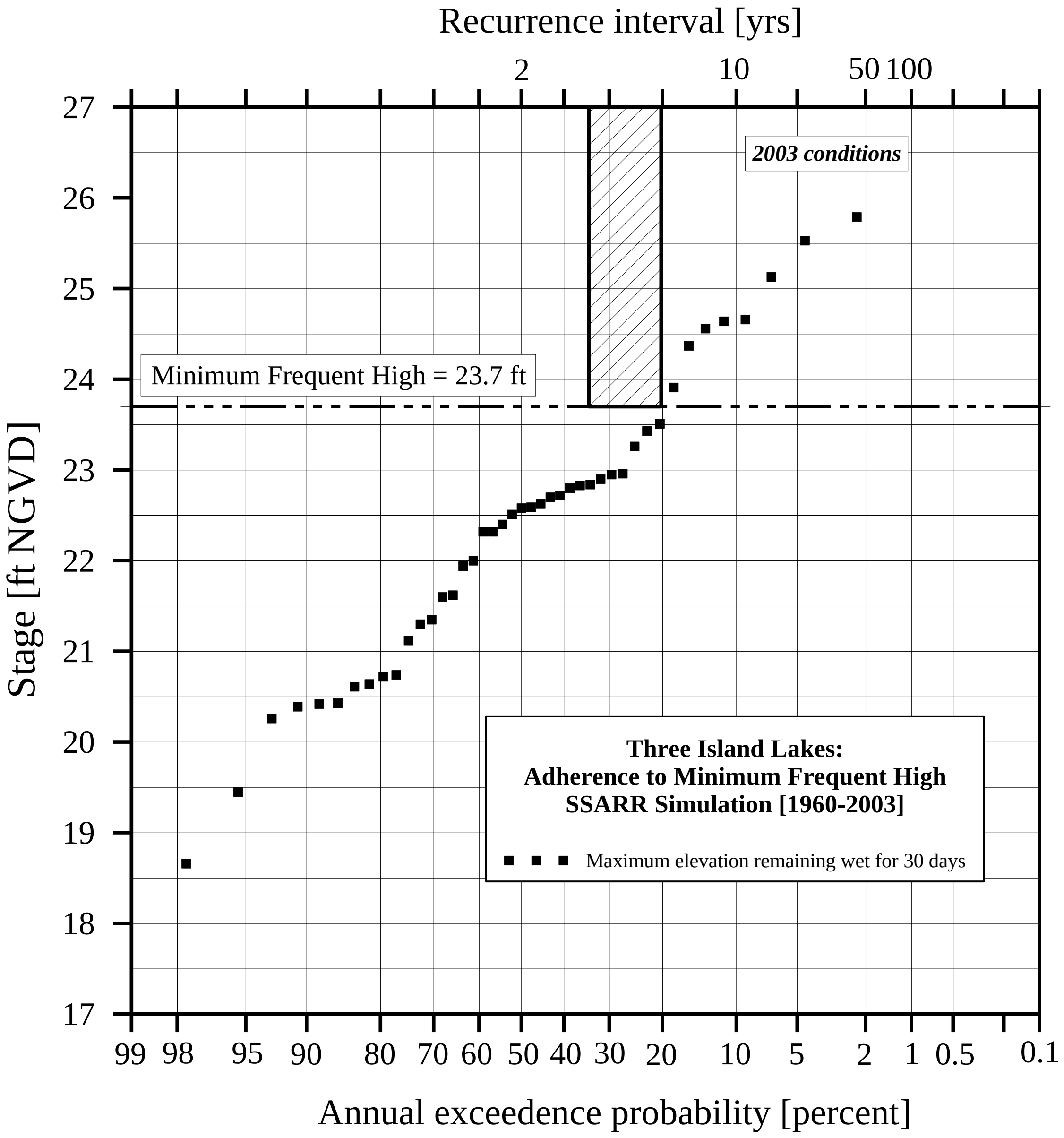

Figure D7. Flood frequencies computed using daily stages from model simulations of Three Island Lakes (for elevations continuously wet for 30 days and 2003 conditions), with a superimposed box bounded by: (1) the FH; (2) a vertical line corresponding to a return period of 3 years; and (3) a vertical line corresponding to a return period of 5 years

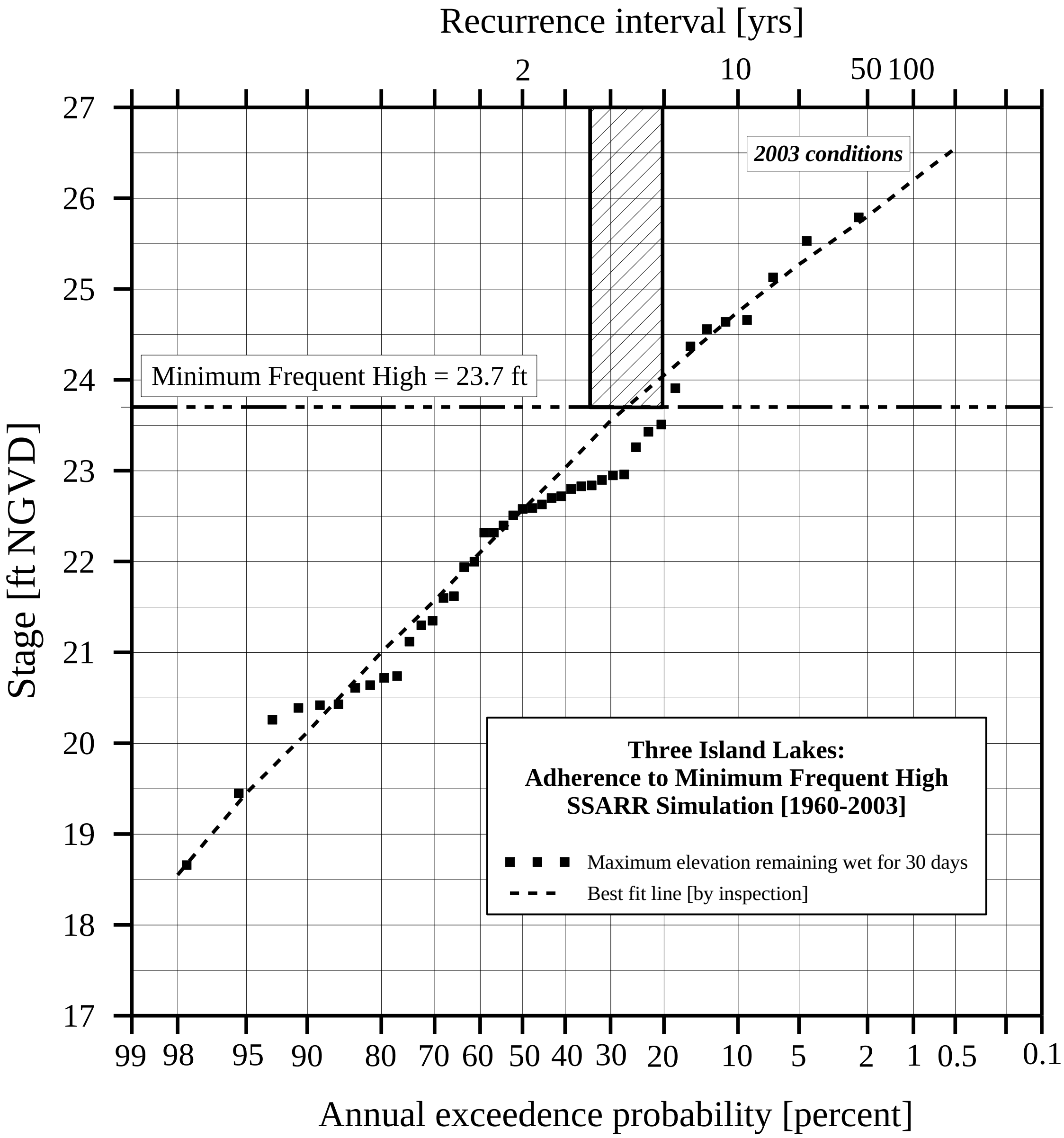

Figure D8. Flood frequencies computed using daily stages from model simulations of Three Island Lakes (for elevations continuously wet for 30 days and 2003 conditions), with a best-fit line superimposed

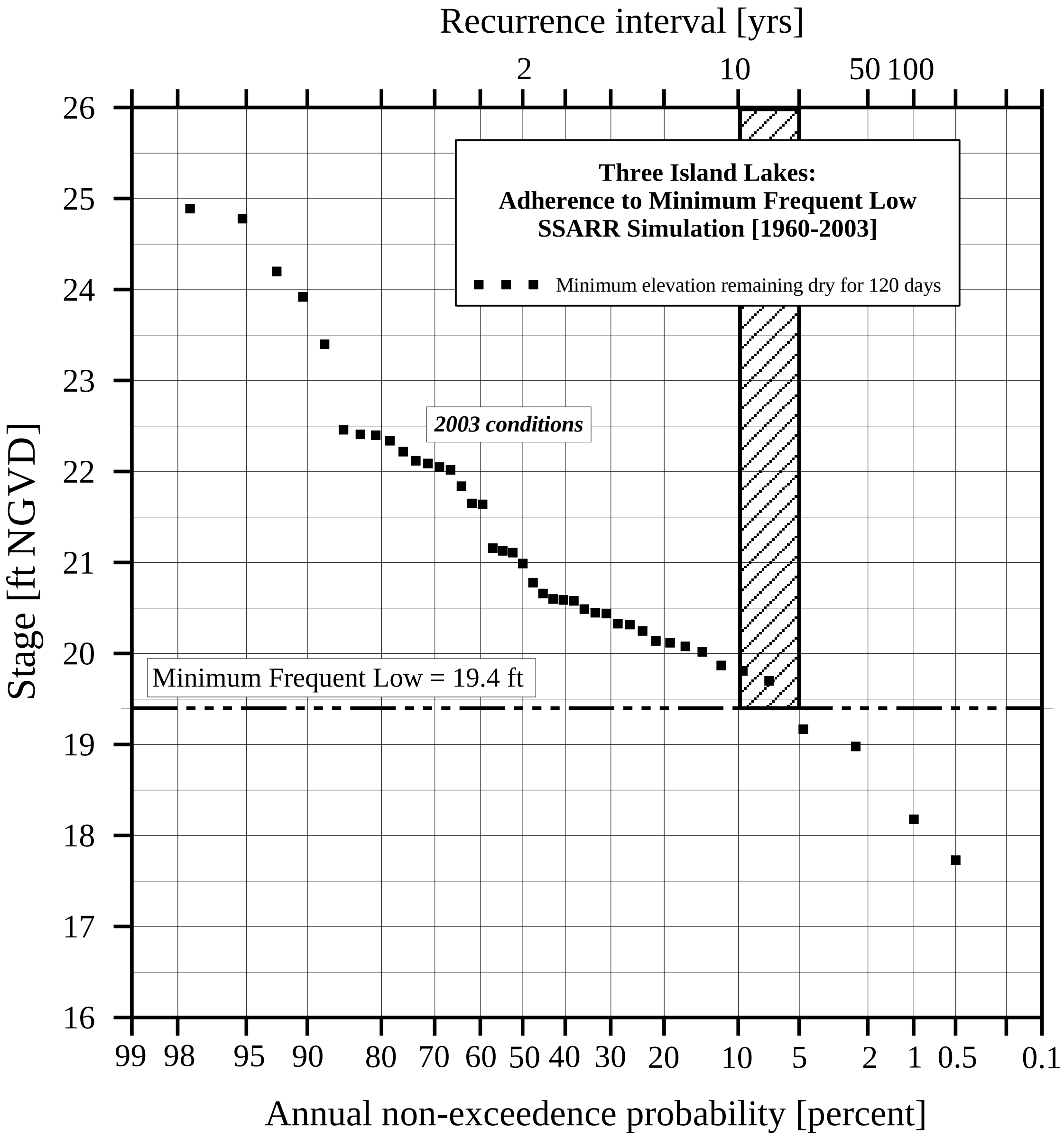

Figure D9. Drought frequencies computed using daily stages from model simulations of Three Island Lakes (for the FL level and 2003 conditions)

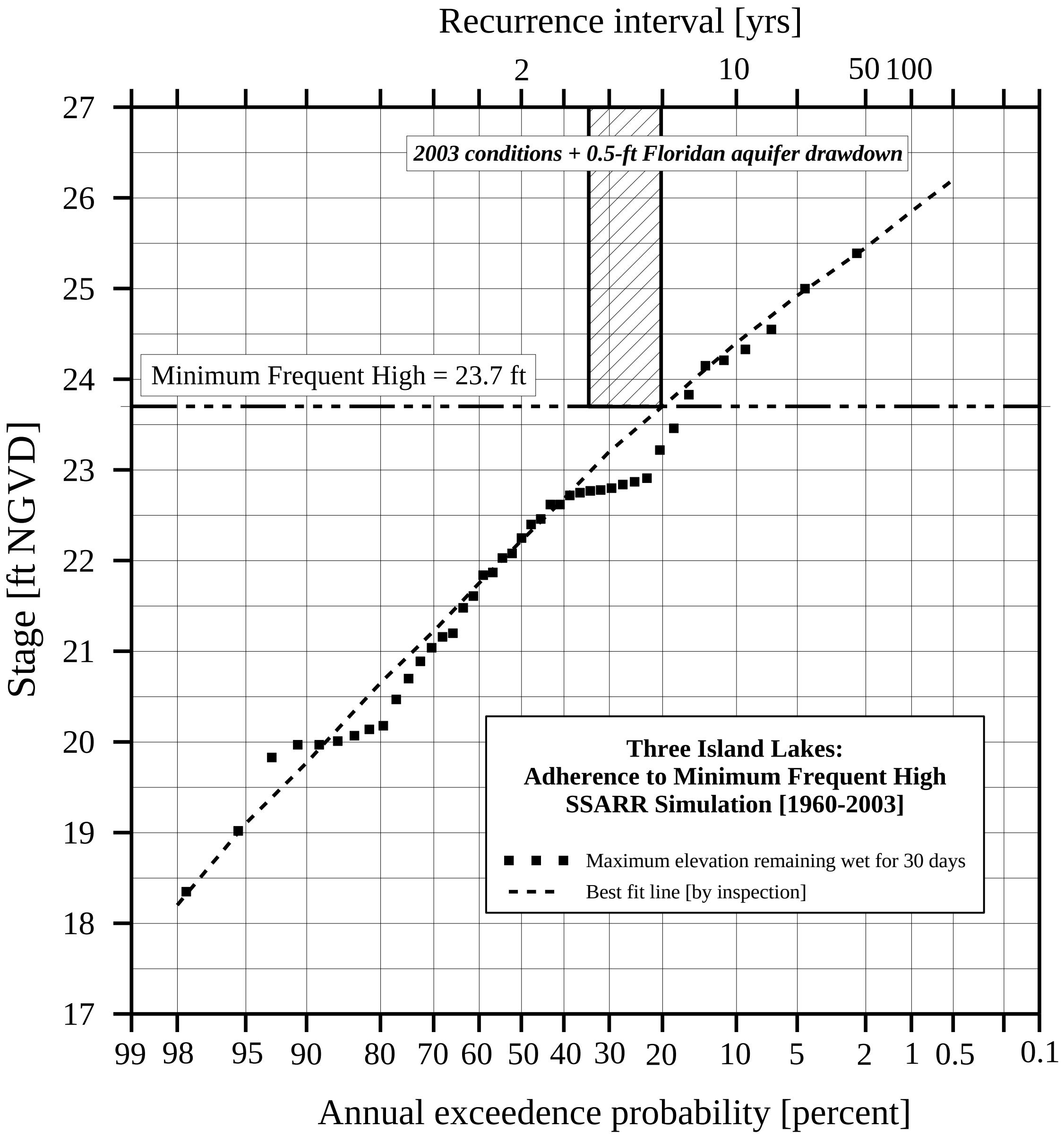

Figure D10. Flood frequencies computed using daily stages from model simulations of Three Island Lakes (for the FH level and 2003 conditions plus a 0.5-ft Floridan aquifer drawdown), with a best-fit line superimposed

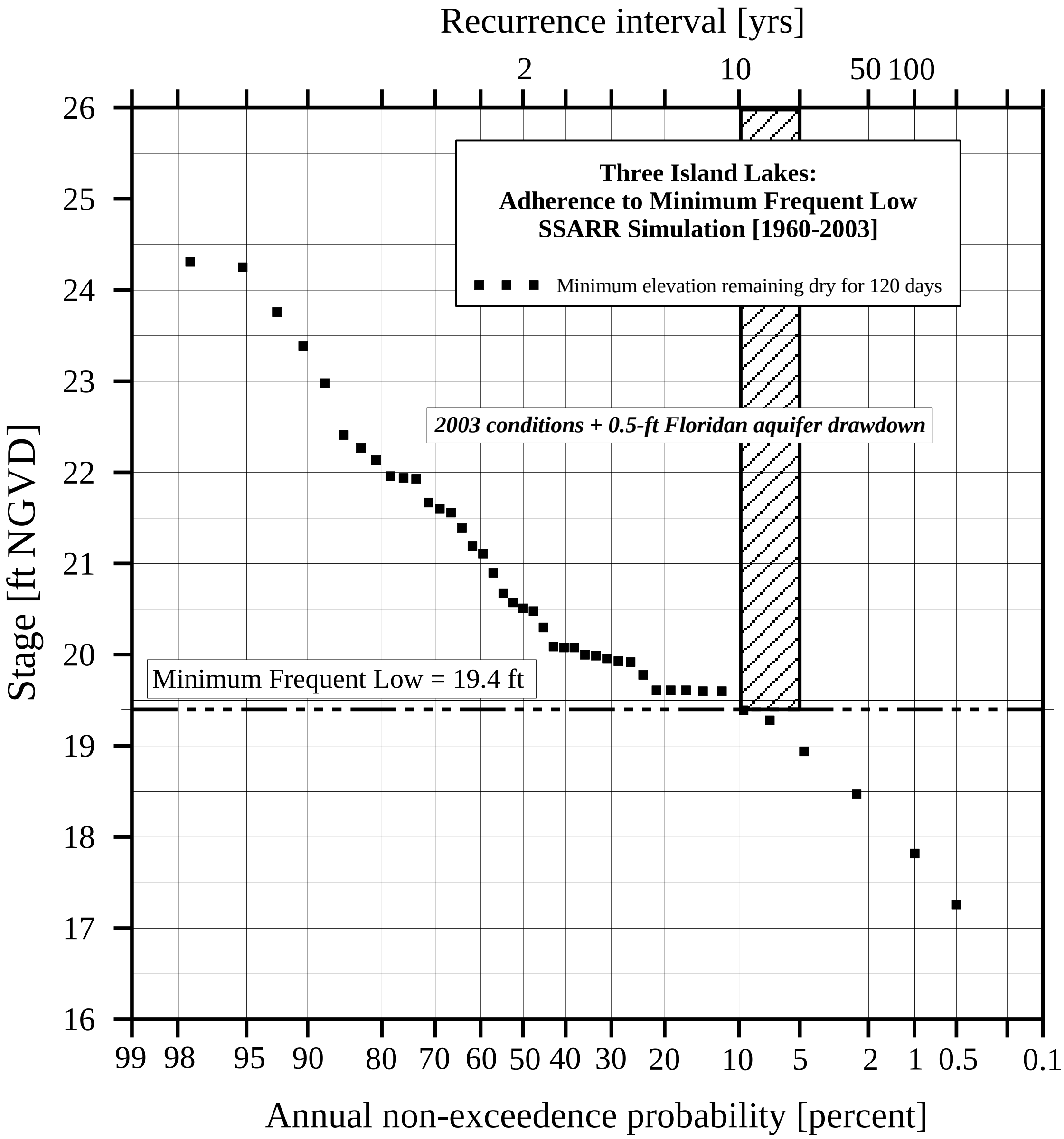

Figure D11. Drought frequencies computed using daily stages from model simulations of Three Island Lakes (for the FL level and 2003 conditions plus a 0.5-ft Floridan aquifer drawdown)