Technical Publication SJ2014-1

MINIMUM LEVELS REEVALUATION: INDIAN LAKE VOLUSIA COUNTY, FLORIDA

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by

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Palatka, Florida

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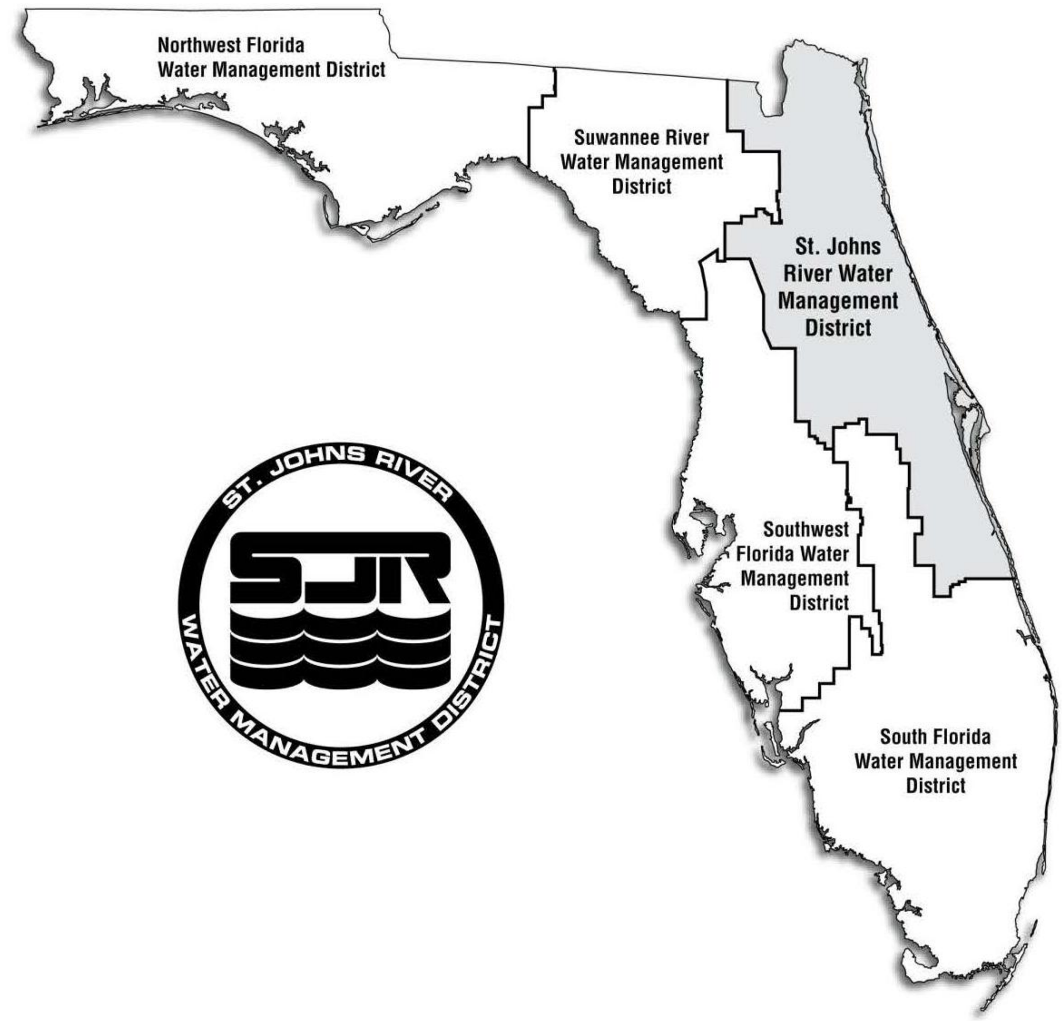

The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the District conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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EXECUTIVE SUMMARY

This report describes the St. Johns River Water Management District's (SJRWMD) minimum flows and levels (MFLs) reevaluation for Indian Lake in Volusia County. The SJRWMD Governing Board adopted MFLs for Indian Lake on January 12, 2004 (Chapter 40C-8, *Florida Administrative Code* [*F.A.C.*]); Valentine-Darby 1998). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [*F.S.*]). Use of a recently completed hydrologic model for Indian Lake (Robison 2013) indicated that the adopted MFLs were not being met under 2005 modeled conditions. Consequently, a reevaluation of the adopted Indian Lake MFLs was performed. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Indian Lake (Table ES–1) based on current SJRWMD MFLs determination methodology.

SJRWMD's MFLs program, which is implemented based on the requirements of Section 373.042 and Section 373.0421, *F.S.*, establishes MFLs for lakes, streams and rivers, wetlands, and groundwater aquifers. SJRWMD expresses MFLs in 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 (Section 373.042(1), *F.S.*).

The recommended minimum levels for Indian Lake in Volusia County, Florida (Table ES–1) are intended to support the protection of aquatic and wetland ecosystems from significant ecological harm caused by the consumptive use of water. In addition, MFLs provide technical support to SJRWMD's regional water supply planning process (Section 373.0361, *F.S.*), the consumptive use permitting program (Chapter 40C-2, [*F.A.C.*]), and the environmental resource permitting program (Chapter 40C-44, *F.A.C.*).

SJRWMD reviewed the 10 environmental values identified in Rule 62-40.473, *F.A.C.*, and determined for Indian Lake that the environmental value, "fish and wildlife habitats and the passage of fish," was the most restrictive environmental value to the further development of consumptive uses of surface and/or regional groundwater. Hence, the Indian Lake MFLs were developed primarily to protect this environmental value. Based on a qualitative assessment, SJRWMD believes the recommended MFLs developed primarily for the prevention of significant harm to "fish and wildlife habitats and the passage of fish" will protect all other relevant environmental values for Indian Lake.

MFLs take into account the ability of wetlands and aquatic communities to adjust to changes in the return intervals of high and low water events. Therefore, MFLs allow for an acceptable level of hydrologic change relative to existing hydrologic conditions. When the use of water resources shifts the hydrologic conditions below that defined by the MFLs, significant ecological harm is expected to occur. 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 impairment of ecological structures and functions.

The SJRWMD multiple MFLs methodology (SJRWMD 2006; Neubauer et al. 2007) was used to determine the recommended minimum lake levels presented here. MFLs determinations are based on evaluations of topographic, soils, and vegetation data collected within plant communities associated with the water body and with information collected from other aquatic ecosystems and from the scientific literature.

To simplify comparing the adopted with the proposed reevaluated MFLs for Indian Lake, the 1929 datum elevations are shown in Table ES–1 for both the adopted and proposed MFLs, along with the 1988 datum elevations. Thus, based on the 1929 datum the recommended reevaluation frequent high level for Indian Lake is 0.8 ft lower than the adopted minimum frequent high (MFH) because a different MFH level criterion was used. The adopted MFH level at Indian Lake corresponds to the average elevation of a bay swamp community (Valentine-Darby 1998). The recommended, reevaluated MFH level corresponds to the average elevation of all hardwood swamp elevation points surveyed in 2007 at Transects 1 and 2. Recent surface water model results indicated that the average elevation of the bay swamp represents a lake level that occurs less frequently than would be expected for the MFH level with a hydroperiod category of seasonally flooded. Additionally, the bay swamp community as delineated in 1998, located upslope from the hardwood swamp, represents a typical bayhead vegetation community in which shallow groundwater seepage rather than the surface water of Indian Lake primarily maintains the bayhead wetland characteristics.

Based on the 1929 datum the recommended reevaluated minimum average (MA) level for Indian Lake is 1.1 ft lower than the adopted MA level, because a different MA level criterion was used. The adopted MA level for Indian Lake equals the combined average elevation of the hardwood swamp at Transect 1 and the mixed swamp at Transect 2 (Valentine-Darby 1998). The recommended, reevaluated MA level equals a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep (>8 in. thick) surface organic soils observed in 2007 at Transects 1 and 2 within the shallow marshes and hardwood swamps. The 0.3-ft soil water table drawdown criterion is commonly used to determine a MA level where deep (>8 in. thick) surface organic soils are identified (SJRWMD 2006).

Based on the 1929 datum the recommended reevaluated minimum frequent low (MFL) level for Indian Lake is 1.6 ft lower than the adopted MFL, due to more detailed soil sampling in 2007, which increased the elevation range where organic soils were observed at Indian Lake. In 1998, when the original soil sampling was performed at Indian Lake, the lake stage was at an extremely high level, which prohibited soil sampling within the deeply flooded shallow marsh. The adopted MFL level for Indian Lake equaled a 20-in. soil water table drawdown below the average ground surface elevation, where the Samsula muck was observed in the gum swamp at Transect 1 and the mixed swamp at

Transect 2 (Valentine-Darby 1998). Currently, a 30-in. soil water table drawdown from the average ground surface elevation, where histic epipedon (surface organic horizon 8 to 16 in. thick) or histosol (surface organic horizon ≥16 in. thick) was identified in 2007 and was used in the reevaluation of Indian Lake MFLs as the primary recommended MFL level criterion.

The hydrologic model for Indian Lake was calibrated for 2005 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2005 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Indian Lake are not being met under 2005 conditions. The Indian Lake hydrologic model determined the Floridan aquifer potentiometric level increases needed to meet the recommended MFLs for Indian Lake. The FL level was the most sensitive (i.e., needed the most Floridan aquifer potentiometric level increase to meet the minimum level). A 1.3 ft Floridan aquifer potentiometric surface increase or recovery would be needed for the FL level to be met. The MA and FH levels would be met with the 1.3 ft potentiometric recovery.

The following conclusions and recommendations are drawn from the work performed in association with the reevaluation of the minimum levels for Indian Lake.

1. Establishment and enforcement of the reevaluated minimum levels for Indian Lake, as presented in this document, should adequately provide for the protection of the water resources or ecology of the area, which includes the associated floodplain at Indian Lake, from significant harm as a result of consumptive uses of water (Table ES–1).
2. Information included in Appendix C concerning the use of the hydrologic model and applicable SJRWMD regional groundwater flow model should be used to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions.
3. Periodic reassessments of these recommended minimum levels, based on monitoring data collected in the future, would better assure that these levels are providing the expected levels of protection of the water resources and ecology of the area. Monitoring data would include periodic vegetation and soil resampling, as well as hydrologic model updates with future stage and aquifer data.
4. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Indian Lake based on current SJRWMD MFLs determination methodology (Table ES–1).
5. The recommended modified MFLs for Indian Lake are not effective until adopted by the SJRWMD Governing Board.

The results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule.

Table ES–1. Adopted (Chapter 40C-8, *F.A.C.* 2004; Valentine-Darby 1998) and recommended, reevaluated minimum surface water levels for Indian Lake, Volusia County

Minimum Levels	Adopted Elevation (ft NGVD) 1929 Datum*	Adopted Hydroperiod Categories	Recommended Elevation (ft NGVD) 1929 Datum*	Recommended Elevation (ft NAVD) 1988 Datum**	Recommended Duration	Recommended Return Interval
Minimum frequent high	37.0	Seasonally flooded	36.2	35.2	30 days	3 years
Minimum average	36.1	Typically saturated	35.0	34.0	180 days	1.7 years
Minimum frequent low	34.4	Semipermanently flooded	32.8	31.8	120 days	5 years

Note:
*ft NGVD = feet National Geodetic Vertical Datum 1929; ft NAVD = feet North American Vertical Datum 1988
**The recommended, reevaluated minimum levels for Indian Lake were determined using ground elevations based on a 1988 datum, differing from the adopted MFLs, which were determined using a 1929 datum. This datum shift from 1929 to 1988 has occurred districtwide at SJRWMD to increase the accuracy of the ground elevation data. The amount of datum shift is location dependent and at Indian Lake the shift from the 1929 to 1988 datum results in a decrease in the numeric elevation values of -0.98 ft.

Note: These recommended levels for Indian Lake (Table ES-1) were adopted on August 22, 2013, by the SJRWMD Governing Board.

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ACRONYMS AND ABBREVIATIONS

BH	bayhead
CUP	consumptive use permit
dbh	diameter at breast height
DO	dissolved oxygen
F.A.C.	*Florida Administrative Code*
F.S.	*Florida Statutes*
FACW	facultative wet
FD	forested depression
FWDM	Florida Wetlands Delineation Manual
GIS	geographic information system
GPS	global positioning system
HS	hardwood swamp
LF	low flatwoods
LF-BH	transition low flatwoods-bayhead
MA	minimum average
MFH	minimum frequent high
MFL	minimum frequent low
MFLs	minimum flows and levels
mgy	million gallons per year
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
OBL	Obligate
SCS	Soil Conservation Service
SJRWMD	St. Johns River Water Management District
SM	shallow marsh
SR	State Road
SSURGO	Soil Survey Geographic
U	Upland
UPL	upland
USDA	U.S. Department of Agriculture
WRV	Water resource value

INTRODUCTION

This report describes the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Indian Lake in Volusia County, Florida. The SJRWMD Governing Board adopted MFLs for Indian Lake on January 12, 2004 (Chapter 40C-8, *Florida Administrative Code* [*F.A.C.*]), based on work performed by Valentine-Darby 1998 (Appendix A). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [*F.S.*]). Use of a recently completed hydrologic model for Indian Lake (Robison 2013) indicated that the adopted MFLs were not being met under 2005 land use and water use conditions. Consequently, a reevaluation of the adopted Indian Lake MFLs was performed. This document describes that reevaluation.

MINIMUM FLOWS AND LEVELS PROGRAM OVERVIEW

The SJRWMD MFLs program, based on the requirements of Section 373.042 and Section 373.0421, *F.S.*, establishes MFLs for lakes, streams and rivers, wetlands, springs, and aquifers. Further, the MFLs program is subject to the provisions of Chapter 40C-8, *F.A.C*, and provides technical support to SJRWMD's regional water supply planning process (Section 373.0361, *F.S.*), the consumptive use permitting (Chapter 40C-2, *F.A.C.*), and environmental resource permitting (Chapter 40C-4, *F.A.C.*) programs. 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 MINIMUM FLOWS AND LEVELS

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:

a. Recreation in and on the water (Rule 62.40.473(1)(a), *F.A.C.*)

b. Fish and wildlife habitats and the passage of fish (Rule 62.40.473(1)(b), *F.A.C.*)

c. Estuarine resources (Rule 62.40.473(1)(c), *F.A.C.*)

d. Transfer of detrital material (Rule 62.40.473(1)(d), *F.A.C.*)

e. Maintenance of freshwater storage and supply (Rule 62.40.473(1)(e), *F.A.C.*)

f. Aesthetic and scenic attributes (Rule 62.40.473(1)(f), *F.A.C.*)

g. Filtration and absorption of nutrients and other pollutants (Rule 62.40.473(1)(g), *F.A.C.*)

h. Sediment loads (Rule 62.40.473(1)(h), *F.A.C.*)

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

j. Navigation (Rule 62.40.473(1)(j), *F.A.C.*)

For several large system MFLs, such as the St. Johns River at State Road (SR) 50, Lake Monroe, and Wekiwa Spring, a separate, detailed analysis was conducted of each environmental value (HSW Engineering 2007; Environmental Consulting and Technology 2007; Wetland Solutions, Inc. 2008). A detailed analysis of environmental values at Indian Lake was not performed. 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, average, and low water events necessary to protect biologically relevant goals, criteria, and indicators that prevent significant harm to aquatic and wetland habitats. Three MFLs are usually defined for each system—MFH, MA, and MFL—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 comprised of three components: magnitude (water level and/or flow), duration (days), and frequency or return interval (years). Historically, SJRWMD 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 the return intervals of high and low water events. 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 of water level and/or flow events of defined magnitude and duration, causing impairment or loss of ecological structures and functions.

MFLs apply to decisions affecting 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.*).

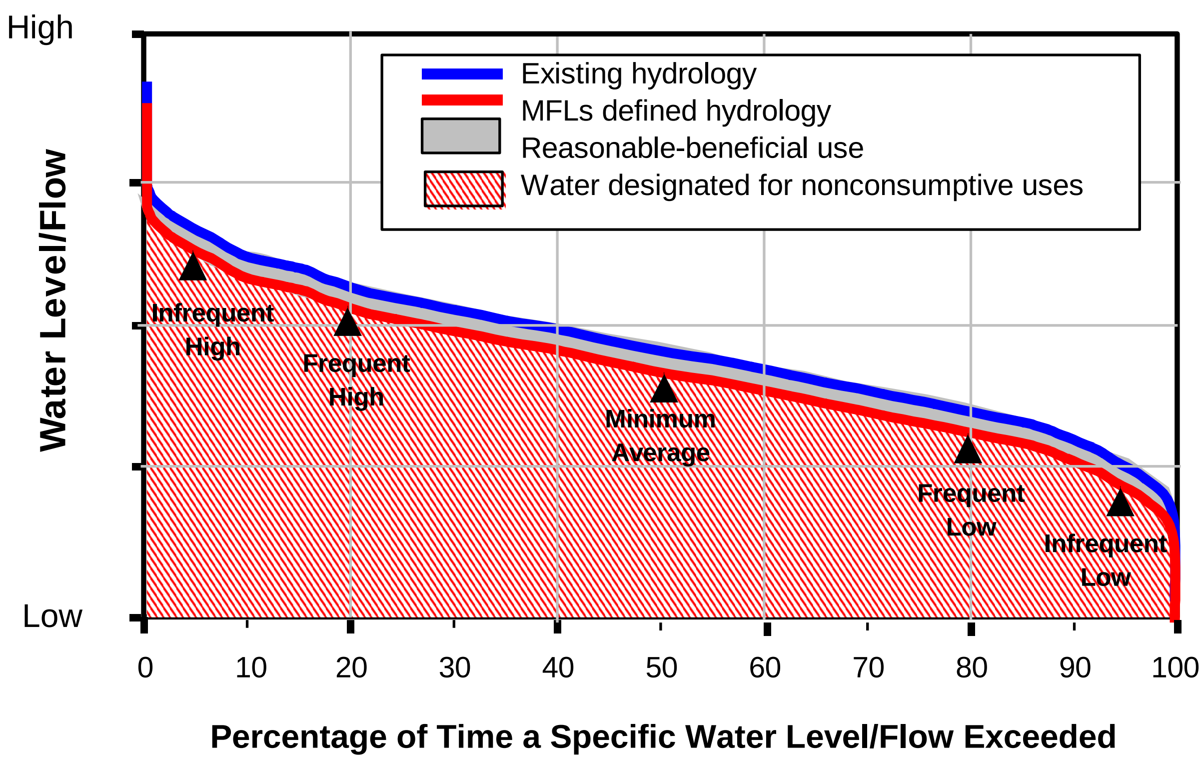

Figure 1. Hypothetical percentage exceedence curves for existing and MFLs defined hydrologic conditions. The existing hydrology curve represents the current lake or river stage or flow regime. The MFLs defined hydrology curve represents the new lake or river stage or flow regime, which provides for the reasonable, beneficial use of water (gray shaded area)

MFLs METHODOLOGY

MFLs determinations incorporate biological and topographical information collected in the field with stage data, wetlands, soils, and landownership data from geographic 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 methodology and assumptions used in the MFLs determination process for Indian Lake, 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 2006).

FIELD SITE SELECTION

Many factors are considered in the selection of field transect sites. Transects are fixed sample lines across a river, lake, or wetland floodplain. Transects usually extend from open water to uplands. Elevation, soils, and vegetation data 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 compiled all pertinent existing information by conducting data searches of SJRWMD library documents, project record files, the hydrologic database, and SJRWMD Division of Surveying Services files. The types of information include:

- 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

The field investigation at Indian Lake for the recommended minimum levels described in this document occurred in April and May 2007. All the previously identified types of information were considered in the selection of field transect sites at Indian Lake, as well as the information obtained in Valentine-Darby (1998).

Data Analysis and Transect Site Identification

The compiled data were reviewed to familiarize the investigator with site characteristics, locate important basin features that needed to be evaluated, and assess prospective sampling locations. Copies of this information were organized and placed in permanent files for future reference (SJRWMD 2006).

Potential transect locations at Indian Lake were initially identified from maps of wetlands, soils, topography, and landownership. Specific transect site selection goals included:

- Establishing transects at sites where multiple wetland communities of the most commonly occurring types were traversed
- Selecting multiple transect locations with common wetland communities among them
- Establishing transects that traverse unique wetland communities

Transect characteristics were subsequently field verified to ensure the particular locations contained representative wetland communities, hydric soils, and reasonable upland access. These goals help to ensure ecosystem protection of commonly occurring and unique wetland ecosystems at Indian Lake. Individual transect site selection criteria for the final two transects are described in the Results and Discussion section of this document.

Field Data Collection

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

Site Survey

Once a transect was established at Indian Lake, vegetation was trimmed to allow a line of sight along the length of the transect. A measuring tape was then laid out along the transect. Elevation measurements were surveyed at regular intervals on the ground along the length of the transect. In general, the elevation gradient is low and the vegetation communities are narrow in extent at the two Indian Lake transects. Consequently, elevations were typically recorded at 10-ft intervals. Additional elevations were measured, including obvious changes in elevation, vegetation community, and soil.

Latitude and longitude data were also collected, using a global positioning system (GPS) receiver at selected points along the length of the Indian Lake transects. These data will be used to accurately locate specific features along the transects and facilitate recovering transect locations in the future.

Soil Sampling Procedures

The primary soil criteria considered in the MFLs determination are the presence and depth of organic soils, as well as the extent of hydric soils observed along the field transects (SJRWMD 2006). 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 in. and, using 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 (NRCS 1998).

At Indian Lake, detailed soil profiles were observed at selected stations along each transect line. Soil profiles were described following standard Natural Resources Conservation Service (NRCS; previously Soil Conservation Service [SCS]) procedures (SCS 1987). Each soil horizon (unique layer) was described with respect to texture, thickness, Munsell color (Kollmorgen Corp. 1992), structure, consistency, boundary, and presence of roots.

Soil sampling intervals varied along the two Indian Lake transects. The sampling interval was dependent upon on-site soil changes. Additional soil sampling procedures are documented in the draft Minimum Flows and Levels Methods Manual (SJRWMD 2006).

The following soil features, if present at the Indian Lake transects, were identified and the location marked along the transect line so that soil surface elevations could also be determined for these features:

- Landward extent of hydric soils
- Landward extent of surface organics
- Landward extent of histic epipedon (surface organic horizon 8 to 16 in. thick)

- Landward extent of histosols (≥16 in.-thick surface organic horizon)
- Thickness of organic surface horizon

Vegetation Sampling Procedures

SJRWMD has wetland maps developed from aerial photography using 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 on 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. The transect belt width will vary depending on the type of plant community to be sampled (SJRWMD 2006). 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 2006). Percent cover was estimated visually using cover classes (ranges of percent cover). The cover class and percent cover ranges 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 2006). Plant species, plant community, and percent cover data were recorded on field vegetation data sheets. The data sheets are formatted to facilitate field data collection and computer transcription.

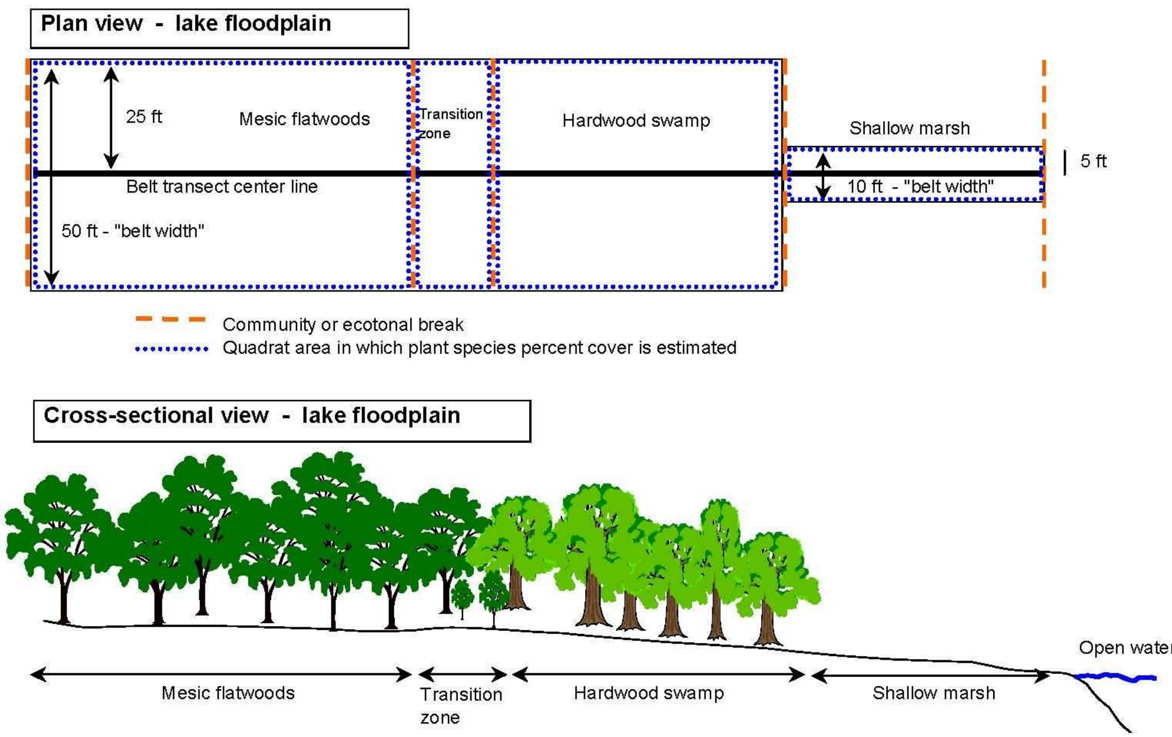

Figure 2. Example of belt transect through forested and herbaceous plant communities

DATA ANALYSIS

The primary data analysis for information collected at Indian Lake consisted of using a computer spreadsheet file to perform basic statistical analyses on the surveyed elevation data. Vegetation and soils information collected along the transects were incorporated with the elevation data. Descriptive statistics were calculated for the elevations of the vegetation communities and specific hydric soil indicators. For example, the average soil surface elevation of a hardwood swamp was calculated together with the average surface elevation of histosols within the hardwood swamp.

Transect elevation data were 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 Indian Lake 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. Protecting the most sensitive environmental value or values for each water body or watercourse provides the best opportunity to establish MFLs protective of all the identified applicable environmental values identified in Rule 62-40.473, *F.A.C.*

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 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 channel width.

SJRWMD examined the 10 environmental values identified in Rule 62-40.473, *F.A.*C., through a matrix screening tool (Table 1) to determine the most restrictive environmental value. The screening process used field data collected at Indian Lake, the scientific literature, and expert opinion to evaluate and score each environmental value relative to: (1) level of risk of harm from water withdrawals; (2) importance of the criterion to the water body; and (3) legal constraints on the resource/water body (e.g., presence of endangered species, Outstanding Florida Water, state-owned lands). The environmental screening scores indicate which environmental values are relevant to Indian Lake and which criterion MFLs development should be based on to afford protection to all other relevant environmental values. The screening process serves to focus the evaluation and to shape the types of analyses needed to complete the MFLs process.

For several large system MFLs (e.g., the St. Johns River at State Road 50, Lake Monroe, and Wekiwa Springs) a separate, detailed analyses of each environmental value was conducted (HSW Engineering 2007; Environmental Consulting and Technology 2007; Wetland Solutions, Inc. 2008). A detailed analysis of environmental values at Indian Lake was not performed.

Table 1. Minimum flows and levels (MFLs) decision matrix—Indian Lake

Criterion	Level of Resource Risk*	Importance of Resource Value†	Resource Legal Constraints‡	Screening Value§	Criterion Stage Related?**	Criterion Limiting?††
Recreation in and on the water	1	3	1	5	Y	N
Fish and wildlife habitats and passage of fish§§	3	3	1	7	Y	Y
Estuarine resources	0	0	NA	0	N	NA
Transfer of detrital material	2	2	1	5	Y	N
Maintenance of freshwater storage and supply	1	1	1	3	Y	N
Aesthetic and scenic attributes	1	2	1	4	Y	N
Filtration and absorption of nutrients and other pollutants	2	3	1	6	Y	N
Sediment loads	0	0	NA	0	N	NA
Water quality	2	3	1	6	Y	N
Navigation	1	3	1	5	Y	N

Note:

* Evaluation of the level to which the resource is at risk. 0 = no risk; 1 = low risk, 2 = medium risk, 3 = high risk

† Evaluation of importance of the criterion with respect to resource. 0 = no importance; 1 = low importance, 2 = medium importance, 3 = highly important

‡ Legal constraints on resource, such as endangered species, Outstanding Florida Water, etc. 1 = low, 2 = medium, 3 = high

§ Screening value = sum of columns 1, 2, and 3. Indicates overall importance of criterion to MFLs development.

** Evaluation as to whether criterion is related to water level in resource. (Yes or No)

†† Evaluation as to whether criterion is potentially limiting for MFLs development. (Yes or No)

CONSIDERATION OF BASIN ALTERATIONS IN ESTABLISHING MFLS

When establishing MFLs, SJRWMD considers changes and structural alterations to watersheds, surface waters, and aquifers as well as the effects and constraints of such changes and alterations on the hydrology of an affected watershed, surface water, or aquifer based on the provisions of Section 373.0421(1)(a), *F.S.* 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 in existence 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 large enough to affect vegetation and soils and have been in place for a sufficiently long 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 neither respond to all hydrologic changes nor respond instantaneously to changes in hydrology that are sufficiently large to cause such change. SJRWMD typically develops recommended MFLs based on 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 for 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 Indian Lake was developed to provide a means of assessing whether MFLs compliance is achieved under specific water use and land use conditions (Robison 2013). This hydrologic model was calibrated for 2005 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2005 regional water use.

Any projected or planned hydrologic changes for Indian Lake need to be assessed from the standpoint of MFLs. In the case of Indian Lake, the most likely significant changes will be caused by declines in the potentiometric surface of the Floridan aquifer caused by increased groundwater withdrawals. Therefore, before any increased withdrawals are permitted, potential aquifer declines will be assessed with the regional groundwater model (Williams 2006) and then with the hydrologic model (Robison 2013). Declines determined by the groundwater model are superimposed on the updated conditions surface water model to determine MFLs compliance. A more detailed 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 use and land use conditions is presented in Appendix C. This appendix also includes an introduction to the use of hydrologic statistics in the SJRWMD MFLs program.

INDIAN LAKE GENERAL INFORMATION

Indian Lake is located in Volusia County, approximately 8 miles west of Daytona Beach (Figures 3 and 4), within the Volusia Ridge Sets physiographic division of the Eastern Flatwoods District. The Volusia Ridge Sets physiographic division contains accreted coastal deposits consisting of four distinct parts: a flatwoods plain of subdued beach ridge sets, an eastern boundary sand ridge, an eastern set of beach ridges forming a flatwoods plain, and a high coastal ridge. The plains are underlain directly by fine sands and silty sand with some clay; whereas the ridges have well-drained sand soils (Brooks 1982). Recharge to the Floridan aquifer around Indian Lake is moderate (4 to 8 in/year; Boniol and Fortich 2004). Land use for the area surrounding Indian Lake is classified as forest, wetland, upland non-forested, or water (Figure 5).

Indian Lake also resides within the Tiger Bay State Forest. The Florida Department of Agriculture and Consumer Services, Division of Forestry, manages Tiger Bay State Forest. Tiger Bay State Forest consists of large areas of swamp with embedded pine islands and a large pine ridge area. The purchase of this forest began in 1977, under the Environmentally Endangered Lands Program, with additional acquisitions made in 1994 and 1998. Tiger Bay State Forest was severely impacted by the 1998 summer wildfire firestorm. Approximately 15,000 acres of the forest were burned, including an area adjacent to Indian Lake (FFS 2007).

Tiger Bay State Forest is also managed as a Wildlife Management Area by the Florida Fish and Wildlife Conservation Commission. Indian Lake and Rattlesnake Pond are open for fishing and small boat use. Hunting for white-tailed deer, hogs, and small game is permitted during designated seasons. Additional recreational opportunities in Tiger Bay State Forest include wildlife viewing, hiking, picnicking, horseback riding, and bicycling on designated forest roads. Wildlife in the area includes white-tailed deer, wild turkey, black bear, Wood Stork, wading birds, and Bachman's Sparrow (FFS 2007).

Tiger Bay State Forest also contains two well fields, one for the City of Ormond Beach and one for the City of Daytona Beach, primarily providing potable water for residential use. The City of Ormond Beach wells are located more than 4 miles north of Indian Lake. The City of Daytona Beach western well field contains 21 wells, with 12 of the wells within a 2-mile radius of Indian Lake (Figure 4). The City of Daytona Beach consumptive use permit (CUP) (Permit ID 8834), issued by SJRWMD on March 9, 2005, authorized the use of 5,898.4 million gallons per year (mgy) of Floridan aquifer withdrawals from a total of 26 wells, to serve a projected population of 96,400 people in 2011, with water for household, commercial/industrial, urban landscape, and water utility type uses. During 2006, approximately 1,706.0 mgy were pumped from the 12 City of Daytona wells located within a 2-mile radius of Indian Lake (P. Fairbank, SJRWMD, pers. comm. 2007). An additional active Floridan aquifer CUP within a 2-mile radius of Indian Lake exists for the Tomoka Correctional Institute (5.5 mgy; Permit ID 4363).

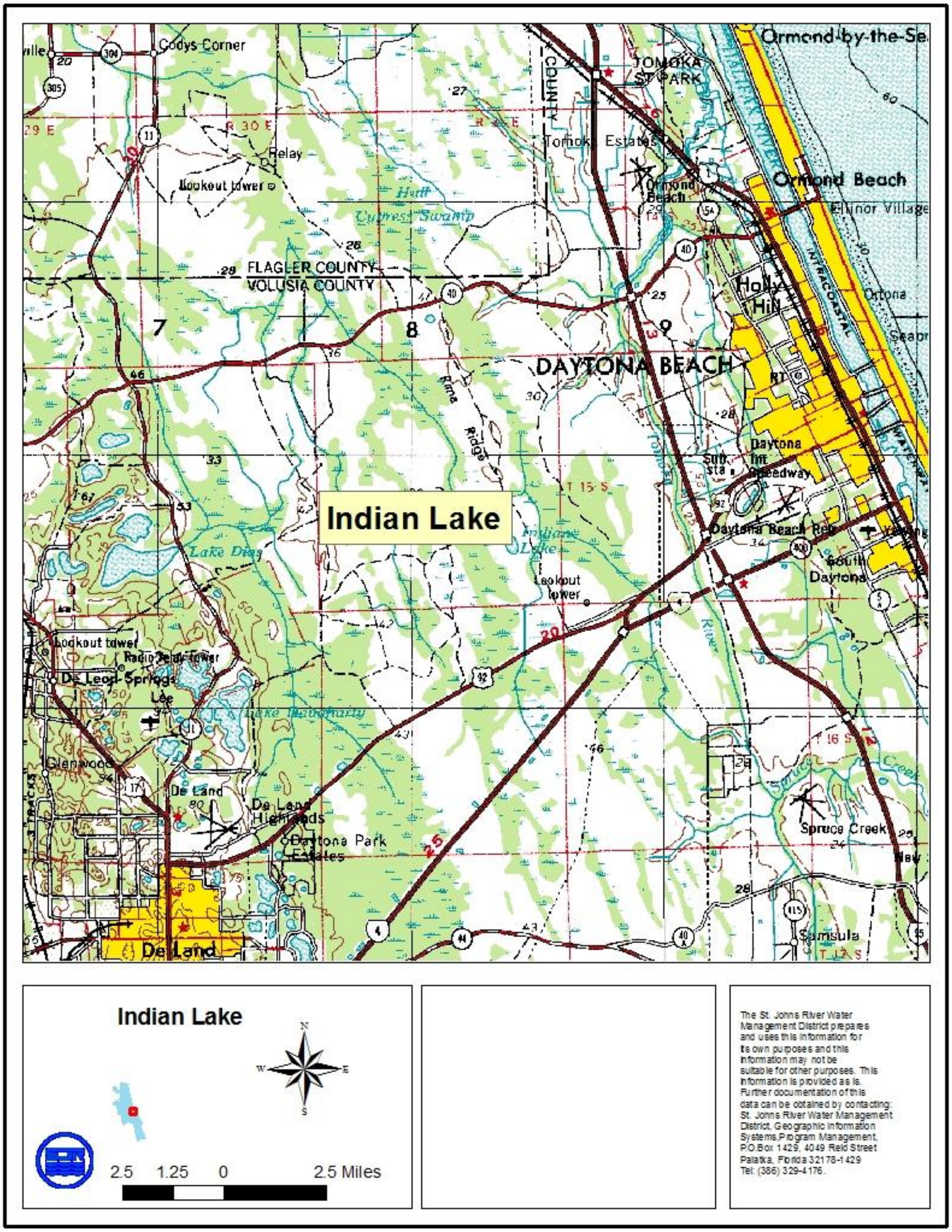

Figure 3. Indian Lake location map

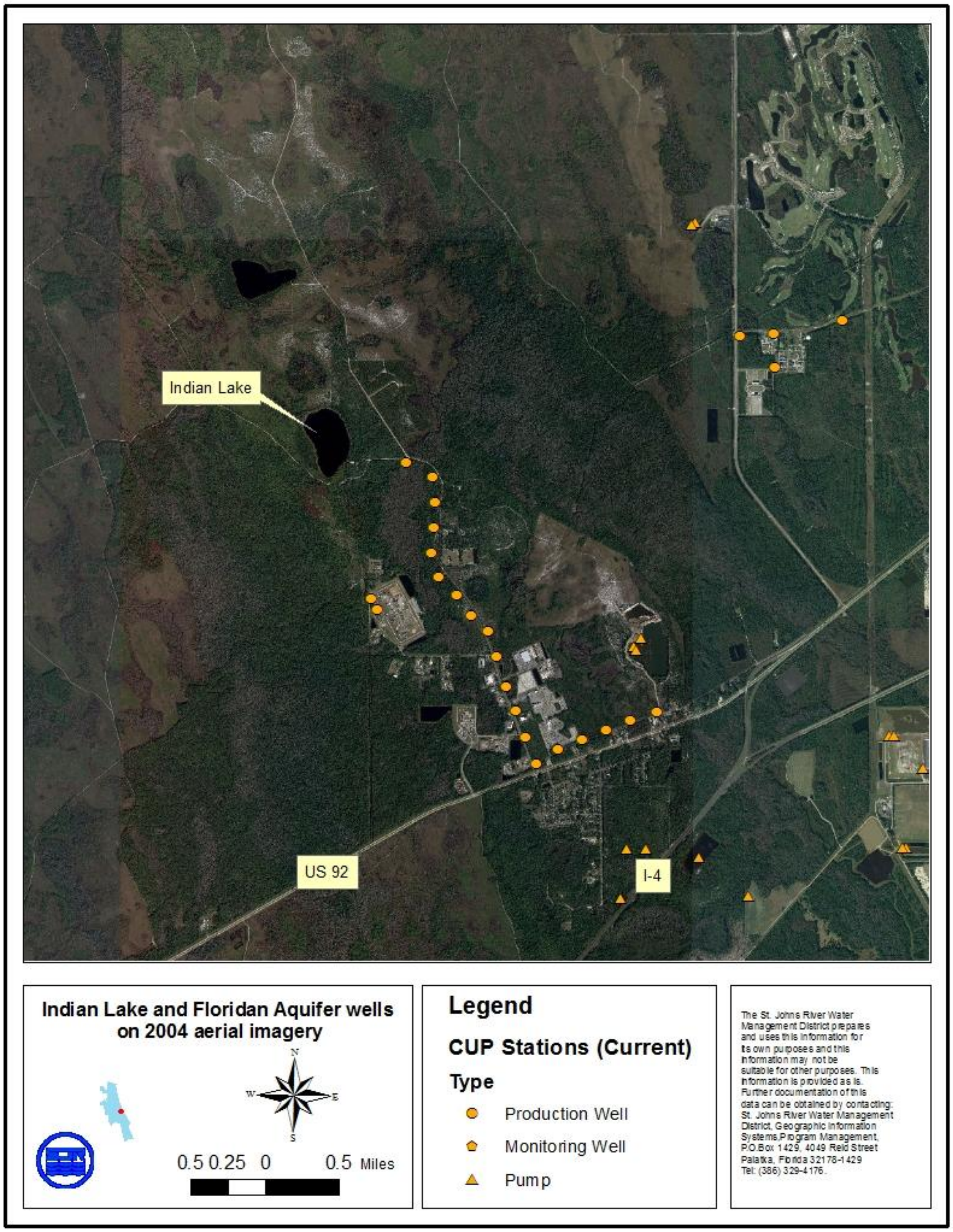

Figure 4 Aerial photograph of Indian Lake with consumptive use permit (CUP) wells

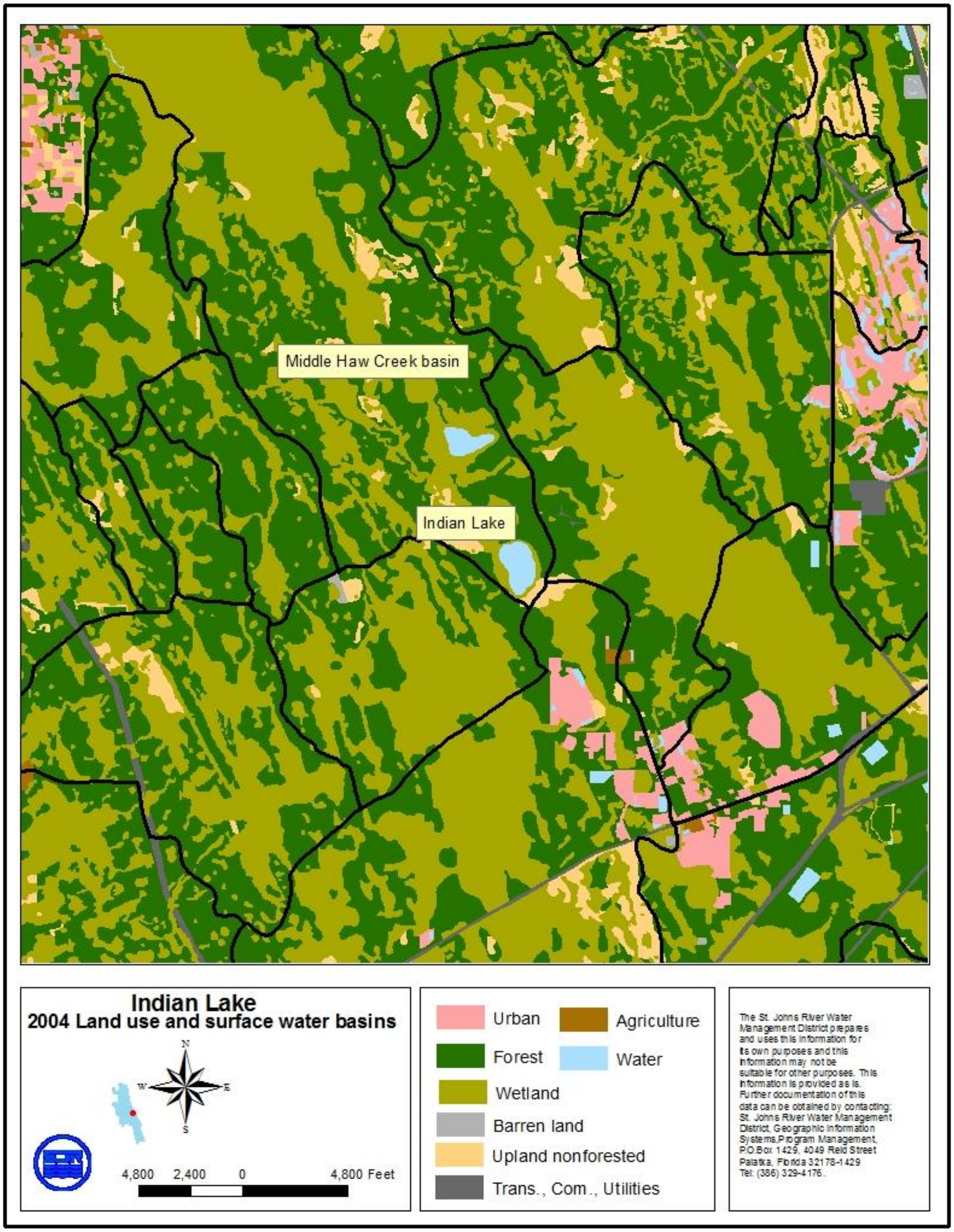

Figure 5. Indian Lake 2004 land use and surface water basin

INDIAN LAKE MORPHOMETRY AND HYDROLOGY

Indian Lake covers approximately 65 acres when the stage equals 37.0 ft National Geodetic Vertical Datum (NGVD), according to the U.S. Geological Survey (USGS) quadrangle map (1:24,000 scale). Indian Lake is located at the headwaters of the Middle Haw Creek surface water sub-basin, which drains to the north within the Lower St. Johns River basin (Figure 5). However, Indian Lake stage must equal approximately 39.0 ft NGVD to discharge into Little Haw Creek (CDM 2002). The lake basin has a simple morphology comprised of a single, relatively deep pool. Fathometer data indicated that the majority of the lake bottom occurred at elevations between 23 and 28 ft NGVD, and the minimum recorded Indian Lake bottom elevation equaled 19.6 ft NGVD (SJRWMD 2005).

Indian Lake typifies a seepage or sandhill lake. Seepage or sandhill lakes located in recharge areas, such as Indian Lake, generally experience greater lake stage fluctuations than lakes in discharge areas (Schiffer 1996). Indian Lake was classified as a well-drained ridge lake with moderate leakage and a high range of stage fluctuation (Epting et al. 2008). Sandhill lakes receive water from rainfall and the surficial aquifer. As the rain enters the soil and recharges the surficial aquifer system, the water table near a lake rises above the lake water level, allowing the lake to receive seepage from the surficial aquifer (Schiffer 1996). During periods of intense rainfall the lake water level may rise above the local water table, and the general surficial aquifer flow direction will be away from the lake. This condition usually is temporary (Schiffer 1996).

Surface water level data (Figure 6) for Indian Lake has been collected generally on a weekly schedule from March 8, 1988, to the present. The gauge is located on the east lakeshore near the boat ramp. At the time of this MFLs reevaluation, during the period of record, the lake level fluctuated between 27.9 and 38.8 ft NGVD (range 10.9 ft), with median and average levels equal to median 33.7 and average 33.9 ft NGVD, respectively. Figure 7, a simulated stage duration curve, illustrates typical water levels for Indian Lake. The simulated stage data were used to create the stage duration curve due to the data gaps in the actual stage data. Additional hydrologic information on Indian Lake, including a description of the hydrologic model analyses, the Indian Lake watershed, surficial and intermediate groundwater movement, and MFLs compliance is located in Appendix C.

INDIAN LAKE WETLANDS

SJRWMD geographic information system (GIS) wetland coverage (Figure 8) illustrates the bayhead-hardwood swamp wetland community completely encircling Indian Lake. The bayhead-hardwood swamp wetland community designation indicates that the two vegetation community types were difficult to delineate individually on the aerial imagery. The two field transects surveyed in 2007 at Indian Lake traversed shallow marsh, hardwood swamp, bayhead, transitional low flatwoods-bayhead, and low flatwoods vegetation communities. Detailed wetland community descriptions are presented in the Results and Discussion section of this document for the two transects located at Indian Lake.

INDIAN LAKE SOILS

Lake hydrology is related to the development of hydric soils. These substrates are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part of the soil (SCS 1987). Hydric soil (Samsula series) was mapped exclusively at the shoreline of Indian Lake (Figure 9; Soil Survey Geographic [SSURGO] Database 2001). The Samsula series consists of very deep, very poorly drained, rapidly permeable soils that formed in moderately thick beds of hydrophilic plant remains and are underlain by sandy marine sediments.

AEV Consulting LLC, contractor to SJRWMD, performed field soil sampling at Indian Lake on April 17 and May 1, 2007. Hydric soils, with extensive areas of organic soil, were identified at each transect. Extensive areas of organic soils are atypical at sandhill lakes, such as Indian. The field soil sampling results were integral to the MFLs determinations. Transect-specific field soil sample descriptions are presented in the Results and Discussion section of this document.

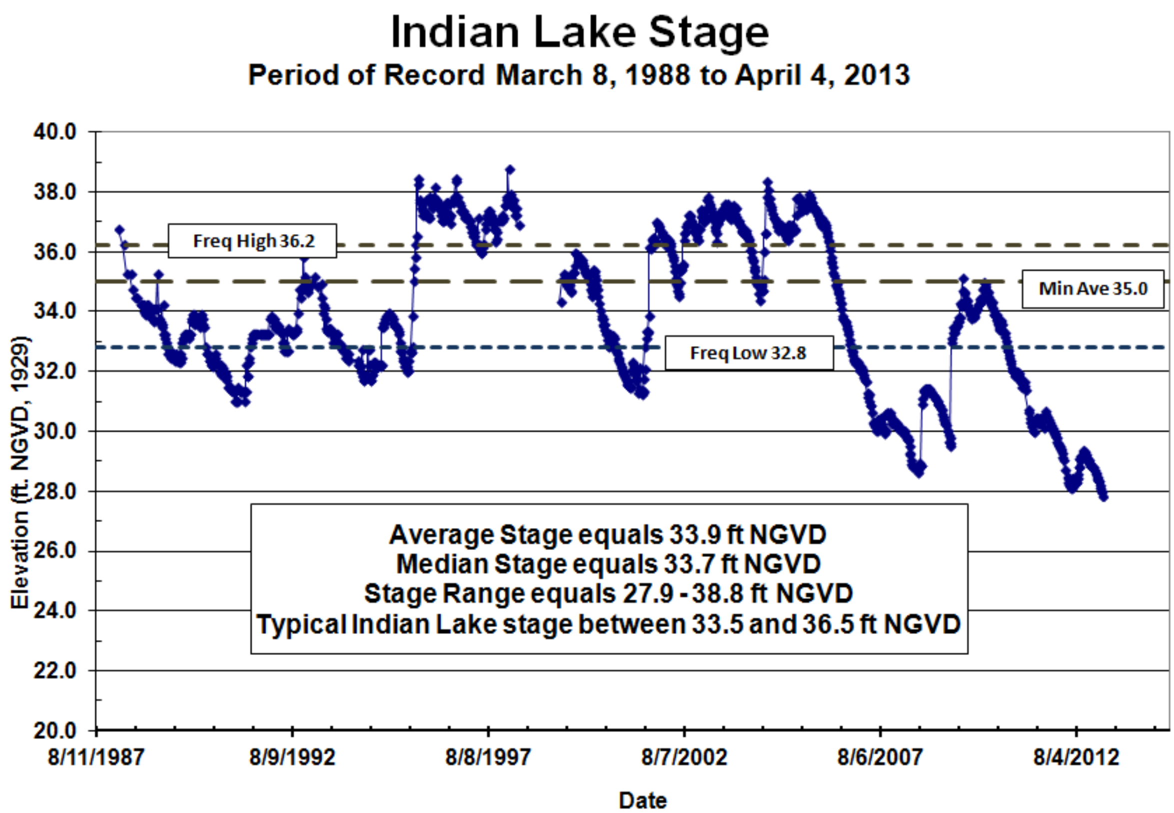

Figure 6. Indian Lake stage from March 1988–April 2013

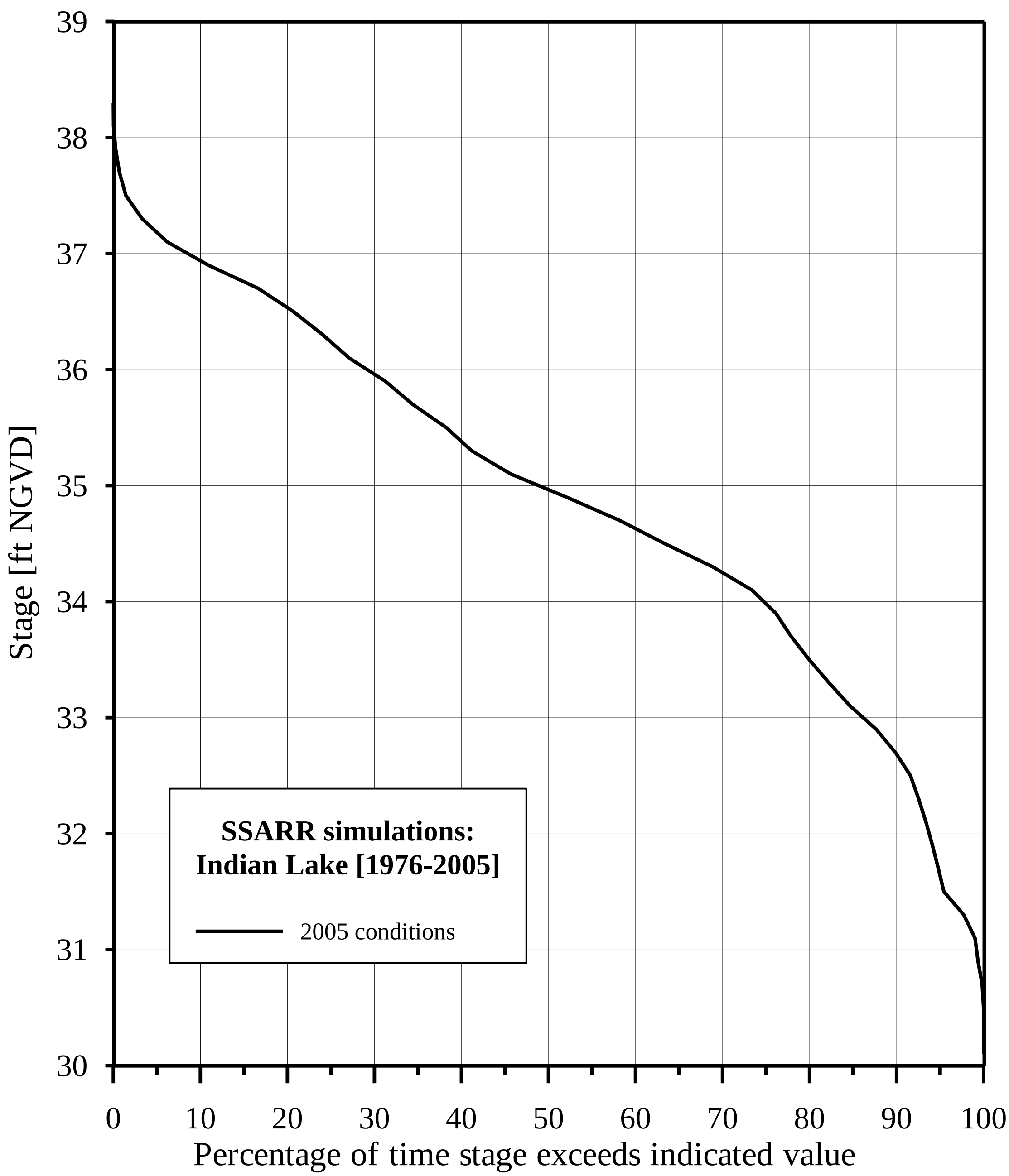

Figure 7. Stage (ft NGVD) duration curve for Indian Lake

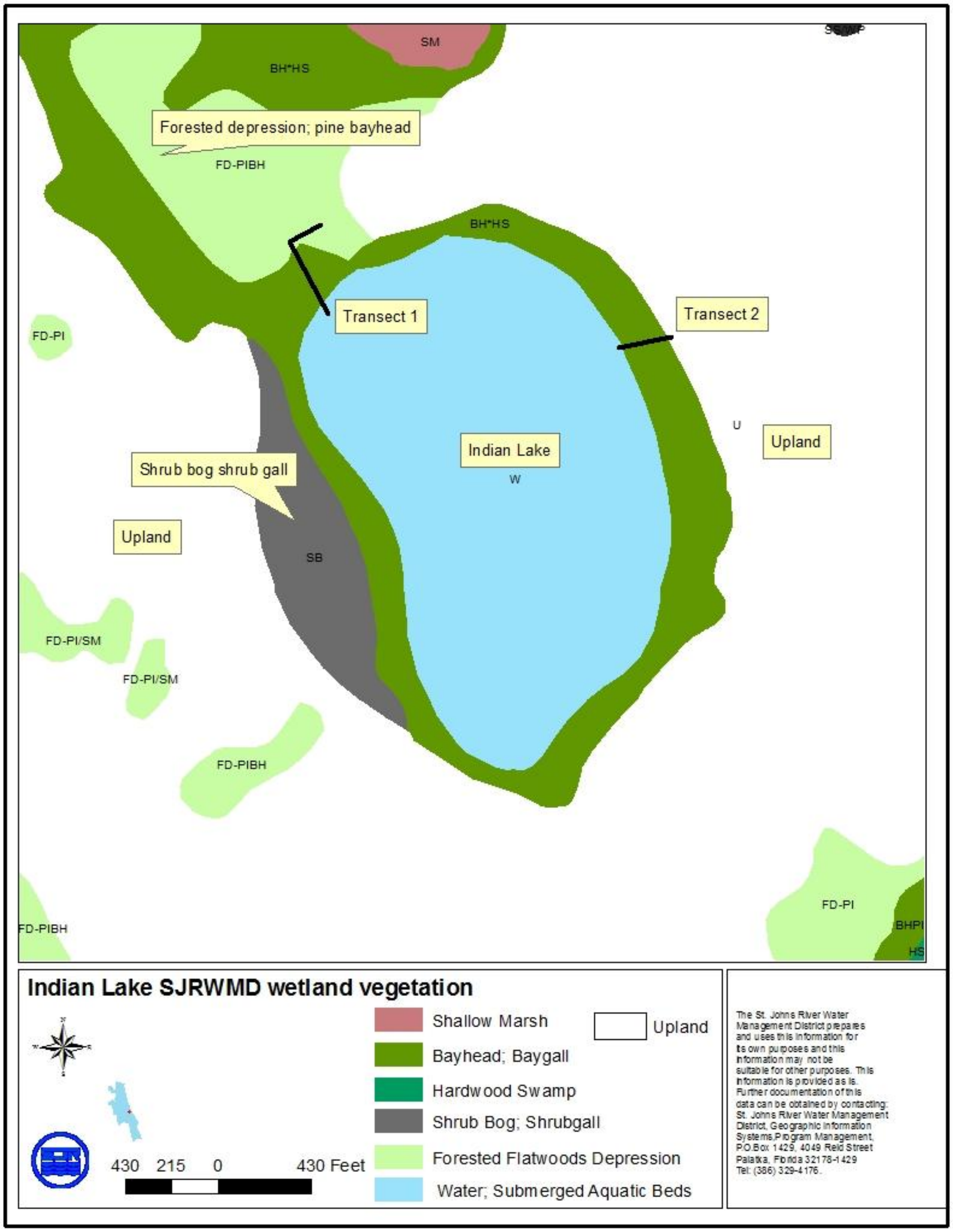

Figure 8. Indian Lake wetland vegetation map

FD-PI = forested depression-
FD-PIBH =

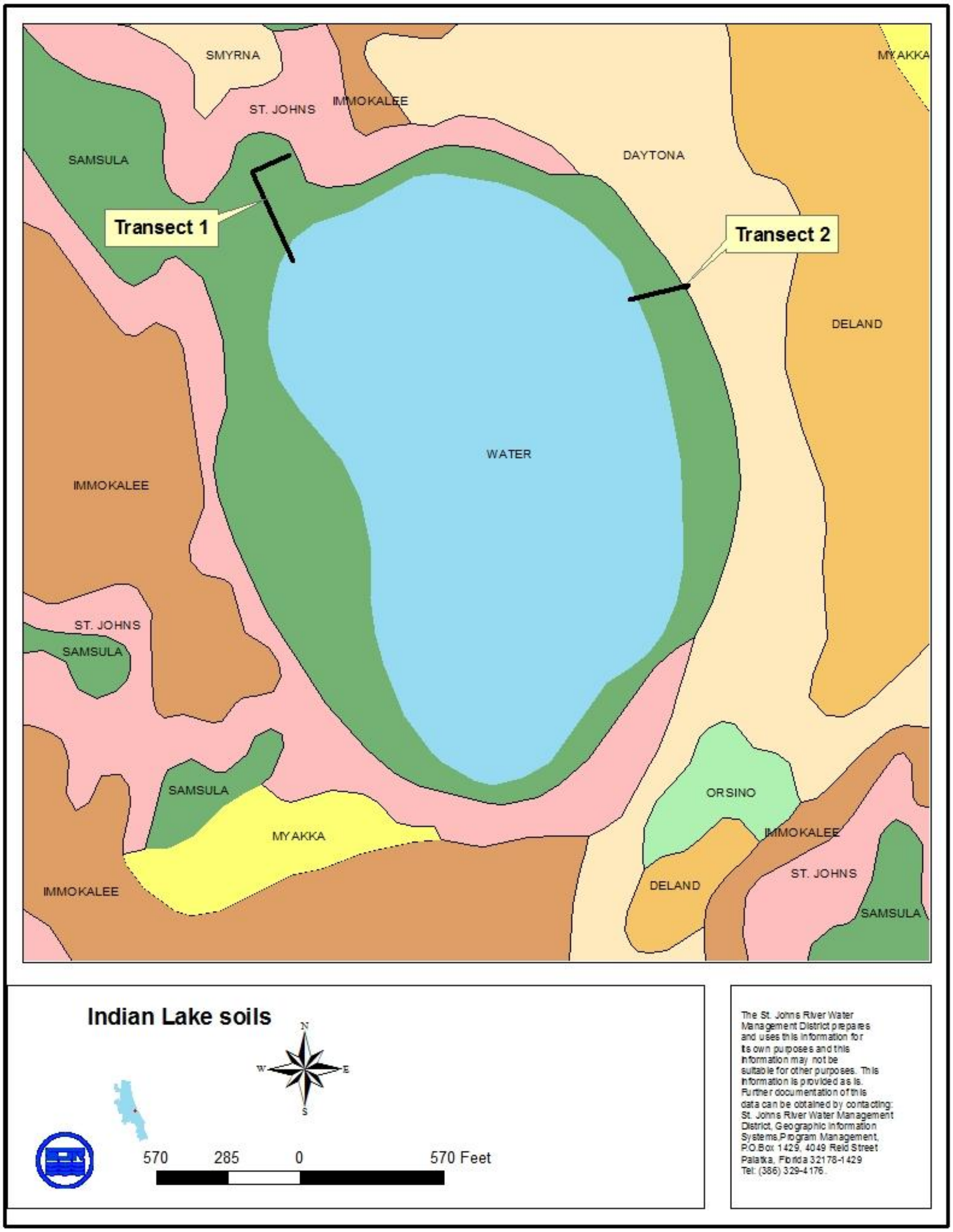

Figure 9. Indian Lake soil series map

RESULTS AND DISCUSSION

To reevaluate and recommend MFLs for Indian Lake in 2007, elevation, soils, and vegetation field data were obtained at two transect locations. This section describes the Indian Lake transect site selection criteria, the data collected at each transect location, the primary level determination criteria, concluding with a description of the MFLs determinations for Indian Lake.

FIELD DATA TRANSECT 1

Transect 1 was located on the north shore of Indian Lake to characterize the shallow marsh, hardwood swamp, bayhead, and low flatwoods communities at this location (Table 2; Figure 8 and Figure 10. At Transect 1, the bayhead community is relatively broad, extending to the north toward Coon Pond and Scoggin Lake.

Table 2. Transect 1 location and fieldwork dates

Latitude, Longitude (Station 0; low flatwoods)	Latitude, Longitude (Station 169; bayhead and direction change)	Latitude, Longitude (Station 560; lake edge–open water)	Transect 1—Location and Dates of Fieldwork
29 10 17.71, 81 10 02.99	29 10 17.08, 81 10 04.66	29 10 13.60, 81 10 02.69	North shore of Indian Lake, April–May 2007

Note: Degrees, minutes, seconds

Vegetation at Transect 1

Transect 1 began in the low flatwoods (stations 0–70) and traversed 169 ft in a southwesterly direction and then an additional 391 ft in a southerly direction through a transitional low flatwoods-bayhead (stations 70–90), a bayhead (stations 90–380), a hardwood swamp (stations 380–430), a shallow marsh (430–540), and terminated in the open water of Indian Lake (station 550–600) (Figures 10, 11, and 12; Tables 3 and 4).

The low flatwoods (stations 0–70) was a pine plantation containing slash pines less than 15 ft in height and approximately 7 years in age. The low flatwoods vegetation included abundant broomsedge (*Andropogon virginicus*) and Virginia chain fern (*Woodwardia virginica*); numerous saw palmetto (*Serenoa repens*), slash pine (*Pinus elliottii*), bracken fern (*Pteridium aquilinum*), and loblolly bay (*Gordonia lasianthus*) saplings; and scattered hatpins (*Eriocaulon sp*.) and sphagnum.

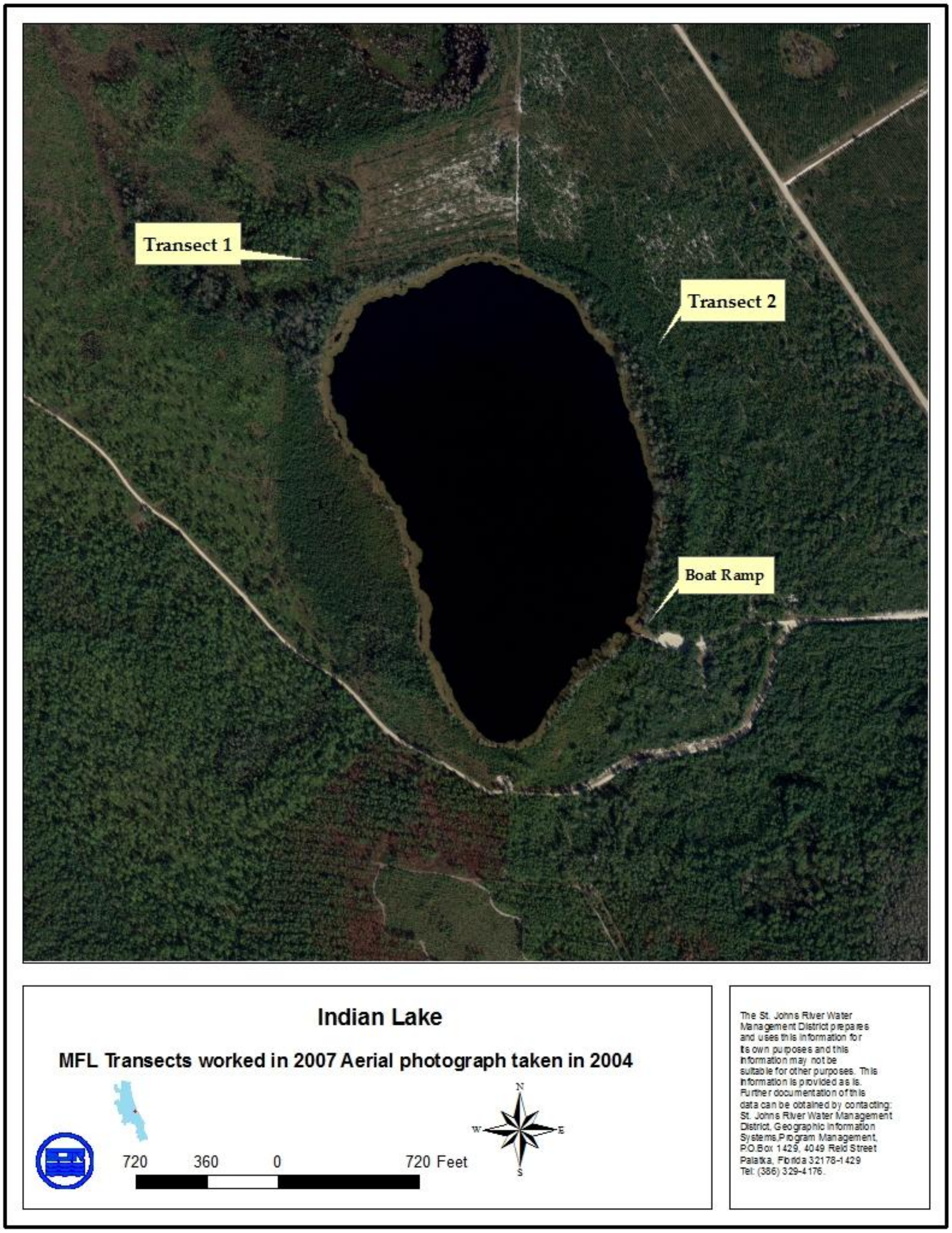

Figure 10. Aerial image of Indian Lake with Transects 1 and 2 denoted

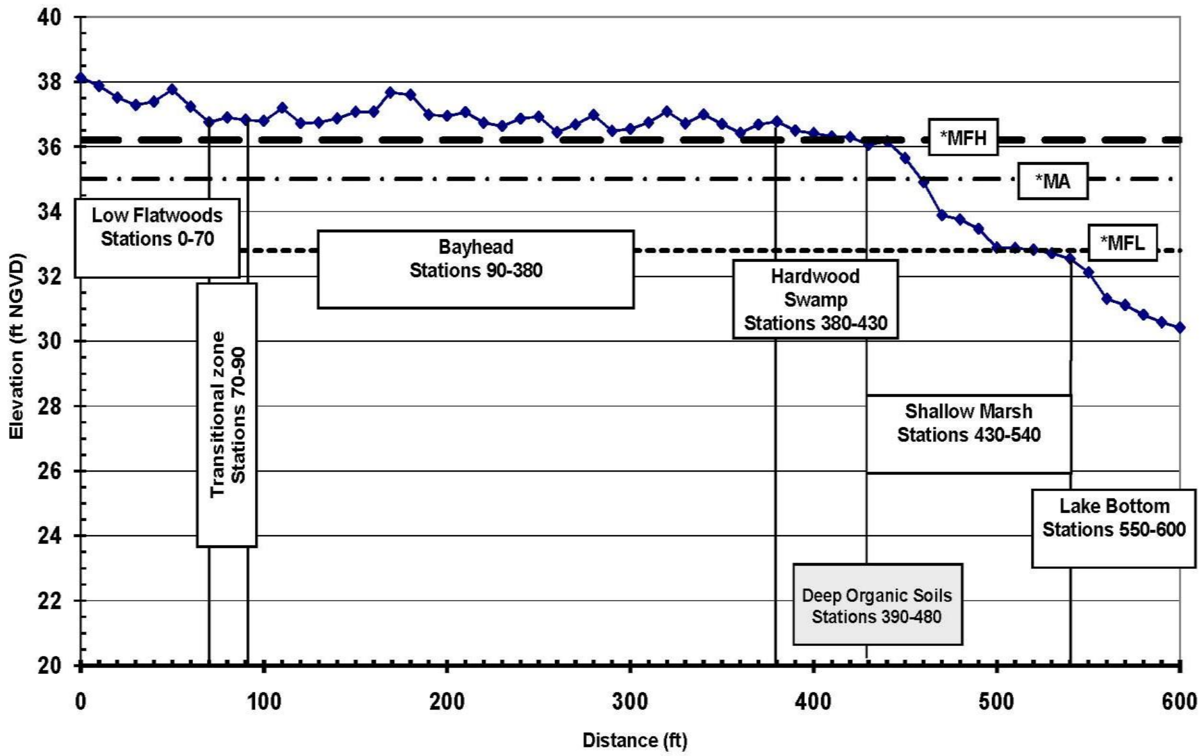

Figure 11. Indian Lake Transect 1 topography and ecological communities (*The minimum frequent high [MFH] equals 36.2 ft NGVD, the minimum average [MA] equals 35.0 ft NGVD, and the minimum frequent low [MFL] equals 33.6 ft NGVD)


Low flatwoods, station 60


Bayhead, station 300


Shallow marsh with hardwood swamp in background, station 500


Shallow marsh, station 470

Figure 12. Indian Lake Transect 1 photographs

Table 3. Indian Lake Transect 1 vegetation community elevation statistics

Vegetation Community	Station Distance (ft)	Mean (ft NGVD*)	Median (ft NGVD*)	Min (ft NGVD*)	Max (ft NGVD*)	N†
Low flatwoods	0–70	37.5	37.4	36.8	38.1	8
Transitional low flatwoods-bayhead community	70–90	36.8	36.8.	36.8	36.9	3
Bayhead	90–380	36.9	36.8	36.4	37.7	30
Hardwood swamp	380–430	36.4	36.4	36.0	36.8	6
Deep organic soils††	390–480	35.6	36.1	33.8	36.5	10
Shallow marsh	430–540	34.0	33.6	32.5	36.2	12
Open water Indian Lake	550–600	31.1	31.0	30.4	32.1	6

Note:
*ft NGVD is feet National Geodetic Vertical Datum

†N is the number of elevation readings surveyed in each vegetation community

††Histic epipedon or histosol sampled within the hardwood swamp and shallow marsh

Immediately adjacent to the low flatwoods was a transitional low flatwoods-bayhead community (stations 70–90). Transitional low flatwoods-bayhead community vegetation included abundant loblolly bay saplings; numerous fetterbush (*Lyonia lucida*) and Virginia chain fern; and scattered slash pine saplings.

Downslope from the transitional low flatwoods-bayhead community was a bayhead community (stations 90–380). Bayhead vegetation included codominant loblolly bay saplings and fetterbush, abundant cat briar (*Smillax* sp.), numerous muscadine grape (*Vitis rotundifolia*) and Virginia chain fern, and scattered slash pine. Within the bayhead, the loblolly bays were predominately saplings with scattered large (>12 in. diameter at breast height [dbh]) living trees. Additionally, numerous large, dead loblolly bays were still standing and blown-over. Presumably these large, dead loblolly bays were killed by the El Niño flooding during the winter of 1998 and/or by the wildfires of July 1998, which burned much of the land around Indian Lake.

Downslope from the bayhead, Transect 1 traversed a hardwood swamp (stations 380–430). Hardwood swamp vegetation included abundant loblolly bay saplings, fetterbush, swamp blechnum (*Blechnum serrulatum*), cat briar, and muscadine grape; numerous mature black gum (*Nyssa aquatica*); and scattered swamp bay (*Persea palustris*). Large loblolly bays were no longer living in the hardwood swamp, but were prevalent as dead windblown trees.

Downslope from the hardwood swamp, Transect 1 traversed a shallow marsh (stations 430–540). Shallow marsh vegetation included dominant para grass (*Urochloa mutica*); numerous maidencane (*Panicum hemitomon*) and swamp blechnum; and scattered saw grass (*Cladium jamaicense*). The swamp blechnum occurred in the shallow marsh only between stations 430 and 438, while the saw grass occurred only between stations 430 and 470. Coincidently, a break in slope occurs in the shallow marsh at station 470 (Figure 11). Additional plant species identified at Transect 1 are listed in Table 4.

Table 4. Indian Lake Transect 1 vegetation species list

Common Name	Scientific Name	FWDM Code*	Plant Communities† With Plant Species Cover Estimates††				
			LF	LF-BH	BH	HS	SM
Black gum	*Nyssa aquatica*	OBL				2	
Bracken fern	*Pteridium* sp.	FAC	2				
Broomsedge	*Andropogon virginicus*	FAC	3				
Cat brier	*Smilax* sp.	FAC			3	3	
Elliott's milkpea	*Galactia elliottii*	UPL	0				
Fetterbush	*Lyonia lucida*	FACW		2	4	3	
Hatpins	*Eriocaulon* sp.	OBL	1				
Loblolly bay	*Gordonia lasianthus*	FACW	2	3	3	3	0
Maidencane	*Panicum hemitomon*	OBL					2
Mayberry	*Vaccinium elliottii*	FAC	0				
Muscadine grape	*Vitis rotundifolia*	FAC			2	3	
Para grass	*Urochloa mutica*	FACW					5
Primrose willow	*Ludwigia peruviana*	OBL					0
Saw grass	*Cladium jamaicense*	OBL					1
Saw palmetto	*Serenoa repens*	UPL	2				
Slash pine (<15 ft tall)	*Pinus elliottii*	FACW	2	1	1		
Sphagnum	*Sphagnum* sp.	UPL	1				
Swamp bay	*Persea palustris*	OBL				1	
Swamp blechnum	*Blechnum serrulatum*	FACW				2-3	2
Virginia chainfern	*Woodwardia virginica*	FACW	3	2	2		

Note:
*FWDM code indicator categories established in *The Florida Wetlands Delineation Manual* (Gilbert et al. 1995):
UPL = Upland plants that occur rarely in wetlands, but occur almost always 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, which is subject to surface water flooding and/or soil saturation; rarely uplands

† Plant community abbreviations:
LF = low flatwoods (stations 0–70)
LF-BH = transition low flatwoods-bayhead (stations 70–90)
BH = bayhead (stations 90–380)
HS = hardwood swamp (stations 380–430)
SM = shallow marsh (stations 430–540)

††Plant Species Cover Estimates: Aerial extent of vegetation species along transect within given community where 0 = <1% (rare); 1 = 1%–10% (scattered); 2 = 11%–25% (numerous); 3 = 26%–50% (abundant); 4 = 51%–75% (codominant); 5 = > 75% (dominant)

Soils at Transect 1

Soils were mapped (Figure 9; SSURGO soil map) as Samsula muck the entire length of Transect 1. Soils sampled at Transect 1 on April 16 and May 1, 2007, by a professional soil scientist/consultant to SJRWMD, varied from the SSURGO map (Figure 9) delineation, presumably due to the map scale. Detailed soil sampling to identify the soil series occurred at five locations along Transect 1. Additional soil sampling to determine the hydric soil indicators and surface organic soil depths occurred at 15 other locations along Transect 1.

Hydric soils are defined as soils that form under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil (NRCS 2003). Certain characteristics are used to indicate wet ecosystems, such as accumulation of muck (histosol, histic epipedon) or the presence of reduced sulfur odor (rotten egg odor). Other hydric soil indicators are routinely used to delineate the extent of wetlands, which implies they form at the hydric/nonhydric soil edge (sandy redox, stripped matrix, and dark surface) (Carlisle and Hurt 2000). The hydric soil indicators identified at Transect 1 are listed below, as observed along the hydrologic gradient from stripped matrix and dark surface at the higher elevations, followed by muck presence as the elevation decreases, and grading to a thick accumulation of muck as the ground elevation drops further and the hydroperiod increases (Table 5).

- **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 is routinely used to delineate hydric soils throughout Florida (Carlisle and Hurt 2000). A stripped matrix has a seasonal high saturation within 6 in. of the soil surface.
- **Dark Surface**—A predominately black layer 4 in. or thicker starting within the upper 6 in. of the soil surface. The matrix color value is 3 or less and chroma is 1 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 2 or less (NRCS 2003). A dark surface has a seasonal high saturation within 6 in. of the soil surface (Carlisle and Hurt 2000).
- **Organic Bodies**—Presence of 2% or more organic bodies of muck or mucky modified texture, approximately 0.5 to 1 in. in diameter, and starting within 6 in. of the soil surface.

Table 5. Indian Lake Transect 1 Soil Descriptions

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
30	Deland	Hydric indicator →			Sandy dark surface (S7)	10YR
30		A1	0-7	Sandy loam	Loose granular structure; 20% uncoated grains; many fine roots	10YR 2/1
30		A2	7-12	Loamy sand	50% uncoated grains; no mottles; weak medium sub-angular blocky structure	10YR 3/1
30		E	12-51	Fine sand	Few medium 10YR 2/1 mottles; loose granular structure	10YR 8/1
30		Bh1	51-60	Loamy sand	Strong medium to coarse angular blocky structure; many medium-coarse plinthite nodules	10YR 3/1
30		Bh2	60-71	Loamy sand	Weak medium angular blocky structure; few fine 10YR 4/4 redox concentrations; many coarse N 2.5/ mottles	10YR 2/1
30		Bh3	71-80	Loamy sand	Many med to coarse N2.5/ plinthite nodules - very firm consistency	5YR 3/1
60		Hydric indicator →			Stripping (S6); sandy dark surface (S7)	
60		Oi	0-1	Peat (Fibric)	Duff	10YR
60		A1	1-4	Fine sand	Rubbed; 20% uncoated grains	10YR 2/1
60		A2	4-6	Fine sand	Rubbed; 30% uncoated grains; many distinct 10YR 6/1 pockets, uncoated grains, sharp boundaries	10YR 2/1
60		Eg	6-12	Fine sand	Rubbed; many fine faint to distinct 10YR6/1 and 7/1 redox depletions	10YR 4/1
70		Hydric indicator →			Mucky mineral (A7); dark surface (S7), stripping (S6)	
70		Oe	0-1	Mucky peat (Hemic)		2.5YR 3/4
70		A	1-5	Mucky fine sand		10YR 2/1
70		Eg	5-14	Fine sand	Rubbed; 80% uncoated fine sand; many faint-distinct N7/ and N8/ redox depletions; grading to VC N7/ sand pockets	N 5/

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
80		Hydric indicator	→		Mucky mineral (A7) and dark surface (S7) — No stripping	10YR
80		Oe	0–3	Mucky peat (Hemic)		2.5YR 3/4
80		A1	3–7	Mucky fine sand	5% uncoated grains; many fine roots	10YR 3/1
80		A2	7–10	Mucky fine sand	20% uncoated grains	N 2.5/
80		Eg	10–14	Fine sand		N 6/
90		Hydric indicator	→		Muck presence (A8 — landward extent), Dark surface (S7)	10YR
90		Oe	0–2	Mucky peat (Hemic)		2.5YR 3/4
90		Oa	2–8	Muck (Sapric)	Many fine roots; few uncoated grains (<2%)	10YR 2/1
90		A1	6–12	Sandy loam	30% uncoated grains	N 2.5/
190	St. Johns	Hydric indicator	→		Dark surface (S7), muck presence (A8)	
190		Oe	0–4	Mucky peat (Hemic)		5YR 3/4
190		Oa	4–6	Muck (Sapric)		10YR 2/1
190		A1	6–15	Mucky fine sand	5% uncoated grains grading to 50%	10YR 2/1
190		AE	15–21	Loamy sand	Loose granular structure; thin grain coatings	5YR 3/2
190		Bh1	21–27	Loamy sand	Loose granular structure	5YR 3/4
190		Bh2	27–37	Fine sand	Loose granular structure; many faint fine 5YR 3/4 mottles	5YR 4/6
190		Bw	37–49	Loamy sand	Weak medium sub-angular blocky structure	5YR 4/4
190		E'/C	49–70	Fine sand	Loose granular structure; few medium 10YR 3/2 pockets stained sand	10YR 6/3
190		B'h1	70–78	Fine sand	Loose granular structure; many medium faint 7.5 YR 2.5/1 mottles	7.5YR 4/2

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
190		B'h2	78–84	Fine sand	Weak medium to coarse sub-angular blocky structure	7.5YR 2.5/1
230		Hydric indicator		→	Muck presence (A8), dark surface (S7)	10YR
260		Hydric indicator		→	Muck presence (A8); organic bodies (A6); dark surface (S7)	
300	St. Johns	Hydric indicator		→	Muck presence (A8)	
300		Oi/Oe	0–6	Peat (Fibric)		7.5YR 2.5/3
300		A	6–11	Mucky fine sand	Rubbed; loose granular structure; muck grading to fine sand through horizon - 20% uncoated grains	10YR 3/1
300		E	11–17	Loamy sand	Rubbed; loose granular structure; many coarse pockets washed sand (10YR 7/1) redox depletions and few fine to med. 10YR 4/4 redox concentrations	10YR 2/1
300		Bh1	17–28	Sandy loam	Weak coarse sub-angular blocky structure	5YR 4/2
300		Bh2	28–46	Loamy sand	Moderate medium to coarse angular blocky structure; grading to 7.5 YR 4/2	7.5YR 4/3
300		Bw	46–54	Sandy loam	Strong medium to coarse sub-angular blocky structure	5YR 3/1
300		E'	54–68	Fine sand	Loose granular structure; grading to 10YR 8/3	10YR 8/1
300		B'h1	68–83	Fine sand	Loose granular structure	10YR 7/6
300		B'h2	83–90	Fine sand	Saturated loose granular structure	7.5YR 3/2
300		B'h2	83–90	Fine sand	Saturated loose granular structure	7.5YR 3/2
380		Hydric indicator		→	Histic epipedon (A2)	
380		Oe	0–5	Mucky peat (Hemic)		2.5YR 3/4
380		A1	5–10	Mucky fine sand	5% uncoated grains; many fine-coarse charcoal nodules	N 2.5/
380		Ob	10–14	Muck (Sapric)	Many 10YR 3/4 mottles	10YR 2/1
390		Hydric indicator		→	Histic epipedon (A2)	

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
390		Oe	0–5	Mucky peat (Hemic)		2.5YR 3/4
390		A1	5–10	Mucky fine sand	5% uncoated grains; many fine-coarse charcoal nodules	N 2.5/
390		Ob	10–14	Muck (Sapric)	Many 10YR 3/4 mottles	10YR 2/1
400		Hydric indicator		→	Histosol (A1)	
400		Oe	0–9	Mucky peat (Hemic)	Many fine to medium roots	5YR 3/4
400		Oa	9–20	Muck (Sapric)	Many 5YR 3/4 mottles as hemic; <1% uncoated grains; no stickiness	5YR 2.5/1
415		Hydric indicator		→	Histosol (A1)	
415		Oa	0–20	Muck (Sapric)		5YR 2.5/1
430	Samsula	Hydric indicator		→	Histosol (A1)	
430		Oe	0–3	Mucky peat (Hemic)		2.5YR 2.5/3
430		Oa	3–21	Muck (Sapric)	Strong fine to coarse sub-angular blocky structure; soft, plastic; not sticky	10YR 2/1
430		A1	21–28	Mucky fine sand	Strong medium to coarse structure; grading/parting to sandy loam	10YR 2/1
430		A2	28–36	Fine sand	10% uncoated grains; weak medium to coarse sub-angular blocky structure	10YR 2/1
430		Bh1	36–62	Fine sand		5YR 3/2
430		Bh2/Eb	62–72	Fine sand	Loose granular structure; few, very coarse distinct 10YR 5/4 pockets of sand	5YR 3/1
430		Bh3	72–82	Fine sand	Weak medium sub-angular blocky; common, coarse 10YR 4/2 mottles	10YR 3/1

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
470		Hydric indicator →			Histic epipedon (A2)	
470		Oe	0–3	Mucky peat (Hemic)		2.5YR 2.5/3
470		Oa	3–9	Muck (Sapric)		10YR 2/1
470		Eg	9–10	Fine sand	Washed sand	10YR 8/1
470		Bh1	10–16	Loamy sand	Few faint fine 5YR 3/3 redox concentrations as rhizospheres	5YR 2.5/1
480		Hydric indicator →			Histic epipedon (A2) - waterward extent; stratified layers (A6)	
480		Oe	0–3	Mucky peat (Hemic)	50% fibers; 20% rubbed;	10YR 2/1
480		Oa	3–8	Muck (Sapric)	10% fibers; < 5% after rubbing	10YR 2/1
480		A1	8–9	Fine sand	Washed sand	10YR 7/1
480		A2	9–14	Fine sand		7.5YR 2.5/1
490		Hydric indicator →			Muck presence (A8) — Same epipedon as 480 above except Oe + Oa are 7" thick combined	
500		Hydric indicator →			Muck presence (A8); Stratified layers (A5)	
500		Oe	0–1	Mucky peat (Hemic)		2.5YR 2.5/3
500		Oa	1–3	Muck (Sapric)		10YR 2/1
500		E/Ab	3–5	Fine sand	Many medium to coarse 10YR 2/2 pockets coated sand	10YR 7/1
500		Ab	5–14	Loamy sand	Few very coarse pockets washed sand	2.5YR 3/1
540	Smyrna	Hydric indicator →			Muck presence (A8); stratified layers (A5)	
540		Oa	0–4	Muck (Sapric)	Streaks of mucky fine sand and mucky peat	10YR 2/1
540		Eg	4–6	Fine sand	Single grain structure	10YR 7/2
540		Bh	6–22	Fine sandy loam	Medium to coarse sub-angular blocky structure;	10YR 3/1

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
540		E'	22–40	Fine sand	Loose granular structure; few very coarse pockets 10YR 6/1 washed sand	10YR 4/2
540		B'h	40–62	Loamy sand	Weak medium to coarse sub-angular blocky structure; many coarse 5YR 4/2 mottles; Augured to refusal	5YR 2.5/1
555		Hydric indicator		→	Muck presence (A8) — lakebed	
560		Hydric indicator		→	No muck — lake bed	

- **Mucky Mineral—**A mucky modified mineral surface layer at least 2 in. thick, starting within 6 in. of the soil surface (NRCS 2003). Mucky mineral has a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).
- **Muck Presence**—A layer of muck of any thickness that occurs within the upper 6 in. of the soil surface and contains a color value of 3 or less and chroma of 1 or less. This indicator is used in land resource regions U, V, and Z (NRCS 2003). Muck presence has a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).
- **Histic Epipedon**—A surface organic layer that is 8 to 16 in. thick. The required organic carbon content in the histic epipedon is dependent on clay content (NRCS 2003). Histic epipedons have a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).
- **Histosol**—A soil that has organic soil material in more than half of the upper 80 cm (32 in.) or any thickness if overlying rock (NRCS 2003). Histosols have a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).

Beginning at station 30, in the low flatwoods community (stations 0–70) at Transect 1, the soil series was identified as DeLand. The DeLand soil series consists of very deep, well-drained, moderately permeable soils on low, broad, sand hills. The water table in DeLand soil fluctuates between depths of 75 to 90 in. during periods of high rainfall (NRCS 2007). The DeLand soil sampled at station 30 was comprised of sandy loam, loamy sand, and fine sand, with a hydric soil indicator of dark surface. DeLand soil is in the soil taxonomic classification subgroup Entic Grossarenic. The soil taxonomic classification subgroup provides additional information for each soil series and is interpreted starting at the right-hand side of the subgroup name and progressing to the left (Table 5). Entic Grossarenic soils contain a spodic horizon dominated by aluminum complexes. The spodic horizon is a hardpan layer that impedes vertical water movement. The adjective grossarenic indicates that the spodic horizon occurs greater than 40 in. below the soil surface (JEA Inc. 2004). Meanwhile, the adjective entic indicates that the upper portion (2 cm) of the spodic horizon has less than 3% organic carbon.

Traversing downslope within the low flatwoods, the hydric soil indicators of stripping and dark surface were observed at station 60, while hydric soil indicators of mucky mineral, dark surface, and stripping were observed at station 70.

Continuing downslope into the transitional low flatwoods-bayhead vegetation community (stations 70–90), hydric soil indicators mucky mineral, dark surface, and stripping were observed at station 80, while muck presence and dark surface were observed at station 90.

Adjacent and downslope of the transitional low flatwoods-bayhead vegetation community, the soil series was identified as St. Johns at station 190 in the bayhead vegetation community (stations 90–380). St. Johns series soils are very deep, very poorly or poorly drained, moderately permeable mineral soils located on broad flats and depressional areas of the lower coastal plain (NRCS 2007). The water table in St. Johns series soil ranges from the soil surface to 15 in. below the soil surface for 20% to 50% of the year but may range between 15 and 30 in. below the soil surface during periods of low rainfall. Depressional areas with St. Johns soil are ponded for 6 months or more during most years (NRCS 2007). The St. Johns soil sampled at station 190 contained a shallow surface organic horizon (6 in. thick), underlain by mucky fine sand, loamy sand, and fine sand with the hydric soil indicators of dark surface and muck presence.

St. Johns soil is in the soil taxonomic classification subgroup Typic Alaquods. Typic Alaquods are spodosols with a subsurface accumulation of organic matter and oxides of aluminum and/or iron. The spodic horizon is a hardpan layer that impedes vertical water movement and can cause surface saturation during high rain events. The hardpan layer, combined with a low landscape position, contributes to the poorly drained moisture classification of St. Johns soil. Typic Alaquods have an aquic moisture regime, which indicates the soils are saturated with water and virtually free of gaseous oxygen for periods sufficient to induce poor aeration (Brady and Weil 1996). Typic Alaquods contain a light-colored albic horizon. The adjective typic indicates that this soil subgroup does not have lithic, duric, histic, arenic, grossarenic, alfic, ultic, or aeric characteristics (NRCS 2003).

Continuing downslope within the bayhead vegetation community, soils were sampled to determine the hydric soil indicators at stations 230 and 260. Based on shallow soil sampling, the soil at these locations resembled the St. Johns series and contained hydric indicators of dark surface and muck presence at both locations. Additionally, the organic bodies' hydric indicator was observed at station 260. Continuing downslope and lakeward in the bayhead vegetation community, St. Johns series occurred again at station 300 with the hydric soil indicator histic epipedon (Table 5).

Downslope from the bayhead vegetation community, soil sampling in the hardwood swamp (stations 380–430) to determine hydric soil indicators occurred at stations 390, 400, and 415. In addition, the soil series was determined at station 430 at the hardwood swamp-shallow marsh ecotone. Hydric soil indicators observed within the hardwood swamp were histic epipedon (station 390) and histosol (stations 400, 415, and 430), indicative of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil (NRCS 2003). The soil series identified at station 430 was Samsula. The Samsula series consists of very deep, very poorly drained, rapidly permeable organic soils that formed in moderately thick beds of hydrophilic plant remains. These organic soils typically occur in swamps, poorly defined drainageways, and floodplains (NRCS 2007). The Samsula muck soil water table occurs at or above the soil surface except during extended dry periods (NRCS 2007).

Samsula muck is in the taxonomic classification subgroup Terric Haplosaprist. Terric Haplosaprists are histosols, which are soils where more than half of the upper 32 in. is dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low and water-holding capacity is very high in mucks (Carlisle and Hurt 2000). Haplosaprists are simple soils with minimum horizon development. Terric Haplosaprists have a mineral horizon 12 in. or more thick with its upper boundary in the control section (NRCS 2003). The control section of a soil is that part of the soil on which the classification is based and varies among different kinds of soil. The control section for a histosol is from 10 to 40 in. below the soil surface (NRCS 2003).

Continuing downslope into the shallow marsh (stations 430–540), soil sampling occurred at stations 470, 480, 490, and 500 to identify the hydric soil indicators. Additionally, the soil series was determined at station 540, at the lake edge of the shallow marsh. Shallow marsh hydric soil indicators were histosol, histic epipedon, muck presence, and stratified layers (Table 5). Notably, the organic soil depth decreased in the shallow marsh at Transect 1, as the elevation decreased, and the transect extended toward the open water of Indian Lake. Comparing the 2004 aerial photograph (Figure 13) of Indian Lake with the 1984 aerial photograph (Figure 14) indicates that during the 20-year period the shallow marsh at Transect 1 has extended into what had been open water in 1984. The dominant shallow marsh vegetation, para grass, is attached to the shallow marsh sediment and contains long rhizomes, which allow the para grass to float up and remain visible during times of deep inundation. Thus, the open water adjacent to the shallow marsh in 1984 most likely did not include inundated vegetation, and the organic soil depths observed in 2007 at Indian Lake are less deep at the lower elevations in the shallow marsh, where the vegetation is relatively new.

The Smyrna soil series was observed at the shallow marsh-lakeshore ecotone (station 540). Smyrna soil is a poorly to very poorly drained mineral soil with a soil water table that occurs at depths of less than 18 in. below the soil surface for 1 to 4 months in most years. The soil water table is between 12 and 40 in. below the soil surface for more than 6 months. In the rainy season, the water table briefly rises above the soil surface and in depressions, and water stands above the surface for 6 to 9 months or more in most years (NRCS 2007). The soil taxonomic classification subgroup for Smyrna soil is Aeric Alaquods.

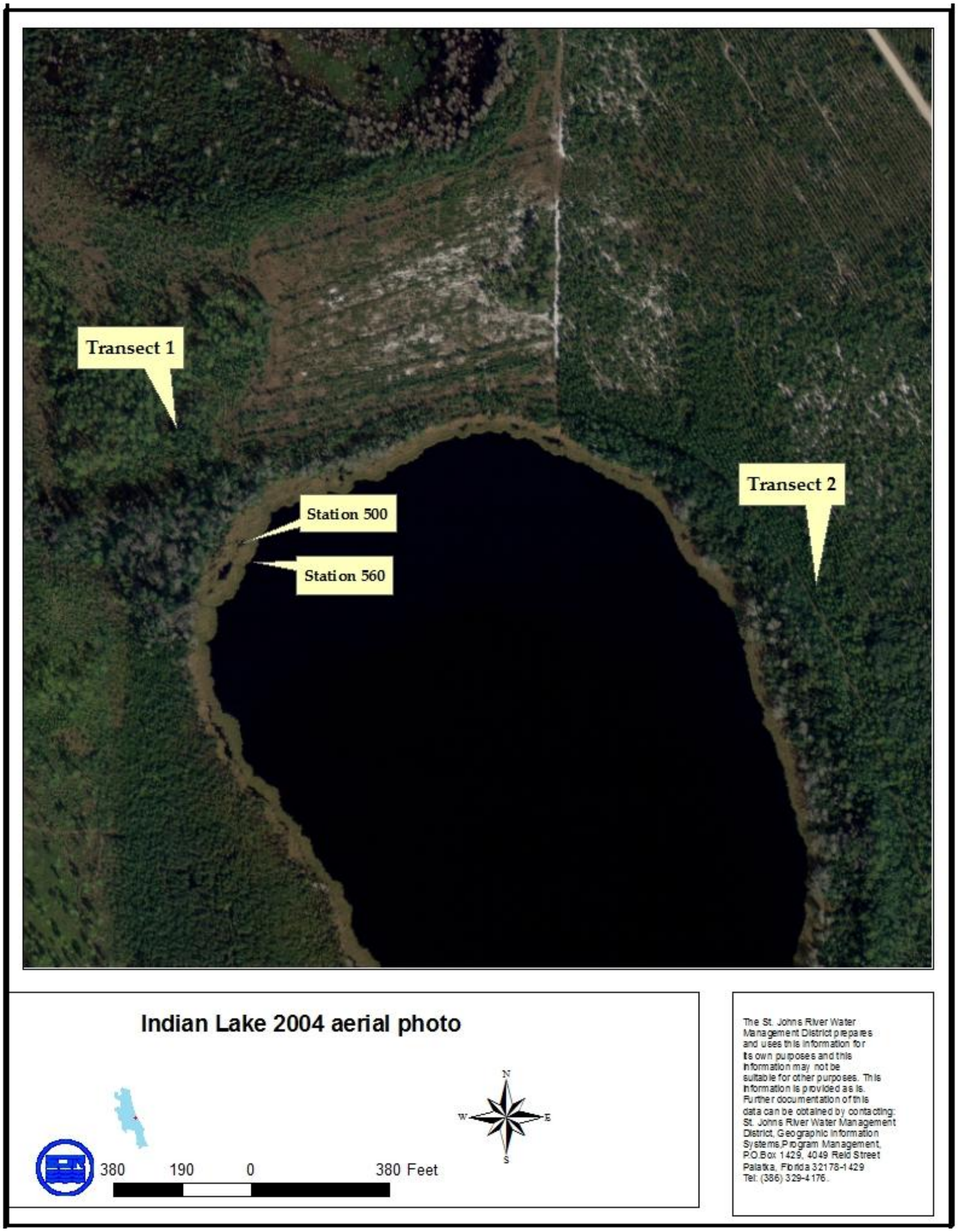

Figure 13. 2004 aerial photograph illustrating shallow marsh extent

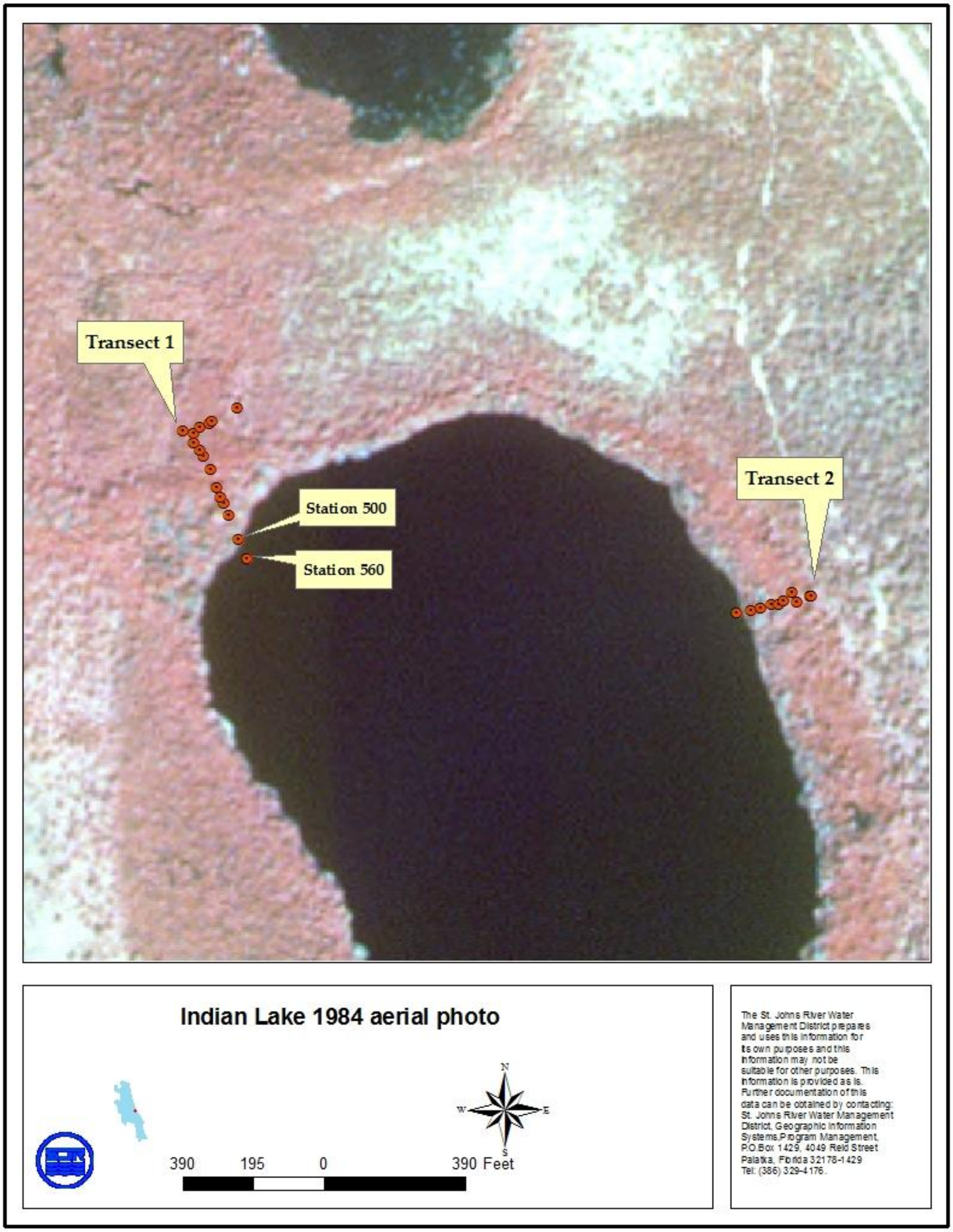

Figure 14. 1984 aerial photograph illustrating greater extent of open water at transects

Aeric Alaquods are spodosols characterized by a subsurface horizon with an accumulation of organic matter and oxides of aluminum with or without iron oxides (Brady and Weil 1996). An aquic moisture regime indicates that the soils are saturated with water and virtually free of gaseous oxygen periods sufficient for poor aeration to occur (Brady and Weil 1996). Aeric Alaquods contain a light-colored albic horizon above a spodic horizon and an ochric epipedon. Aeric Alaquods are alaquods that have an ochric epipedon. The ochric epipedon fails to meet the definitions of 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 (JEA Inc. 2004).

Ssoils were shallowly sampled within the lake bottom at stations 555 and 560 to identify possible organic horizons (Table 5). At station 555, a shallow organic horizon was observed (<8 in. thick), while at station 560 no organic horizon was identified.

In summary, the soils observed at Transect 1 within the low flatwoods, the transitional low flatwoods-bayhead, and the bayhead vegetation communities were mineral with hydric soil indicators. The hydric soil indicators ranged from stripped matrix and dark surface at the higher elevations to mucky mineral and muck presence in the bayhead. The hydric soil indicators emphasize the wet conditions typical in the bayhead and low flatwoods adjacent to Indian Lake. Organic soils, indicative of long-term soil saturation or inundation, were observed in the hardwood swamp and upper elevations of the shallow marsh at Transect 1 (Table 5). Additionally, groundwater discharge from the upland to the edge of the floodplain, occurring along the transitional low flatwoods-bayhead vegetation community, may contribute to the anaerobic soil conditions within the bayhead and hardwood swamp and promote organic soil development (Lindbo and Richardson 2001).

FIELD DATA TRANSECT 2

Transect 2 was located on the east shore of Indian Lake (Figures 10, 15 and 16). This transect site was established in order to characterize the shallow marsh, hardwood swamp, and bayhead communities at this location (Table 6). An additional noteworthy characteristic of Transect 2 was the numerous pond cypress (*Taxodium ascendens*) within the hardwood swamp.

Table 6. Transect 2 location and fieldwork dates

Latitude, Longitude (Station 26; edge of water)	Latitude, Longitude (Station 250; upland end)	Transect 2—Location and Dates of Fieldwork
29 10 12.11, 81 09 47.44	29 10 12.59, 81 09 45.10	East shore of Indian Lake, April and May 2007

Note: Degrees, minutes, seconds

Vegetation at Transect 2

Transect 2 originated in the open water of Indian Lake, approximately 23 ft from the waterward edge of the shallow marsh. This transect traversed 250 ft in an easterly direction through a shallow marsh, a hardwood swamp, a bayhead, a transitional low flatwoods-bayhead, and terminated within a low flatwoods community (Figures 8, 15 and 16; Tables 7 and 8).

Table 7. Indian Lake Transect 2 vegetation community elevation statistics

Vegetation Community	Stations Distance (ft)	Mean (ft NGVD*)	Median (ft NGVD*)	Min (ft NGVD*)	Max (ft NGVD*)	N†
Open water	0–23	30.6	30.6	30.2	31.0	4
Shallow marsh	23–70	34.0	34.5	31.0	36.6	6
Deep organic soils††	23–140	35.1	35.8	31.0	36.6	13
Hardwood swamp	70–140	36.1	36.2	35.1	36.6	8
Bayhead	140–210	37.1	37.2	36.1	37.7	8
Transitional low flatwoods-bayhead	210–240	38.0	38.0	37.4	38.8	4
Low flatwoods	240–250	38.7	38.7	.38.2	39.3	2

Note:
†ft NGVD = feet National Geodetic Vertical Datum
N = the number of elevation readings surveyed in each vegetation community

††Histic epipedon or histosol sampled in the shallow marsh and hardwood swamp. At Transect 2, the deep organic soils extended to station 200 in the bayhead vegetation community.

The shallow marsh (stations 23–70) vegetation included codominant para grass; abundant primrose willow (*Ludwigia peruviana)* and swamp blechnum; numerous buttonbush (*Cephalanthus occidentalis*) and fetterbush; and scattered maidencane, wax myrtle (*Myrica cerifera*), and loblolly bay saplings.

Adjacent to the shallow marsh, Transect 2 traversed a hardwood swamp (stations 70–140). The overstory vegetation within the hardwood swamp included abundant to numerous pond cypress; numerous dead loblolly bay; and scattered black gum (*Nyssa aquatica*). The hardwood swamp mid-canopy vegetation included abundant fetterbush; numerous loblolly bay saplings, cat briar, and muscadine grape; and scattered buttonbush and wax myrtle. The hardwood swamp understory vegetation included abundant swamp blechnum and scattered maidencane.

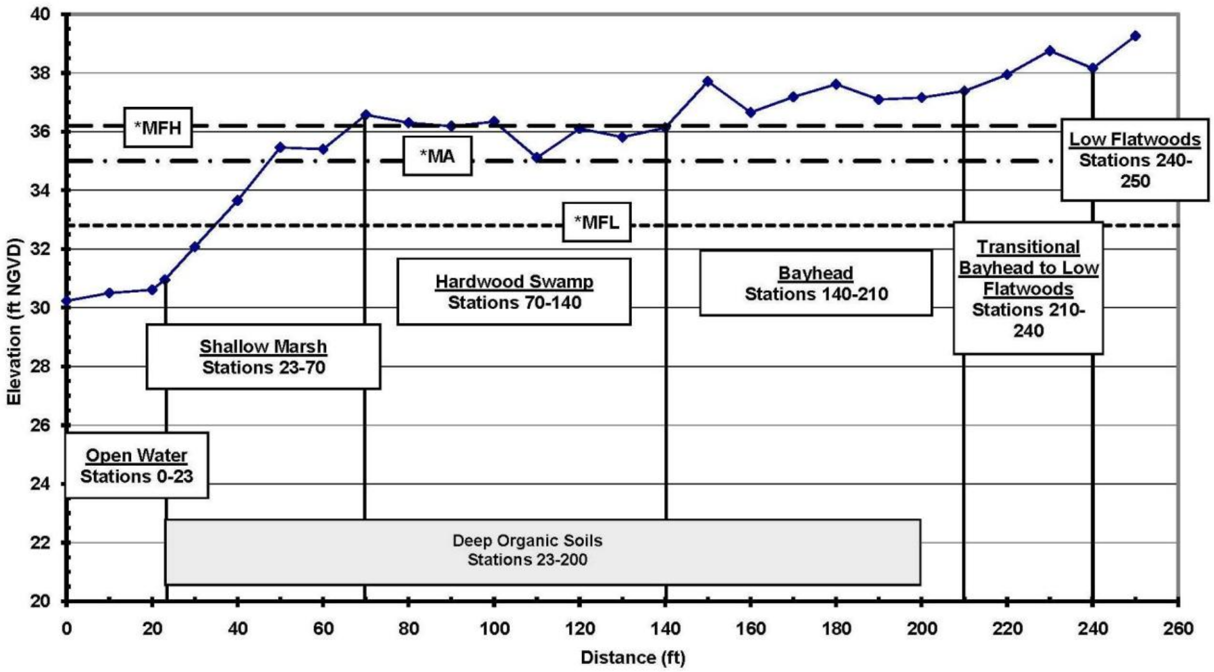

Figure 15. Indian Lake Transect 2 topography and ecological communities (*The minimum frequent high (MFH) equals 36.2 ft NGVD, the minimum average (MA) equals 35.0 ft NGVD, and the minimum frequent low (MFL) equals 33.6 ft NGVD)

Shallow marsh, station 40 looking north

Hardwood swamp, station 70

Bayhead, station 140

Transitional bayhead to low flatwoods, station 220

Low flatwoods to the right in photo; fire trail at station 235

Figure 16. Indian Lake Transect 2 photographs

Adjacent and upslope of the hardwood swamp, Transect 2 traversed a bayhead (stations 140–210). The bayhead overstory vegetation included abundant living, mature loblolly bay. The bayhead mid-canopy vegetation included codominant fetterbush; and abundant loblolly bay saplings and cat briar. The thick mid-canopy of fetterbush and loblolly bay saplings prevented understory vegetation in the bayhead.

Adjacent and upslope of the bayhead, Transect 2 traversed a transitional low flatwoods-bayhead (stations 210–240). The transitional low flatwoods-bayhead overstory was sparsely vegetated with scattered mature loblolly bay. The transitional low flatwoods-bayhead mid-canopy vegetation included abundant loblolly bay saplings and fetterbush; numerous muscadine grape, cat briar, and scattered mayberry. The transitional low flatwoods-bayhead understory vegetation included numerous saw palmetto and scattered Virginia chain fern.

Transect 2 terminated in a low flatwoods community. The low flatwoods vegetation at Transect 2 was similar to the adjacent transitional low flatwoods-bayhead vegetation except for the presence of planted slash pine. The slash pines were approximately 6 in. to 8 in. dbh. Additional vegetation species identified at Transect 2 are listed in Table 8.

Table 8. Indian Lake Transect 2 vegetation species list

Common Name	Scientific Name	FWDM Code*	Plant Communities† With Plant Species Cover Estimates††				
			SM	HS	BH	LF-BH	LF
Bracken fern	*Pteridium* sp.	FAC					0
Buttonbush	*Cephalanthus occidentalis*	OBL	2	1			
Cat brier	*Smilax* sp.	FAC		2	3	2	1
Fetter-bush	*Lyonia lucida*	FACW	2	3	4	3	1
Loblolly bay mature	*Gordonia lasianthus*	FACW		0	3	1	
Loblolly bay saplings	*Gordonia lasianthus*	FACW	1	2	3	3	2
Maidencane	*Panicum hemitomon*	OBL	1	1			
Mayberry	*Vaccinium elliottii*	FAC				0	
Muscadine grape	*Vitis rotundifolia*	FAC		2		2	
Para grass	*Urochloa mutica*	FACW	4				
Pond cypress	*Taxodium ascendens*	OBL		2-3			
Primrose willow	*Ludwigia peruviana*	OBL	3				
Saw palmetto	*Serenoa repens*	UPL				2	2
Slash pine (<15 ft tall)	*Pinus elliottii*	FACW		0		0	3
Swamp bay	*Persea palustris*	OBL		1			
Swamp blechnum	*Blechnum serrulatum*	FACW	2	2			
Virginia chainfern	*Woodwardia virginica*	FACW				1	
Wax myrtle	*Myrica cerifera*	FAC	1	1			
Winged sumac	*Rhus copallina*	UPL				0	

Note:
*FWDM code indicator categories established in *The Florida Wetlands Delineation Manual* (Gilbert et al. 1995):
UPL = Upland plants that occur rarely in wetlands, but occur almost always 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, which is subject to surface water flooding and/or soil saturation; rarely uplands
† Plant community abbreviations:
LF = low flatwoods (stations 0–70)
LF-BH = transition low flatwoods-bayhead (stations 70–90)
BH = bayhead (stations 90–380)
HS = hardwood swamp (stations 380–430)
SM = shallow marsh (stations 430–540)
††Plant Species Cover Estimates: Aerial extent of vegetation species along transect within given community where 0 = <1% (rare); 1 = 1%–10% (scattered); 2 = 11%–25% (numerous); 3 = 26%–50% (abundant); 4 = 51%–75% (codominant); 5 = > 75% (dominant)

Soils at Transect 2

Soils were mapped (Figure 9; SSURGO map 2001) as Samsula muck the entire length of Transect 2. Soils sampled at Transect 2 on May 1, 2007, with a professional soil scientist/consultant to SJRWMD, varied from the SSURGO map (Figure 9) delineation, presumably due to the map scale. Detailed soil sampling to identify the soil series occurred at three locations along Transect 2. Additional soil sampling to determine the hydric soil indicators and surface organic soil depths occurred at nine other locations along Transect 2 (Table 9).

As mentioned previously, hydric soils are defined as soils that form under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil (NRCS 2003). Certain characteristics are used to indicate wet ecosystems, such as accumulation of muck (histosol, histic epipedon) or the presence of reduced sulfur odor (rotten egg odor). Other hydric soil indicators are routinely used to delineate the extent of wetlands, which implies they form at the hydric/nonhydric soil edge (sandy redox, stripped matrix, and dark surface) (Carlisle and Hurt 2000). The hydric soil indicators identified at Transect 2 were dark surface at the higher elevation of the transitional low flatwoods-bayhead, followed by histic epipedon in the bayhead, and grading to a thick accumulation of muck in the hardwood swamp and shallow marsh as the ground elevation decreased further and the hydroperiod increased (Table 9).

Beginning in the higher elevations at Transect 2, soils were sampled in the transitional low flatwoods-bayhead vegetation community at station 220. The soil at station 220 was identified as St. Johns series with a hydric soil indicator of dark surface. St. Johns series soils are very deep, very poorly or poorly drained, moderately permeable mineral soils located on broad flats and depressional areas of the lower coastal plain (USDA,NRCS 2007). The water table in St. Johns series soil ranges from the soil surface to 15 in. below the soil surface for 20% to 50% of the year, but may range between 15 and 30 in. below the soil surface during periods of low rainfall. Depressional areas with St. Johns soil are ponded for 6 months or more during most years (NRCS 2007).

St. Johns soil is in the soil taxonomic classification subgroup Typic Alaquods. Typic Alaquods are spodosols with a subsurface accumulation of organic matter and oxides of aluminum and/or iron. The spodic horizon is a hardpan layer that impedes vertical water movement and can cause surface saturation during high rain events. The hardpan layer, combined with a low landscape position, contributes to the poorly drained moisture classification of St. Johns soil. Typic Alaquods have an aquic moisture regime, which indicates the soils are saturated with water and virtually free of gaseous oxygen for sufficient periods to induce poor aeration (Brady and Weil 1996). Typic Alaquods contain a light-colored albic horizon. The adjective typic indicates that this soil subgroup does not have lithic, duric, histic, arenic, grossarenic, alfic, ultic, or aeric characteristics (NRCS 2003).

Table 9. Indian Lake Transect 2 Soil Descriptions

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
20		Hydric indicator →			Histic epipedon (A2)	
25		Hydric indicator →			Histosol (A1)	
25		Oe	0–3	Mucky peat (Hemic)	60% fiber; 35% after rubbing	7.5YR 2.5/1
25		Oa1	3–11	Mucky peat (Hemic)	60% fibers; 10% after rubbing	5YR 2.5/2
25		Oa2	11–16	Muck (Sapric)	40% fibers; 5% after rubbing; no stickiness	5YR 3/1
35	Samsula	Hydric indicator →			Histosol (A1)	
35	Samsula	Oa1	0–6	Muck (Sapric)	30% fibers; 10% after rubbing; many fine to medium roots; weak fine sub-angular blocky structure	7.5YR 2.5/1
35	Samsula	Oa2	6–36	Muck (Sapric)	20% fibers; < 5% after rubbing; moderate coarse sub-angular blocky structure; no stickiness	5YR 2.5/2
35	Samsula	Bh1	36–44	Fine sand	Single grain structure; many distinct medium 7.5YR 4/1 mottles	7.5YR 4/3
35	Samsula	Bh2	44–54	Fine sand	Weak fine granular structure; few faint fine 10YR 5/3 mottles	7.5YR 3/2
35	Samsula	Bhv1	54–60	Loamy sand	Weak medium coarse sub-angular blocky structure; many medium 2.5YR 2.5/4 plinthite nodules	2.5YR 2.5/3
35	Samsula	Bhv2	60–80	Loamy fine sand	Single grain structure; few uncoated grains; parting to 2.5YR 3/4; many fine to medium plinthite nodules	2.5YR 3/1
50		Hydric indicator →			Histosol (A1) – likely Samsula	
60		Hydric indicator →			Histosol (A1) – likely Samsula	

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
80		Hydric indicator		→	Histosol (A1)	
100		Hydric indicator		→	Histosol (A1) - Muck greater than 24" <5% fibers after rubbing	
120		Hydric indicator		→	Histosol (A1) - > 24" Organic soil material	
140	Samsula	Hydric indicator		→	Histosol (A1)	
140		Oe	0–16	Mucky peat (Hemic)	70% fibers; 20% after rubbing; Weak fine to medium granular structure	7.5YR 2.5/2
140		Oa	16–34	Muck (Sapric)	10% fibers; <2% after rubbing; Weak coarse sub-angular blocky structure; few medium 5YR 6/1 sand pockets	2.5YR 2.5/1
140		E	34–41	Fine sand	10YR 8/1 dry single grain structure; many faint fine 10YR 6/1 mottles	10YR 7/2
140		Bh1	41–58	Loamy sand	Weak coarse granular structure	N 3/
140		Bh2	58–64	Loamy sand	Many coarse to very coarse N 2.5/ plinthite nodules; very firm consistency; weak coarse platy structure	2.5YR 2.5/3
140		Bh3	64–66		Ortstein; augured to refusal	
185		Hydric indicator		→	Histosol (A1) - landward extent of Histosol	
185		Oe	0	Mucky peat (Hemic)	< 15% fibers after rubbing; many fine to medium roots	2.5YR 3/4
185		Oa	7	Muck (Sapric)		N 2.5/
185		A1	18	Mucky fine sand	Few uncoated grains	N 2.5/
185		A2	24	Fine sand		10YR 2/1
200		Hydric indicator		→	Histic epipedon (A2) - begin landward	
200		Oe	0–6	Mucky peat	80% fibers; 30% after rubbing	2.5YR 2.5/4

Station	Soil Series	Horizon Name	Horizon depth (in.)	Texture	Soil Description	Soil Color
				(Hemic)		
200		Oa	6–11	Muck (Sapric)	Few uncoated grains on ped faces	N 2.5/
200		A	11–15	Sandy loam		10YR 2/1
220	St. Johns	Hydric indicator		→	Dark surface (S7)	
220		A	0–5	Fine sand	Weak fine granular structure; 30% uncoated grains	10YR 2/1
220		E1	5–12	Fine sand	Single grain structure	N 6/
220		E2	12–21	Fine sand	Single grain structure; many fine N2.5/ mottles as pore linings	N 7/
220		Bh1	21–26	Fine sand	Weak very fine granular structure; parting to moderate medium sub-angular blocky structure; common fine to medium 10YR 3/1 organic body concentrations	10YR 4/2
220		Bh2	26–46	Loamy sand	Weak fine to medium sub-angular blocky structure	5YR 2.5/1
220		Bh3	46–58	Fine sand	Weak medium granular structure	5YR 3/1
220		Bw	58–75	Loamy sand	Parting to N 2.5/ loamy sand; weak fine to medium sub-angular blocky structure	5YR 3/1
220		Bwv	75–84	Loamy sand	Weak fine sub-angular blocky structure; common medium plinthite nodules/masses (friable/soft)	5YR 2.5/2

Traversing downslope into the bayhead vegetation community (Figure 15; stations 140–210), soil sampling occurred at stations 200 and 185 to identify hydric soil indicators and surface organic horizon depths. Additional, detailed soil sampling to identify the soil series occurred at station 140. Hydric soil indicators observed at stations 200 and 185 were histic epipedon and histosol, respectively. As mentioned previously, histic epipedon is a surface organic layer that is 8 to 16 in. thick. The required organic carbon content in the histic epipedon is dependent on clay content (NRCS 2003). Histic epipedons have a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000). Meanwhile, histosol is a soil that has organic soil material in more than half of the upper 80 cm (32 in.) or of any thickness if overlying rock (NRCS 2003). Histosols have a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).

Continuing downslope at Transect 2, the soil series identified at station 140, the bayhead and hardwood swamp ecotone, was Samsula (Table 9). As mentioned previously, the Samsula series consists of very deep, very poorly drained, rapidly permeable organic soils that formed in moderately thick beds of hydrophilic plant remains. These organic soils typically occur in swamps, poorly defined drainageways, and floodplains (NRCS 2007). The Samsula muck soil water table occurs at or above the soil surface except during extended dry periods (NRCS 2007).

Samsula muck is in the taxonomic classification subgroup Terric Haplosaprist. Terric Haplosaprists are histisols, which are soils where more than half of the upper 32 in. is dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low and water-holding capacity is very high in mucks (Carlisle and Hurt 2000). Haplosaprists are simple soils with minimum horizon development. Terric Haplosaprists have a mineral horizon 12 in. or more thick, with its upper boundary in the control section (NRCS 2003). The control section of a soil is that part of the soil on which the classification is based and varies among different kinds of soil. The control section for a histosol is from 10 to 40 in. below the soil surface (NRCS 2003).

Continuing downslope, soils were sampled for hydric soil indicators at stations 120, 100, and 80, in the hardwood swamp at Transect 2. The histosol hydric soil indicator was observed at all soil sampling locations within the hardwood swamp. The thick accumulation of surface organic matter characteristic of a histosol is a response to longer and nearly continuous soil saturation or inundation in moderately thick beds of hydrophilic plant remains.

Downslope and adjacent to the hardwood swamp, Transect 2 traversed a shallow marsh (stations 23–70). Samsula series soil was observed at station 25 in the shallow marsh. As mentioned previously, Samsula series are deep organic soils that typically occur in swamps, poorly defined drainageways, and floodplains (NRCS 2007). The Samsula muck soil water table occurs at or above the soil surface except during extended dry periods (NRCS 2007).

Additional soil sampling in the shallow marsh at Transect 2 to identify hydric soil indicators and surface organic horizon depths occurred at stations 60, 50, and 25 (Table 9). The histosol hydric soil indicator was observed at all soil sampling locations within the shallow marsh. Again, the thick accumulation of surface organic matter characteristic of a histosol is a response to longer and nearly continuous soil saturation or inundation in moderately thick beds of hydrophilic plant remains.

Soils were shallowly sampled within the lake bottom at station 20 to identify possible organic horizons (Table 9). At station 20, histic epipedon was identified. As mentioned previously, histic epipedon is a surface organic layer that is 8 to 16 in. thick. Histic epipedons have a seasonal high saturation at the surface or inundation above the soil surface (Carlisle and Hurt 2000).

In summary, the soils observed at Transect 2 within the transitional low flatwoods-bayhead were mineral (St. Johns series), while all soils sampled downslope, in the bayhead, hardwood swamp, and shallow marsh communities, were organic soils. The organic soils, indicative of long-term soil saturation, or inundation, emphasize the wet conditions typical in the bayhead, hardwood swamp, and shallow marsh vegetation communities adjacent to Indian Lake. In addition, groundwater discharge from the upland to the edge of the floodplain, occurring along the transitional low flatwoods-bayhead vegetation community, may contribute to the anaerobic soil conditions within the bayhead and hardwood swamp and promote organic soil development (Lindbo and Richardson 2001).

STRUCTURAL ALTERATIONS AND OTHER CHANGES

No significant structural alterations exist in the Indian Lake Basin (CDM 2002). Minor alterations include several culverts located under the perimeter sand road. The majority of these culverts do not drain directly into Indian Lake and, except for along the south lakeshore, the perimeter road at Indian Lake is over 1,000 ft from the lake. On the southeast lakeshore, one culvert drains into Indian Lake, removing excess water from a pine plantation. The outfall elevation of this culvert is not known. Additionally, the dirt boat ramp is periodically reworked with heavy equipment due to erosion.

RELEVANT 62-40.473, *FLORIDA ADMINISTRATIVE CODE* (*F.A.C.*), ENVIRONMENTAL VALUES

Based on screening analysis (see Table 1), the following environmental values (Rule 62-40.473, *F.A.C.*) were determined to be relevant to identify the limiting conditions for MFLs development for Indian Lake:

- Recreation in and on the water
- Fish and wildlife habitats and the passage of fish
- Transfer of detrital material
- Maintenance of freshwater storage and supply
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Water quality
- Navigation

The following environmental values were determined not relevant to identify the limiting conditions for MFLs development for Indian Lake:

- Estuarine resources. This environmental value is not relevant because the Lower St. Johns River estuary is far downstream from Indian Lake (the lake is landlocked and has no surface water connection to any estuarine resources) outflow
- Sediment loads. This environmental value is not relevant to establishing MFLs for Indian Lake. Transport of inorganic materials as bed load is considered relevant only in flowing systems, where riverine fluvial dynamics are critical to the maintenance of geomorphic features (i.e., bed forms and the floodplain) and their associated ecological communities. These functions do not operate in lake systems. Lakes serve as sinks instead of sources of sediment load.

The environmental value, "fish and wildlife habitats and the passage of fish," was determined to be the most limiting environmental value to the further development of consumptive uses of surface and/or regional groundwater, and the primary criterion on which the Indian Lake MFLs were developed.

MINIMUM LEVELS DETERMINATION CRITERIA

Recommended, reevaluated minimum levels for Indian Lake are based on the concept that if the essential characteristics of the natural flooding and drying regime are maintained, then the basic structure and functions of the environmental system will be maintained. Each recommended minimum level is based primarily on elevation, soil, and vegetation community data collected in the Indian Lake floodplain. The elevations of the wetland communities in the Indian Lake floodplain can be associated with the long-term lake stage record, where typical durations and frequencies of flooding and drying are known. These wetland community elevations can be applied toward the development of recommended minimum levels. The standardized procedures for setting each level, using the best available information, as described in detail in the (draft) Minimum Flows and

Levels Methods Manual (SJRWMD 2006), was followed as the basis of developing the recommended minimum levels for Indian Lake. Minimum level criteria vary depending on the level being determined (i.e., MFH, MA, or MFL) and the on-site wetland community characteristics.

For example, the primary MFH criterion may equal the average elevation of a wetland community that experiences flooding approximately 20% of the time, based on the scientific literature and hydrologic data. Additional MFH criteria may include the maximum elevation of a vegetation community that typically floods frequently, and/or the elevation equal to the landward extent of the hydric soils or the landward extent of a shallow (depth < 8 in.) surface organic soil. The MFH level should maintain the seasonal flooding regime. Seasonal high water flows or levels occur in natural systems with unaltered hydrology that provide for out-of-bank flooding of the wetlands adjacent to the main stem of a river or lake at a duration and return interval sufficient to support important ecological processes (Hill et al. 1991). Levels equal to the MFH level should occur for at least 30 continuous days in the growing season at least every 2 to 3 years, on average. Aquatic biota rely on inundation of the floodplain for habitat and for the exchange of nutrients and organic matter (McArthur 1989). Flooding of wetlands and upland fringes redistributes and concentrates organic particulates across the floodplain (Junk et al. 1989).

At Indian Lake, the primary recommended MFH level criterion equaled the average elevation (36.2 ft NGVD) of all the hardwood swamp stations surveyed at Transects 1 and 2 in 2007. This level will ensure that the majority of the hardwood swamps are inundated at least every 1 to 3 years for a period of several weeks to several months. The hardwood swamp, average ground elevation is a MFH criterion used repeatedly in past SJRWMD MFLs determinations and is based on the scientific literature, indicating that hardwood swamps are typically flooded seasonally (Monk 1968). In addition, soil sampling indicated consistent organic soils across the hardwood swamps at Transects 1 and 2. These organic soil depths indicate that frequent and prolonged saturation or inundation is typical within the hardwood swamps at Transects 1 and 2.

The MA level represents the surface water level necessary over a long period to maintain the integrity of hydric soils and wetland plant communities. This level is considered the minimum that must be sustained for extended periods to maintain floodplain hydric soils and to impede the encroachment of upland plant species into the wetland plant communities. The MA level determination criteria typically focus on soil characteristics, when extensive histosols or histic epipedon are sampled. An appropriate MA water level is necessary to conserve the floodplain organic soils. Low water levels for extended periods cause oxidation of organic soils, ultimately resulting in soil subsidence. Consequently, due to the extensive organic soils identified at Indian Lake, the primary MA level criterion for Indian Lake equaled a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep organic soils observed in the shallow marsh and hardwood swamp surveyed at both Indian Lake transects. Deep organic soils are histosols

(≥16 in. thick surface organic horizon) or soils with histic epipedon (8 to 16 in. thick surface organic horizon). Deep organic soils are indicative of long-term soil saturation or inundation. The 0.3-ft drawdown will ensure saturated soil conditions, thereby preventing soil oxidation in the deep organic soils observed at Indian Lake.

This MA level criterion (0.3 ft below mean surface elevation of deep organic soils) has been used to protect muck soils in other MFLs determinations where extensive organic soils were sampled and was developed for Everglades peat soils (Stephens 1974). Studies of marshes in the Upper St. Johns River Basin (Brooks and Lowe 1984; Hall 1987) determined that this 0.3-ft depth corresponds to a water level exceeded approximately 60% of the time. Studies of the Wekiva River system found this hydrologic condition can also be expressed as the low stage occurring, on average, every 1 to 2 years, with a duration of ≤180 days (Hupalo et al. 1994).

When the Indian Lake stage equals the MA level, soil saturation at the average elevation of the deep organic soils sampled in the hardwood swamp and shallow marshes will impede the invasion of upland plant species into the hardwood swamps and shallow marshes and prevent organic soil oxidation. Meanwhile, shallow inundation at the lower elevations of the shallow marshes will provide aquatic refugia for numerous small fish, amphibians, and small reptiles. Also, the shallow water depths are ideal for wading bird foraging. Wading birds can only forage in relatively shallow water. Great egrets need water depths of less than 10 in., and the small herons need depths of less than 6 in. Dropping water levels cause fish to be concentrated in isolated sloughs throughout the shallow marshes. Birds effectively exploit these concentrations (Bancroft et al. 1990).

MFL level criteria also typically focus on soil characteristics if extensive histosols or histic epipedon were sampled. If deep (≥8 in. thick) continuous surface organic soils occur, the MFL level is based on a 20 to 30-in. soil water table drawdown from the average surface elevation of the deep organic soils. This 20 to 30-in. drawdown criterion was based on the best available supporting information from the literature, which described seasonally flooded marsh systems' average minimum dry season water table depth of 15.6 to 26.2 in. with an average hydroperiod of 255 ± 11.1 days (ESE 1991). Additionally, the soil surveys for Volusia (SCS 1980) and Brevard (SCS 1974) counties describe typical drought organic soils water table depths at 10 to 30 in. below the soil surface.

Due to the sandhill lake characteristics of Indian Lake, as well as the shallow groundwater seepage within the bayhead vegetation community that contributes soil moisture to the wetland communities downslope from the bayhead, the primary reevaluated MFL level criterion for Indian Lake was a 30-in. organic soils water table drawdown from the average ground surface elevation of the deep (≥8 in. thick) organic soils observed in the hardwood swamps and shallow marshes at Transects 1 and 2.

MINIMUM LEVELS REEVALUATION FOR INDIAN LAKE

Minimum Frequent High (MFH) Level (36.2 ft NGVD 1929 datum; 35.2 NAVD 1988 datum)

The re-evaluated FH level determined for Indian Lake equals 36.2 ft NGVD, with a hydroperiod category of seasonally flooded. Seasonally flooded is defined in Chapter 40C-8, *F.A.C.*, as a hydroperiod category where surface water is typically present for extended periods (30 days or more) during the growing season, resulting in a predominance of submerged or submerged and transitional wetland species. During extended periods of normal or above-normal rainfall, lake levels causing inundation are expected to occur several weeks to several months every 1 to 2 years (Rule 40C-8.021(15), *F.A.C.*). Based on results from a number of water bodies, SJRWMD estimates FH level events should reoccur, on average, at least 1 in every 3 years for 30 or more consecutive days. Modeling results for Indian Lake (Robison 2013) support the recommended FH level and hydroperiod category of seasonally flooded, indicating that a lake level equal to or greater than 36.2 ft NGVD should occur under 2005 conditions for at least 30 continuous days, on average, once every 3 years. Due to the Floridan aquifer potentiometric recovery necessary at Indian Lake in order for the MA and FL levels to be met, this recovery will increase the return interval of the FH level to more frequent than once every three years (i.e., approximately every 2.2 years).

The recommended MFH level of 36.2 ft NGVD equals the average of all the ground surface elevation points surveyed in the hardwood swamps at Transects 1 and 2 (Tables 10 and 11; Figures 11 and 15). This recommended MFH level would ensure surface water inundation across the majority of the hardwood swamps surveyed at Transects 1 and 2 during periods of normal or above normal rainfall. The hardwood swamp average ground elevation is a MFL level criterion used repeatedly in past SJRWMD MFLs determinations and is based on the scientific literature, indicating that hardwood swamps are typically flooded seasonally. Monk (1968) described mixed hardwood swamps as being dominated primarily by broad-leaved deciduous species and as occurring along creeks, rivers, sloughs, and basins that are flooded seasonally.

Table 10. Indian Lake transects vegetation and soils summary statistics

Vegetation Community	Stations Distance (ft)	Mean (ft NGVD*)	Median (ft NGVD*)	Min (ft NGVD*)	Max (ft NGVD*)	N†
Low flatwoods—Transect 2	240–250	38.7	38.7	38.1	39.3	2
Low flatwoods—Transect 1	0–70	37.5	37.5	36.8	38.1	8
Transitional low flatwoods-bayhead—Transect 2	210–240	38.0	38.0	37.4	38.8	4
Transitional low flatwoods-bayhead—Transect 1	70–90	36.8	36.8	36.8	36.9	2
Bayhead—Transect 2	140–210	37.1	37.2	36.1	37.7	8
Bayhead—Transect 1	90–380	36.9	36.8	36.4	37.7	30
Hardwood swamp—Transect 1	380–430	36.4	36.4	36.0	36.8	6
Hardwood swamp—Transect 2	70–140	36.1	36.2	35.1	36.6	8
Deep organic soils observed at Transect 1 and Transect 2*	390–480 23–140	35.3	36.0	31.0	36.6	23
Shallow marsh—Transect 1		34.0	33.6	32.5	36.2	12
Shallow marsh—Transect 2		34.0	34.5	30.9	36.6	6

Note:
*ft NGVD = feet National Geodetic Vertical Datum
†N = the number of elevation readings surveyed in each vegetation community
††Histic epipedon or histosol sampled in shallow marshes and hardwood swamps

Obligate wetland plants (Tables 4 and 8) were common within the hardwood swamps at Transects 1 and 2. The location, structure, and functions of seasonally flooded wetland plant communities adjacent to Indian Lake will be protected if flooding occurs at the average elevation of the hardwood swamps for a duration of at least 30 consecutive days in the growing season, with a return interval of at least every 3 years, as provided by the recommended MFH level of 36.2 ft NGVD.

Soil indicators of frequent inundation and/or soil saturation were observed at Indian Lake in the hardwood swamps at Transects 1 and 2. These soil indicators were histosol, identified at all but one soil sampling location within the hardwood swamps at Transects 1 and 2. The one location that did not meet the histosol organic soil thickness requirement contained a histic epipedon (8 to 16 in. thick surface organic horizon). Thick surface organic soil, characteristic of a histosol or histic epipedon, indicates that soil saturation and inundation occurs for extended periods within the hardwood swamps traversed at Indian Lake. Figures 11 and 15 illustrate that the recommended MFH level (36.2 ft NGVD) will provide soil inundation and/or saturation at the majority of the stations surveyed with deep organic soils at Indian Lake.

Likewise, the recommended MFH level will ensure inundation of the shallow marshes, where organic soils were also observed (Tables 5 and 9), downslope from the hardwood swamps at Transects 1 and 2. Shallow marshes surveyed at Transects 1 and 2 will be inundated with an average water depth equal to 2.2 ft when Indian Lake equals the recommended MFH level (Table 10).

Additional benefits from the recommended MFH level include the greatly expanded aquatic fauna habitat when Indian Lake inundates the hardwood swamps and shallow marshes traversed at Transect 1 and Transect 2. Interactions with the adjacent hardwood swamps and shallow marshes by connecting the lake to the floodplain are extremely important to animal productivity in the lower coastal plain (Bain 1990; Poff et al. 1997). When the floodplains are flooded, many fish 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 floodplain forests are inundated (Light et al. 1998). Also, lake water quality may improve significantly as water flows through the floodplain. The floodplain, with its swamp, functions as an important filter and sink for dissolved and suspended constituents (Wharton et al. 1982).

Natural vegetation communities upslope from the hardwood swamps traversed at Indian Lake included the bayheads identified immediately landward of the hardwood swamps at Transects 1 and 2 (Figures 11 and 15). Hydric soil indicators (dark surface, muck presence, and organic bodies) were observed in the bayhead at Transect 1 (Table 5). At Transect 2 deep organic soils were observed in the bayhead (Table 9). Bayheads are reportedly dependent on seepage flow and/or a high water table (FNAI 1990). Lindbo and Richardson (2001) described groundwater discharge from the upland to the edge of the floodplain often occurring along seepage slopes, resulting in organic-rich soils at the upper edge of the floodplain. Consequently, the organic soil and hydric soil characteristics observed upslope from the hardwood swamps in the bayheads at Indian Lake may be maintained by groundwater movement, as well as by occasional surface water inundation.

Table 11 summarizes the recommended MFH level primary criteria along with the previously adopted MFH level primary criteria for Indian Lake.

Table 11. Minimum frequent high (MFH) adopted and recommended levels primary criteria

MFH Minimum Levels	Elevation (ft NGVD) 1929 Datum	Elevation (ft NAVD) 1988 Datum	Hydroperiod Categories, Duration; Return Interval	MFH Level Criteria
Adopted MFH	37.0	NA	Seasonally flooded	Corresponds to the average elevation of the bay swamp at Transect 1 and is similar to the minimum elevation of the bay swamp at Transect 2 (Valentine-Darby 1998).
Recommended MFH	36.2	35.2	30-day duration; 3-year return interval	Corresponds to the average elevation of all the hardwood swamp points surveyed in 2007. Recent surface water model results indicated that the average elevation of the bay swamp represents a lake level, which occurs less frequently than would be expected for the minimum MFH level. Additionally, the bay swamp community as delineated in 1998, located upslope from the hardwood swamp, represents a typical bayhead vegetation community, where shallow groundwater seepage, rather than the surface water of Indian Lake, primarily maintains the bayhead wetland characteristics.

Minimum Average (MA) Level (35.0 ft NGVD 1929 Datum; 34.0 NAVD 1988 Datum)

The recommended MA level for Indian Lake is 35.0 ft NGVD. The MA level approximates a typical lake stage that is slightly lower than the long-term median stage. At the MA level, substrates may be exposed during non-flooding periods of typical years, but the substrate remains saturated. The MA level corresponds to a water level that is expected to occur, on average, every year or two for about 6 months during the dry season (Rule 40C-8.021(15), *F.A.C.* The recommended MA level of 35.0 ft NGVD for Indian Lake would occur under 2005 modeled conditions for a duration of 180 days approximately 70 times in 100 years (return interval of 1.4 years) (Robison 2013). The recommended MA level results in a change from the current modeled 2005 conditions return interval of every 1.4 years to a 1.7 year return interval (59 times in 100 years), indicating that no additional water is available for consumptive use and that a recovery strategy is necessary for Indian Lake. As mentioned previously, the FL level was the most sensitive (i.e., needed the most Floridan aquifer potentiometric level increase to meet the level). A 1.3 ft Floridan aquifer potentiometric surface increase or recovery would be needed for the FL level to be met. The recommended MA level of 35.0 ft NGVD would be met with the 1.3 ft potentiometric recovery. The recommended MA return interval, 1.7 years or a 59% annual average non-exceedence probability, occurs at the driest value for the 180 day duration for 21 lakes in the SJRWMD evaluated with deep organic soils and reflects a dry hydrologic signature.

An intermediate or minimum average water level is required to maintain the water table, on average, near the soil surface of floodplain wetlands. Topographic gradients result in a complex continuum of hydrologic and soil (edaphic) factors across the lake floodplain. A critical point on the topographic gradient occurs at the elevation where anoxic soil conditions prevail for sufficient periods to exclude upland plant species. Plants and soils at or below this elevation require saturation of the upper soil horizon for a significant portion of each year. However, constant flooding of wetlands is inappropriate. The seeds of many species of wetland plants require an unflooded (exposed), moist soil surface for germination (Van der Valk 1981).

The recommended MA level equals a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep organic soils observed in the shallow marshes and hardwood swamps at the Indian Lake transects (Table 12). Deep organic soils are histosols (≥16 in. thick surface organic horizon) or soils with a histic epipedon (8 to 16 in. thick surface organic horizon). The average deep organic soil surface elevation was calculated from soil surface elevations where the deep organic soils were sampled at Transect 1 (stations 390–480) and Transect 2 (stations 23–140) in the shallow marshes and hardwood swamps. Deep organic soils extended upslope from the hardwood swamp into the bayhead vegetation community at Transect 2. All bayhead elevation points were excluded from the minimum average determination organic soil drawdown calculation because soil saturation, and ultimately organic soil development and maintenance in bayheads, is greatly influenced by groundwater seepage and less directly related to lake stage (FNAI 1990; Lindbo and Richardson 2001).

Deep organic soils at Transect 1 did not extend below station 480 into the lower elevations of the shallow marsh. Comparing aerial photographs from 1984 (Figure 14) with 2004 imagery (Figure 13) indicated that the shallow marsh around the perimeter of Indian Lake has extended during this 20-year time period into the open water of the lake. Thus, the lower elevations of shallow marsh stations traversed at Transect 1 were open water in 1984, lacking the vegetation necessary for the development of organic soils. At Transect 2, the shallow marsh topography is quite steep and the lateral shift of shallow marsh vegetation into the open water of Indian Lake is less notable. In summary, the primary MA level criterion for Indian Lake equals a 0.3-ft soil water table drawdown from the average deep organic soils surface elevation calculated from all shallow marsh and hardwood swamp locations where deep organic soils were sampled.

Deep organic soils are indicative of long-term soil saturation or inundation. The 0.3-ft drawdown will ensure saturated soil conditions, thereby preventing soil oxidation in the deep organic soils observed at Indian Lake. Typically, where deep organic soils are observed, a 0.3-ft organic soil drawdown criterion is employed when determining the MA level. This criterion (0.3 ft below mean surface elevation of deep organic soils) has been used to protect organic soils in other MFLs determinations and was developed for Everglades peat soils (Stephens 1974). Studies of marshes in the Upper St. Johns River Basin (Brooks and Lowe 1984; Hall 1987) determined that the 0.3-ft depth below the soil surface in deep organic soils corresponds to a water level exceeded approximately 60% of the time. Studies of the Wekiva River system found this hydrologic condition can also be expressed as the low stage, occurring, on average, every 1 to 2 years with a duration of less than or equal to 180 days (Hupalo et al. 1994). Also, the mineral soil water table depths, predicted to occur in the bayheads and low flatwoods when Indian Lake equals the recommended MA level are within reported dry season levels (SCS 1980; NRCS 2007).

Additionally, at the recommended MA level of 35.0 ft NGVD shallow ponding will occur at the average elevations of the shallow marshes (Table 10) surveyed at Indian Lake. Shallow ponding will provide aquatic refugia for numerous small fish, amphibians, and small reptiles. Aquatic habitats connected to the open water of Indian Lake are of crucial importance to fishes and invertebrates of the floodplain.

Table 12 summarizes the recommended MA level primary criteria along with the previously adopted MA level primary criteria for Indian Lake.

Table 12. Minimum average (MA) adopted and recommended levels primary criteria

MA Levels	Elevation (ft NGVD) 1929 Datum	Elevation (ft NAVD) 1988 Datum	Hydroperiod Categories; Duration and Return Interval	MA Level Criteria
Adopted MA elevation	36.1	NA	Typically saturated	Corresponds to the combined average elevation of the hardwood swamp at Transect 1 and the mixed swamp at Transect 2 (Valentine-Darby 1998)
Recommended MA elevation	35.0	34.0	180 day duration; 1.7 year return interval	Corresponds to a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep (> 8 in. thick) surface organic soils observed in 2007 at Transects 1 and 2 within the shallow marshes and hardwood swamps. The 0.3-ft soil water table drawdown criterion is commonly used to determine a MA level where deep (>8 in. thick) surface organic soils are identified (SJRWMD 2006).

Minimum Frequent Low (MFL) Level (32.8 ft NGVD 1929 Datum; 31.8 NAVD 1988 Datum)

The recommended FL level for Indian Lake is 32.8 ft NGVD. This level represents a low lake stage that generally occurs only during mild droughts. The FL level is expected to occur, on average, approximately once every 5 years for a duration of several months (Rule 40C-8.021(15), *F.A.C.*). The recommended FL level for Indian Lake would occur under 2005 modeled conditions for a duration of 120 continuous days, on average, 37 times in 100 years (return interval 2.7 years) (Robison 2013). The recommended FL level results in a change from the current modeled 2005 conditions return interval to an event, which would occur on average once every 5 years or 20 times in 100 years. This recommended FL indicates that no additional water is available for consumptive use and that a recovery strategy is necessary for Indian Lake due to the return interval change from approximately every 2.7 years (2005 conditions) to every 5 years (recommended FL) for a moderate drought event. As mentioned previously, the FL level was the most sensitive (needed the most potentiometric level increase to meet the minimum level). A

1.3 ft Floridan aquifer potentiometric surface increase or recovery would be needed for the Indian Lake FL level to be met.

The MFL level typically results in dewatered wetlands. This dewatering 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 in order to germinate (Van der Valk 1981). Exposing the floodplain for suitable durations maintains the composition of emergent wetland plant species and increases plant diversity. Low water levels also allow for the decomposition and/or the compaction of flocculent organic sediments. Aerobic microbial breakdown of the sediment begins with receding water levels, which results in a release of nutrients; thereby stimulating primary production. Normally, upon reflooding, conditions are improved for fish nesting and foraging since the wetland surface has consolidated, structural cover has increased, and forage resources (terrestrial and aquatic invertebrates) are abundant (Kushlan and Kushlan 1979; Merritt and Cummins 1984).

The recommended MFL level of 32.8 ft NGVD for Indian Lake equals a 30-in. soil water table drawdown from the average soil surface elevation of the deep organic soils observed in the shallow marshes and hardwood swamps traversed at Transects 1 and 2 (Table 13). Typically, where extensive organic soils occur, the MFL level is based on an average organic soil water table drawdown of 20 to 30 in. The 20 to 30-in. average soil water table drawdown criterion was based on the following literature:

Soil Survey of Brevard County, Florida, (SCS 1974). “In Tomoka muck, the soil water table is within a depth of 10 in. from the soil surface for 9 to 12 months in most years, and water is frequently above the surface. In dry periods, it is between 10 in. and 30 in. below the soil surface. In Monteverde peat, the water table is within a depth of 10 in. from the soil surface for 9 to 12 months in most years, and water stands on the surface each year for more than 6 months. In dry seasons the water table is lower, but seldom falls below a depth of 30 in.”

South Florida Water Management District Wetland Hydroperiods Study Task 2 Report (Literature Review and Analysis), (ESE 1991). “Seasonally flooded marsh systems had an average hydroperiod of 255 ± 11.1 days (n = 29), with an average minimum dry-season depth of –53 cm ± 13.5 cm (20.9 in.; ± 5.3 in.) below the soil surface.”

Soil Survey of Volusia County, Florida, (SCS 1980). “In Gator muck the water table is at or above the soil surface in spring, summer, and fall and is within 10 in. of the soil surface in winter. In Samsula muck, the water table is at or above the soil surface except during long dry periods. In Terra Ceia muck the water table is as much as 2 ft above the soil surface during the rainy season. It is at or above the surface for 6 to 9 months in most years and is seldom below a depth of 10 in. except during extended dry periods.”

Additional considerations regarding the MFL level 30-in. organic soil water table drawdown at Indian Lake include soil moisture in the mineral soils in the bayhead, transitional low flatwoods-bayhead, and low flatwoods vegetation communities traversed at Indian Lake. Moisture is likely available to the vegetation at depths considerably closer to the soil surface than that predicted from the 30-in. soil water table drawdown criterion due to groundwater seepage and the capillary fringe zone in mineral soils. A capillary fringe of varying thickness exists above the mineral soil water table. In the capillary fringe zone, the soil is nearly water saturated; and the water is absorbed to soil particles to a greater degree than water below the water table. The capillary fringe zone contains various amounts of water depending upon the pore size and the height in the soil above the water table (Richardson et al. 2001). A loamy soil, as observed at the higher elevations at Transects 1 and 2, with an average porosity of 0.005 cm should have a saturated zone extending at least 30 cm (12 in.) above the free water surface (Mausbach 1992). Additionally, shallow groundwater seepage typically occurs in bayhead vegetation communities providing soil saturation to an elevation above the lake stage. Lindbo and Richardson (2001) described groundwater discharge from the upland to the edge of the floodplain often occurring along seepage slopes at the upper edge of the floodplain. Thus, groundwater seepage helps maintain the hydric soil characteristics in the bayhead, transitional low flatwoods-bayhead, and low flatwoods vegetation communities when the lake stage occurs at elevations below these vegetation communities' ground elevations.

At the recommended MFL level, shallow ponding will occur at the lower elevations of the shallow marshes at Indian Lake. Shallow ponding provides aquatic refugia for numerous small fish, amphibians, and small reptiles. Aquatic habitats, such as the shallow marshes, connected to the open water of Indian Lake are of crucial importance to fishes and invertebrates of the floodplain. Connected habitats provide shallow, quiet waters as refugia from the deep, rough waters of the main channel and lake (Light et al. 1998). In addition, the shallow ponding at the lower elevations of the shallow marshes provides favorable water depths for wading bird foraging. Wading birds can only forage in relatively shallow water. Great egrets need water depths of less than 10 in., and the small herons need depths of less than 6 in. Dropping water levels cause fish to be concentrated in isolated pools throughout the marshes. Birds effectively exploit these concentrations (Bancroft et al. 1990).

Table 13 summarizes the recommended MFL level primary criteria along with the previously adopted MFL level primary criteria for Indian Lake.

Table 13. Minimum frequent low (MFL) adopted and recommended levels primary criteria

MFL Levels	Elevation (ft NGVD) 1929 Datum	Elevation (ft NAVD) 1988 Datum	Hydroperiod Categories; Duration and Return Interval	MFL Level Criteria
Adopted MFL elevation	34.4	NA	Semipermanently flooded	Corresponds to a 20-in. soil water table drawdown below the average ground surface elevation where the Samsula muck was observed in the gum swamp at Transect 1 and the mixed swamp at Transect 2 (Valentine-Darby 1998)
Recommended MFL elevation	32.8	31.8	120-day duration; 5-year return interval	Corresponds to a 30-in. soil water table drawdown from the average ground surface elevation where deep organic soils (>8 in. thick) were identified in the hardwood swamps and shallow marshes in 2007. Due to more detailed soil sampling in 2007, the elevation range where deep organic soils were observed increased, resulting in a decrease in the average elevation of deep organic soils.

PROTECTION OF 62-40.473, *FLORIDA ADMINISTRATIVE* CODE, ENVIRONMENTAL VALUES

SJRWMD qualitatively assessed whether the recommended Indian Lake MFLs developed to protect “fish and wildlife habitats and passage of fish” were protective of all other relevant environmental values identified in Rule 62-40.473, *F.A.C*. The results of this assessment are listed in Table 14. SJRWMD concludes that the recommended MFLs developed for the protection from significant harm to “fish and wildlife habitats and the passage of fish” will protect all other relevant Rule 62-40.473, *F.A.C.*, environmental values.

Table 14. Summary consideration for each 62-40.473, Florida Administrative Code, environmental resource value for Indian Lake

Environmental Value	
Recreation in and on the water	**Environmental Value Definition:** The active use of water resources and associated natural systems for personal activity and enjoyment.
	Criterion of Protection Hydrologic regime characteristics (low stage events) associated with the water depth necessary to safely operate boats and allow water sports activities.
	Discussion The most restrictive recreational use on Indian Lake is the water depth necessary to launch and operate safely trolling motor boats at Indian Lake. The Florida Fish and Wildlife Conservation Commission rule prohibits all motor boats, except for trolling motors, on Indian Lake. Thus, the necessity of adequate draft depths for trolling motor boat launching and operation is the most restrictive recreational use at Indian Lake.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Compliance with the recommended MFL level provides for the protection of low water events necessary for the safe operation of motorboats for water sports activities in Indian Lake. Therefore, "recreation in and on the water" is considered to be protected.
Fish and wildlife habitats and the passage of fish	**Environmental Value Definition:** 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.
	Criterion of Protection Hydrologic regime characteristics (high and low stage events) associated with conservation of the floodplain wetland vegetation composition, structure, and function for fish and wildlife habitats.
	Discussion Fish and wildlife are dependent on local vegetation communities to provide food, cover, and/or nesting sites. Therefore, to protect fish and wildlife, it is necessary to protect their associated habitat (i.e., vegetation communities and soils). Water level fluctuations influence the colonization and survival of plants, thereby affecting the species composition and structure of plant communities (Schneider and Sharitz 1986; Kushlan 1990; Huffman 1980) The life cycles of many fishes are related to seasonal water level fluctuations, with flooded areas affecting productivity by providing feeding and spawning habitat and refugia for juveniles (Bain 1990; Poff et al. 1997;Guillory 1979;Ross and Baker 1983; Finger and Stewart 1987). Flooding events redistribute and concentrate organic particulates (Junk et al. 1989), while increasing aquatic vegetation structure as substrates for bacterial and fungal growth, affecting the aquatic faunal food chain (Cuffney 1988). Anaerobic soil conditions within the flooded wetland communities favor hydrophytic vegetation and eliminate upland plant species that have invaded during low water events (CH2M HILL 2005), while increasing vegetative structure available to aquatic organisms (Light et al. 1998). High water events allow the lateral movement of fish and other aquatic organisms between hydrologically connected lake lobes and lakes, as well as onto the floodplain to forage and reproduce. The increased spatial area and vegetation structure provide forage for juveniles and refugia from predators. Low water events allow for the decomposition and/or the compaction of flocculent organic sediments, improving habitat conditions for fish nesting and foraging (Kushlan and Kushlan 1979; Merritt and Cummins 1984). Shallow ponding provides aquatic refugia for fish, amphibians, and small reptiles, creating ideal depths for wading bird foraging and concentration of resources in isolated pools (Bancroft et al. 1990, Kushlan 1990). Dewatering events increase the habitats and area available for use by terrestrial fauna, while enabling germination of wetland plant seeds (Kushlan 1990; Van der Valk 1981).
	Do Recommended Minimum Flows and Levels Protect Environmental Value? One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. The recommended MFLs for Indian Lake were primarily based on the protection of fish and wildlife habitats with a sufficient frequency and duration of high water (flooding) and low water (dewatering) events to prevent a down-slope shift in the location of floodplain wetlands (i.e., no net loss of wetlands). Fish and wildlife require access to these habitats and the terrestrial and aquatic passages between them under

Environmental Value	
	varying water levels for the continuance of their life cycle and various biological processes (e.g., foraging, reproduction, growth). Compliance with all three recommended MFLs provides for the protection of "fish and wildlife habitats and the passage of fish" for Indian Lake. Therefore, this WRV is considered to be protected.
Estuarine resources	**Environmental Value Definition:** Coastal systems and their associated natural resources that depend on the habitat where oceanic saltwater meets freshwater.
	Criterion of Protection Not applicable
	Discussion Not applicable
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Not applicable
Transfer of detrital material	**Environmental Value Definition:** The movement by surface water of loose organic material and associated biota.
	Criterion of Protection Hydrologic regime characteristics (high and low stages) associated with depth and area of inundation necessary for adequate detrital transfer to the water column of the lake.
	Discussion Detrital material is an important component of the food web in aquatic ecosystems (Mitsch and Gosselink 1993). The ecology of the floodplain and aquatic communities is dependent to a large extent on the events that deliver detrital material to the system. A significant portion of the detrital material transfer occurs during periods of high water events when accumulated detrital materials on the floodplain are detached from the land surface due to buoyancy or turbulence, and moved by currents. Therefore, maintaining the hydrologic regime characteristics in the lake floodplain is essential to the supply and transport of detrital material.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Compliance with the recommended MFH level provides for the protection of flooding events necessary for the transfer of most detrital material in Indian Lake. Therefore, the "transfer of detrital material" is considered to be protected.
Maintenance of freshwater storage and supply	**Environmental Value Definition:** The protection of an amount of freshwater supply for permitted users at the time of MFLs determinations.
	Criterion of Protection Protect existing permitted surface water and/or groundwater withdrawals.
	Discussion Maintenance of freshwater storage and supply is assessed by including existing permitted surface and/or groundwater withdrawals in the initial MFLs compliance analysis. SJRWMD uses two modeling tools in this process. A regional groundwater flow model includes any permitted groundwater withdrawals. A lake water budget model includes permitted surface water withdrawals and accounts for the interaction between the lake and the regional groundwater system. Any projected or planned hydrologic changes for Indian Lake would be assessed, from the standpoint of MFLs compliance, on top of existing permitted withdrawals.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Compliance with the recommended MFLs for Indian Lake protects existing permitted water uses from impacts associated with potential future surface water and/or groundwater withdrawals because existing permitted surface and/or groundwater withdrawals are included in the initial MFLs compliance analysis. Therefore, "maintenance of freshwater storage and supply" is considered to be protected.

Environmental Value	
Aesthetic and scenic attributes	**Environmental Value Definition:** 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.
	Criterion of Protection Hydrologic regime characteristics (high and low stage events) associated with the preferred stage exceedence range associated with optimal scenic viewing and recreational use.
	Discussion Southwest Florida Water Management District (SWFWMD) conducted a survey to determine a representative group of lake users' perceptions regarding lake aesthetics and recreational use in relation to lake stage (Hoyer et al. 2006). The results suggested that lake users were willing to accept water level fluctuations between a stage exceedence of 20% to 90%. Outside of this range, lake users felt that lake aesthetics and/or recreational use were impaired.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. Compliance with all three recommended MFLs provides for the protection of "aesthetic and scenic attributes" for Indian Lake.
Filtration and absorption of nutrients and other pollutants	**Environmental Value Definition:** The reduction in concentration of nutrients and other pollutants through the processes 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.
	Criterion of Protection Hydrologic regime characteristics (high stage events) associated with depth and area of inundation necessary for adequate filtration and absorbing nutrients and other pollutants.
	Discussion Wetlands serve important functions by filtering and absorbing nutrients from runoff (which typically contains nutrients at concentrations greater than the parent soil), serving as sinks for nutrients deposited from the drainage basin during periods of inundation, and allowing long-term nutrient removal through microbial action (Adams 1997; Boudreau et al. 2004; Labaree 1992). The ability of wetlands to perform these functions depends on cycles of flooding and drying as both anaerobic and aerobic processes are involved (Boudreau et al. 2004). Recognition of the importance of wetlands to the aquatic health of neighboring bodies of water has resulted in the creation or restoration of wetland areas throughout the country. The biogeochemical processing of dissolved constituents is controlled by complex interactions between the rate at which water flows through surface and subsurface flow paths and the rate at which dissolved constituents are processed by methods such as adsorption to sediments or uptake by microorganisms and vegetation (Phillips et al. 1993; Hamilton and Helsel 1995). The conceptual model relevant to the WRV assessment is that filtration and absorption occur in the pervious soils in the floodplain; hence, the frequency, duration, and return period of overbank flooding are the defining characteristics (Battelle 2004).
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Compliance with the recommended MFH level provides for the protection of flooding events necessary for the "filtration and absorption of nutrients and other pollutants" in Indian Lake. Therefore, "filtration and absorption of nutrients and other pollutants" is considered to be protected.
Sediment loads	**Environmental Value Definition:** 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.
	Criterion of Protection Not applicable
	Discussion Not applicable
	Do Recommended Minimum Flows and Levels Protect Environmental Value? Not applicable

Environmental Value	
Water quality	**Environmental Value Definition:** The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in "filtration and absorption of nutrients and other pollutants."
	Criterion of Protection Hydrologic regime characteristics (high and low stage events) necessary to prevent excessive low dissolved oxygen (DO) events.
	Discussion Algal blooms can occur naturally during dry seasons with moderate to severe droughts when water level conditions are low, resulting in seasonally elevated water temperatures and elevated concentrations of nutrients. Similarly, algal blooms can occur naturally after the onset of rainy seasons when nutrient loading is high because of runoff from upland and dewatered wetland areas and flushing (e.g., residence time is high when flushing is low) from the lake is low (e.g., an isolated lake). Thus, natural algal blooms can occur following wet or dry season events when conditions for algal growth are favorable. More severe algal blooms can result in low DO concentrations that may negatively affect aquatic biota (e.g., fish kills). Water withdrawals can increase the number of low water events or decrease the number of high water events per century, on average, and affect the number of low DO events. The time needed for system recovery from natural and human caused low DO events is important to this WRV assessment.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. Therefore, the compliance with all three recommended MFLs provides for the protection of "water quality" for Indian Lake.
Navigation	**Environmental Value Definition:** The safe passage of watercraft (e.g., boats and ships), which is dependent on adequate water depth and channel width.
	Criterion of Protection Minimum depth of water necessary for safe motorboat operation.
	Discussion Watercraft navigation in most lakes is closely tied to recreation and necessitates adequate draft depths and channel widths for safe boat operation.
	Do Recommended Minimum Flows and Levels Protect Environmental Value? One of the advantages of setting multiple MFLs is that the overall fluctuation range of the lake is largely protected. Therefore, the compliance with all three recommended MFLs provides for the protection of "navigation" for Indian Lake. The lake does not support commercial boating, shipping, or barge traffic. Passage by recreational vessels, canoes, etc., was considered under the "recreation in and on the water" environmental value.

CONCLUSIONS AND RECOMMENDATIONS

The SJRWMD Governing Board adopted MFLs for Indian Lake on January 12, 2004, (Chapter 40C-8; *F.A.C.* 2004; Valentine-Darby 1998) before a hydrologic model was completed for Indian Lake. MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *F.S.*). Recent completion of a hydrologic model for Indian Lake (Robison 2013) indicated that the adopted MFLs were not being met under 2005 modeled conditions. Consequently, a reevaluation of the adopted Indian Lake MFLs was performed.

The hydrologic model for Indian Lake was calibrated for 2005 conditions (Robison 2013). These conditions included the most recent land use information and groundwater levels consistent with 2005 regional water use. Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Indian Lake are not being met under 2005 conditions. The Indian Lake hydrologic model determined the Floridan aquifer potentiometric level increases needed to meet the recommended MFLs for Indian Lake. The FL level was the most sensitive (i.e., needed the most Floridan aquifer potentiometric level increase to meet the minimum level). A 1.3 ft Floridan aquifer potentiometric surface increase or recovery would be needed for the FL level to be met. The MA and FH frequent high levels would be met with the 1.3 ft potentiometric recovery.

The following conclusions and recommendations are drawn from the information presented in this document:

1. Establishment and enforcement of the recommended, reevaluated minimum levels for Indian Lake, as presented in this document, should adequately provide for the protection of the water resources or ecology of the area, which includes Indian Lake and its associated floodplain from significant harm as a result of consumptive water use. SJRWMD concludes that the recommended MFLs developed primarily for the prevention of significant harm to "fish and wildlife habitats and the passage of fish" will protect all other relevant Rule 62-40.473, *F.A.C.*, environmental resource values (Table 14).
2. Information included in Appendix C concerning use of the hydrologic model and applicable SJRWMD regional groundwater flow model should be used to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions.
3. Periodic reassessments of these recommended, reevaluated minimum levels, based on monitoring data collected in the future, would better assure that these levels are providing the expected levels of protection of the water resources and ecology of the area. Monitoring data would include periodic vegetation and soil

resampling, as well as hydrologic model updates with future stage and aquifer data.

4. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Indian Lake based on SJRWMD's current MFLs determination methodology (Table 15).

The results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule.

Table 15. Adopted and recommended, reevaluated minimum surface water levels for Indian Lake, Volusia County (*F.A.C*. 2004; Valentine-Darby 1998)

Minimum Levels	Adopted Elevation (ft NGVD) 1929 Datum	Adopted Hydroperiod Categories	Recommended Elevation (ft NGVD) 1929 Datum*	Recommended Elevation (ft NAVD) 1988 Datum†	Recommended Duration	Recommended Return Interval
Minimum frequent high (MFH)	37.0	Seasonally flooded	36.2	35.2	30 days	3 years
Minimum average (MA)	36.1	Typically saturated	35.0	34.0	180 days	1.7 years
Minimum frequent low (MFL)	34.4	Semipermanently flooded	32.8	31.8	120 days	5 years

Note:
*ft NGVD = feet National Geodetic Vertical Datum 1929; ft NAVD = feet North American Vertical Datum 1988
†The recommended, reevaluated minimum levels for Indian Lake were determined using ground elevations based on a 1988 datum, differing from the adopted MFLs which were determined using a 1929 datum. This datum shift from 1929 to 1988 has occurred districtwide at SJRWMD to increase the accuracy of the ground elevation data. The amount of datum shift is location dependent, and at Indian Lake the shift from the 1929 to 1988 datum results in a decrease in the numeric elevation values of -0.98 ft.

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APPENDIX A—INDIAN LAKE MEMORANDUM 1998

MEMORANDUM **F.O.R. 94-1514**

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DATE: July 22, 1998

TO: Jeff Elledge, Director JE
Resource Management Department

THROUGH: Charles A. Padera, Director
Water Resources Department

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

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

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

FROM: Patty Valentine-Darby, Environmental Specialist PLV
Environmental Sciences Division

RE: Recommended minimum Surface Water Levels determined for Indian Lake, Volusia County, Project #01-43-00-5161-XXXX-10900

The purpose of this memorandum is to forward recommended minimum lake levels (Table 1) for Indian Lake, in Volusia County, to the Department of Resource Management. Indian Lake was identified as a priority system scheduled for levels establishment in 1998 (FL Admin. Weekly, Volume 23, Number 52, December 26, 1997). A groundwater drawdown of greater than 2.5 ft. is projected by the year 2010 in the vicinity of Indian Lake. Field data for this memorandum were collected on April 15 and May 12, 1998.

Table 1. Recommended minimum surface water levels for Indian Lake. Terminology is defined in 40C-8.021, F.A.C.; the category names and definitions are adapted from the water regime modifiers of Cowardin et al. (1979).

MINIMUM LEVEL	ELEVATION (ft. NGVD)	HYDROPERIOD CATEGORY
Minimum Frequent High Level	37.0	Seasonally Flooded
Minimum Average Level	36.1	Typically Saturated
Minimum Frequent Low Level	34.4	Semipermanently Flooded

Indian Lake is located in Volusia County, approximately eight miles southwest of Daytona Beach (Figure 1). The lake is within the Tiger Bay State Forest, which is managed by the Florida Division of Forestry (DOF). Eleven thousand acres of land to the east of the lake, within the area outlined on Figure 1, were jointly purchased in December 1997 by the District and the DOF. The property will be managed by the DOF as part of the state forest. The land was purchased by the District for several reasons: the land is the wellfield for the City of Daytona Beach; the DOF was pursuing the property because of its proximity to the state forest; it has a high recharge potential; a substantial portion of the property is wetland; and the area was recognized by the Florida Natural Areas Inventory as a sensitive area needing protection (Steve R. Miller, Land Management Division, pers. com., 5/27/98).

Indian Lake is located in the Volusia Ridge Sets Division of the Eastern Flatwoods District (Brooks 1982). The Eastern Flatwoods District, in which elevations are generally less than 90 feet, arose as a sequence of barrier islands and lagoons during Plio-Pleistocene and Recent times (Brooks 1982). The Volusia Ridge Sets Division consists of accreted coastal deposits composed of four unique parts: a flatwoods plain of subdued beach ridge sets; an eastern boundary sand ridge; an eastern set of beach ridges "forming" a flatwoods plain; and the high coastal ridge. The plains are underlain by fine sands and silty sand with clay, the ridges have well drained sand soils, and the high coastal ridge is underlain by coquina deposits (Brooks 1982). In the vicinity of Indian Lake, recharge to the Floridan Aquifer is an estimated 4-8 inches per year (Boniol et al. 1993).

HYDROLOGY

Indian Lake has an area of approximately 65 acres when the lake level is 37 ft. NGVD. According to the USGS quadrangle (1:24,000 scale) (Figure 2), there are no surface water inflows or outflows from the lake; none were observed during the site visits.

No consumptive use permits (CUPs) exist for surface water withdrawals from Indian Lake. However, there are two CUPs for groundwater withdrawals in the vicinity of the lake. The first permit, to the City of Daytona Beach, allows for a maximum allocation of 5,439.57 million gallons per year (MGY) from 33 wells; the major use is residential (Mary McKinney, Resource Management, pers. com., 6/9/98). Twelve of the 33 wells are within an approximate two mile radius of the lake (i.e., AG, AF, AE, AD, AC, AB, AA, Z, Y, X, W, V) (Figure 3). The second CUP is to the Florida Department of Corrections' Tomoka Correctional Institution; it allows for a maximum allocation of 6.00 MGY from two wells for urban landscaping (Mary McKinney, Resource Management, pers. com., 6/9/98).

Additional information on the City of Daytona Beach wells is presented in Table 2; shown is Public Supply Water Use Information (for the 12 wells closest to the lake) collected in 1996 by the Division of Needs and Sources (Beth Wilder, Resource

Management, 6/9/98). ES staff calculated the last column in the table to obtain an idea of the average number of gallons per day individual wells, within a two mile radius of the lake, *may* be pumping.

Table 2. Public Supply Water Use Information on the City of Daytona Beach wells within an approximate 2 mile radius of Indian Lake (from Division of Needs and Sources, 1996 data). The CUP includes 21 additional wells further from the lake.

Well ID	Distance from lake (mi)	AOP Rate* (gal./min)	OPHR Day$ (hrs./day)	Gallons per day (*)($)(60
AG	within 1	640	12	460,800
AF	within 1	1030	12	741,600
AE	within 1	1005	12	723,600
AD	within 1	530	12	381,600
AC	within 1	1130	12	813,600
AB	within 1	1200	12	864,000
AA	within 2	350	12	252,000
Z	within 2	300	12	216,000
Y	within 2	370	12	266,400
X	within 2	1050	12	756,000
W	within 2	730	12	525,600
V	within 2	720	12	518,400
Total				=6,519,600

* AOP Rate = the average annual flow rate; gal./min the well pumps when in operation.
$ OPHR Day = the # hrs./day that the pump is operated; it is averaged over a long term period, such as 1 year or more.

There is no staff gauge on Indian Lake. However, the City of Daytona Beach has been monitoring lake levels on a weekly basis since 1988 (Jay Thurott, City of Daytona Beach, pers. com., 3/5/98). They began monitoring approximately one year before the wells closest to the lake became active. The City records water depths at the waterward end of a wooden dock on the lake's southeast shore. When the water depth drops below the lake bed at the monitoring station, they record a horizontal distance from the monitoring location to the edge of the water.

The water depth data obtained from the City of Daytona Beach were converted into an approximate lake stage curve by ES staff. To accomplish this, lake bottom elevations were determined at the end of the dock (i.e., the monitoring station) and every 5 ft. along a 100-ft. transect extending waterward from the dock. The stage data (Figure 4) must be considered as approximate, because: the exact location at the dock at which the City records depths was not marked, and therefore was assumed when obtaining the bottom elevation at that point and along the transect; and, more importantly, the lake bottom elevations were recorded by ES staff at 5 ft. intervals, as opposed to the 1 ft. intervals used by the City.

An indication of the accuracy of the City's measurements and/or our derivation of the data was obtained by comparing one day's lake level derived from the monitoring station depth to the next day's lake level obtained by ES staff using survey equipment. The City's converted measurement was approximately .2 ft. lower. It should be noted that the lake levels derived from the horizontal measurements (all those less than or equal to 33.3 ft. NGVD) are less accurate because of how they were obtained (discussed above). According to Figure 4, the lake level fluctuated by almost eight feet during the period of record (minimum lake stage =~ 31.0 ft. NGVD on 2/21/91 and four subsequent dates through 5/23/91; maximum stage = 38.8 ft. NGVD on 2/9/98; and average stage = 34.2 ft. NGVD).

HYDRIC SOILS

One hydric soil type was mapped adjacent to Indian Lake (SCS 1980) (Figure 5). Samsula muck (# 56) entirely surrounds the lake. Daytona sand, 0 to 5 percent slopes (#17) and St. Johns fine sand (#61), both nonhydric, are adjacent to the Samsula muck "ring" around the lake.

Samsula muck (#56) is described by SCS (1980) as a very poorly drained, nearly level organic soil that occurs in broad low flats, small depressions, freshwater marshes, and swamps. The natural vegetation is typically wetland grasses, cypress, wetland hardwoods, or a combination of these and longleaf pine. Samsula muck's surface layer is usually black muck about 9 inches thick, underlain by dark reddish muck about 27 inches thick; below the muck layer is sand to a depth of at least 60 inches. According to SCS (1980), the water table is at or above the soil surface except during extended dry periods.

WETLANDS

The U.S. Fish and Wildlife Service's National Wetlands Inventory (Dayton Beach NW quadrangle, 1987) identified 3 classes of wetlands in and immediately adjacent to the lake (Table 3 and Figure 6).

Table 3. Wetlands mapped at Indian Lake by the National Wetlands Inventory.

Wetland ID	Description
L1OWH	Lacustrine Limnetic Open Water (Unknown bottom) Permanently Flooded
PFO3C	Palustrine Forested Broad-Leaved Evergreen Seasonally Flooded
PSS3F	Palustrine Scrub-shrub Broad-leaved Evergreen Semipermanently Flooded

The lake itself was mapped as L1OWH. Except for one small area on the southern lake shore mapped as PSS3F, the lake is surrounded by forested wetlands mapped as PFO3C. Two elevation/vegetation transects, described below, were established on the

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lake shore and traversed PFO3C wetlands. For a comprehensive list of plant species recorded at the transects, see Table 5.

Transect 1

Transect 1 (T-1) was located on the northwest lake shore (Figure 6). This 405-ft. transect began in open water and first traversed an aquatic bed consisting of a floating mat of para grass (*Panicum purpurascens*), an exotic (Figure 7). At the landward edge of this zone were scattered clumps of sawgrass and sawfern blechnum. The second community along this transect was a hardwood (or gum) swamp dominated by swamp blackgum with abundant loblolly bay. Also present were scattered dahoon holly, swamp bay, fetterbush, wax myrtle and netted chain fern, and numerous sawfern blechnum. Much of the vegetation in this zone was elevated above the predominant grade and growing on hummocks. Hummocks are composed of plant debris, roots, and soils, and enable the vegetation to avoid the prolonged effects of soil anoxia (Gilbert et al. 1995). According to Gilbert et al. (1995), hummocks occur in areas that are shallowly inundated for prolonged periods or where the soil is saturated to the surface for long periods of time.

The third community, also containing hummocks in the lower elevations, was a bay swamp dominated by loblolly bay. Swamp blackgum were scattered to numerous up to station 125; other vegetation in this community included scattered dahoon holly, scattered cypress (*Taxodium* sp.), and abundant fetterbush. There were also two slash pines (13" dbh) on hummocks around stations 165-175. The fourth community, a bay/upland transition zone, was dominated by loblolly bay and saw palmetto. Scattered slash pine were no longer growing on hummocks, and highbush blueberry was scattered to numerous. The final community was a low flatwoods characterized by slash pine, loblolly bay, and saw palmetto. Also present were dangleberry, tar-flower, and rare (i.e., in number) pond pine. The wetland indicator status of the plants in each of the communities is shown in Figure 8.

To more accurately reflect the predominant elevation of the area, extreme hummocks were removed when calculating an average surface elevation of the gum swamp and bay swamp. A total of 10 points, not shown on Figure 7, were removed between stations 35 and 145; the average elevation of the 10 hummocks was 38.0 ft. NGVD (range= 37.4 to 38.3). Soils were sampled a short distance from the base of hummocks. The muck depth (including muck and mucky peat) ranged from over 4.0 ft. at station 25 (elev. at this location = 35.9 ft. NGVD) to 0.5 ft. at station 230 (elev. at this location = 37.9 ft. NGVD) (Figure 7). A nonhydric soil was first observed along the transect at station 245 (elev. = 38.2 ft. NGVD). At this transect, and especially in a large area to the south, up-rooted trees were observed.

Transect 2

Transect 2 (T-2) traversed forested wetlands on the lake's north shore (Figure 6). The transect originated in open water and traversed a floating mat of para grass (Figure 9). The second, narrow zone consisted of a relatively diverse mix of trees and shrubs,

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such as cypress (*Taxodium* sp.), loblolly bay, dahoon holly, slash pine, fetterbush, and buttonbush. The third community was a bay swamp characterized by loblolly bay (slightly more abundant at higher elevations) and fetterbush. At lower elevations of the bay swamp, dahoon holly was numerous and sweet bay and swamp bay were present; at higher elevations, highbush blueberry was abundant. One or two saw palmettos were growing near station 60 (elev. = 38.2 ft. NGVD). The fourth community was a transition zone between bay swamp and upland; it was dominated by loblolly bay and abundant, tall saw palmetto. Also present were scattered highbush blueberry, fetterbush and red chokeberry, and rare cinnamon and bracken fern. The final community encountered was a low flatwoods dominated by loblolly bay and slash pine; saw palmetto was abundant. Also present in low coverages were cinnamon fern, bracken fern, red chokeberry, dangleberry, inkberry, and tar-flower. The wetland indicator status of the plants in each of the communities is shown in Figure 10.

Soils were sampled at three stations at Transect 2 (Figure 9). Hydric soils existed at the two lowest of the three stations. At station 40-45 (elev. = 36.5 ft. NGVD) there was 2 ft. of mucky peat, and at station 70-75 (elev. = 38.5 ft. NGVD) there was .25 ft. of mucky peat underlain by almost 1 ft. of mucky sand. At station 90-95 (elev. = 39.1 ft. NGVD), the soil consisted of a nonhydric sand overlain by a root mat.

MINIMUM LEVELS

The recommended minimum levels for Indian Lake are based on two elevation transects, vegetation and soils analyses, approximate lake level data, information contained in the Volusia County Soil Survey (SCS, 1990), and the U.S. Fish and Wildlife Service's National Wetlands Inventory map. Transect elevation data were collected by Environmental Sciences and Surveying Services staff on April 15, 1998. All soils work was done by Bob Baldwin, SCS soil scientist under contract to the District. Table 4 contains elevations of various features measured at Indian Lake.

Table 4. Spot, mean, maximum and minimum elevations measured at Indian Lake. Elevations are in feet NGVD.

LOCATION	FEATURE	SPOT	MEAN	MAX	MIN	N
Transect #1	Aquatic Bed (floating mat) (-35-20ft.)		32.8	34.8	31.4	9
Transect #1	Muck > 4.0 ft. (station 25 ft.)	35.9				
Transect #1	Hardwood (Gum) Swamp (20-90 ft.)		36.2	37.3	34.8	8
Transect #1	Muck ≥ 0.5 ft. (5-230 ft.)		36.6	37.9	33.3	36
Transect #1	Bay Swamp (90-220 ft.)		37.0	37.7	36.4	24
Transect #1	Bay/Upland Transition (220-300 ft.)		38.2	38.7	37.7	17
Transect #1	Low Flatwoods (300-370 ft.)		38.5	38.7	38.3	15
T #1 and #2	Hardwood (Gum) & Mixed Swamps		36.1	37.3	34.8	11
Transect #2	Aquatic Bed (floating mat) (0-30 ft.)		33.7	35.0	32.6	4
Transect #2	Mixed Swamp (30-45 ft.)		36.0	36.7	35.0	3
Transect #2	Muck = 2.0 ft. (40-45 ft.)	36.5				

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Transect #2	Bay Swamp (45-70 ft.)		37.7	38.4	36.7	6
Transect #2	Muck = 0.3 ft. (70-75 ft.)	38.5				
Transect #2	Bay/Upland Transition (70-95 ft.)		38.8	39.2	38.4	6
Transect #2	Nonhydric Soil (90-95 ft.)	39.1				
Transect #2	Low Flatwoods (95-160 ft.)		39.9	40.6	39.2	14

Three levels with corresponding hydroperiod categories are recommended. Short descriptions of the functions of each minimum level and the related data used in the determination are presented below.

MINIMUM FREQUENT HIGH LEVEL

The recommended Minimum Frequent High level (37.0 ft. NGVD) with the assigned hydroperiod category of Seasonally Flooded corresponds to the average elevation (and the median elevation) of the bay swamp at Transect 1 (T-1). This level is also near, and slightly above, the minimum elevation of the bay swamp at T-2.

This minimum level results in the inundation of the hardwood (gum) swamp at T-1 with an average of 0.8 ft. of water. At T-2, the narrow mixed swamp zone (30-45 ft.) would be inundated with an average of 1.0 ft. of water. Shallow inundation or soil saturation would occur in the bay swamp at T-1 and at the lowest elevations in the bay swamp at T-2. T-1's bay swamp is characterized by four facultative wet species and three obligate wetland species, with the three obligate species occuring more at lower elevations. The recommended Minimum Frequent High level allows for water levels of sufficient frequency and duration to 1) inhibit the invasion of wetland areas by upland plant species, and 2) allow aquatic species access to the wetlands associated with the lake.

Based on the available information, the recommended Minimum Frequent High level is approximately 1.8 ft. below the maximum recorded water level (38.8 ft. NGVD, 2/9/98). According to the approximate lake stage data, this recommended level has been exceeded much of the time over the last 2 and one-half years (Figure 4). The only existing dock at the lake is the one at which water depths were monitored; the recommended minimum level (37.0) would be below the dock surface.

MINIMUM AVERAGE LEVEL

The recommended Minimum Average level (36.1 ft. NGVD) with the assigned hydroperiod category of Typically Saturated corresponds to the combined average elevation of the hardwood (gum) swamp at T-1 and the mixed swamp zone at T-2. Both of these communities contain a high proportion of obligate wetland species (Figures 8 and 10).

This Minimum Average level would result in the saturation of the muck soils in the hardwood and bay swamps. This level protects the lower elevation muck soils from

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oxidation while allowing for wetland plant seed germination on the exposed soils present at higher elevations along the transects. This recommended minimum level (36.1 ft. NGVD) has apparently been exceeded most of the time over the past 2 and one-half years (Figure 4). However, according to these same data, the lake has been lower than this level for most of the period of record prior to the fall of 1995. A discussion of this discrepancy will follow the next section.

MINIMUM FREQUENT LOW LEVEL

The recommended Minimum Frequent Low level (34.4 ft. NGVD) with the assigned hydroperiod category of Semipermanently Flooded corresponds to the combined average elevation of the Samsula muck soils in the gum swamp at T-1 and the mixed swamp at T-2 minus 1.67 ft. (36.07-1.67 = 34.4 ft. NGVD). The figure 1.67 ft. reflects a twenty inch reduction in the soil water table, which is considered reasonable for a moderate drought. Occasional drawdown conditions are necessary in wetlands to stimulate decomposition, seed germination, and new vegetative growth. This minimum level recognizes the benefits of low water conditions during periods of low rainfall.

This Minimum Frequent Low level results in a drawdown of the water table in the hardwood and bay swamps at T-1 and T-2. This minimum level would result in 1.6 ft. of water over the average elevation of the para grass aquatic bed at T-1 and 0.7 ft. of water over the average elevation of the para grass bed at T-2. According to Figure 4, the level of Indian Lake has been below this recommended level (34.4) for much of the time since 1988, when stage recording was initiated.

ADDITIONAL DISCUSSION AND RECOMMENDATIONS

The minimum levels recommended here for Indian Lake were developed using the standard criteria for minimum levels determinations. However, the discrepancies between the recommended levels and the approximate levels that the lake has experienced since 1988 (Figure 4) are large. For instance, the recommended minimum average level (36.1 ft. NGVD), typically near the 50th percentile of exceedence, has been met or exceeded for most of the time since September 1995, but it was exceeded only once before that date. The median water level, according to the data in Figure 4, was 33.6 ft. NGVD for the period of record. This is 2.5 ft. lower than the recommended minimum average level. The situation is similar for the recommended minimum frequent low level (34.4 ft. NGVD) versus the 80th percentile of exceedence (32.4 ft. NGVD); there is a difference of 2.0 ft. The recommended minimum frequent high level, however, does correspond to the 20th percentile of exceedence.

I believe that these apparent discrepancies may be due to the following factors. First, the approximate stage data for Indian Lake are from a ten year time period; this period of time is likely not extensive enough to adequately reflect the long-term

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hydrology of Indian Lake. Second, the stage data were collected for only a short period of time (approximately one year) before the wells closest to the lake became active. Hence, there is little base-line data. Third, the permitted withdrawal of groundwater in the vicinity of Indian Lake may have led to lower-than-historic lake levels.

I recommend that models be developed to further evaluate these discrepancies. Additionally, I recommend that consideration be given to installing a staff gauge at the lake to collect more accurate stage data. Please call me (ext. 2309), Cliff Neubauer (ext. 4343), or Jane Mace (ext. 4389) if you wish to discuss these minimum levels.

PLV/ras

attachments

cc:				
	Kathryn Mennella	Hal Wilkening	Tommy Walters	Larry Battoe
	David Clapp	Chris Ware	Jane Mace	Larry Fayard
	Dwight Jenkins	Sandy McGee	Price Robison	Bob Freeman
	MFL-REG	David Watt	Eric Olsen	Dale Jones
	Donna Curtis			

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Figure 1. Location of Indian Lake, Volusia County. The land recently purchased by the District and the FL Division of Forestry is within the circled area (east of the lake and west of I-95).

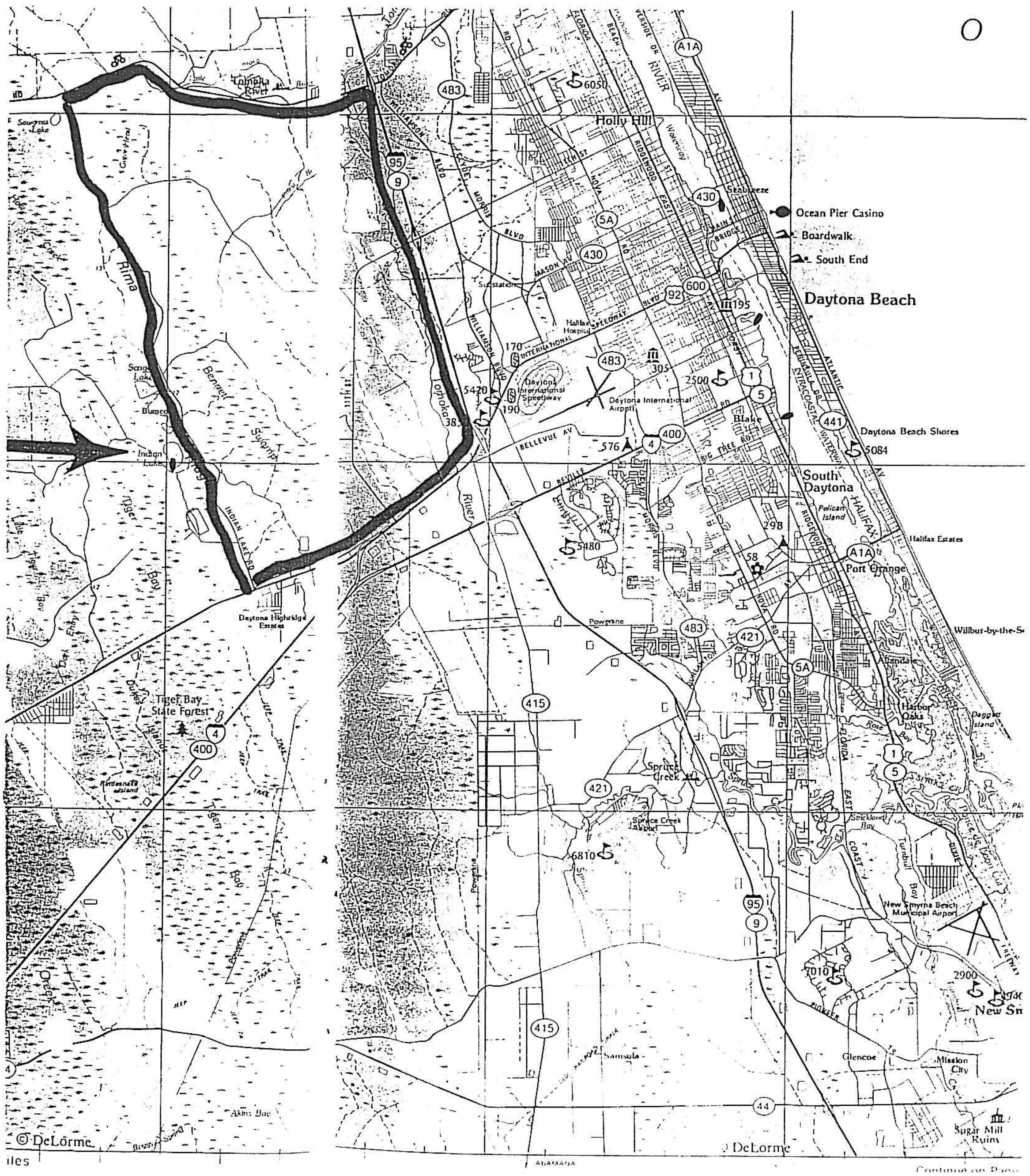
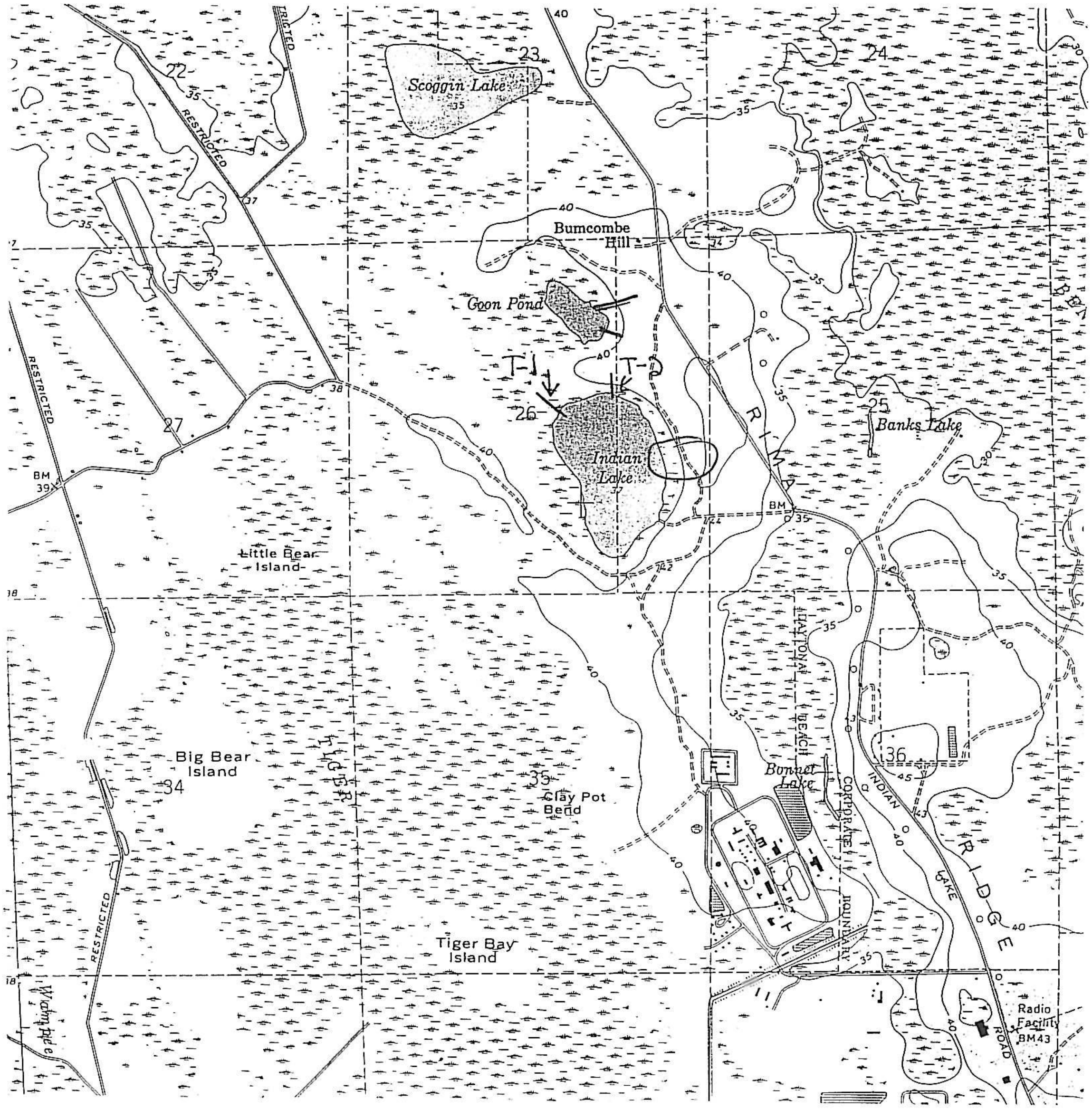


Figure 2. U.S.G.S. topographic map of the Indian Lake area (Daytona Beach, NW quad.). Locations of the two transects (T-1 and T-2) are shown.



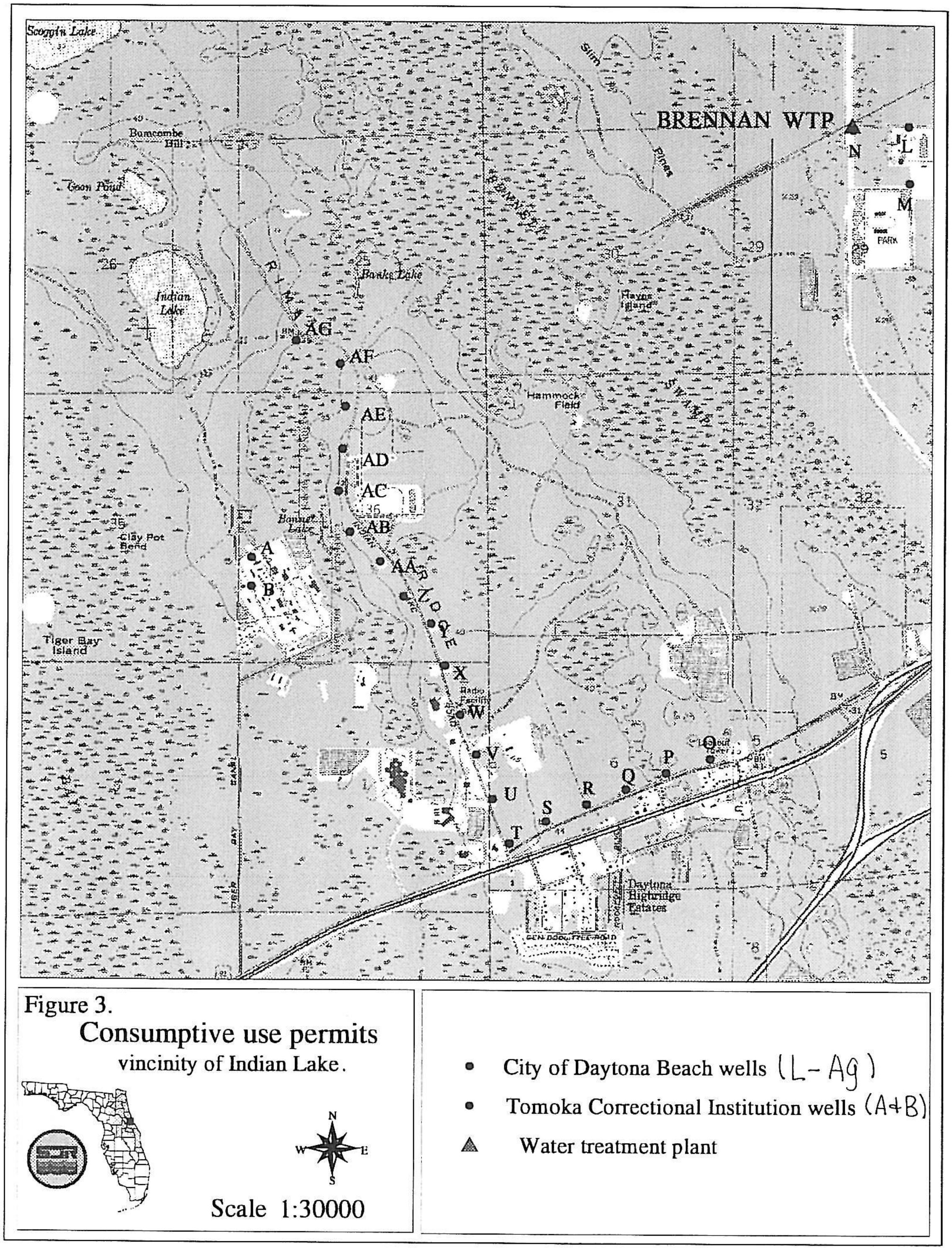


Figure 3.
Consumptive use permits
vincinity of Indian Lake.

Figure 4. Indian Lake stage data from March 1988 to April 1998. Data derived from depth data collected by the City of Daytona Beach. Levels below 33.3 ft. NGVD are approximate (see text for explanation).

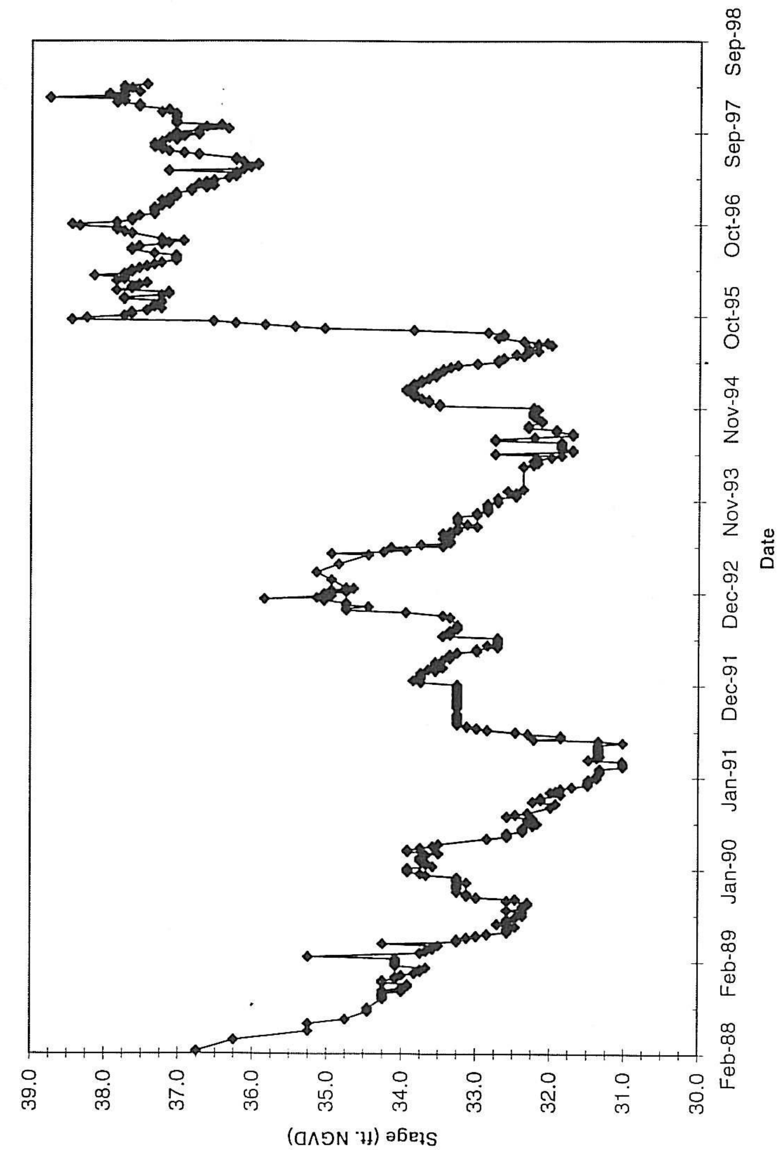


Figure 5. S.C.S. soils map for Indian Lake.

Figure 6. National Wetlands Inventory map of Indian Lake (Daytona Beach, NW quad.).

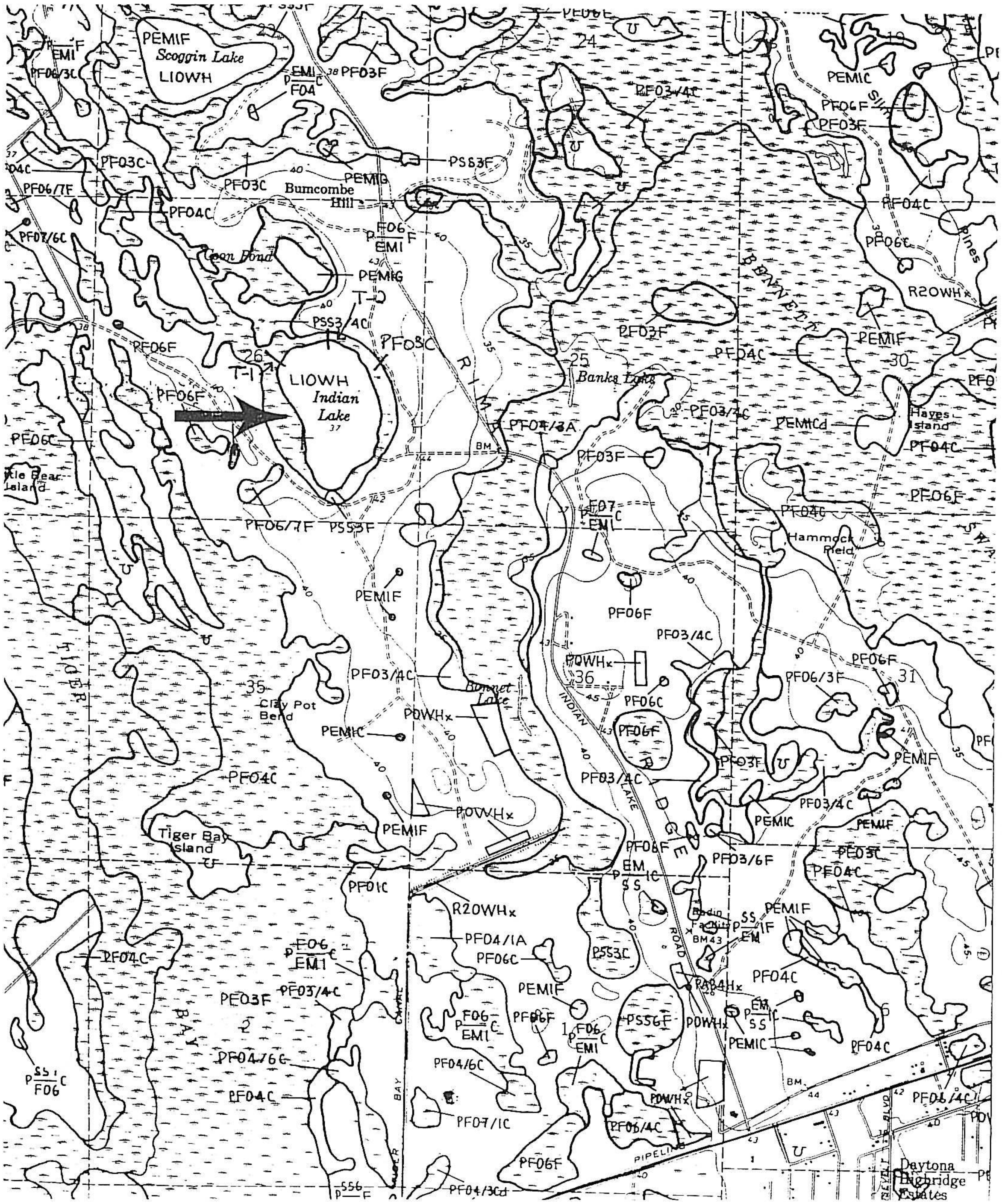


Table 5. Plant species observed at Indian Lake.

SPECIES	COMMON NAME	FWDM*	USACOE**
Aronia arbutifolia	red chokeberry	FACW	FACW
Befaria racemosa	tar-flower	UPL	FAC-
Blechnum serrulatum	sawfern blechnum	FACW	FACW+
Cephalanthus occidentalis	buttonbush	OBL	OBL
Cladium jamaicense	sawgrass	OBL	OBL
Gaylussacia frondosa var. nana	dangleberry $	FAC	FAC
Gaylussacia frondosa var. tomentosa	dangleberry $	FAC	FAC
Gordonia lasianthus	loblolly bay	FACW	FACW
Ilex cassine	dahoon holly	OBL	FACW
Ilex glabra	inkberry	UPL	FACW
Lyonia lucida	fetterbush	FACW	FACW
Magnolia virginiana	sweetbay	OBL	FACW+
Myrica cerifera	wax myrtle	FAC	FAC+
Nyssa biflora	swamp blackgum	OBL	OBL
Osmunda cinnamomea	cinnamon fern	FACW	FACW+
Panicum purpurascens Raddi.	para grass		
Persea palustris	swamp bay	OBL	FACW
Pinus elliottii	slash pine	UPL	FACW
Pinus serotina	pond pine	FACW	FACW+
Pteridium aquilinum	braken fern	UPL	FACU
Serenoa repens	saw palmetto	UPL	FACU
Taxodium sp.	cypress	OBL	OBL
Vaccinium corymbosum	highbush blueberry	FACW	FACW
Woodwardia areolata	netted chain fern	OBL	OBL
Woodwardia virginica	virginia chain fern	FACW	OBL

* FWDM list from the Florida Wetlands Delineation Manual 1995.

** U.S. Army Corps of Engineers list developed from U.S. Fish and Wildlife Service (Reed (1988)).

$ Only G. frondosa is listed in the FWDM & COE lists; both varieties were assumed to be FAC.

Figure 7.

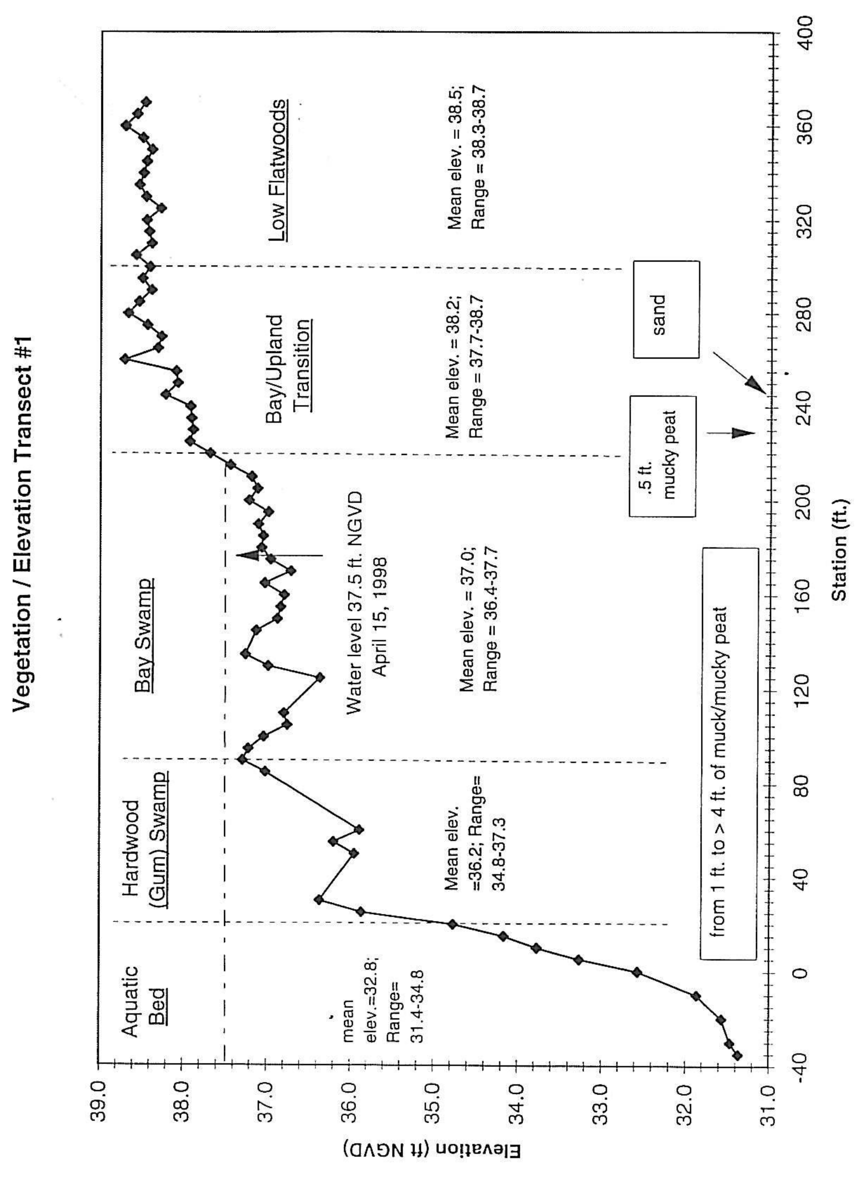

Vegetation / Elevation Transect #1
Aquatic Bed
Hardwood (Gum) Swamp
Bay Swamp
Bay/Upland Transition
Low Flatwoods
mean elev.=32.8; Range= 31.4-34.8
Mean elev. =36.2; Range= 34.8-37.3
Water level 37.5 ft. NGVD April 15, 1998
Mean elev. = 37.0; Range = 36.4-37.7
Mean elev. = 38.2; Range = 37.7-38.7
Mean elev. = 38.5; Range = 38.3-38.7
.5 ft. mucky peat
sand
from 1 ft. to > 4 ft. of muck/mucky peat
Elevation (ft NGVD)
Station (ft.)

Figure 8.

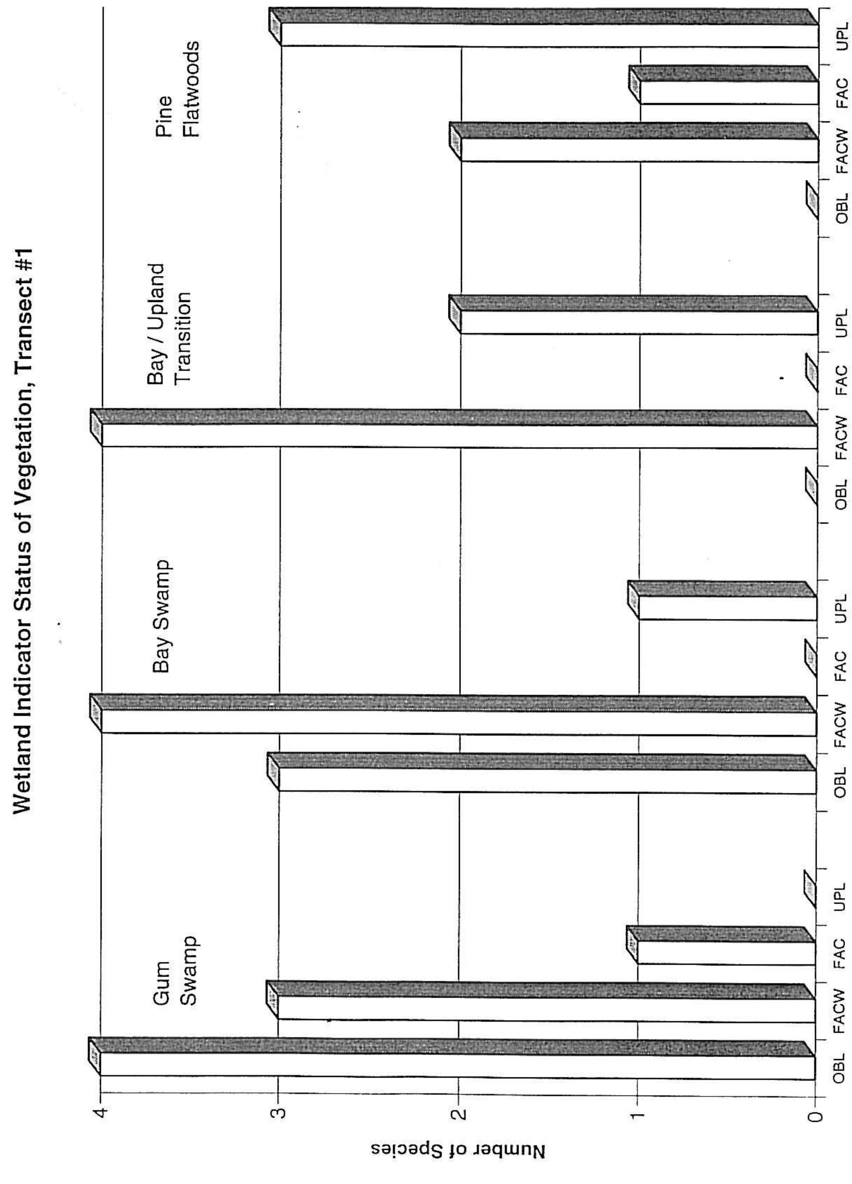

Wetland Indicator Status of Vegetation, Transect #1
Gum Swamp
Bay Swamp
Bay / Upland Transition
Pine Flatwoods
OBL
FACW
FAC
UPL
Number of Species
0
1
2
3
4

Figure 9.

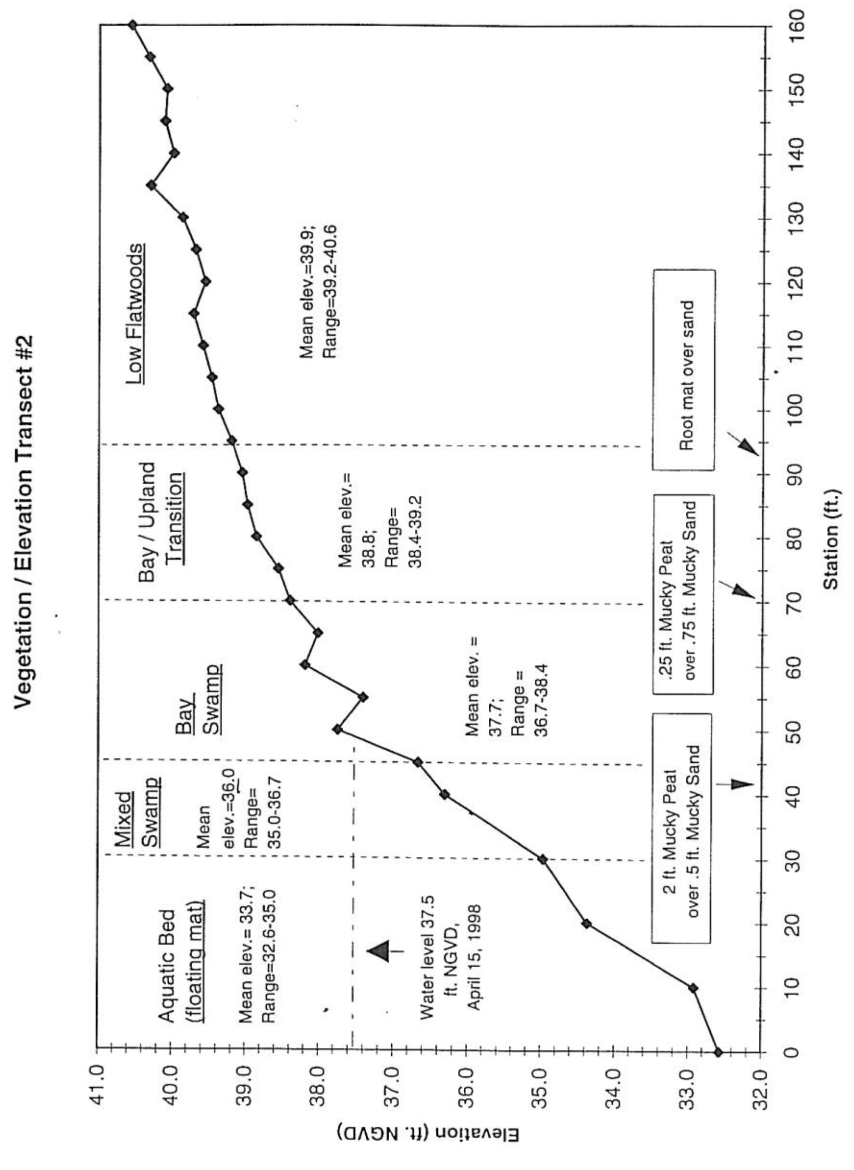
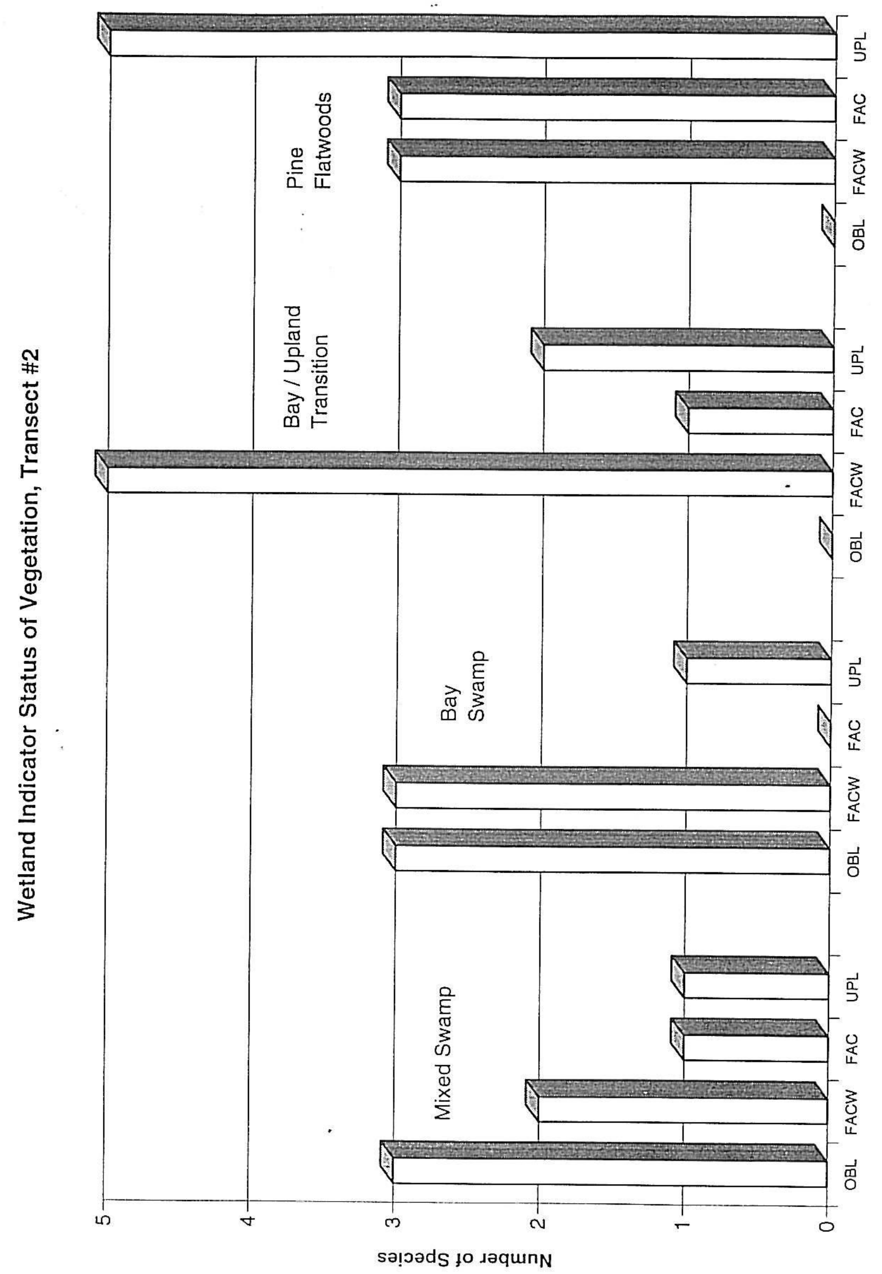

Vegetation / Elevation Transect #2
Aquatic Bed (floating mat)
Mean elev.= 33.7; Range=32.6-35.0
Mixed Swamp
Mean elev.=36.0 Range= 35.0-36.7
Bay Swamp
Mean elev. = 37.7; Range = 36.7-38.4
Bay / Upland Transition
Mean elev.= 38.8; Range= 38.4-39.2
Low Flatwoods
Mean elev.=39.9; Range=39.2-40.6
Water level 37.5 ft. NGVD, April 15, 1998
2 ft. Mucky Peat over .5 ft. Mucky Sand
.25 ft. Mucky Peat over .75 ft. Mucky Sand
Root mat over sand
Elevation (ft. NGVD)
Station (ft.)
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
32.0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160

Figure 10.


Wetland Indicator Status of Vegetation, Transect #2
Number of Species
0
1
2
3
4
5
Mixed Swamp
Bay Swamp
Bay / Upland Transition
Pine Flatwoods
OBL
FACW
FAC
UPL

APPENDIX B—VEGETATION FIELD 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— IMPLEMENTATION OF MINIMUM FLOWS AND LEVELS FOR INDIAN LAKE

Prepared by

C. Price Robison, P.E., St. Johns River Water Management District (2012)

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 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 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, etc.

Frequency analysis estimates how often, on average, a given event will occur. If annual series data are used to generate the statistics, frequency analysis estimates 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 peak in any given year being greater than or equal to $\hat{S}_1$ would be

$$P(S \geq \hat{S}_1) = \frac{1}{n} = \frac{1}{10} = 0.1 \qquad \text{(A1)}$$

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

$$P(S \geq \hat{S}_2) = \frac{2}{10} = 0.2 \qquad \text{(A2)}$$

The probability of the stage equaling or exceeding $\hat{S}_{10}$ would be

$$P(S \geq \hat{S}_{10}) = \frac{10}{10} = 1.0 \qquad \text{(A3)}$$

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:

$$P(S \geq \hat{S}_m) = \frac{m}{n+1} \tag{A4}$$

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

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{11} = 0.0909 \tag{A5}$$

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

$$P(S \geq \hat{S}_{10}) = \frac{10}{11} = 0.9091 \tag{A6}$$

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

$$P(S < \hat{S}_{10}) = 1 - P(S \geq \hat{S}_{10}) = 1 - \frac{10}{11} = 1 - 0.9091 = 0.0909 \tag{A7}$$

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

$$T = \frac{1}{P} \tag{A8}$$

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

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = \frac{1}{\frac{1}{11}} = 11 \tag{A9}$$

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,

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{21} = 0.048 \quad \text{(A10)}$$

and

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = 21 \quad \text{(A11)}$$

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 A1 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 A2 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 A3). This method is beyond the scope of this appendix; therefore, 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 A4).

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 Indian Lake Minimum Flows and Levels (MFLs)

This section describes the process used to relate long-term hydrologic statistics to the establishment of MFLs. SJRWMD has determined three recommended MFLs for Indian Lake: 1) a minimum frequent high (MFH) level, 2) a minimum average (MA) level, and 3) a minimum frequent low (MFL) level. The MFH level for this lake is used here to illustrate how long-term hydrologic statistics of a lake relate to MFLs.

Each of the three MFLs is tied to characteristic stage durations and return frequencies. For example, the ground elevation represented by the MFH 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 3 years.

The standard stage frequency analysis described previously in this appendix was performed on stage data from lake model simulations of Indian Lake (Robison 2007). In particular, stages continuously exceeded (ground elevations remaining wet) for 30 days were determined, sorted, ranked, and plotted (Figure A5). These stages were obtained assuming that long-term groundwater withdrawals occurred at the same level at which they occurred in 2005. The ground elevation of the MFH level can be superimposed on the plot (Figure A6) to demonstrate how the level is related to the pertinent hydrologic statistics. Finally, a box bounded by 1) the MFH level on the bottom, 2) a vertical line corresponding to a frequency of occurrence of once in every 3 years on the right, and 3) a vertical line corresponding to a frequency of occurrence of once in every 2 years on the left, is superimposed on the plot (Figure A7). Similar analyses were performed for the MA level (Figure A8) and for the MFL level (Figure A9). All three levels are being met under these conditions.

A summary of the recommended MFLs for Indian Lake is shown in Table A1. Values in this table will be used as benchmarks for modeling outputs to determine if groundwater withdrawals in the vicinity of Indian Lake 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 Indian Lake 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 Indian Lake, 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 represents 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 A7 through A9 assume long-term Floridan aquifer withdrawals at 2005 levels. Any withdrawal increases beyond 2005 would tend to lower potentiometric levels in the area and, therefore, would tend to lower levels in Indian Lake. To determine the freeboard present at Indian Lake from the standpoint 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 Indian Lake. In the case of Indian Lake, for a Floridan aquifer water level drawdown of 0.5 ft, the MA level would still be met (Figure A10). However, any drawdowns greater than 0.5 ft would cause water levels to fall below the established MA level. At a drawdown of 0.5 ft, the MFH level (Figure A11) and the MFL level would still be met (Figure A12). Therefore, future Floridan aquifer water level drawdowns beyond 2005 conditions will be limited to 0.5 ft in the Indian Lake 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.

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 2005 conditions by the Volusia Regional Groundwater Flow Model, drawdown in the vicinity of Indian Lake between 1995 and 2003 was approximately 0.6 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 2005 freeboard for Indian Lake is 0.5 ft and the drawdown in the vicinity of Indian Lake between 1995 and 2005 was approximately 0.6 ft, then the allowable drawdown from 1995 to some future year would be limited to 1.1 ft.

Table C1. Summary of recommended minimum flows and levels (MFLs) for the Indian Lake system

Minimum Flows and Levels (MFLs)	Level (ft NGVD*)	Duration (days)	Series	Water Year	Statistical Type	Minimum Return Period	Maximum Return Period
Indian Lake (Recommended)							
Minimum frequent high	36.2	30	Annual	Jun 1–May 31	Maximum, continuously exceeded	NA†	3 yrs
Minimum average	35.0	180	Annual	Oct 1–Sep 30	Minimum mean, not exceeded	1.7 yrs	NA
Minimum frequent low	32.8	120	Annual	Oct 1–Sep 30	Minimum, continuously not exceeded	5 yrs	NA

*ft NGVD = feet National Geodetic Vertical Datum
†NA = Not applicable

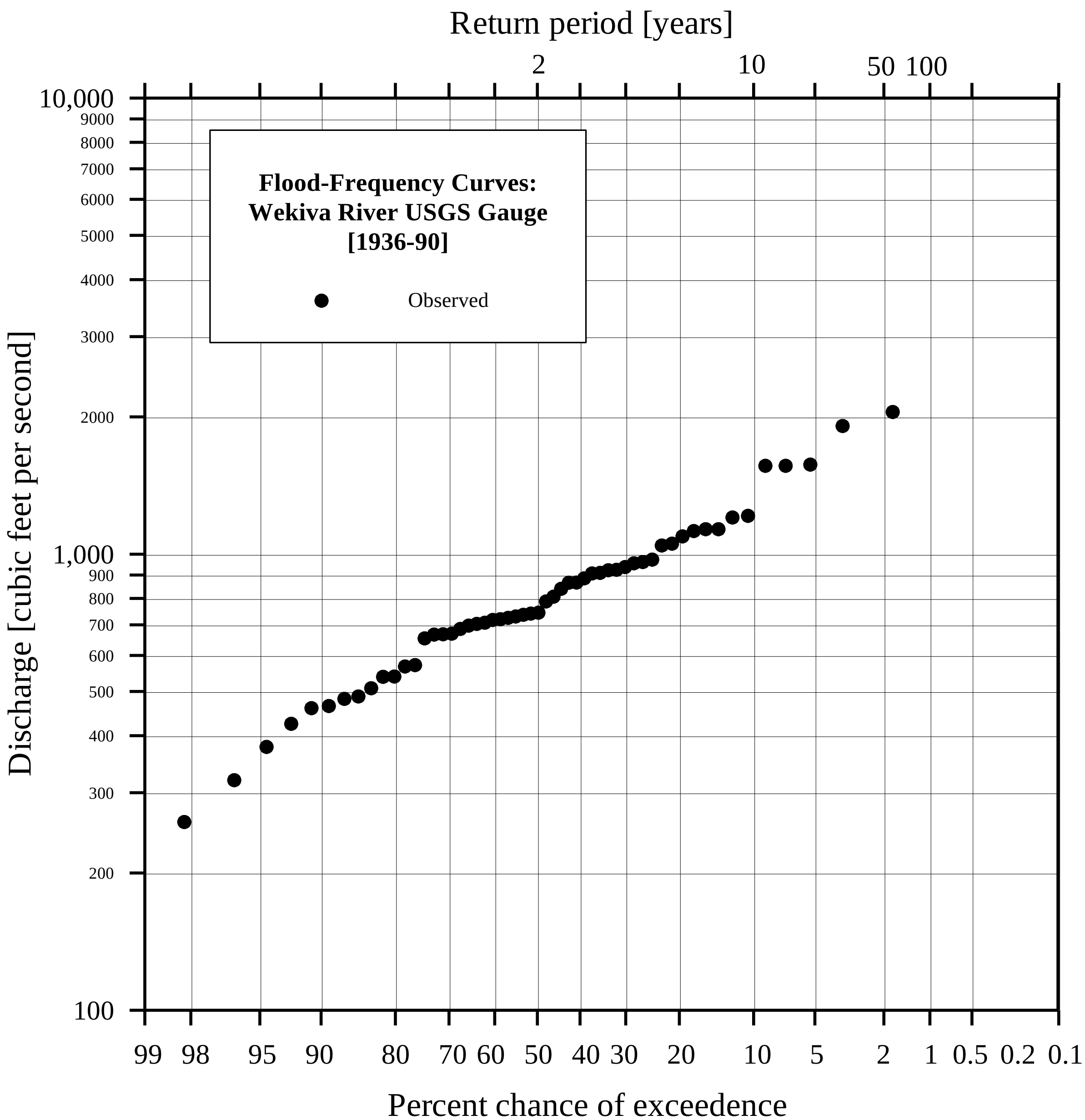


Figure C1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Florida. The 1–day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula

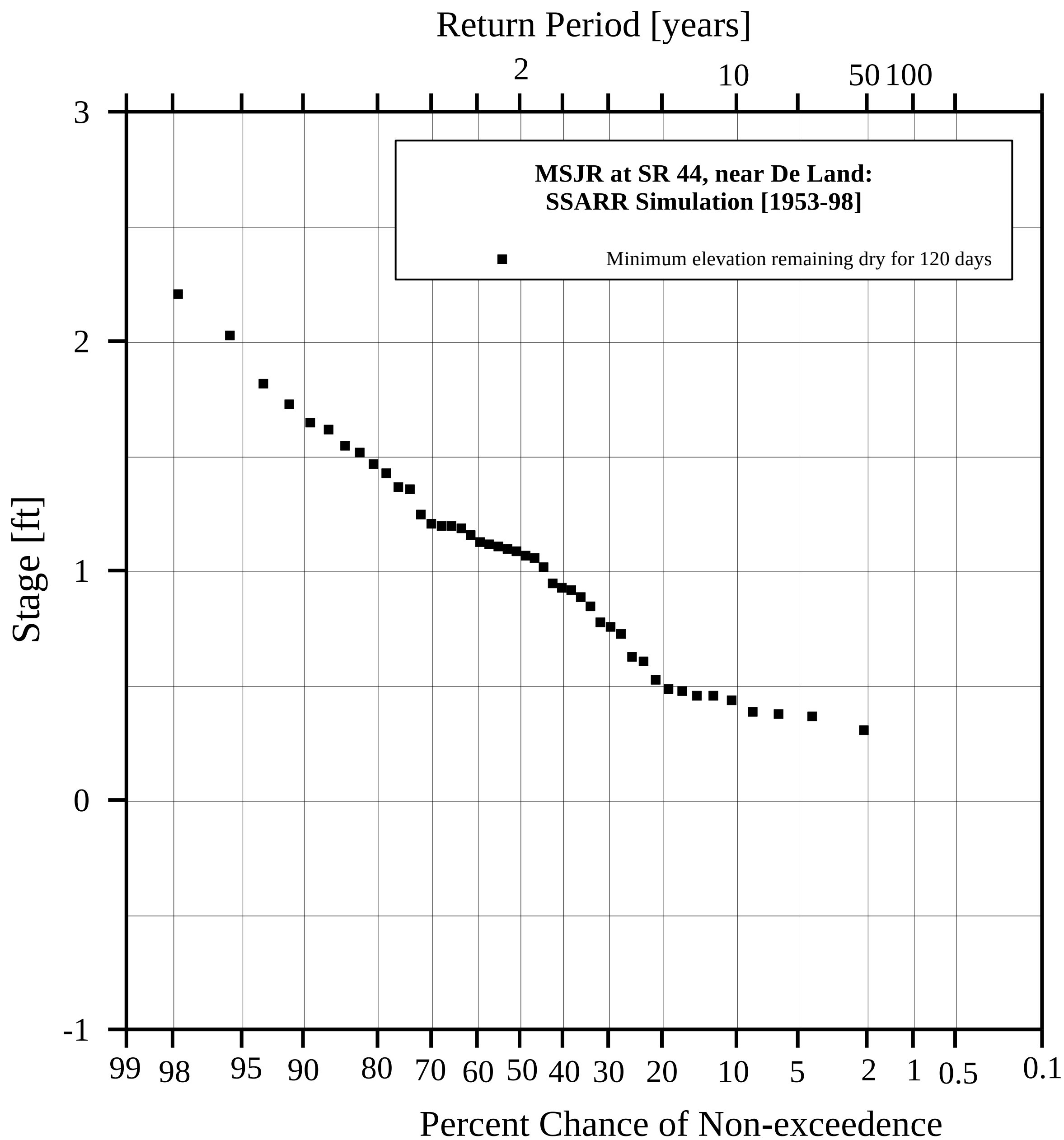


Figure C2. Drought frequencies computed using daily stages simulated by the Middle St. Johns River (MSJR) Streamflow Synthesis and Reservoir Regulation (SSARR) model at State Road 44, near DeLand, Florida. The minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula

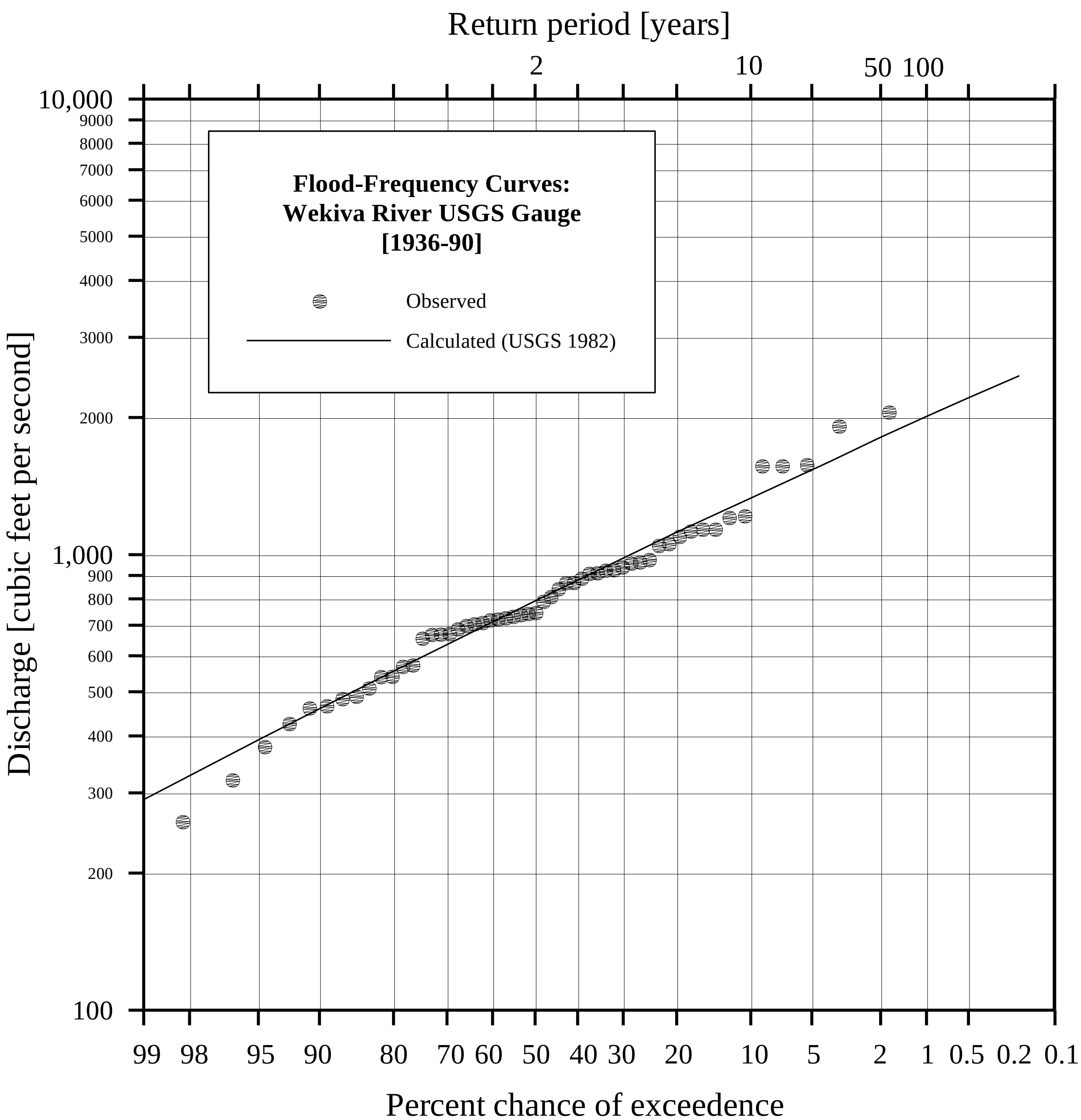


Figure C3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Florida, fitted by standard mathematical procedure

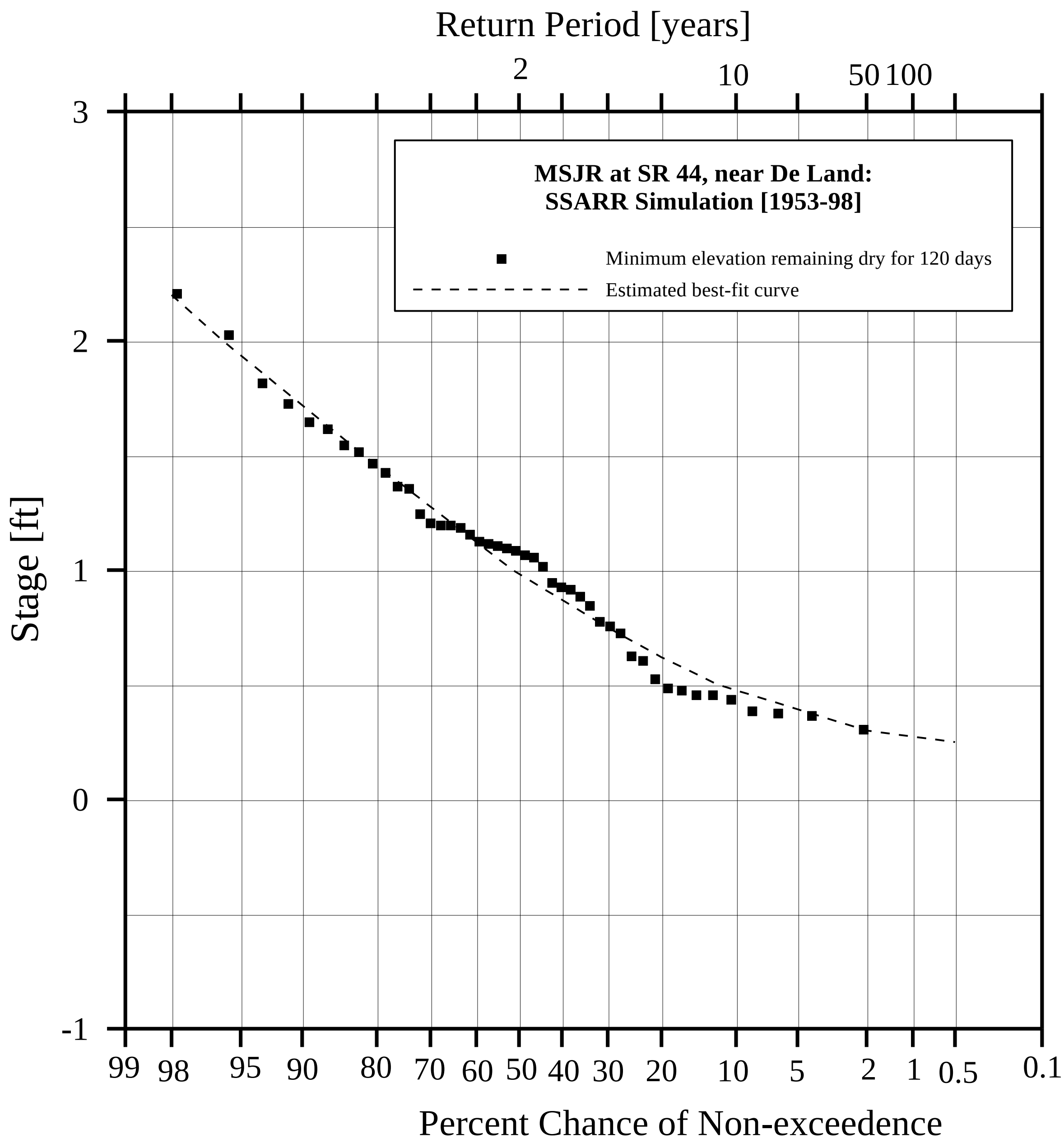


Figure C4. Drought frequencies computed using daily stages simulated by the Middle St. Johns River (MSJR) Streamflow Synthesis and Reservoir Regulation (SSARR) model at State Road (SR) 44, near DeLand, Florida, fitted by the graphical method

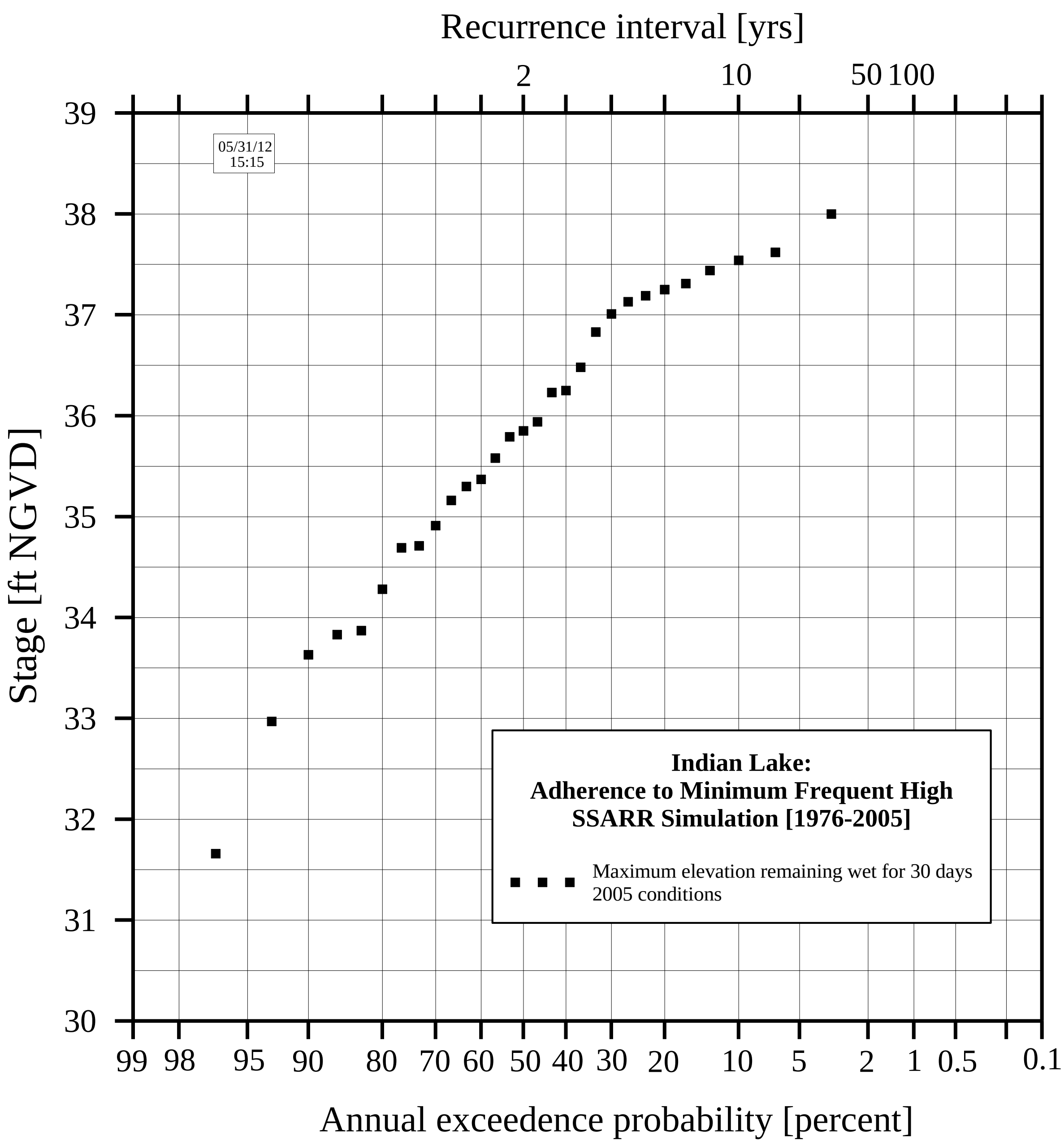


Figure C5. Flood frequencies computed using daily stages from model simulations of Indian Lake, for elevations continuously wet for 30 days and 2005 conditions
Note: SSARR = Streamflow Synthesis and Reservoir Regulation model

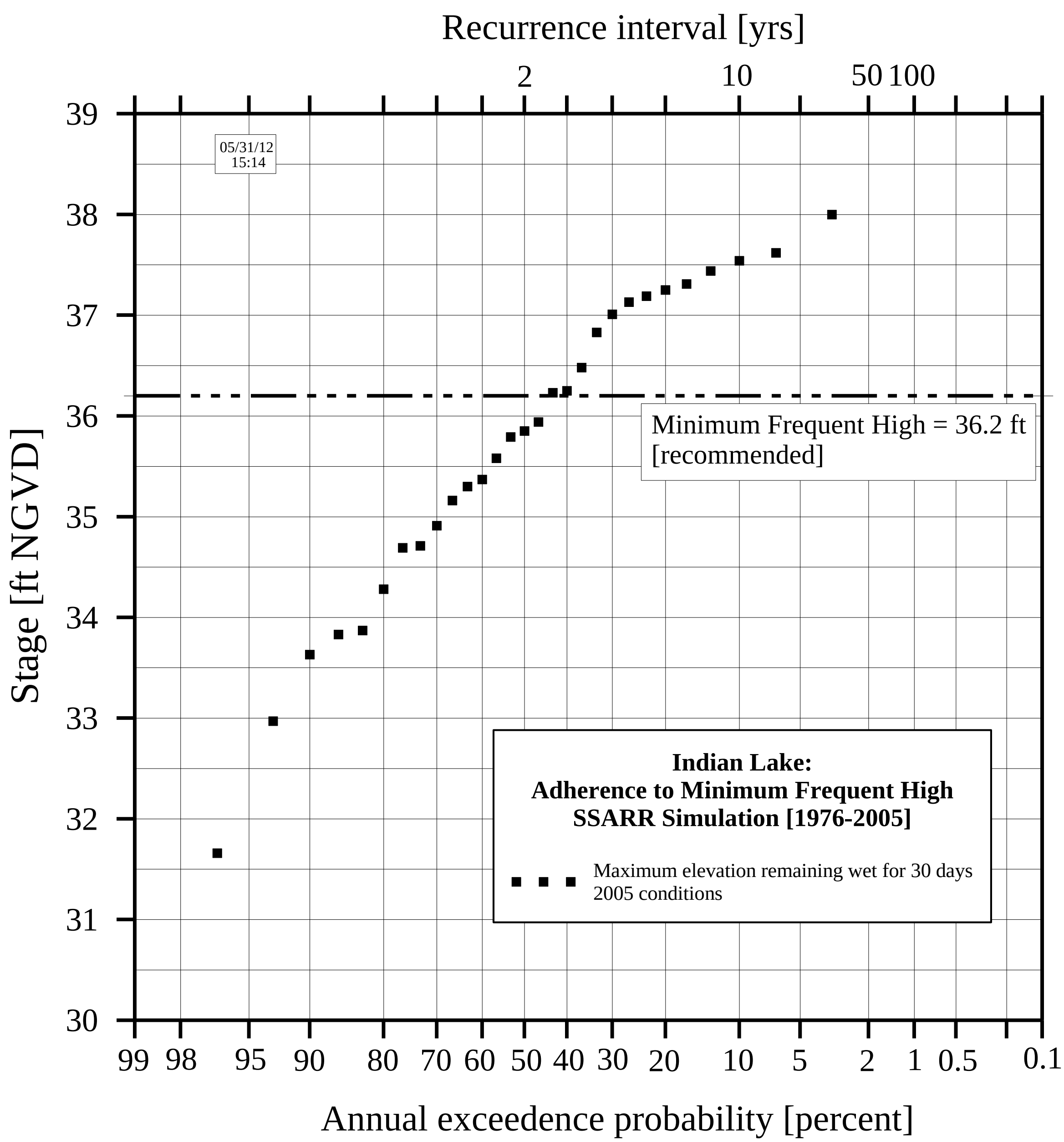


Figure C6. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Indian Lake, for elevations continuously wet for 30 days and 2005 conditions with the recommended minimum frequent high (MFH) of 36.2 ft NGVD superimposed

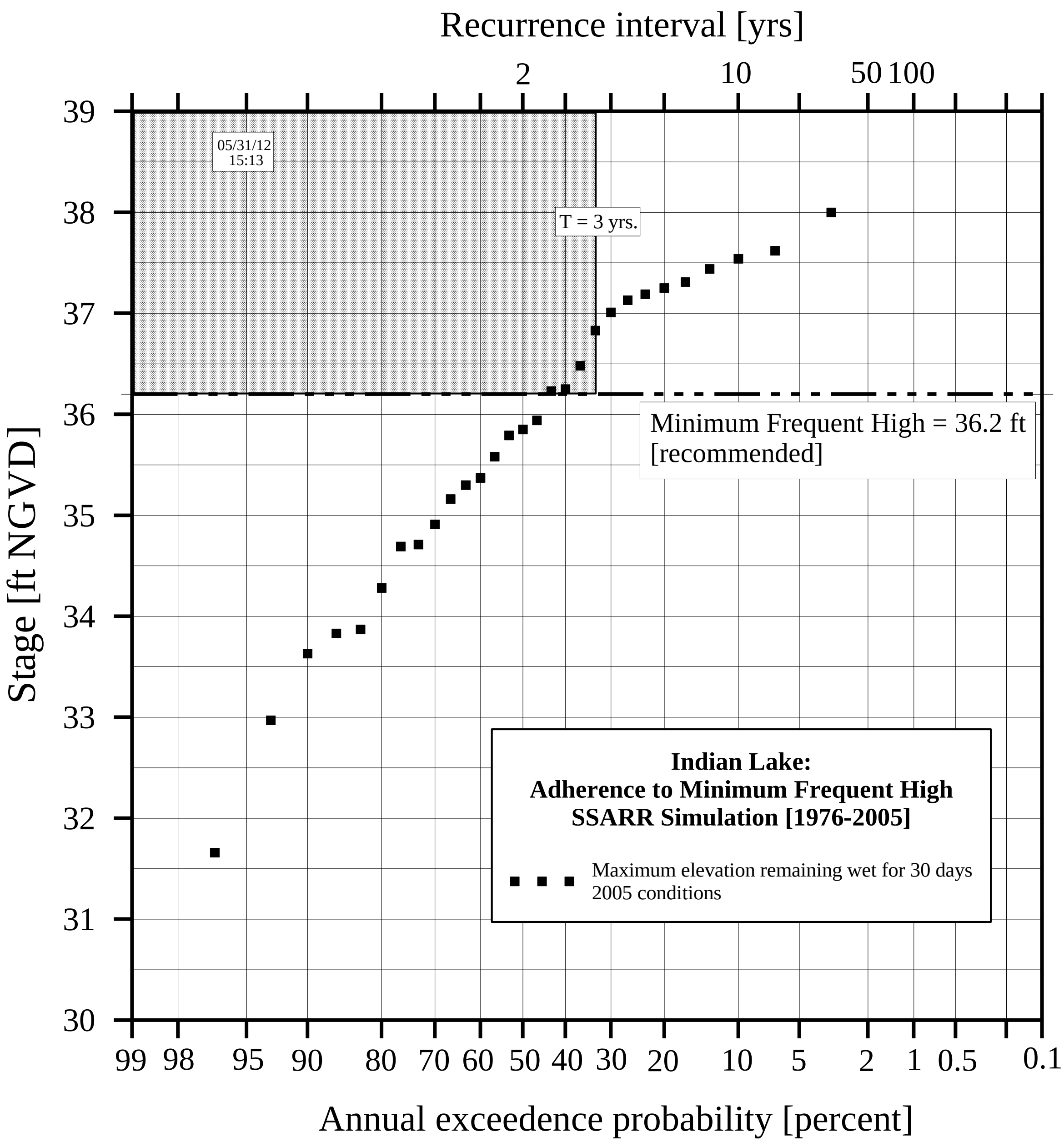


Figure C7. Flood frequencies computed using daily stages from model simulations of Indian Lake, for elevations continuously wet for 30 days and 2005 conditions with a superimposed box bounded on the bottom by the recommended minimum frequent high (MFH), and on the right by a vertical line corresponding to a return period of 3 years. Any part of the frequency curve crossing this shaded box indicates that the MFH is being met.

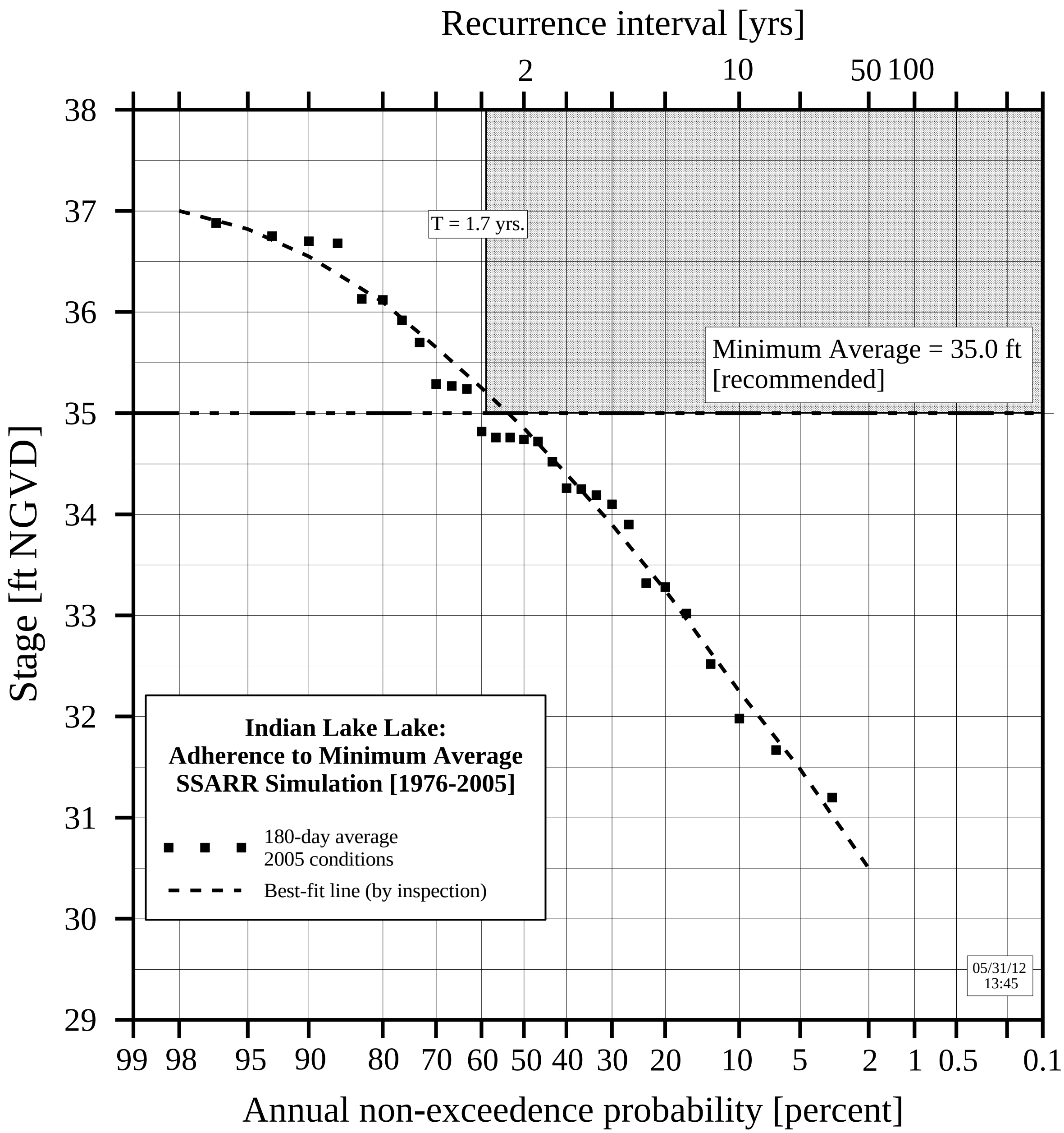


Figure C8. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation SSARR model simulations of Indian Lake, for the recommended minimum average (MA) level and 2005 conditions

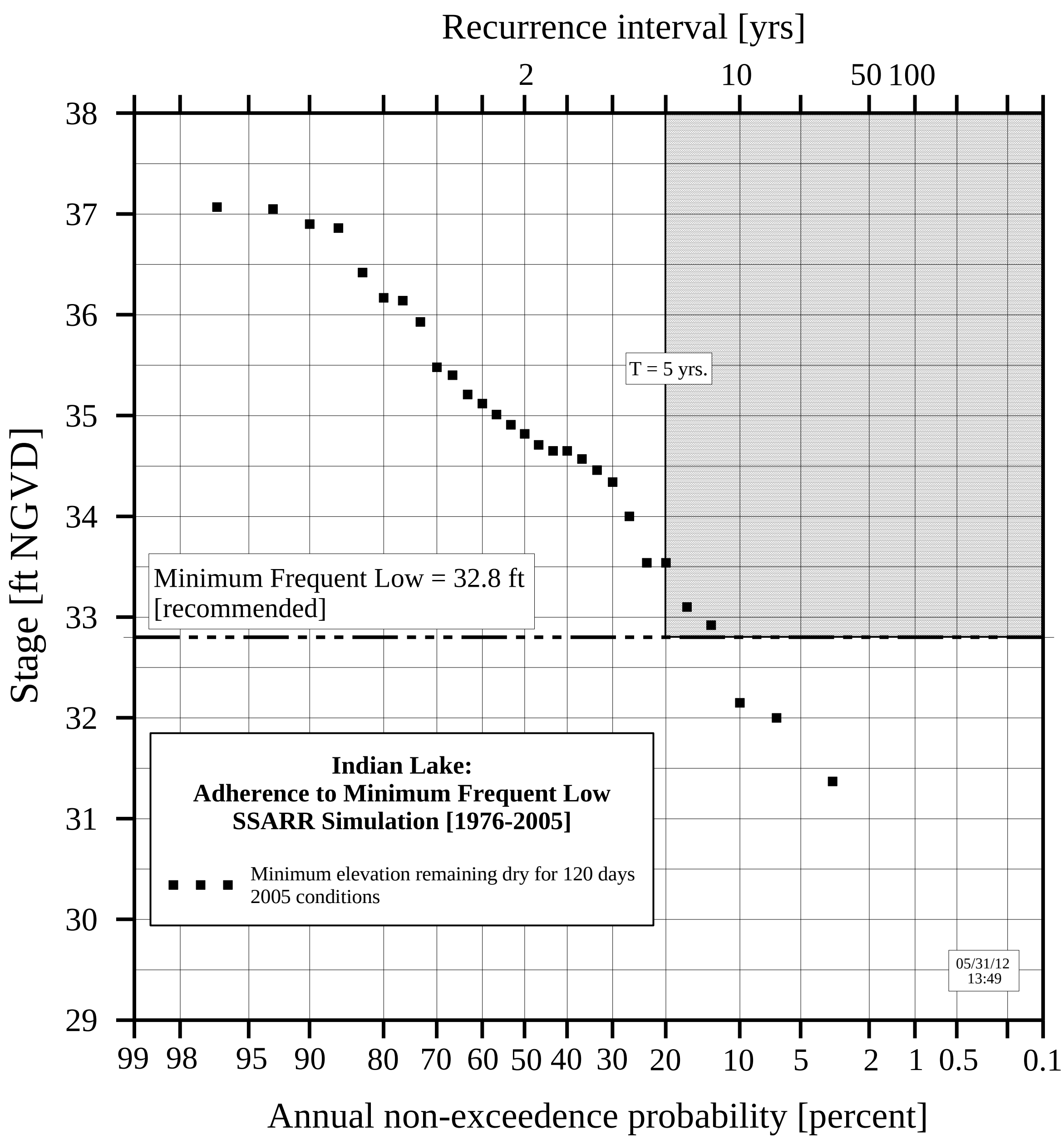


Figure C9. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Indian Lake, for the recommended minimum frequent low (MFL) level and 2005 conditions

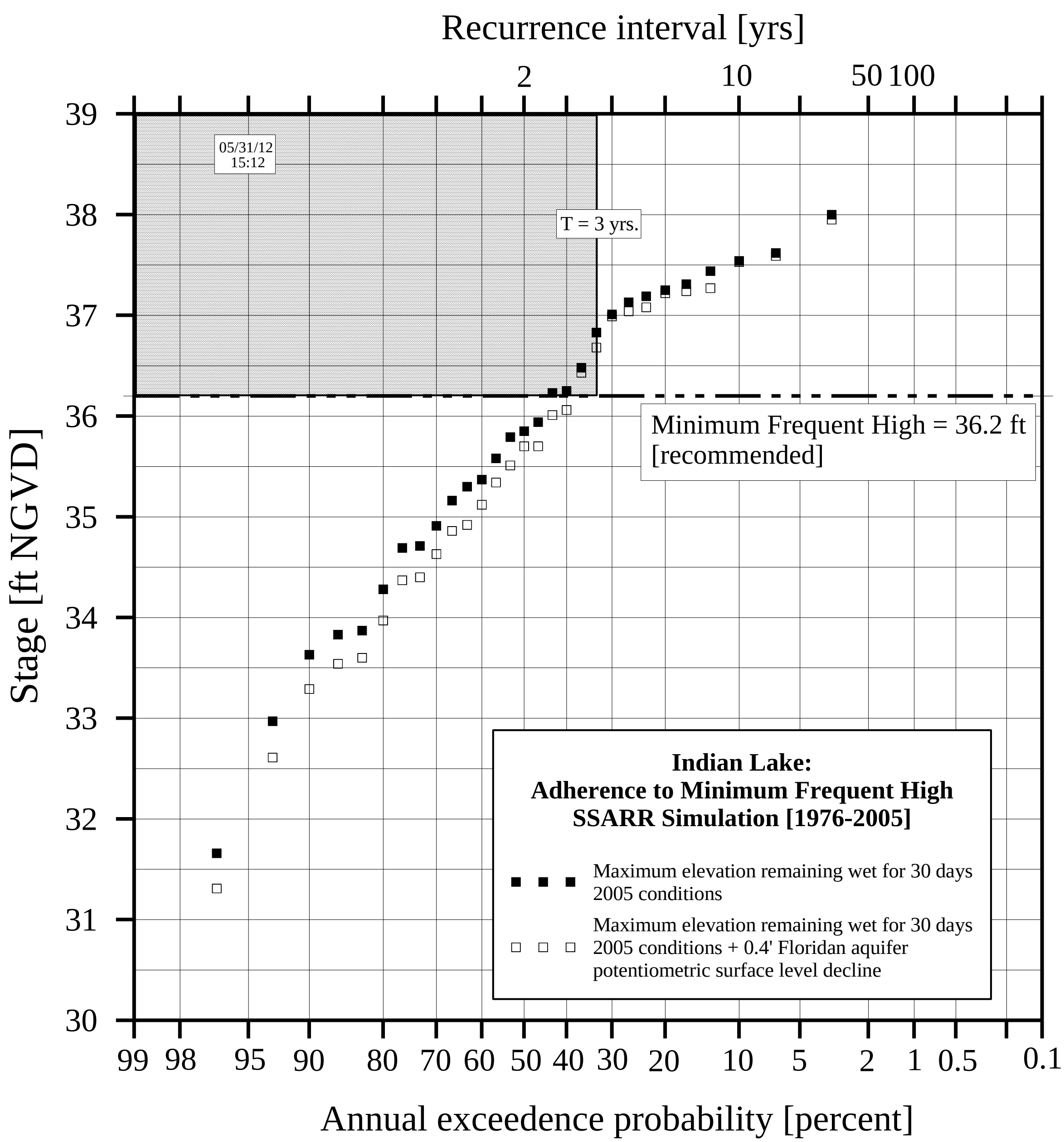


Figure C10. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Indian Lake, for the recommended minimum frequent high (MFH) level and 2005 conditions plus a 0.4-ft Floridan aquifer potentiometric surface level decline

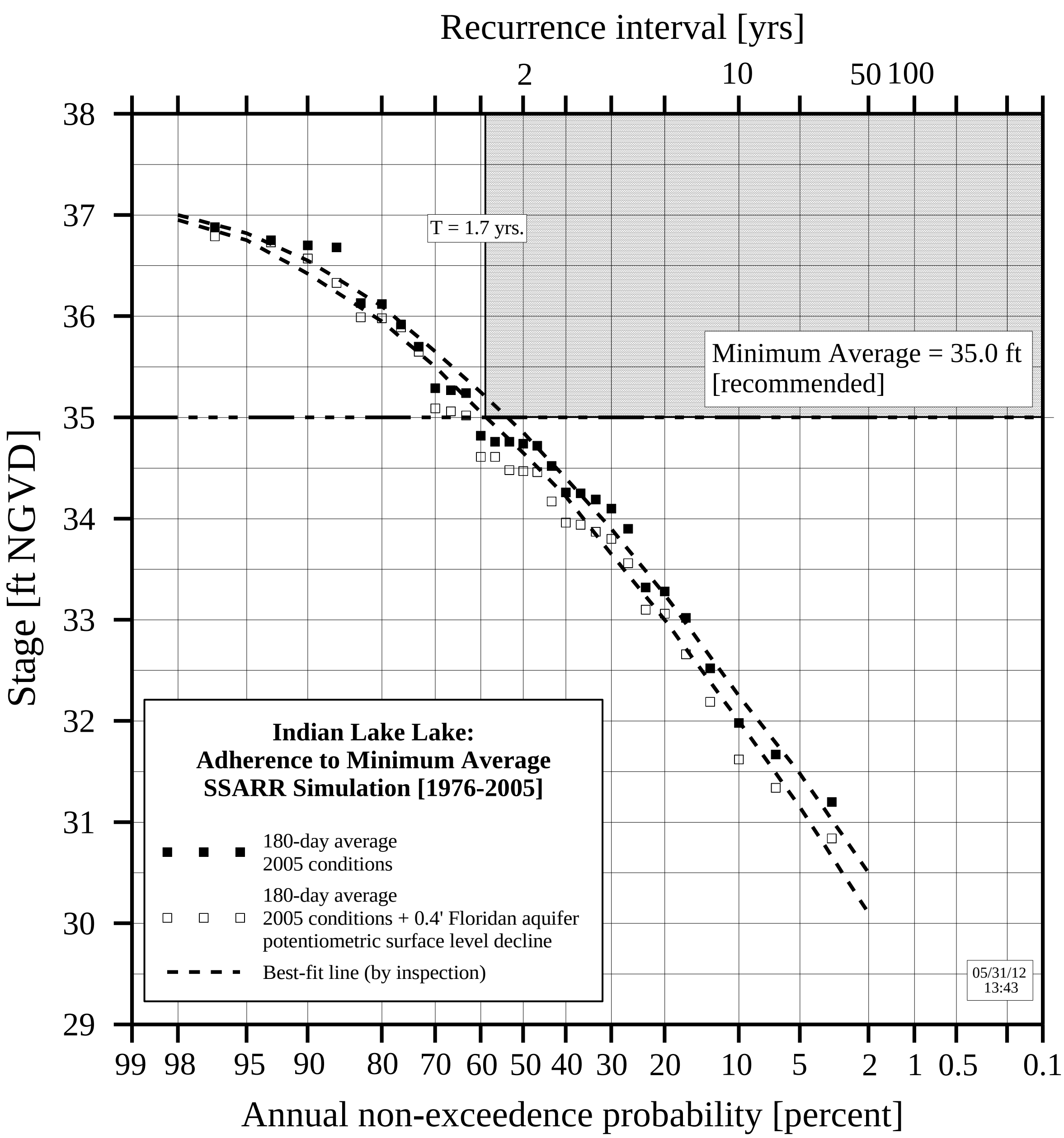


Figure C11. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Indian Lake, for the recommended minimum average (MA) level and 2005 conditions plus a 0.4-ft Floridan aquifer potentiometric surface level decline

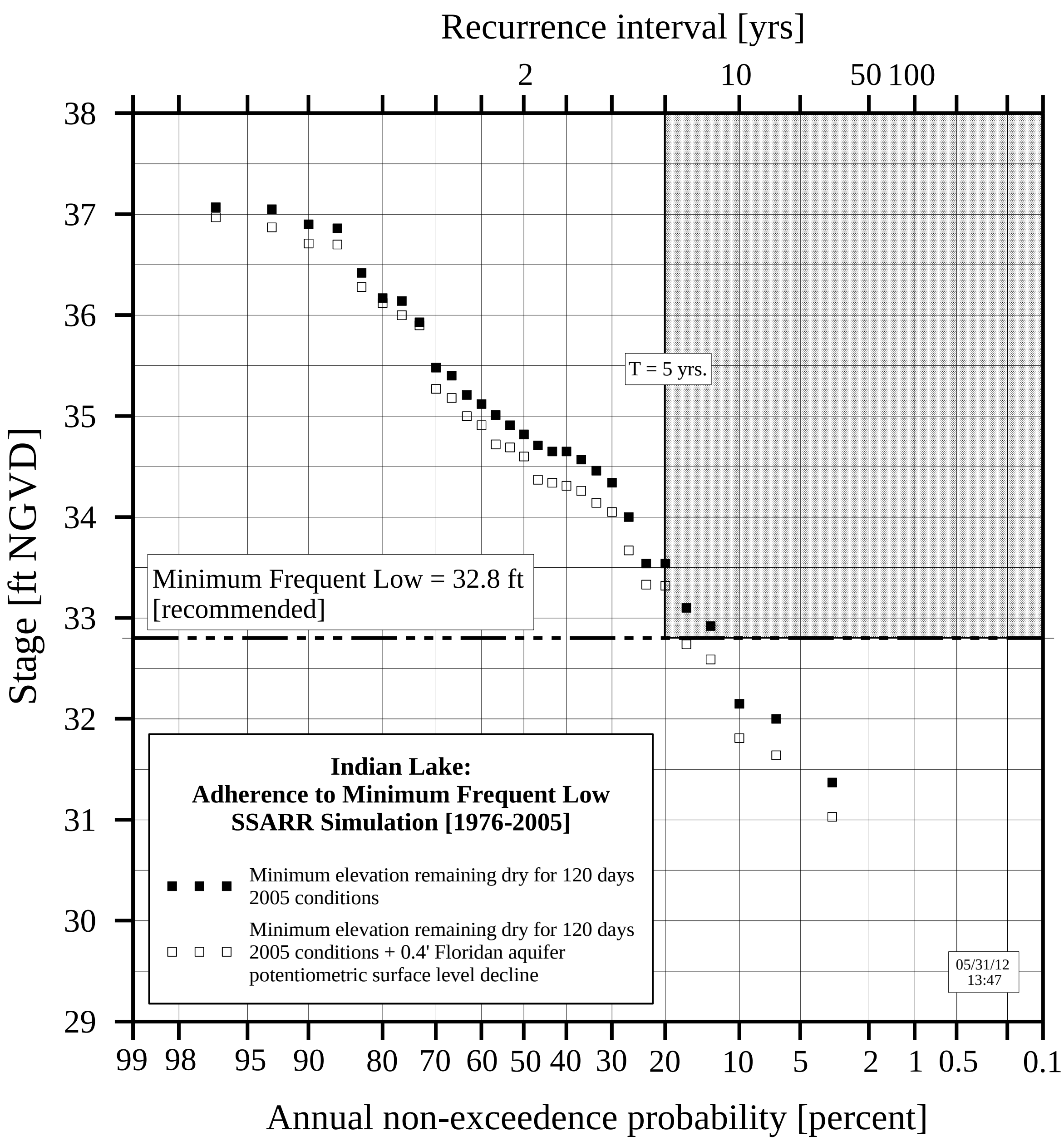


Figure C12. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Indian Lake, for the recommended minimum frequent low (MFL) level and 2005 conditions plus a 0.4-ft Floridan aquifer potentiometric surface level decline

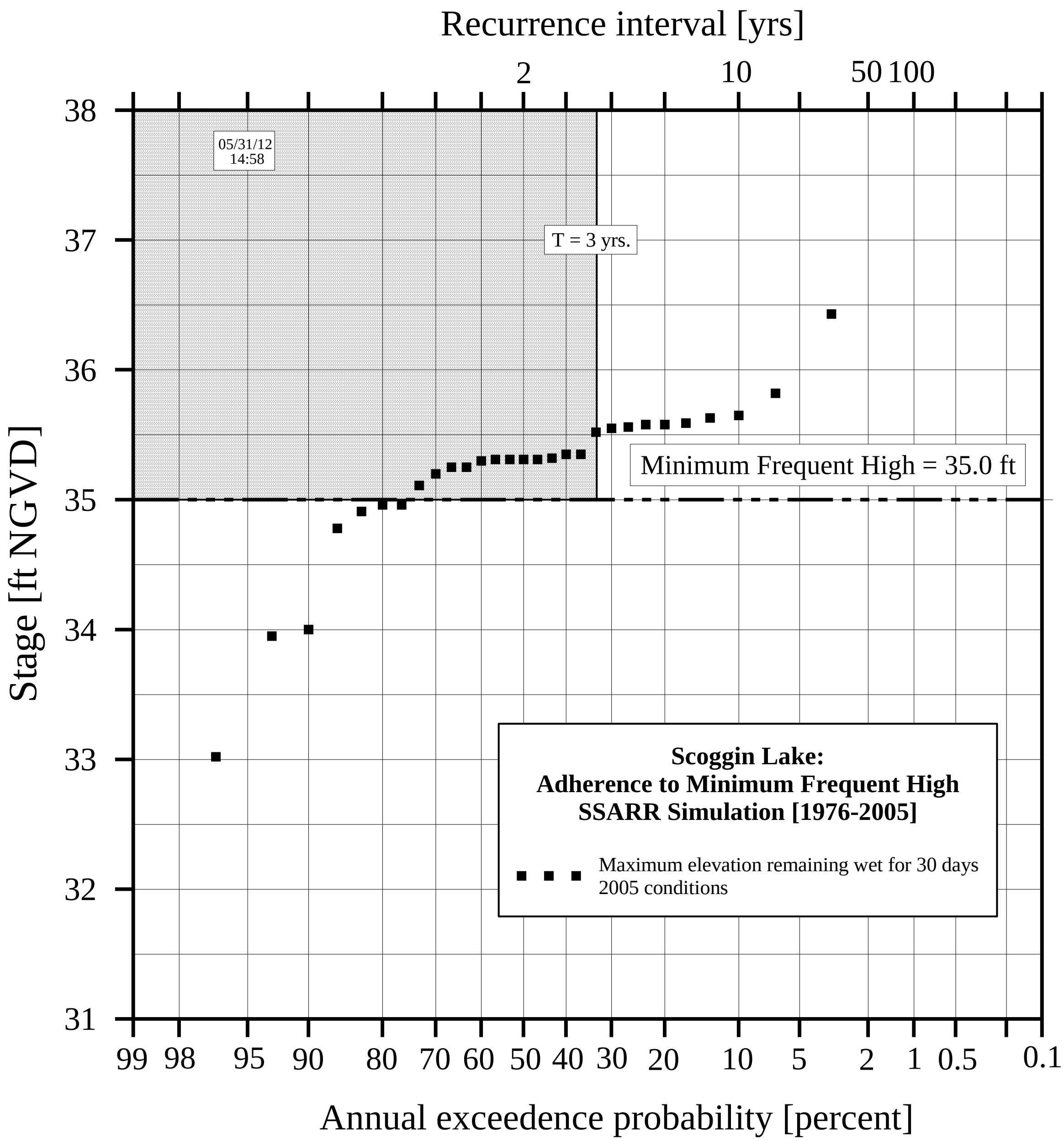


Figure C13. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for elevations continuously wet for 30 days and 2005 conditions

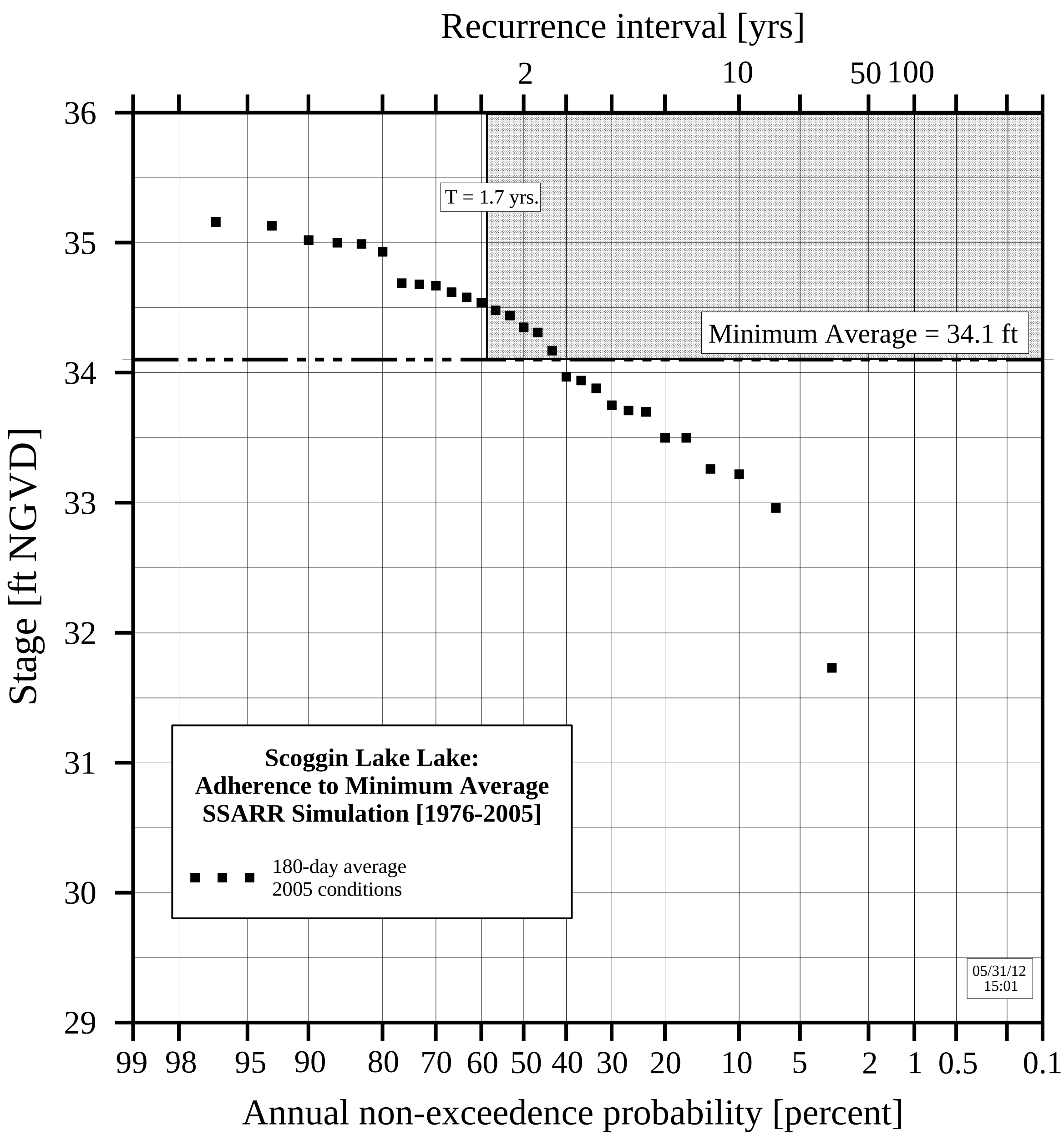


Figure C14. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for the minimum average (MA) level and 2005 conditions

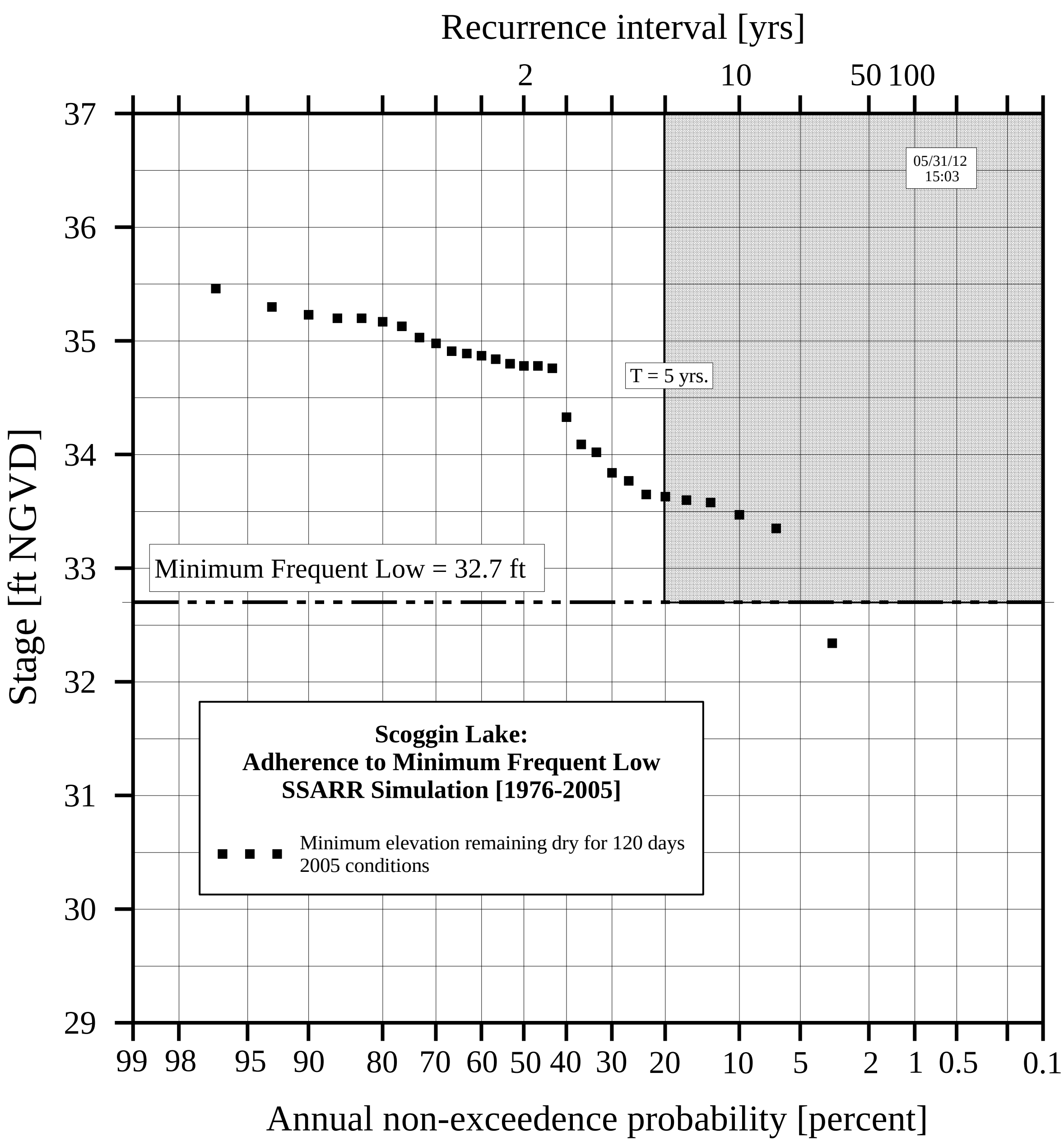


Figure C15. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for the minimum frequent low (MFL) level and 2005 conditions

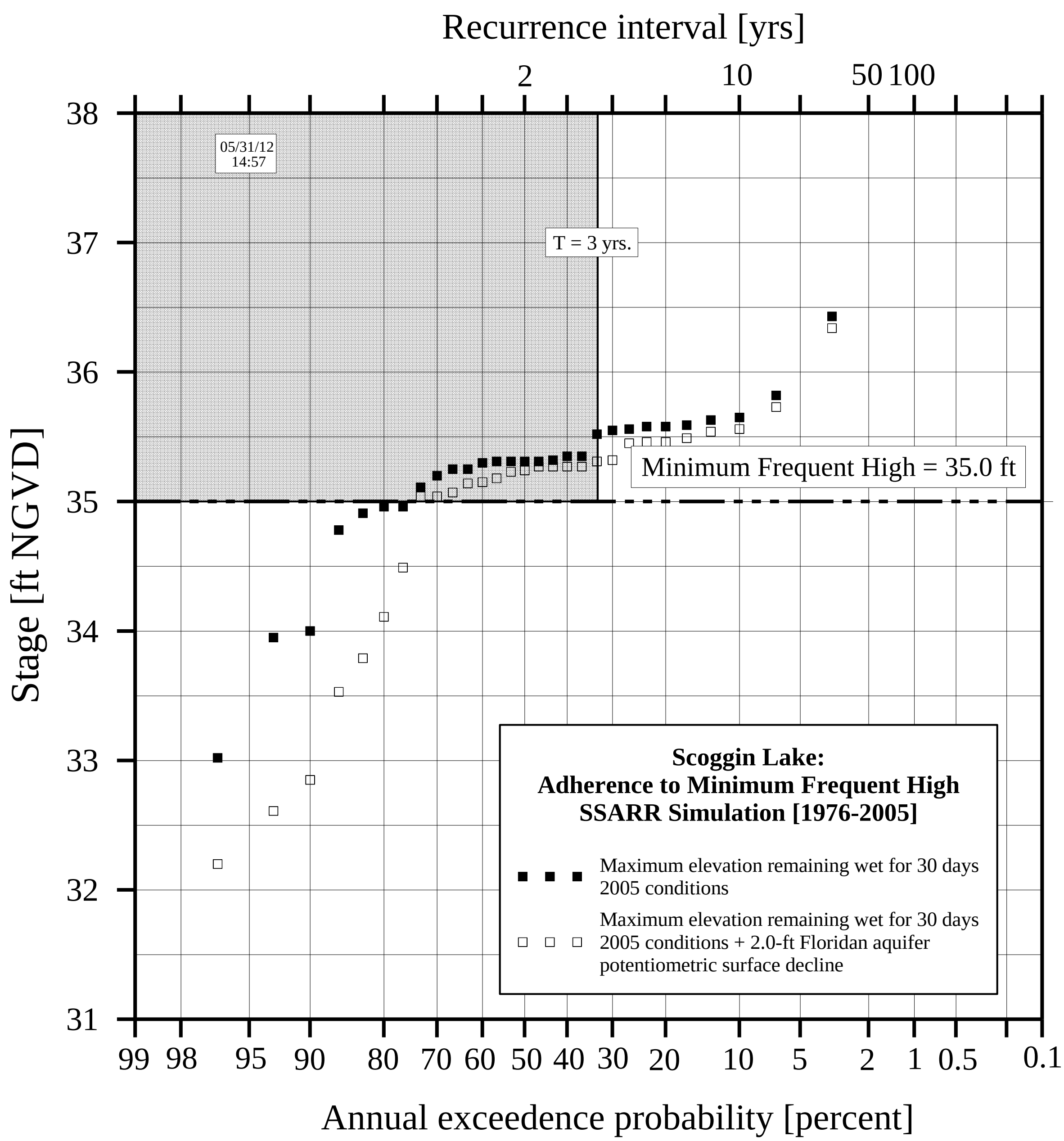


Figure C16. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for the minimum frequent high (MFH) level and 2005 conditions plus a 2.0-ft Floridan aquifer potentiometric surface level decline

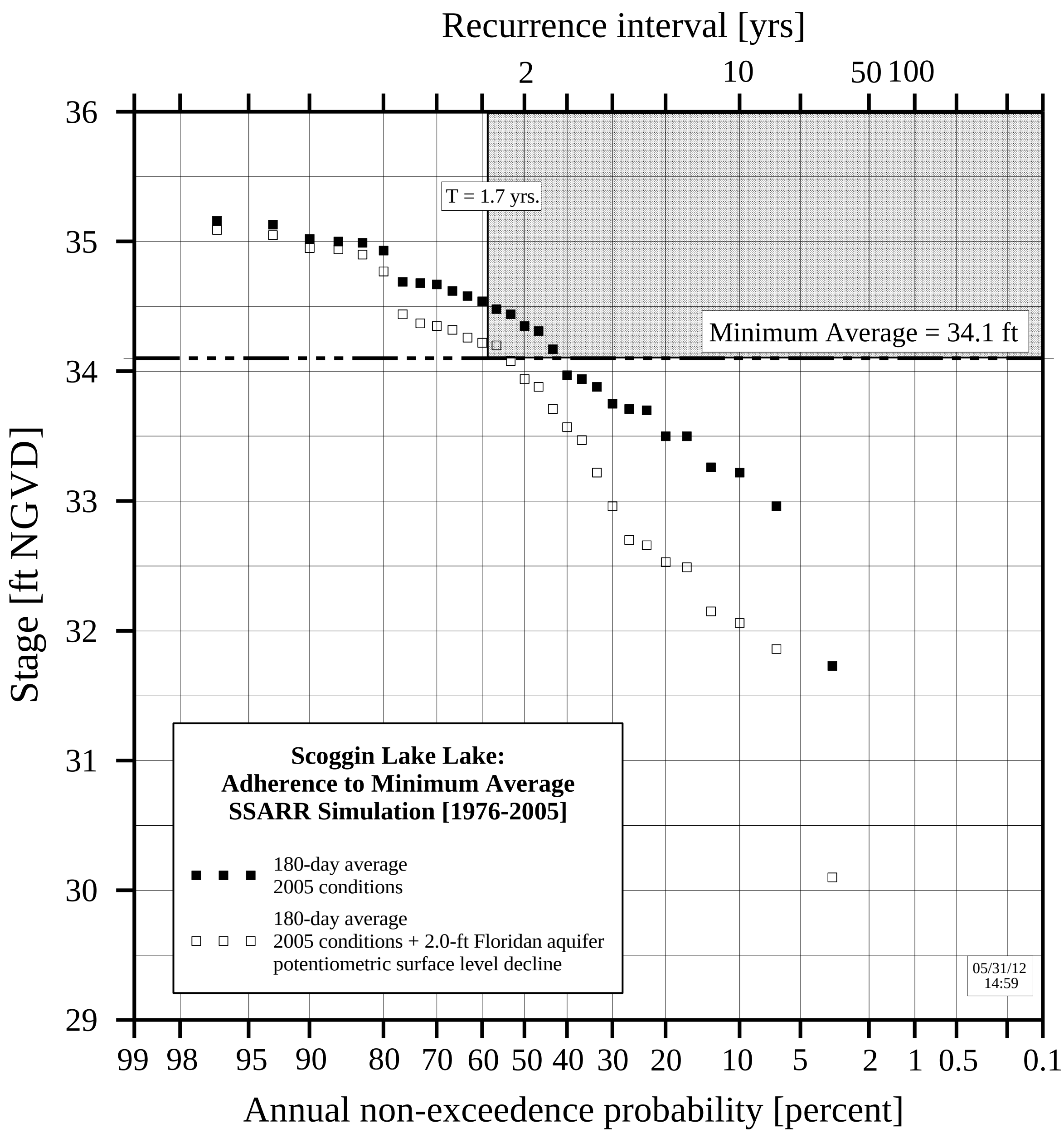


Figure C17. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for the minimum average (MA) level and 2005 conditions plus a 2.0-ft Floridan aquifer potentiometric surface level decline

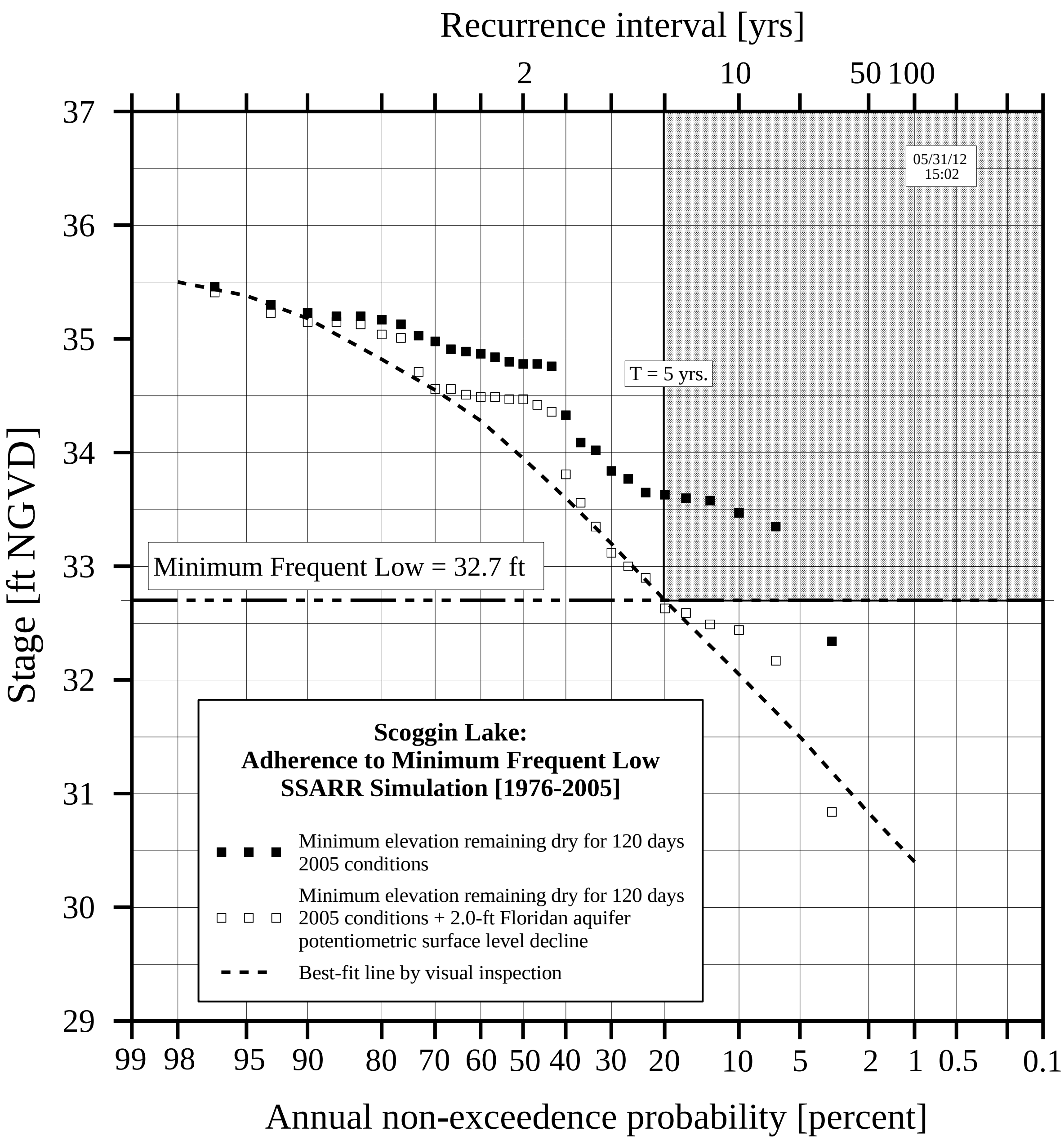


Figure C18. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Scoggin Lake, for the minimum frequent low (MFL) level and 2005 conditions plus a 2.0-ft Floridan aquifer potentiometric surface level decline

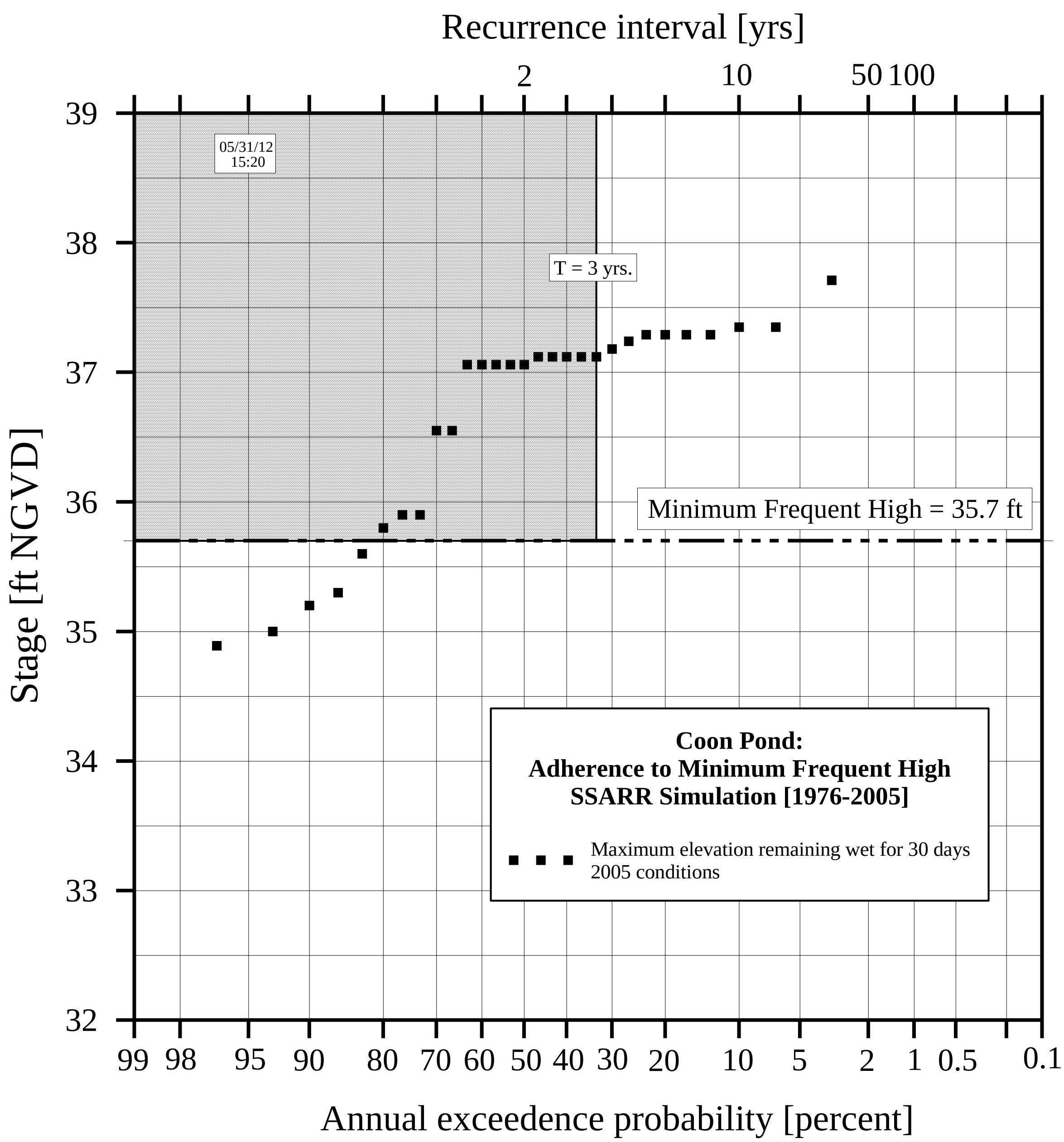


Figure C19. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for elevations continuously wet for 30 days and 2005 conditions

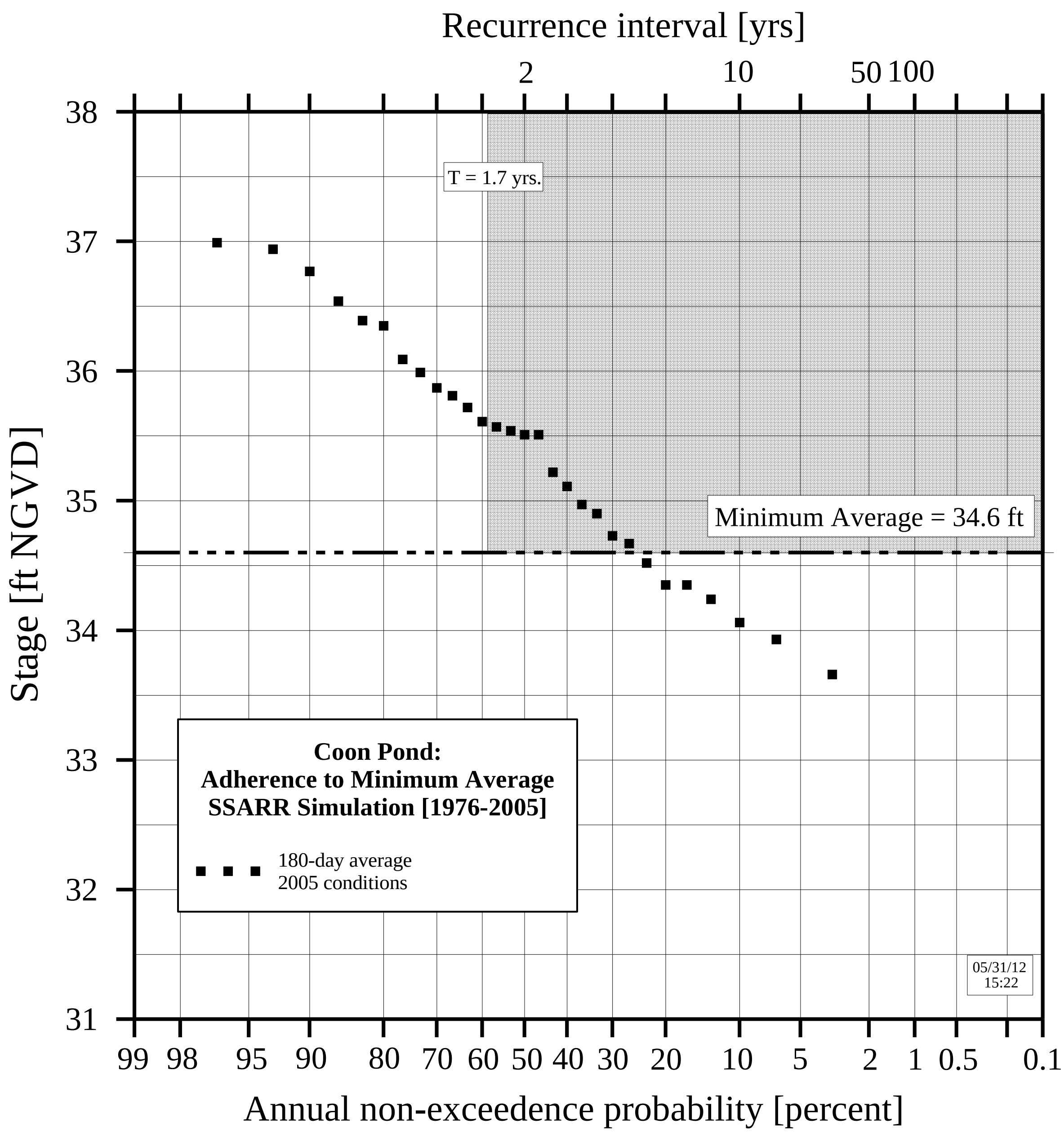


Figure C20. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for the minimum average (MA) level and 2005 conditions

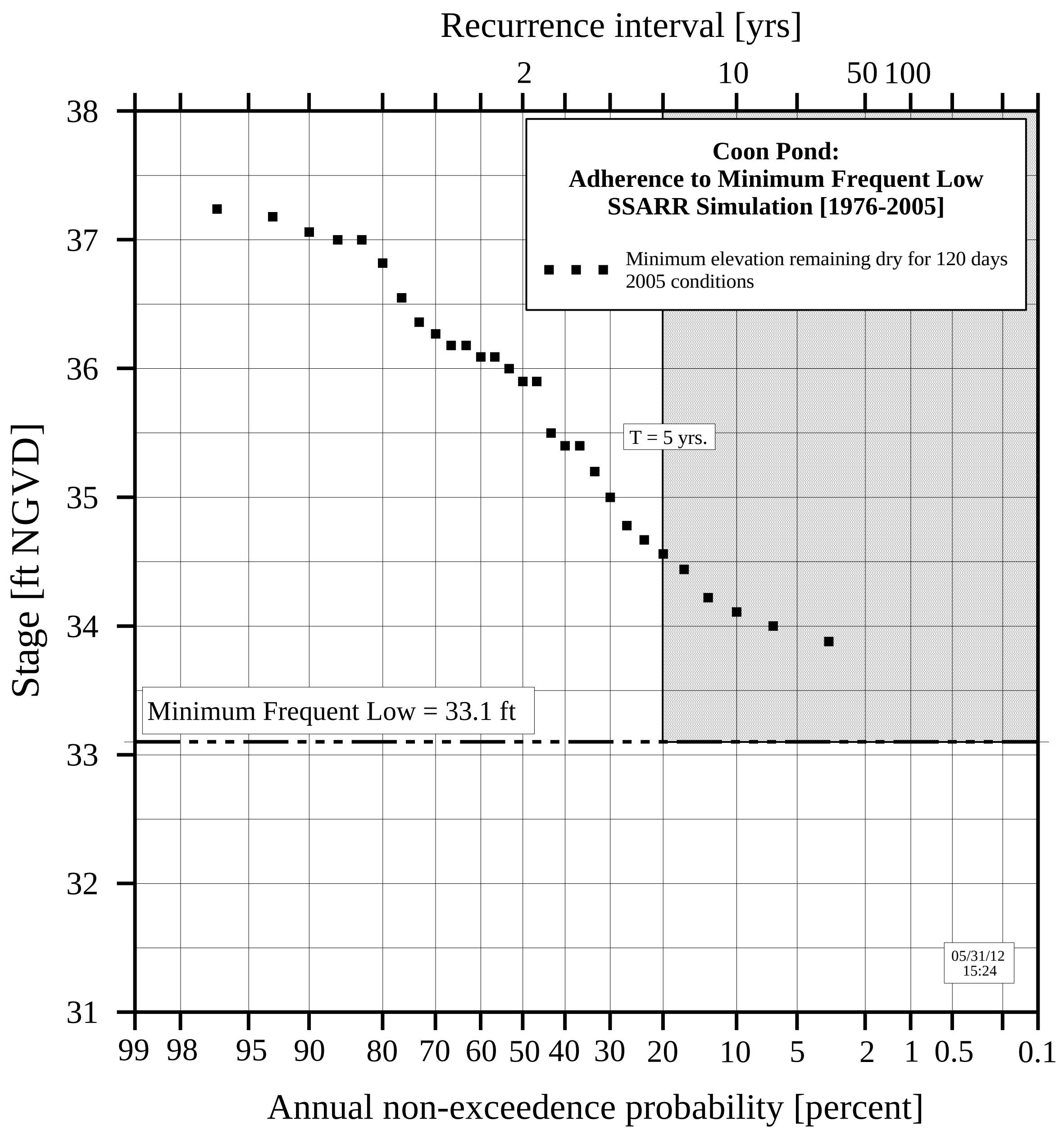


Figure C21. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for the minimum frequent low (MFL) level and 2005 conditions

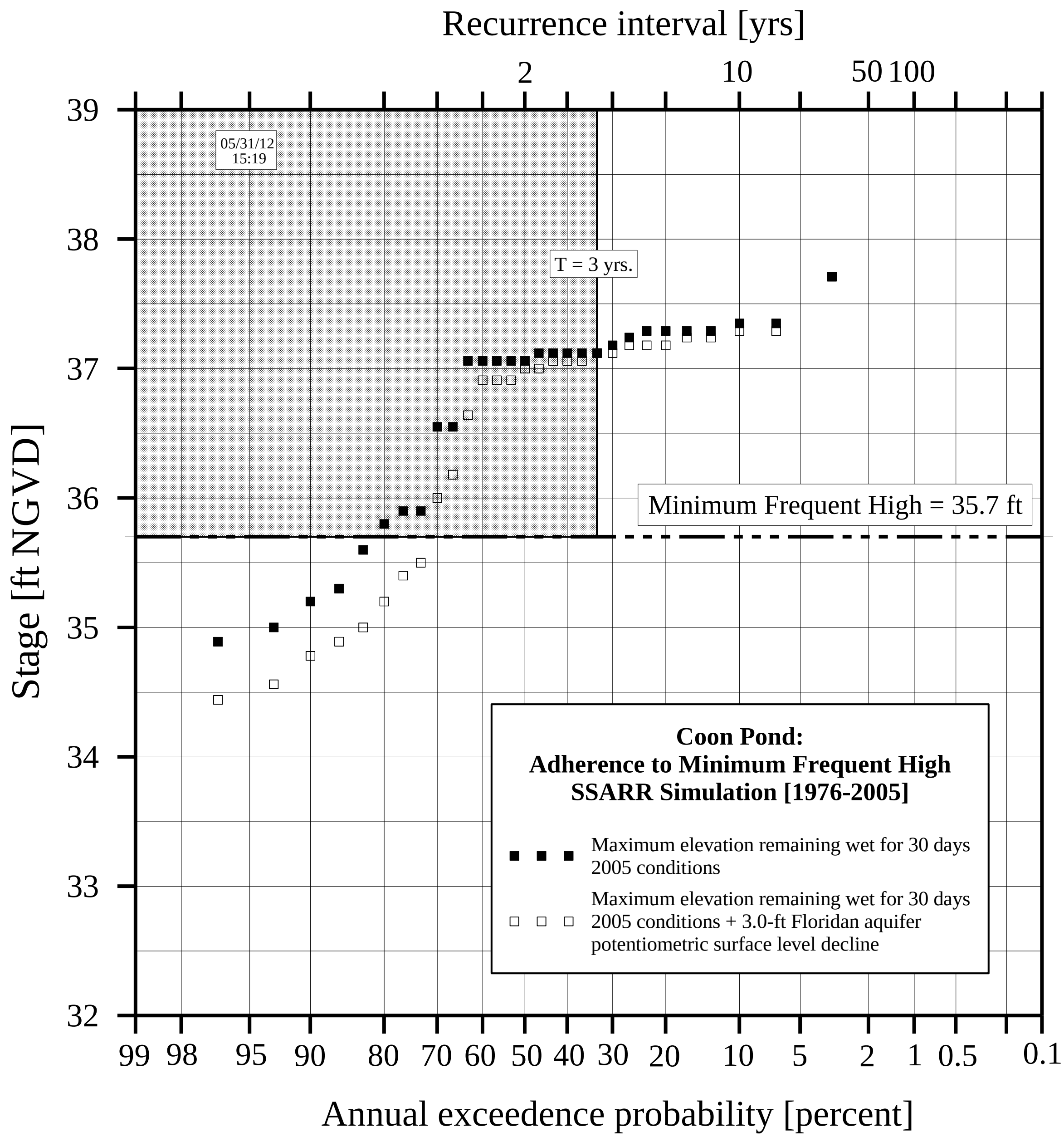


Figure C22. Flood frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for the minimum frequent high (MFH) level and 2005 conditions plus a 3.0-ft Floridan aquifer potentiometric surface level decline

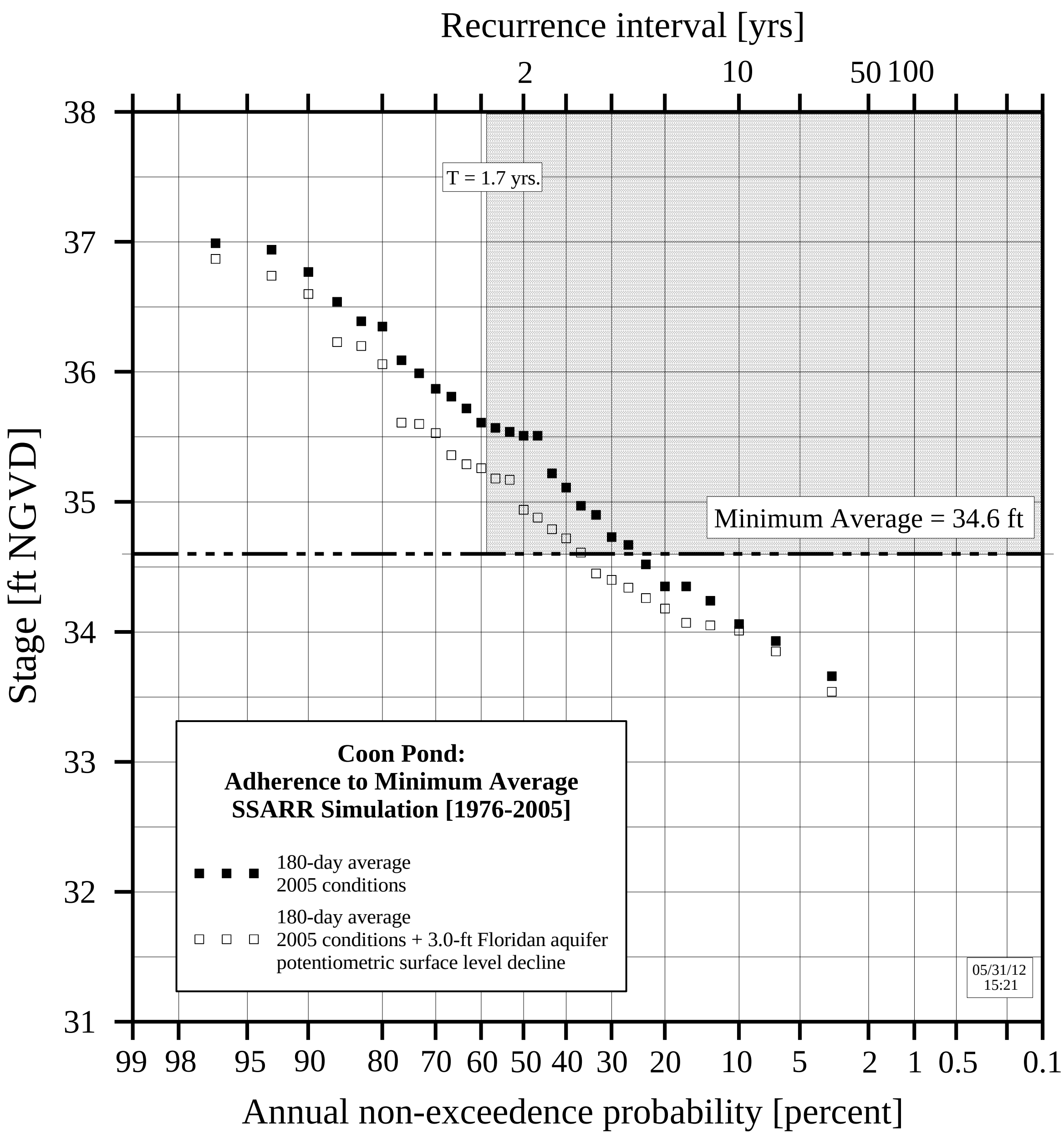


Figure C23. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for the minimum average (MA) level and 2005 conditions plus a 3.0-ft Floridan aquifer potentiometric surface level decline

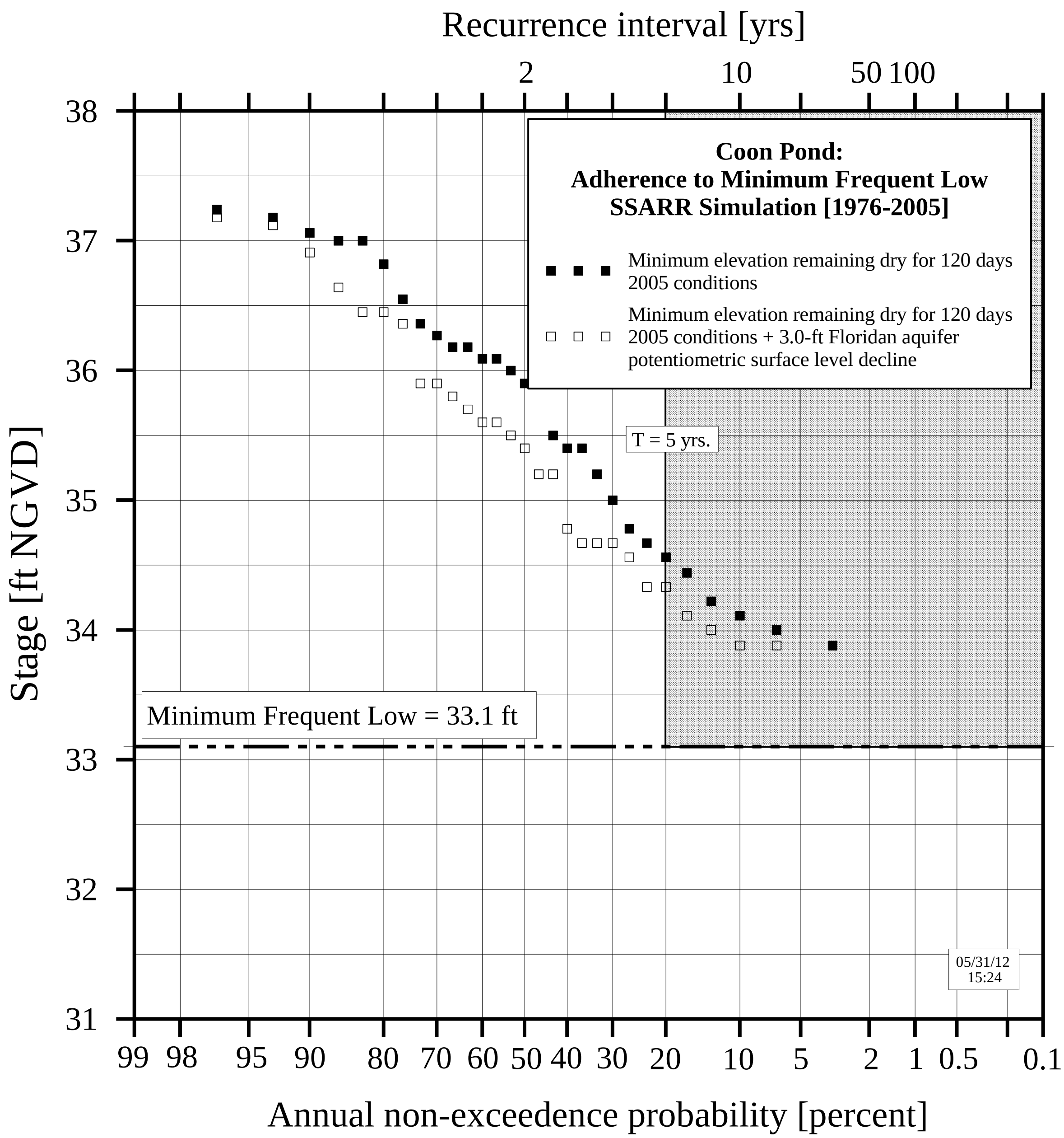


Figure C24. Drought frequencies computed using daily stages from Streamflow Synthesis and Reservoir Regulation (SSARR) model simulations of Coon Pond, for the minimum frequent low (MFL) level and 2005 conditions plus a 3.0-ft Floridan aquifer drawdown

References

Robison, C.P. 2013 (draft). *Indian Lake System Minimum Flows and Levels Hydrologic Methods Report*. St. Johns River Water Management District, Palatka, Fla.