

**TECHNICAL PUBLICATION SJ2009-1**

**MINIMUM LEVELS REEVALUATION  
FOR SHAW LAKE  
VOLUSIA COUNTY, FLORIDA**





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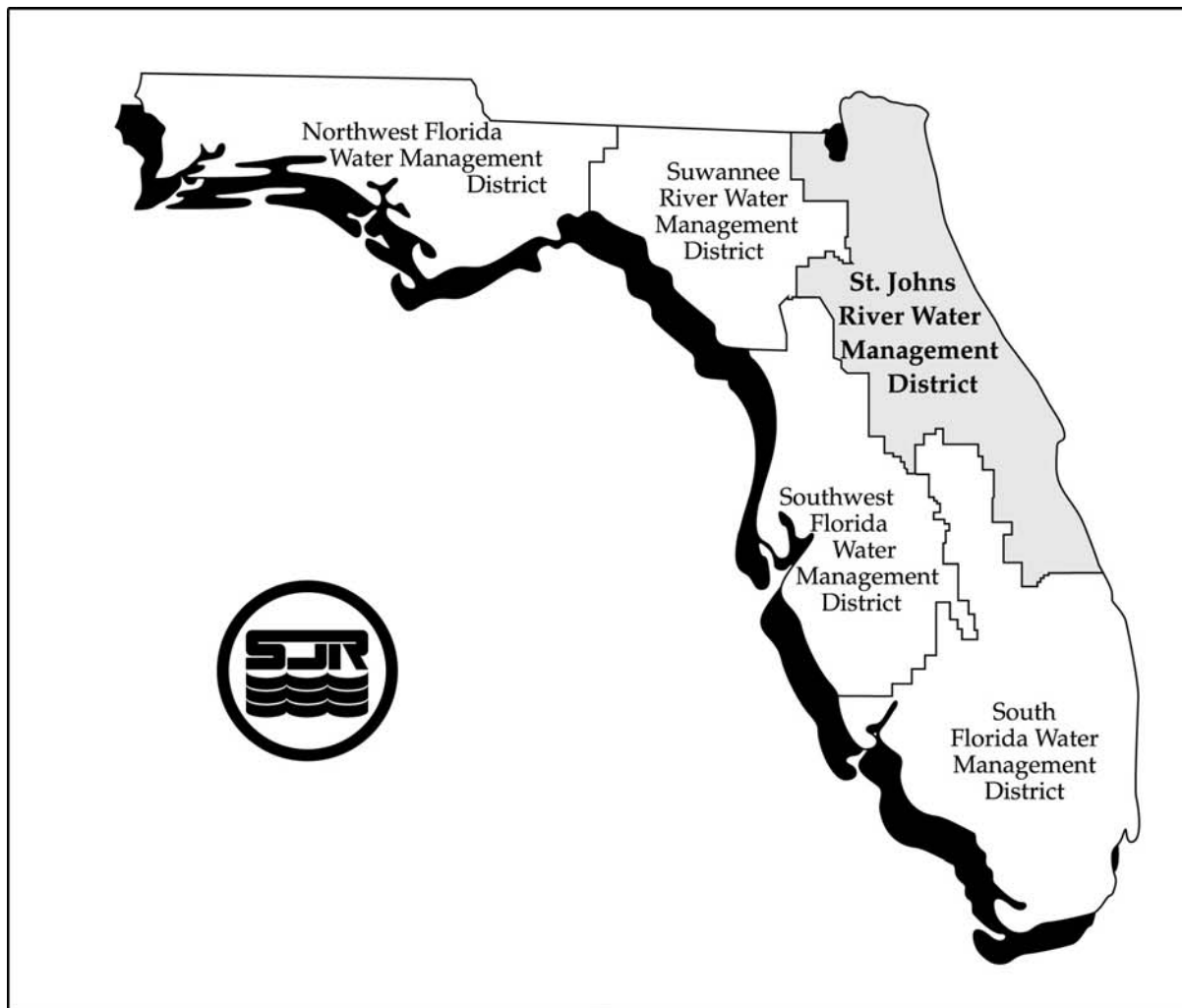
by

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Palatka, Florida

2009





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

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## EXECUTIVE SUMMARY

This report describes the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Shaw Lake in Volusia County, Florida. The SJRWMD Governing Board adopted minimum levels for Shaw Lake in 1994 (Neubauer 1993). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). A recently completed hydrologic model for Shaw Lake (Robison 2007) indicated that the established MFLs for Shaw Lake were not being met under 2004 modeled hydrologic conditions. Consequently, a reevaluation of the established MFLs for Shaw Lake was performed.

The MFLs reevaluation resulted in the recommendation to modify the established minimum frequent high, minimum average, and minimum frequent low levels for Shaw Lake (Table ES-1) based on the SJRWMD's current MFLs determination

Table ES-1. Adopted and recommended minimum surface water levels for Shaw Lake, Volusia County, Florida

Minimum Level	Adopted Level 1994 (ft NGVD)	Adopted Duration (days)	Adopted Return Interval (years)	Recommended Level (ft NGVD)	Recommended Duration (days)	Recommended Return Interval (years)
Infrequent high level	38.5	30	5.0	-	-	-
Frequent high (FH) level	36.9	30	2.0	36.7	30	3.0
Minimum average (MA) level	36.2	180	2.0	35.4	180	1.7
Frequent low (FL) level	34.0	120	5.0	33.7	120	3.0
Infrequent low level	32.0	90	10.0	-	-	-

ft NGVD = feet National Geodetic Vertical Datum

methodology (Neubauer et al. 2008a, SJRWMD 2006). The need for the minimum infrequent high/minimum infrequent low levels adopted in 1994 was considered, and it is recommended that these MFLs be deleted from Rule 40C-8.031(2), *Florida Administrative Code (F.A.C.)* for this system. Since the date of the original MFLs determination for Shaw Lake, MFLs method implementation has shown that the minimum frequent high, minimum average, and minimum frequent low levels are typically the most ecologically sensitive MFLs for wetland-type lake systems and are,

therefore, considered protective of aquatic and wetland resources. The minimum infrequent high- and low levels are products of more extreme climatic events (i.e., hurricanes and extended droughts) and may be more critical to the protection of riverine, spring, and sandhill-type lake systems. Therefore, only minimum frequent high, minimum average, and minimum frequent low levels are recommended.

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 ecology of the area (Section 373.042(1), F.S.).

The protection of nonconsumptive uses of water, including navigation, recreation, fish and wildlife habitat, and other natural resources, is considered when developing MFLs. 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 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 levels and/or flow events, causing impairment of ecological structures and functions.

The SJRWMD multiple MFLs methodology (Neubauer et al. 2008a, SJRWMD 2006) 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.

The hydrologic model for Shaw Lake was calibrated for 2004 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2004 regional water use. To determine if changes in groundwater use allocations subsequent to 2004 would cause lake levels to fall below the recommended MFLs for Shaw Lake, the existing Shaw Lake hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.



The minimum levels recommended for Shaw Lake are intended to protect the aquatic and wetland ecosystems from significant ecological harm caused by consumptive use of water. In addition, the 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-4, *F.A.C.*).



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## INTRODUCTION

This report describes the St. Johns River Water Management District's (SJRWMD) minimum flows and levels (MFLs) reevaluation for Shaw Lake in Volusia County, Florida. The SJRWMD Governing Board adopted minimum levels for Shaw Lake in 1994 (Neubauer 1993). MFLs are reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). Recent completion of a hydrologic model for Shaw Lake (Robison 2007) indicated that the adopted minimum average (MA) and the minimum frequent low (FL) levels were not being met under 2004 modeled hydrologic conditions. Consequently, a reevaluation for the adopted Shaw Lake levels was performed, and minimum frequent high, minimum average, and minimum frequent low levels were determined based on current SJRWMD MFLs methodology, criteria, and indicators (Neubauer et al. 2008a, SJRWMD 2006). This document describes that reevaluation.

## MFLS PROGRAM OVERVIEW

SJRWMD's minimum flows and levels program, based on the requirements of Sections 373.042 and 373.0421, F.S., establishes MFLs for lakes, streams and rivers, wetlands, springs, and aquifers. Further, the minimum flows and levels program is subject to the provisions of Chapter 40C-8, *Florida Administrative Code* (F.A.C.) and provides technical support to the SJRWMD regional water supply planning process (Section 373.0361, F.S.), consumptive use permitting program (Chapter 40C-2, F.A.C.), and the environmental resource permitting program (Chapter 40C-4, F.A.C.). Based on the provisions of Rule 40C-8.011(3), F.A.C., "... the Governing Board shall use the best information and methods available to establish limits which prevent significant harm to the water resources or ecology." Significant harm, or the environmental effects resulting from the reduction of long-term water levels and/or flows below MFLs, is prohibited by Section 373.042(1a)(1b), F.S. In addition, MFLs should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area (Rule 62-40.473(2), F.A.C.).

## FACTORS TO BE CONSIDERED WHEN DETERMINING MFLS

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

- 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.*)

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

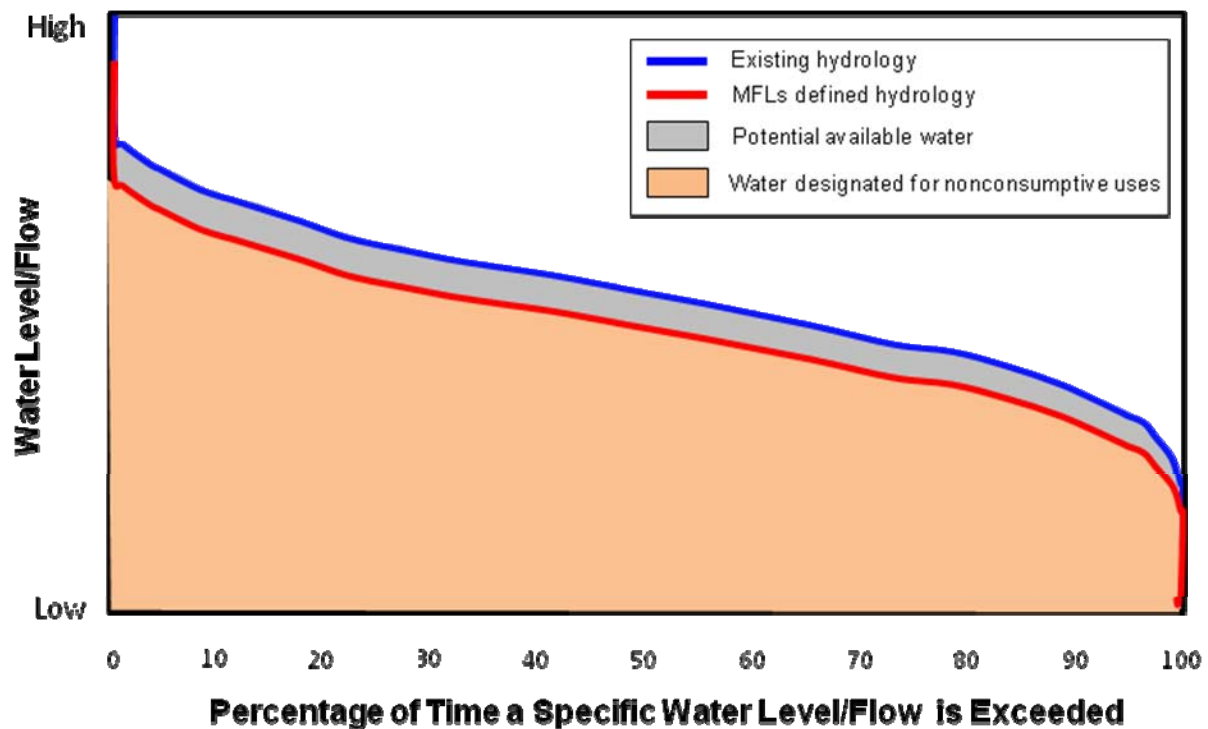
“When establishing minimum flows and levels pursuant to Section 373.042, the department or Governing Board shall consider changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations 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

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. The 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—minimum frequent high, minimum average, and minimum frequent low—flows and/or water levels. If deemed necessary, minimum infrequent high and/or minimum infrequent low flow and/or water levels are also defined. The MFLs represent hydrologic statistics composed of three components: a magnitude (a water level and/or flow), duration (days), and a frequency or return interval (years). Historically, SJRWMD 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 minimum levels have not been previously established, these hydroperiod categories are now replaced with specific duration and return intervals.

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.



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

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

MFLs 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 may 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.).

## **MFLS METHODOLOGY**

MFLs determinations incorporate biologic and topographic information collected in the field with stage data, wetland and soils data from geographical information system (GIS) coverage, aerial photography, the scientific literature, and hydrologic and hydraulic models, to generate an MFLs regime. MFLs methodology provides a process for incorporating these factors. This section describes the MFLs methodology and assumptions used in the MFLs determination process, including field procedures such as site selection, field data collection, and data analyses. Additional MFLs methodology descriptions are located in the 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, that usually extend from open water to uplands, along which elevation, soils, and vegetation are sampled to characterize the influence of surface water flooding on the distribution of soils and plant communities.

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

- 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 compiled data were reviewed to familiarize the investigator with site characteristics, the location of important basin features that needed to be evaluated, and

to assess prospective sampling locations. Copies of this information were organized and placed in permanent files for future reference (SJRWMD 2006).

Potential transect locations were identified from maps of wetlands, soils, topography, and landownership. Specific transect site selection goals included the following:

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

Transect characteristics were subsequently field-verified to ensure the particular locations contain representative wetland communities, hydric soils, and reasonable upland access. These goals helped to ensure ecosystem protection of commonly occurring and unique wetland ecosystems at Shaw Lake. Individual transect site selection criteria for Shaw Lake 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 (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 distance in the minimum time (Martin and Coker 1992).

## **SITE SURVEY**

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

Once a transect site was established, vegetation was trimmed to allow a line-of-sight along the length of the transect. A measuring tape was laid out along the length of the transect. Elevation measurements were surveyed at regular intervals (i.e., 5 feet [ft], 10 ft, 20 ft) to adequately characterize the topography and transect features. Additional elevations were measured at obvious elevation changes, vegetation community changes, soil changes, and within river channels where applicable.

Using a global positioning system (GPS), latitude and longitude were also collected along the length of each transect. GPS was used to accurately locate specific features along each transect and to facilitate recovery of transect locations in the future.

### **SOIL SAMPLING PROCEDURES**

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

- 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 (USDA–NRCS 1998).

Soil profiles were described along each transect to gain an understanding of past and present hydrologic, geologic, and anthropogenic processes that have occurred and which have resulted in the observed transect soil features. Soil profiles were described following standard Natural Resources Conservation Service (NRCS) procedures (USDA–NRCS 1998). Each soil horizon (unique layer) was generally described with respect to texture, thickness, Munsell color (Kollmorgen Corp. 1992), structure, consistency, boundary, and presence of roots. Additional procedures for soil sampling are documented in the Minimum Flows and Levels Methods Manual (SJRWMD 2006).

### **VEGETATION SAMPLING PROCEDURES**

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

The spatial extent of plant communities or transition zones (i.e., ecotones) among plant communities was determined using reasonable scientific judgment. Reasonable

scientific judgment involves the ability to collect and analyze information using technical knowledge, personal skills, and experience to serve as a basis for decision making (Gilbert et al. 1995). In this case, such judgment was based upon field observations of relative abundance of dominant plant species, occurrence and distribution of soils and hydric soil indicators, and changes in land slope or elevation along the hydrologic gradient. Plant communities and transition zones were delineated along a specialized line transect called a belt transect. A belt transect is a line with width (belt width). It is essentially a widening of the line transect to form a long, thin, rectangular plot divided into smaller sampling areas called quadrats that correspond to the spatial extent of plant communities or transitions between plant communities (Figure 2). The transect belt width will vary depending upon the type of plant community to be sampled (SJRWMD 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 Minimum Flows and Levels Methods Manual (SJRWMD 2006). Plant species, plant communities and percent cover data were recorded on field vegetation data sheets. The data sheets are formatted to facilitate data collection in the field and, also, computer transcription.

## **DATA ANALYSIS**

For information collected during the MFLs determination process, a computer spreadsheet file was used 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, as well as for sandhill lake soil indicators, where applicable, and other relevant site characteristics.



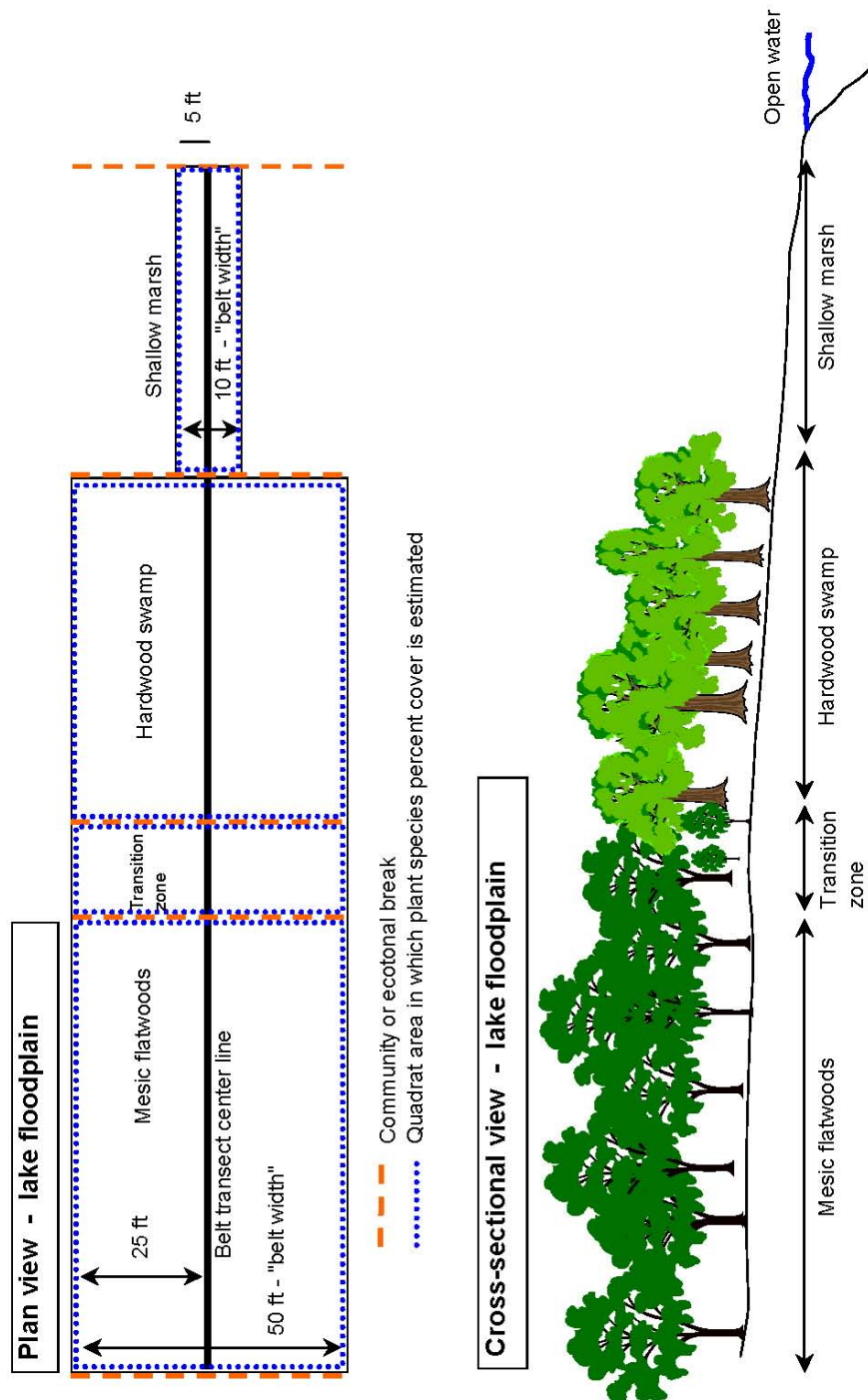


Figure 2. Example of belt transect through forested and herbaceous plant communities

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, were typically labeled on the graph. Specific transect elevation data from Shaw Lake are illustrated in the Results and Discussion section.

### **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/course. 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/courses for which the most sensitive environmental values may be wetlands and organic substrates, recommended MFLs would reflect the number of flooding or dewatering events that allow for no net loss of wetlands and organic substrates. By protecting the most sensitive environmental value or values for each water body/course, the 10 environmental values identified in Rule 62-40.473, F.A.C., are considered to be protected.

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

1. Recreation in and on the water—The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include, but are not limited to, swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. Fish and wildlife habitat and the passage of fish—Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies, and durations sufficient to support the life cycles of wetlands and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.

5. Maintenance of freshwater storage and supply—The protection of an amount of freshwater supply for permitted users at the time of MFLs determinations.
6. Aesthetic and scenic attributes—Those features of a natural or modified waterscape usually associated with passive uses, such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation, that usually result in human emotional responses of well-being and contentment.
7. Filtration and absorption of nutrients and other pollutants—The reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.
8. Sediment loads—The transport of inorganic material, suspended in water, which may settle or rise. These processes are often dependent upon the volume and velocity of surface water moving through the system.
9. Water quality—The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in definition number 7 (i.e., nutrients and other pollutants).
10. Navigation—The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and width.

## CONSIDERATION OF BASIN ALTERATIONS IN ESTABLISHING MFLS

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

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

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

SJRWMD considers that the existing hydrologic condition, which is used to calibrate and verify the models, reflects the changes and structural alterations that have occurred in addition to changes that are the result of groundwater and surface water withdrawals existing at the time of model development. This consideration may also apply to vegetation and soils conditions if the changes, structural alterations, and water withdrawals have been sufficiently large to affect vegetation and soils and have been in place for a sufficiently long-enough period to allow vegetation and soils to respond to the altered hydrology. However, the condition of vegetation and soils may not reflect the long-term existing hydrologic condition if the changes, structural alterations, and water withdrawals are relatively recent. This is because vegetation and soil conditions do not respond to all hydrologic changes nor respond instantaneously to changes in hydrology that are sufficiently large 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 of determining if the MFLs are protecting the water resources or if the MFLs are appropriately set. If SJRWMD determines, based on modeling and this data collection and evaluation process, that MFLs have not been appropriately set, SJRWMD can establish revised MFLs.

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

## **MFLs COMPLIANCE ASSESSMENT**

A hydrologic model for Shaw Lake was developed to provide a means of assessing whether compliance with MFLs is achieved under specific water use and land use conditions (Robison 2007). This hydrologic model was calibrated for 2004 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2004 regional water use.

An explanation of the use of this hydrologic model and the applicable SJRWMD regional groundwater flow model to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions is presented in the attached

Appendix A. This appendix also includes an introduction to the use of hydrologic statistics in the SJRWMD MFLs program.



## SHAW LAKE GENERAL INFORMATION

Shaw Lake is located approximately 1 mile southeast of Pierson, Florida (Figure 3). The lake has an open water area of about 150 acres at a water level of 38 feet (ft) National Geodetic Vertical Datum (NGVD), (estimated from U.S. Geological Survey [USGS] Pierson quadrangle map, scale 1:24,000). Shaw Lake is connected to Cain Lake to the south by a culvert at 37.9 ft NGVD (Neubauer 1993). Shaw Lake is generally surrounded by undeveloped land and ferneries, with some residential units on the east shore (Figure 4). The lake is in the Central Lake physiographic district (Brooks 1982). The Central Lake district is the principle recharge area of the Floridan aquifer. The region is a sandhill karst composed of uplifted limestone and characterized by solution basins with sinkholes. Shaw Lake is in a high recharge area surrounded by a 4- to 8-inch (in.) recharge area with 8- to 12-in. areas and greater than 12-in. areas on the periphery (Boniol et al. 1993).

Shaw Lake was selected for reevaluation because recent development of a water budget model and frequency analysis of the modeled stage data show that the hydrologic conditions defined by the adopted minimum frequent high (FH) level are being achieved, but the hydrologic conditions defined by the adopted minimum average (MA) and minimum frequent low (FL) levels are not being achieved (Figures 5, 6, 7, and 8; Robison 2007). This reassessment is necessary to ensure that the minimum levels are appropriate prior to any remedial action (i.e., development of a recovery strategy, and permit amendment).

### SHAW LAKE HYDROLOGY

A hydrologic model for Shaw Lake was developed to provide a means of assessing whether the recommended MFLs are achieved under specific water use and land use conditions (Robison 2007). This hydrologic model was calibrated for 2004 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2004 regional water use. An example of the use of a hydrologic model to assess whether MFLs are achieved under specific water use and land use conditions is presented in Appendix A.

The period-of-record water levels for Shaw Lake are from December 19, 1986, to April 15, 2006 (Figure 9). Approximately daily lake-level readings were taken from December 19, 1986–October 5, 1996; virtually no readings from October 6, 1996–November 7, 2003; and approximately weekly readings from November 8, 2003–April 15, 2006. Data were supplied by SJRWMD’s Division of Hydrologic Data Services.

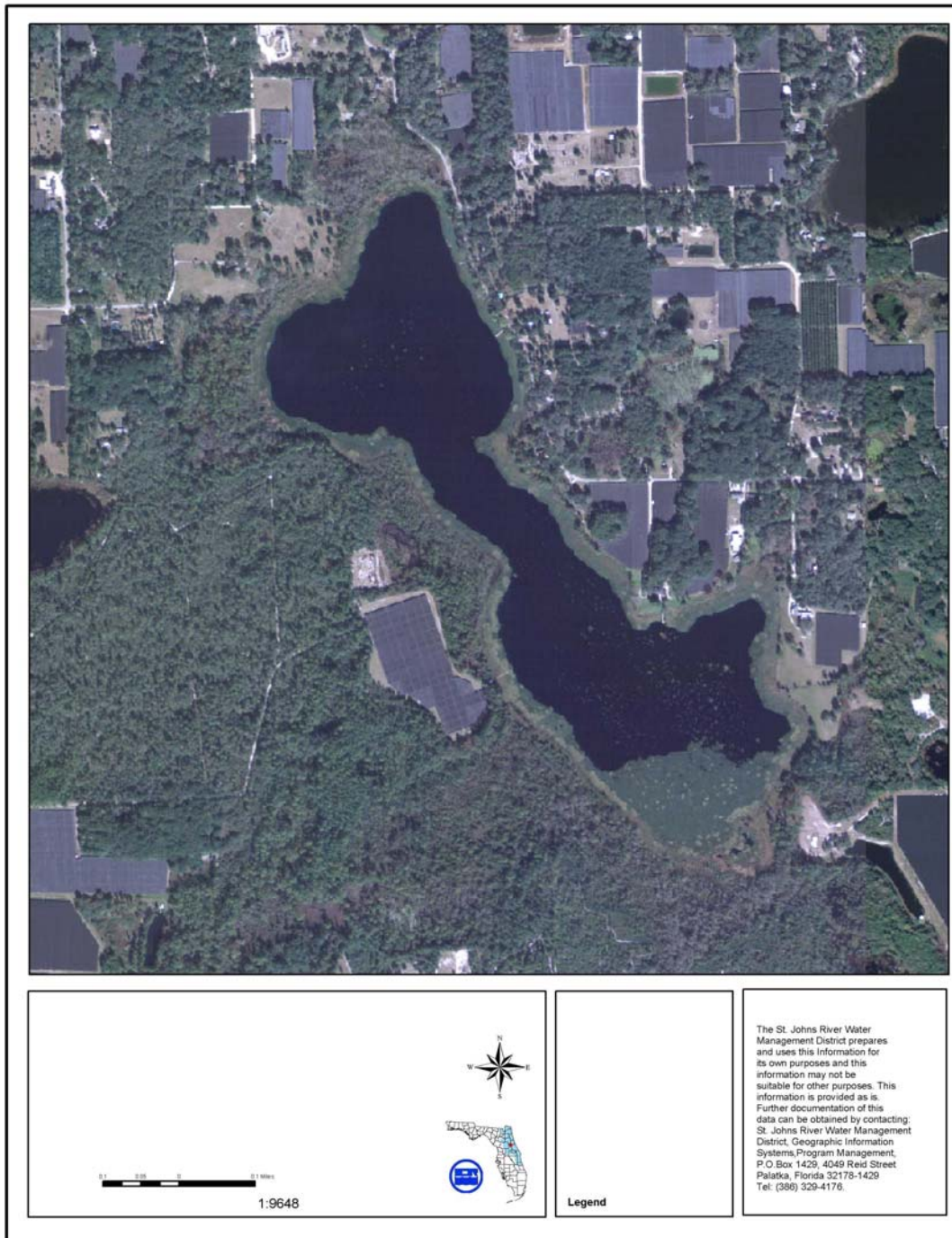
Minimum Levels Reevaluation for Shaw Lake, Volusia County, Florida



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Figure 3. Shaw Lake location map





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Figure 4. Shaw Lake aerial photograph

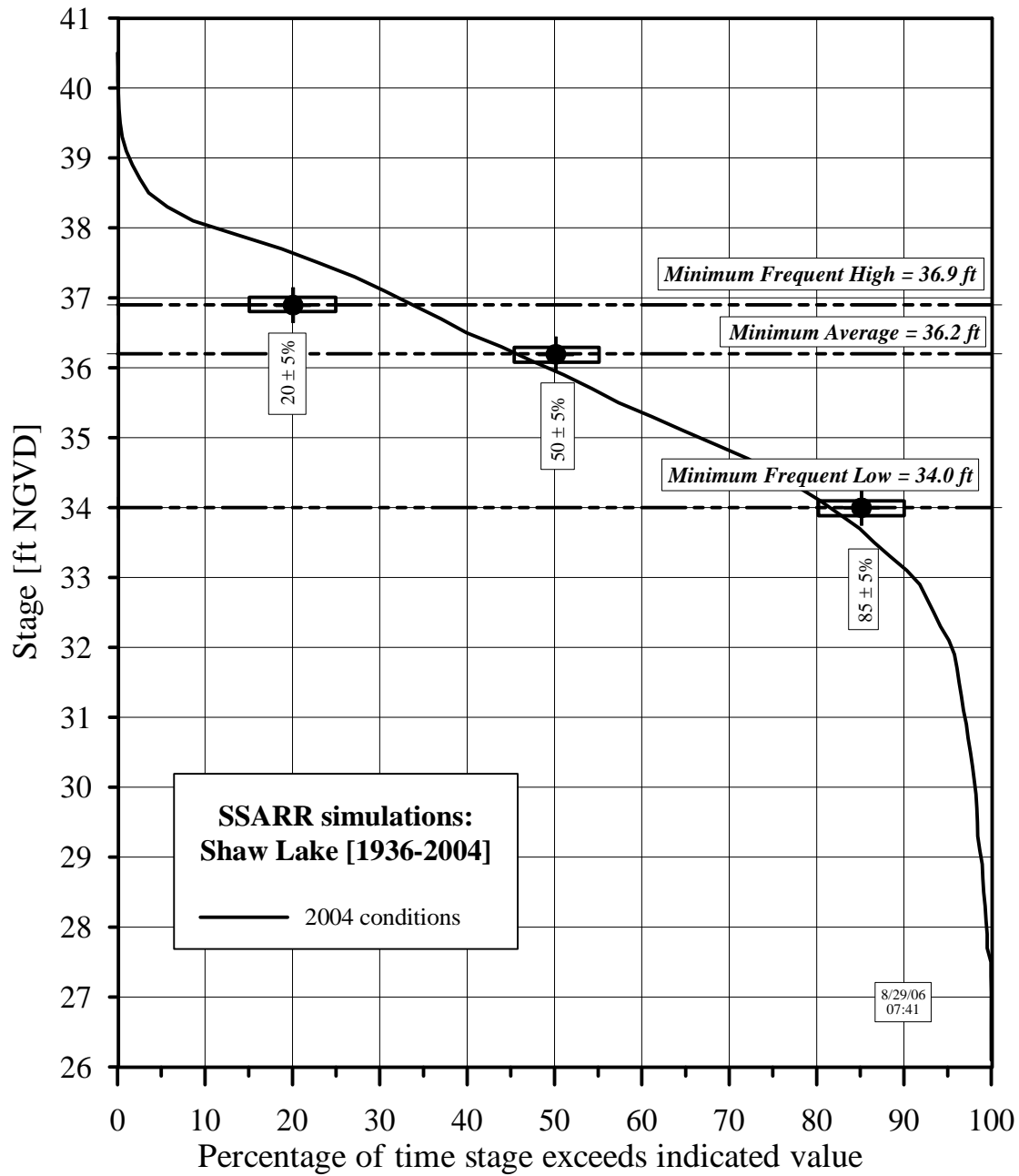


Figure 5. Modeled percent exceedence with adopted minimum levels for Shaw Lake

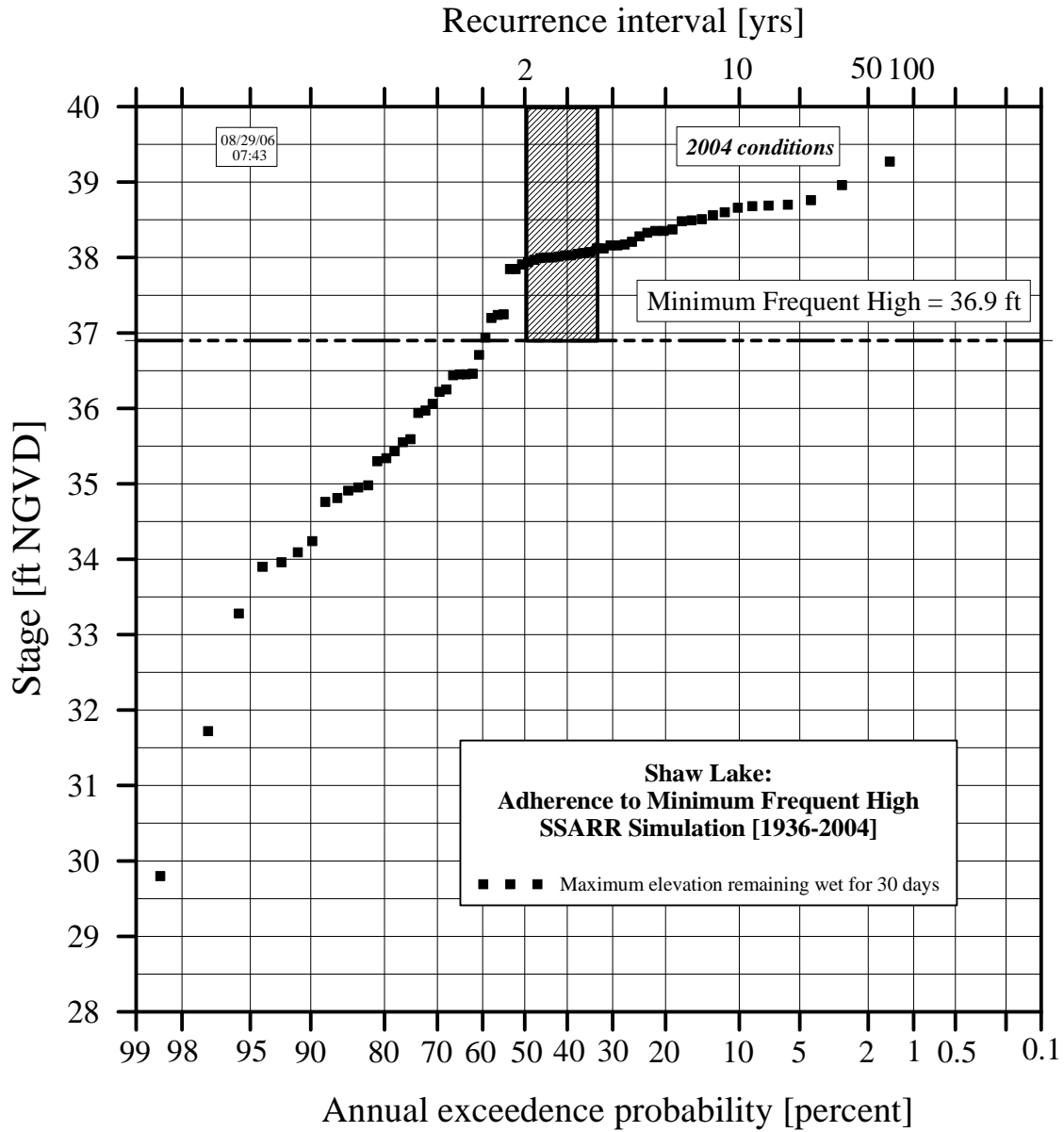


Figure 6. Modeled frequency analysis for the adopted minimum frequent high (FH) level for Shaw Lake

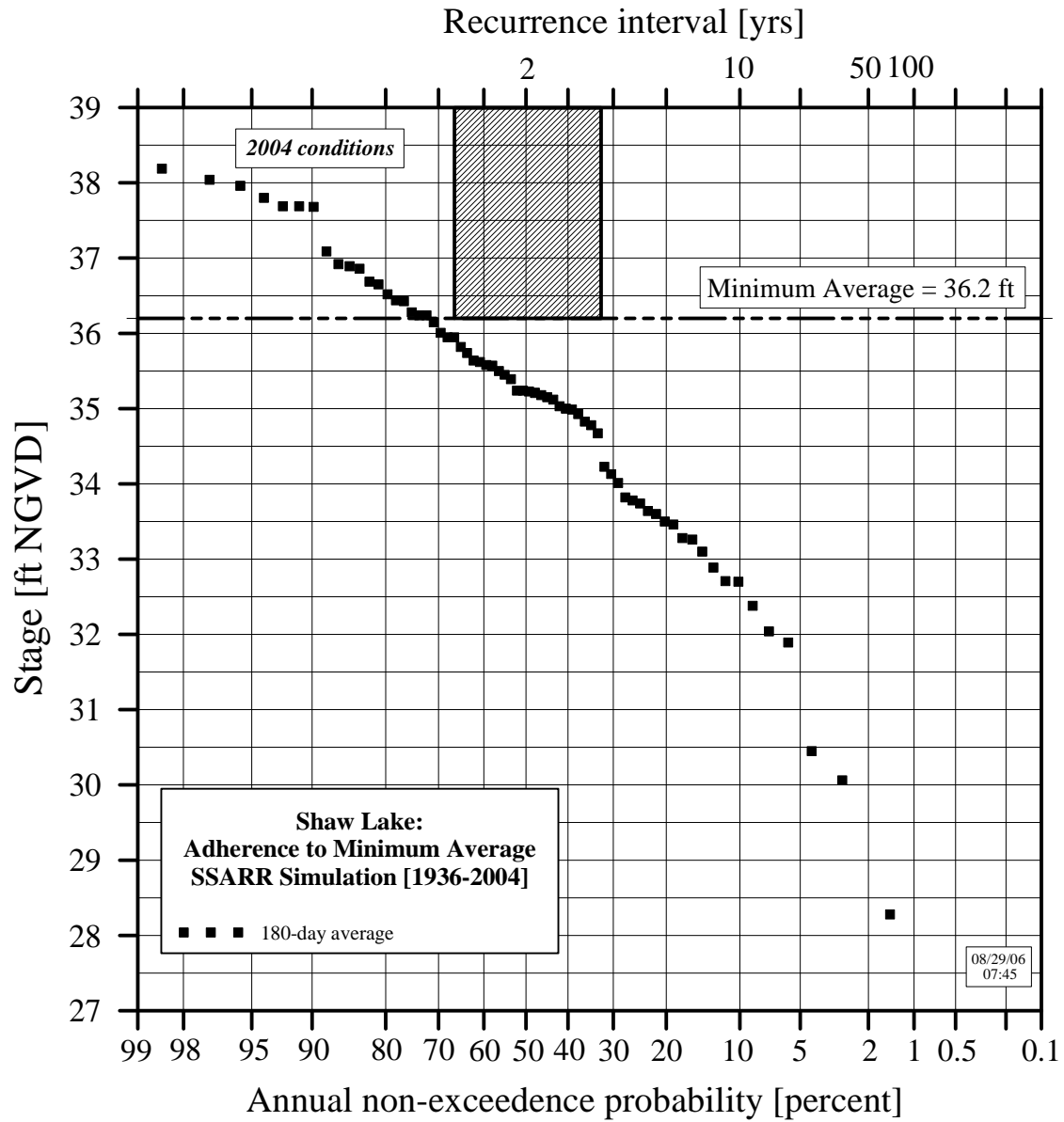


Figure 7. Modeled frequency analysis for the adopted minimum average (MA) level for Shaw Lake

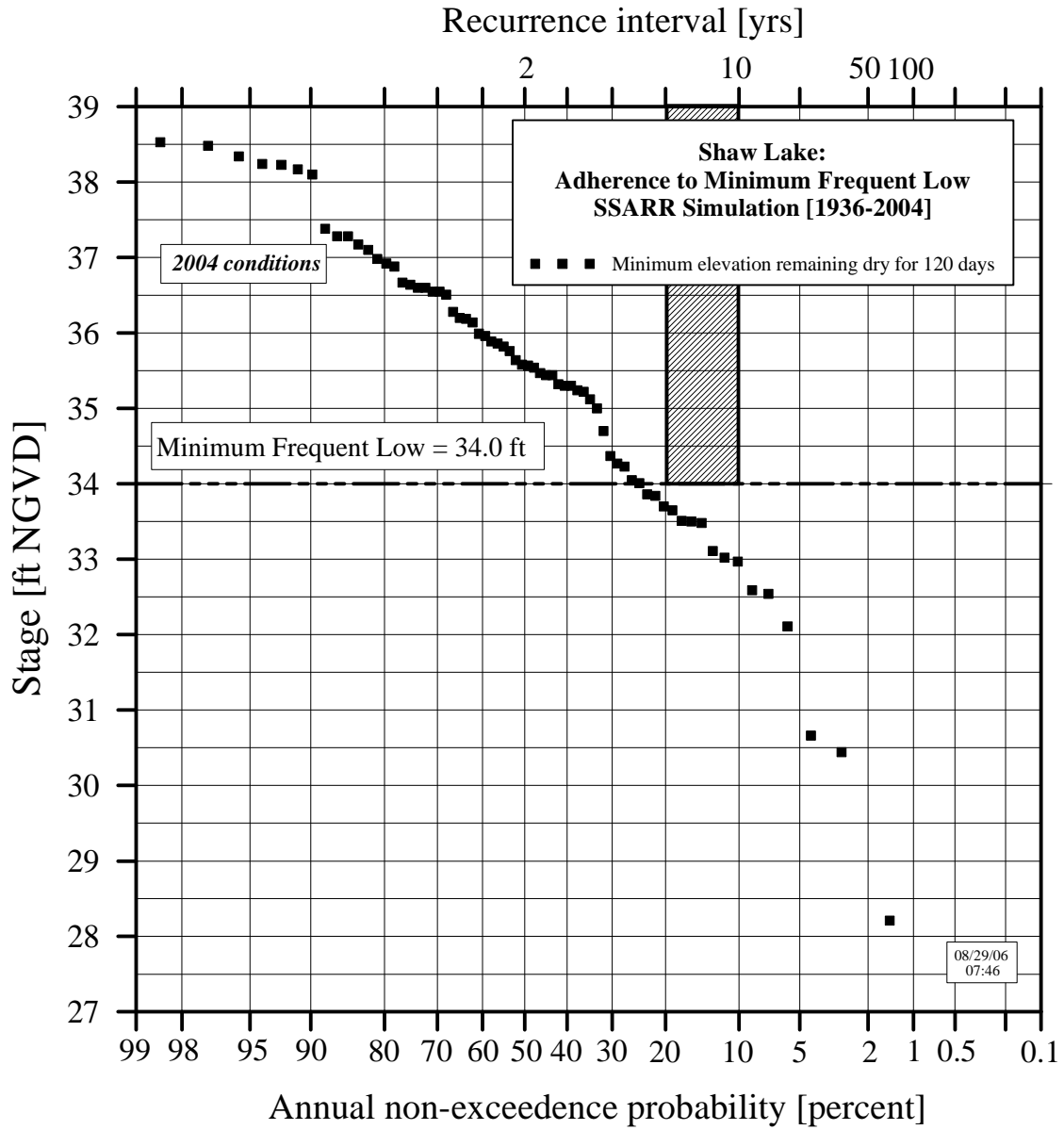


Figure 8. Modeled frequency analysis for the adopted minimum frequent low (FL) level for Shaw Lake

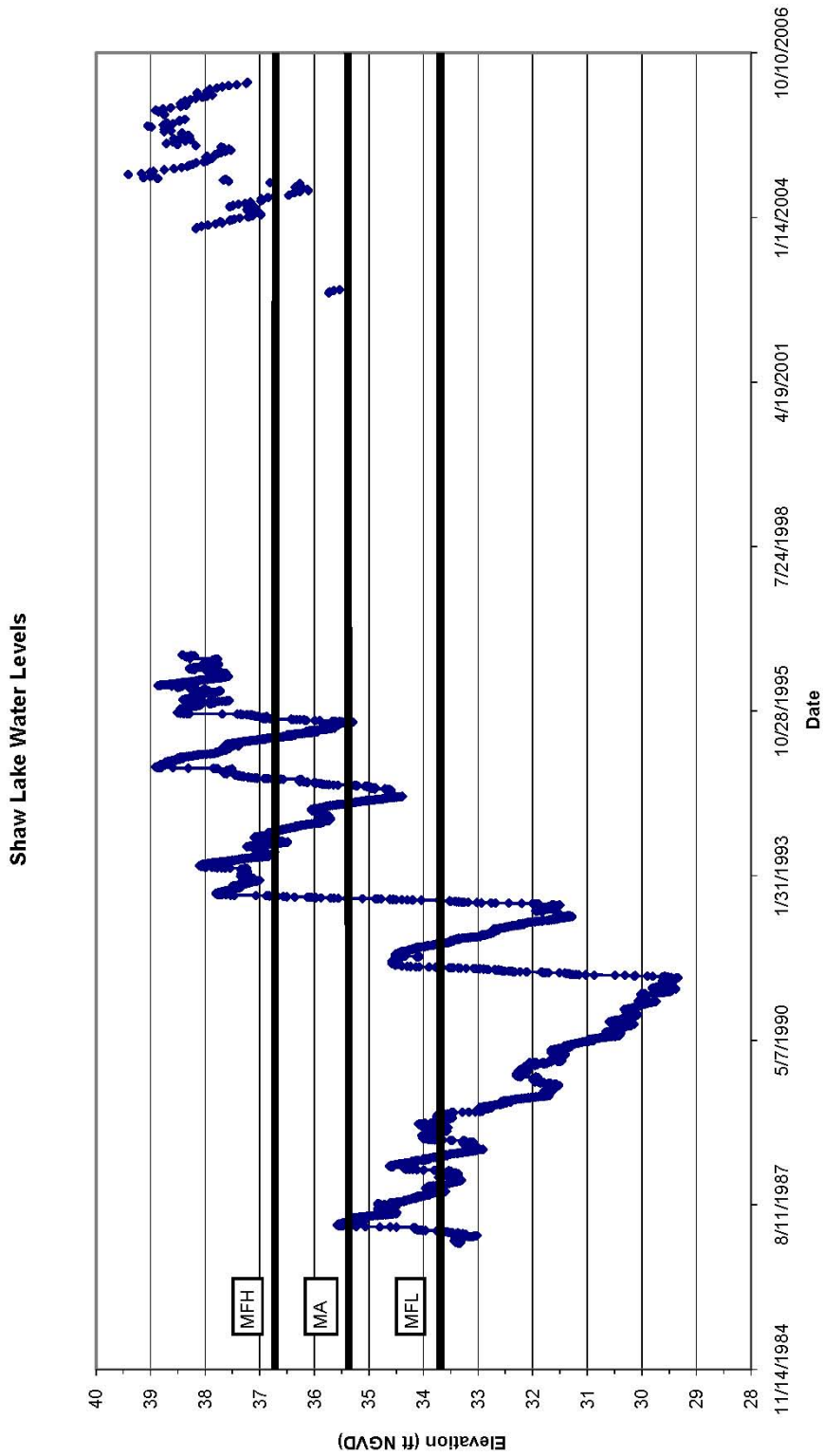


Figure 9. Shaw Lake period-of-record stage data (December 1986–April 2006)

**WETLANDS**

Four predominant wetland communities occur in the immediate vicinity of Shaw Lake (Figure 10), as classified by the SJRWMD wetlands vegetation classification system (Kinser 1996). The vegetation and hydroperiod descriptions for these wetland communities are summarized in Table 1.

Table 1. SJRWMD wetland vegetation classification system for wetland communities in the vicinity of Shaw Lake

Vegetation Description	Hydroperiod Description
Bayhead	Nearly constantly saturated, at least occasionally flooded
Forested flatwoods depression	Brief, seasonal inundation or prolonged soil saturation
Hydric hammock	Seldom inundated, but prolonged soils saturation
Wet prairie	Relatively short inundation period, but prolonged soil saturation

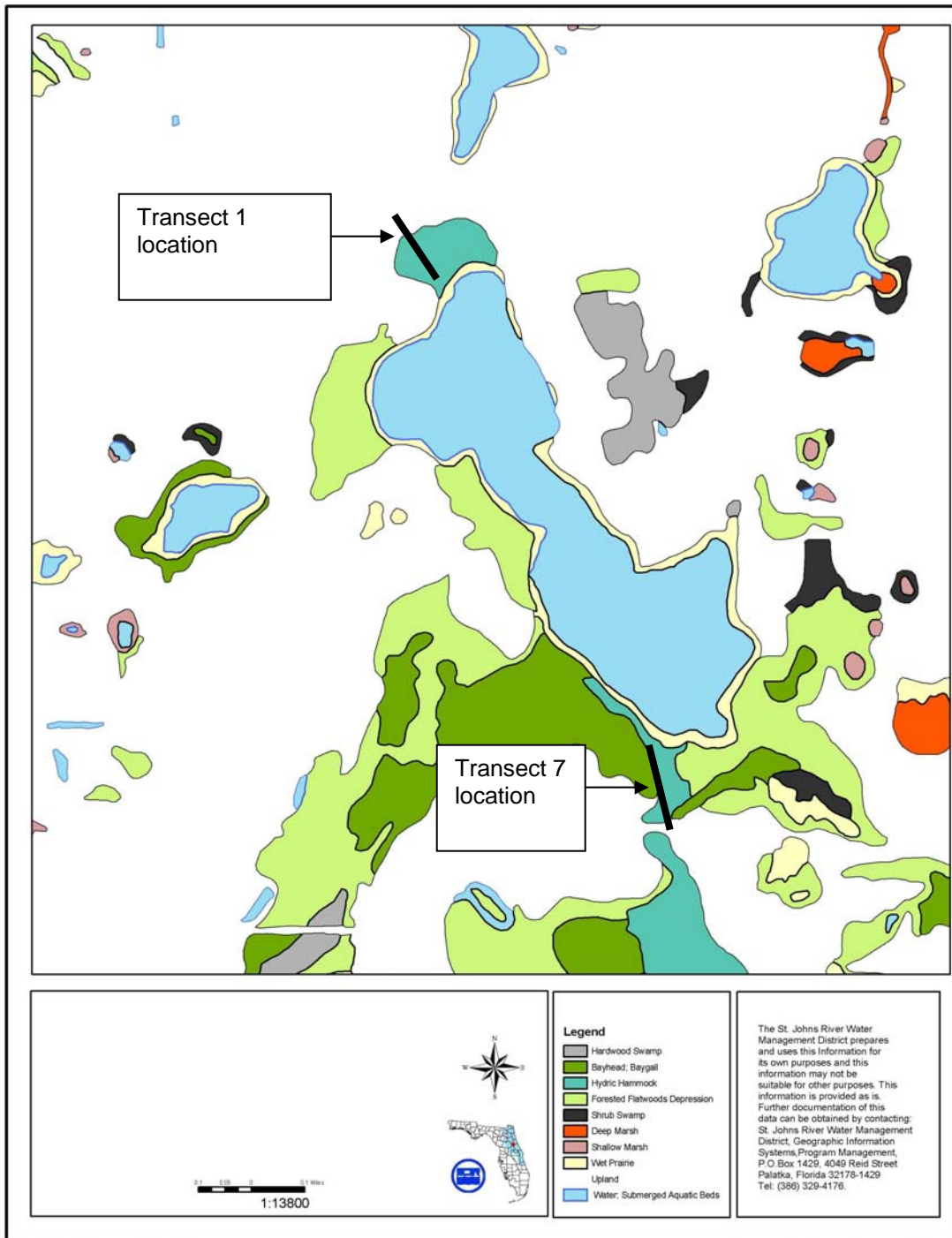
**SOILS**

Three hydric soils series were mapped adjacent to Shaw Lake: Samsula occurring to the west and south, Hontoon to the northwest, and Myakka to the southeast (Figure 11).

Samsula soils are very poorly drained organic soils with slopes less than 2%. They occur in broad low flats, small depressions, and freshwater marshes and swamps with a water table at or above the surface except during long dry periods (USDA, SCS 1980).

Hontoon soils are very poorly drained organic soils with slopes less than 1%. They occur in freshwater swamps and marshes and, in most years, are completely saturated except during extended dry periods (USDA, SCS 1980).

Myakka soils are poorly drained sandy soils with slopes ranging from 0.0%–2%. They occur in the flatwoods with a water table that is at or near the surface during the summer rainy season, with depressional areas seasonally ponded (USDA, SCS 1980).



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Figure 10. Shaw Lake vegetation map



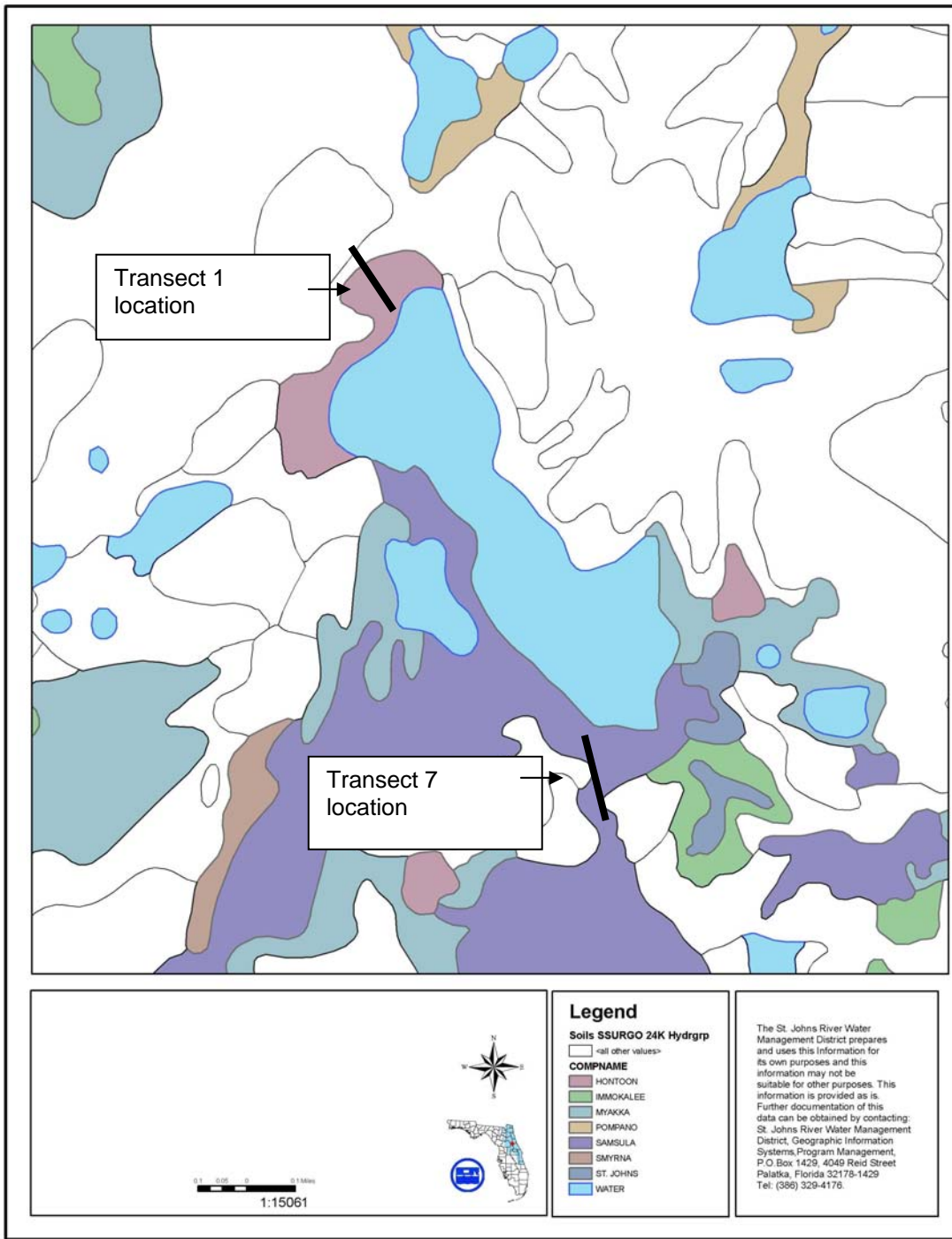


Figure 11. Shaw Lake mapped hydric soils



## RESULTS AND DISCUSSION

To reevaluate the minimum levels for Shaw Lake, elevation, soils, and vegetation field data were obtained from two transect locations sampled in the original determination (Neubauer 1993). This section describes the transect site selection criteria, the data collected at each transect site, and the primary level determination criteria, concluding with a description of the minimum level determinations for Shaw Lake.

Fieldwork for the original determination of minimum levels was performed in 1991 (Neubauer 1993) and the data reassessed in this reevaluation. Elevation, vegetation, and soils data were determined along two elevation transects: Transect 1 north of the lake and Transect 7 in the south (Figure 10 and Figure 11). Vegetation and soils data were taken at approximately 50-ft to 100-ft intervals, with elevation data taken more frequently. SJRWMD's Division of Surveying Services staff collected elevation data; vegetation and muck soils data were collected by SJRWMD's MFLs staff.

### FIELD DATA TRANSECT 1

Transect 1, located on the north shore of Shaw Lake, extended 650 ft in a northwesterly direction, from the open water area to the edge of the uplands (Figure 10 and Figure 11). Figure 12 depicts the extent, elevation ranges, and dominant plant species for each major plant community.

### VEGETATION

The 1993 Shaw Lake MFLs determination (Neubauer 1993) identified a mean floodplain elevation from Transect 1 and derived from it much of the information to determine the original minimum levels. The MFLs reevaluation reexamined the earlier point coverage vegetation data from Shaw Lake (Table 2 and Figure 12) and identified hardwood swamp and bayhead communities along Transect 1 using the SJRWMD Wetland Vegetation Classification System (Kinser 1996). The vegetation cover classifications used for the 1993 MFLs determination are listed in Table 3. The hardwood swamp community extends from 136 ft to 426 ft and is dominated by red maple, sweet bay, dahoon holly, and blackberry. The bayhead community extends from 426 ft to 639 ft and is dominated by sweet bay. The uplands edge begins at 639 ft. The hardwood swamp is distinguished from the bayhead by the presence of dahoon holly, a greater coverage by red maple, and lower elevations. The bayhead community ends at the point where muck disappears and bayhead species (e.g., sweet bay) is replaced by plant species more indicative of drier conditions (e.g., transitional species and slash pine). At station 639, there is no muck; however, no vegetation

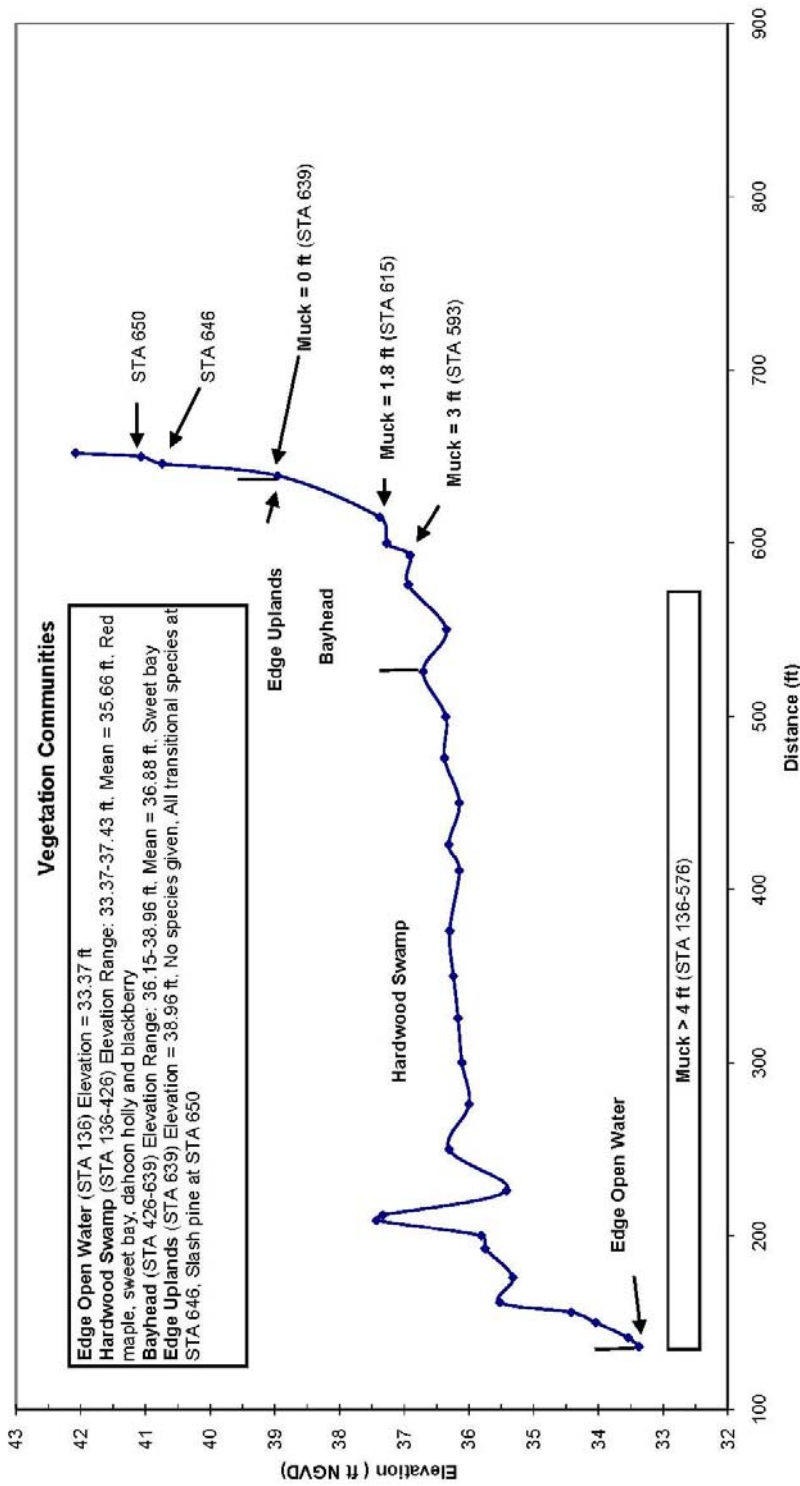


Figure 12. Elevation, biologic features and dominant plant species for each community in Transect 1

Table 2. Transect 1 vegetation species list and cover

Plant Species List		Vegetation Cover									
Common Name	Plant Species	FWDM*	136 ft	176 ft	226 ft	276 ft	326 ft	376 ft	426 ft		
Blackberry	<i>Rubus sp.</i>	FAC	-	-	<b>C</b>	<b>D</b>	<b>D</b>	<b>D</b>	-	<b>C</b>	
Chainfern	<i>Woodwardia aereolata</i>	OBL	-	-	-	-	-	-	-	<b>C</b>	
Dahoon holly	<i>Ilex cassine</i>	OBL	<b>D</b>	<b>D</b>	<b>C</b>	-	-	-	-	-	
Elderberry	<i>Sambucus canadensis</i>	FAC	-	-	-	-	-	-	-	-	
Grape	<i>Vitis sp.</i>	N/A	<b>C</b>	<b>C</b>	-	-	-	-	-	-	
Greenbriar	<i>Smilax sp.</i>	N/A	-	-	-	-	-	-	-	<b>I</b>	
Loblolly bay	<i>Gordonia lasianthus</i>	FACW	-	-	-	-	-	-	-	-	
Poison ivy	<i>Toxicodendron sp.</i>	N/A	-	-	<b>P</b>	-	-	-	-	-	
Red maple	<i>Acer rubrum</i>	FACW	<b>P</b>	-	<b>C</b>	<b>CD</b>	<b>CD</b>	<b>D</b>	<b>D</b>	<b>D</b>	
Royal fern	<i>Osmunda regalis</i>	OBL	-	-	<b>C</b>	<b>C</b>	<b>C</b>	-	-	<b>C</b>	
Slash pine	<i>Pinus elliotii</i>	UPL	-	-	-	-	-	-	-	-	
Swamp bay	<i>Persea palustris</i>	OBL	-	-	-	-	-	<b>P</b>	<b>P</b>	-	
Swamp fern	<i>Blechnum serrulatum</i>	FACW	-	-	-	<b>P</b>	<b>P</b>	<b>P</b>	<b>P</b>	<b>C</b>	
Swamp gum	<i>Nyssa sylvatica</i>	OBL	-	-	<b>P</b>	-	-	-	-	-	
Sweet bay	<i>Magnolia virginiana</i>	OBL	-	<b>C</b>	<b>C</b>	<b>CD</b>	<b>CD</b>	-	-	<b>C</b>	
Virginia willow	<i>Itea virginica</i>	OBL	-	<b>P</b>	<b>P</b>	<b>I</b>	<b>I</b>	-	-	-	

Table 2—Continued

Plant Species List		Vegetation Cover							
Common Name	Plant Species	FWDM*	426 ft	476 ft	526 ft	576 ft	593 ft	615 ft	639 ft**
Blackberry	<i>Rubus sp.</i>	FAC	C	I	I	-	-	-	-
Chainfern	<i>Woodwardia aereolata</i>	OBL	-	-	-	-	-	-	-
Dahoon holly	<i>Ilex cassine</i>	OBL	-	-	-	-	-	-	-
Elderberry	<i>Sambucus canadensis</i>	FAC	-	-	-	C	C	C	-
Grape	<i>Vitis sp.</i>	N/A	-	-	-	-	-	-	-
Greenbriar	<i>Smilax sp.</i>	N/A	-	-	-	-	-	-	-
Loblolly bay	<i>Gordonia lasianthus</i>	FACW	-	-	-	-	-	-	-
Poison ivy	<i>Toxicodendron sp.</i>	N/A	-	-	-	-	-	-	-
Red maple	<i>Acer rubrum</i>	FACW	D	C	C	C	C	C	-
Royal fern	<i>Osmunda regalis</i>	OBL	C	C	C	-	-	-	-
Slash pine	<i>Pinus elliotii</i>	UPL	-	-	-	-	-	-	-
Swamp bay	<i>Persea palustris</i>	OBL	-	-	-	-	-	-	-
Swamp fern	<i>Blechnum serrulatum</i>	FACW	C	C	C	-	-	-	-
Swamp gum	<i>Nyssa sylvatica</i>	OBL	-	-	-	-	-	-	-
Sweet bay	<i>Magnolia virginiana</i>	OBL	C	D	D	D	D	D	-
Virginia willow	<i>Itea virginica</i>	OBL	-	-	-	-	-	C	-

Table 2—Continued

Common Name	Plant Species List		Vegetation Cover		
	Plant Species	FWDM*	639 ft**	646 ft***	650 ft
Blackberry	<i>Rubus sp.</i>	FAC	-	-	-
Chainfern	<i>Woodwardia aereolata</i>	OBL	-	-	-
Dahoon holly	<i>Ilex cassine</i>	OBL	-	-	-
Elderberry	<i>Sambucus canadensis</i>	FAC	-	-	-
Grape	<i>Vitis sp.</i>	N/A	-	-	-
Greenbriar	<i>Smilax sp.</i>	N/A	-	-	-
Loblolly bay	<i>Gordonia lasianthus</i>	FACW	-	-	-
Poison ivy	<i>Toxicodendron sp.</i>	N/A	-	-	-
Red maple	<i>Acer rubrum</i>	FACW	-	-	-
Royal fern	<i>Osmunda regalis</i>	OBL	-	-	-
Slash pine	<i>Pinus elliotii</i>	UPL	-	-	-
Swamp bay	<i>Persea palustris</i>	OBL	-	-	-
Swamp fern	<i>Blechnum serrulatum</i>	FACW	-	-	-
Swamp gum	<i>Nyssa sylvatica</i>	OBL	-	-	-
Sweet bay	<i>Magnolia virginiana</i>	OBL	-	-	-
Virginia willow	<i>Itea virginica</i>	OBL	-	-	-

\*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.
- N/A= No FWDM code assigned
- I= Information not given in original data or insufficient to make a determination
- Bold=** Important plant species used in the MFLs determination
- \*\*= No vegetation description given
- \*\*\*= Vegetation described as all transitional species

Table 3. Shaw Lake vegetation cover class system

Percentage Cover Range	Descriptor
<10	O = Occasional
10–25	P = Present
25–50	C = Common
50–75	CD = Co-dominant
> 75	D = Dominant

description is given (Table 2 and Figure 12). At the next higher station (646), there is also no muck, but the vegetation is described as all transitional species. The replacement of bay species by plant species indicative of drier hydrologic conditions is complete at station 646 and is thought to have begun at station 639. Plant species occurring along the transect, common names, and wetland indicator status from *The Florida Wetlands Delineation Manual* (FWDM, Gilbert et al. 1995) appear in Table 2. The majority of plants are wetland species. Important biologic features observed on Transect 1 are summarized in Table 4.

Table 4. Statistics of important features measured at Transect 1

Location	Feature	N	Spot	Mean	Max	Min
Transect 1	Edge open water	-	33.37	-	-	-
Transect 1	Hardwood swamp	19	-	35.66	37.43	33.37
Transect 1	Bayhead	11	-	36.88	38.96	36.15
Transect 1	Muck	28	-	36.00	37.43	33.37
Transect 1	Edge uplands	-	38.96	-	-	-

N = the number of elevations surveyed for each vegetation community

## SOILS

Muck depths on Transect 1, as determined by peat probe, were greater than 4 ft from stations 136–576 ft. The muck layer thinned to 3.0, 1.8, and 0.0 ft thick at stations 593 ft, 615 ft, and 639 ft, respectively (Figure 12, Table 2).



## FIELD DATA TRANSECT 7

Transect 7, located on the south shore of Shaw Lake, extended 700 ft in a southerly direction from open water to the edge of uplands (Figure 10 and Figure 11). Figure 13 depicts the extent, elevation ranges, and dominant plant species for each major plant community.

### VEGETATION

The 1993 Shaw Lake MFLs determination identified a mean floodplain elevation from Transect 1 and derived from it much of the information to determine the original minimum levels. The MFLs reevaluation reexamined the earlier point coverage vegetation data (Table 5 and Figure 13) for Transect 7 and identified a hardwood swamp and bayhead communities using the SJRWMD Wetland Vegetation Classification System (Kinser 1996). The hardwood swamp community extends from 481 ft to 881 ft and is dominated by sweet bay and swamp bay with swamp tupelo generally present. The bayhead community extends from 881 ft to 1,131 ft and is dominated by loblolly bay, sweet bay, and swamp bay. The edge of uplands begins at 1,131 ft. The hardwood swamp is distinguished from the bayhead by the presence of swamp tupelo, the absence of loblolly bay, and lower elevations. The bayhead community ends at the point where muck disappears and bayhead species (e.g., loblolly bay) begins to be replaced by plant species more indicative of drier conditions (e.g., slash pine). At station 1131, slash pine, an indicator of drier hydrologic conditions, has begun to replace bay species and no muck was observed. Plant species occurring along Transect 7, with common names and *The Florida Wetlands Delineation Manual* (FWDM, Gilbert et al. 1995) wetland indicator status appear in Table 5. The majority of plants are wetland species. Important biologic features observed on Transect 7 are summarized in Table 6.

### SOILS

Muck depths on Transect 7, as determined by peat probe, were greater than 4 ft from stations 481–1,031 ft. The muck layer thinned to 2.5 ft and 0.0 ft thick at 1,081 ft and 1,131 ft, respectively (Figure 13). Important biologic features observed on Transect 1 and Transect 7 are summarized in Table 7.

## MINIMUM LEVELS DETERMINATION CRITERIA

Three minimum levels with associated durations and return intervals are recommended. A short description of the criteria used to determine these minimum levels and the important ecologic structures and functions protected by the minimum levels follows.

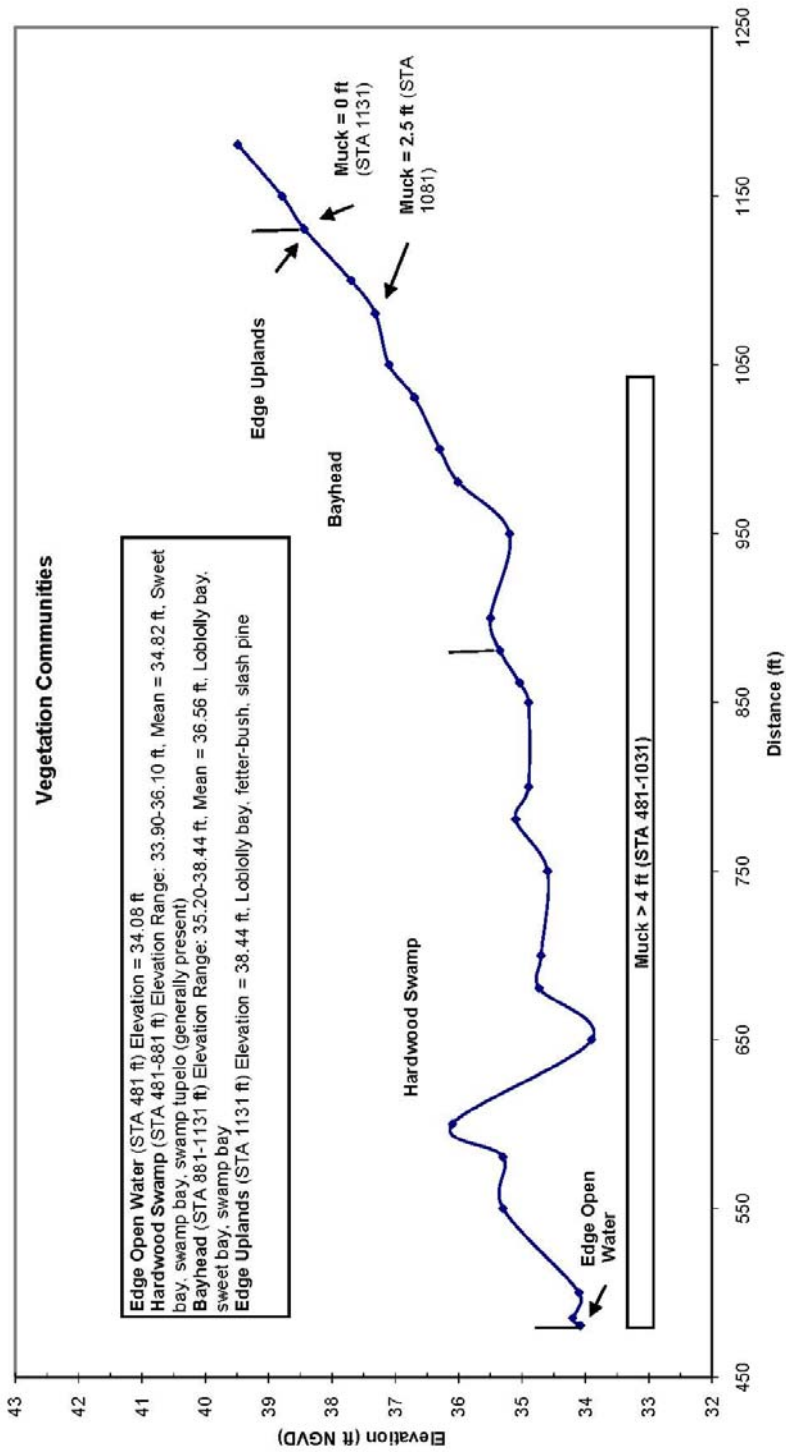


Figure 13. Elevation, biologic features and dominant plant species for each community in Transect 7

Table 5. Transect 7 vegetation species list and cover

Plant Species List		Vegetation Cover						
Common Name	Plant Species	FWDM*	481 ft	581 ft	681 ft	781 ft	862 ft	881 ft
Buttonbush	<i>Cephalanthus occidentalis</i>	OBL	-	-	P	-	-	-
Cinnamon fern	<i>Osmunda cinnamomea</i>	FACW	-	-	-	P	-	P
Dahoon holly	<i>Ilex cassine</i>	OBL	-	-	-	C	-	C
Fetter-bush	<i>Lyonia lucida</i>	FACW	-	-	-	-	-	-
Loblolly bay	<i>Gordonia lasianthus</i>	FACW	-	-	-	-	-	-
Red cedar	<i>Juniperus silicicola</i>	UPL	-	-	-	-	I	-
Royal fern	<i>Osmunda regalis</i>	OBL	-	-	-	I	I	I
Slash pine	<i>Pinus elliotii</i>	UPL	-	-	-	-	-	-
Swamp bay	<i>Persea palustris</i>	OBL	D	I	C	C	-	C
Swamp fern	<i>Blechnum serrulatum</i>	FACW	-	I	-	-	-	-
Swamp tupelo	<i>Nyssa sylvatica</i>	OBL	-	-	C	P	-	P
Sweet bay	<i>Magnolia virginiana</i>	OBL	-	D	D	D	-	D
Virginia chainfern	<i>Woodwardia aereolata</i>	FACW	-	-	-	P	-	P
Virginia willow	<i>Itea virginica</i>	OBL	-	-	-	-	-	-

Table 5—Continued

Common Name	Plant Species List		FWD <sup>M</sup> *	Vegetation Cover Bayhead (881–131 ft)				
	Plant Species			881 ft	981 ft	1031 ft	1081 ft	1131 ft
Buttonbush	<i>Cephalanthus occidentalis</i>		OBL	-	-	-	-	-
Cinnamon fern	<i>Osmunda cinnamomea</i>		FACW	P	-	-	-	-
Dahoon holly	<i>Ilex cassine</i>		OBL	C	I	-	CD	-
Fetter-bush	<i>Lyonia lucida</i>		FACW	-	-	-	-	<b>C</b>
Loblolly bay	<i>Gordonia lasianthus</i>		FACW	-	<b>CD</b>	<b>CD</b>	<b>D</b>	<b>D</b>
Red cedar	<i>Juniperus silicicola</i>		UPL	-	-	-	-	-
Royal fern	<i>Osmunda regalis</i>		OBL	I	-	-	-	-
Slash pine	<i>Pinus elliptii</i>		UPL	-	-	-	-	<b>C</b>
Swamp bay	<i>Persea palustris</i>		OBL	<b>C</b>	<b>CD</b>	<b>CD</b>	-	P
Swamp fern	<i>Blechnum serrulatum</i>		FACW	-	-	-	-	-
Swamp tupelo	<i>Nyssa sylvatica</i>		OBL	<b>P</b>	-	-	-	-
Sweet bay	<i>Magnolia virginiana</i>		OBL	<b>D</b>	<b>CD</b>	<b>CD</b>	-	-
Virginia chainfern	<i>Woodwardia aereolata</i>		FACW	P	P	P	-	-
Virginia willow	<i>Itea virginica</i>		OBL	-	C	C	-	-

Table 5—Continued

Plant Species List			Vegetation Cover	
Common Name	Plant Species	FWDM*	1131 ft	Edge Uplands (>1131 ft)
Buttonbush	<i>Cephalanthus occidentalis</i>	OBL	-	-
Cinnamon fern	<i>Osmunda cinnamomea</i>	FACW	-	-
Dahoon holly	<i>Ilex cassine</i>	OBL	-	-
Fetter-bush	<i>Lyonia lucida</i>	FACW	<b>C</b>	-
Loblolly bay	<i>Gordonia lasianthus</i>	FACW	<b>D</b>	<b>I</b>
Red cedar	<i>Juniperus silicicola</i>	UPL	-	-
Royal fern	<i>Osmunda regalis</i>	OBL	-	-
Slash pine	<i>Pinus elliotii</i>	UPL	<b>C</b>	<b>I</b>
Swamp bay	<i>Persea palustris</i>	OBL	P	-
Swamp fern	<i>Blechnum serrulatum</i>	FACW	-	-
Swamp tupelo	<i>Nyssa sylvatica</i>	OBL	-	-
Sweet bay	<i>Magnolia virginiana</i>	OBL	-	-
Virginia chainfern	<i>Woodwardia aereolata</i>	FACW	-	-
Virginia willow	<i>Itea virginica</i>	OBL	-	-

\*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.  
 N/A= No FWDM code assigned  
 I= Information not given in original data or insufficient to make a determination  
**Bold=** Important plant species used in the MFLs determination

Table 6. Statistics of important features measured at Transect 7

Location	Feature	N	Spot	Mean	Max	Min
Transect 7	Edge open water	-	34.08	-	-	-
Transect 7	Hardwood swamp	15	-	34.82	36.10	33.90
Transect 7	Bayhead	10	-	36.56	38.44	35.20
Transect 7	Muck	22	-	35.29	37.32	33.90
Transect 7	Edge uplands	-	38.44	-	-	-

N = the number of elevations surveyed at each vegetation community

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Table 7. Statistics of important combined features for Transect 1 and Transect 7

Location	Feature	N	Mean	Max	Min
Transects 1 and 7	All hardwood swamp	34	35.29	37.43	33.37
Transects 1 and 7	All bayhead	21	36.73	38.96	35.20
Transects 1 and 7	All muck	50	35.69	37.43	33.37

N = the number of elevations surveyed at each vegetation community

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Criteria vary depending upon the level being determined and the on-site wetland community characteristics. For example, the primary criterion for a level may be the average or extreme (high or low) elevation associated with a vegetation community or soil indicator based on the scientific literature and hydrologic data.

Vegetation communities occur along a continuum from dry (upland) to wet (open water) and were used together with the published literature concerning the hydrology and functions of individual communities to determine the recommended minimum levels. Muck depths occurring within the vegetation communities along the transects were also used to determine levels.

This reevaluation employs the most recent MFLs methodology and criteria (SJRWMD 2006). Many of the MFLs criteria currently used were not developed as of 1994, resulting in different minimum levels recommendations than those previously adopted. MFLs criteria are continually being refined over time as more analysis proceeds and relevant information becomes available.

The minimum levels are also supported by current surface water inundation/dewatering signatures (SWIDS, Neubauer et al., 2006). SWIDS quantitatively define the hydrologic range for wetland vegetation communities. These hydrologic signatures provide a threshold for MFLs determinations that are based on vegetation communities and which provide an estimate of how much the return interval of a flooding or dewatering event can be shifted and still maintain a vegetation community within its observed hydrologic range.

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## MINIMUM LEVELS REEVALUATION FOR SHAW LAKE

### MINIMUM FREQUENT HIGH (FH) LEVEL

The recommended FH level elevation component for Shaw Lake is 36.7 ft NGVD, with an associated duration of 30 days and return interval of once every 3 years (i.e., 33 flooding events in 100 years), on average. The FH level is defined as “... a chronically high surface water level or flow with an associated frequency and duration that allows for inundation of the floodplain at a depth and duration sufficient to maintain wetlands functions” (Rule 40C-8.021(7), *F.A.C.*).

The recommended FH level elevation component is equivalent to the mean elevation of all the bayhead community elevation points on Transect 1 and Transect 7 (36.7 ft NGVD, Table 8). This FH level is 0.2 ft lower than the 1994 adopted FH (36.9 ft, Table 9) because the 1994 FH level was derived with a different criterion (0.5 ft above mean flood elevation). The bayhead communities had similar mean (36.88 ft and 36.56 ft NGVD) and maximum elevations (38.96 ft and 38.44 ft NGVD) for Transect 1 and Transect 7, respectively, but the minimum elevations were more variable (36.15 ft and 35.20 ft NGVD). The minimum elevations variability could be due to differences in topography (Figure 12 and Figure 13) and species composition (Table 2 and Table 5) along the transects.

The recommended FH level is supported by current SWIDS analysis of wetland vegetation communities (Neubauer et al. 2008b). SWIDS analysis of six bayhead systems (Figure 14) indicates this elevation could flood for 30 continuous days with an approximate return interval of 3 years. The return interval associated with the FH level (3 years) is somewhat wetter than the median (see Lakes Bowers and Dorr, Figure 14) of the hydrologic range observed for bayheads at other systems, yet is drier than the 2004 modeled conditions. This allows for some hydrologic shift, as compared to 2004 modeled conditions, while maintaining a natural hydrologic signature that is close to the median for bayhead communities.

Frequency analysis of the modeled stage data (Figure 6) shows that the recommended FH level (36.7 ft NGVD) will be exceeded for 30 continuous days with an approximate return interval of 1.7 years (approximately 59 times per 100 years), on average, under 2004 modeled conditions. This duration/return interval shows that the hydrologic requirements of the recommended FH level are met under the 2004 modeled hydrologic conditions and that this minimum level would allow for some additional consumptive use.

Table 8. Shaw Lake vegetation transects summary statistics

Vegetation Community	Stations Distance (ft)	Mean (ft NGVD)	Max (ft NGVD)	Min (ft NGVD)	Spot (ft NGVD)	N
Hardwood swamp—Transect 1	136–426	35.66	37.43	33.77	-	19
Hardwood swamp—Transect 7	481–881	34.82	36.10	33.90	-	15
All hardwood swamp	-	35.29	37.43	33.37	-	34
Bayhead—Transect 1	426–639	36.88	38.96	36.15	-	11
Bayhead—Transect 7	881–1131	36.56	38.44	35.20	-	10
All bayhead	-	36.73	38.96	35.20	-	21
Muck—Transect 1	136–615	36.00	37.43	33.37	-	28
Muck—Transect 7	481–1081	35.29	37.32	33.90	-	22
All muck	-	35.69	37.43	33.37	-	50
Edge open water—Transect 1	136	-	-	-	33.37	1
Edge open water—Transect 7	481	-	-	-	34.08	1
All hardwood swamp/open water ecotone	-	33.73	-	-	-	2
Edge upland—Transect 1	639	-	-	-	38.96	1
Edge upland—Transect 7	1131	-	-	-	38.44	1

N = the number of elevations surveyed at each vegetation community

ft NGVD = feet National Geodetic Vertical Datum



Table 9. Adopted and recommended minimum surface water levels, Shaw Lake

Minimum Level	Adopted Level 1994 (ft NGVD)	Adopted Duration (days)	Adopted Return Interval (years)	Recommended Level (ft NGVD)	Recommended Duration (days)	Recommended Return Interval (years)
Infrequent high level	38.5	30	5.0	-	-	-
Frequent high (FH) level	36.9	30	2.0	36.7	30	3.0
Minimum average (MA) level	36.2	180	2.0	35.4	180	1.7
Frequent low (FL) level	34.0	120	5.0	33.7	120	3.0
Infrequent low level	32.0	90	10.0	-	-	-

ft NGVD = feet National Geodetic Vertical Datum

The recommended FH level provides inundation or saturation within the bayhead communities at Shaw Lake for a frequency and duration that is intended to prevent permanent upland encroachment and sufficient to maintain the spatial extent of this community.

The recommended FH level elevation component, 36.7 ft NGVD, provides about 1.4 ft of water over the mean elevation of all hardwood swamp communities on Transect 1 and Transect 7 (35.29 ft, Table 7). The longer duration and more frequent inundation in the hardwood swamp communities are sufficient to support the obligate and facultative wetland plant species within and the spatial extent and functions of the hardwood swamp communities. This level also allows sufficient water depths for fish and other aquatic organisms to feed and spawn on the lake floodplain. Bain (1990) and Poff et al. (1997) have reported that connecting the lake and floodplain are extremely important to animal productivity. Similar benefits likely result from flooding the hardwood swamp communities at Shaw Lake. As water levels rise, the amount of habitat available to aquatic organisms increases greatly as large areas of the floodplain are inundated (Light et al. 1998).

Bayhead - Hydrologic signatures for mean elevations continuously exceeded (stays wet)

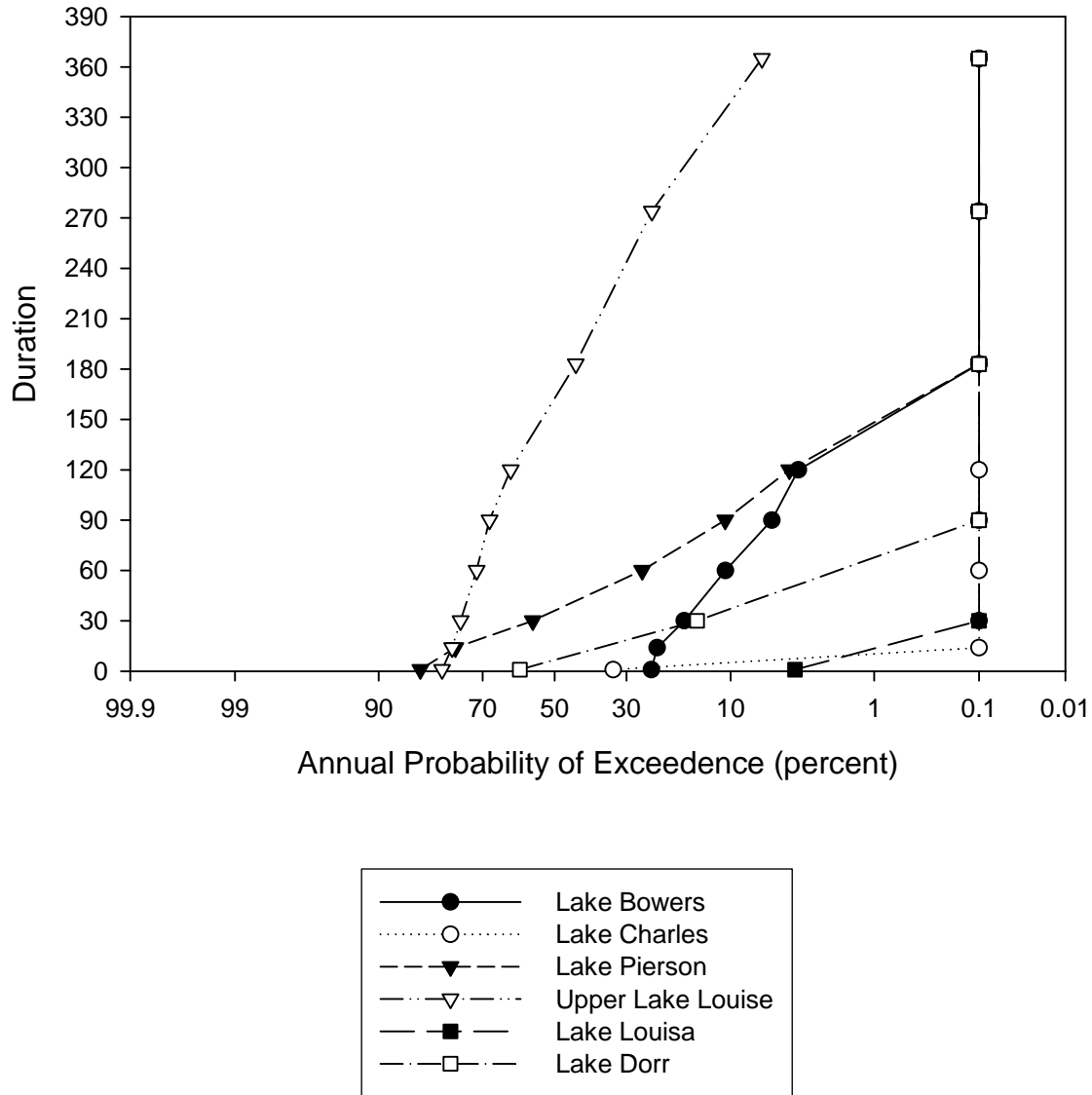


Figure 14. SWIDS for mean elevations of bayhead communities

The life cycles of many fishes are related to seasonal water level fluctuations, particularly the annual flood pattern (Guillory 1979). The floodplain provides feeding and spawning habitat (Guillory 1979; Ross and Baker 1983) and refugia for juvenile fishes (Finger and Stewart 1987). The minimum FH water level component may be exceeded during wet years and may not occur during dry years; most fish and other aquatic fauna are adapted to year-to-year variations of the natural hydrologic regime.

An appropriate normal high water level is necessary to maintain the structure and functions of the wetlands at Shaw Lake. High water levels of this duration and frequency conserve the vegetation composition and structure, and the nature and ecological functions of the hydric soils within the transitional wetland communities at Shaw Lake. Schneider and Sharitz (1986) reported that short-term flooding events are important to the redistribution of plant seeds within aquatic habitats. The species composition and structural development of floodplain plant communities are influenced by the time and duration of floods occurring during the growing season (Huffman 1980). Floods affect reproductive success as well as plant growth. The resulting anaerobic soil conditions within the wetland communities favor hydrophytic vegetation, which is tolerant of longer periods of soil saturation, thus, eliminating upland plant species that have invaded during low water events. Inundation of the floodplain is also necessary for the exchange of particulate organic matter and nutrients (McArthur 1989). Flooding events redistribute and concentrate organic particulates (i.e., decomposing plant and animal parts, seeds, etc.) across the floodplain (Junk et al. 1989). This organic matter is assimilated by bacteria and invertebrate populations (Cuffney 1988), becoming food for larger fauna.

#### **MINIMUM AVERAGE (MA) LEVEL**

The recommended MA level elevation component for Shaw Lake is 35.4 ft NGVD with an associated duration of 180 days and a return interval of once every 1.7 years, on average. The recommended MA corresponds to a dewatering event that may reoccur approximately 60 times per 100 years, for six months or more, during the dry season (Rule 40C-8.021(18), *F.A.C.*).

The recommended level and hydroperiod category approximate a “typical” level that is slightly less than the long-term median water level while still protecting the wetland resource. Extended periods of anaerobic soil conditions are needed to prevent soil oxidation and subsidence and prevent long-term encroachment of upland plant species into wetland communities.

The MA level was calculated by subtracting 0.3 ft from the mean elevation of all muck soils’ surface elevation points surveyed on Transect 1 and Transect 7 (Table 7, Figure 12 and Figure 13). This MA level is 0.8 ft lower than the 1994 adopted MA (36.2 ft, Table 9) because the 1994 MA level was derived with a different criterion

(mean floodplain elevation of 36.41 ft–0.25 ft). Transect 1 and Transect 7 maximum elevations of muck soils (37.43 ft and 37.32 ft NGVD) and minimum elevations (33.37 ft and 33.90 ft NGVD) were similar, while the mean elevations (36.00 ft and 35.29 ft NGVD) were varied. The differences among the mean elevations are mostly due to the flatness of Transect 1 at higher elevations as compared to Transect 7, and seepage may also be a factor.

This criterion (0.3 ft below mean surface elevation of organic soils) has been used to protect muck 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 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, which occurs, on average, every 1 to 2 years with a duration of less than or equal to 180 days (Hupalo et. al. 1994).

The recommended MA level is also supported by current SWIDS analysis of muck soils associated with the MA level -0.3 ft. (Neubauer et al. 2008b; Richardson 2007) and corresponds to the driest dewatering signature observed for these soils at other systems (Figure 15). SWIDS analysis of 24 MA level soil systems indicates this elevation could be dewatered for 180 days (averaged) with an approximate return interval of 1.7 years (approximately 59 times per 100 years). The return interval associated with the MA level (1.7 years) lies at the dry end of the hydrologic range observed for these soils at other systems and is somewhat drier than 2004 modeled conditions. This allows for some hydrologic shift while maintaining a natural hydrologic signature for muck soils.

Frequency analysis of the modeled stage data (Figure 7) shows that the recommended MA elevation (35.4 ft NGVD) will be dewatered for 180 continuous days with an approximate return interval of 1.85 years (approximately 54 times per 100 years), on average, under 2004 modeled conditions. This duration/return interval shows that the hydrologic requirements of the recommended MA elevation are met under the 2004 modeled hydrologic conditions and that the recommended minimum level (35.4 ft NGVD, duration 180 days, and return interval of 1.7 years) allows for some additional consumptive use.

A minimum average (MA) water level is required to maintain the water table, on average, near floodplain surface. 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

Mean Histosol/Histic Epipedon minus 0.3 ft  
 Hydrologic signatures for minimum average elevations  
 average non-exceedence (stays dry)

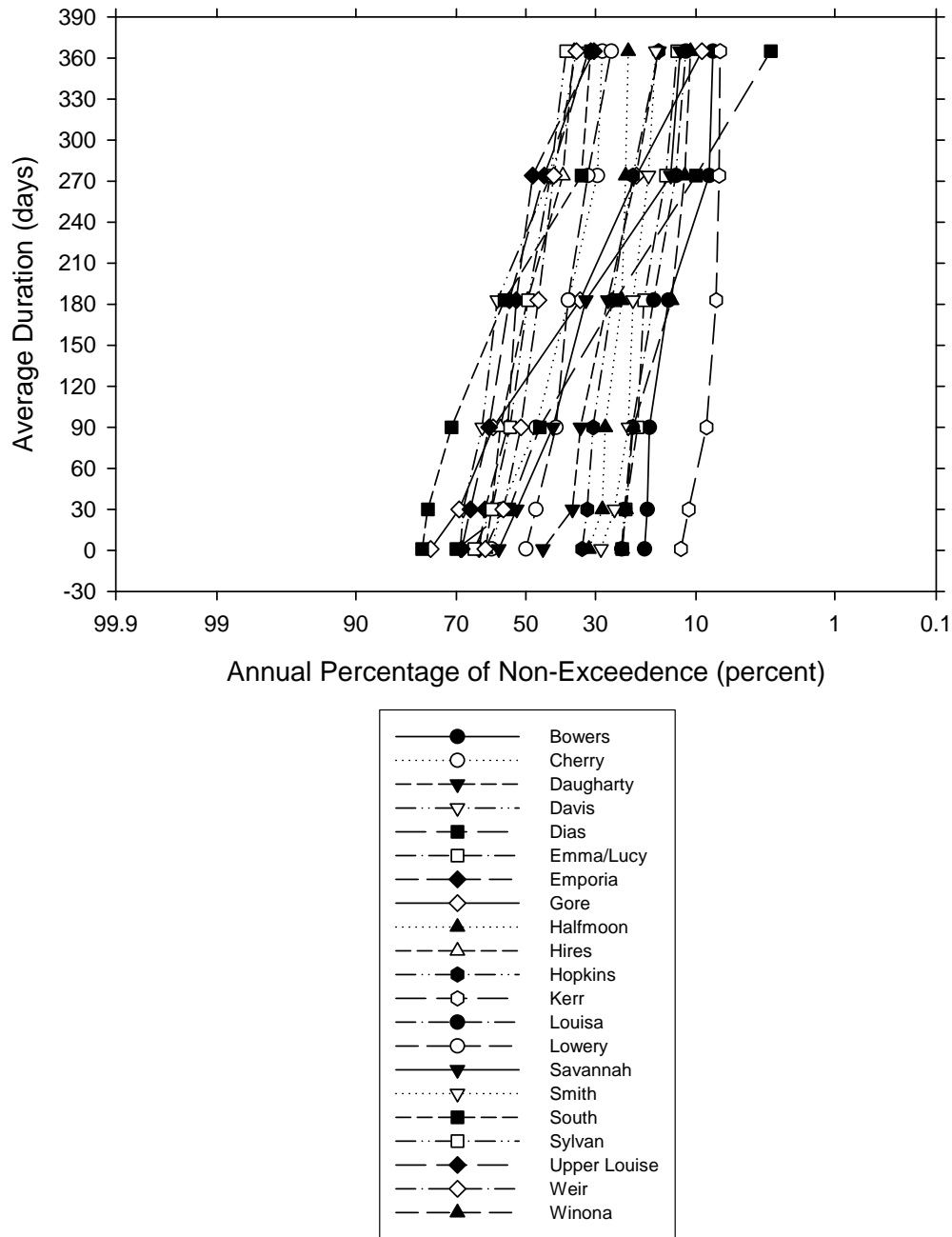


Figure 15. SWIDS for muck soils associated with the minimum average (MA) level

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).

#### **MINIMUM FREQUENT LOW (FL) LEVEL**

The recommended FL level elevation component for Shaw Lake is 33.7 ft NGVD with an associated duration of 120 days and a return interval of once every 3 years (approximately 33 times per 100 years), on average. The FL level is defined as “... a chronically low surface water level or flow that generally occurs only during periods of reduced rainfall. This level is intended to prevent deleterious effects to the composition and structure of the floodplain soils, the species composition and structure of floodplain and instream biotic communities, and the linkage of aquatic and floodplain food webs” (Rule 40C-8.021(10), *F.A.C.*).

The recommended FL elevation component is equivalent to the mean hardwood swamp/open water ecotone elevation at Transect 1 and Transect 7 (33.73 ft NGVD, Table 8). This FL level is 0.3 ft lower than the 1994 adopted FL (34.0 ft, Table 9) because the 1994 FL level was derived with a different criterion (the waterward tree line on Transect 7).

The recommended FL level is supported by current SWIDS analysis for hardwood swamp minimum elevations (Neubauer et al. 2006) and corresponds to the approximate median observed for this ecotone at 12 other lake systems (Figure 16). This level allows dewatering of the hardwood swamp minimum elevations for 120 days every 3 years (approximately 33 times per 100 years), on average, over the long term. The recommended duration/return intervals are drier than 2004 modeled conditions (see below) but approximate the median for this ecotone.

Frequency analysis of the modeled stage data (Figure 8) shows that the recommended FL elevation is dewatered, on average, for 120 continuous days with an approximate return interval of 5 years (approximately 20 times per 100 years) under 2004 modeled conditions. This duration/return interval shows that the hydrologic requirements of the recommended FL level are met under 2004 modeled conditions and that some additional water may be available for consumptive use.

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

Hardwood Swamp - Hydrologic signatures for minimum elevations continuously non-exceeded (stays dry)

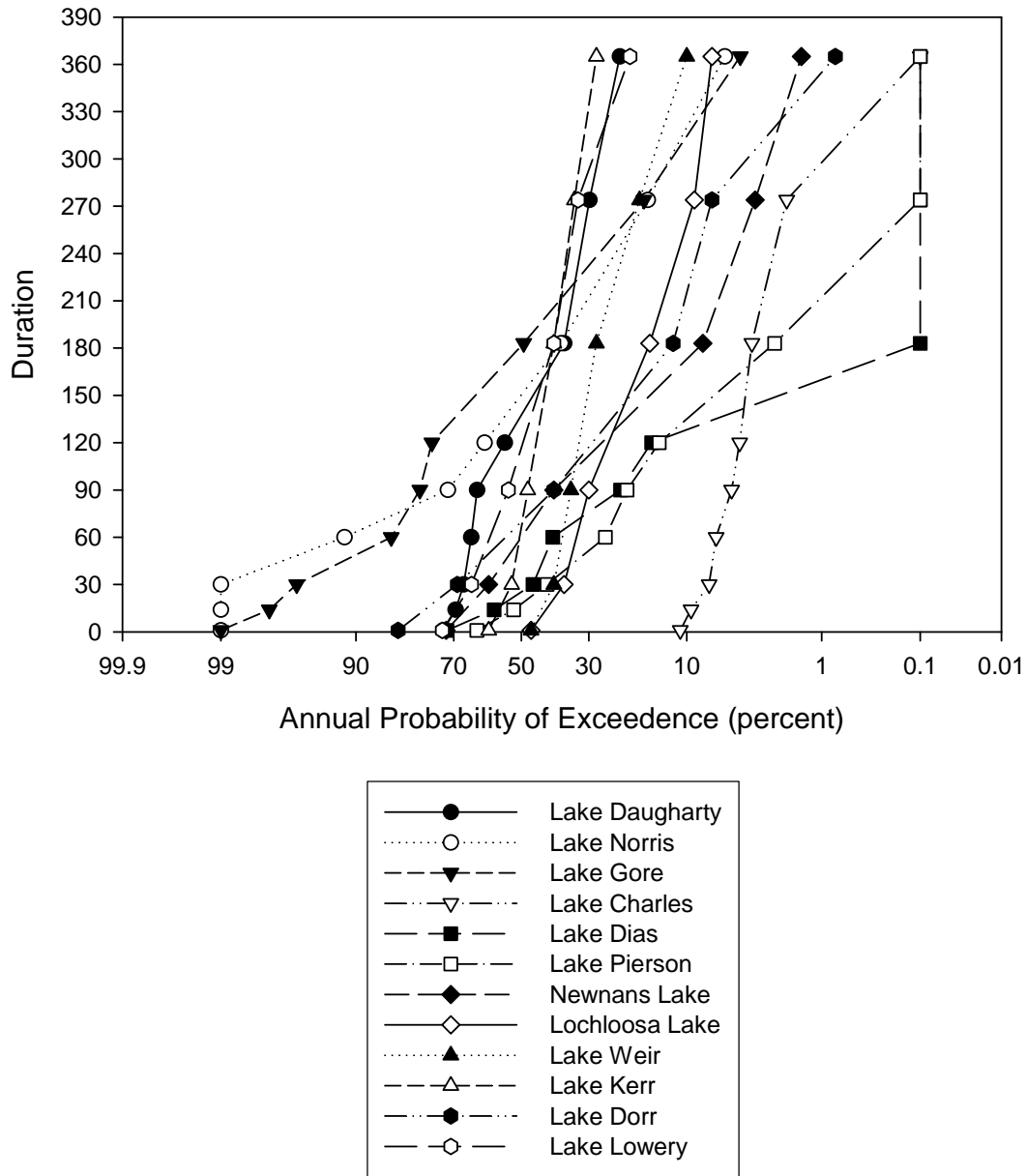


Figure 16. SWIDS for lake system minimum elevations of hardwood swamp communities

communities. Upland plant species are able to invade the floodplain and become established during low water events. When these species die in response to rising water, their biomass becomes a significant substrate for bacterial and fungal growth, which becomes a critical food source of invertebrate collector-gathering and collector-filtering guilds (Cuffney 1988).



## CONCLUSIONS AND RECOMMENDATIONS

The intent for establishing minimum flows and levels (MFLs) for Shaw Lake in Volusia County, Florida, is to protect the aquatic and wetland ecosystems from significant ecological harm caused by consumptive use of water. In addition, the 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-4, F.A.C.).

Recent completion of a hydrologic model for Shaw Lake indicated that the adopted minimum average (MA) and minimum frequent low (FL) levels for Shaw Lake (Neubauer 1993) were not being met under 2004 modeled hydrologic conditions. Consequently, a reevaluation of the adopted levels was performed. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Shaw Lake (Table 9). The minimum frequent high (FH), minimum average (MA) and minimum frequent low (FL) levels were determined based on current SJRWMD MFLs methodology, criteria, and indicators (SJRWMD 2006).

The recommended FH level is 36.7 ft NGVD with a duration of 30 days and a return interval of 3 years (i.e., 33 flooding events in 100 years). This water level corresponds to the mean elevation of all elevation points of the seasonally flooded bayhead communities on Transect 1 and Transect 7. The recommended FH level is 0.2 ft lower than the 1994 adopted FH level (36.9 ft, Table 9). The 1994 adopted FH level was derived by using a different criterion (0.5 ft above mean floodplain elevation).

The recommended MA level is 35.4 ft NGVD with a duration of 180 days and a return interval of 1.7 years. This water level corresponds to the mean elevation of all muck (muck determined using a peat probe) soils surface elevation points on Transect 1 and Transect 7 minus 0.3 ft. This MA level is 0.8 ft lower than the 1994 adopted MA level (36.2 ft, Table 9). The 1994 MA level was derived by using a different criterion (mean floodplain elevation of 36.41 ft–0.25 ft).

The recommended FL level is 33.7 ft NGVD with a duration of 120 days and return interval of 3 years. This water level corresponds to the mean hardwood swamp–open water ecotone elevation on Transect 1 and Transect 7. The level is 0.3 ft lower than the 1994 adopted FL level (34.0 ft NGVD, Table 9). The 1994 adopted FL level was derived by using a different criterion (the waterward tree line on Transect 7).

SJRWMD's multiple MFLs methodology (Neubauer et al. 2008a, SJRWMD 2006) was used to determine the minimum lake levels. MFLs determinations are based on evaluations of topographic, soils, and vegetation data collected within plant

communities associated with the water body, with information collected from other aquatic ecosystems and from the scientific literature.

The hydrologic model for Shaw Lake was calibrated for 2004 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2004 regional water use (Robison 2007). Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Shaw Lake are protected under 2004 conditions. To determine if changes in groundwater use allocations subsequent to 2004 would cause lake levels to fall below the recommended MFLs for Shaw Lake, the existing Shaw Lake hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation. Appendix A contains information regarding the hydrologic model and applicable SJRWMD regional groundwater flow model, which should be used to assess whether water levels are likely to fall below MFLs under specific water use or land use conditions.

Results presented in this report are preliminary and will not become effective unless the recommended MFLs are adopted by SJRWMD Governing Board rule. Periodic reassessment of these levels should be conducted in order to determine if these levels are being achieved and if they are adequate to prevent significant ecological harm from occurring at Shaw Lake.

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## **APPENDIX A—IMPLEMENTATION OF MFLS FOR SHAW LAKE**

*Prepared by*

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

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

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

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

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

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

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

### Frequency analysis

As discussed previously, aquatic resources are sustained by a certain hydrologic regime. Depending on the resource in question, a selected ground elevation 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 and with a certain frequency.

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  $S_1, S_2, \dots, S_{10}$ . Once sorted and ranked, these events can be written as  $\hat{S}_1, \hat{S}_2, \dots, \hat{S}_{10}$ , with  $\hat{S}_1$  being the highest peak. Based on this limited sample, the estimated probability of the yearly peak being greater than or equal to  $\hat{S}_1$  would be

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

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

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

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

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

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:



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

where,

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

$$m = \text{rank of the event}$$

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

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

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

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

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

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

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

$$T = \frac{1}{P} \quad (\text{A8})$$

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

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

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; 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 Shaw Lake 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 Shaw Lake: (1) a minimum frequent high (FH) level; (2) a minimum average (MA) level; and (3) a minimum frequent low (FL) level. The FH level for this lake is used here to illustrate how long-term hydrologic statistics of a lake relate to MFLs.

Each of the three MFLs is tied to characteristic stage durations and return frequencies. For example, the ground elevation represented by the FH level is expected to remain wet continuously for a period of at least 30 days. This event is expected to occur, on average, at least once every 3 years.

The standard stage frequency analysis described previously in this appendix was performed on stage data from lake model simulations of Shaw 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 2004. The ground elevation of the FH 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 FH 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 FL level (Figure A9). All three levels are being met under these conditions.

A summary of the recommended MFLs for Shaw 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 Shaw 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 near Shaw 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 Shaw Lake, at the time of preparation of this document, SJRWMD was using the North Central Florida Regional Groundwater Flow Model (Motz 2004) for this purpose. This steady-state model is calibrated to 1995 conditions; therefore, the projected drawdown in the potentiometric surface represents the estimated drawdown that would occur from 1995 to the last year of simulation. In association with consumptive use permit evaluations, the last year of simulation represents the year through which issuance of the permit is contemplated. In SJRWMD's water supply assessment and planning processes the last year of simulation represents the planning horizon year and/or other intermediate years that may represent significant water use targets.

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

As stated previously, the model simulation results depicted in Figures A7 through A9 assume long-term Floridan aquifer withdrawals at 2004 levels. Any withdrawal increases beyond 2004 would tend to lower potentiometric levels in the area and,

therefore, would tend to lower lake levels in Shaw Lake. In order to determine the freeboard present at Shaw Lake from the point of view of Floridan aquifer water level drawdowns, a trial-and-error process was undertaken assuming incrementally increasing drawdowns. Drawdowns are represented by subtracting a set amount from the well hydrograph used in simulation of Shaw Lake. In the case of Shaw Lake, for a Floridan aquifer water level drawdown of 1.2 ft, the MA level would still be met (Figure A10). However, any drawdowns greater than 1.2 ft would cause water levels to fall below the established MA level. At a drawdown of 1.2 ft, the FH level (Figure A11) and the FL level would still be met (Figure A12). Therefore, future Floridan aquifer water level drawdowns beyond 2004 conditions will be limited to 1.2 ft in the Shaw 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.
- 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.

Table A1. Summary of recommended MFLs for Shaw Lake

MFLs	Level (ft NGVD)	Duration	Series	Water Year	Statistical Type	Minimum Return Period	Maximum Return Period
Minimum frequent high (FH)	36.7	30 days	Annual	June 1–May 31	Maximum, continuously exceeded	NA	3 yrs
Minimum average (MA)	35.4	180 days	Annual	Oct. 1–Sept. 30	Minimum mean, not exceeded	1.5 yrs	NA
Minimum frequent low (FL)	32.0	120 days	Annual	Oct. 1–Sept. 30	Minimum, continuously not exceeded	3 yrs	NA

ft NGVD = feet National Geodetic Vertical Datum

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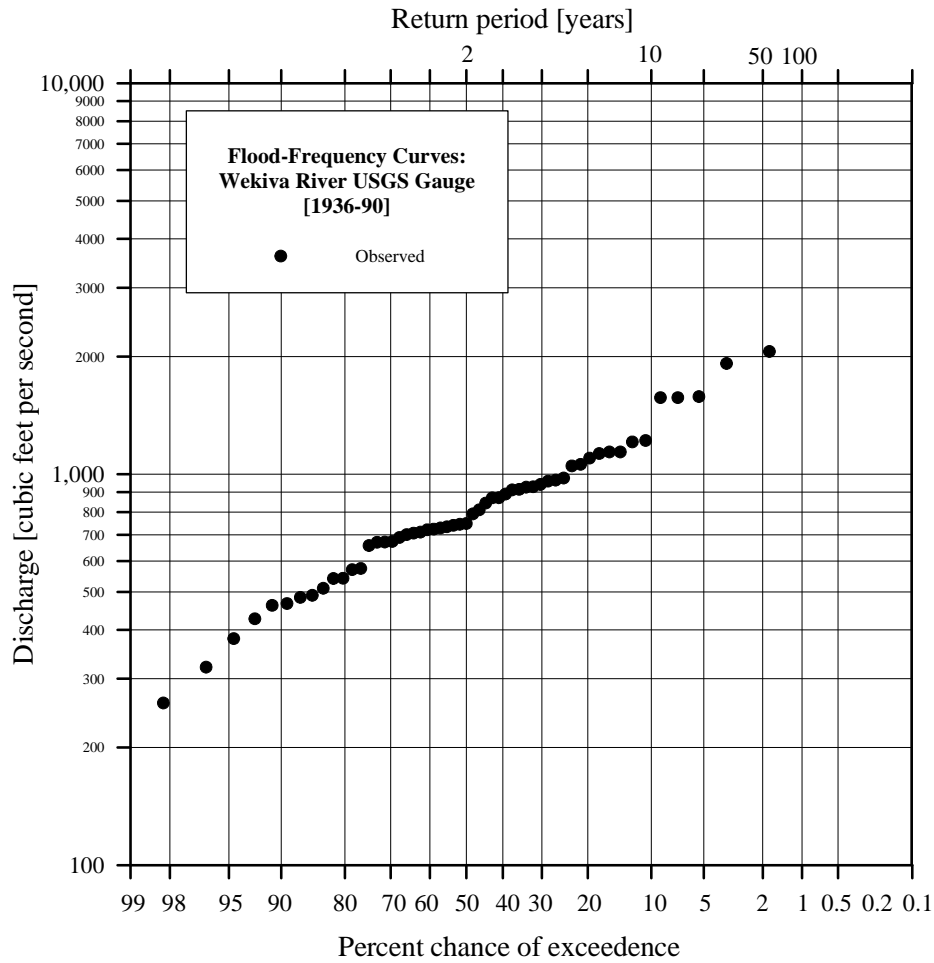


Figure A1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla.; the 1-day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula

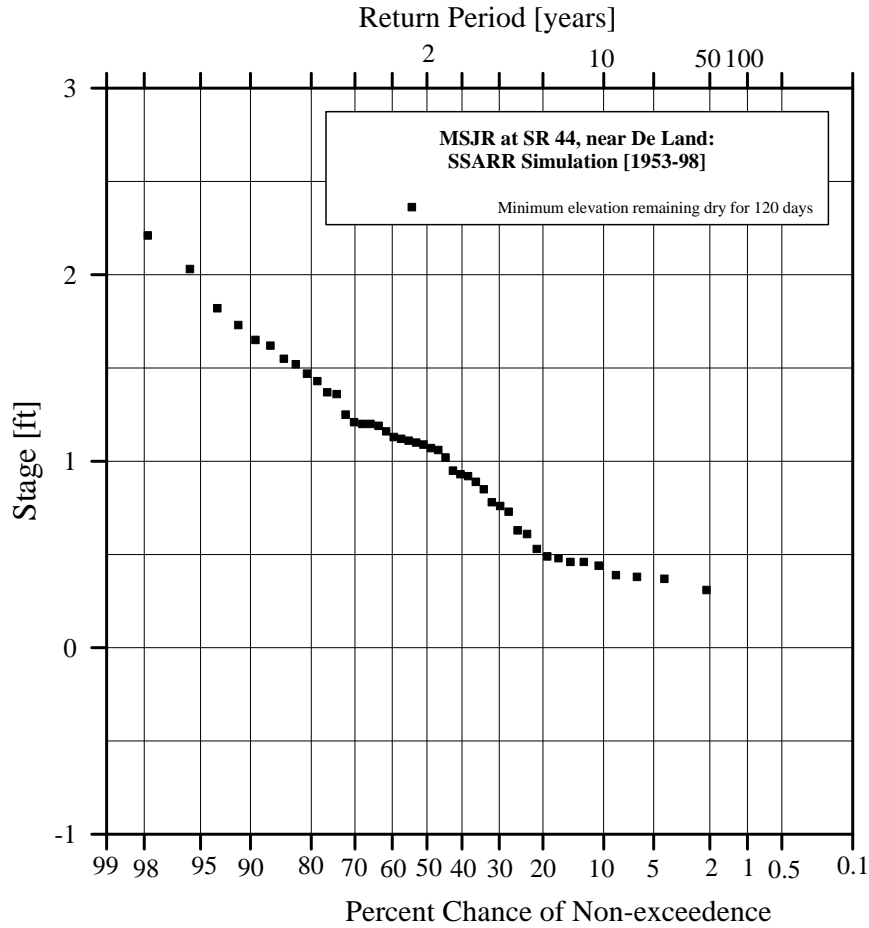


Figure A2. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand; the minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula

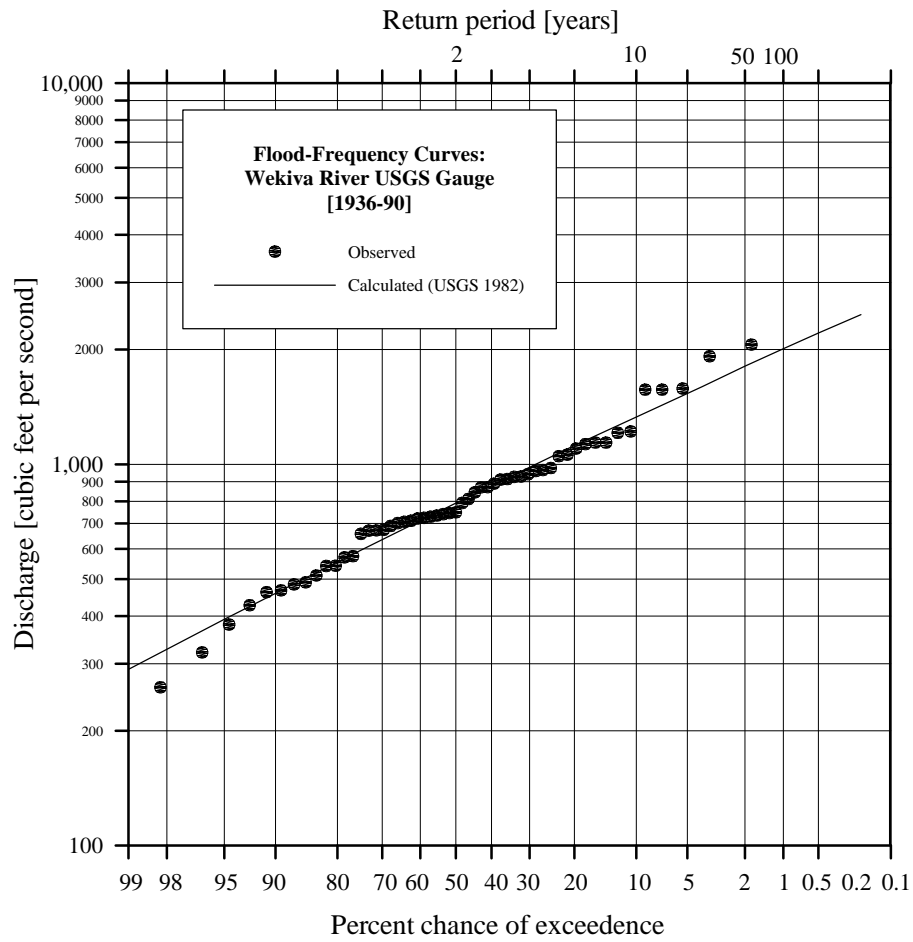


Figure A3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla., fitted by standard mathematical procedure

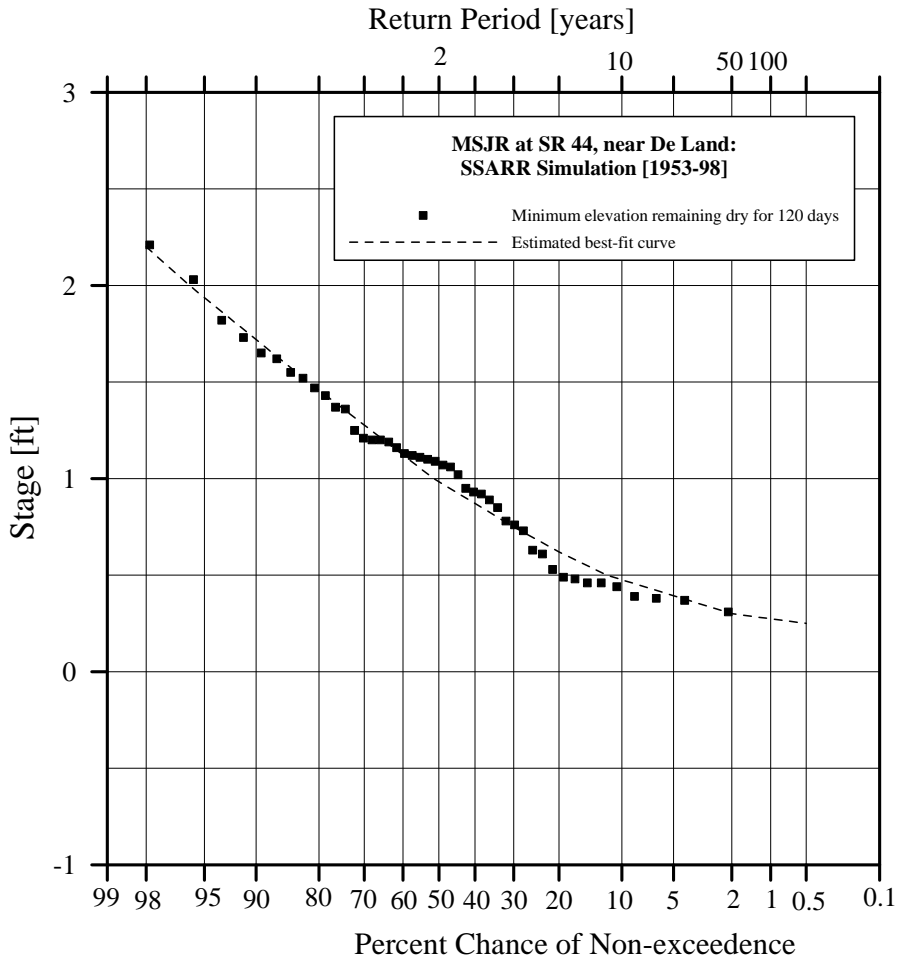


Figure A4. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand, fitted by the graphical method

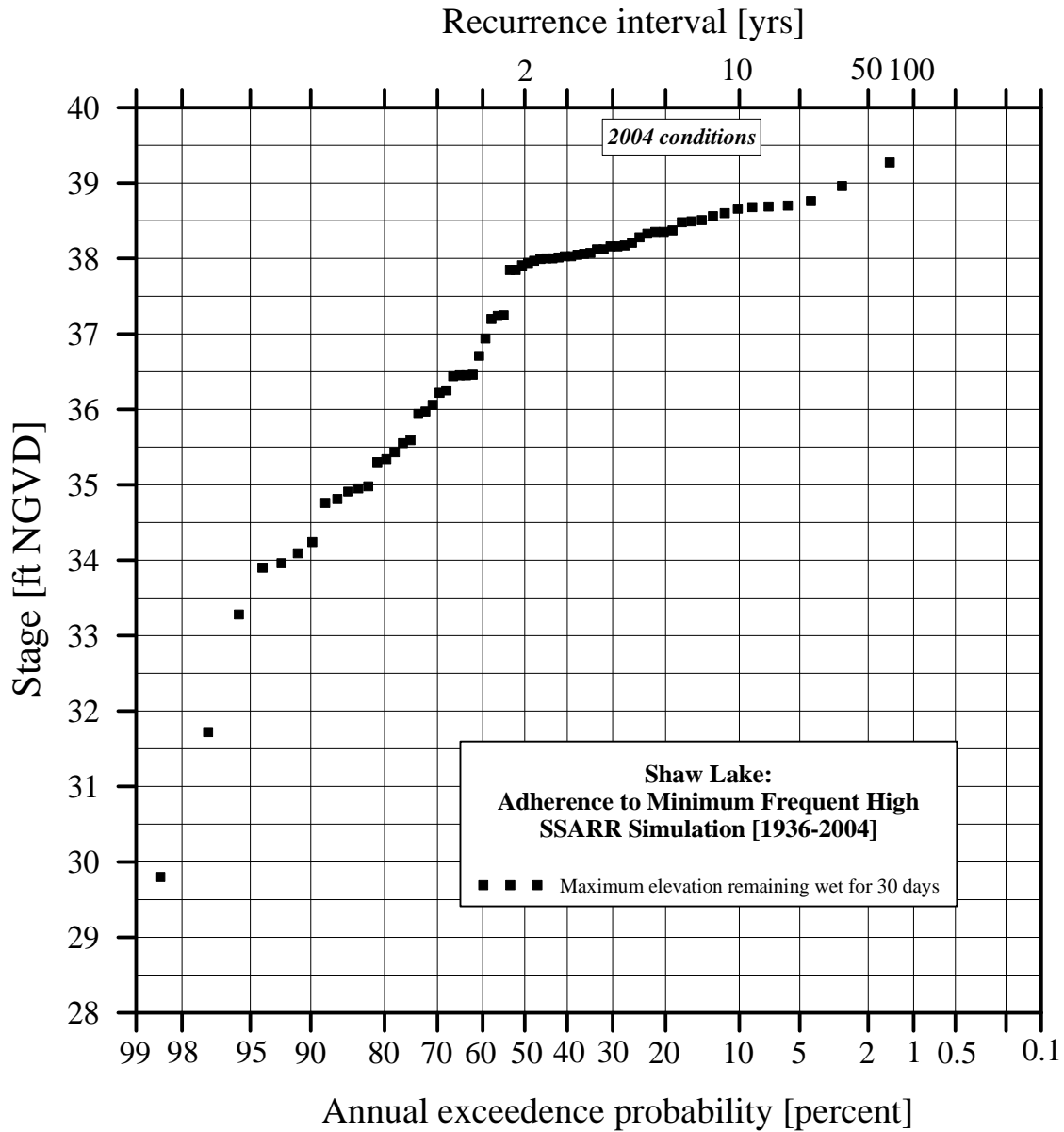


Figure A5. Flood frequencies computed using daily stages from model simulations of Shaw Lake, for elevations continuously wet for 30 days and 2004 conditions

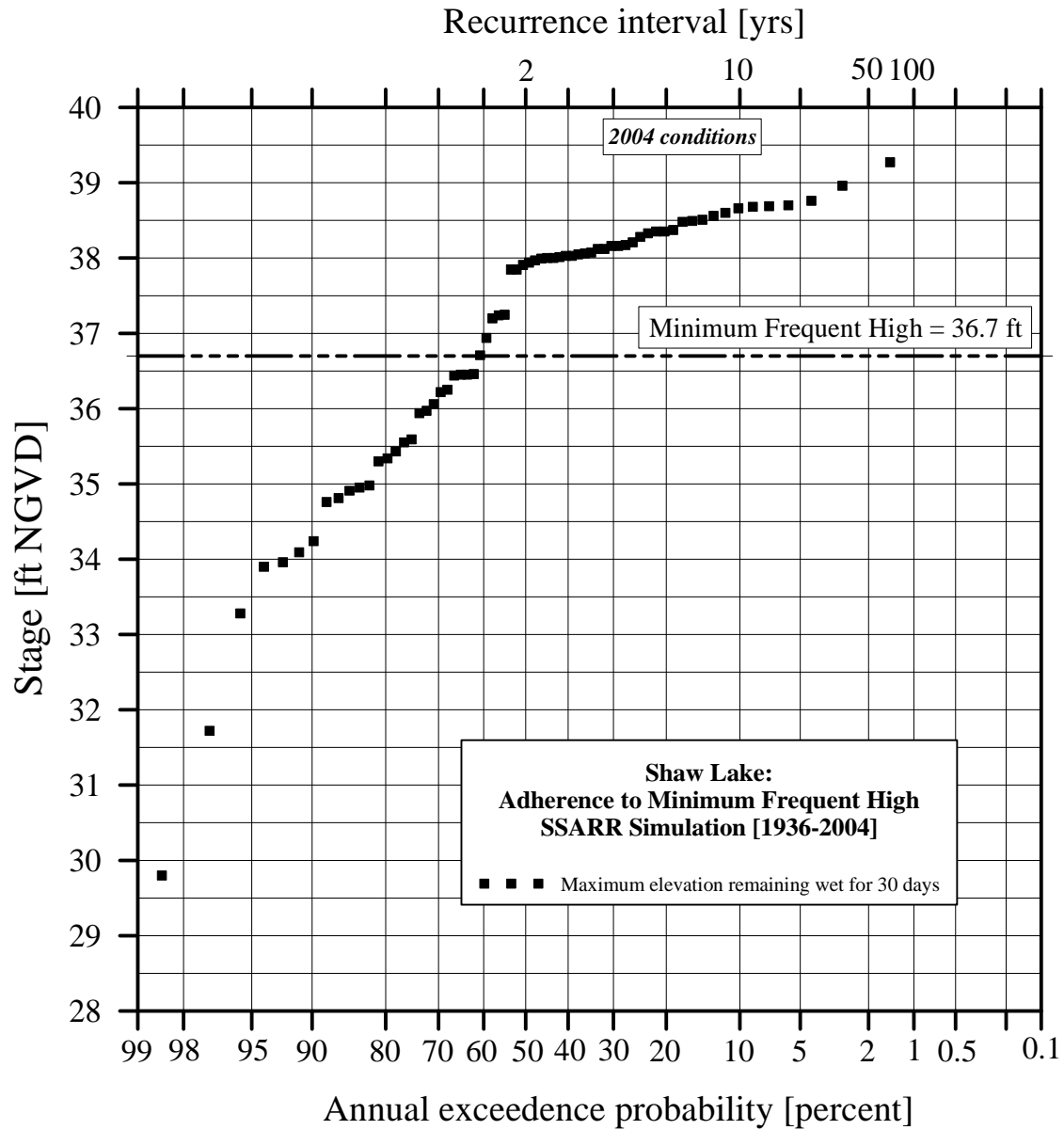


Figure A6. Flood frequencies computed using daily stages from model simulations of Shaw Lake, for elevations continuously wet for 30 days and 2004 conditions with the FH level of 36.7 ft NGVD superimposed

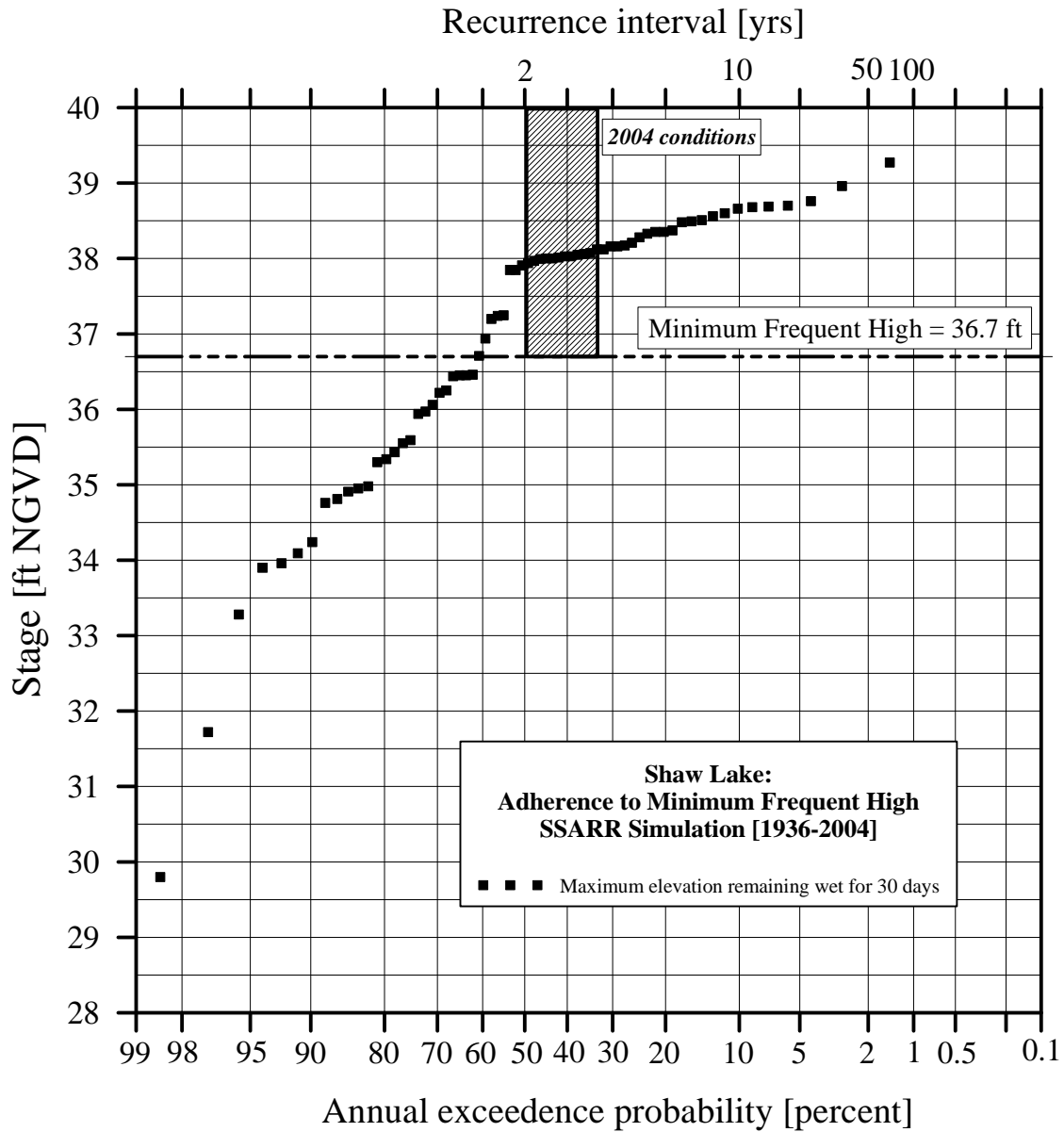


Figure A7. Flood frequencies computed using daily stages from model simulations of Shaw Lake, for elevations continuously wet for 30 days and 2004 conditions with a superimposed box bounded by: (1) the FH; (2) a vertical line corresponding to a return period of 2 years; and (3) a vertical line corresponding to a return period of 3 years

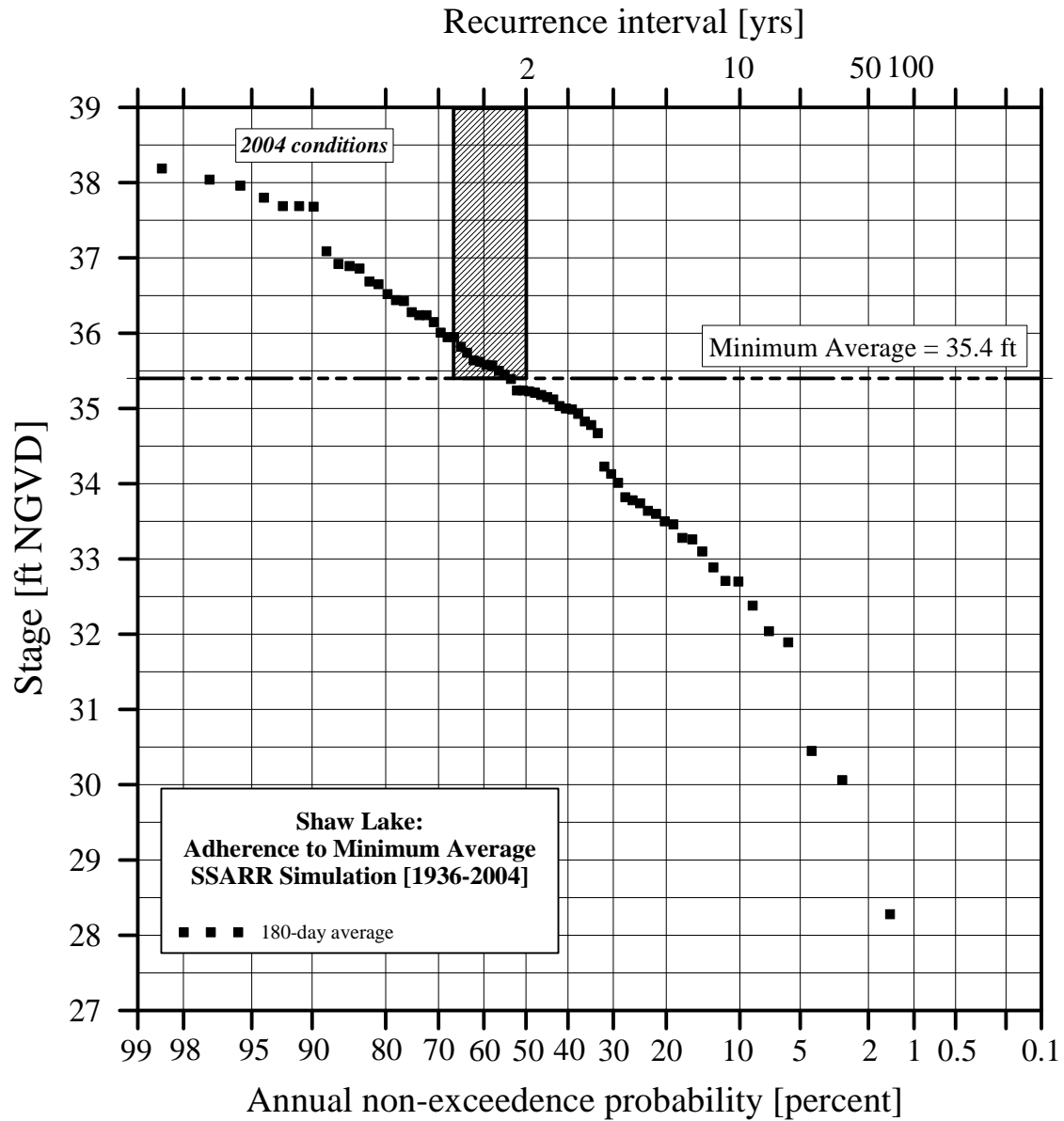


Figure A8. Drought frequencies computed using daily stages from model simulations of Shaw Lake, for the MA level and 2004 conditions



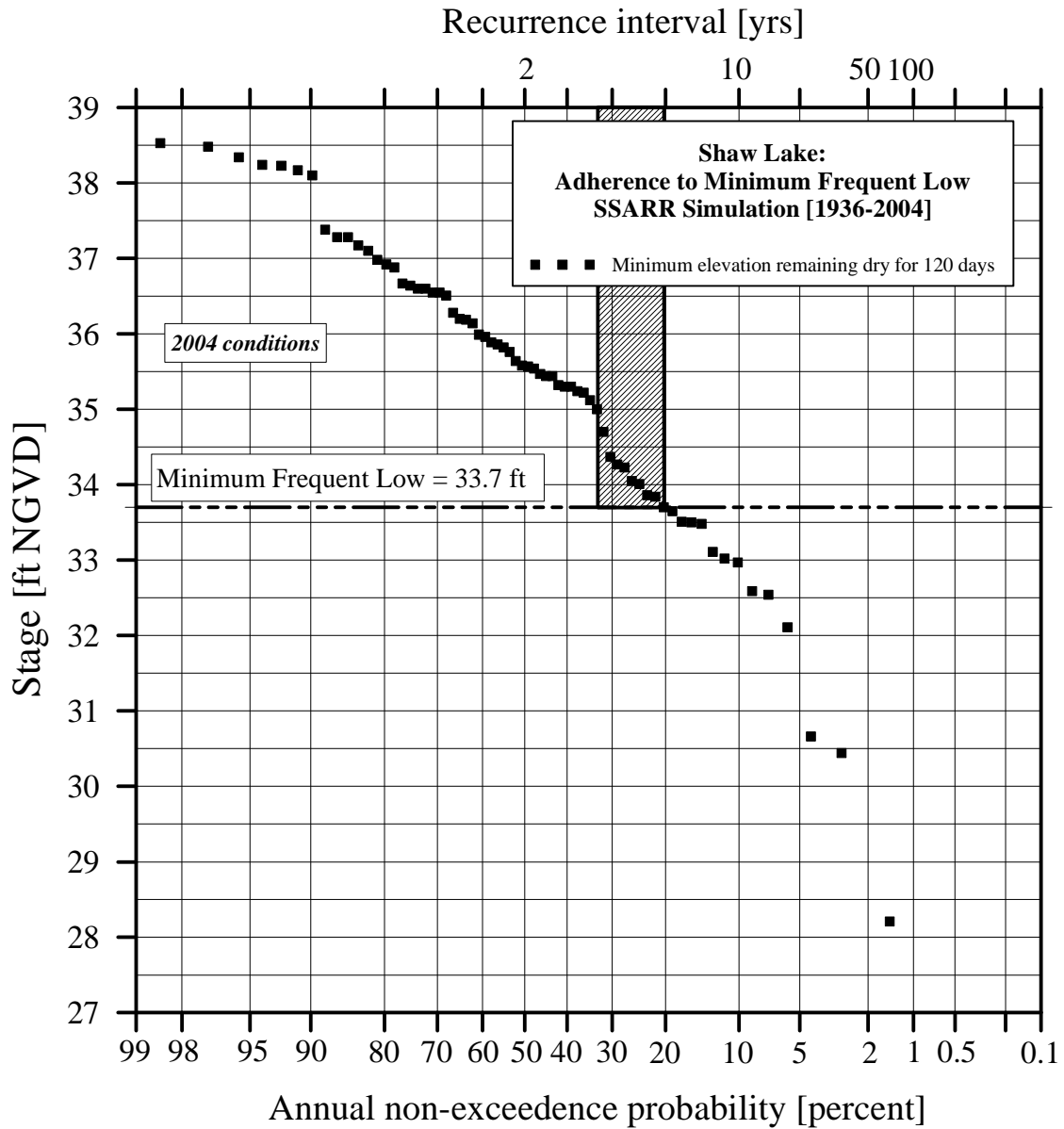


Figure A9. Drought frequencies computed using daily stages from model simulations of Shaw Lake, for the FL level and 2004 conditions

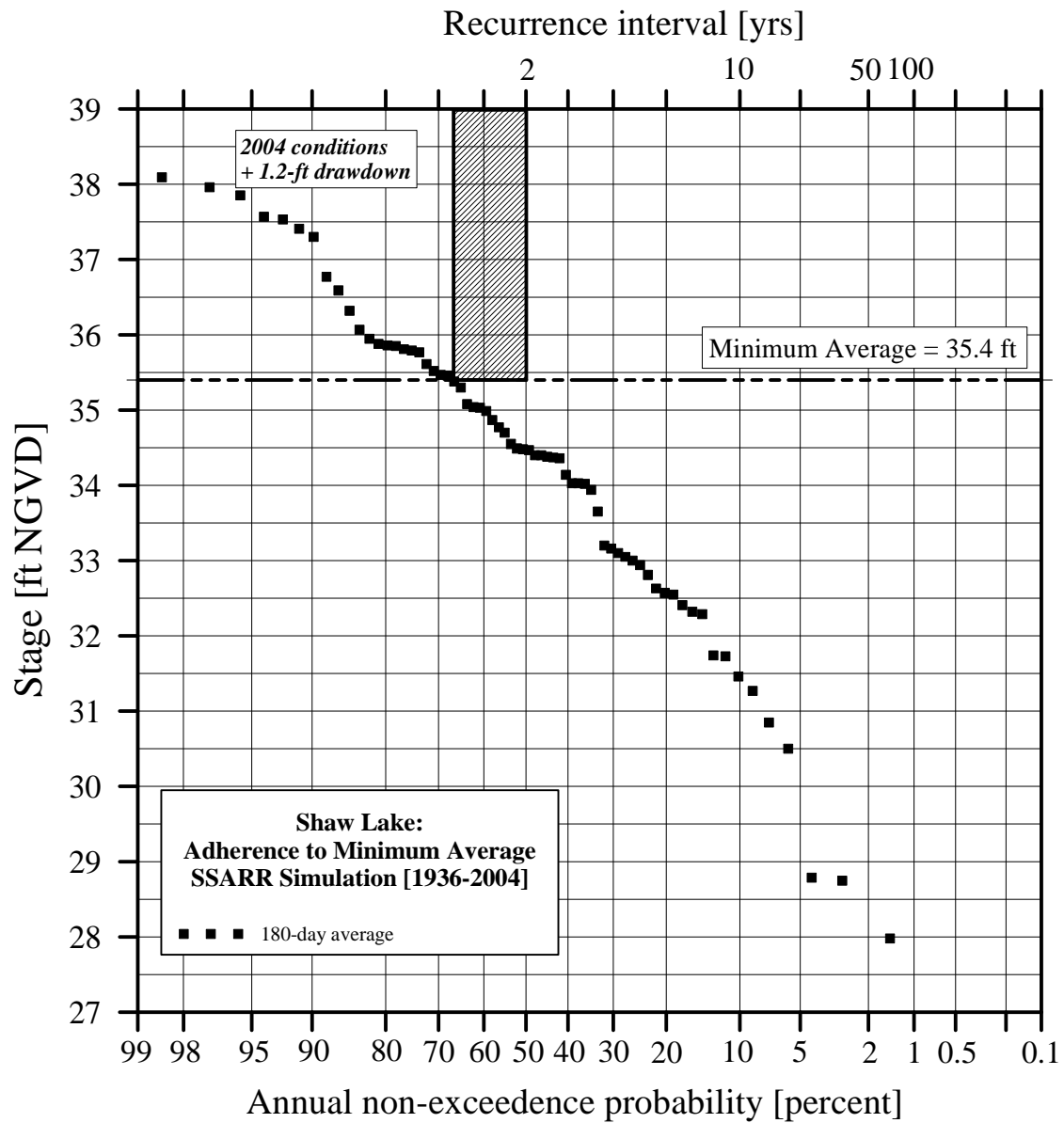


Figure A10. Drought frequencies computed using daily stages from model simulations of Shaw Lake, for the MA level and 2004 conditions plus a 1.2-ft Floridan aquifer drawdown

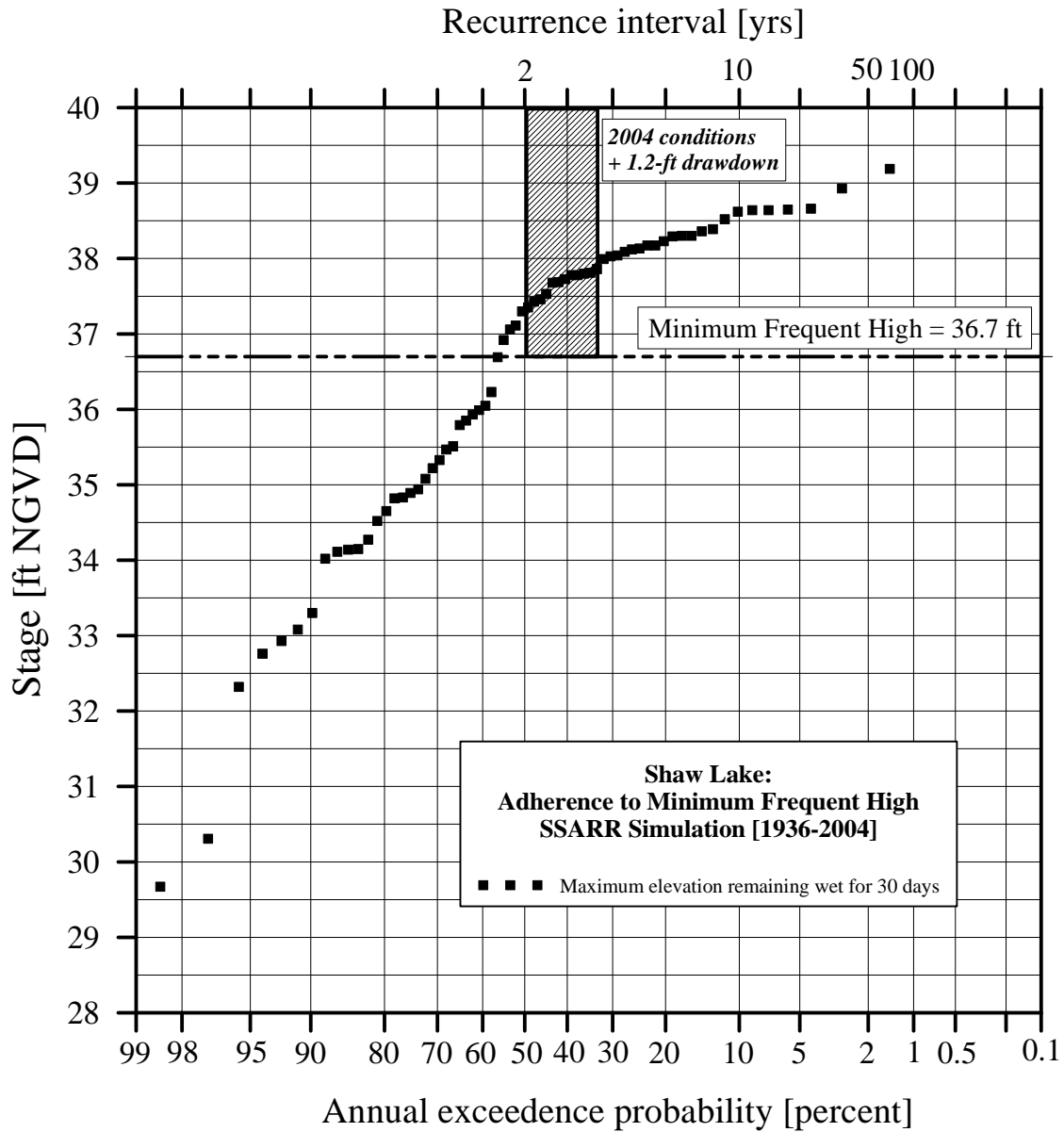


Figure A11. Flood frequencies computed using daily stages from model simulations of Shaw Lake, for the FH level and 2004 conditions plus a 1.2-ft Floridan aquifer drawdown

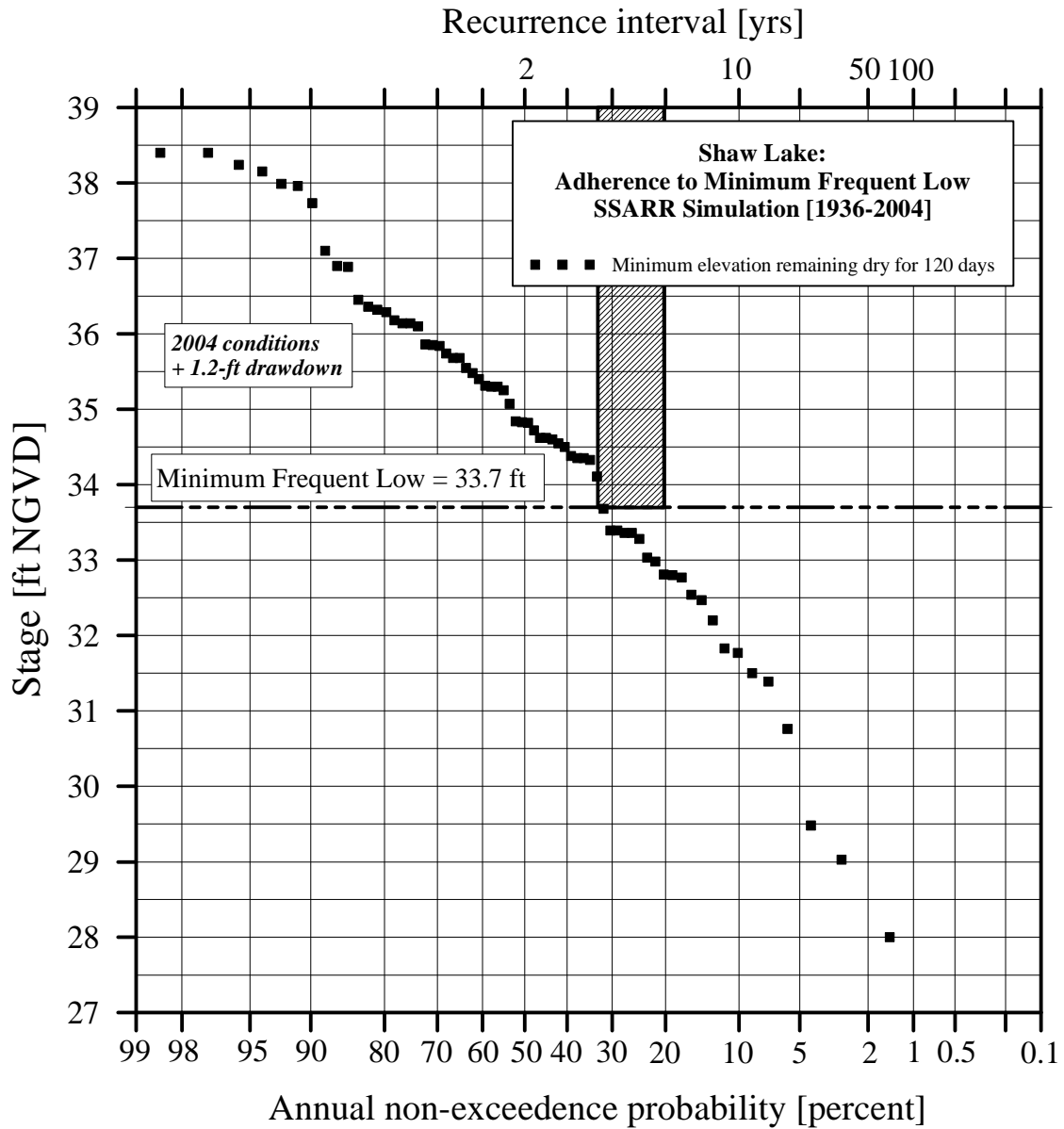


Figure A12. Drought frequencies computed using daily stages from model simulations of Shaw Lake, for the FL level and 2004 conditions plus a 1.2-ft Floridan aquifer drawdown