TECHNICAL PUBLICATION SJ2009-3

# MINIMUM LEVELS REEVALUATION: GORE LAKE
# FLAGLER COUNTY, FLORIDA

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# MINIMUM LEVELS REEVALUATION: GORE LAKE FLAGLER COUNTY, FLORIDA

by

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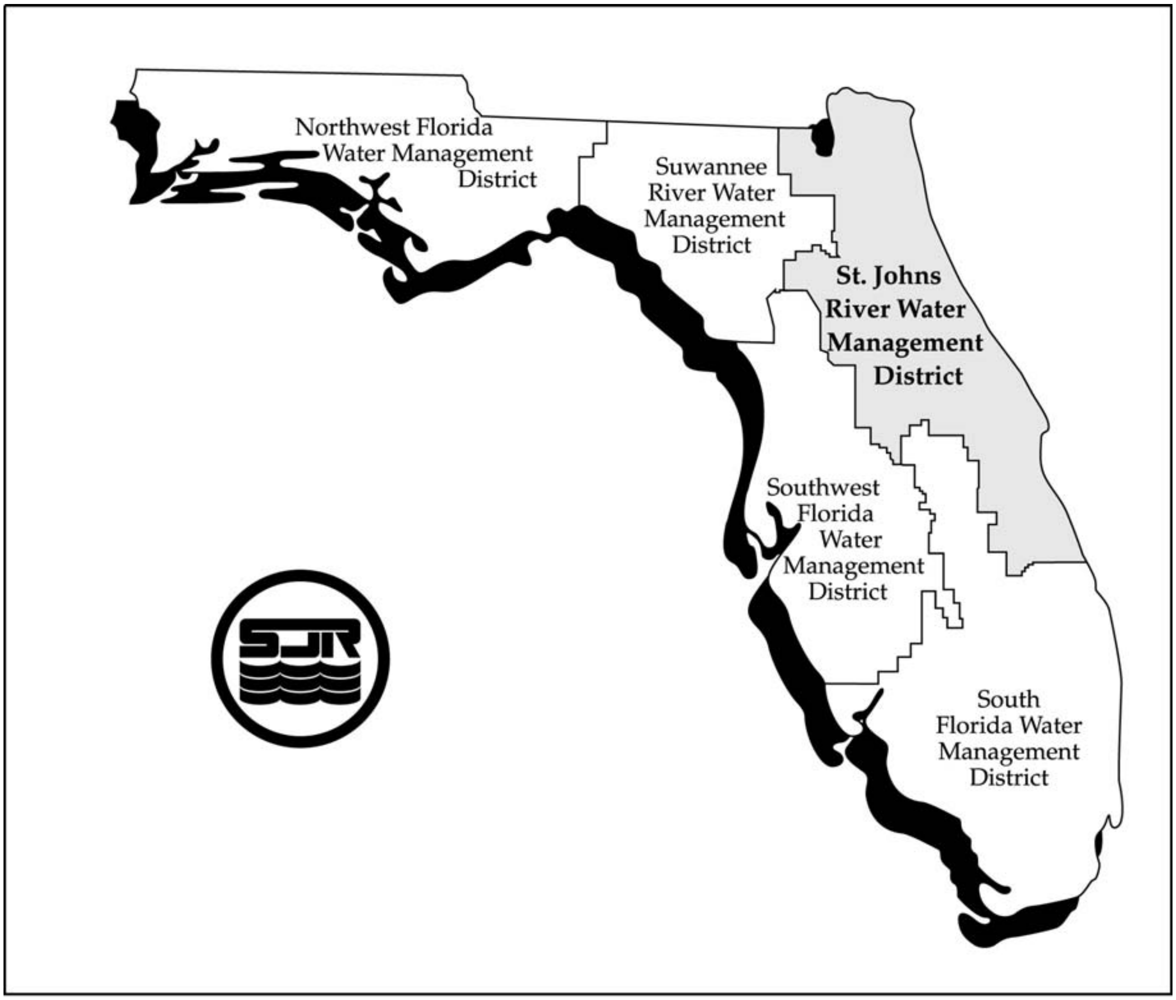
Palatka, Florida

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 Gore Lake in Flagler County. The SJRWMD Governing Board adopted minimum levels for Gore Lake in 1998 (Mace 1997). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). Recent completion of a hydrologic model for Gore Lake (CDM 2005) indicated that the adopted minimum frequent high and minimum average levels were barely being met under 2003 modeled hydrologic conditions. Consequently, a reevaluation of the adopted Gore Lake MFLs was performed. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Gore Lake (Table ES-1) based on current SJRWMD MFLs determination methodology.

Table ES-1. Adopted (Mace 1997) and recommended reevaluated minimum surface water levels for Gore Lake, Flagler County

| Minimum Levels | Adopted Elevation (ft NGVD) 1929 Datum | Adopted and Recommended Hydroperiod Categories | Recommended Elevation (ft NGVD) 1929 Datum | Recommended Duration | Recommended Return Interval |
|---|---|---|---|---|---|
| Minimum frequent high (FH) level | 21.6 | Seasonally flooded | 21.1 | 30 days | 3 years |
| Minimum average (MA) level | 20.8 | Typically saturated | 20.6 | 180 days | 1.5 years |
| Minimum frequent low (FL) level | 19.8 | Semi-permanently flooded | 19.2 | 120 days | 5 years |

ft NGVD = feet National Geodetic Vertical Datum

The SJRWMD multiple MFLs methodology (SJRWMD 2006; Neubauer et al. 2008) was used to determine the 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, with information collected from other aquatic ecosystems and from the scientific literature. The recommended minimum frequent high level for Gore Lake is 0.5 foot (ft) lower than the adopted minimum frequent high because a different minimum frequent high level criterion was used. The adopted minimum frequent high level at Gore Lake corresponds to the upper hardwood swamp and seepage slope ecotone elevation. The recommended minimum frequent high level corresponds to the average elevation of all hardwood swamp and upper hardwood swamp elevation points surveyed in 2005 at Transects 1 and 2. Recent surface water model results indicated that the upper hardwood swamp–seepage slope ecotone elevation represents a lake level that occurs less frequently than the minimum frequent high level and has a hydroperiod category of seasonally flooded.

The recommended minimum average level for Gore Lake is 0.2 ft lower than the adopted minimum average level, because a different minimum average level criterion was used. The adopted minimum average level for Gore Lake equals the average elevation of the lower cypress swamp. The recommended minimum average level equals a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep (≥ 8 inches [in.] thick) surface organic soils observed in 2005 at Transects 1 and 2. The 0.3-ft soil water table drawdown criterion is commonly used to determine a minimum average level where deep (≥ 8 in. thick) surface organic soils are identified (SJRWMD 2006).

The recommended minimum frequent low level for Gore Lake is 0.6 ft lower than the adopted minimum frequent low, because a different minimum frequent low level criterion was used. The adopted minimum frequent low level for Gore Lake equaled a 20-in. soil water table drawdown below the average ground surface elevation, where muck depth was 2 ft in thickness. Currently, a 20-in. soil water table drawdown from the average ground surface elevation, where a histic epipedon (surface organic horizon 8 in. to 16 in. thick) or histosol (surface organic horizon ≥ 16 in. thick) is identified, is commonly used and was used herein as the primary minimum frequent low level criterion when deep (≥ 8 in. thick) organic soils are identified (SJRWMD 2006). An additional factor resulting in the slightly changed recommended minimum frequent low level includes the fact that a professional soil scientist collected soil data at Gore Lake in 2005 as part of this reevaluation, while professional soil scientist services were not used in 1997. Determining where the soil horizon grades from muck to a mucky-fine sand is best performed by a professional soil scientist. Thus, the elevations and locations of the deep organic soils vary between the 1997 and 2005 field soil sampling efforts.

Recommended minimum levels based on SJRWMD’s reevaluation and associated hydroperiod categories are presented in Table ES-1. Terms are defined in Rule 40C-8.021, *Florida Administrative Code* (*F.A.C.*). Hydroperiod categories and definitions are adapted from water regime modifiers developed by Cowardin et al. (1979).

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

Results presented in this report are considered recommended until the MFLs are adopted by SJRWMD Governing Board rule.

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# INTRODUCTION

This report describes the St. Johns River Water Management District's (SJRWMD's) minimum flows and levels (MFLs) reevaluation for Gore Lake in Flagler County, Florida. The SJRWMD Governing Board adopted minimum levels for Gore Lake in 1998 (Mace 1997, Appendix A). MFLs are to be reviewed periodically and revised as needed (Section 373.0421(3), *Florida Statutes* [F.S.]). Recent completion of a hydrologic model for Gore Lake (CDM 2005) indicated that the adopted minimum frequent high and minimum average levels were barely being met under 2003 modeled hydrologic conditions. Consequently, a reevaluation of the adopted Gore Lake levels was performed. This document describes that reevaluation.

## MFLS PROGRAM OVERVIEW

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

### Factors to Be Considered When Determining MFLs

According to Rule 62-40.473, *F.A.C.*, in establishing MFLs pursuant to Sections 373.042 and 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 reasonable–beneficial use. MFLs define the frequency and duration of high-, average-, and low water events necessary to protect relevant water resource values criteria, and indicators that prevent significant harm to aquatic and wetland habitats. Three MFLs are usually defined for each system—minimum frequent high, minimum average, and minimum frequent low—flows and/or water levels. If deemed necessary, minimum infrequent high and/or minimum infrequent low flows and/or water levels are also defined. The MFLs represent hydrologic statistics composed of three components: a magnitude (a water level and/or flow), duration (days), and a frequency or return interval (years). SJRWMD has historically synthesized the continuous duration and frequency components of the MFLs into seven discrete hydroperiod categories to facilitate MFLs determinations for lakes and wetlands. However, for MFLs associated with reevaluations of established MFLs and MFLs for water bodies for which MFLs have not been previously established, these hydroperiod categories are now being replaced with specific duration and return interval values (Table 1).

Table 1. MFLs hydroperiod categories and approximate frequencies and durations

| Hydroperiod Category | Approximate Frequency | Approximate Duration |
|---|---|---|
| Intermittently flooded | Once every 10 years high | Weeks to months |
| Temporarily flooded | Once every 5 years high | Weeks to months |
| Seasonally flooded | Once every 2 years high | Weeks to months |
| Typically saturated | Once every 2 years low | Months |
| Semipermanently flooded | Once every 5 to 10 years low | Months |
| Intermittently exposed | Once every 20 years low | Weeks to months |
| Permanently flooded | More extreme drought | Days to weeks |

MFLs are water levels and/or flows that primarily serve as hydrologic constraints for water supply development, but they may also apply in environmental resource permitting (Figure 1). 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 (Figure 1).

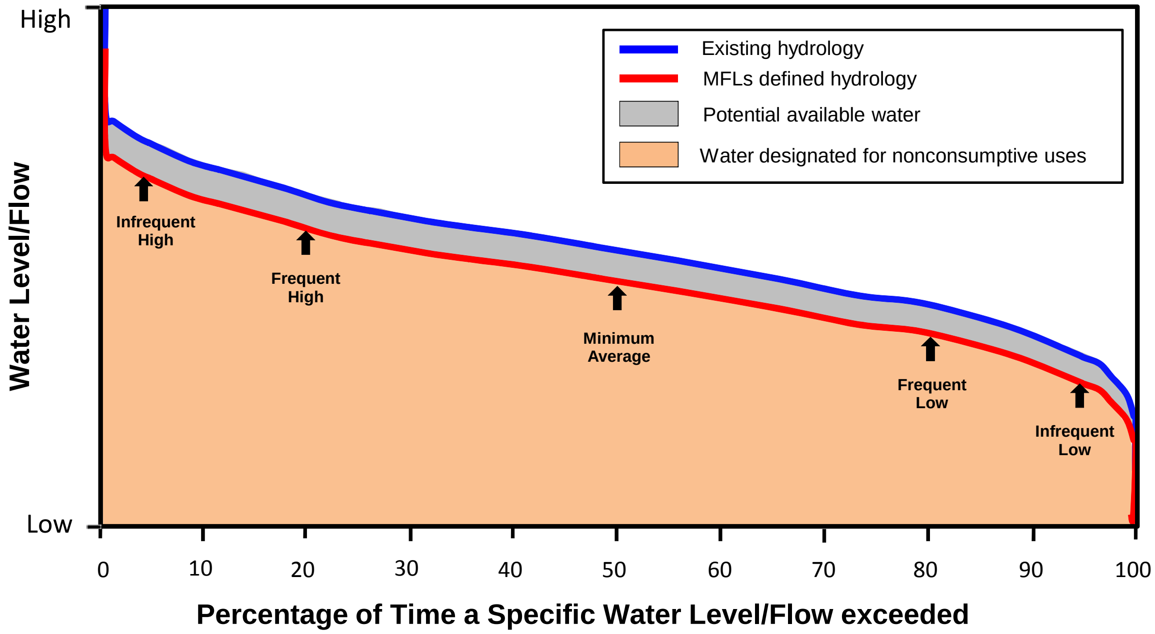


Figure 1. Hypothetical percentage exceedence curves for existing and MFLs-defined hydrologic conditions

As it applies to wetland and aquatic communities, significant harm is a function of changes in the frequencies water level and/or flow events of defined duration, causing impairment or loss of ecological structures and functions. Significant harm can be prevented if water withdrawals do not cumulatively alter the hydrology beyond the minimum hydrologic regime defined by the MFLs.

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

# GORE LAKE BACKGROUND INFORMATION

Gore Lake is located in Flagler County approximately 2 miles southeast of Bunnell, adjacent to the Flagler County Airport. Gore Lake is used for landing and departing of seaplanes. An airplane/boat ramp is located on the southeast shore (Figure 2), providing seaplanes access to the airport terminal via the land runways. Based upon the SJRWMD 2000 land use coverage, the land use in the Gore Lake watershed consists primarily of wetlands (317 acres; 50%) and airport land (188 acres; 30%). The remaining land uses were rangeland, upland forest, commercial, and low-density residential (Figure 2).

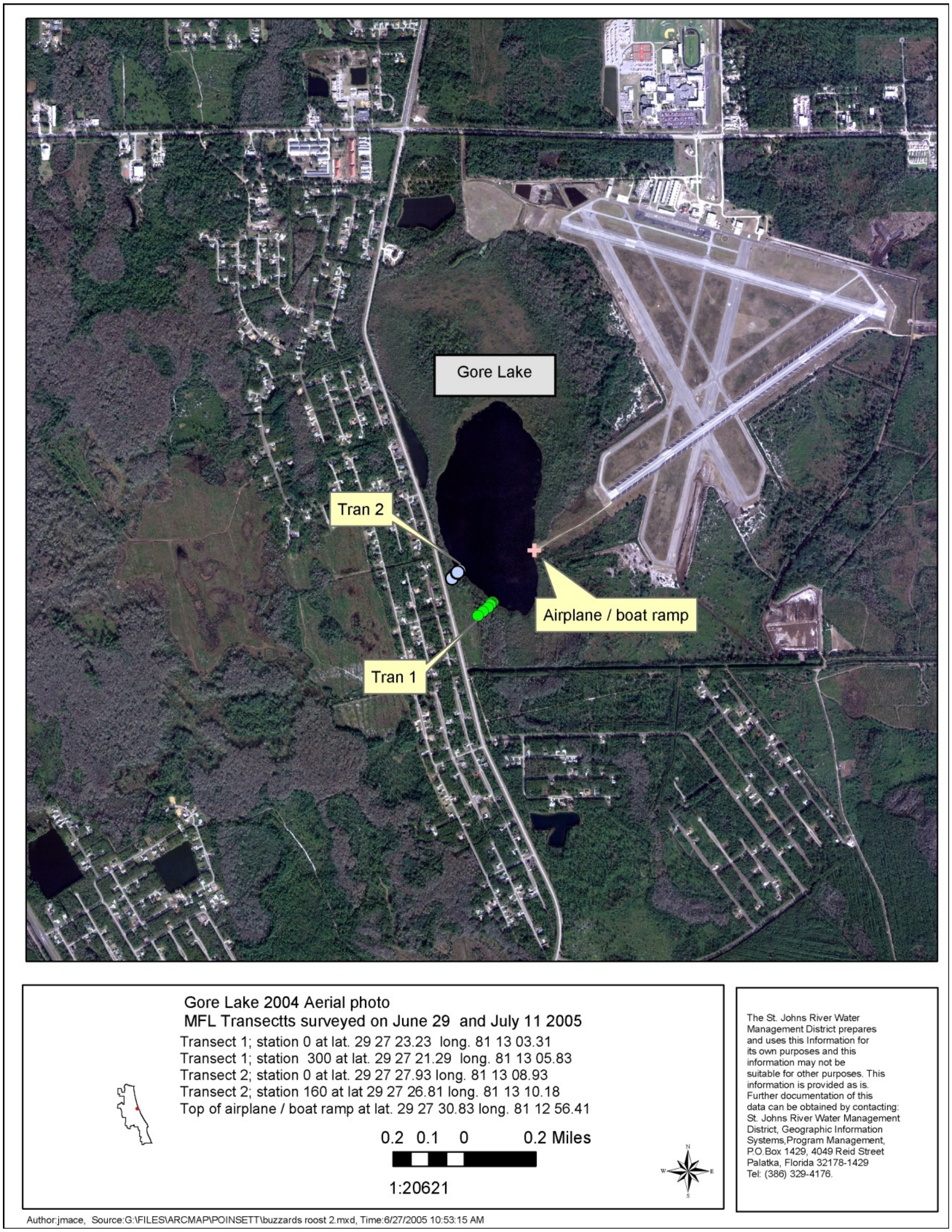
## GORE LAKE HYDROLOGY

Gore Lake covers approximately 84 acres when the stage equals 22.0 ft National Geodetic Vertical Datum (NGVD). Based upon Fathometer readings taken on September 21, 2005, the lake bottom elevation of Gore Lake averaged 13.2 ft NGVD within the open water area approximately 100 ft from the shoreline.

Surface water level data (Figure 3) for Gore Lake has been collected generally on a weekly schedule from December 4, 1995, to the present. The gauge is located on the east lakeshore at the edge of an airport runway. At the time of this MFLs reevaluation, during the period of record, the lake level ranged between 18.98 ft and 22.82 ft NGVD (range 3.84 ft), with median and average levels of 21.34 ft and 21.24 ft NGVD, respectively (Figure 4). Based on aerial photography (Figure 2) and stage data analyses, it appears that Gore Lake receives nearly constant inflow from the canal to the south and/or the water body, wetlands to the north, as well as storm water from the Flagler County Airport. These inflows have caused Gore Lake to have unusually stable and high water levels during the past 10 years.

## GORE LAKE WETLANDS

The wetland communities adjacent to Gore Lake include shrub swamp, hardwood swamp and bayhead (Figure 5). The two field transects surveyed at Gore Lake traversed shrub swamp and hardwood swamp communities before terminating in upland vegetation. Detailed wetland community descriptions for the two transects located at Gore Lake are presented in the Results and Discussion section.



Gore Lake 2004 Aerial photo
MFL Transectts surveyed on June 29 and July 11 2005
Transect 1; station 0 at lat. 29 27 23.23 long. 81 13 03.31
Transect 1; station 300 at lat. 29 27 21.29 long. 81 13 05.83
Transect 2; station 0 at lat. 29 27 27.93 long. 81 13 08.93
Transect 2; station 160 at lat 29 27 26.81 long. 81 13 10.18
Top of airplane / boat ramp at lat. 29 27 30.83 long. 81 12 56.41

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Figure 2. Aerial photograph of Gore Lake

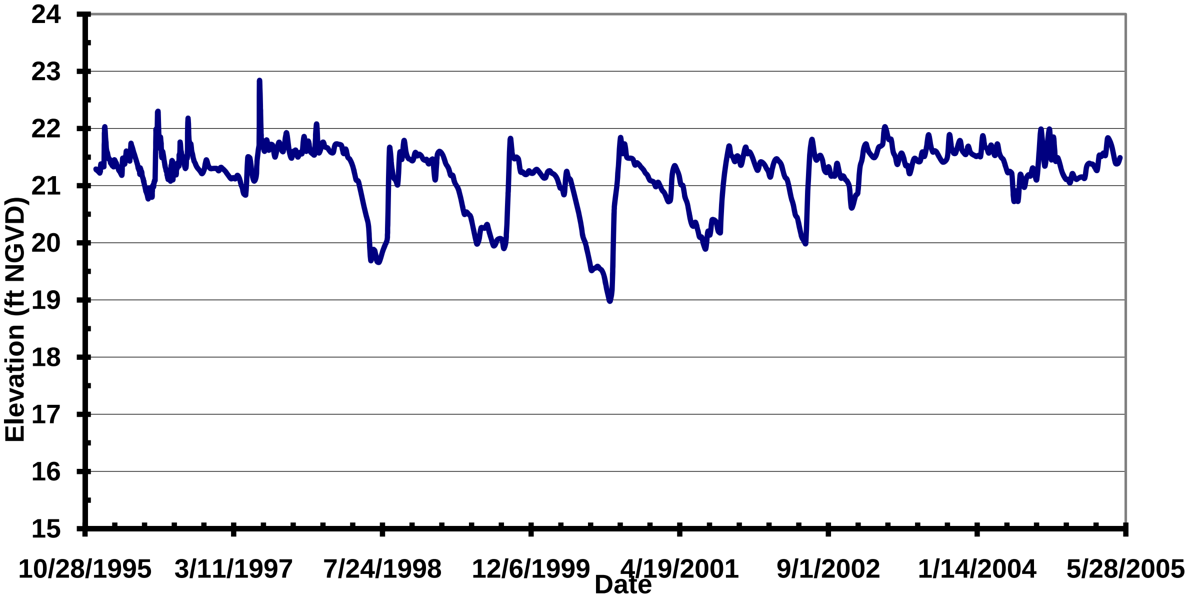

Figure 3. Gore Lake stage from December 1995–May 2005

## GORE LAKE SOILS

Lake hydrology is related to the development of hydric soils. These substrates are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part (USDA–SCS 1987). Hydric soil (Samsula series) was mapped nearly exclusively at the shoreline of Gore Lake (Figure 6; Soil Survey Geographic [SSURGO] database). The Samsula series consists of very deep, very poorly drained, rapidly permeable soils that formed in moderately thick beds of hydrophytic plant remains and are underlain by sandy marine sediments. The only other soil mapped immediately adjacent to Gore Lake was Pomona series. Pomona series consists of very deep, poorly drained and very poorly drained, moderately to moderately slow permeable soils.

Field soil sampling was performed at Gore Lake by a soil scientist of Jones, Edmunds and Assoc. Inc., contractor to SJRWMD. Hydric soils were identified at each transect. The field soil sampling results were integral to the MFLs determinations. Transect-specific field soil sample descriptions are presented here in the Results and Discussion section.

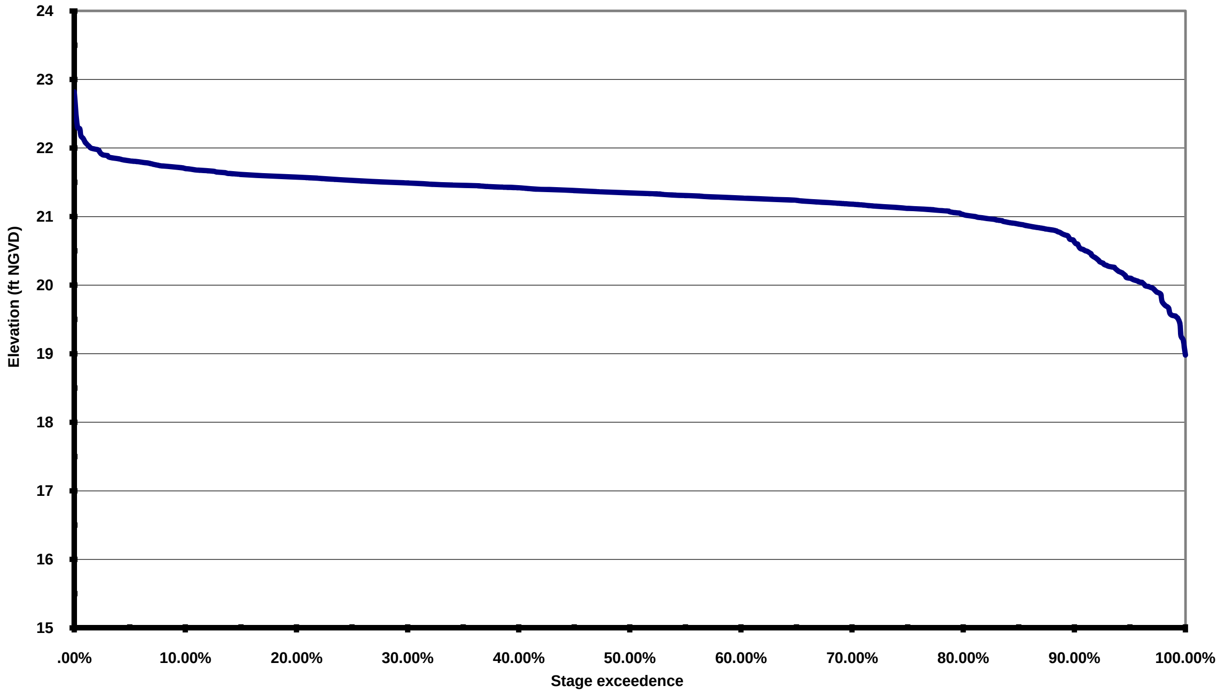

Figure 4. Stage duration curve for Gore Lake

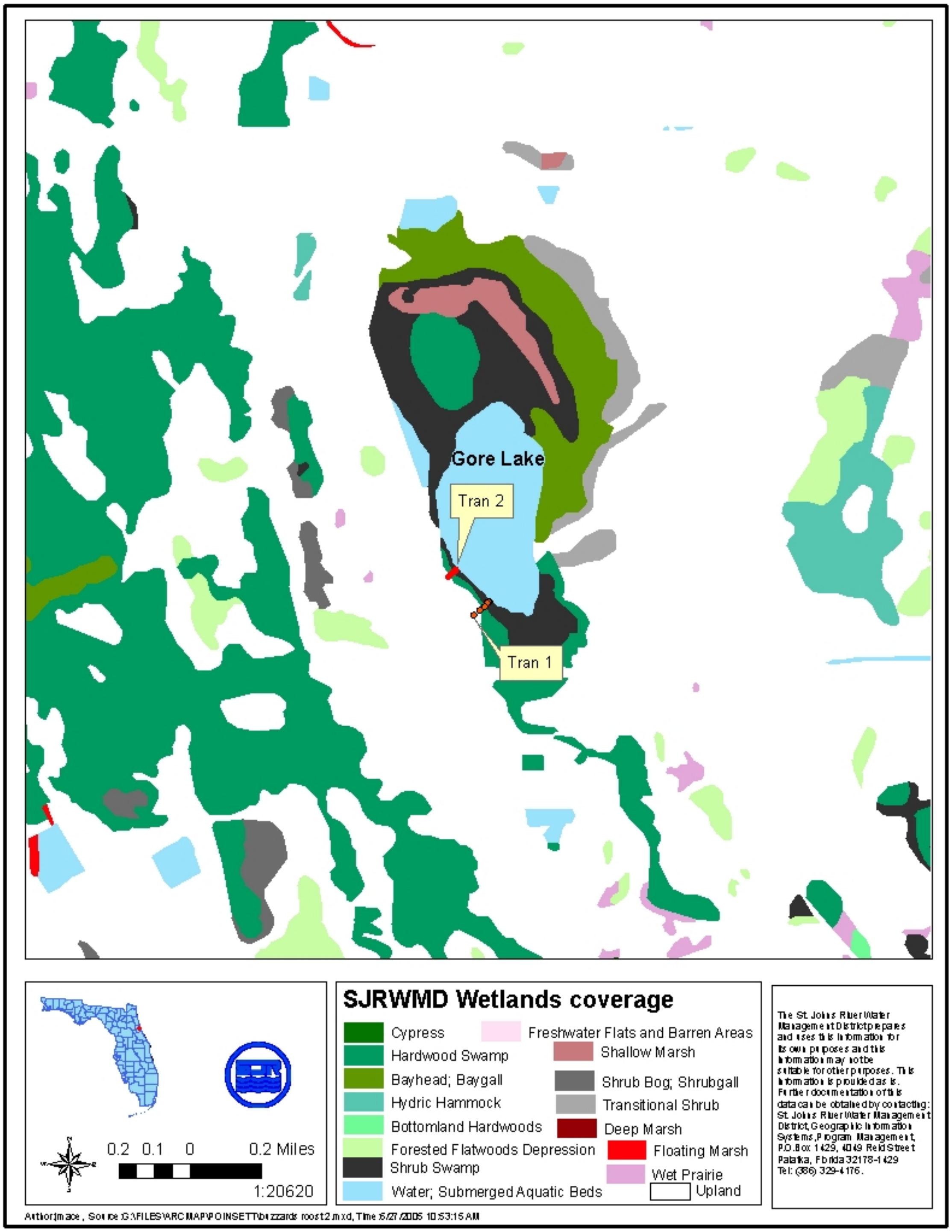

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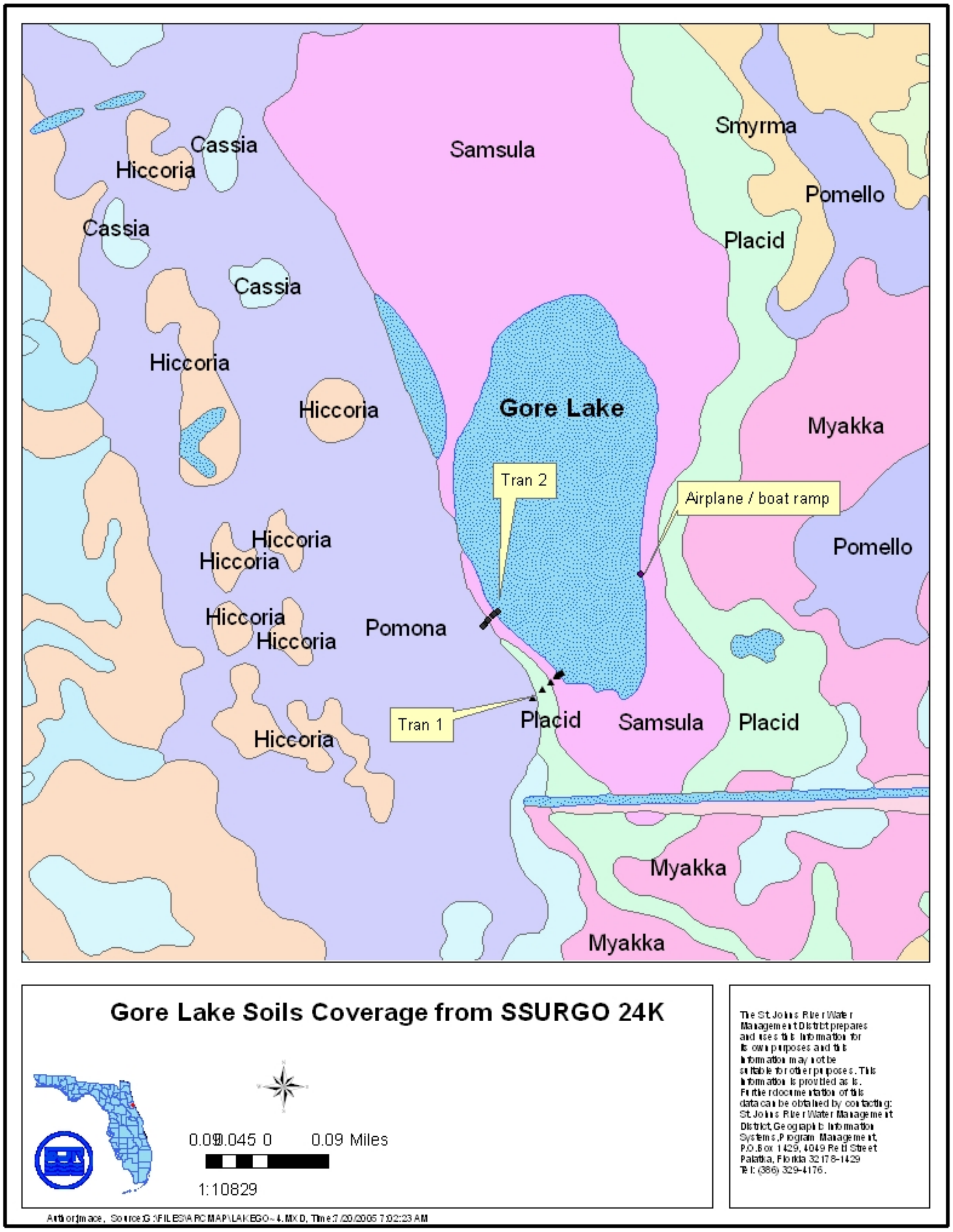
Figure 5. Gore Lake wetland map



Gore Lake Soils Coverage from SSURGO 24K

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Figure 6. Gore Lake soil series, from Soil Survey Geographic (SSURGO) database

# METHODS

MFLs determinations incorporate biologic and topographic information collected in the field with stage data; wetland, soils, and landownership data from geographic information system (GIS) coverages; aerial photography; the scientific literature; and hydrologic and hydraulic models to generate an MFLs regime. MFLs methodology provides a process for incorporating these factors. This section describes the methodology and assumptions used in the MFLs determination process for Gore Lake, 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 TRANSECT SITE SELECTION

Many factors are considered in the selection of field transect sites. Transects are fixed sample lines across a river, lake, or wetland floodplain. Transects usually extend from open water to uplands, 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 include:

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

The field investigation at Gore Lake occurred in June, July, and September 2005. All the previously identified types of information were considered in the selection of field transect sites at Gore Lake.

### Data Analysis and Transect Site Identification

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

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

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

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

## FIELD DATA COLLECTION

The field data collection procedure for determining MFLs involved collecting elevation, soils, and vegetation data along fixed lines, or transects, across a hydrologic gradient. Transects were established in areas where there are changes in vegetation and soil, 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

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

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

### Soil Sampling Procedures

The primary soil criteria considered in the MFLs determination are the presence and depth of organic soils, as well as the extent of hydric soils observed along the field transects (SJRWMD 2006). The procedure to document hydric soils includes:

- Removing all loose leaf-matter, needles, bark, and other easily identified plant parts to expose the soil surface; digging a hole and describing the soil profile to a depth of at least 20 in. and, with the use of the completed soil description, specifying which hydric soil indicators have been matched.
- Performing deeper examination of the 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).

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

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

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

- Landward extent of hydric soils
- Landward extent of surface organics
- Landward extent of histic epipedon (surface organic horizon 8–15 in. thick)
- Landward extent of histosols (> 16-in.-thick surface organic horizon)
- Thickness of organic surface horizon

### Vegetation Sampling Procedures

SJRWMD has wetland maps developed from aerial photography 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) between plant communities was determined using reasonable scientific judgment. Reasonable scientific judgment involves the ability to collect and analyze information using technical knowledge, and 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 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 7). The belt transect 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 7).

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 and is 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

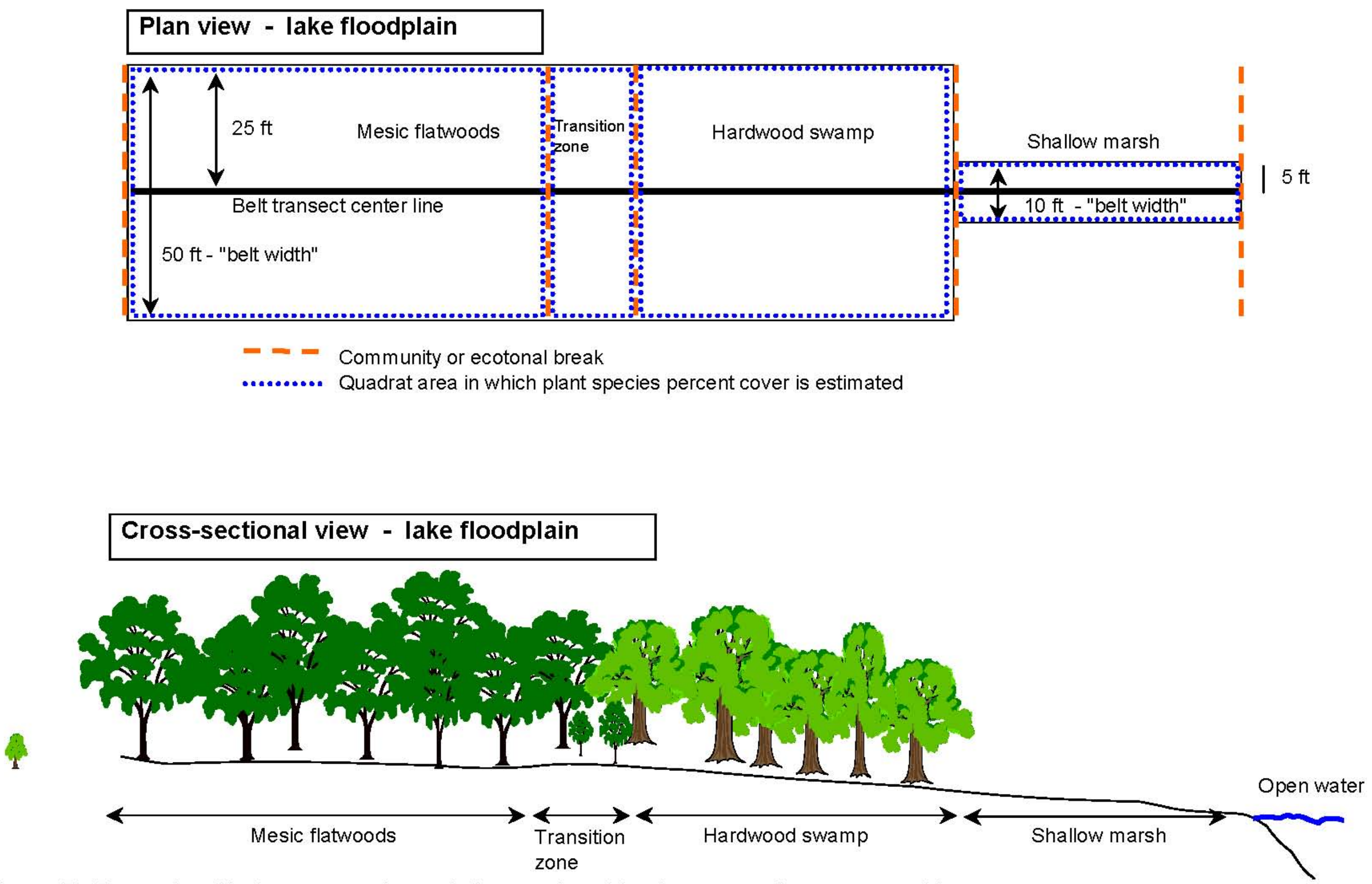

Figure 7. Example of belt transect through forested and herbaceous plant communities

better measure of plant biomass than the number of individuals. The canopies of the plant 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).

Table 2. Summary of cover classes and percent cover ranges (SJRWMD 2006)

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

Percent cover was estimated visually using cover classes (ranges of percent cover). The cover class and percent cover ranges (Table 2) are a variant of the Daubenmire method (Mueller-Dombois and Ellenberg 1974) and are 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 were formatted to facilitate data collection in the field and, also, computer transcription.

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

## DATA ANALYSIS

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

Transect elevation data were also graphed to illustrate the elevation profile between the open water and upland community. Location of vegetation communities along the transect, with a list of dominant species, statistical results and soils information, are typically labeled on the graph. Specific transect elevation data from Gore 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 wetland and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater; these highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.

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

## CONSIDERATION OF BASIN ALTERATIONS IN ESTABLISHING MFLS

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

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

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

SJRWMD considers that the existing hydrologic condition, which is used to calibrate and verify the models, reflects the changes and structural alterations that have occurred in addition to changes that are the result of groundwater and surface water withdrawals 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 have been in place for a sufficiently long period to allow vegetation and soils to respond to the altered hydrology. However, the condition of vegetation and soils may not reflect the long-term existing hydrologic condition if the changes, structural alterations, and water withdrawals are relatively recent. This is because vegetation and soil conditions 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 Gore Lake was developed to provide a means of assessing whether compliance with MFLs is achieved under specific water use and land use conditions (CDM 2005; Appendix C). This hydrologic model was calibrated for 2003 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2003 regional water use.

An explanation of the use of this hydrologic model and applicable SJRWMD regional groundwater flow model to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions is presented in Appendix C. This appendix also includes an introduction to the use of hydrologic statistics in the SJRWMD MFLs program.

# RESULTS AND DISCUSSION

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

## FIELD DATA TRANSECT 1

Transect 1 was located on the southwest shore of Gore Lake, (Figures 3 and 6). This transect site was established in order to characterize the hardwood swamp and shrub swamp at this location (Table 3).

Table 3. Transect 1 location and fieldwork dates

| Latitude–Longitude (Station 0; water’ s edge) | Latitude–Longitude (Station 300; upland) | Location and Dates of Fieldwork |
|---|---|---|
| 292723.24 – 811303.31 | 292721.29 – 811305.84 | Southwest shore of Gore Lake, June–July 2005 |

### Vegetation at Transect 1

Transect 1 traversed 330 ft in a westerly direction from the open water of Gore Lake through a shrub swamp (stations 10–100), a hardwood swamp (stations 100–220), an upper hardwood swamp (220–270), a seepage slope (station 270–300), and terminated in a low flatwoods (station 300–330) (Figures 8 and 9; Tables 4 and 5).

The shrub swamp (stations 10–100) vegetation included abundant wax myrtle (*Myrica cerifera*), buttonbush (*Cephalanthus occidentalis*), and royal fern (*Osmunda regalis*); numerous swamp lily (*Crinum americanum*), swamp-loosestrife (*Decodon verticillatus*), and saw grass (*Cladium jamaicense*); and scattered bull arrowhead (*Sagittaria lancifolia*), dahoon holly (*Ilex cassine*), lizard’s tail (*Saururus cernuus*), and fetter-bush (*Lyonia lucida*).

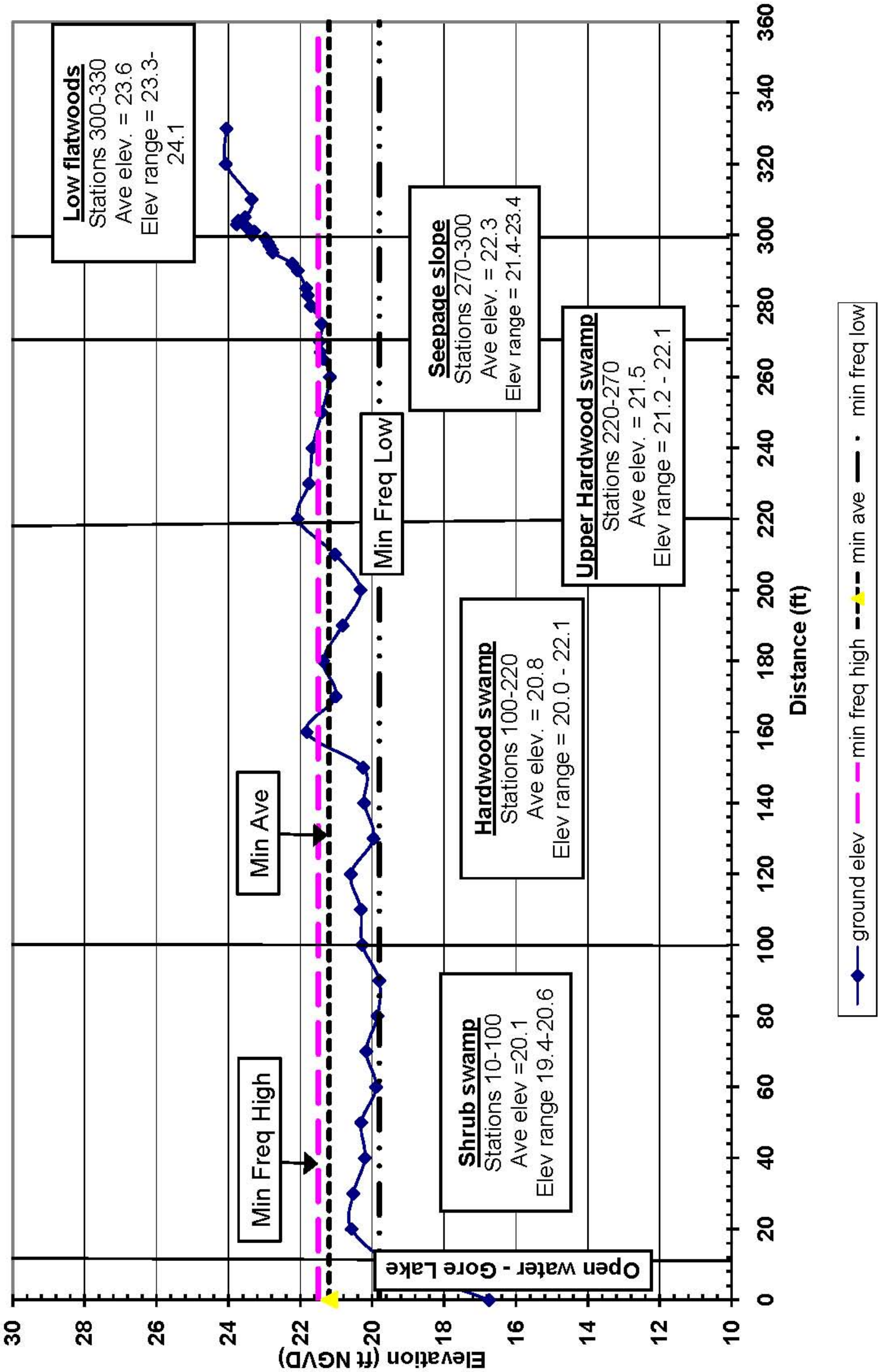

Figure 8. Gore Lake transect 1 topography with ecological communities

Figure 9. Gore Lake Transect 1 photographs

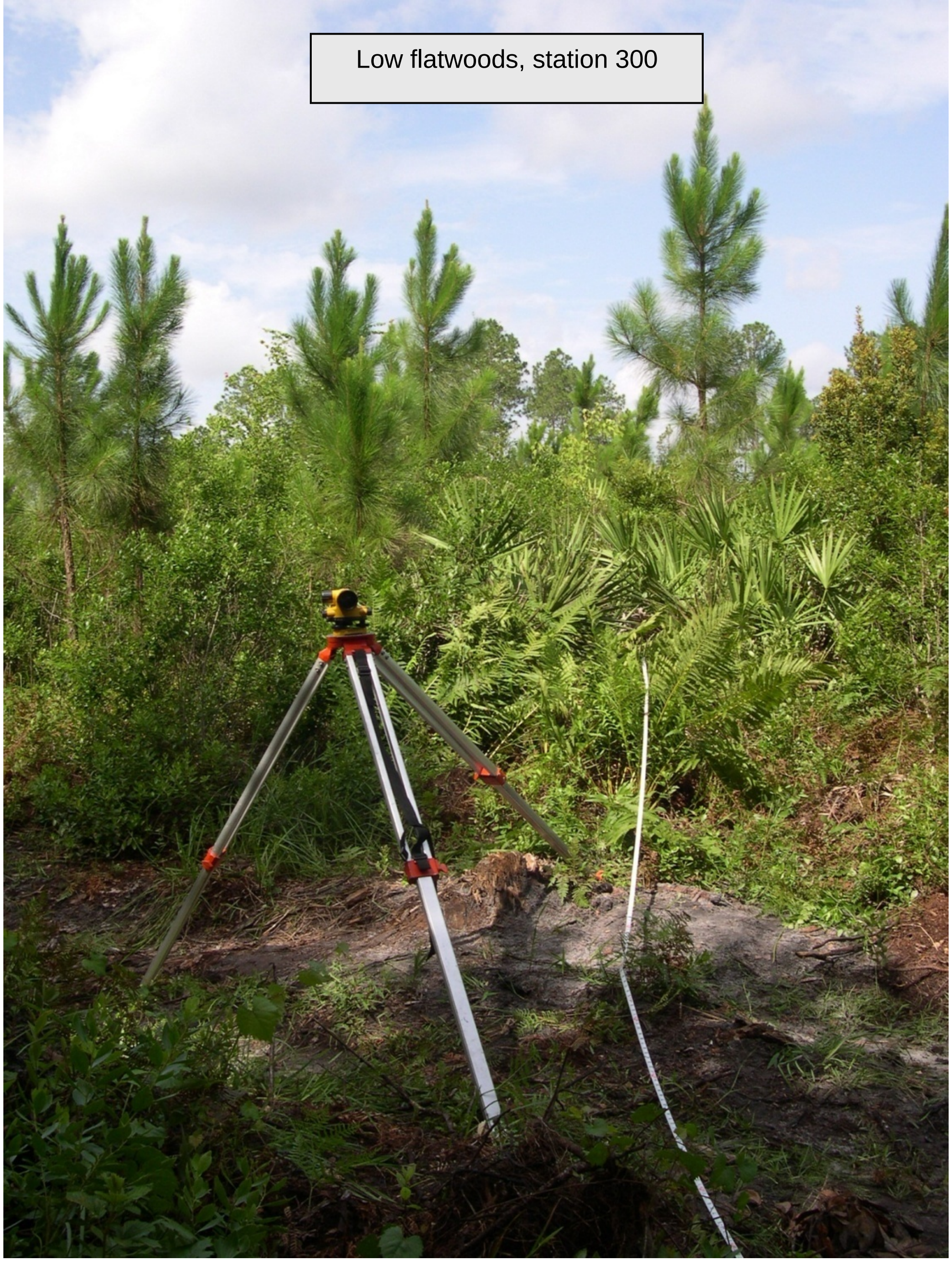

Figure 9—*Continued*

Table 4. Gore Lake Transect 1 vegetation community elevation statistics

| Vegetation Community | Stations Distance (ft) | Mean (ft NGVD) | Median (ft NGVD) | Min (ft NGVD) | Max (ft NGVD) | N |
|---|---|---|---|---|---|---|
| Shrub swamp | 10–100 | 20.1 | 20.2 | 19.4 | 20.6 | 10 |
| Deep organic soils* | 50–283 | 20.8 | 20.8 | 19.8 | 22.1 | 25 |
| Hardwood swamp | 100–220 | 20.8 | 20.6 | 20.0 | 22.1 | 13 |
| Upper hardwood swamp | 220–270 | 21.5 | 21.4 | 21.2 | 22.1 | 6 |
| Seepage slope | 270–300 | 22.3 | 22.2 | 21.4 | 23.4 | 13 |
| Low flatwoods | 300–330 | 23.6 | 23.5 | 23.3 | 24.1 | 9 |

*Histic epipedon or histosol sampled except at station 250, where 6 inches of muck was observed
ft NGVD = feet National Geodetic Vertical Datum
N = the number of elevations surveyed at each location

The hardwood swamp community (stations 100–220) overstory vegetation included co-dominant pond cypress (*Taxodium ascendens*) and scattered slash pine (*Pinus elliottii*). The hardwood swamp mid-canopy vegetation included abundant wax myrtle; numerous to abundant dahoon holly; and scattered red maple (*Acer rubrum*), highbush blueberry (*Vaccinium corymbosum*) and swamp bay (*Persea palustris*). The hardwood swamp understory vegetation included abundant royal fern; numerous cinnamon fern (*Osmunda cinnamonea*); and scattered Virginia chainfern (*Woodwardia virginica*), wild taro (*Colocasia esculenta*), swamp-loosestrife, lizard’s tail, and fetter-bush.

The upper hardwood swamp (stations 220–270) vegetation was very similar to the adjacent hardwood swamp except for the aerial extent of pond cypress. Pond cypress was scattered in the upper hardwood swamp overstory and co-dominant in the hardwood swamp overstory. In addition, swamp-loosestrife was scattered in the hardwood swamp and not identified in the upper hardwood swamp (Table 5).

Landward of the upper hardwood swamp community, Transect 1 traversed a seepage slope (stations 270–300). The seepage slope vegetation included co-dominant saw palmetto (*Serenoa repens*); numerous muscadine grape (*Vitis rotundifolia*); and scattered swamp bay, bracken fern (*Pteridium sp.*), and red maple.

Landward of the seepage slope, Transect 1 terminated within a low flatwoods community. The low flatwoods had been cleared and replanted with slash pine approximately 4 years ago. Currently, the low flatwoods vegetation included co-dominant gallberry (*Ilex glabra*); abundant slash pine saplings; numerous saw palmetto; and scattered muscadine grape, broomsedge (*Andropogon virginicus*), and bracken fern. Additional plant species identified at Transect 1 are listed in Table 5.

Table 5. Gore Lake Transect 1 vegetation species list

| Common Name | Scientific Name | FWDM Code[1] | Plant Communities[2] With Plant Species Cover Estimates[3] | | | | |
|---|---|---|---|---|---|---|---|
| | | | SS | HS | UHS | SEEP | LF |
| Blackberry | *Rubus sp* | FAC | 0 | | | | |
| Black gum | *Nyssa aquatica* | OBL | | | 0 | | |
| Bracken fern | *Pteridium sp.* | FAC | | | | 1 | 1 |
| Bull arrowhead | *Sagittaria lancifolia* | OBL | 1 | | | | |
| Buttonbush | *Cephalanthus occidentalis* | OBL | 3 | | | | |
| Broomsedge | *Andropogon virginicus* | FAC | | | | 0 | 1 |
| Catbrier | *Smilax bona-nox* | FAC | 1 | | | | |
| Cinnamon fern | *Osmunda cinnamonea* | FACW | | 2 | 2 | | |
| Dahoon holly | *Ilex cassine* | OBL | 1 | 2–3 | 2–3 | | |
| Fetter-bush | *Lyonia lucida* | FACW | 1 | 1 | 1 | | |
| Gallberry | *Ilex glabra* | FACW | | | | | 4 |
| Green arum | *Peltandra virginica* | OBL | 0 | 0 | 0 | | |
| Highbush blueberry | *Vaccinium corymbosum* | FACW | | 1 | 1 | | |
| Lizard’s tail | *Saururus cernuus* | OBL | 1–2 | 1 | 1 | | |
| Muscadine grape | *Vitis rotundifolia* | FAC | | | | 2 | 1 |
| Pond cypress | *Taxodium ascendens* | OBL | | 4 | 1 | | |
| Red maple | *Acer rubrum* | FACW | 0 | 1 | 1 | 1 | |
| Royal fern | *Osmunda regalis* | OBL | 3 | 3 | 3 | | |
| Saw grass | *Cladium jamaicense* | OBL | 2 | 0 | 0 | | |
| Saw palmetto | *Serenoa repens* | UPL | | | | 4 | 2 |
| Slash pine | *Pinus elliottii* | FACW | | 1 | 1 | | 3 |
| Spoonflower | *Peltandra sagittifolia* | OBL | 0 | 0 | 0 | | |
| Swamp bay | *Persea palustris* | OBL | 0 | 1 | 1 | 1 | |
| Swamp lily | *Crinum americanum* | OBL | 2 | | | | |
| Swamp-loosestrife | *Decodon verticillatus* | OBL | 2 | 1 | | | |
| Tarflower | *Befaria racemosa* | FAC | | | | | 0 |
| Titi | *Cyrilla racemiflora* | FAC | 0 | | | | |
| Virginia chainfern | *Woodwardia virginica* | FACW | | 1 | 1 | | |
| Wax myrtle | *Myrica cerifera* | FAC | 3 | 3 | 3 | | |
| Wild taro | *Colocasia esculenta* | FACW | 0 | 1 | 1 | | |

[1] 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

[2] Plant community abbreviations:
SS = shrub swamp (stations 10–100)
HS = hardwood swamp (stations 100–220)
UHS = upper hardwood swamp (stations 220–270)
SEEP = seepage slope (stations 270–300)
LF = low flatwoods (stations 300–330)

[3] Plant species cover estimates: Aerial extent of vegetation species along transect within given community where 0 = <1% (rare); 1 = 1–10% (scattered); 2 = 11–25% (numerous); 3 = 26–50% (abundant); 4 = 51–75% (co-dominant); 5 = greater than 75% (dominant)

### Soils at Transect 1

Soils were mapped (Figure 6; SSURGO soil map) as Samsula muck within the shrub swamp, placid sand within the hardwood swamp, and Pomona sand within the upper hardwood swamp, seepage slope, and low flatwoods at Transect 1. Soils sampled at Transect 1 on July 11, 2005, varied from the SSURGO map (Figure 6) delineation presumably due to the map scale.

Beginning in the shrub swamp community at station 50, the soil was identified as Terra Ceia muck. Terra Ceia muck has a deep surface organic horizon (Table 6) and is very poorly drained. In undrained areas, the Terra Ceia soil water table is at or above the soil surface except during extended dry periods (USDA–NRCS 2005). Terra Ceia muck is in the soil taxonomic classification subgroup typic haplosaprist. The soil taxonomic classification subgroup provides additional information for each soil series and is interpreted starting at the right-hand side of the subgroup name and progressing to the left. Typic haplosaprists are histosols, which are soils that have more than one-half of the upper 32 in. dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Haplosaprists are “simple” soils with minimum horizon development. Typic conditions in a haplosaprist soil is the remaining category after the exclusion of lithic contact, limnic contact, saline environment, fluvial horizon, hemic or fibric horizons, and less than 12 in. of mineral content within the 10-in. to 40-in. control section (USDA–NRCS 2003).

Traversing landward and upslope from the shrub swamp into the hardwood swamp (Figure 8; stations 100–220), soils were sampled at stations 140, 180, and 200. Tomoka muck was identified at stations 140 and 180, while Denaud muck was identified at station 200. Tomoka series soils are organic soils with surface organic depths less deep than the Terra Ceia muck sampled in the shrub swamp. Tomoka muck is also very poorly drained, with a soil water table at or above the soil surface except during extended dry periods (USDA–NRCS 2005). Tomoka soils are in the taxonomic classification subgroup terric haplosaprists. Terric haplosaprists are histosols, which are soils that have more than one-half of the upper 32 in. dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low and water-holding capacity is very high in mucks (Carlisle and Hurt 2000). Haplosaprists are “simple” soils with minimum horizon development. Terric haplosaprists have a mineral horizon 12 in. or more thick, with its upper boundary in the control section (USDA–NRCS 2003). The control section of a soil is that part of the soil on which the classification is based and varies among different kinds of soil. The control section for a histosol is from 10 in. to 40 in. below the soil surface (USDA–NRCS 2003).

Table 6. Gore Lake Transect 1 soil descriptions

| Station | Vegetation Community | Soil Horizon | Horizon Description |
|---|---|---|---|
| 50/Terra Ceia | Shrub swamp | Oa; 0–63 in. | Muck; 10YR 3/2 |
| | | C; 63 in.+ | Fine sand; 10YR 5/1 |
| 140/ Tomoka | Hardwood swamp | Oe 0–12 in. | Muck |
| | | Oa1; 12–22 in. | Muck, N2.5 |
| | | Oa2; 22–39 in. | Muck, 10YR 2/2 |
| | | E; 39 in.+ | Fine sand, 10YR 5/3 |
| 180/ Tomoka | Hardwood swamp | Oe; 0–5 in. | Muck |
| | | Oa1; 5–10 in. | Muck, N2.5 |
| | | Oa2; 10–32 in. | Muck, 10YR 3/4 |
| | | E; 32–62 in.+ | Fine sand, 10YR 6/3 |
| 200/ Denaud | Hardwood swamp | Oa; 0–12 in. | Muck, N2.5 |
| | | E; 12–50 in.+ | Fine sand, 10YR 4/2 with 20% 10YR 5/2 |
| 250/ Samsula | Upper hardwood swamp | Oa; 0–6 in. | Muck; N2.5 |
| | | A; 6–18 in. | Coarse sand, 10yr 3/1 |
| | | Oab; 18–26 in. | Muck, N2.5 |
| | | A2; 26–30 in. | Fine sand, 10YR 3/1 with 10% 10YR 5/1 |
| | | E; 30–50 in.+ | Fine sand, 10YR 4/1 with 10% 10YR 5/2 |
| 267 | Upper hardwood swamp | Oa; 0–16 in.+ | Histosol |
| 283 | Seepage slope | Oa; 0–8 in. | Histic epipedon |
| 292 | Seepage slope | Hydric indicator | Muck present |
| 296 | Seepage slope | Hydric indicator | Mucky mineral |
| 301 | Low flatwoods | Hydric indicator | Dark surface |
| 320 | Low flatwoods | Hydric indicator | Stripped matrix at 6 in. below soil surface |
| 330/ Smyrna | Low flatwoods | Ap; 0–6 in. | Fine sand, 10YR 2/1; salt and pepper |
| | | E; 6–14 in. | Fine sand, 10YR 5/1; stripping at 7 in. |
| | | Bh1; 14–24 in. | Fine sand; possibly Ab |
| | | Bh2; 24–36 in. | Fine sand; 10YR 3/3 |
| | | Bh3; 36–52 in. | Fine sand, 10YR 2/2 |
| | | Bh4; 52–60 in.+ | Fine sand, 10YR 4/3 |

Note: in. = inches

Denaud muck, sampled at station 200 in the hardwood swamp, is a shallow organic soil with a histic epipedon (8–16-in. surface organic horizon). Denaud muck is also very poorly drained. Under natural conditions, Denaud muck is ponded for 6 to 9 months and saturated to the soil surface the rest of the time during most years (USDA–NRCS 2005). Denaud soils are in the taxonomic classification subgroup histic humaquept. Histic humaquepts are inceptisols, which are somewhat young soils that have less horizon development than ultisols or alfisols. This soil has an aquic moisture regime, which indicates the soil is saturated with water and virtually free of gaseous oxygen for sufficient periods for poor aeration to occur (Brady and Weil 1996). Histic humaquepts have an accumulation of organic matter or humus, which is 8 in. to 16 in. thick (histic).

Continuing landward at Transect 1, soils were sampled at stations 250 and 267 in the upper hardwood swamp (Figure 8; stations 220–270). Samsula muck was sampled at station 250. Similarly to the other organic soils sampled at Gore Lake, Samsula muck is very poorly drained with a soil water table at or above the soil surface except during extended dry periods (USDA–NRCS 2005). Samsula muck is in the taxonomic classification subgroup terric haplosaprist. As mentioned previously with Tomoka muck, terric haplosaprists are histosols, which are soils that have more than one-half of the upper 32 in. dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low, and water-holding capacity is very high in mucks (Carlisle and Hurt 2000). Haplosaprists are “simple” soils with minimum horizon development. Terric haplosaprists have a mineral horizon 12 in. or more thick, with its upper boundary in the control section (USDA–NRCS 2003). As mentioned previously, the control section of a soil is that part of the soil on which the classification is based and varies among different kinds of soil. The control section for a histosol is from 10 in. to 40 in. below the soil surface (USDA–NRCS 2003).

A histosol hydric soil indicator was identified at station 267 in the upper hardwood swamp (Table 6). A histosol soil has organic soil material in more than one-half of the upper 32 in. or that is of any thickness if overlying rock (JEA 2005). The soil at station 267 was not sampled to the depth necessary to determine the soil series.

Continuing upslope, soils were sampled to identify hydric soil indicators at stations 283, 292, and 296 in the seepage slope and at stations 301 and 320 in the low flatwoods. Hydric soil indicators result from repeated periods of saturation and/or inundation for more than a few days. Anaerobic microbiological activity in soils promotes the accumulation of organic matter and the reduction of iron, manganese, and sulfur, which results in characteristics that persist in the soil during wet and dry periods (Carlisle and Hurt 2000). Hydric soil indicators were observed along the transect gradient with the very wet hydric soil indicators (histic epipedon, muck presence, and mucky mineral) identified at stations 283, 292, and 296, respectively, within the seepage slope. The less wet hydric soil indicators (dark surface and stripped matrix) were identified at stations 301 and 320, respectively, in the low flatwoods (Table 6 and Figure 8). The soils at these stations were not sampled to the depth necessary to determine the soil series.

Last, Smyrna fine sand was identified at station 330 in the low flatwoods (Table 6). Smyrna fine sand is a poorly drained to very poorly drained mineral soil with a soil water table that occurs at depths of less than 18 in. below the soil surface for 1 to 4 months in most years. The soil water table is between 12 in. and 40 in. below the soil surface for more than 6 months. In the rainy season, the water table briefly rises above the soil surface, and in depressions, water stands above the surface for 6 to 9 months or more in most years (USDA–NRCS 2005). The soil taxonomic classification subgroup for Smyrna soil is aeric alaquods. Aeric alaquods are spodosols characterized by a subsurface horizon with an accumulation of organic matter and oxides of aluminum with or without iron oxides (Brady and Weil 1996). An aquic moisture regime indicates that the soils are saturated with water and virtually free of gaseous oxygen for sufficient periods for poor aeration to occur (Brady and Weil 1996). Aeric alaquods contain a light-colored albic horizon above a spodic horizon and an ochric epipedon. Aeric alaquods are alaquods that have an ochric epipedon. Ochric epipedon fails to meet the definitions of the other seven epipedons because it is too thin or too dry; has too high of a color value, or chroma; contains too little organic carbon; or is massive and hard when dry (JEA 2005).

In summary, the soils observed at Transect 1 within the shrub swamp, hardwood swamp, and upper hardwood swamp were deep organic soils, except for station 200, where the organic soil was slightly less extensive (Table 5). The organic soils at Transect 1 indicate that these wetland communities at Gore Lake are typically saturated or inundated except during droughts. In addition, the hydric soil indicators, including a histic epipedon, muck presence, mucky mineral, dark surface, and stripped matrix (Table 6), observed in the seepage slope and low flatwoods further emphasize the wet conditions typical in the wetlands and low flatwoods adjacent to Gore Lake. Groundwater discharge from the upland to the edge of the floodplain, occurring along the seepage slope, may contribute to the anaerobic soil conditions within the seepage slope and upper hardwood swamp and promote organic soil development (Lindbo and Richardson 2001). (See Transect 1 photos in Figure 9.)

## FIELD DATA TRANSECT 2

Transect 2 was also located on the southwest shore of Gore Lake (Figures 3 and 6). This transect site was established in order to characterize the shrub swamp and hardwood swamp at this location (Table 7).

### Vegetation at Transect 2

Transect 2 originated in the open water of Gore Lake, approximately 20 ft from the waterward edge of the shrub swamp. This transect traversed 165 ft. in a westerly direction through a shrub swamp, a hardwood swamp, and a seepage slope; and terminated within a low flatwoods community (Figures 10 and 11; Tables 8 and 9).

Table 7. Transect 2 location and fieldwork dates

| Latitude–Longitude (Station 0; open water) | Latitude–Longitude (Station 160; upland end) | Location and Dates of Fieldwork |
|---|---|---|
| 292727.94 – 811308.94 | 292726.617 – 811310.18 | Southwest shore of Gore Lake, June and July 2005 |

The shrub swamp (stations 20–60) vegetation included co-dominant wax myrtle; abundant royal fern; numerous bull arrowhead, buttonbush, dahoon holly, lizard’s tail, red maple, and saw grass; and scattered swamp lily, spoonflower (*Peltandra sagittifolia*), slash pine, titi (*Cyrilla racemiflora*), and blackberry (*Rubus sp.*).

Adjacent to the shrub swamp, Transect 2 traversed a hardwood swamp (stations 60–130). The overstory vegetation within the hardwood swamp included co-dominant pond cypress; numerous slash pine; and scattered black gum (*Nyssa aquatica*). The hardwood swamp mid-canopy vegetation included co-dominant wax myrtle; numerous dahoon holly; and scattered red maple. The hardwood swamp understory vegetation included numerous fetter-bush, royal fern, and Virginia chainfern; and scattered blackberry, buttonbush, lizard’s tail, spoonflower, and titi.

Adjacent and west of the hardwood swamp, Transect 2 traversed a seepage slope (stations 130–140). The seepage slope vegetation included co-dominant saw palmetto; abundant wax myrtle; numerous cinnamon fern; and scattered swamp bay, rusty lyonia (*Lyonia ferruginea*), loblolly bay (*Gordonia lasianthus*), bracken fern, and muscadine grape.

Transect 2 terminated in the same low flatwoods community as Transect 1. However, the Transect 2 endpoint occurred at a corner of the low flatwoods, where few slash pines were planted. The Transect 2 low flatwoods vegetation included abundant sand live oak (*Quercus geminata*); numerous saw palmetto and myrtle oak (*Quercus myrtifolia*); and scattered slash pine saplings, muscadine grape, goldenrod (*Solidago sp*.), fireweed (*Erechtites hieracifolia*), and dog fennel (*Eupatorium capillifolium*).

### Soils at Transect 2

Soils were mapped (Figure 6; SSURGO map) as Samsula muck within the shrub swamp and most of the hardwood swamp at Transect 2. The remainder of Transect 2 (seepage slope and low flatwoods) was mapped as Pomona sand. Soils sampled at Transect 2 on July 11, 2005, varied from the SSURGO map (Figure 6) delineation presumably due to the map scale.

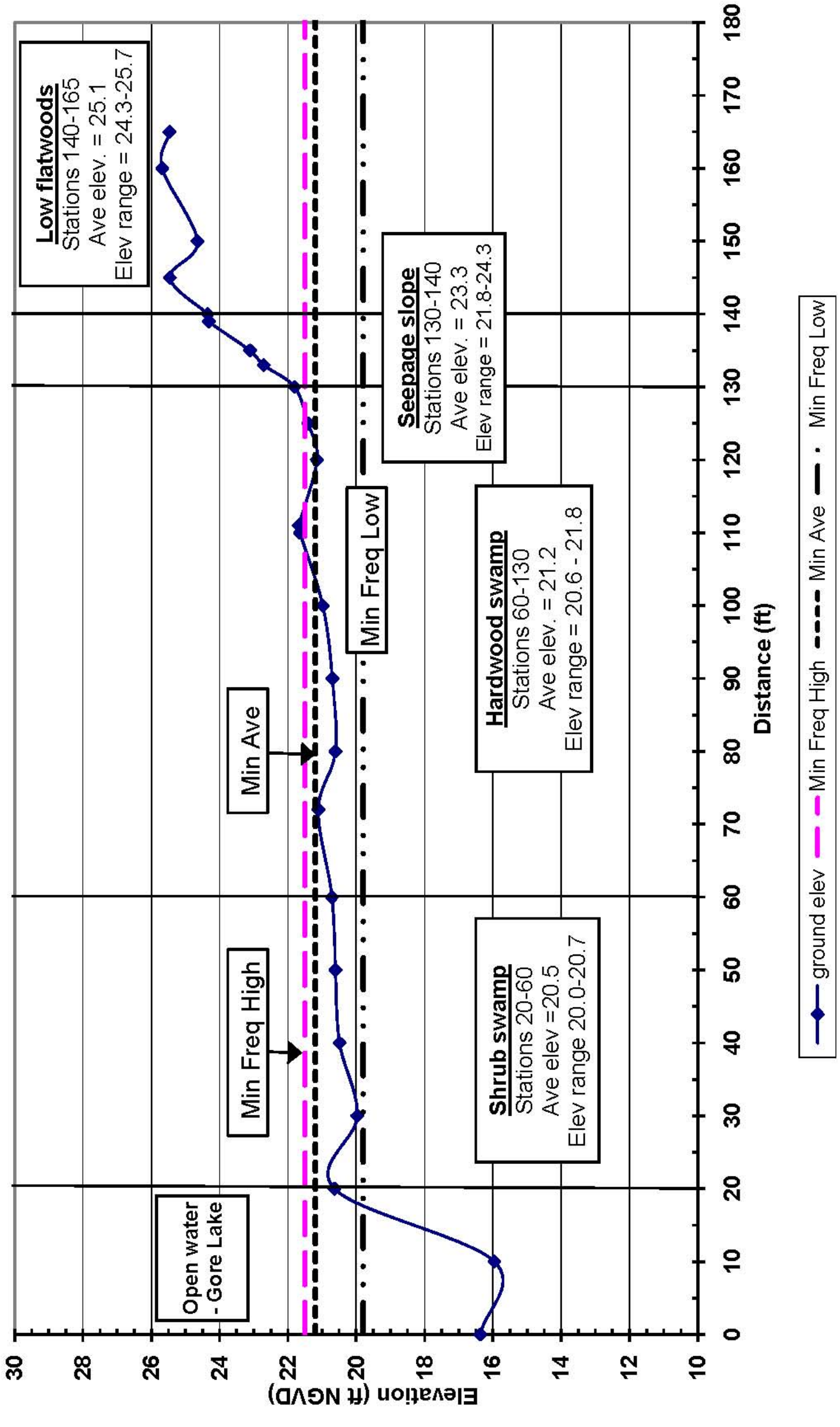

Figure 10. Gore Lake Transect 2 topography with ecological communities

Figure 11. Gore Lake Transect 2 photographs

Figure 11—*Continued*

Table 8. Gore Lake Transect 2 vegetation community elevation statistics

| Vegetation Community | Stations Distance (ft) | Mean (ft NGVD) | Median (ft NGVD) | Min (ft NGVD) | Max (ft NGVD) | N |
|---|---|---|---|---|---|---|
| Shrub swamp | 20–60 | 20.5 | 20.6 | 20.0 | 20.7 | 5 |
| Deep organic soils* | 40–111 | 21.0 | 20.8 | 20.5 | 21.7 | 8 |
| Hardwood swamp | 60–130 | 21.2 | 21.1 | 20.6 | 21.8 | 10 |
| Seepage slope | 130–140 | 23.3 | 23.1 | 21.8 | 24.3 | 5 |
| Low flatwoods | 140–165 | 25.1 | 25.5 | 24.3 | 25.7 | 5 |

*Histic epipedon or histosol sampled
ft NGVD = feet National Geodetic Vertical Datum
N = the number of elevations surveyed at each community

Table 9. Gore Lake Transect 2 vegetation species list

| Common Name | Scientific Name | FWDM Code[1] | Plant Communities[2] With Plant Species Cover Estimates[3] | | | |
|---|---|---|---|---|---|---|
| | | | SS | HS | SEEP | LF |
| Blackberry | *Rubus sp* | FAC | 1 | 1 | | |
| Black gum | *Nyssa aquatica* | OBL | | 1 | | |
| Bracken fern | *Pteridium sp.* | FAC | | | 1 | |
| Bull arrowhead | *Sagittaria lancifolia* | OBL | 2 | | | |
| Buttonbush | *Cephalanthus occidentalis* | OBL | 2 | 1 | | |
| Catbrier | *Smilax bona-nox* | FAC | 1 | 1 | | |
| Cinnamon fern | *Osmunda cinnamonea* | FACW | | | 2 | |
| Coontie | *Zamia pumila* | UPL | | | | 0 |
| Dahoon holly | *Ilex cassine* | OBL | 2 | 2 | | |
| Dog fennel | *Eupatorium capillifolium* | UPL | | | | 1 |
| Fetter-bush | *Lyonia lucida* | FACW | | 2 | | |
| Fireweed | *Erechtites hieracifolia* | FAC | | | | 1 |
| Goldenrod | *Solidago sp* | UPL | | | | 1 |
| Lizard’s tail | *Saururus cernuus* | OBL | 2 | 1 | | |
| Loblolly bay | *Gordonia lasianthus* | FACW | | | 1 | |
| Muscadine grape | *Vitis rotundifolia* | FAC | | | 1 | 1 |
| Myrtle oak | *Quercus myrtifolia* | UPL | | | | 2 |
| Pond cypress | *Taxodium ascendens* | OBL | | 4 | | |
| Red maple | *Acer rubrum* | FACW | 2 | 1 | | |
| Royal fern | *Osmunda regalis* | OBL | 3 | 2 | | |
| Rusty lyonia | *Lyonia ferruginea* | FAC | | | 1 | |
| Sand live oak | *Quercus geminata* | UPL | | | | 3 |
| Saw grass | *Cladium jamaicense* | OBL | 2 | 1 | | |
| Saw palmetto | *Serenoa repens* | UPL | | | 4 | 2 |
| Slash pine | *Pinus elliottii* | FACW | 1 | 2 | | 1 |
| Spoonflower | *Peltandra sagittifolia* | OBL | 1 | 1 | | |
| Swamp bay | *Persea palustris* | OBL | | | 1 | |
| Swamp lily | *Crinum americanum* | OBL | 1 | | | |
| Titi | *Cyrilla racemiflora* | FAC | 1 | 1 | | |
| Virginia chainfern | *Woodwardia virginica* | FACW | | 2 | | |
| Wax myrtle | *Myrica cerifera* | FAC | 4 | 4 | 3 | |

[1] 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

[2] Plant community abbreviations:
SS = shrub swamp (stations 10–100)
HS = hardwood swamp (stations 100–220)
UHS = upper hardwood swamp (stations 220–270)
SEEP = seepage slope (stations 270–300)
LF = low flatwoods (stations 300–330)

[3] Plant species cover estimates: Aerial extent of vegetation species along transect within given community where 0 = <1% (rare); 1 = 1–10% (scattered); 2 = 11–25% (numerous); 3 = 26–50% (abundant); 4 = 51–75% (co-dominant); 5 = greater than 75% (dominant)

Beginning in the shrub swamp at station 40, the soil was identified as Terra Ceia muck. Terra Ceia muck was also identified in the shrub swamp at Transect 1. As mentioned previously, Terra Ceia muck has a deep surface organic horizon (Table 8) and is very poorly drained. In undrained areas, the Terra Ceia soil water table is at or above the soil surface except during extended dry periods (USDA–NRCS 2005). Terra Ceia muck is in the soil taxonomic classification subgroup typic haplosaprist. The soil taxonomic classification subgroup provides additional information for each soil series and is interpreted starting at the right-hand side of the subgroup name and progressing to the left. Typic haplosaprists are histosols, which are soils that have more than half of the upper 32 in. dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Haplosaprists are “simple” soils with minimum horizon development. Typic conditions in a haplosaprist soil is the remaining category after the exclusion of lithic contact, limnic contact, saline environment, fluvial horizon, hemic or fibric horizons, and less than 12 in. of mineral content within the 10 in. to 40-in. control section (USDA–NRCS 2003).

Traversing landward and upslope into the hardwood swamp (Figure 10; stations 60–130), detailed soil sampling occurred at stations 80, 100, and 110. Tomoka muck was observed at the three detailed soil sampling locations in the hardwood swamp (Table 10). Tomoka muck was also observed in the hardwood swamp at Transect 1. As mentioned previously, Tomoka soils are organic soils with surface organic depths less deep than the Terra Ceia muck sampled in the shrub swamp. Tomoka muck is very poorly drained with a soil water table at or above the soil surface except during extended dry periods (USDA–NRCS 2005). Tomoka muck is in the taxonomic classification subgroup terric haplosaprists. Terric haplosaprists are histosols, which are soils that have more than one-half of the upper 32 in. dominated by organic material. Sapric soil material is muck that contains less than one-sixth recognizable fibers (after rubbing) of undecomposed plant remains. Bulk density is usually very low, and water-holding capacity is very high in mucks (Carlisle and Hurt 2000). Haplosaprists are “simple” soils with minimum horizon development. Terric haplosaprists have a mineral horizon 12 in. or more thick, with its upper boundary in the control section (USDA–NRCS 2003). The control section of a soil is that part of the soil on which the classification is based and varies among different kinds of soil. The control section for a histosol is from 10 in. to 40 in. below the soil surface (USDA–NRCS 2003).

Continuing upslope at Transect 2, soils were sampled to identify hydric soil indicators at stations 111 and 120 in the hardwood swamp and at stations 133, 135, and 139 in the seepage slope (Table 8). As mentioned previously, hydric soil indicators result from repeated periods of saturation and/or inundation for more than a few days. Anaerobic microbiological activity in soils promotes the accumulation of organic matter and the reduction of iron, manganese, and sulfur, which results in characteristics that persist in the soil during wet and dry periods (Carlisle and Hurt 2000). Hydric soil indicators histosol, muck presence, mucky mineral, dark surface, and stripped matrix were observed, with the wettest hydric soil indicator (histosol) occurring at station 111 in the hardwood swamp and the driest (stripped matrix) at station 139 at the upper edge of the seepage slope (Table 9 and Figure 10). The soils at these stations were not sampled to the depth necessary to determine the soil series.

Last, Immokalee fine sand was identified at station 165 in the low flatwoods community (Table 10). Immokalee soil series consists of poorly or very poorly drained mineral soils. The Immokalee soil water table is at depths of 6 in. to 18 in. below the soil surface for 1 to 4 months, during most years, and at depths of 18 in. to 36 in. below the soil surface for 2 to 10 months, during most years. The Immokalee soil water table is greater than 60 in. below the soil surface during the dry periods of most years. Depressional areas with Immokalee fine sand are covered with standing water for periods of 6 to 9 months or more in most years (USDA–NRCS 2005). Immokalee fine sand is in the soil taxonomic classification subgroup arenic alaquods. Arenic alaquods are spodosols, which are characterized by a subsurface horizon with an accumulation of organic matter and oxides of aluminum with or without iron oxides (Brady and Weil 1996). Arenic alaquods have an aquic moisture regime, which indicates that the soils are saturated with water and virtually free of gaseous oxygen for sufficient periods for poor aeration to occur (Brady and Weil 1996). Arenic alaquods contain a light-colored albic horizon above a spodic horizon. The “arenic” adjective indicates these soils have a sandy particle-sized class throughout a layer extending from the mineral soil surface to the top of a spodic horizon, at a depth of 30 in. to 50 in.

In summary and similarly to the soils sampled at Transect 1, the soils sampled at Transect 2 within the shrub swamp and hardwood swamp were deep organic soils, except for station 120 near the landward edge of the hardwood swamp, where only 1 in. of surface muck was identified (Table 10). The organic soils at Transect 2 indicate that these wetland communities at Gore Lake are typically saturated or inundated except during droughts. In addition, the hydric soil indicators, including mucky mineral, dark surface, and stripped matrix (Table 10), which were observed in the seepage slope, further emphasize the wet conditions typical in the wetlands adjacent to Gore Lake. As mentioned previously, groundwater discharge from the upland to the edge of the floodplain, occurring along the seepage slope, may contribute to the anaerobic soil conditions within the seepage slope and hardwood swamp and, therefore, promote organic soil development (Lindbo and Richardson 2001). Gore Lake field Transect 2 photographs are presented in Figure 11.

Table 10. Gore Lake Transect 2 soil descriptions

| Station/Soil Series | Vegetation Community | Soil Horizon | Horizon Description |
|---|---|---|---|
| 40/Terra Ceia | Shrub swamp | Oa; 0–57 in. | Muck, 10YR 2/2 |
| | | C; 57 in.+ | Fine sand, 10YR 5/2 |
| 80/Tomoka | Hardwood swamp | Oi; 0–4 in. | Duff |
| | | Oa; 0–33 in. | Muck, 10YR 3/2 |
| | | E; 33 in.+ | Fine sand 10YR 5/2 |
| 100/Tomoka | Hardwood swamp | Oi;+4–0 | Duff |
| | | Oa; 0–24 in. | Muck, 10YR 3/3 |
| | | E; 24+ | Fine sand; 10YR 5/2 |
| 110/Tomoka | Hardwood swamp | Oi; +8–0 | Duff |
| | | Oa; 0–17 in. | Muck, N2.5 |
| | | E; 17 in.+ | Fine sand, 10YR 5/3 with 5% 10YR 2/1 |
| 111 | Hardwood swamp | 17 in. muck | Histosol |
| 120 | Hardwood swamp | 1 in. muck present | Hydric soil indicator |
| 133 | Seepage slope | Mucky mineral | Hydric soil indicator |
| 135 | Seepage slope | Dark surface | Hydric soil indicator |
| 139 | Seepage slope | Stripped matrix 6 in. from soil surface | Hydric soil indicator |
| 165/ Immokalee | Low flatwoods | A; 0–2 in. | Fine sand; 10YR 5/1 |
| | | E1; 2–9 in. | Fine sand; 10YR 6/1 |
| | | E2; 9–27 in. | Fine sand; 10YR 7/1 with 20% 10YR 5/6 |
| | | E3; 27–37 in. | Fine sand; 10YR 6/2 |
| | | Bh; 37–40 in.+ | Fine sand; 10YR 3/3 |

Note:
in. = inches

Soils and vegetation community field-collected data are the principle components of each MFLs determination. Standardized procedures for setting each level using the best available information are described in the Minimum Flows and Levels Methods Manual (SJRWMD 2006). Criteria vary depending upon the level being determined (i.e., high, average, or low) and the on-site wetland community characteristics. For example, the primary high-level criterion may be the average elevation of a wetland community, which is flooded seasonally, based upon the scientific literature and hydrologic data. Additional high-level criteria may include the maximum elevation of a community, which typically floods frequently, and/or the elevation of the landward extent of hydric soil, or the landward extent of shallow (< 8 in. in depth) surface organic soil.

At Gore Lake, the primary minimum frequent high level criterion equaled the average elevation (21.1 ft NGVD) of all the hardwood swamps stations surveyed at Transects 1 and 2, including the upper hardwood swamp stations at Transect 1. In the upper hardwood swamp, 6 in. and 16 in. of surface organic soil occurred at stations 250 and 267, respectively. In addition, soil sampling indicated consistent organic soils across the hardwood swamp at Transects 1 and 2. These organic soil depths indicate that frequent and prolonged saturation or inundation is typical within the upper hardwood swamp and hardwood swamps at Transects 1 and 2. Consequently, the average elevation of all hardwood swamp stations, including the upper hardwood swamp, surveyed at Transects 1 and 2, was chosen as the primary criterion for the determination of the minimum frequent high level.

Minimum average level determination criteria typically focus on soil characteristics when extensive histosols or a histic epipedons are sampled. The Gore Lake minimum average level primary criterion was a 0.3-ft soil water table drawdown from the average ground surface elevation of the histosols and organic soils, with a histic epipedon observed at Transects 1 and 2. An appropriate minimum average water level is necessary to conserve the floodplain histosols. Low water levels for extended periods cause the oxidation of organics present in histosols, ultimately resulting in soil subsidence. A 0.3-ft soil water table drawdown below the average histosol, or histic epipedon, surface elevation has been used to protect organic soils in many MFLs determinations and was developed for the Everglades' peat soils (Stephens 1974). Studies of marshes in the Upper St. Johns River Basin (Brooks and Lowe 1984; Hall 1987) determined that this 0.3-foot depth corresponds to a water level exceeded approximately 60% of the time. Studies of the Wekiva River system found this hydrologic condition can also be expressed as the low stage occurring, on average, every 1 to 2 years, with a duration of less than or equal to 180 days (Hupalo et. al. 1994).

Minimum frequent low level criteria also typically focus on soil characteristics if extensive histosols, or a histic epipedons, are sampled. If deep (≥ 8 in.) continuous organic soils occur, the low level is based upon a 20-in. soil water table drawdown from the average surface elevation of the deep organic soils. This 20-in. drawdown criterion was based on the best available supporting information from the literature, which described a seasonally flooded marsh systems' average minimum dry-season water table depth of 15.6 in. to 26.2 in., with an average hydroperiod of 255 (± 11.1) days (ESE 1991). At Gore Lake, the primary minimum frequent low level criterion was a 20-in. organic soils water table drawdown from the average ground surface elevation of the histosols and organic soils, with histic epipedon observed at Transects 1 and 2.

## STRUCTURAL ALTERATIONS AND OTHER CHANGES

The Lake Gore drainage basin has undergone some urbanization (Figure 2). The lake's drainage basin area is approximately 634 acres. Based upon the SJRWMD 2000 land use geographic information system (GIS) coverage, the watershed contains approximately 317 acres (50%) of wetlands, 189 acres (30%) airport land with associated impervious surfaces such as runways and roads, 63 acres (10%) rangeland, 58 acres (9%) upland forest, 3 acres commercial (< 1%), and 1 acres (< 1%) low-density residential. The increased development of the basin has likely caused water levels in the lake to rise more rapidly during rainfall events, as compared to predevelopment conditions.

Lake Gore's natural outlet has also undergone improvements, although the timing of these improvements in unknown. The lake discharges to the southern wetland that is drained by a ditch that runs from west to east. Camp Dresser and McKee Inc. (CDM) estimated the invert level to be 21.0 ft NGVD, with a peak discharge of 40 cubic feet per second (cfs) at a lake stage of 23.0 ft NGVD (CDM 2004).

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

## RECOMMENDED MINIMUM LEVELS FOR GORE LAKE

### Minimum Frequent High Level (21.1 ft NGVD)

The minimum frequent high level determined for Gore Lake equals 21.1 ft NGVD, with a hydroperiod category of seasonally flooded. Seasonally flooded is defined in Chapter 40C-8, *F.A.C.*, as a hydroperiod category where surface water is typically present for extended periods (30 days or more) during the growing season, resulting in a predominance of submerged or submerged and transitional wetland species. During extended periods of normal- or above-normal rainfall, lake levels causing inundation are expected to occur several weeks to several months every 1 to 2 years (Rule 40C-8.021(15), *F.A.C.*). Based on results from a number of water bodies, SJRWMD estimates minimum frequent high level events reoccur, on average, at least once every 3 years, for 30 or more consecutive days. Modeling results for Gore Lake (CDM 2005) support the recommended minimum frequent high level and hydroperiod category of seasonally flooded, indicating that a lake level equal to or greater than 21.1 ft NGVD will occur for at least 30 continuous days, on average, once every 2 years, under the MFLs regime.

The recommended minimum frequent high level of 21.1 ft NGVD equals the average of all the ground surface elevation points surveyed in the upper hardwood swamp and hardwood swamps at Transects 1 and 2 (Table 11; Figures 8 and 10). This recommended minimum frequent high level is to ensure surface water inundation across the majority of the hardwood swamp points at Transects 1 and 2 during periods of normal- or above-normal rainfall. Monk (1968) described mixed hardwood swamps as being dominated primarily by broad-leaved deciduous species and as occurring along creeks, rivers, sloughs, and basins that are flooded seasonally. Obligate wetland plants (Tables 4 and 7) were prevalent within the upper hardwood swamp at Transect 1 and the hardwood swamps at Transects 1 and 2. The location, structure, and function of seasonally flooded wetland plant communities adjacent to Gore Lake will be protected if flooding occurs at the average elevation of all the hardwood swamps and upper hardwood swamp stations for a duration of at least 30 consecutive days in the growing season, with a return interval of at least every 2 years, as provided by the recommended minimum frequent high level of 21.1 ft NGVD.

Soil indicators of frequent inundation and/or soil saturation were observed at Gore Lake in the upper hardwood swamp, as well as the hardwood swamps, at Transects 1 and 2. These soil indicators included surface organic soil identified 14 in. and 16 in., in thickness, at stations 250 and 267 in the upper hardwood swamp at Transect 1 and 2 and 6 in., 10 in., and 12 in., in thickness, at stations 140, 180, and 200, respectively, in the hardwood swamp at Transect 1. Surface organic soil observed within the hardwood swamp at Transect 2 was 33 in., 17 in., and 1 in., in thickness, at stations 80, 110, and 120, respectively. This thickness of organic soil indicates that soil saturation and inundation occurs for extended periods within the swamps traversed at Gore Lake. Figures 8 and 10 illustrate that the recommended minimum frequent high level (21.1 ft NGVD) will provide soil inundation and/or saturation at the majority of the stations surveyed with deep organic soils at Gore Lake.

Likewise, the recommended minimum frequent high level will ensure inundation of the shrub swamps, where even thicker surface organic soils were observed (Tables 6 and 10), downslope from the hardwood swamps at Transects 1 and 2. Shrub swamps surveyed at Transects 1 and 2 will be inundated with an average water depth equal to 1.0 ft and 0.6 ft, respectively, when Gore Lake equals the recommended minimum frequent high level.

Additional natural vegetation communities upslope from the hardwood swamps traversed at Gore Lake included the seepage slopes identified as a transitional zone, immediately landward of the upper hardwood swamp at Transect 1, and the hardwood swamp at Transect 2 (Figures 8 and 10). The seepage slopes have a relatively steep topography that rises over a short distance to the low flatwoods vegetation community. Hydric soil indicators were observed within the seepage slopes at both transects. In fact, at Transect 1, histic epipedon was observed near the bottom of the seepage slope. In addition, muck was present and mucky mineral was observed near the top of the seepage slope (Table 6). Hydric soil indicators (mucky mineral, dark surface, and a stripped matrix 6 in. below the soil surface) were observed along the seepage slope at Transect 2 (Table 10). Lindbo and Richardson (2001) described groundwater discharge from upland to the edge of the floodplain, often occurring along seepage slopes, resulting in organic-rich soils at the upper edge of the floodplain. Consequently, the organic and hydric soil characteristics observed along the seepage slopes, as well as the landward extent of deep organic soil, at station 267 in the upper hardwood swamp at Transect 1 and at station 110 in the hardwood swamp at Transect 2, may be maintained by groundwater movement, as well as by surface water inundation at Gore Lake.

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Table 11. Gore Lake vegetation transects summary statistics

| Vegetation Community | Stations Distance (ft) | Mean (ft NGVD) | Median (ft NGVD) | Min (ft NGVD) | Max (ft NGVD) | N |
|---|---|---|---|---|---|---|
| Low flatwoods—Transect 2 | 140–165 | 25.1 | 25.5 | 24.3 | 25.7 | 5 |
| Low flatwoods—Transect 1 | 300–330 | 23.6 | 23.5 | 23.3 | 24.1 | 9 |
| Seepage slope—Transect 2 | 130–140 | 23.3 | 23.1 | 21.8 | 24.3 | 5 |
| Seepage slope—Transect 1 | 270–300 | 22.3 | 22.2 | 21.4 | 23.4 | 13 |
| Upper hardwood swamp—Transect 1 | 220–270 | 21.5 | 21.4 | 21.2 | 22.1 | 8 |
| Hardwood swamp—Transect 2 | 60–130 | 21.2 | 21.1 | 20.6 | 21.8 | 10 |
| All hardwood swamp points—Transects 1 and 2 | 100–270<br>60–130 | 21.1 | 21.1 | 20.0 | 22.1 | 30 |
| Hardwood and upper hardwood swamp—Transect 1 | 100–270 | 21.0 | 21.1 | 20.0 | 22.1 | 20 |
| Deep organic soils*—observed at Transect 2 | 40–111 | 21.0 | 20.8 | 20.5 | 21.7 | 8 |
| Deep organic soils—observed at Transects 1** and 2* | 50–283<br>40–111 | 20.9 | 20.8 | 19.8 | 22.1 | 33 |
| Deep organic soils**—observed at Transect 1 | 50–283 | 20.8 | 20.8 | 19.8 | 22.1 | 25 |
| Hardwood swamp—Transect 1 | 100–220 | 20.8 | 20.6 | 20.0 | 22.1 | 13 |
| Airplane/boat ramp | mid-slope | 20.6 | 20.6 | 17.1 | 22.1 | 6 |
| Shrub swamp—Transect 2 | 20–60 | 20.5 | 20.6 | 20.0 | 20.7 | 5 |
| Shrub swamp—Transect 1 | 10–100 | 20.1 | 20.2 | 19.4 | 20.6 | 10 |

*Histic epipedon or histosol sampled at Transect 2
**Histic epipedon or histosol sampled except at station 250, where 6 in. of muck was observed
ft NGVD = feet National Geodetic Vertical Datum
N = the number of elevations surveyed at each location

Additional benefits from the recommended minimum frequent high level include the greatly expanded aquatic fauna habitat when Gore Lake inundates the hardwood swamps and shrub swamps traversed at Transects 1 and 2. Interactions with the adjacent swamps by connecting the lake to the floodplain are extremely important to animal productivity in the lower coastal plain (Bain 1990; Poff, et. al. 1997). When the floodplains are flooded, many fish migrate from the lake to the inundated areas for spawning and feeding. As water levels continue to rise, the amount of vegetative structure available to aquatic organisms increases greatly as large areas of floodplain forests are inundated (Light, et. al. 1998).

In addition, lake water quality may improve significantly as water flows through the floodplain. The floodplain with its back swamp, functions as an important filter and sink for dissolved and suspended constituents (Wharton et. al. 1982).

### Minimum Average Level (20.6 ft NGVD)

The minimum average level determined for Gore Lake is 20.6 ft NGVD, with a hydroperiod category of typically saturated. Typically saturated is a hydroperiod category during which, for extended periods of the year, the water level should saturate or inundate. This results in saturated substrates for periods of one-half year or more during nonflooding periods of typical years (Chapter 40C-8, *F.A.C.*). The typically saturated hydroperiod category corresponds to a water level that may reoccur approximately every 1 to 2 years, for no longer than 6 months, during the dry season. The recommended average 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. Modeling results (CDM 2005) support the recommended minimum average level and hydroperiod category of typically saturated for Gore Lake. These model results indicate that under the MFLs regime, Gore Lake stage will equal the minimum average level for a duration of 180 days every 1.5 years, on average. Based on the aerial photography (Figure 2) and stage data analyses, it appears that Gore Lake receives nearly constant inflow from the canal to the south and/or the water body and wetlands to the north, as well as storm water from the Flagler County Airport. These inflows have caused Gore Lake to have unusually stable and high water levels in the past 10 years.

The minimum average level of 20.6 ft NGVD corresponds to a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep organic soils observed at Transects 1 and 2 (Table 11). Deep organic soils are indicative of long-term soil saturation or inundation. The 0.3 ft drawdown will ensure saturated soil conditions, thereby preventing soil oxidation in the deep organic soils observed at Gore Lake. Typically, where deep organic soils (histosol or histic epipedon) are observed, a 0.3-ft organic soil drawdown criterion is employed when determining the minimum average level. This criterion (0.3 ft below mean surface elevation of organic soils) has been used to protect muck soils in other MFL 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 this 0.3-ft depth corresponds to a water level exceeded approximately 60% of the time. Studies of the Wekiva River system found this hydrologic condition can also be expressed as the low stage occurring, on average, every 1 to 2 years with a duration of less than or equal to 180 days (Hupalo et. al. 1994).

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

Also, at the recommended minimum average level, surface water inundation in the shrub swamps at Transects 1 and 2 will average 0.1 ft and 0.5 ft in depth, respectively. Thus, the minimum average level will also prevent organic soil oxidation in the shrub swamps traversed at Transects 1 and 2 where deep (> 34 in.) organic soils were observed (Tables 6 and 10). Shallow ponding within the shrub swamps will also provide aquatic habitat for small aquatic fauna.

An additional consideration when determining the minimum average lake level at Gore Lake is the airplane/boat ramp elevation, to ensure an adequate water level for seaplane takeoffs and landings. The airplane/boat ramp is a wooden structure, approximately 20 ft in length. Midway down the ramp, the average elevation equaled 20.6 ft NGVD, while bottom-of-the-ramp average elevation equaled 17.2 ft NGVD (Table 11). Consequently, when Gore Lake is at the minimum average level (20.6 ft NGVD), water will cover the lower half of the ramp, with an average water depth equal to 3.4 ft at the ramp bottom. At the minimum average level, adequate water depths will also occur for airplane takeoffs and landings, with the average water depth equal to 7.4 ft over the majority of the open water area of Gore Lake. In the case of seaplanes, it is a point-in-time elevation that is critical, not a statistically calculated elevation.

### Minimum Frequent Low Level (19.2 ft NGVD)

The recommended minimum frequent low level for Gore Lake is 19.2 ft NGVD, with an associated hydroperiod category of semipermanently flooded. Semipermanently flooded is a hydroperiod with surface water inundation that persists in most years. In many lakes with emergent marshes, the minimum frequent low level with a hydroperiod category of semipermanently flooded is near the lower elevation that supports emergent marsh or floating vegetation and peat substrates or other highly organic hydric substrates (Chapter 40C-8, *F.A.C.*). At Gore Lake, the shrub swamps at the waterward edge of Transects 1 and 2 had a 10-ft-wide band of saw grass; otherwise emergent marsh vegetation was absent. The lowest elevation of the sawgrass band occurred at an elevation of 19.4 ft NGVD, very similar to the recommended minimum frequent low level. Based on aerial photography (Figure 2) and stage data analyses, it appears that Gore Lake receives nearly constant inflow from the canal to the south and/or the water body and wetlands to the north, as well as storm water from the Flagler County Airport. These inflows have caused Gore Lake to have unusually stable and typically high water levels for the past 10 years. These stable water levels have likely resulted in the marsh vegetation evolving into the shrub swamp community at Gore Lake.

The minimum frequent low level and hydroperiod category of semipermanently flooded typically occurs every 5 to 10 years, for several months, during moderate droughts (Chapter 40C-8, *F.A.C.*). Modeling results (CDM 2005) support the recommended minimum frequent low level and hydroperiod category of semipermanently flooded for Gore Lake, indicating a lake level equal or less than 19.2 ft NGVD will not occur more often than once every 5 years, for no longer than 120 continuous days, under the MFLs regime.

The recommended minimum frequent low level of 19.2 ft NGVD for Gore Lake equals a 20-in. soil water table drawdown from the average ground surface elevation of the deep organic soils observed at Transects 1 and 2 (Table 11). Typically, where extensive organic soils occur, the minimum frequent low level is based upon an average organic soil water table drawdown of 20 in. The 20-in. average soil water table drawdown criterion was based upon the following literature:

*South Florida Water Management District's wetlands hydroperiods study, task 2, final report* (ESE 1991)—"Seasonally flooded marsh systems had an average hydroperiod of 255 ± 11.1 days (n = 29), with an average minimum dry season depth of –53 cm ± 13.5 cm (20.9 in.; ± 5.3 in.)."

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

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

In addition, topographic features at Transects 1 and 2 likely provide groundwater seepage from the low flatwoods upslope and, thus, wetter soil water table conditions within the hardwood swamps than expected by the minimum frequent low lake surface water level. As mentioned previously, Lindbo and Richardson (2001) described groundwater discharge from the upland to the edge of the floodplain often occurring along seepage slopes, resulting in organic-rich soils at the upper edge of the floodplain. Consequently, the organic and hydric soil characteristics observed along the seepage slopes, as well as the landward extent of deep organic soil at station 267 in the upper hardwood swamp at Transect 1 and at station 110 in the hardwood swamp at Transect 2, may be maintained by groundwater movement, as well as by surface water inundation at Gore Lake.

The recommended minimum frequent low level for Gore Lake results in dewatered wetlands. This dewatering is a natural consequence of drought and has ecological benefits. Drawdown conditions enable seeds of emergent wetland plants to germinate from the seed banks of the floodplain. Seeds of many wetland plant species require exposed soils to germinate (Van der Valk 1981). Exposing the floodplain and the littoral zone of Gore Lake for suitable durations maintains the composition of emergent plant species and increases plant diversity. As mentioned previously, the relatively stable and high water levels at Gore Lake for at least the past 10 years have likely resulted in a shallow marsh community evolving into the shrub swamp.

Low water levels also allow for the decomposition and/or the compaction of flocculent organic sediments. Aerobic microbial breakdown of the sediment begins with receding water levels, which results in a release of nutrients, thereby stimulating primary production. Normally upon reflooding, conditions are improved for fish nesting and foraging since the wetland surface has consolidated, structural cover has increased, and forage resources (terrestrial and aquatic invertebrates) are abundant (Kushlan and Kushlan 1979; Merritt and Cummins 1984).

Additional considerations when determining the minimum frequent low lake level (19.2 ft NGVD) at Gore Lake included the airplane/boat ramp elevation, to ensure an adequate water level for seaplane takeoffs and landings. As mentioned previously, the airplane/boat ramp is a wooden structure, approximately 20 ft, in length. Midway down the ramp the average elevation equaled 20.6 ft NGVD, while the bottom-of-the-ramp average elevation equaled 17.2 ft NGVD (Table 11).

Consequently, when Gore Lake is at the minimum frequent low level, the average water depth will equal 2.0 ft at the ramp bottom. At the minimum frequent low level, adequate water depths will also occur for airplane takeoffs and landings, with the average water depth equal to 6.0 ft over the majority of open water area of Gore Lake.

# CONCLUSIONS AND RECOMMENDATIONS

The intent of the establishment of minimum levels for Gore Lake in Flagler County, Florida, is to protect its aquatic ecosystems from significant harm caused by the consumptive use of water. In addition, the minimum flows and levels (MFLs) provide technical support to St. Johns River Water Management District's (SJRWMD's) regional water supply planning process and the consumptive use permitting program (Chapter 40C-2, *F.A.C.*). Recent completion of a hydrologic model for Gore Lake (CDM 2005) indicated that the adopted minimum frequent high and minimum average levels for Gore Lake (Mace 1997) were barely being met under 2003 modeled hydrologic conditions. Consequently, a reevaluation of the adopted Gore Lake levels was performed. This reevaluation has resulted in the recommendation to modify the adopted MFLs for Gore Lake (Table 12), based on current SJRWMD MFLs methodology (SJRWMD 2006).

Table 12. Adopted (Mace 1997) and recommended reevaluated minimum surface water levels for Gore Lake, Flagler County

| Minimum Levels | Adopted Elevation (ft NGVD) 1929 Datum | Adopted and Recommended Hydroperiod Categories | Recommended Elevation (ft NGVD) 1929 Datum | Recommended Duration | Recommended Return Interval |
|---|---|---|---|---|---|
| Minimum frequent high level (FH) | 21.6 | Seasonally flooded | 21.1 | 30 days | 3 years |
| Minimum average level (MA) | 20.8 | Typically saturated | 20.6 | 180 days | 1.5 years |
| Minimum frequent low level (FL) | 19.8 | Semi-permanently flooded | 19.2 | 120 days | 5 years |

ft NGVD = feet National Geodetic Vertical Datum

The SJRWMD multiple MFLs methodology (SJRWMD 2006; Neubauer et al. 2008) was used to determine the minimum Gore Lake levels presented here. The recommended MFLs for Gore Lake are primarily based on the evaluation of field-collected soils, wetland communities, and topography data obtained at the two transects, together with the results of hydrological modeling (CDM 2005). Use of the best available information from the scientific literature, ecological maps, analyses of stage data, and surface water modeling, when combined with the field data collection effort, resulted in the recommended set of levels for Gore Lake.

The recommended minimum frequent high level for Gore Lake is 0.5 ft lower than the adopted minimum frequent high because a different minimum frequent high level criterion was used. The adopted minimum frequent high level at Gore Lake corresponded to the upper hardwood swamp and seepage slope ecotone elevation. The recommended minimum frequent high level corresponds to the average elevation of all hardwood swamp and upper hardwood swamp elevation points surveyed in 2005 at Transects 1 and 2. Recent surface water model results indicated that the upper hardwood swamp–seepage slope ecotone elevation represents a lake level that occurs less frequently than the minimum frequent high level, with a hydroperiod category of seasonally flooded.

The recommended minimum average level for Gore Lake is 0.2 ft lower than the adopted minimum average because a different minimum average level criterion was used. The adopted minimum average level for Gore Lake equaled the average elevation of the lower cypress swamp. The recommended minimum average level equals a 0.3-ft soil water table drawdown from the average soil surface elevation of the deep ($\geq$ 8 in. thick) organic soils observed in 2005 at Transects 1 and 2. The 0.3-ft soil water table drawdown criterion is commonly used to determine a minimum average level where deep ($\geq$ 8 in. thick) organic soils are identified (SJRWMD 2006).

The recommended minimum frequent low level for Gore Lake is 0.6 ft lower than the adopted minimum frequent low because a different minimum frequent low level criterion was used. The adopted minimum frequent low level for Gore Lake equaled a 20-in. soil water table drawdown below the average ground elevation, where the muck depth was 2 ft in thickness. Currently, a 20-in. soil water drawdown from the average ground surface elevation, where a histic epipedon (surface organic horizon 8–16 in. thick) or histosol (surface organic horizon $\geq$16 in. thick) is identified, is commonly used and was used herein as the primary minimum frequent low level criterion when deep ($\geq$ 8 in. thick) organic soils are identified (SJRWMD 2006). An additional factor resulting in the slightly changed recommended minimum frequent low level includes the fact that a professional soil scientist collected soil data at Gore Lake in 2005 as part of this reevaluation, while the services of a professional soil scientist were not used in 1997. Determining where the soil horizon grades from muck to a mucky-fine sand is best performed by a professional soil scientist. Thus, the elevations and locations of the deep organic soils vary between the 1997 and 2005 field-soil sampling efforts.

The hydrologic model for Gore Lake was calibrated for 2003 conditions. These conditions included the most recent land use information and groundwater levels consistent with 2003 regional water use (CDM 2005). Based on hydrologic model results, SJRWMD concludes that the recommended MFLs for Gore Lake are protected under 2003 conditions. To determine if changes in groundwater use allocations subsequent to 2003 would cause lake levels to fall below the recommended MFLs for Gore Lake, the existing Gore Lake hydrologic model should be run using Floridan aquifer potentiometric level declines that reflect these changes in water use allocation.

Information included in Appendix C concerning use of the hydrologic model and applicable SJRWMD regional groundwater flow model should be utilized to assess whether water levels are likely to fall below MFLs under specific water use and land use conditions.

Periodic reassessment of these levels is recommended to ensure that these levels are maintained and to prevent significant harm from occurring at Gore Lake. Reassessments will include periodic monitoring of the vegetation communities and the soil water table at the Gore Lake transects to ensure these areas are protected. In addition, stage data from Gore Lake should be analyzed periodically to ensure that there is no unexpectedly great change in the hydrologic conditions.

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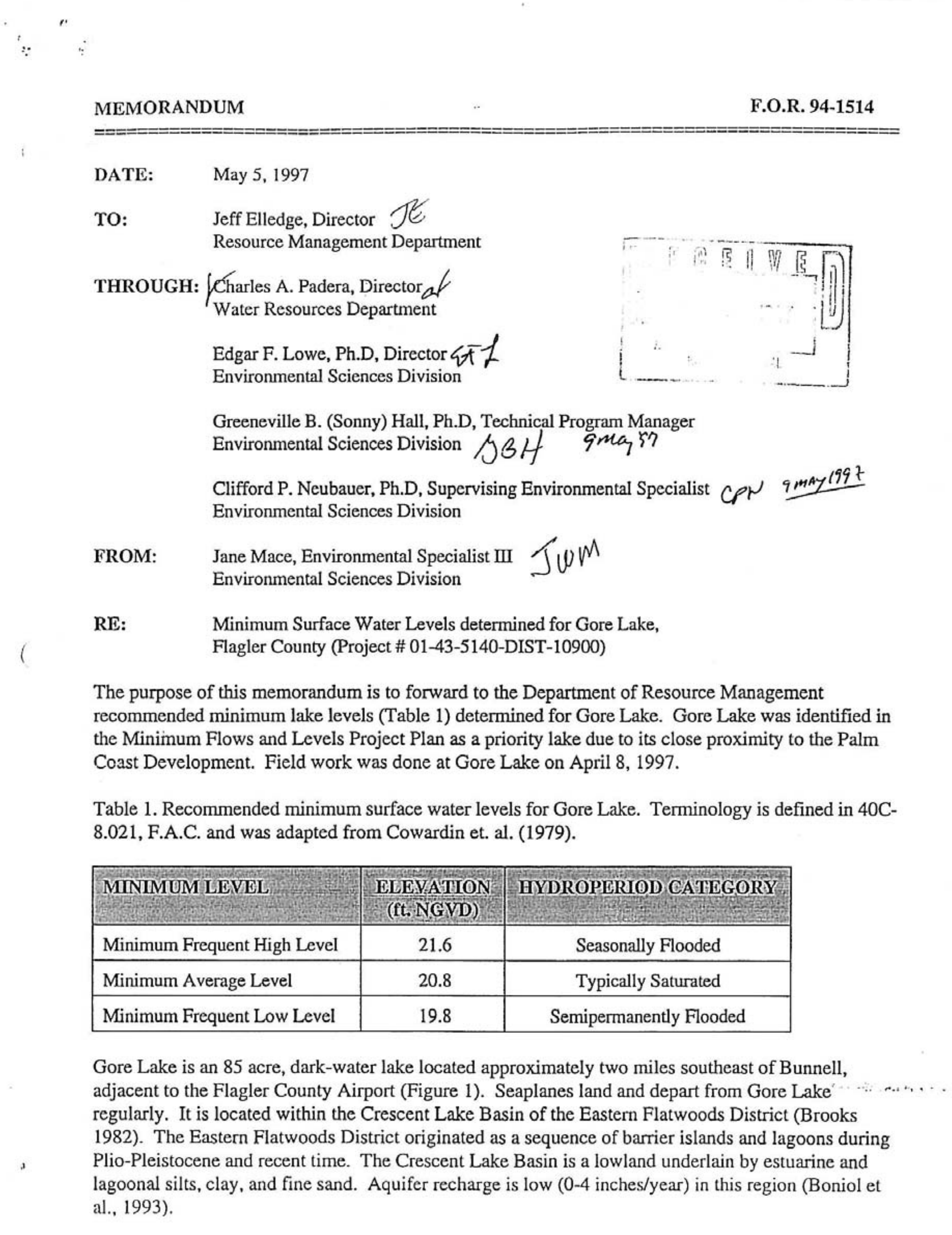
# APPENDIX A—MINIMUM SURFACE WATER LEVELS DETERMINED FOR GORE LAKE, MAY 5, 1997



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

**DATE:** May 5, 1997

**TO:** Jeff Elledge, Director JE
Resource Management Department

RECEIVED

**THROUGH:** Charles A. Padera, Director
Water Resources Department

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

Greeneville B. (Sonny) Hall, Ph.D, Technical Program Manager
Environmental Sciences Division GBH 9may 97

Clifford P. Neubauer, Ph.D, Supervising Environmental Specialist CPN 9 MAY 1997
Environmental Sciences Division

**FROM:** Jane Mace, Environmental Specialist III JWM
Environmental Sciences Division

**RE:** Minimum Surface Water Levels determined for Gore Lake,
Flagler County (Project # 01-43-5140-DIST-10900)

The purpose of this memorandum is to forward to the Department of Resource Management recommended minimum lake levels (Table 1) determined for Gore Lake. Gore Lake was identified in the Minimum Flows and Levels Project Plan as a priority lake due to its close proximity to the Palm Coast Development. Field work was done at Gore Lake on April 8, 1997.

Table 1. Recommended minimum surface water levels for Gore Lake. Terminology is defined in 40C-8.021, F.A.C. and was adapted from Cowardin et. al. (1979).

| MINIMUM LEVEL | ELEVATION (ft. NGVD) | HYDROPERIOD CATEGORY |
|---|---|---|
| Minimum Frequent High Level | 21.6 | Seasonally Flooded |
| Minimum Average Level | 20.8 | Typically Saturated |
| Minimum Frequent Low Level | 19.8 | Semipermanently Flooded |

Gore Lake is an 85 acre, dark-water lake located approximately two miles southeast of Bunnell, adjacent to the Flagler County Airport (Figure 1). Seaplanes land and depart from Gore Lake regularly. It is located within the Crescent Lake Basin of the Eastern Flatwoods District (Brooks 1982). The Eastern Flatwoods District originated as a sequence of barrier islands and lagoons during Plio-Pleistocene and recent time. The Crescent Lake Basin is a lowland underlain by estuarine and lagoonal silts, clay, and fine sand. Aquifer recharge is low (0-4 inches/year) in this region (Boniol et al., 1993).

Memo to Jeff Elledge
May 5, 1997
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## Hydrology and Basin Features

A 16 month stage record exists from December 4, 1995 to the present (Figure 2). The lake has fluctuated 1.53 feet during the period of record with the mean and median stage equal to 21.36 and 21.34 ft. NGVD, respectively.

Surface water inflows and outflows may occur via a drainage ditch parallel to the west lake shore and via a ditch perpendicular to the west shore (Figure 1). The hydraulic control elevations at these ditches are not known. The stage data indicates that the outflow control elevation occurs below the record high of 22.3 ft. NGVD based on the short duration (less than 10 consecutive days) of high (greater than 21.8 ft NGVD) water levels. Additional water inputs likely include stormwater runoff from the airport.

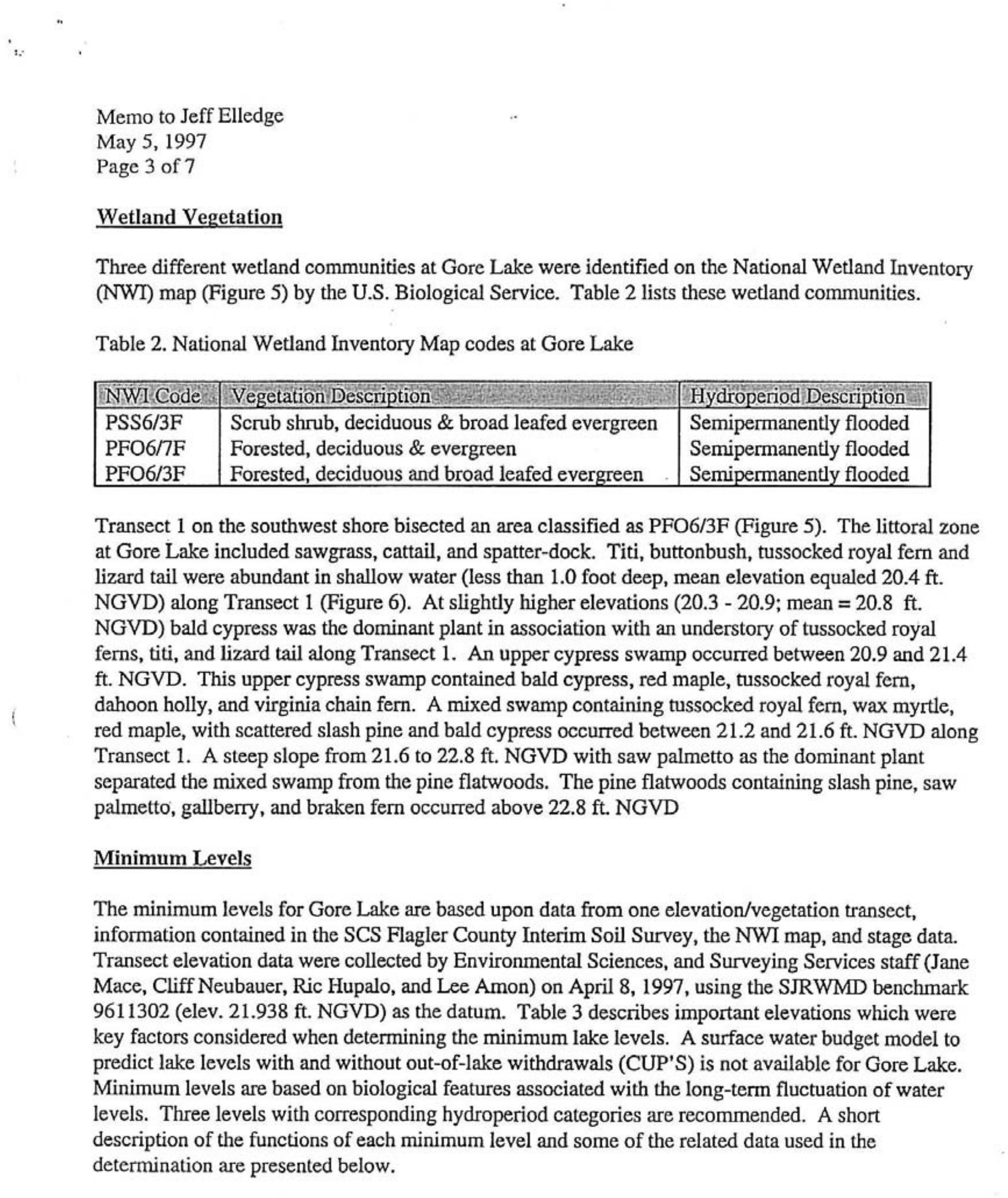
Water depths were measured at three locations near the center of Gore Lake. The average water depth was 8.5 ft (12.5 ft. NGVD). No piling docks occurred along the shore. Two adjustable floating docks exist for the seaplanes.

Three consumptive use permits (CUPs) for groundwater withdrawal occur within an approximate one mile radius of Gore Lake (Figure 3). No permitted surface water withdrawals occur from Gore Lake. The three groundwater withdrawal CUPs have a total maximum allocation of 2,890.19 million gallons per year (MGY). However, the largest allocation, 2,500.6 MGY for the Palm Coast Development, includes withdrawals from 58 wells of which only 3 reside within one mile of Gore Lake (Figure 3). A breakdown of the actual withdrawals from the wells near Gore Lake was not determined (Mary McKinney, Resource Management, 4/22/97).

## Soils

The perimeter of Gore Lake is composed entirely of the hydric soil Samsula and Hontoon, depressional (map no. 3; Figure 4, Flagler County Interim Soil Survey Report, SCS, 1993). The Samsula soil horizon is characterized by a top layer (0-31 inches) of muck with sand from 31 to 80 inches below the soil surface. The Hontoon soil horizon is comprised entirely of muck in the top 80 inches of soil (SCS, 1993). Both the Samsula and Hontoon have a high water table, zero to two feet above the soil surface, from June to April every year. Typical trees growing on this soil type include bald cypress, blackgum, white ash, loblolly bay, red maple, sweetbay, and pond pine (SCS, 1993).

The soil along Transect 1 consisted of muck to a depth greater than three feet within the elevation range of 20.0 - 21.4 ft. NGVD. The high water table at this location was near or above the soil surface with the lake level equal to 20.99 ft. NGVD on April 8, 1997. Two feet of muck was measured at an elevation of 21.4 and 21.5 ft. NGVD and 1.3 feet of muck occurred at 22.3 ft. NGVD, equal to the recorded high lake stage. Muck soil observed at 22.3 ft. NGVD is likely maintained by seepage. Above 22.3 ft. NGVD the mineral content of the soil increased, similar to a mucky sand.



Memo to Jeff Elledge
May 5, 1997
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## Wetland Vegetation

Three different wetland communities at Gore Lake were identified on the National Wetland Inventory (NWI) map (Figure 5) by the U.S. Biological Service. Table 2 lists these wetland communities.

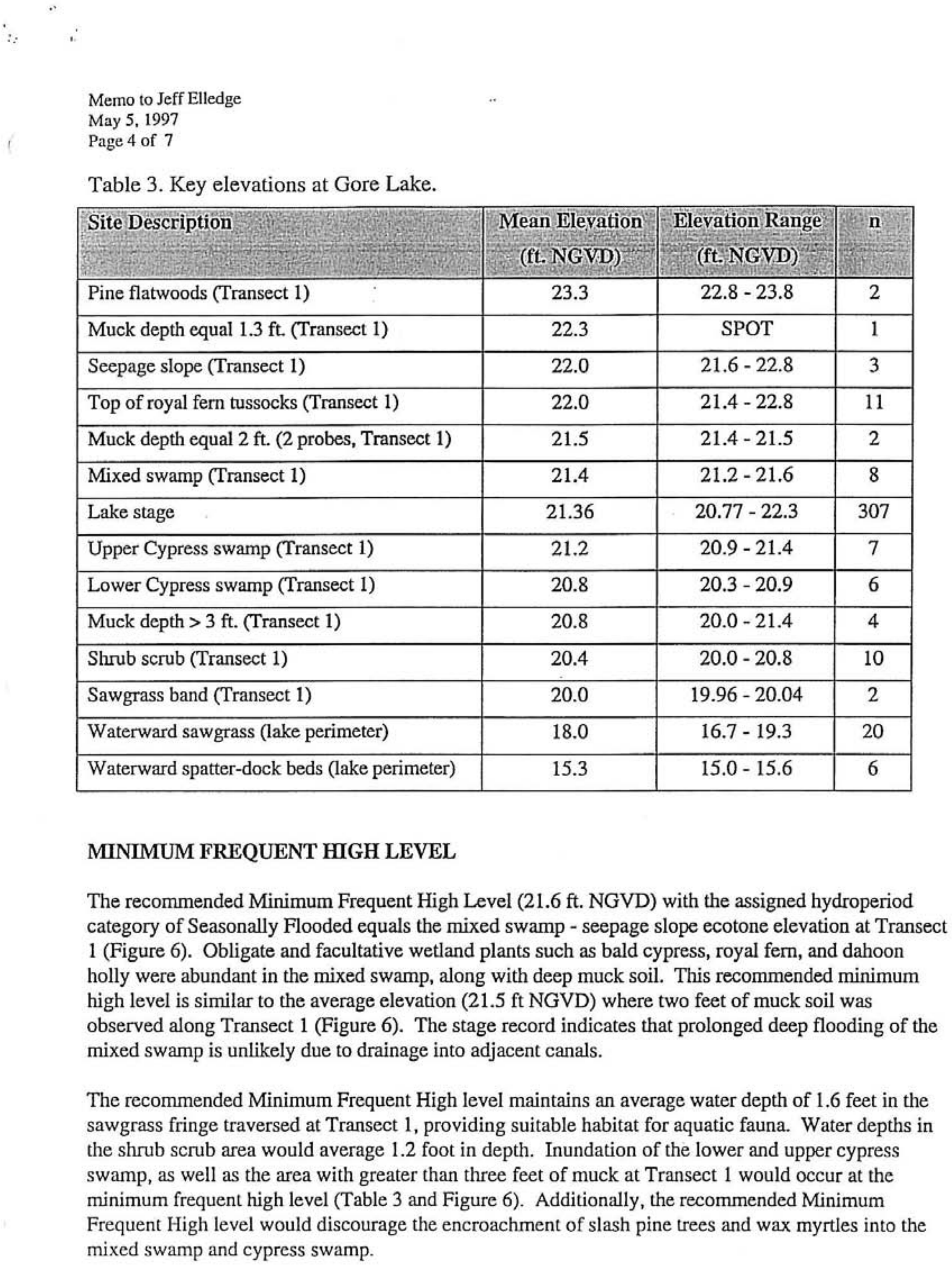
Table 2. National Wetland Inventory Map codes at Gore Lake

| NWI Code | Vegetation Description | Hydroperiod Description |
|---|---|---|
| PSS6/3F | Scrub shrub, deciduous & broad leafed evergreen | Semipermanently flooded |
| PFO6/7F | Forested, deciduous & evergreen | Semipermanently flooded |
| PFO6/3F | Forested, deciduous and broad leafed evergreen | Semipermanently flooded |

Transect 1 on the southwest shore bisected an area classified as PFO6/3F (Figure 5). The littoral zone at Gore Lake included sawgrass, cattail, and spatter-dock. Titi, buttonbush, tussocked royal fern and lizard tail were abundant in shallow water (less than 1.0 foot deep, mean elevation equaled 20.4 ft. NGVD) along Transect 1 (Figure 6). At slightly higher elevations (20.3 - 20.9; mean = 20.8 ft. NGVD) bald cypress was the dominant plant in association with an understory of tussocked royal ferns, titi, and lizard tail along Transect 1. An upper cypress swamp occurred between 20.9 and 21.4 ft. NGVD. This upper cypress swamp contained bald cypress, red maple, tussocked royal fern, dahoon holly, and virginia chain fern. A mixed swamp containing tussocked royal fern, wax myrtle, red maple, with scattered slash pine and bald cypress occurred between 21.2 and 21.6 ft. NGVD along Transect 1. A steep slope from 21.6 to 22.8 ft. NGVD with saw palmetto as the dominant plant separated the mixed swamp from the pine flatwoods. The pine flatwoods containing slash pine, saw palmetto, gallberry, and braken fern occurred above 22.8 ft. NGVD

## Minimum Levels

The minimum levels for Gore Lake are based upon data from one elevation/vegetation transect, information contained in the SCS Flagler County Interim Soil Survey, the NWI map, and stage data. Transect elevation data were collected by Environmental Sciences, and Surveying Services staff (Jane Mace, Cliff Neubauer, Ric Hupalo, and Lee Amon) on April 8, 1997, using the SJRWMD benchmark 9611302 (elev. 21.938 ft. NGVD) as the datum. Table 3 describes important elevations which were key factors considered when determining the minimum lake levels. A surface water budget model to predict lake levels with and without out-of-lake withdrawals (CUP'S) is not available for Gore Lake. Minimum levels are based on biological features associated with the long-term fluctuation of water levels. Three levels with corresponding hydroperiod categories are recommended. A short description of the functions of each minimum level and some of the related data used in the determination are presented below.



Memo to Jeff Elledge
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Table 3. Key elevations at Gore Lake.

| Site Description | Mean Elevation (ft. NGVD) | Elevation Range (ft. NGVD) | n |
|---|---|---|---|
| Pine flatwoods (Transect 1) | 23.3 | 22.8 - 23.8 | 2 |
| Muck depth equal 1.3 ft. (Transect 1) | 22.3 | SPOT | 1 |
| Seepage slope (Transect 1) | 22.0 | 21.6 - 22.8 | 3 |
| Top of royal fern tussocks (Transect 1) | 22.0 | 21.4 - 22.8 | 11 |
| Muck depth equal 2 ft. (2 probes, Transect 1) | 21.5 | 21.4 - 21.5 | 2 |
| Mixed swamp (Transect 1) | 21.4 | 21.2 - 21.6 | 8 |
| Lake stage | 21.36 | 20.77 - 22.3 | 307 |
| Upper Cypress swamp (Transect 1) | 21.2 | 20.9 - 21.4 | 7 |
| Lower Cypress swamp (Transect 1) | 20.8 | 20.3 - 20.9 | 6 |
| Muck depth > 3 ft. (Transect 1) | 20.8 | 20.0 - 21.4 | 4 |
| Shrub scrub (Transect 1) | 20.4 | 20.0 - 20.8 | 10 |
| Sawgrass band (Transect 1) | 20.0 | 19.96 - 20.04 | 2 |
| Waterward sawgrass (lake perimeter) | 18.0 | 16.7 - 19.3 | 20 |
| Waterward spatter-dock beds (lake perimeter) | 15.3 | 15.0 - 15.6 | 6 |

## MINIMUM FREQUENT HIGH LEVEL

The recommended Minimum Frequent High Level (21.6 ft. NGVD) with the assigned hydroperiod category of Seasonally Flooded equals the mixed swamp - seepage slope ecotone elevation at Transect 1 (Figure 6). Obligate and facultative wetland plants such as bald cypress, royal fern, and dahoon holly were abundant in the mixed swamp, along with deep muck soil. This recommended minimum high level is similar to the average elevation (21.5 ft NGVD) where two feet of muck soil was observed along Transect 1 (Figure 6). The stage record indicates that prolonged deep flooding of the mixed swamp is unlikely due to drainage into adjacent canals.

The recommended Minimum Frequent High level maintains an average water depth of 1.6 feet in the sawgrass fringe traversed at Transect 1, providing suitable habitat for aquatic fauna. Water depths in the shrub scrub area would average 1.2 foot in depth. Inundation of the lower and upper cypress swamp, as well as the area with greater than three feet of muck at Transect 1 would occur at the minimum frequent high level (Table 3 and Figure 6). Additionally, the recommended Minimum Frequent High level would discourage the encroachment of slash pine trees and wax myrtles into the mixed swamp and cypress swamp.

Other indicators which are more related to an Infrequent High Level are the seepage slope elevation and the pine flatwoods elevation at Transect 1 (21.6 - 22.8 and > 22.8 ft. NGVD, respectively) (Figure 6). Also noteworthy is the average elevation (22.0 ft. NGVD) of the top of the large tussocked royal ferns in the shrub scrub at Transect 1.

## MINIMUM AVERAGE LEVEL

The recommended Minimum Average Level (20.8 ft. NGVD) with the assigned hydroperiod category of Typically Saturated equals the average elevation of the lower cypress swamp at Transect 1 (Figure 6). This recommended level will provide saturated soils in the upper cypress swamp and the mixed swamp while partially inundating the muck soil in the lower cypress swamp at Transect 1. Additionally, greater than 3.0 feet of muck was found at four locations along Transect 1 where the average soil surface elevation equaled 20.8 ft. NGVD (Figure 6). The Flagler County Interim Soil Survey Report, (SCS, 1993) indicates the water table in the muck soil along Transect 1 will be at or exceed the soil surface for 6 to 9 months in a typical year. Soil saturation, as provided by the minimum average level, is necessary to prohibit oxidation and subsidence of the muck.

The recommended Minimum Average Level provides for soil saturation and inundation in the shrub scrub zone at Transect 1 with water depths ranging from 0 to 0.8 feet. Inundation of the sawgrass band at Transect 1 with water depths averaging 0.8 feet provides ideal wading bird foraging habitat at the recommended minimum average level. Great Egrets need water depths less than 0.8 feet to forage efficiently when water levels are receding (Bancroft, et. al., 1990).

## MINIMUM FREQUENT LOW LEVEL

The recommended Minimum Frequent Low Level (19.8 ft. NGVD) with the assigned hydroperiod category of Semipermanently Flooded, recognizes the benefits of low water conditions during periods of low rainfall. Occasional drawdown conditions are necessary in wetlands to stimulate decomposition and promote new vegetation growth.

The recommended Minimum Frequent Low Level is 1.7 feet below the average elevation where the muck soil depth equals 2.0 at Transect 1. SCS Soil Surveys describe the typical dry season low water table of many muck and peat soils as less than ten to twelve inches below the soil surface. A moderate drought is expected to lower the water table more than one foot, to approximately 20 inches (1.7 ft) below the soil surface.

The recommended frequent low level is similar to the average elevation (20.0 ft NGVD) of the sawgrass band at Transect 1 (Figure 6). Sawgrass germinates more successfully under saturated conditions than under inundated conditions (Ponzio, et. al, 1995). Therefore, the recommended low level will provide good to excellent conditions for sawgrass germination and survival. Water depths of 4.2 - 4.8 feet would occur in the spatter-dock measured at six different locations within the open water area of Gore Lake at the recommended low level.

Please call me (ext. 4389), Cliff Neubauer (ext. 4343), or Ric Hupalo (ext. 4338) if you wish to discuss these minimum levels or hydroperiod categories.

**Table 3. Vegetation List**

| Scientific Name | Common Name |
|---|---|
| *Acer rubrum* | Red maple |
| *Cephalanthus occidentalis* | Buttonbush |
| *Cladium jamaicense* | Sawgrass |
| *Crinum americanum* | Swamp lily |
| *Cyrilla racemiflora* | Titi |
| *Eichhornia crassipes* | Water hyacinth |
| *Ilex cassine* | Dahoon holly |
| *Ilex glabra* | Gallberry |
| *Ludwigia peruviana* | Primrose willow |
| *Lyonia lucida* | Fetterbush |
| *Mikania scandens* | Climbing hemp-weed |
| *Myrica cerifera* | Wax myrtle |
| *Nuphar luteum* | Spatter-dock |
| *Orontium aquaticum* | Golden club |
| *Osmunda cinnamomea* | Cinnamon fern |
| *Osmunda regalis* | Royal fern |
| *Panicum hemitomon.* | Maidencane |
| *Panicum repens* | Torpedo grass |
| *Persea palustris* | Swamp bay |
| *Pinus elliottii* | Slash pine |
| *Pontedaria cordata* | Pickerelweed |
| *Pteridium aquilinum* | Bracken fern |
| *Quercus laurifolia* | Laurel oak |
| *Rubus betulifolius* | Blackberry |
| *Sagittaria lancifolia* | Arrowhead |
| *Salix caroliniana* | Coastal plain willow |
| *Saururus cernus* | Lizard's tail |
| *Serenoa repens* | Saw palmetto |
| *Smilax laurifolia* | Bamboo vine |
| *Taxodium disticum* | Bald cypress |
| *Typha latifolia* | Cattail |
| *Woodwardia virginica* | Virginia chain fern |

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Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. FWS/OBS-79/31. U.S. Fish and Wildlife Service, Washington, D.C. p. 24.

Ponzio, K.J., S.J. Miller, and M.A. Lee. 1995. Germination of sawgrass, *Cladium jamaicense* Crantz, under varying hydrologic conditions. Aquatic Botany 51:115:120.

Soil Conservation Service, 1993. Interim Soil Survey Report, Maps and Interpretations, Flagler County, Florida,. United States Department of Agriculture, 155 pp.

JM:bs

Attachments

| c: | Eric Olsen | Tommy Walters | Hal Wilkening | Sandy McGee |
|---|---|---|---|---|
| | Larry Battoe | David Clapp | Ric Hupalo | MFL REG |
| | Larry Fayard | Bob Freeman | Price Robison | |

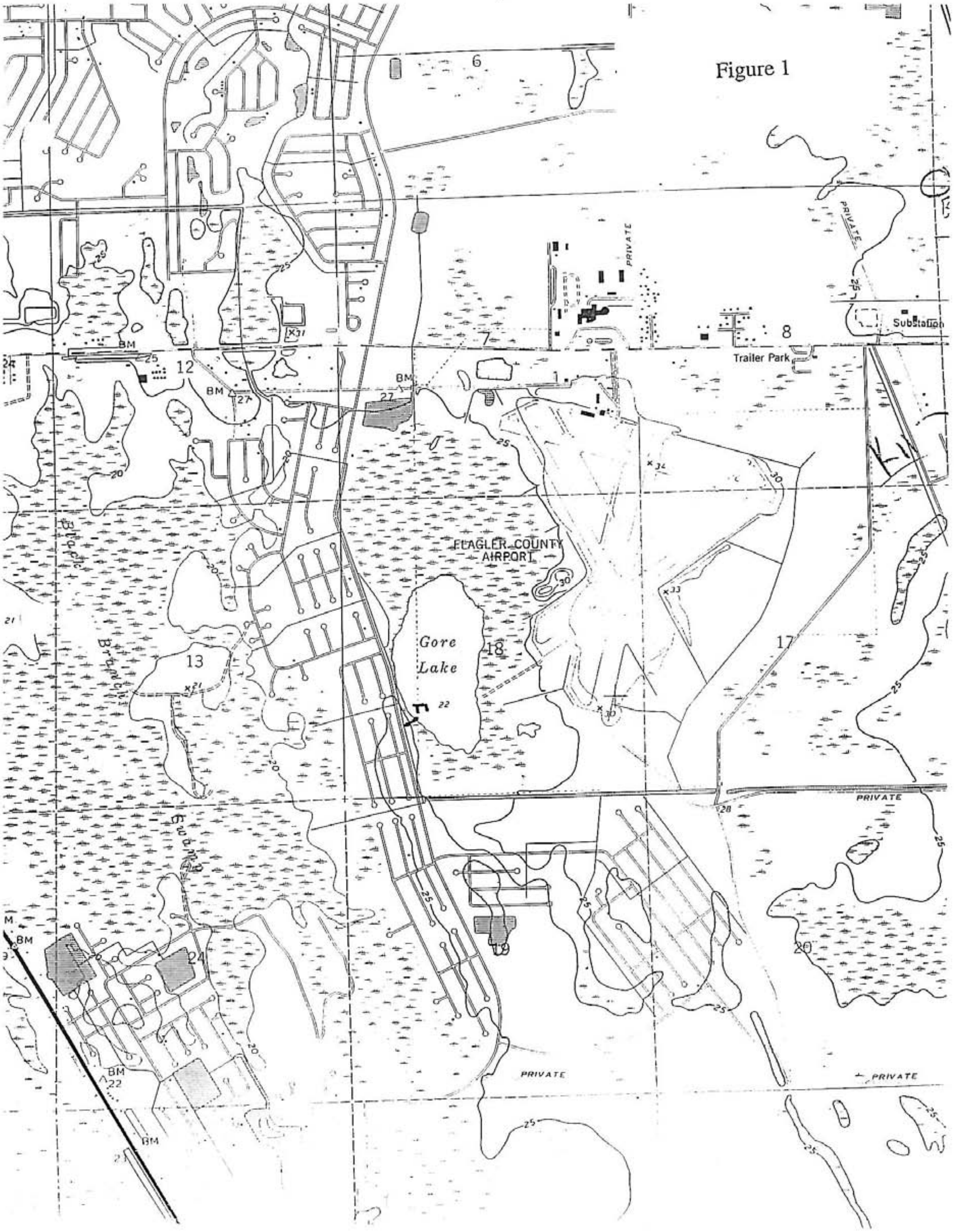
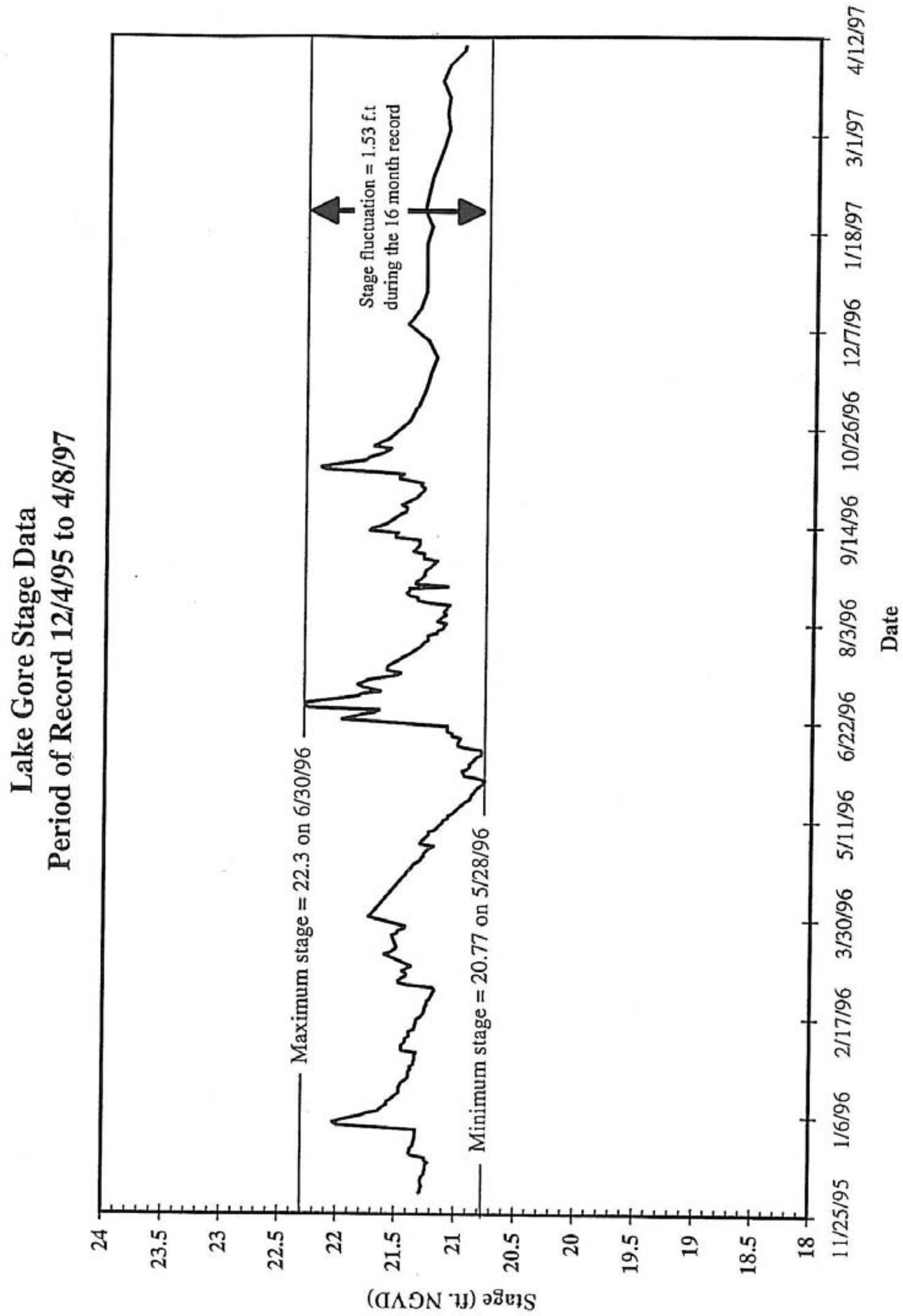


Figure 1

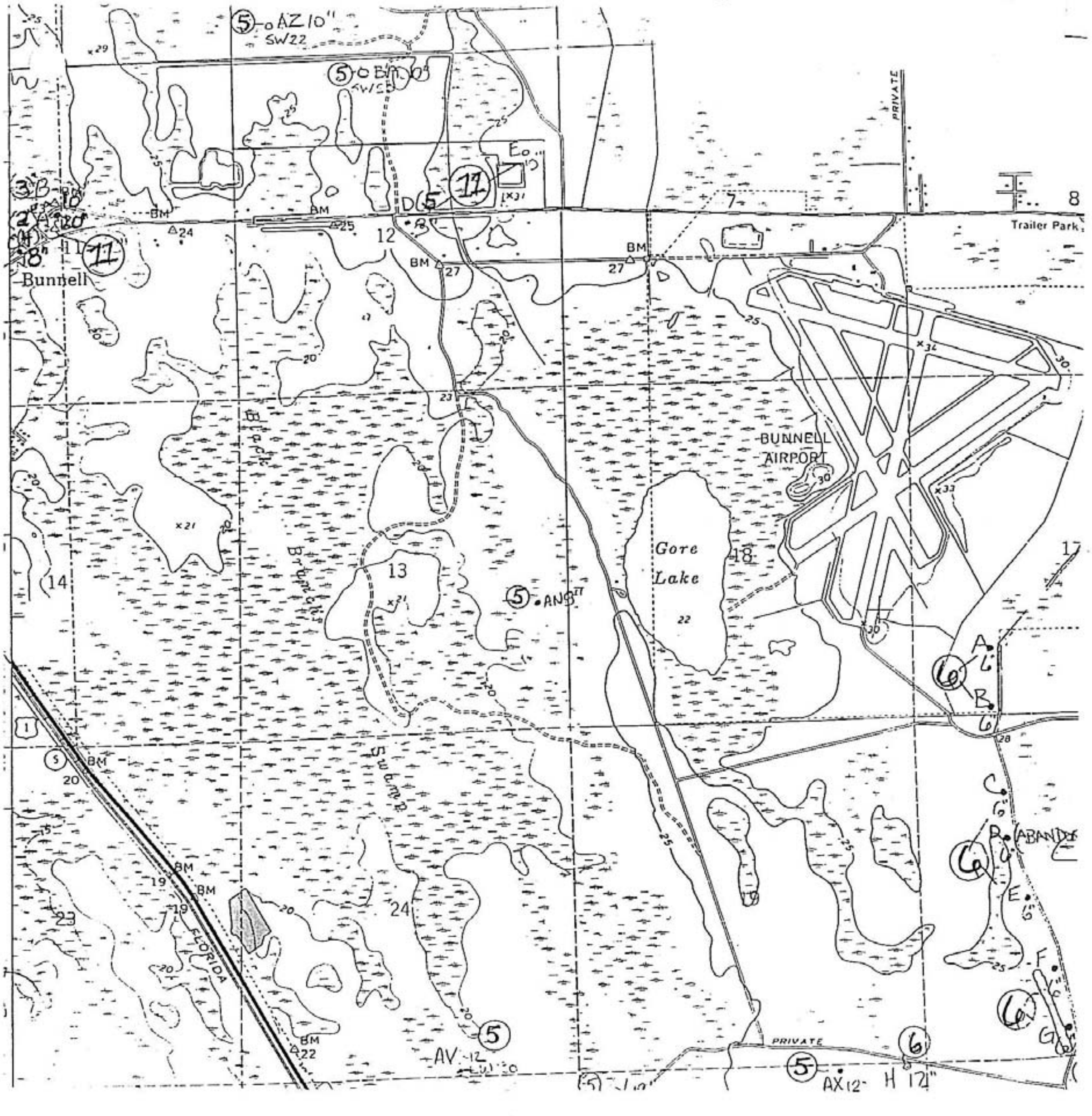
6
PRIVATE
PRIVATE
25
Substation
8
Trailer Park
7
BM
1
12
BM
27
27
×31
×34
30
25
20
FLAGLER COUNTY
AIRPORT
30
×33
Black
Branch
Gore
Lake
18
22
13
17
×21
×30
25
20
28
PRIVATE
25
Swamp
25
BM
24
19
20
25
20
BM
22
BM
PRIVATE
PRIVATE
25
25

Figure 2



GORE.XLS 5/1/97

Figure 3. CUP wells near Lake Gore



| Consumptive User | Map No. | Max. Allocation Million Gallons/Year | No. of wells in 1 mile radius | Total No. of Wells with permit |
|---|---|---|---|---|
| Palm Coast Utilities | 5 | 2500.6 | 3 | 58 |
| City of Flagler Beach | 6 | 283.0 | 6 | 8 |
| City of Bunnell | 11 | 106.59 | 2 | 5 |

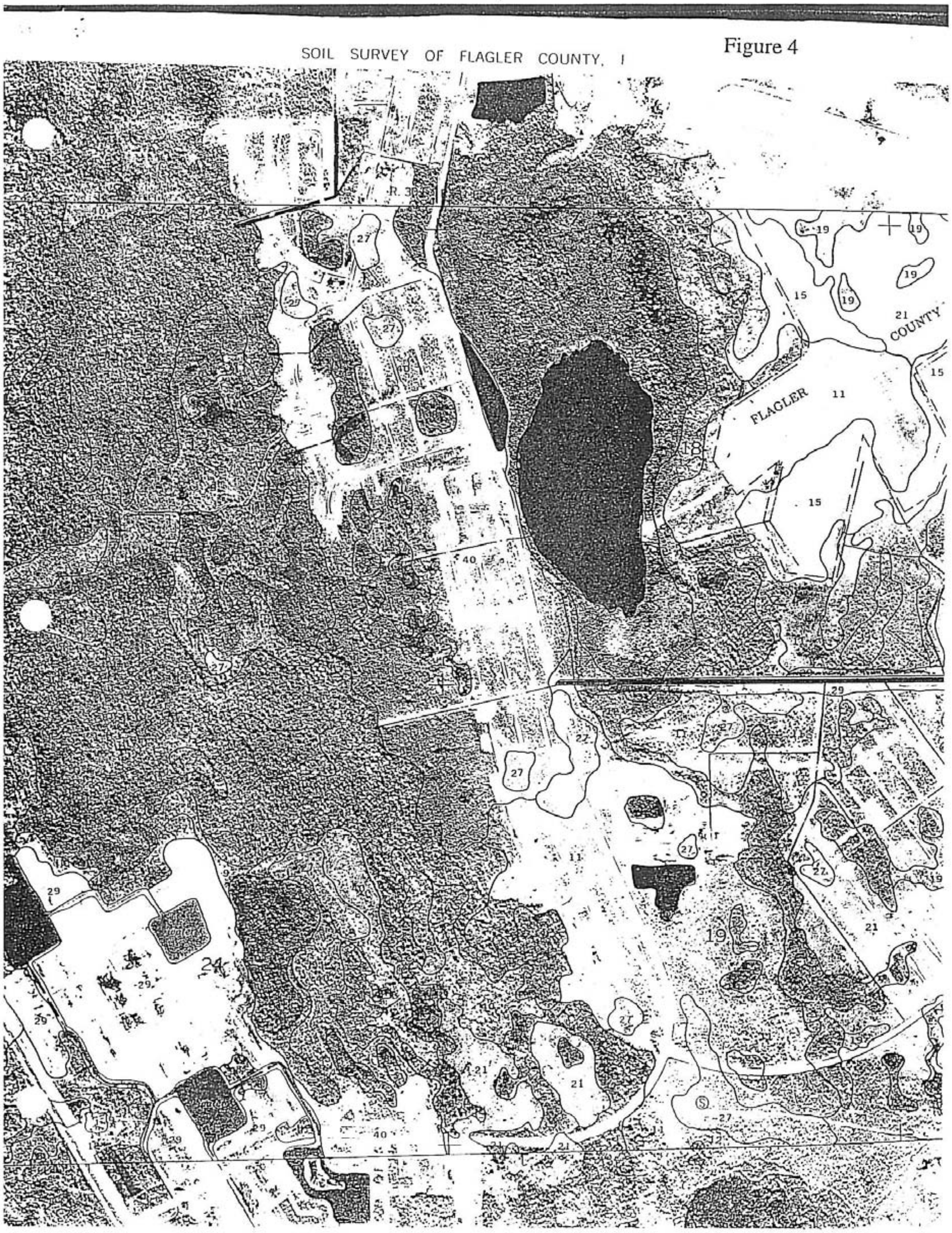
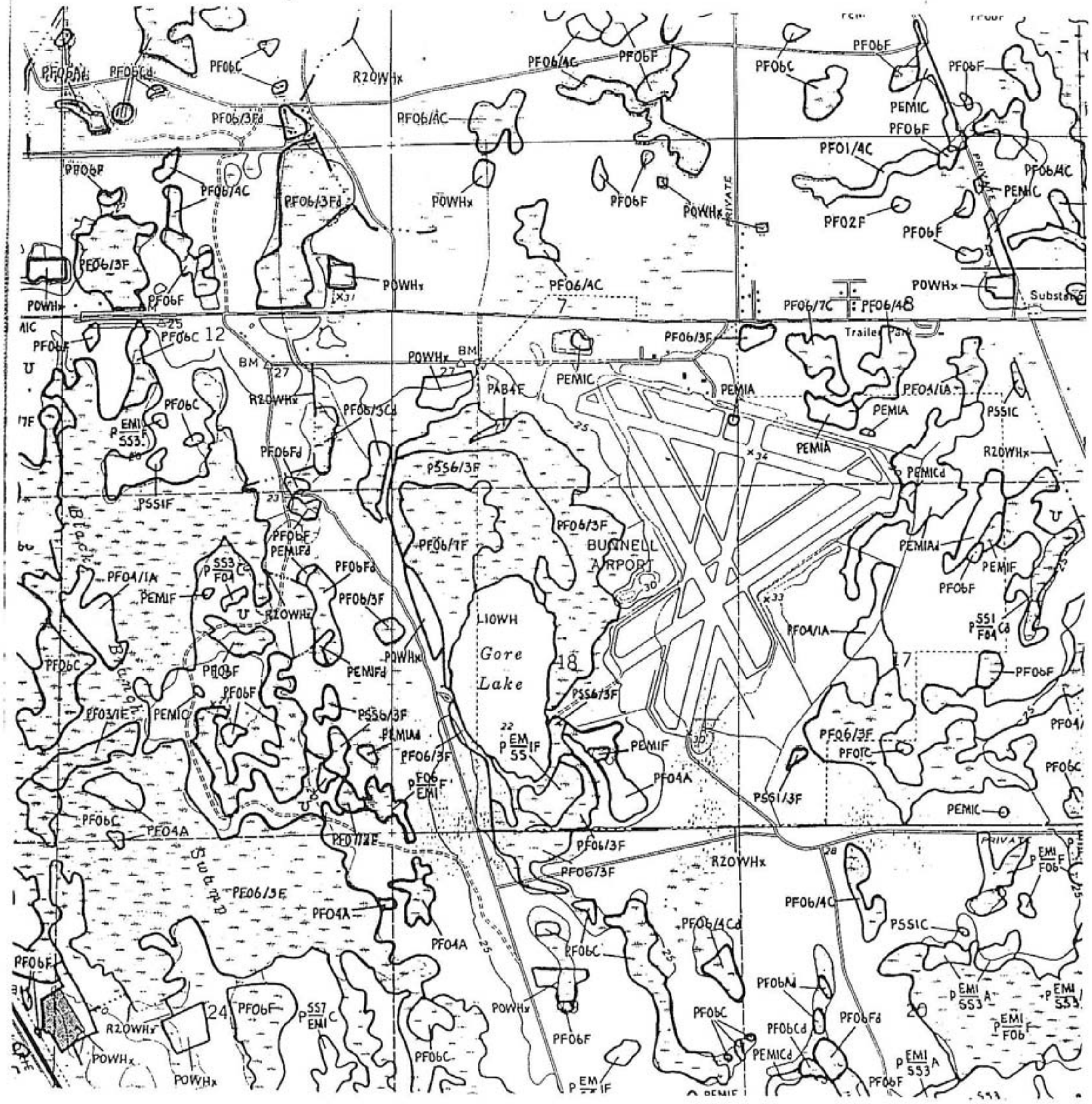

SOIL SURVEY OF FLAGLER COUNTY, F
R. 30
FLAGLER
COUNTY
11
15
19
21
27
29
24
40
18
12

Figure 4

Figure 5


PF06C
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PF06/3Fd
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PF06F
PF06/4C
PF06/3Fd
POWHx
PF06/AC
PF06C
PEMIC
PF01/4C
PF02F
PF06/4C
PEMIC
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Trailer Park
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PF06Fd
PSSIF
PF06/3F
PEMIC
PAB4F
PEMIA
PF04/IA
PSSIC
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PSS6/3F
PF06/3F
PF06/7F
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PF06Fd
PF06/3F
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Gore Lake
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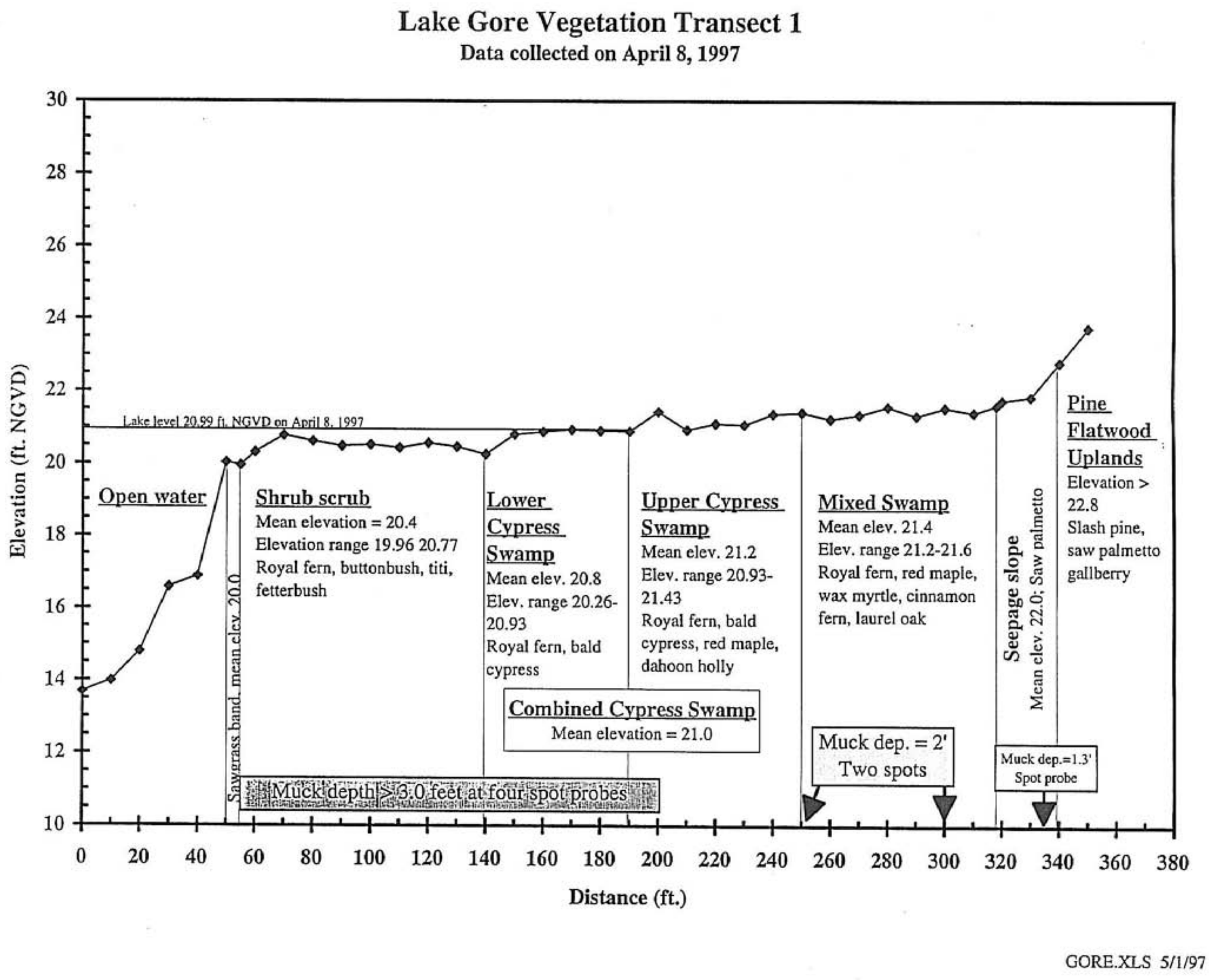
17
PF06F
PF06/3F
PF03/1E
PEMIC
PF06F
PSS6/3F
PEMIAd
PF06/3F
PSS6/3F
PEMIF
PF04A
PF06/3F
PF0TC
PSSI/3F
PEMIC
PF06C
PF04A
PF01/2E
PF06/3F
R2OWHx
PF06/4C
PRIVATE
PF06/3E
PF04A
PF04A
PF06/4Cd
PSSIC
PF06C
PF06Ad
24
PF06F
POWHx
PF06C
PF06F
PF06Cd
PF06Fd
PEMICd
20
R2OWHx
POWHx
POWHx
PF06F
Black
Swamp

Figure 6


Lake Gore Vegetation Transect 1
Data collected on April 8, 1997
Elevation (ft. NGVD)
30
28
26
24
22
20
18
16
14
12
10
Distance (ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Lake level 20.99 ft. NGVD on April 8, 1997
Open water
Sawgrass band, mean elev. 20.0
Shrub scrub
Mean elevation = 20.4
Elevation range 19.96 20.77
Royal fern, buttonbush, titi, fetterbush
Lower Cypress Swamp
Mean elev. 20.8
Elev. range 20.26-20.93
Royal fern, bald cypress
Upper Cypress Swamp
Mean elev. 21.2
Elev. range 20.93-21.43
Royal fern, bald cypress, red maple, dahoon holly
Combined Cypress Swamp
Mean elevation = 21.0
Muck depth > 3.0 feet at four spot probes
Mixed Swamp
Mean elev. 21.4
Elev. range 21.2-21.6
Royal fern, red maple, wax myrtle, cinnamon fern, laurel oak
Muck dep. = 2'
Two spots
Seepage slope
Mean elev. 22.0; Saw palmetto
Muck dep.=1.3'
Spot probe
Pine Flatwood Uplands
Elevation > 22.8
Slash pine, saw palmetto gallberry
GORE.XLS 5/1/97

# APPENDIX B—VEGETATION DATA SHEET

## Vegetation Record Data Sheet

**Date** ____________ **Transect No.** ____________
**Locality** ____________ **Transect Length (ft)** ____________
**Observers** ____________
**Notes** ____________

**Cover Estimates**

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

| V | Plant Species Name: | Plant Community Name | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | | | | | | | |
| | | Distance on Transect (ft) | | | | | | | | | |
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**Note: Estimates of percent cover are made only for plants rooted within a particular habitat**

Page ____ of _____

# APPENDIX C—IMPLEMENTATION OF MFLS FOR GORE LAKE

*Prepared by*
*C. Price Robison, P.E., St. Johns River Water Management District (2006)*

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 include the need to:

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

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

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

$$P(S \geq \hat{S}_1) = \frac{1}{n} = \frac{1}{10} = 0.1 \; ; \qquad \text{(C1)}$$

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

$$P(S \geq \hat{S}_2) = \frac{2}{10} = 0.2 \; ; \qquad \text{(C2)}$$

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

$$P(S \geq \hat{S}_{10}) = \frac{10}{10} = 1.0 \; . \qquad \text{(C3)}$$

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

$$P(S \geq \hat{S}_m) = \frac{m}{n+1} \tag{C4}$$

where

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

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

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{11} = 0.0909\;; \tag{C5}$$

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

$$P(S \geq \hat{S}_{10}) = \frac{10}{11} = 0.9091\;; \tag{C6}$$

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

$$P(S < \hat{S}_{10}) = 1 - P(S \geq \hat{S}_{10}) = 1 - \frac{10}{11} = 1 - 0.9091 = 0.0909 \tag{C7}$$

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

$$T = \frac{1}{P} \tag{C8}$$

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

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = \frac{1}{\frac{1}{11}} = 11 \tag{C9}$$

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 $n = 20$,

$$P(S \geq \hat{S}_1) = \frac{1}{n+1} = \frac{1}{21} = 0.048 \tag{C10}$$

and

$$T(\hat{S}_1) = \frac{1}{P(S \geq \hat{S}_1)} = 21 \tag{C11}$$

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 C1 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 C2 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 C3). 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, USGS Bulletin 17B (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 C4).

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 Gore 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 Gore 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 Gore Lake (CDM 2005). In particular, stages continuously exceeded (ground elevations remaining wet) for 30 days were determined, sorted, ranked, and plotted (Figure C5). 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 C6) 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 C7). Similar analyses were performed for the MA level (Figure C8) and for the FL level (Figure C9). All three levels are being met under these conditions.

A summary of the recommended MFLs for Gore Lake is shown in Table C1. Values in this table will be used as benchmarks for modeling outputs to determine if groundwater withdrawals in the vicinity of Gore Lake will cause water levels to fall below MFLs.

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

This section describes the process used by SJRWMD to determine if proposed or projected increased withdrawals of water from the Floridan aquifer in the vicinity of Gore 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 Gore Lake, at the time of preparation of this document, SJRWMD was using the Northeast Florida Regional Groundwater Flow Model (Birdie 2007) 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 C7 through C9 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 Gore Lake. In order to determine the freeboard present at Gore 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 Gore Lake. In the case of Gore Lake, for a Floridan aquifer water level drawdown of 2.9 feet (ft), the MA level would still be met (Figure C10). However, any drawdowns greater than 2.9 ft would cause water levels to fall below the established FL level. At a drawdown of 2.9 ft, the FH level (Figure C11) and the FL level would still be met (Figure C12). Therefore, future Floridan aquifer water level drawdowns beyond 2004 conditions will be limited to 2.9 ft in the Gore 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.

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

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

- A water use data set for the calibration year of the lake model is prepared and used in the applicable regional groundwater flow model. The resulting drawdowns represent drawdowns from 1995 to the calibration year of the lake model.

- 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 C1. Summary of recommended MFLs for Gore Lake

| MFLs | Level (ft NGVD) | Duration | Series | Water Year | Statistical Type | Minimum Return period | Maximum Return period |
|---|---|---|---|---|---|---|---|
| Minimum frequent high (FH) | 21.1 | 30 days | Annual | June 1–May 31 | Maximum, continuously exceeded | NA | 3 yrs |
| Minimum average (MA) | 20.6 | 180 days | Annual | Oct. 1–Sept. 30 | Minimum mean, not exceeded | 1.5 yrs | NA |
| Minimum frequent low )FL) | 19.2 | 120 days | Annual | Oct. 1–Sept. 30 | Minimum, continuously not exceeded | 5 yrs | NA |

ft NGVD = feet National Geodetic Vertical Datum
NA = not applicable
MFLs = minimum flows and levels

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Linsley, R.K., M.A. Kohler, and J.L.H. Paulhus. 1982. *Hydrology for Engineers*. 3d ed. New York: McGraw-Hill.

Ponce, V.M. 1989. *Engineering Hydrology: Principles and Practices*. Englewood Cliffs, N.J.: Prentice Hall.

[USGS] U.S. Geological Survey. 1982. *Guidelines for Determining Flood Flow Frequency*. Bulletin 17B. Reston, Va.: Interagency Advisory Committee on Water Data.

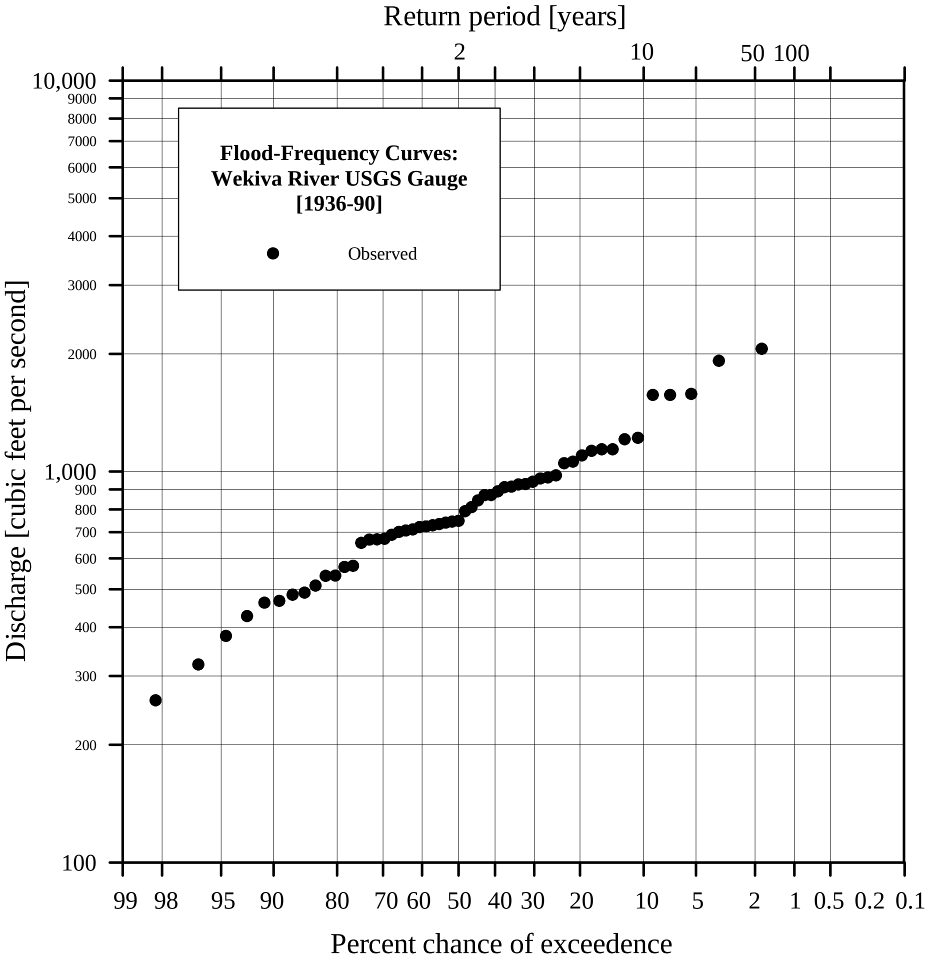

Figure C1. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla.; the 1-day peak flows have been sorted, ranked, and plotted according to the Weibull plotting position formula

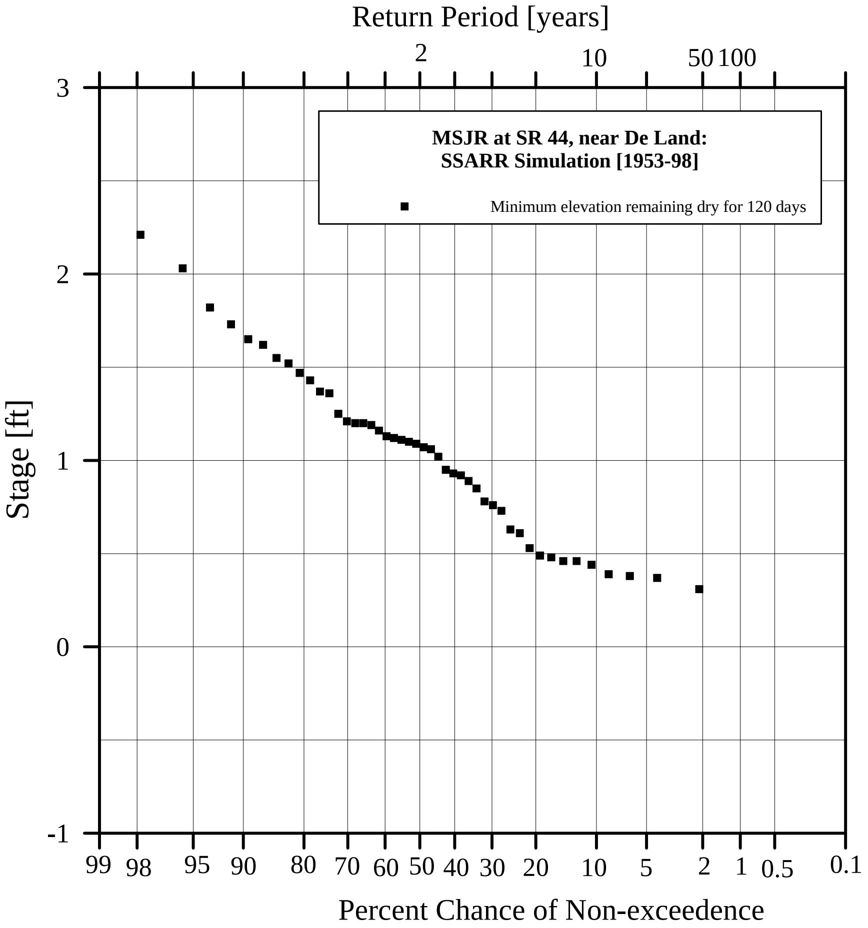

Figure C2. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand; the minimum stages continuously not exceeded for 120 days have been sorted, ranked, and plotted according to the Weibull plotting position formula

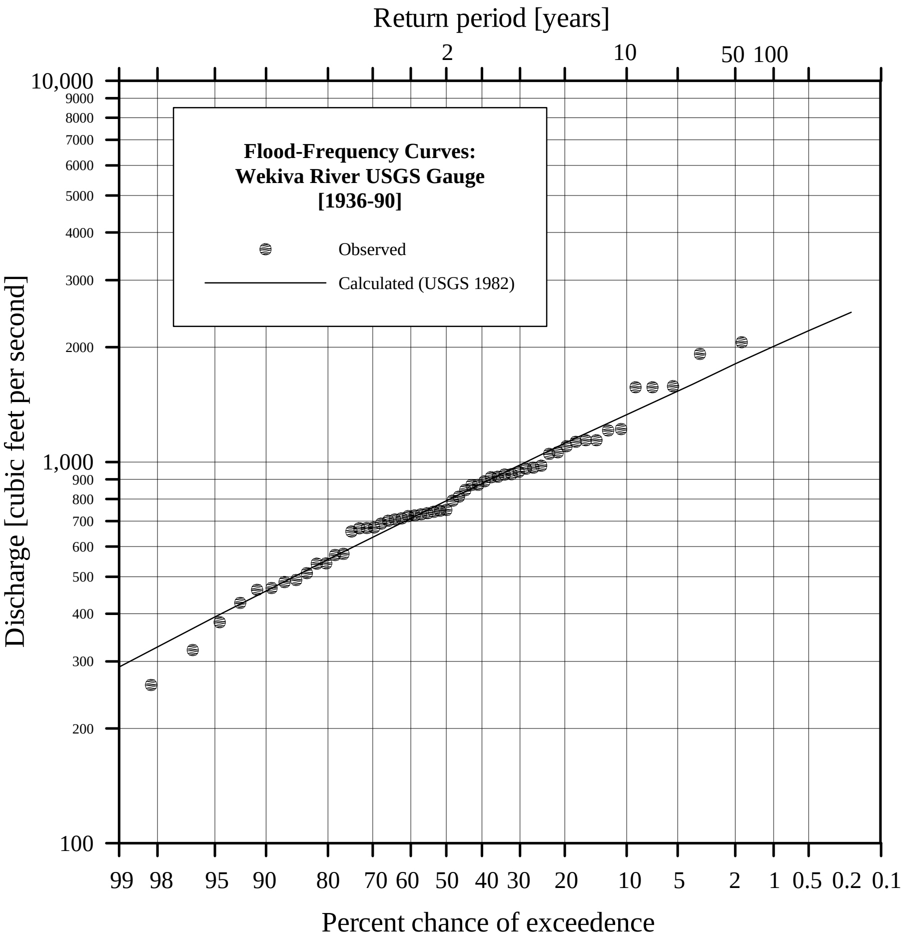

Figure C3. Flood frequencies for the Wekiva River at the USGS gauge near Sanford, Fla., fitted by standard mathematical procedure

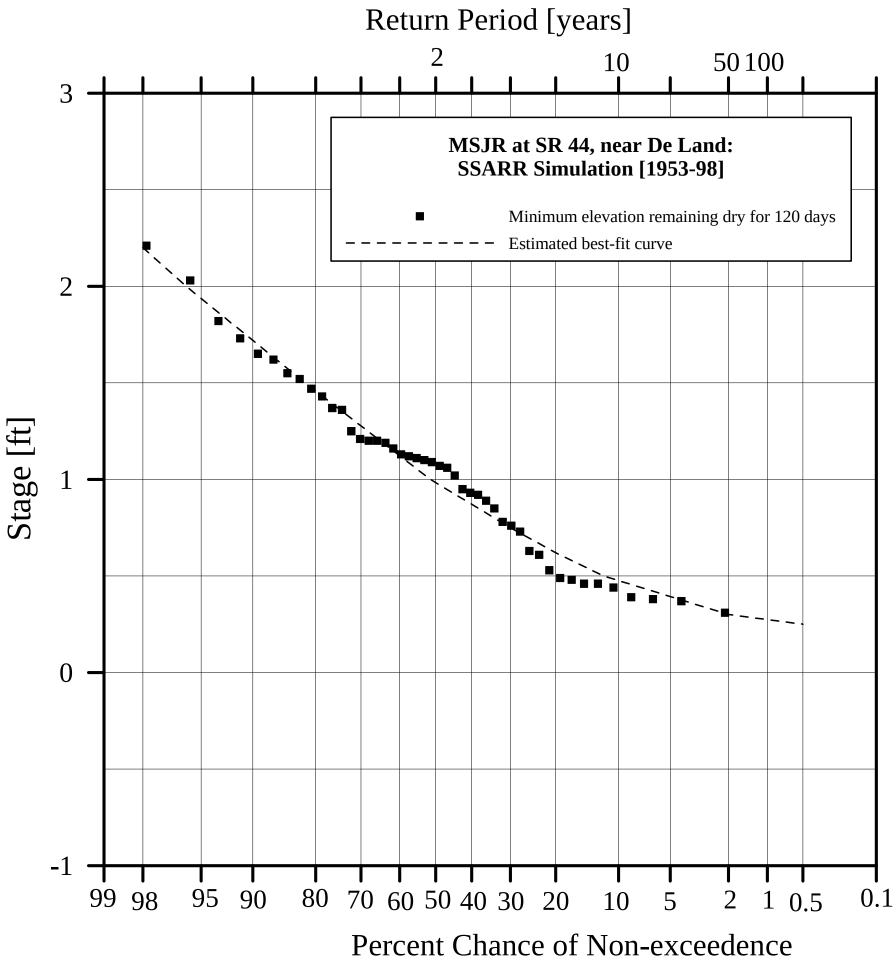

Figure C4. Drought frequencies computed using daily stages simulated by the MSJR SSARR model at SR 44, near DeLand, fitted by the graphical method

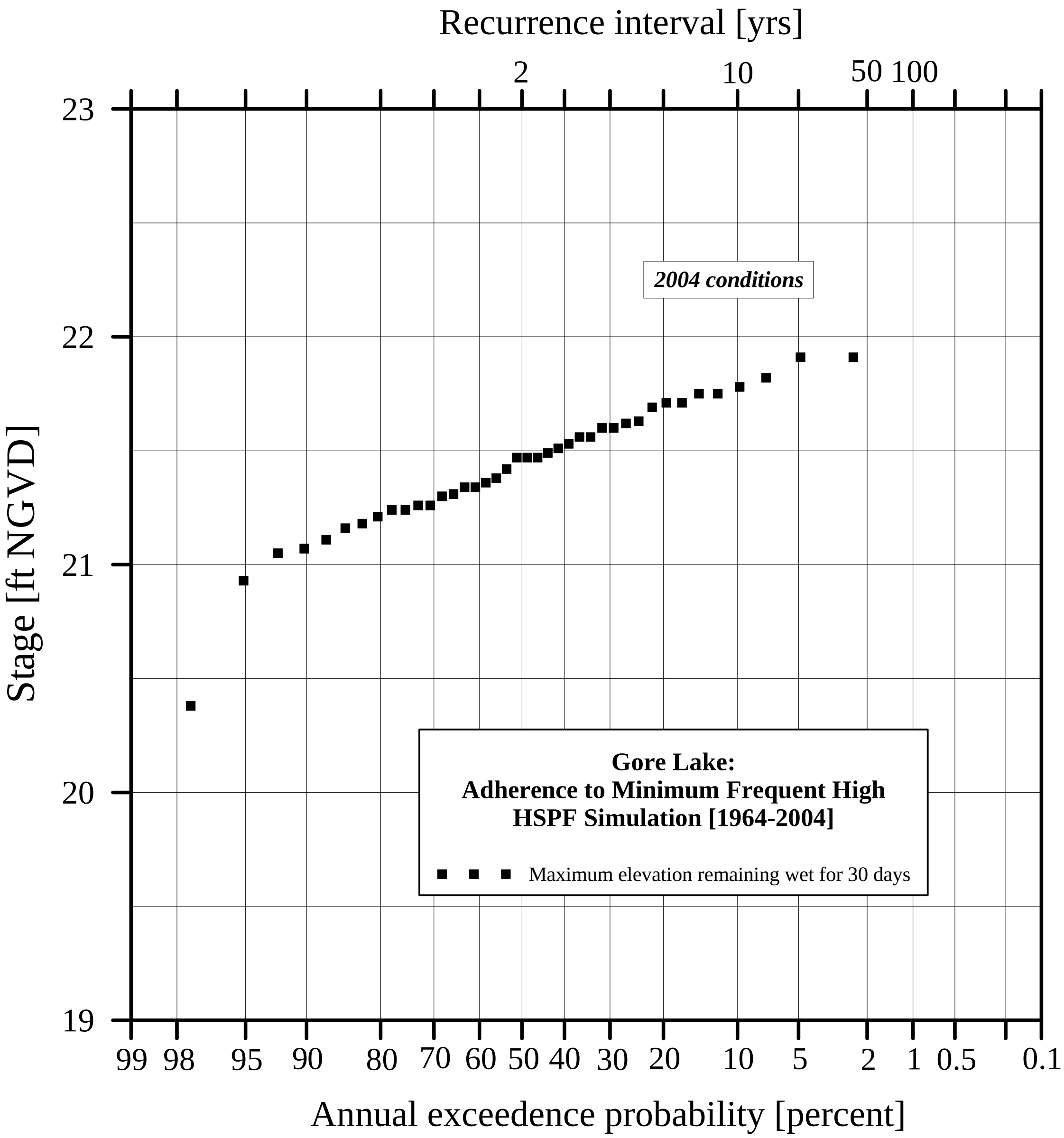

Figure C5. Flood frequencies computed using daily stages from model simulations of Gore Lake, for elevations continuously wet for 30 days and 2004 conditions

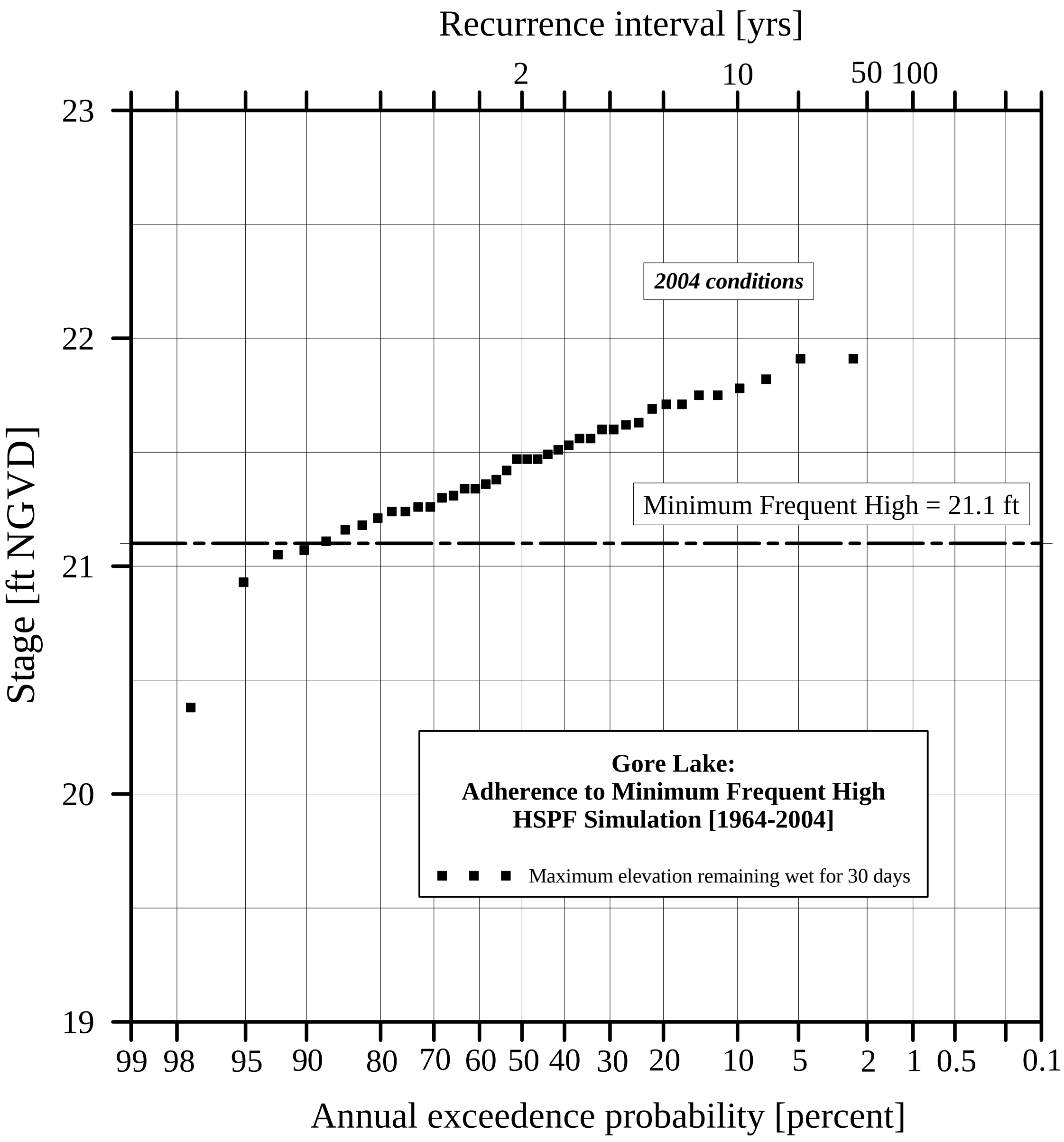

Figure C6. Flood frequencies computed using daily stages from model simulations of Gore Lake, for elevations continuously wet for 30 days and 2004 conditions, with the FH of 21.1 ft NGVD superimposed

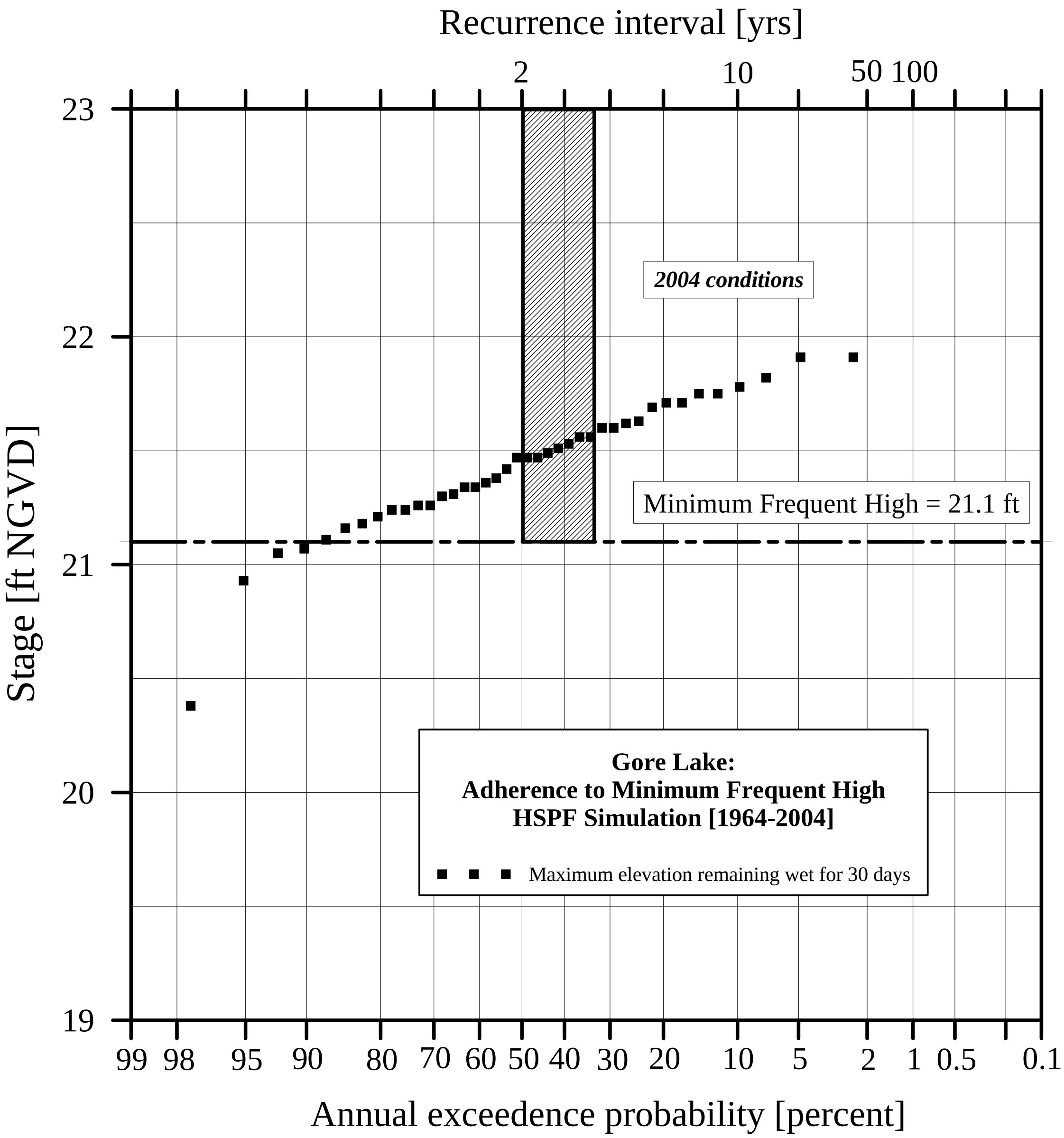

Figure C7. Flood frequencies computed using daily stages from model simulations of Gore Lake, for elevations continuously wet for 30 days and 2004 conditions with a superimposed box bounded by: (1) the FH; (2) a vertical line corresponding to a return period of 2 years; and (3) a vertical line corresponding to a return period of 3 years

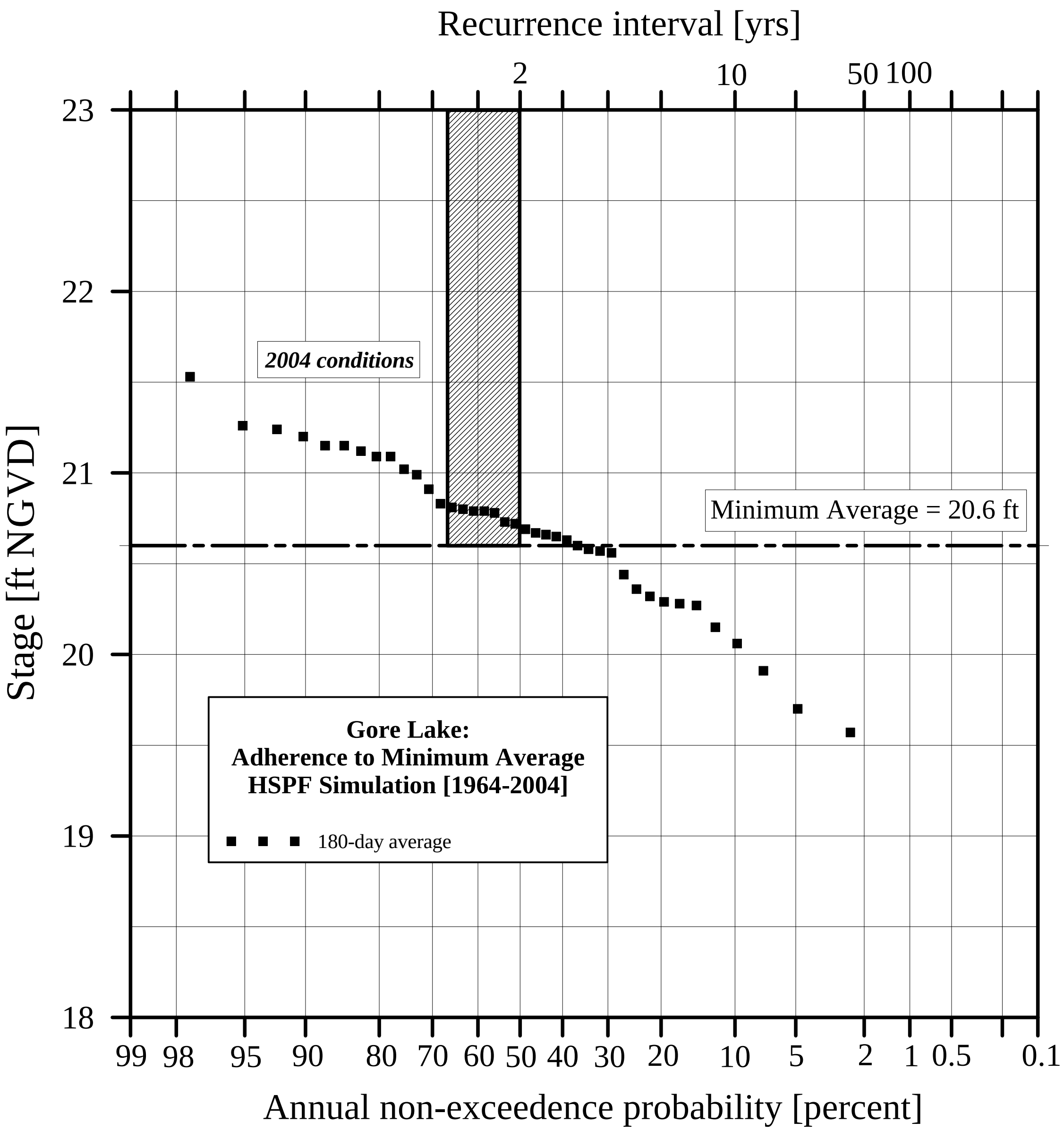

Figure C8. Drought frequencies computed using daily stages from model simulations of Gore Lake, for the MA level and 2004 conditions

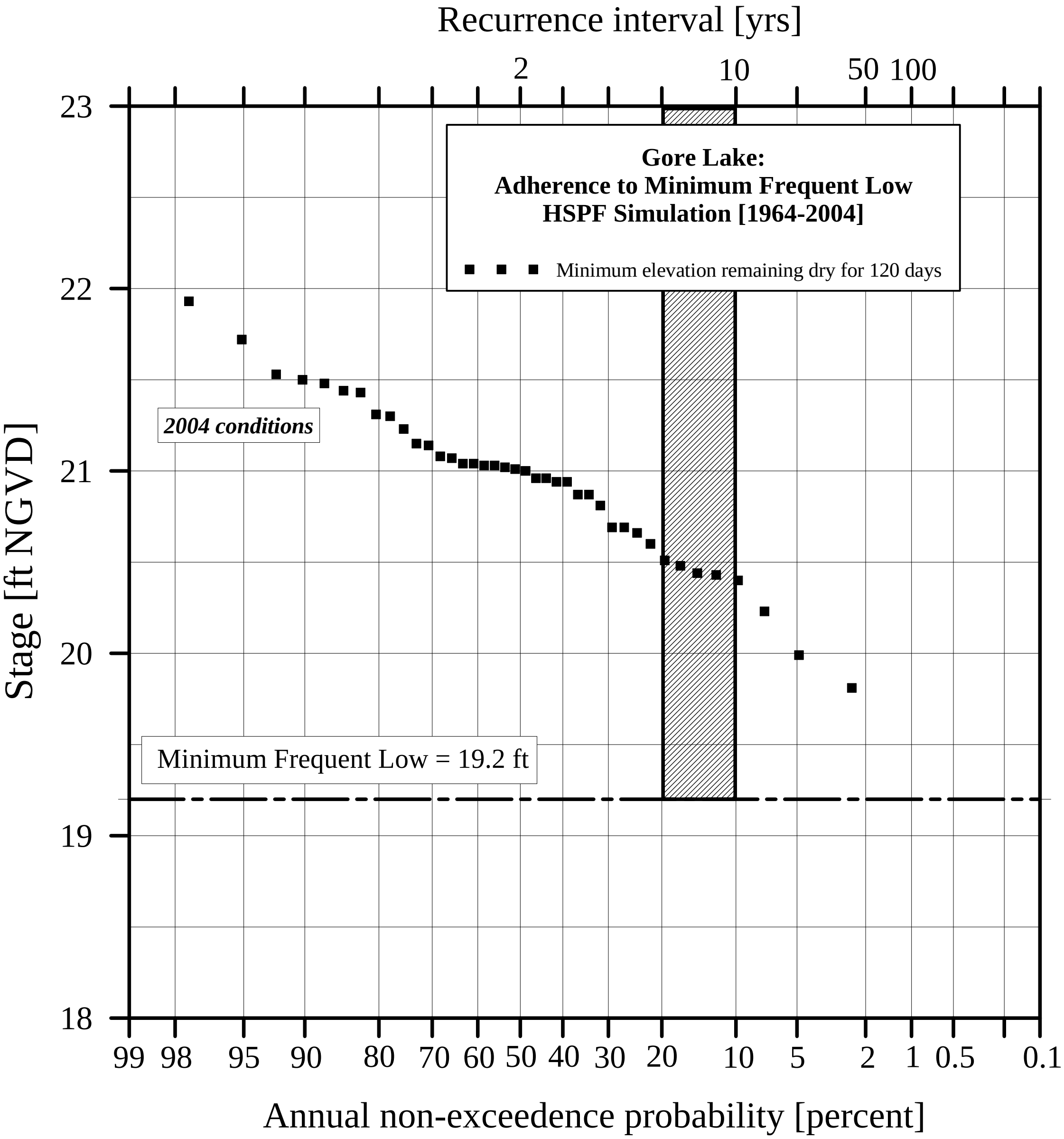

Figure C9. Drought frequencies computed using daily stages from model simulations of Gore Lake, for the FL level and 2004 conditions

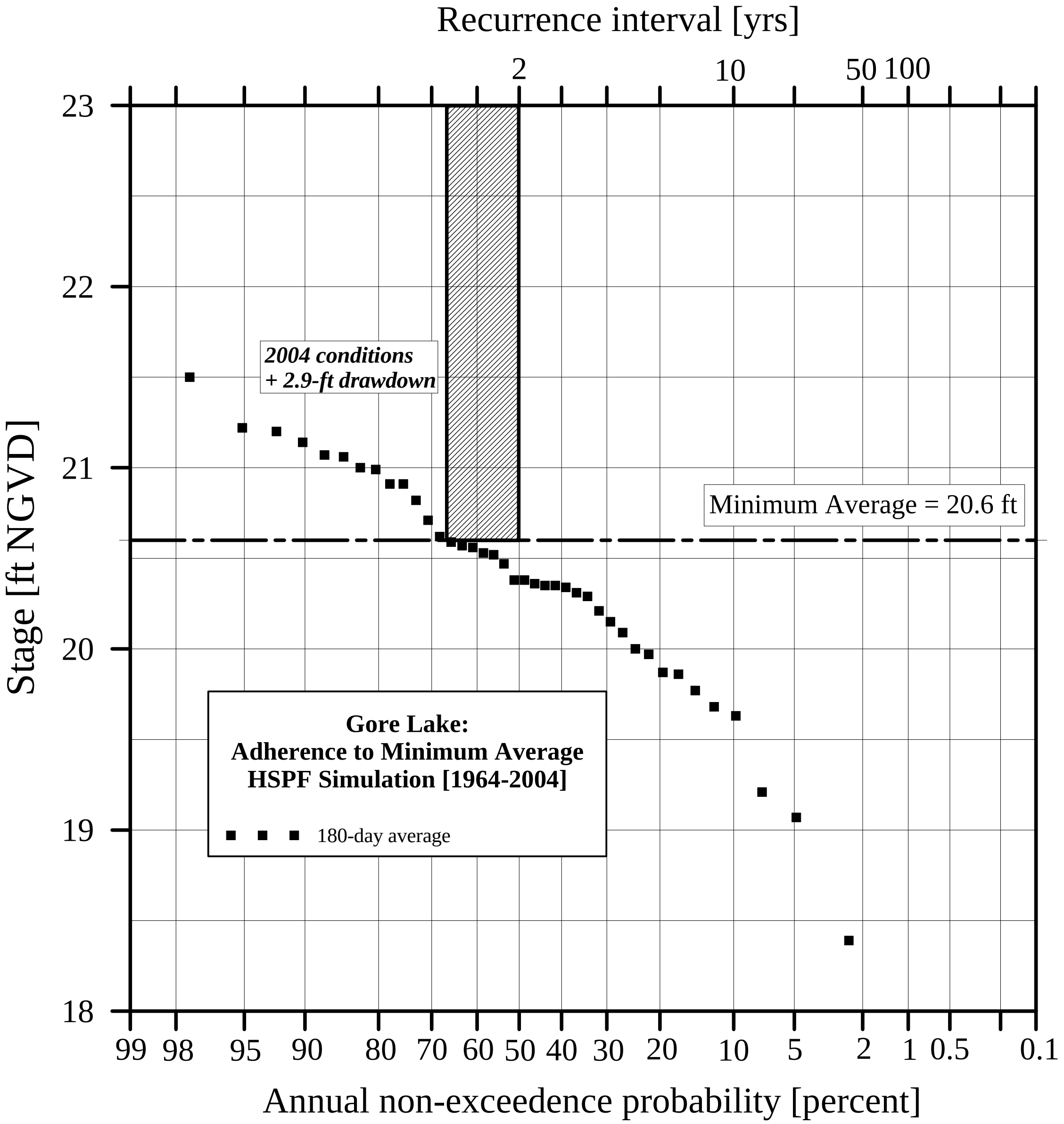

Figure C10. Drought frequencies computed using daily stages from model simulations of Gore Lake, for the MA level and 2004 conditions plus a 2.9-ft Floridan aquifer drawdown

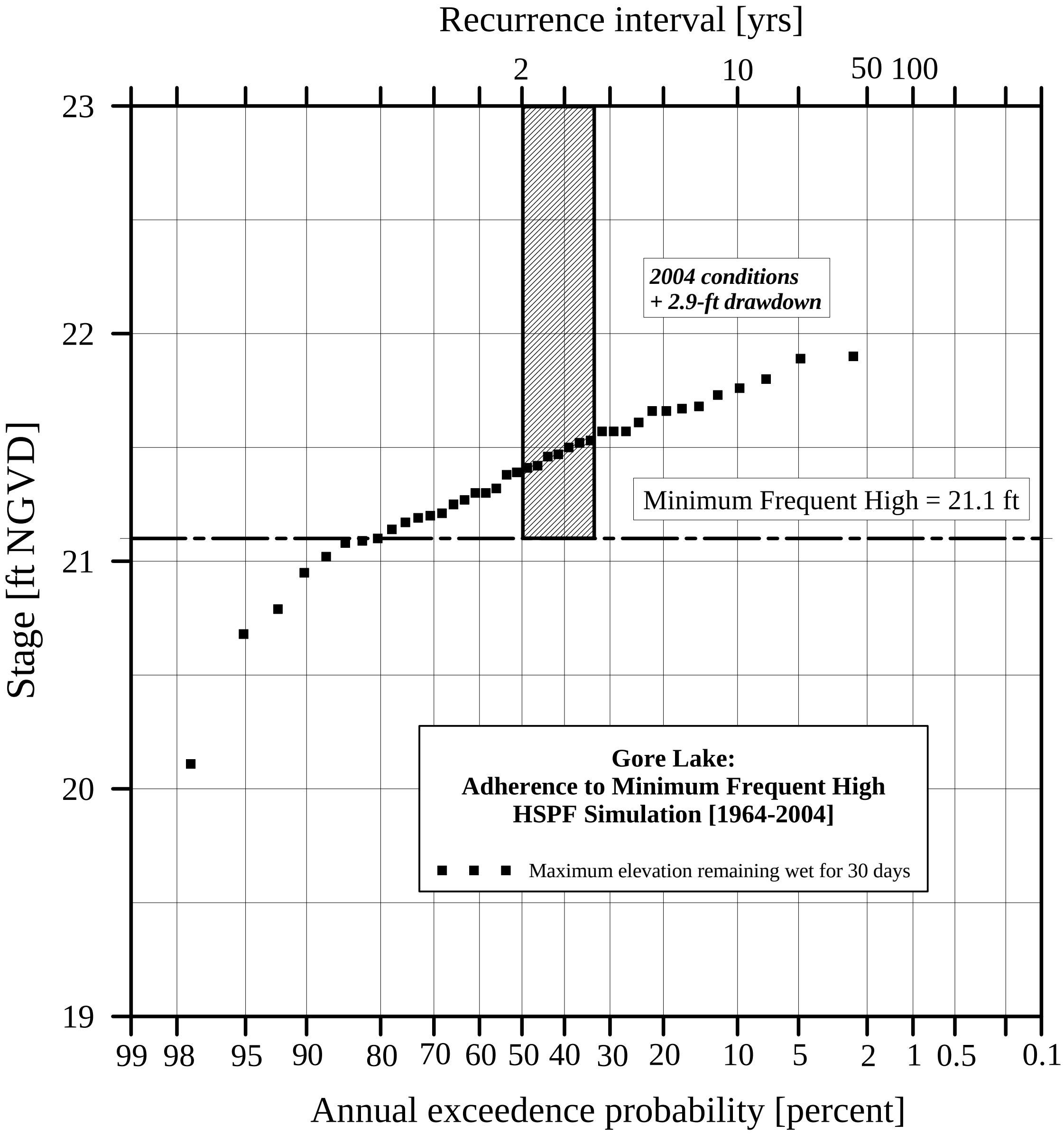

Figure C11. Flood frequencies computed using daily stages from model simulations of Gore Lake, for the FH level and 2004 conditions plus a 2.9-ft Floridan aquifer drawdown

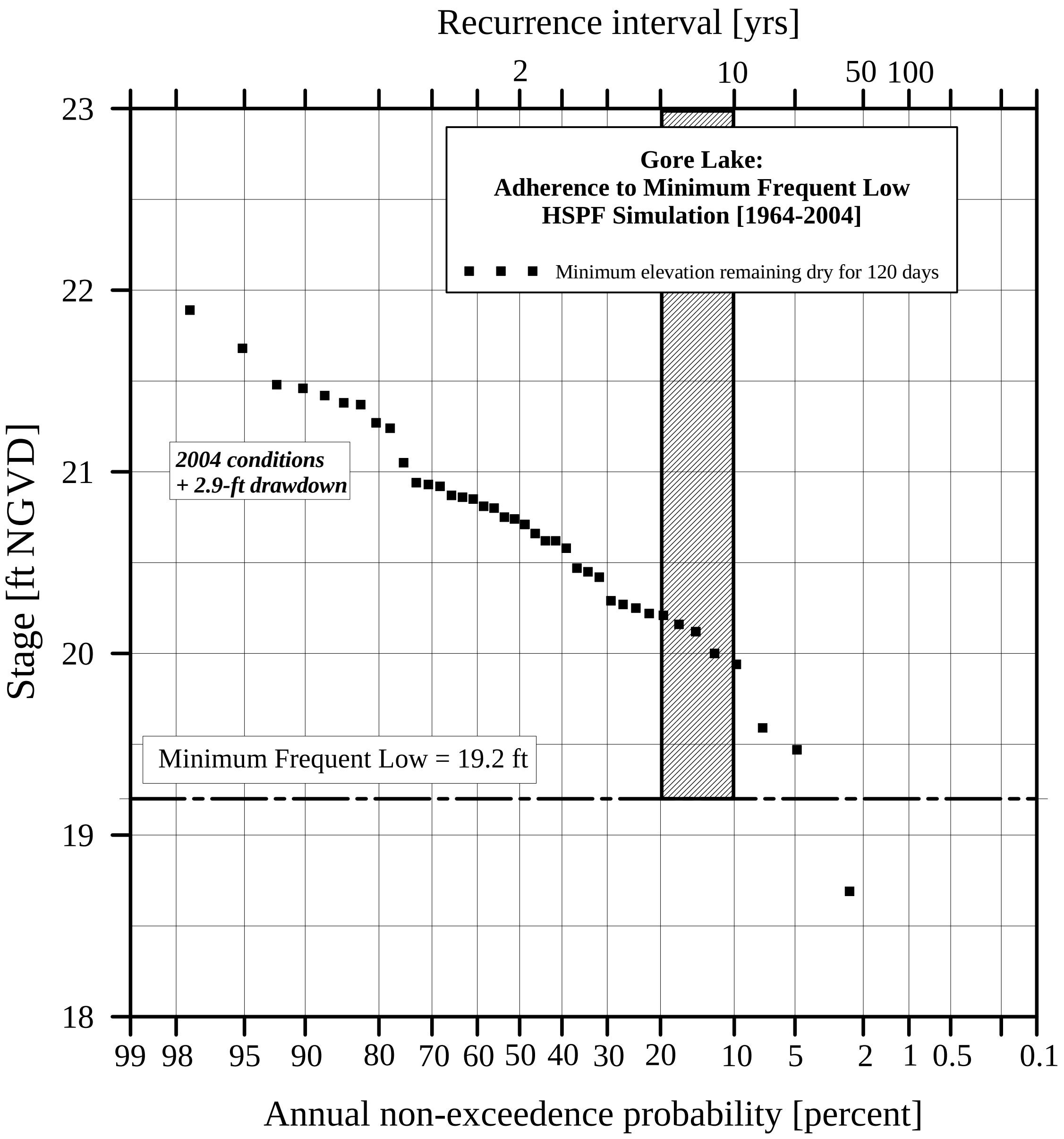

Figure C12. Drought frequencies computed using daily stages from model simulations of Gore Lake, for the FL level and 2004 conditions plus a 2.9-ft Floridan aquifer drawdown