Revised Minimum and Guidance Levels for Big Fish Lake in Hillsborough County, Florida

June 19, 2017

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

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Cover: February 12, 1999 photograph of Big Fish Lake shoreline (Southwest Florida Water Management District files).

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APPENDICES

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of revised minimum levels for Big Fish Lake in Pasco County, Florida. These revised levels (Table 1) were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District (District) and are protected of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, Florida Administrative Code [F.A,C,]). Following a public input process, the minimum and guidance levels were approved by the District Governing Board on August 30, 2016 and became effective on April 3, 2017. Rulemaking for these levels also included removal of previously adopted guidance levels for the lake from District rules.

Table 1. Revised Minimum and Guidance Levels for Big Fish Lake

Minimum and Guidance Levels	Elevation (Feet NGVD29)
High Guidance Level	76.6
High Minimum Lake Level	76.1
Minimum Lake Level	72.8
Low Guidance Level	70.2

Big Fish Lake was selected for reevaluation based on development of modeling tools used to simulate natural water level fluctuations in lake basins that were not available when the previously adopted minimum levels for the lake were developed. Previously adopted levels for Big Fish Lake were also reevaluated to support ongoing District assessment of minimum flows and levels and the need for additional recovery in the Northern Tampa Bay Water Use Caution Area (NTB WUCA), a region of the District where recovery strategies are being implemented to support recovery to minimum flow and level thresholds.

Minimum Flows and Levels Program Overview

Legal Directives

Section 373.042, Florida Statutes (F.S.), directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels (MFLs) for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that "[t]he minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Section 373.042(1)(b), F.S., defines the minimum water level of an aquifer or surface water body as "…the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." MFLs are established and used by the Southwest Florida Water Management District (SWFWMD or District) for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and use of surface water management systems.

Established MFLs are key components of resource protection, recovery and regulatory compliance, as Section 373.0421(2) F.S., requires the development of a recovery or prevention strategy for water bodies "[i]f the existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level established pursuant to S. 373.042." Section 373.0421(2)(a), F.S., requires that recovery or prevention strategies be developed to: "(a) [a]chieve recovery to the established minimum flow or level as soon as practicable; or (b) [p]revent the existing flow or level from falling below the established minimum flow or level." Periodic reevaluation and, as necessary, revision of established minimum flows and levels are required by Section 373.0421(3), F.S.

Minimum flows and levels are to be established based upon the best information available, and when appropriate, may be calculated to reflect seasonal variations (Section 373.042(1), F.S.). Also, establishment of MFLs is to involve consideration of, and at the governing board or department's discretion, may provide for the protection of nonconsumptive uses (Section 373.042(1), F.S.). Consideration must also be given to "…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 the affected watershed, surface water, or aquifer…", with the requirement that these considerations shall not allow significant harm caused by withdrawals (Section 373.0421(1)(a), F.S.). Sections 373.042 and 373.0421 provide additional information regarding the prioritization and scheduling of minimum flows and levels, the independent scientific review of scientific or technical data, methodologies, models and scientific and technical assumptions employed in each model used to establish a minimum flow or level, and exclusions that may be considered when identifying the need for MFLs establishment.

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the establishment of MFLs, requiring that "…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; b) Fish and wildlife habitats and the passage of fish; c) estuarine resources; d) Transfer of detrital material; e) Maintenance of freshwater storage and supply; f) Aesthetic and scenic attributes; g) Filtration and absorption of nutrients and other pollutants; h) Sediment loads; i) Water quality; and j) Navigation."

Rule 62-40.473, F.A.C., also indicates that "[m]inimum flows and levels 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 as provided in Section 373.042(1), F.S." It further notes that, "…a minimum flow or level need not be expressed as multiple flows or levels if other resource protection tools, such as reservations implemented to protect fish and wildlife or public health and safety, that provide equivalent or greater protection of the hydrologic regime of the water body, are developed and adopted in coordination with the minimum flow or level." The rule also includes provision addressing: protection of MFLs during the construction and operation of water resource projects; the issuance of permits pursuant to Section 373.086 and Parts II and IV of Chapter 373, F.S.; water shortage declarations; development of recovery or prevention strategies, development and updates to a minimum flow and level priority list and schedule, and peer review for MFLs establishment.

Development of Minimum Lake Levels in the Southwest Florida Water Management District

Programmatic Description and Major Assumptions

Since the enactment of the Florida Water Resources Act of 1972 (Chapter 373, F.S.), in which the legislative directive to establish MFLs originated, and following subsequent modifications to this directive and adoption of relevant requirements in the Water Resource Implementation Rule, the District has actively pursued the adoption, i.e., establishment of MFLs for priority water bodies. The District implements established MFLs primarily through its water supply planning, water use permitting and environmental resource permitting programs, and through the funding of water resource and water supply development projects that are part of a recovery or prevention strategy. The District's MFLs program addresses all relevant requirements expressed in the Florida Water Resources Act and the Water Resource Implementation Rule.

A substantial portion of the District's organizational resources has been dedicated to its MFLs Program, which logistically addresses six major tasks: 1) development and reassessment of methods for establishing MFLs; 2) adoption of MFLs for priority water bodies (including the prioritization of water bodies and facilitation of public and independent scientific review of proposed MFLs and methods used for their development); 3) monitoring and MFLs status assessments, i.e., compliance evaluations; 4) development and implementation of recovery strategies; 5) MFLs compliance reporting; and 6) ongoing support for minimum flow and level regulatory concerns and prevention strategies. Many of these tasks are discussed or addressed in this proposed minimum levels report; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

The District's MFLs Program is implemented based on a three fundamental assumptions. First, it is assumed that many water resource values and associated features are dependent upon and affected by long-term hydrology and/or changes in long-term hydrology. Second, it is assumed that relationships between some of these variables can be quantified and used to develop significant harm thresholds or criteria that are useful for establishing MFLs. Third, the approach assumes that alternative hydrologic regimes may exist that differ from non-withdrawal impacted conditions but are sufficient to protect water resources and the ecology of these resources from significant harm.

Support for these assumptions is provided by a large body of published scientific work addressing relationships between hydrology, ecology and human-use values associated with water resources (e.g., see reviews and syntheses by Postel and Richter 2003, Wantzen *et al.* 2008, Poff *et al.* 2010, Poff and Zimmerman 2010). This information has been used by the District and other water management districts within the state to identify significant harm thresholds or criteria supporting development of MFLs for hundreds of water bodies, as summarized in the numerous publications associated with these efforts (e.g., SFWMD 2000, 2006, Flannery *et al*. 2002, SRWMD 2004, 2005, Neubauer *et al.* 2008, Mace 2009).

With regard to the assumption associated with alternative hydrologic regimes, consider a historic condition for an unaltered river or lake system with no local groundwater or surface water withdrawal impacts. A new hydrologic regime for the system would be associated with each increase in water use, from small withdrawals that have no measurable effect on the historic regime to large withdrawals that could substantially alter the regime. A threshold hydrologic regime may exist that is lower or less than the historic regime, but which protects the water resources and ecology of the system from significant harm. This threshold regime could conceptually allow for water withdrawals, while protecting the water resources and ecology of the area. Thus, MFLs may represent minimum acceptable rather than historic or potentially optimal hydrologic conditions.

Consideration of Changes and Structural Alterations and Environmental Values

When establishing MFLs, the District 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 or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer…" in accordance with Section 373.0421(1)(a), F.S. Also, as required by statute, the District does not establish MFLs that would allow significant harm caused by withdrawals when considering the changes, alterations and their associated effects and constraints. These considerations are based on review and analysis of best available information, such as water level records, environmental and construction permit information, water control structure and drainage alteration histories, and observation of current site conditions.

When establishing, reviewing or implementing MFLs, considerations of changes and structural alterations may be used to:

- adjust measured flow or water level historical records to account for existing changes/alterations;
- model or simulate flow or water level records that reflect long-term conditions that would be expected based on existing changes/alterations and in the absence of measurable withdrawal impacts;
- develop or identify significant harm standards, thresholds and other criteria;
- aid in the characterization or classification of lake types or classes based on the changes/alterations;

- evaluate the status of water bodies with proposed or established MFLs (i.e., determine whether the flow and/or water level are below, or are projected to fall below the applicable minimum flow or level); and
- support development of lake guidance levels (described in the following paragraph).

The District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers, estuaries and aquifers, subjected the methodologies to independent, scientific peer-review, and incorporated the methods for some system types, including lakes, into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). The rule also provides for the establishment of Guidance Levels for lakes, which serve as advisory information for the District, lakeshore residents and local governments, or to aid in the management or control of adjustable water level structures.

Information regarding the development of adopted methods for establishing minimum and guidance lake levels is included in Southwest Florida Water Management District (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz et al. (2004), Carr and Rochow (2004), Caffrey *et al.* (2006, 2007), Carr *et al.* (2006), Hancock (2006), Hoyer *et al*. (2006), Leeper (2006), Hancock (2006, 2007) and Emery *et al.* (2009). Independent scientific peer-review findings regarding the lake level methods are summarized by Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

For lakes, methods have been developed for establishing Minimum Levels for systems with fringing cypress-dominated wetlands greater than 0.5 acre in size, and for those without fringing cypress wetlands. Lakes with fringing cypress wetlands where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands are classified as Category 1 Lakes. Lakes with fringing cypress wetlands that have been structurally altered such that lake water levels do not rise to levels expected to fully maintain the integrity of the wetlands are classified as Category 2 Lakes. Lakes with less than 0.5 acre of fringing cypress wetlands are classified as Category 3 Lakes.

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop recommend minimum levels. For Category 1 or 2 Lakes, a significant change standard, referred to as the Cypress Standard, is developed. For Category 3 lakes, six significant change standards are typically developed. Other available information, including potential changes in the coverage of herbaceous wetland and submersed aquatic plants is also considered when establishing minimum levels for Category 3 Lakes. The standards and other available information are associated with the environmental values identified for consideration in Rule 62-40.473, F.A.C., when establishing MFLs (Table 2). The specific standards and other information evaluated to support development of revised minimum levels for Big Fish Lake are provided in subsequent sections of this report. More general information on the standards and other information used for consideration when developing minimum lake levels is available in the documents identified in the preceding sub-section of this report.

Table 2. Environmental values identified in the state Water Resource Implementation Rule for consideration when establishing minimum flows and levels and associated significant change standards and other information used by the District for consideration of the environmental values.

Environmental Value	Associated Significant Change Standards and Other Information for Consideration
Recreation in and on the water	Basin Connectivity Standard, Recreation/Ski Standard, Aesthetics Standard, Species Richness Standard, Dock-Use Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Fish and wildlife habitats and the passage of fish	Cypress Standard, Wetland Offset, Basin Connectivity Standard, Species Richness Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Estuarine resources	NA[1]
Transfer of detrital material	Cypress Standard, Wetland Offset, Basin Connectivity Standard, Lake Mixing Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Maintenance of freshwater storage and supply	NA[2]
Aesthetic and scenic attributes	Cypress Standard, Dock-Use Standard, Wetland Offset, Aesthetics Standard, Species Richness Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Filtration and absorption of nutrients and other pollutants	Cypress Standard Wetland Offset Lake Mixing Standard Herbaceous Wetland Information Submersed Aquatic Macrophyte Information
Sediment loads	NA[1]
Water quality	Cypress Standard, Wetland Offset, Lake Mixing Standard, Dock-Use Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
Navigation	Basin Connectivity Standard, Submersed Aquatic Macrophyte Information

NA[1] = Not applicable for consideration for most priority lakes;
NA[2] = Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Lake Classification

Lakes are classified as Category 1, 2, or 3 for Minimum Levels development. According to (Chapter 40D-8.624, F.A.C.), Big Fish Lake meets the classification as a Category 3 lake, as it is not contiguous with any cypress-dominated wetlands. The standards associated with category 3 lakes described below will be developed for Big Fish Lake in a subsequent section of this report.

The Recreation/Ski Standard is developed to identify the lowest elevation within the lake basin that will contain an area suitable for safe water skiing. The standard is based on the lowest elevation (the Ski Elevation) within the basin that can contain a 5-foot deep ski corridor delineated as a circular area with a radius of 418 feet, or a rectangular ski corridor 200 feet in width and 2,000 feet in length, and use of Historic lake stage data or region-specific reference lake water regime statistics where Historic lake data are not available.

The Dock-Use Standard is developed to provide for sufficient water depth at the end of existing docks to permit mooring of boats and prevent adverse impacts to bottom-dwelling plants and animals caused by boat operation. The standard is based on the elevation of lake sediments at the end of existing docks, a two-foot water depth for boat mooring, and use of Historic lake stage data or region-specific reference lake water regime statistics.

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to protect aesthetic values associated with the median lake stage from diminishing beyond the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetic Standard is established at the Low Guidance Level. Water levels equal or exceed the standard ninety percent of the time during the Historic period, based on the Historic, composite water level record.

The Species Richness Standard is developed to prevent a decline in the number of bird species that may be expected to occur at or utilize a lake. Based on an empirical relationship between lake surface area and the number of birds expected to occur at a lake, the standard is established at the lowest elevation associated with less than a fifteen percent reduction in lake surface area relative to the lake area at the Historic P50 elevation.

The Basin Connectivity Standard is developed to protect surface water connections between lake basins or among sub-basins within lake basins to allow for movement of aquatic biota, such as fish, and support recreational use of the lake. The standard is based on the elevation of lake sediments at a critical high spot between lake basins or lake sub-basins, identification of water depths sufficient for movement of biota and/or watercraft across the critical high spot, and use of Historic lake stage data or the region-specific Reference Lake Water Regime statistics where Historic lake data are not available.

The Lake Mixing Standard is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment re-suspension. The standard is established at the highest elevation at or below the Historic P50 elevation where the dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of <0.8 to a value >0.8, or from a value >0.8 to a value of <0.8.

Herbaceous Wetland Information is taken into consideration to determine the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (i.e., basin area with a water depth of four or less feet). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also evaluated, based on water transparency values.

Minimum and Guidance Levels

Two Minimum Levels and two Guidance Levels are typically established for lakes. Upon completion of a public input/review process and, if necessary completion of an independent scientific review, either of which may result in modification of the proposed levels, the levels are adopted by the District Governing Board into Chapter 40D-8, F.A.C. Code (see Hancock *et al.* 2010 for more information on the adoption process). The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD29), may include the following (refer to Rule 40D-8.624, F.A.C.).

- A **High Guidance Level** that is provided as an advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. The High Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ten percent of the time on a long-term basis.

- A **High Minimum Lake Level** that is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis.

- A **Minimum Lake Level** that is the elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis.

- A **Low Guidance Level** that is provided as an advisory guideline for water dependent structures, information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis.

The District is in the process of converting from use of the NGVD29 datum to use of the North American Vertical Datum of 1988 (NAVD 88). While the NGVD29 datum is used for most elevation values included within this report, in some circumstances, notations are made for elevation data that was collected or reported relative to mean sea level or relative to NAVD88 and converted to elevations relative to NGVD29. All datum conversions were derived either by using the Corpscon 6.0 software distributed by the United States Army Corps of Engineers or directly measured survey data associated with benchmarks located adjacent to the lake.

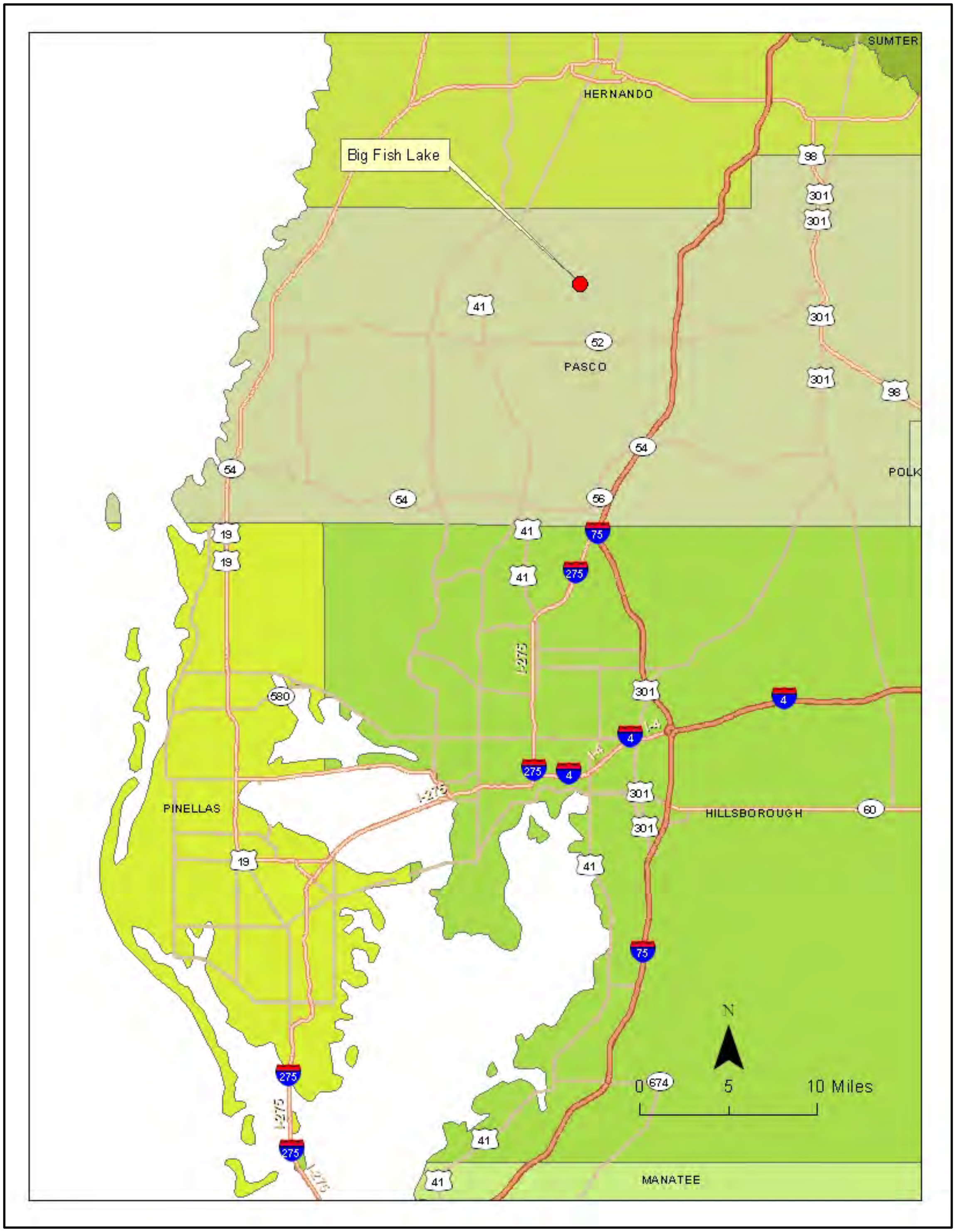

Figure 1. Location of Big Fish Lake in Paso County, Florida.

Development of Minimum and Guidance Levels for Big Fish Lake

Lake Setting and Description

Watershed

Big Fish Lake is located on private property in north-central Pasco County (Sections 21,22,27,28, and 33, Township 24S, Range 19E) and lies on or near the divide for the Pithlachascotee River and Cypress Creek watersheds (Figure 1 & Figure 2). There are no significant inflows or outflows associated with Big Fish Lake, although during very high rainfall periods the lake can overflow into a large, relatively flat area surrounding the lake.

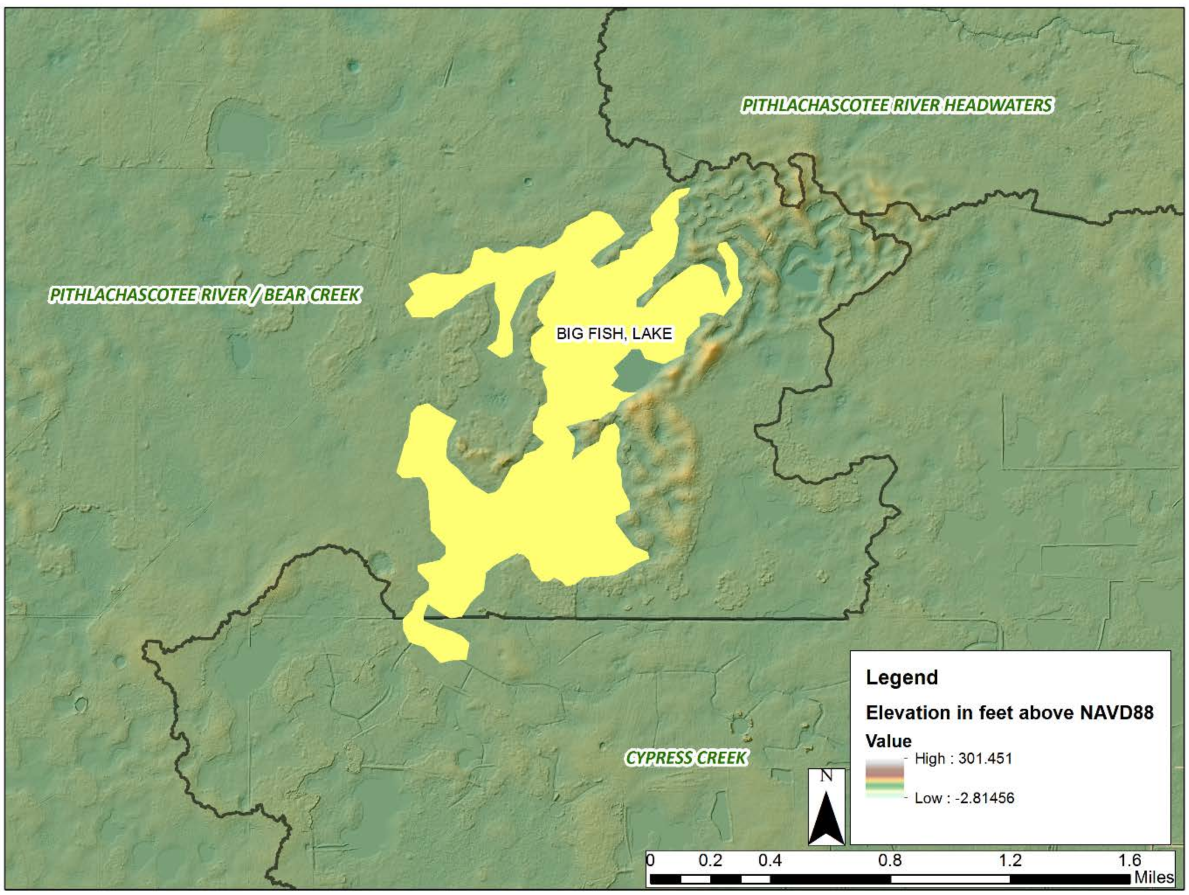

Figure 2. Watershed Delineation and Topography.

Site Specific Details

Land surface elevations in the Big Fish Lake basin and surrounding uplands range from approximately 65 to 100 ft. above NGVD. A sandy ridge runs north to south through the lake's watershed to a berm located along the southern boundary of Sections 27 and 28 and divides the watershed into eastern and western sub-basins. Land surface elevations are lowest in the western sub-basin. An east-west oriented ridge in the eastern sub-basin further divides the sub-basin into numerous smaller basins. Surface water pooled in the various sub-basins results in the development of a complex system of interconnected and isolated open water and wetland habitats, which collectively comprise Big Fish Lake.

Due to concerns of low lake levels, the lake has been intermittently augmented with ground water from the Floridan aquifer since the summer of 2000 (SWFWMD Water Use Permit No. 20005897.005) (Figure 3).

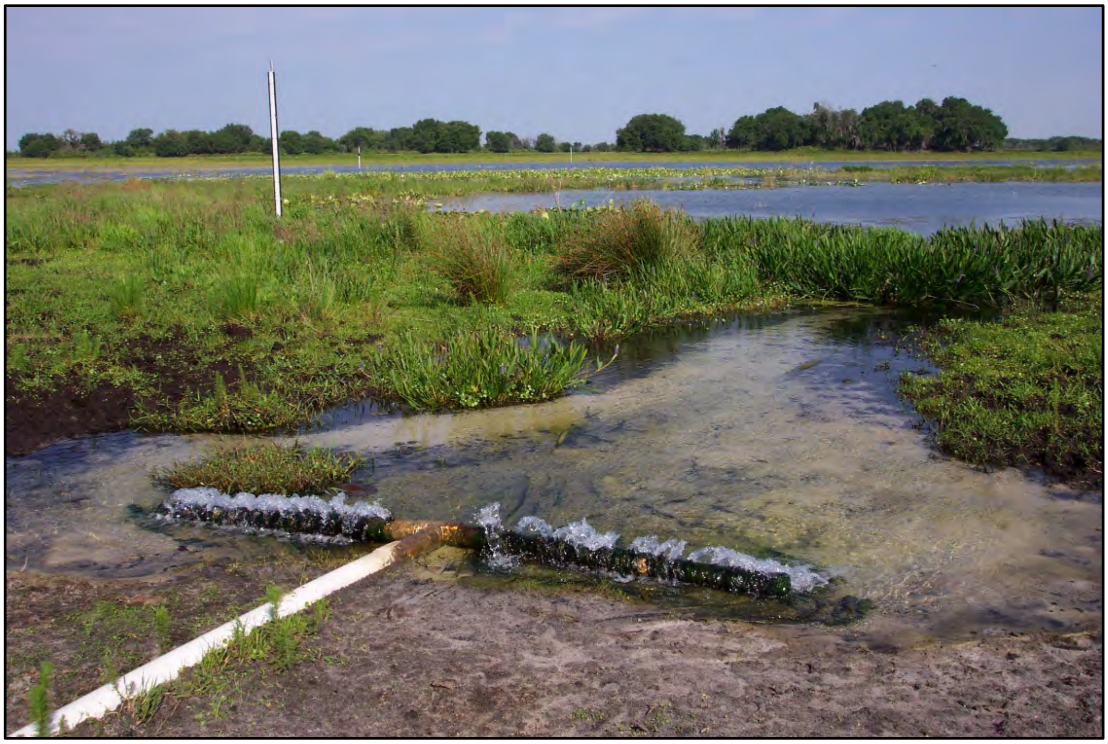

Figure 3. Active augmentation at Big Fish Lake May 2002.

Land Use Land Cover

An examination of the 1990 and more current 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there has been little change to the landscape (specifically the dominant land forms) in the vicinity during this period. Land use surrounding the lake in 1990 was primarily wet prairie, pine flatwoods, and crop and pastureland, with a smaller area of shrub and brushland. In 2011, the dominant land use surrounding the lake remained similar to 1990, with the addition of some hardwood/conifer mix areas (Figure 4). Figures 5 and 6 aerial photography chronicles landscape changes to the immediate lake basin from 1941 to the present.

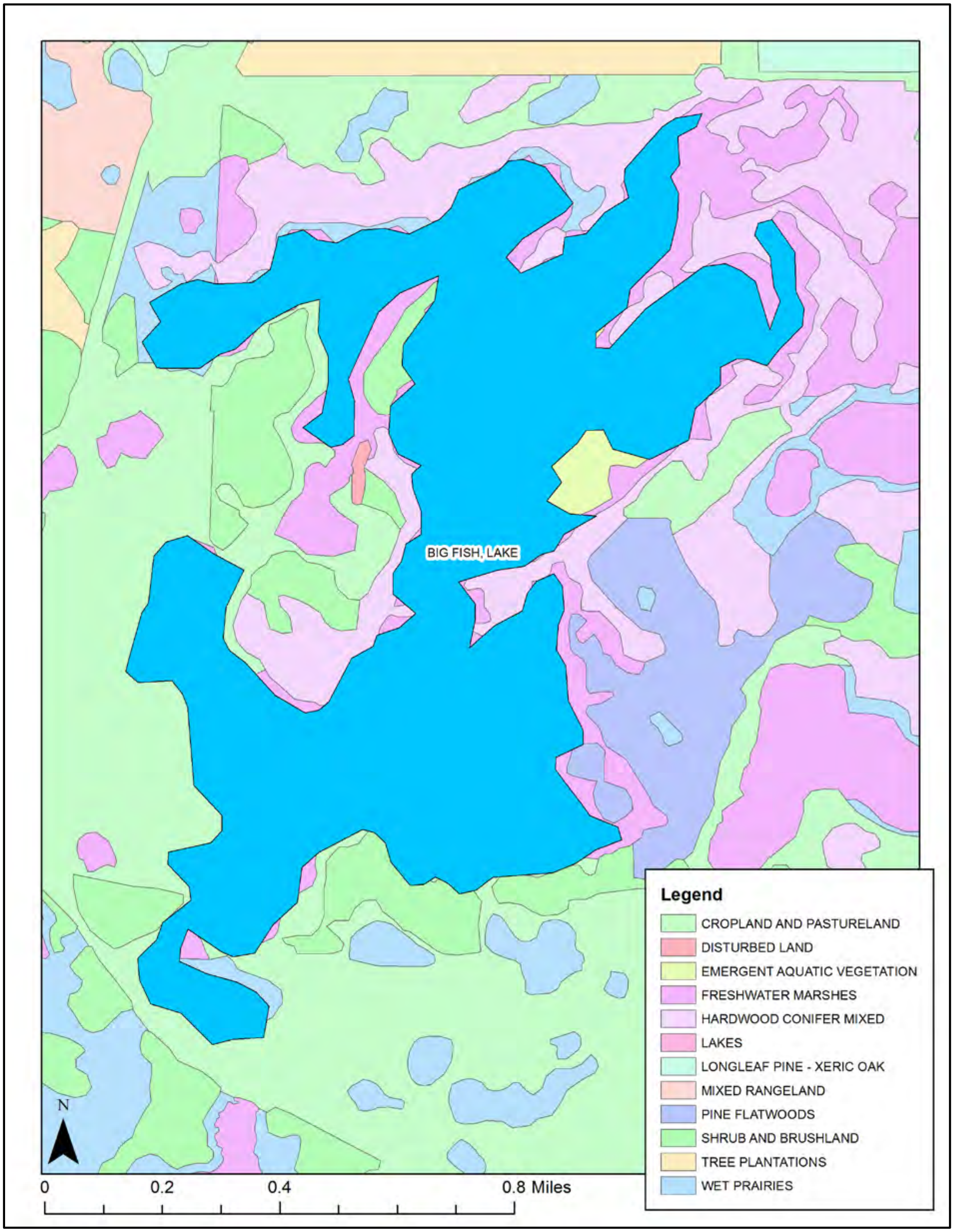

Figure 4. 2011 Land Use Land Cover Map of the Big Fish Lake Vicinity.

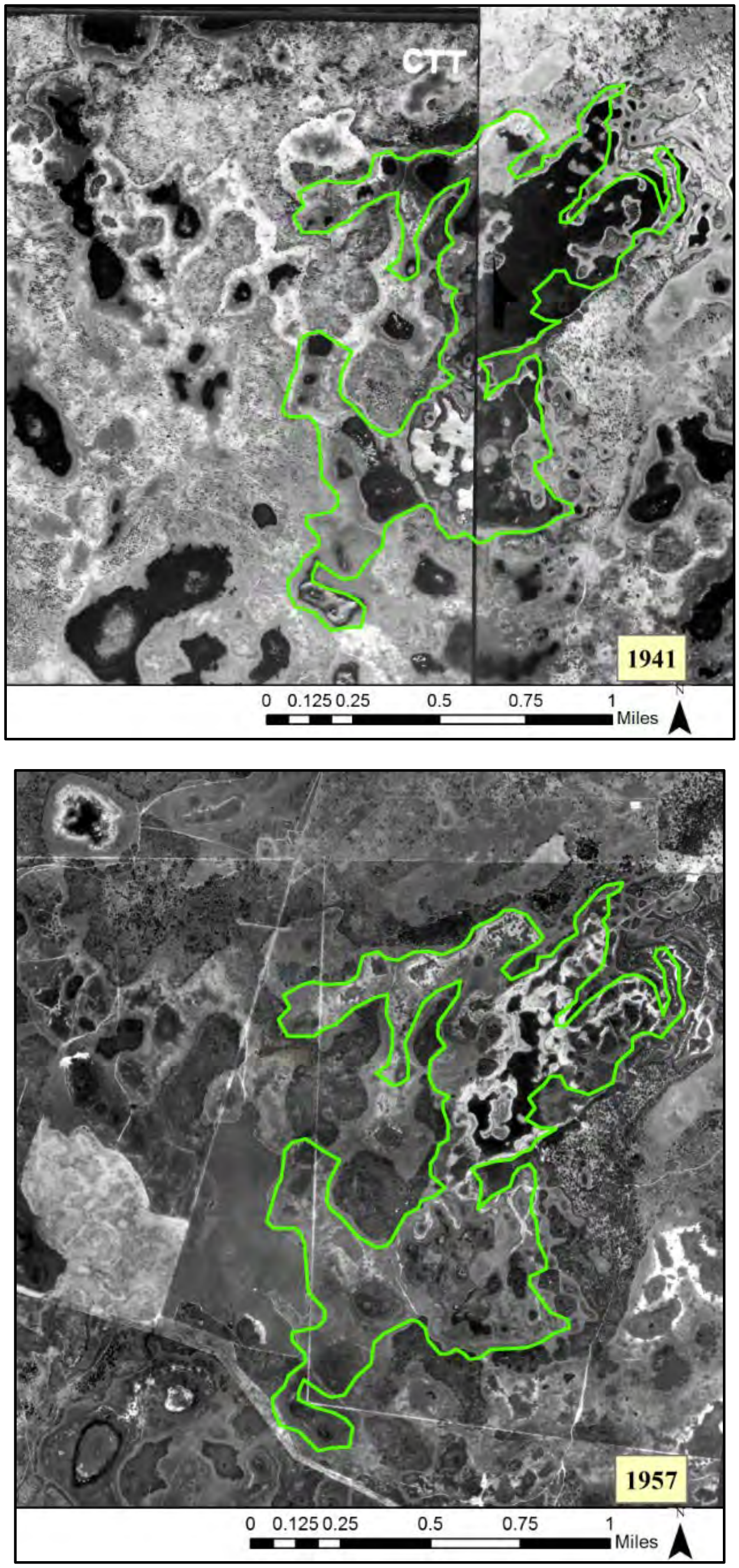

Figure 5. 1941 and 1957 Aerial Photographs of Big Fish Lake.

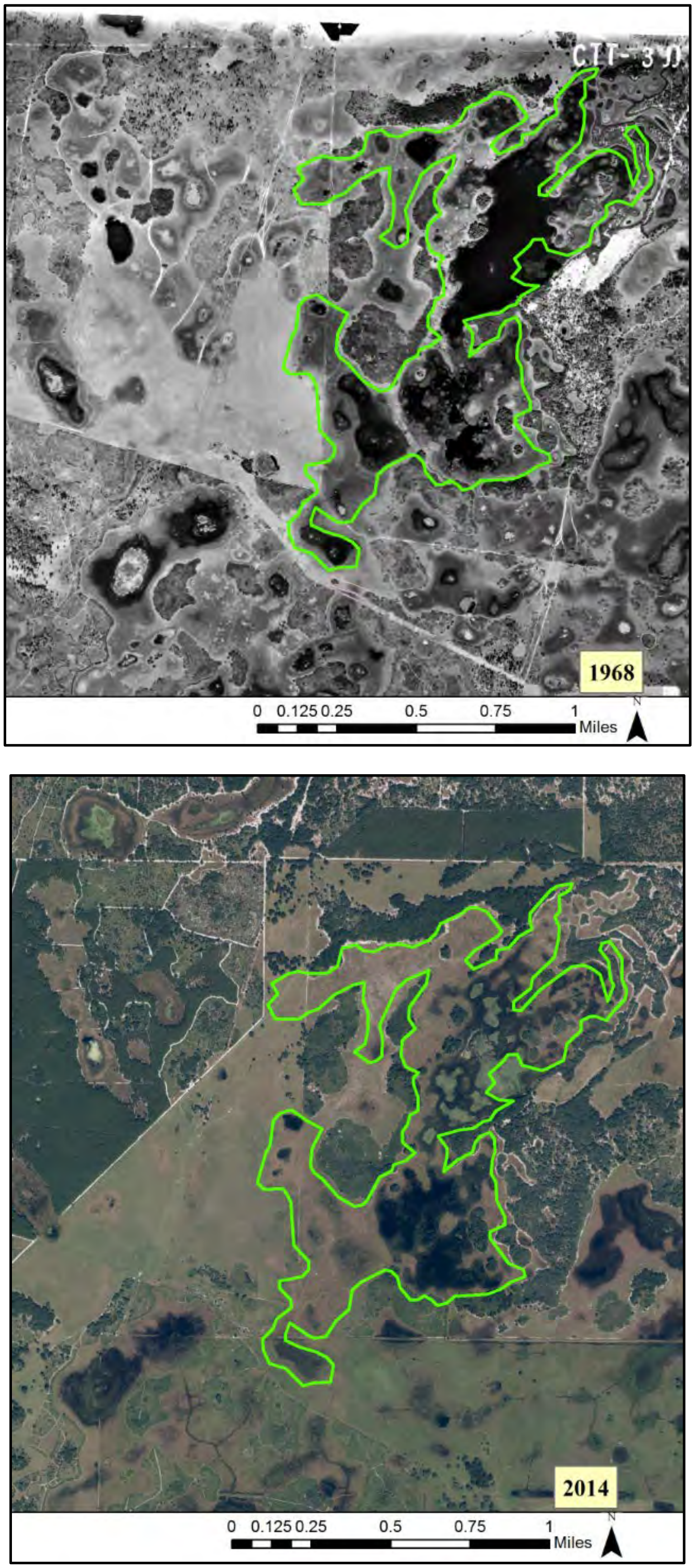

Figure 6. 1968 and 2014 Aerial Photographs of Big Fish Lake.

Topography and Physiography

The topography is very flat, and drainage in to the lake is a combination of overland flow and flow through drainage swales and minor conveyance systems. The physiography approximately 2 miles to the west is characterized as rolling sand hills of the northern gulf coastal lowlands, while the beginning of the Brooksville Ridge lies approximately 2 miles to the east, which is characterized by large hills reaching elevations over 300 feet NGVD29 (Figure 6).

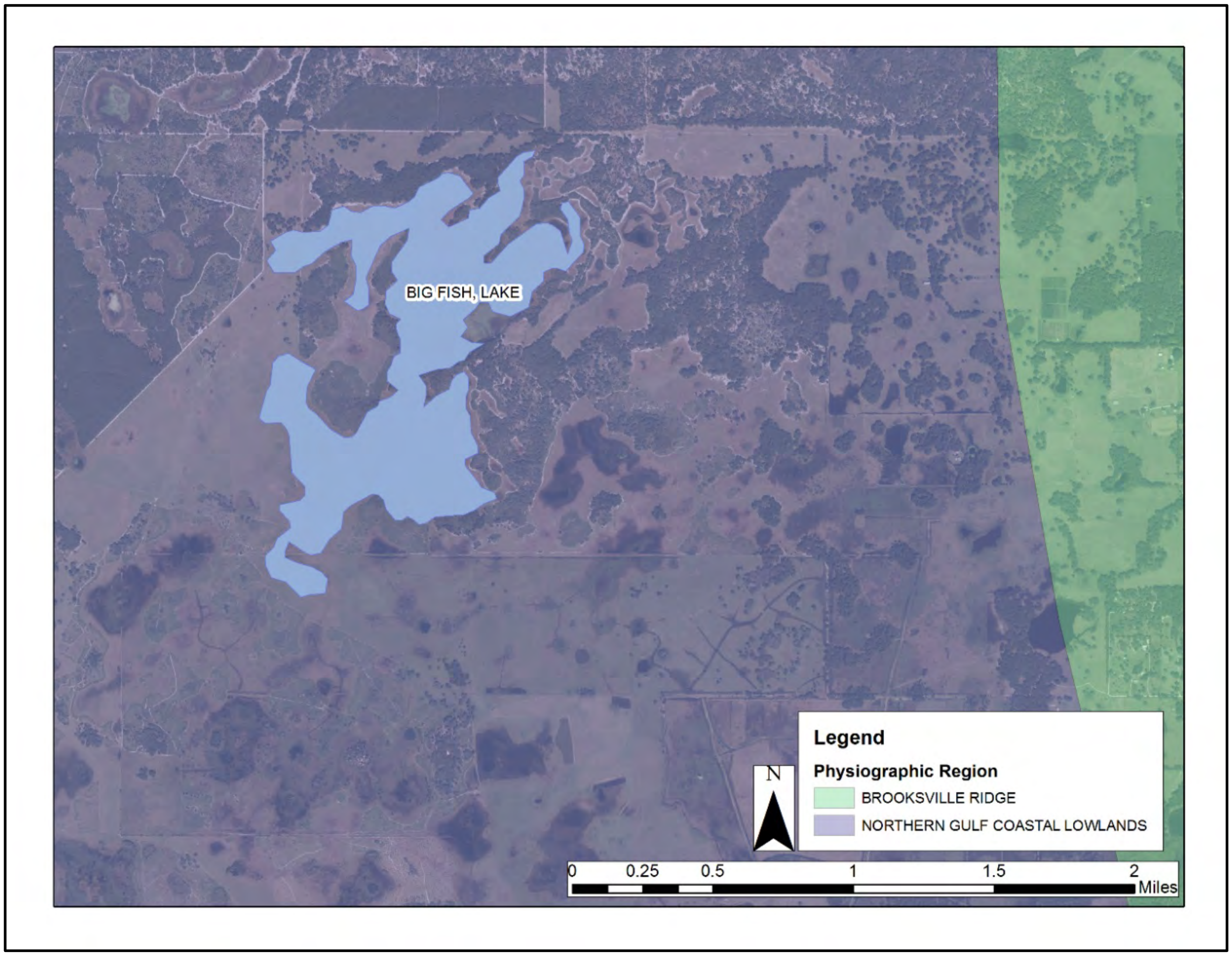

Figure 6. Physiographic Region of the Big Fish Lake Area.

The "Gazetteer of Florida Lakes" (Dickinson et al., 1982) lists the lake area at 270 acres at an elevation of 76 ft. In contrast, The United States Geological Survey 1954 1:24,000 Masaryktown, Fla. and Ehren, Fla. (photorevised in 1988) quadrangle topographic maps indicate that the lake is 711 acres at a water level elevation of 76 ft. above mean sea level. This elevation is based on a topographic map of the basin generated in support of the previous minimum levels development in 2003. Data used for production of the topographic map were obtained from field surveys and 1:200 aerial photography maps containing one-foot contours within the basin. Mapping was limited to areas bounded by a contour line corresponding to an elevation of 89 ft. within the lake basin in Sections 21, 22, 27 and 28, Township 24S, Range 19E. This elevation was selected upon review of lake stage data for the lake and aerial photographs of the region.

Discrepancies in reported area values for Lake Big Fish, may, in part, be explained by differences in criteria used to establish lake area. A study conducted by the Natural Resources Conservation Service in the mid-1990s (Werner 1996) illustrates this point. The study provides estimates of wetland acreage on the ranch containing Big Fish Lake, and lists the surface area of the “main body” of the lake at 313 acres, while the area encompassed by the connection of “flats” or low-lying regions between major pools is estimated at 615 acres. These estimates, derived using soil maps of the area, approximate the surface area values of 711 and 270 acres cited above. Thus, the surface area reported in the Florida Lake Gazetteer (270 acres when the surface water elevation is 76 ft. above mean sea level) corresponds to only a portion of the area within the watershed where open water or wetland habitat exists.

Hydrogeology

The hydrogeology of the area includes a sand surficial aquifer; a discontinuous, intermediate clay confining unit; and the thick carbonate Upper Floridan aquifer. In general, the surficial aquifer in the study area is in good hydraulic connection with the underlying Upper Floridan aquifer because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features. The surficial aquifer is generally ten to thirty feet thick and overlies the limestone of the Upper Floridan aquifer that averages nearly one thousand feet thick in the area (Miller 1986). In between these two aquifers is the Hawthorn Group clay that varies between a few feet to as much as 25 feet thick, but in the area of Big Fish Lake is typically much thinner or absent. Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the Upper Floridan aquifer resulting in moderate-to-high leakage to the Upper Floridan aquifer (Hancock and Basso 1996).

Bathymetry Description and History

At the ten-year flood guidance levels established in 2003 (77.41 ft., Table 3), the lake surface area is near 1000 acres based on stage volume data calculated in support of minimum levels development at that time. One foot interval bathymetric data gathered from recent field surveys resulted in contour lines to 89 ft. (Figure 7). These data revealed that the lowest lake bottom contour (65 ft.) on the eastern shore is the deepest area of the lake. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

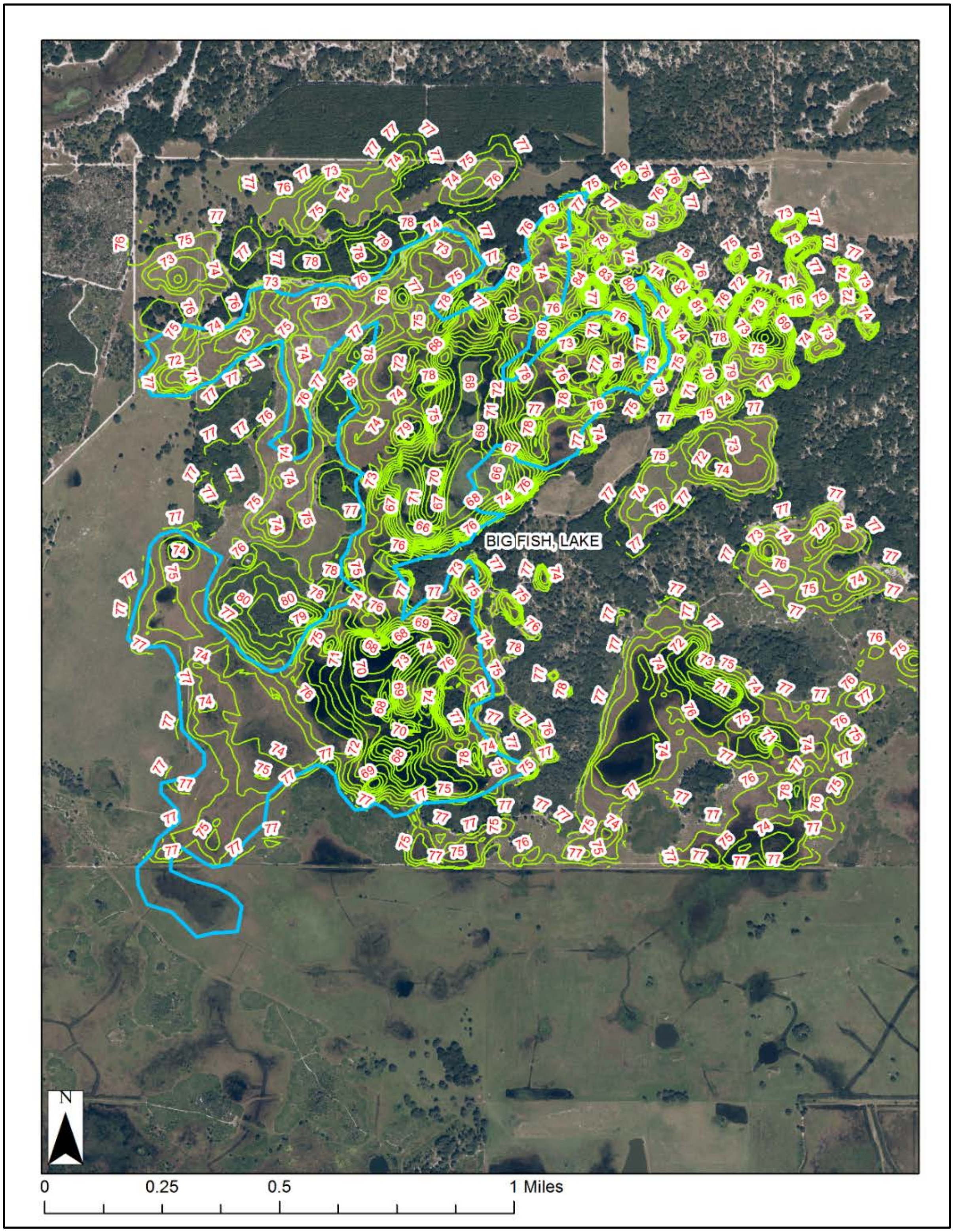

Figure 7. Lake Bottom Contours on a 2014 Natural Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations collected are available for Big Fish Lake from the District's Water Management Information System (SID 20474 and low water gage SID 777816) (Figure 8). The District continues to monitor the water levels on a monthly basis. Data has been collected since June 23, 1980. The highest lake stage elevation on record was 77.40 ft. and occurred in September 2004. The lowest lake stage elevation on record was 65.45 ft. and occurred on June 1997.

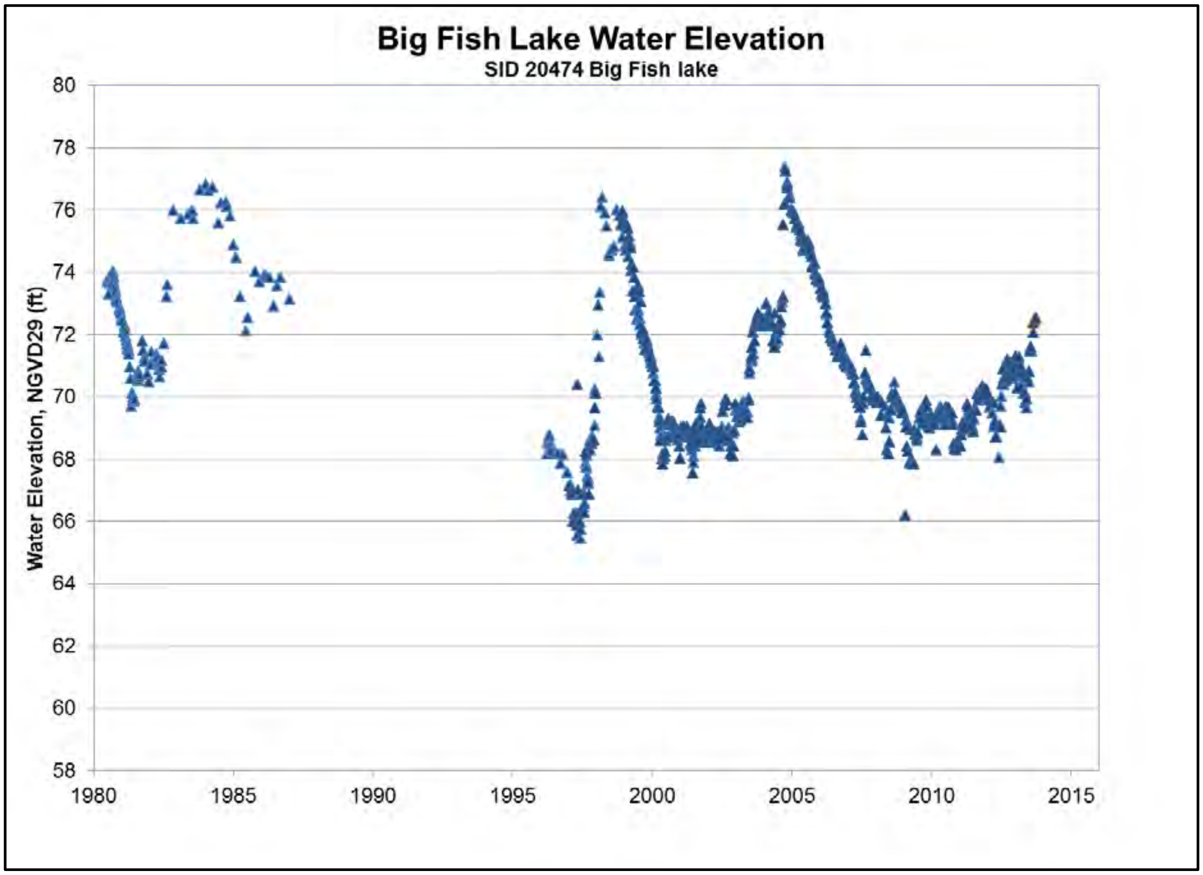

Figure 8. Big Fish Lake Period of Record Stage Data (SID 20474).

Historical and Current Management Levels

The District has a long history of water resource protection through the establishment of lake management levels. With the development of the Lake Levels Program in the mid-1970s, the District began establishing management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes had been adopted into District rules.

The District Governing Board approved Guidance and Minimum levels for Big Fish Lake in October 2003 (Table 3) which were subsequently adopted into Chapter 40D-8, Florida Administrative Code using the methodology for Category 3 Lakes described in SWFWMD (1999a and 1999b).

Table 3. Guidance levels adopted with the associated surface areas for Big Fish Lake:

Level	Elevation (ft., NGVD)	Total Lake Area (acres)
Ten Year Flood Guidance Level	77.41	1001
High Guidance Level	76.05	724
High Minimum Level	75.65	619
Minimum Level	73.05	160
Low Guidance Level	71.75	704

Methods, Results and Discussion

The Minimum and Guidance Levels in this report were developed for Lake Big Fish using the methodology for Category 3 lakes described in Chapter 40D-8, F.A.C. Revised levels along with lake surface area for each level are listed in Table 4 along with other information used for development of the revised levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

Bathymetry

Relationships between lake stage, inundated area and volume can be used to evaluate expected fluctuations in lake size that may occur in response to climate, other natural factors, and anthropogenic impacts such as structural alterations or water withdrawals. Long term reductions in lake stage and size can be detrimental to many of the environmental values identified in the Water Resource Implementation Rule for consideration when establishing MFLs. Stage-area-volume relationships are therefore useful for developing significant change standards and other information identified in District rules for consideration when developing minimum lake levels. The information is also needed for the development of lake water budget models that estimate the lake's response to rainfall and runoff, outfall or discharge, evaporation, leakage and groundwater withdrawals.

Stage-area-volume relationships were determined for Lake Big Fish by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. Elevations of the lake bottom and land surface elevations were used to build the model through a series of analyses using LP360 (by QCoherent) for ArcGIS, ESRI® ArcMap 10.2 software, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the lake basin morphology to develop one continuous 3D digital elevation model. The 3D digital elevation model is then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the largest size of the lake at its peak or flood stage, and working downward to the base elevation (deepest pools in the lake).

Table 4. Lake Stage Percentiles, Normal Pool and Control Point Elevations, and Significant Change Standards, revised Minimum and Guidance Levels associated surface areas for Big Fish Lake.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Historic P10 (1946 to 2013)	76.6	845
Historic P50 (1946 to 2013)	73.3	319
Historic P90 (1946 to 2013)	70.2	99
Normal Pool and Control Point		
Normal Pool	76.2	799
Control Point	76.1	782
Low Floor Slab	NA	NA
Significant Change Standards		
Recreation/Ski Standard	NA	NA
Dock-Use Standard	NA	NA
Wetland Offset Elevation	72.5	240
Aesthetics Standard	70.2	99
Species Richness Standard	72.8	267
Basin Connectivity Standard	NA	NA
Lake Mixing Standard	66.4	4
Minimum and Guidance Levels		
High Guidance Level	76.6	845
High Minimum Lake Level	76.1	782
Minimum Lake Level	72.8	267
Low Guidance Level	70.2	99

NA - not appropriate

Two elevation data sets were used to develop the terrain model for Big Fish Lake. Light Detection and Ranging Data (LiDAR) was processed with LP360 for ArcGIS and merged with bathymetric data collected with both sonar and mechanical (manual) methods. using an LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20) mounted to a boat hull, a Lowrance LMS-350A sonar-based depth finder, and the Trimble GPS Pathfinder Pro XR/Mapping System (Pro XR GPS Receiver, Integrated GPS/MSK Beacon Antenna, TDC1 Asset Surveyor and Pathfinder Office software).

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-one thousandth of a foot elevation change increments. Stage-area results are presented in Figure 10a.

Development of Exceedance Percentiles

A key part of establishing Minimum and Guidance Levels is the development of exceedance percentiles based on Historic water levels (lake stage data). For the purpose of minimum levels determination, lake stage data are categorized as "Historic" for periods when there were no measurable impacts due to water withdrawals, and impacts due to structural alterations were similar to existing conditions. In the context of minimum levels development, "structural alterations" means man's physical alteration of the control point, or highest stable point along the outlet conveyance system of a lake, to the degree that water level fluctuations are affected.

Based on water-use estimates and analysis of lake water levels and regional ground water fluctuations, a modeling approach (Appendix A) was used to estimate Historic lake levels. This approach was considered appropriate for extending the period of record for lake stage values for developing Historic lake stage exceedance percentiles. Development of this stage record was considered necessary for characterization of the range of lake-stage fluctuations that could be expected based on long-term climatic cycles that have been shown to be associated with changes in regional hydrology (Enfield et al. 2001, Basso and Schultz 2003, Kelly 2004). An evaluation of groundwater withdrawal impacts to Horse Lake is available in Appendix C.

The initial approach included developing a water budget model which incorporated the effects of precipitation, evaporation, overland flow, and groundwater interactions (Appendix A). Using the results of the water budget model, regression modeling for lake stage predictions was conducted using a linear line of organic correlation statistical model (LOC) (see Helsel and Hirsch 1992). The procedure was used to derive the relationship between daily water surface elevations for Big Fish Lake and composite regional rainfall.

A combination of model data produced a hybrid model which resulted in a 68 year (1946-2013) Historic water level record. Based on this hybrid data, the Historic P10 elevation, i.e., the elevation of the lake water surface equaled or exceeded ten percent of the time, was 76.6 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 73.3 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 70.2 ft. (Figure 9 and Table 4).

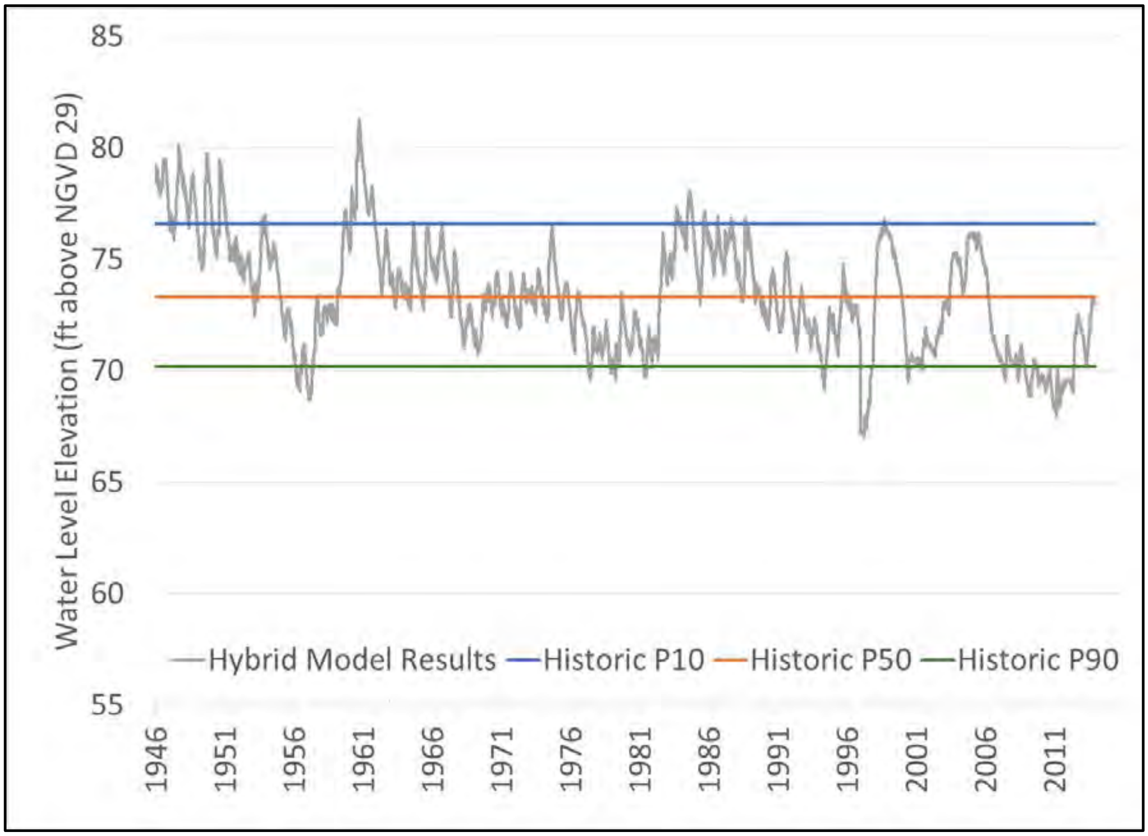

Figure 9. Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Normal Pool Elevation and Additional Information

The Normal Pool elevation, a reference elevation used for development of minimum lake and wetland levels, is established based on the elevation of hydrologic indicators of sustained inundation. The Historic normal pool was determined for Big Fish Lake based on the measurement of the bases of saw palmetto, and was determined to be 76.2 feet NGVD29 (using the median of 28 palmetto bases measured in 2013, to which 0.25 is added – see Southwest Florida Water Management District, 2005) (Table 5).

Table 5. Summary statistics for 2013 hydrologic indicator measurements used for establishing normal pool elevations for Big Fish Lake.

Summary Statistic	Number (N) or Elevation
N	28
Median	76.2
Mean	76.1
Minimum	74.7
Maximum	76.7

Additional information to consider in establishing Minimum and Guidance Levels are the Control Point elevation and the lowest building floor (slab) elevation within the lake basin (determined by field survey data). The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that can principally control the lake water level fluctuations at the high end. The highest fixed spot at the outlet serves as the control point at 76.1 ft. There were no buildings in the lake basin, therefore consideration for a low floor slab elevation was not applicable.

Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Normal Pool elevation. Based on the availability of Historic data developed for Big Fish Lake, the revised High Guidance Level was established at the Historic P10 elevation, 76.6 ft. The High Guidance Level has been exceeded a few times in the Historic data. For example, the two highest peaks were 76.8 ft. in January 1984 and 77.4 ft. in September 2004.

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate Historic or current data are not available. These statistics represent differences between P10, P50 and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals, i.e., reference lakes. Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Big Fish Lake, the revised Low Guidance Level was established at the Historic P90 elevation, 70.2 ft. The High Guidance Level has been exceeded a few times in the Historic data. For example, the two highest peaks were 76.8 ft. in January 1984 and 77.4 ft. in September 2004.

Significant Change Standards

Category 3 significant change standards were established for Big Fish Lake based on the stage-volume relationship which was developed. These standards include a Recreation/Ski Standard, Dock-Use Standard, Wetland Offset Elevation, Aesthetics Standard, Species Richness Standard, Basin Connectivity Standard, and Lake Mixing Standard. These standards were described in the Lake Classification section of this report on page 7. Each were evaluated for minimum levels development for Big Fish Lake and presented in Table 4.

- The Recreation/Ski Standard was not established due to the shallow depth of the lake. There was no area within the lake that was both deep enough and large enough to facilitate water skiing.

- There were no docks on the lake, therefore the Dock-Use Standard was not established.
- An Aesthetic-Standard for Big Fish Lake was established at the Low Guidance Level elevation of 70.2 ft.
- The Species Richness Standard was established at 72.8 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- The Basin Connectivity Standard was not developed, based on the complex arrangement of sub-basins within the greater Big Fish Lake basin.
- The Lake Mixing Standard was established at 66.4ft, the highest elevation at or below the Historic P50 elevation where the dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of > 0.8 to a value of < 0.8.
- Review of changes in potential herbaceous wetland area associated with change in lake stage did not indicate that use of any of the identified standards would be inappropriate for minimum levels development (Figure 10b). Secchi disk depth data were not available, therefore the potential change in area available for aquatic macrophyte colonization (Caffrey *et al.* 2006) was unable to be considered.

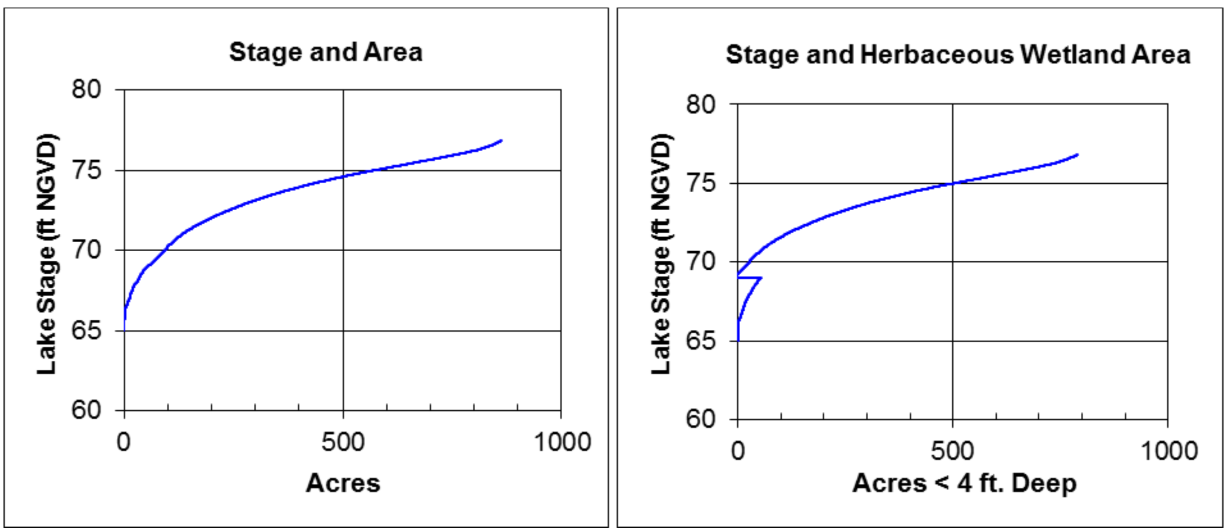

Figure 10 a & b. (a) Surface area (acres), and (b) herbaceous wetland area (acres) as a function of lake stage.

Minimum Levels

The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For a Category 3 lake, the Minimum Lake Level is established at the elevation corresponding to the most conservative (i.e., the highest) standard that does not result in an elevation above the historic P50. In the case of Big Fish Lake, the Minimum Lake Level is thus based on the Species Richness Standard at an elevation of 72.8 ft. (Table 4). For comparison purposes, a recent stage reading on June 27, 2016 was 73.87 ft., and is above the revised minimum level.

The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For a Category 3 lake with historic data available, the High Minimum Lake Level is established at the elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and the Historic P50. Therefore, the revised High Minimum Lake Level for Big Fish Lake is established at 76.1 ft.

Revised Minimum and Guidance levels for Big Fish Lake are plotted on the Historic water level record (Figure 11). To illustrate the approximate locations of the lake margin when water levels equal the revised minimum levels, levels are imposed onto a 2014 natural color photograph in Figure 12.

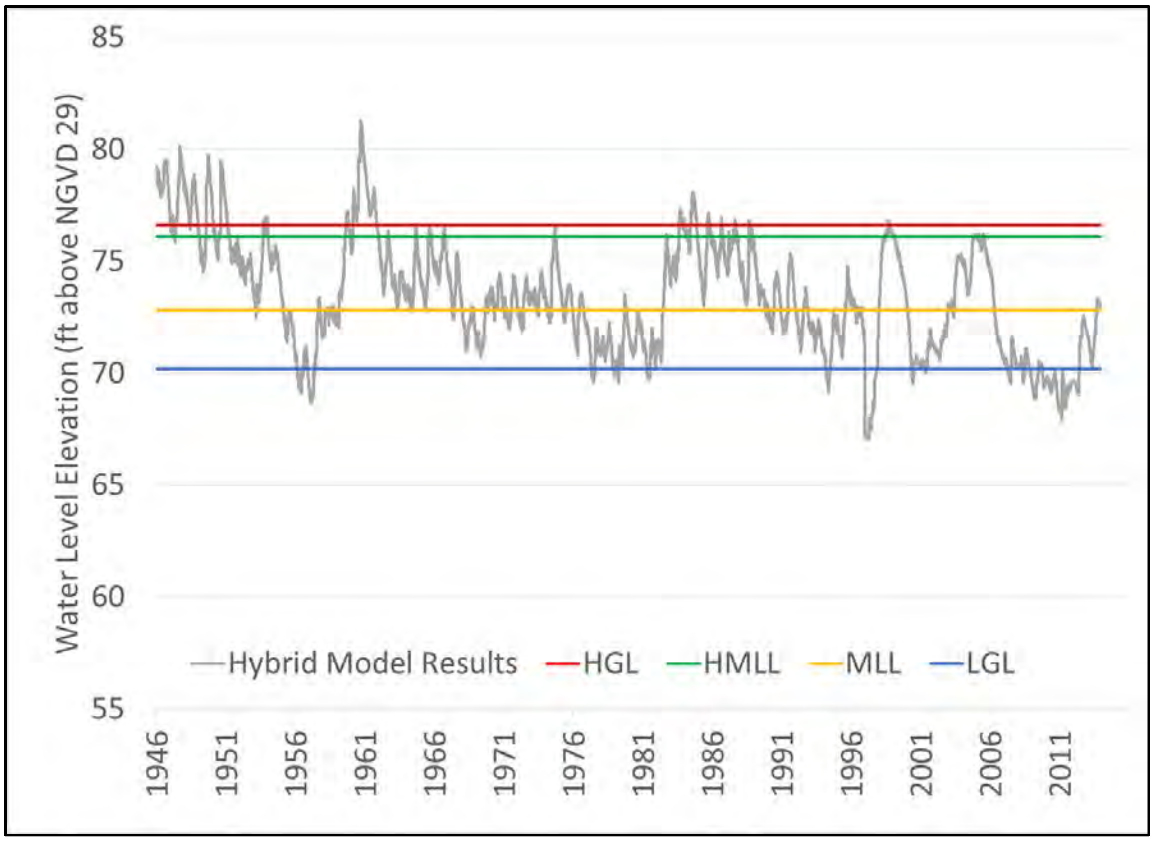

Figure 11. Historic water levels (hybrid) used to calculate the Revised Minimum and Guidance Levels. High Guidance Level (HGL. 76.6 ft.), High Minimum Lake Level (HMLL, 76.1 ft.), Minimum Lake Level (MLL, 72.8 ft.), and Low Guidance Level (LGL, 70.2 ft.).

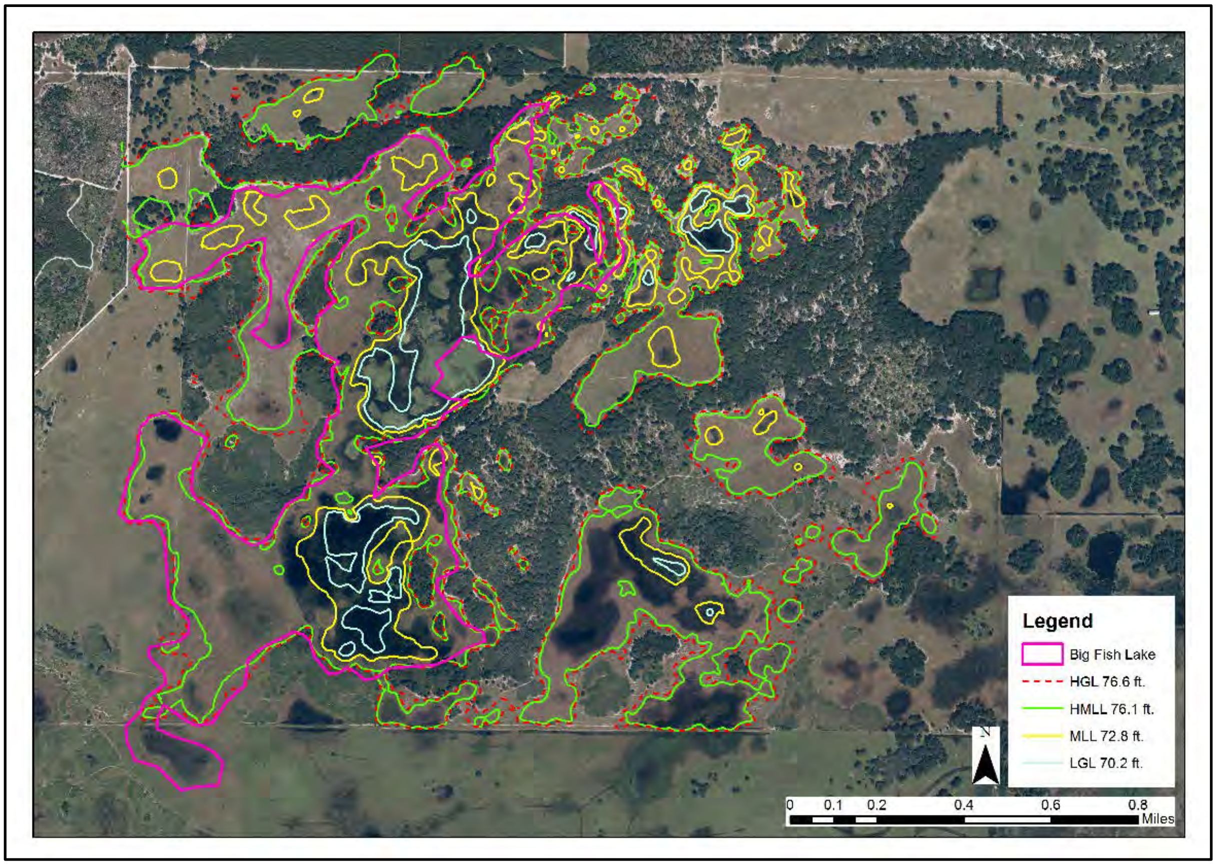

Figure 12. Big Fish Lake Minimum and Guidance Level Contour Lines Imposed Onto a 2014 Natural Color Aerial Photograph.

Many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, United States Geological Survey, and Florida's water management districts are in the process of upgrading from the National Geodetic Vertical Datum (NGVD29) standard to the North American Vertical Datum (NAVD88) standard. For comparison purposes, the revised MFLs for Big Fish Lake are presented in both datum standards (Table 6). The datum shift was calculated based on third-order leveling ties from vertical survey control stations with known elevations above the North American Vertical Datum of 1988. The NGVD29 datum was converted to NAVD88 using the Corpscon conversion of -0.86 ft.

Table 6. Revised Minimum and Guidance Levels for Big Fish Lake in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88
High Guidance Level	76.6	75.7
High Minimum Lake Level	76.1	75.2
Minimum Lake Level	72.8	71.9
Low Guidance Level	70.2	69.3

Consideration of Environmental Values

The revised minimum levels for Big Fish Lake are protective of relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.). As presented above, when developing minimum lake levels, the District evaluates categorical significant change standards and other available information to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. The Species Richness Standard was used for developing revised Minimum Levels for Big Fish Lake based on its classification as a Category 3 lake. This standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C, including: fish and wildlife habitats and the passage of fish, recreation in and on the water, and aesthetics and scenic attributes (refer to Table 2).

The minimum levels revised is protective of three additional environmental values identified in Rule 62-40.473, F.A.C. Wetland Offset, Aesthetics, and Lake Mixing Standards are lower than the revised Minimum Level. They are therefore protective of the filtration and absorption of nutrients and other pollutants, and water quality as well. In addition, the environmental value of maintenance of freshwater storage and supply is also expected to be protected by the minimum levels based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Comparison of Revised and Previously Adopted Levels

The revised High Guidance Level is 0.55 ft. higher than the previously adopted High Guidance Level, while the Low Guidance Level is 1.55 ft. lower than the previously adopted Low Guidance Level (Table 7). These differences are associated with application of a new modeling approach for characterization of Historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions.

The revised High Minimum Lake Level for Big Fish Lake is 0.45 ft. higher than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 0.25 ft. lower than the previously adopted Minimum Lake Level (Table 7). These differences are primarily due to the differences in the water level data used in Minimum and Guidance Level development.

Table 7. Revised Minimum and Guidance Levels for Big Fish Lake compared to previously adopted Minimum and Guidance Levels.

Minimum and Guidance Levels	Revised Elevation (in Feet NGVD29)	Previously Adopted Elevation (in Feet NGVD29)
High Guidance Level	76.6	76.05
High Minimum Lake Level	76.1	75.65
Minimum Lake Level	72.8	73.05
Low Guidance Level	70.2	71.75

Minimum Levels Status Assessment

To assess whether the revised Minimum Lake Level is being met, observed stage data in Big Fish Lake were used to create a long-term record using a modified version of the LOC model developed for predicting long-term lake levels (Appendix A). For the status assessment, the “current” lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable. The stage data observed on Big Fish Lake deemed as “current” for use in the in the model were from 1997 through 2013. Using the current stage data, the LOC model was created. Utilizing rainfall data in the LOC model resulted in a 68-year long-term water level record (1946-2013).

For the status assessment, cumulative median (P50) and cumulative (P10) water surface elevations were compared to the revised Minimum Lake Level and High Minimum Lake Level to determine whether long-term water levels were above the revised levels. Results from these assessments indicate that Big Fish Lake water levels are currently below the revised Minimum Lake Levels and above the revised High Minimum Lake Levels and (see Appendix B).

The lake lies within the region of the District covered by an existing recovery strategy, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution (Rule 40D80-073, F.A.C.). The District plans to continue regular monitoring of water levels in Big Fish Lake and will also routinely evaluate the status of the lake’s water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

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APPENDIX A

Technical Memorandum

July 31, 2016

TO: David Carr, Staff Environmental Scientist, Water Resources Bureau

THROUGH: Jerry L. Mallams, P.G., Manager, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau

Subject: Big Fish Lake Water Budget Model, Rainfall Correlation Model, and Historic Percentile Estimations

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A. Introduction

Water budget and rainfall correlation models were developed to assist the Southwest Florida Water Management District (District) in the reassessment of minimum levels for Big Fish Lake in north-central Pasco County. Big Fish Lake currently has adopted minimum levels which are scheduled to be re-assessed in FY 2016. This document will discuss the development of the Big Fish Lake models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Big Fish Lake is located on private property in north-central Pasco County, approximately 2.5 miles west of Bellamy Brothers Boulevard (CR 581) and 2.5 miles north of State Road 52 (Figure 1). The lake lies on or near the watershed divide for the Pithlachascotee and Hillsborough Rivers There are no significant inflow or outflows associated with the lake. During very high rainfall periods, the lake can overflow into a large, relatively flat area surrounding the lake.

Physiography and Hydrogeology

The area surrounding the lake is categorized as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks, 1981), a region of many lakes on a moderately thick plain of silty sand overlying limestone. The topography is very flat, and drainage in to the lake is a combination of overland flow and flow through drainage swales and minor conveyance systems. The topography approximately 2 miles to the west is characterized as rolling sand hills, while the beginning of the

Brooksville Ridge lies approximately 2 miles to the east, which is characterized by large hills reaching elevations over 300 feet NGVD29.

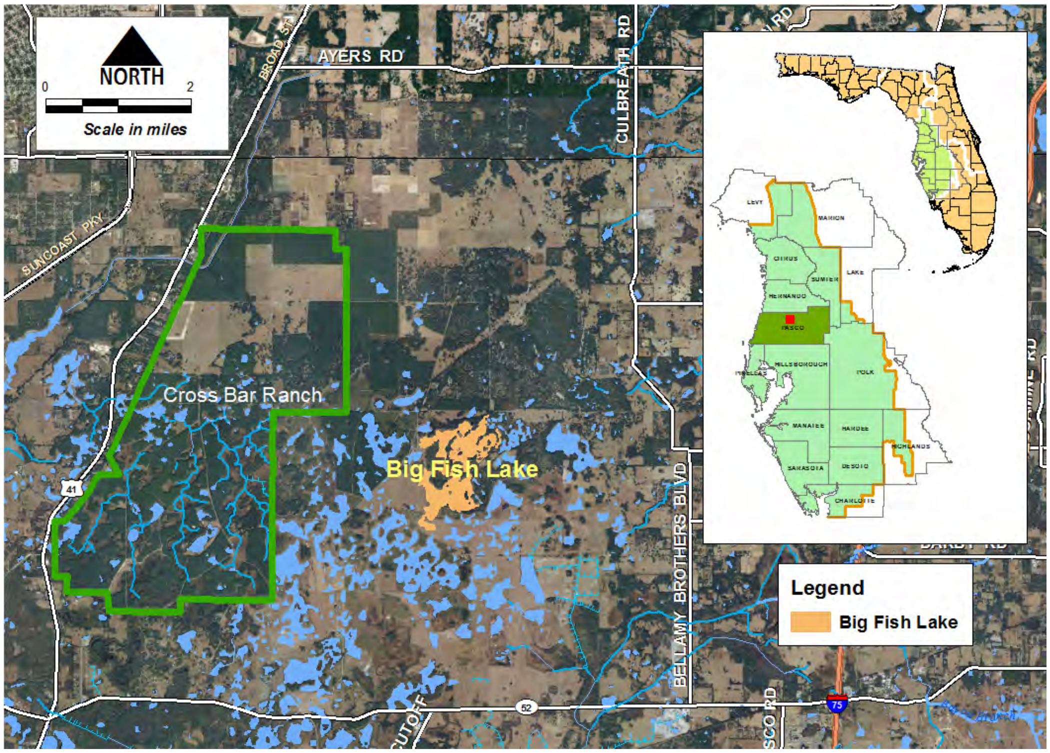

Figure 1. Location of Big Fish Lake in Pasco County, Florida.

The hydrogeology of the area includes a sand surficial aquifer; a discontinuous, intermediate clay confining unit; and the thick carbonate Upper Floridan aquifer. In general, the surficial aquifer in the study area is in good hydraulic connection with the underlying Upper Floridan aquifer because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features. The surficial aquifer is generally ten to thirty feet thick and overlies the limestone of the Upper Floridan aquifer that averages nearly one thousand feet thick in the area (Miller, 1986). In between these two aquifers is the Hawthorn Group clay that varies between a few feet to as much as 25 feet thick, but in the area of Big Fish Lake is typically much thinner or absent. Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the Upper Floridan aquifer resulting in moderate-to-high leakage to the Upper Floridan aquifer (Hancock and Basso, 1996).

Data

Water level data collection at Big Fish Lake began in 1980 by the District (Figure 2), although an approximately 10-year gap in data collection exists from early 1987 to early 1997. Since 1997, data collection frequency has typically occurred monthly or bimonthly throughout the period of record by both the District and Tampa Bay Water.

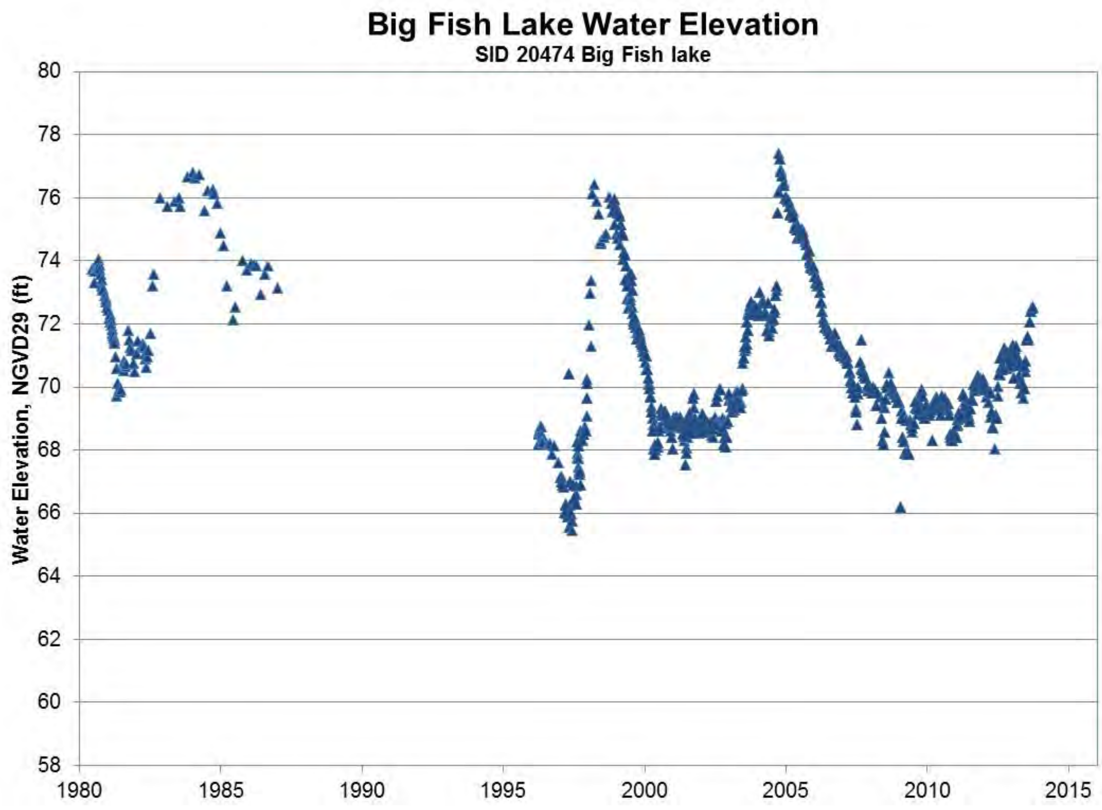

Figure 2. Big Fish Lake water levels.

Water levels from the CB-2E Floridan and surficial aquifer monitor wells and the CB-3E Floridan and surficial aquifer monitor wells are available beginning in 1997 (Figures 3, 4, and 5). The CB-2E wells are located approximately 4,500 feet west of Big Fish Lake, while the CB-3E wells are located along the eastern shore of the north pool of Big Fish Lake. Both well nests have had recorders collecting hourly data throughout most of the period of record. The CB-2E well displays an unconfined Upper Floridan aquifer, while the CB-3E well shows evidence of some confinement near the lake.

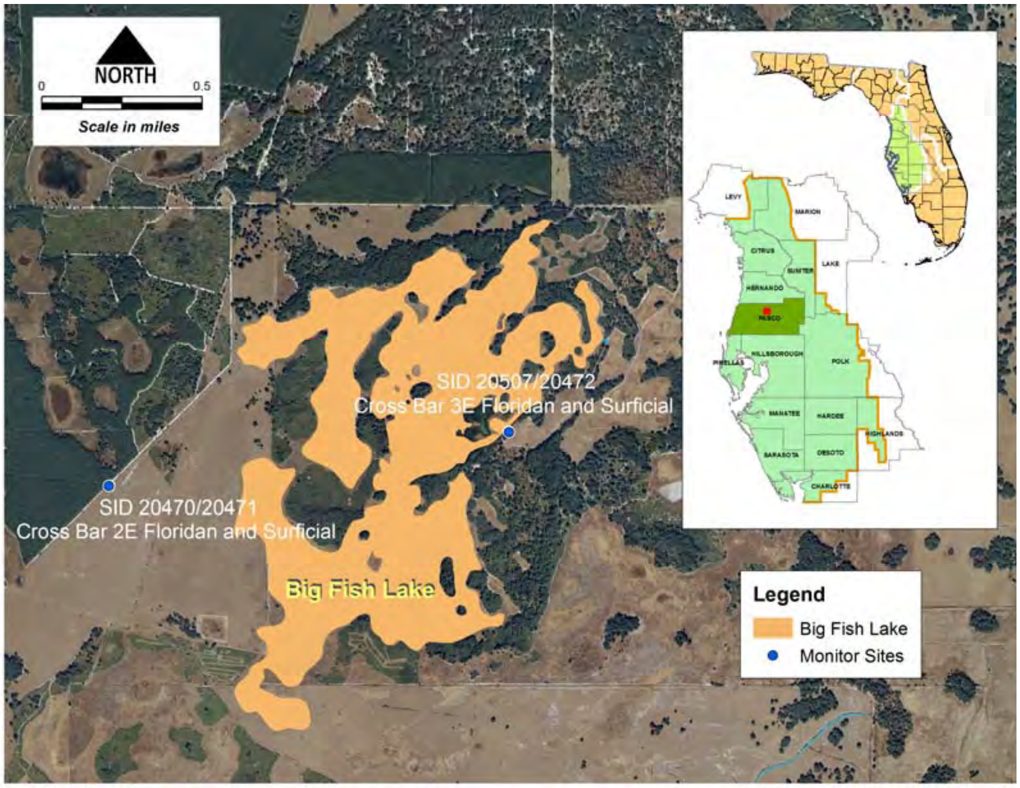

Figure 3. Location of monitor wells near Big Fish Lake.

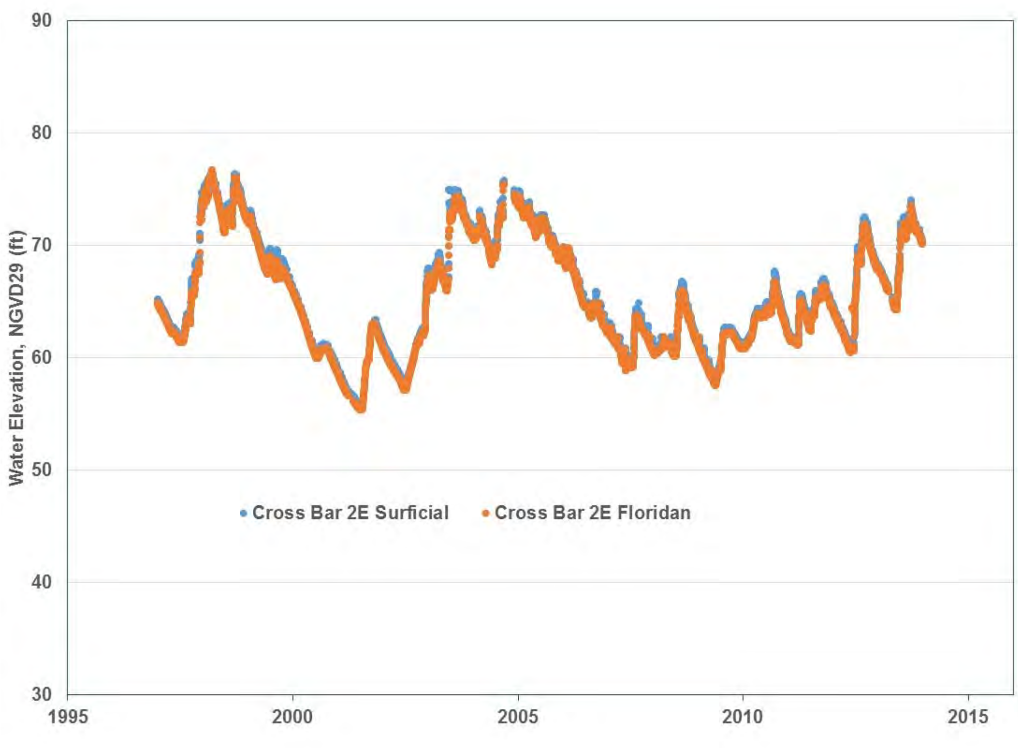

Figure 4. Water levels in the CB-2E Surficial and Floridan aquifer monitor wells.

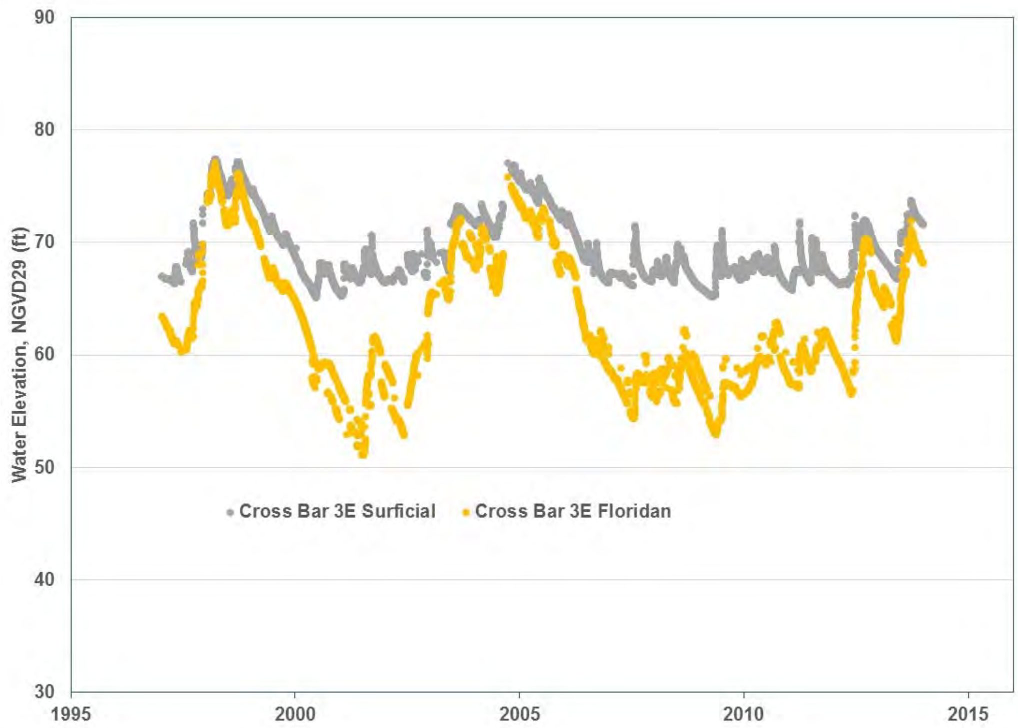

Figure 5. Water levels in the CB-3E Surficial and Floridan aquifer monitor wells.

Land and Water Use

Nearly all of the public water supply withdrawals in the area are associated with Cross Bar Ranch Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water, and located approximately 2.5 miles west of Big Fish Lake (Figure 6). Groundwater withdrawals began at the Cross Bar Ranch Wellfield in 1980 and steadily climbed to approximately 30 million gallons per day (mgd) by the early 1990s (Figure 7). Monthly withdrawal rates since 2005 have averaged from 12 to 18 mgd.

Water levels in many lakes in the Cross Bar Ranch Wellfield area dropped significantly since public supply groundwater withdrawals began (Hancock and Basso, 1996). Because Big Fish Lake water level data collection did not begin until after the beginning of withdrawals from the wellfield (Figure 8), the correlation between ground-water withdrawals and lake level cannot be easily made from the comparison of data. Figure 9 shows the land use and conditions around Big Fish Lake in 1951 and 2011. Much of the land use is pasture in both years. Water levels were generally higher in 1951 throughout the area, although, as seen in Figure 2, the water levels fluctuate significantly depending on rainfall in the area. In more recent years, while the land use surrounding the lake has not seen dramatic changes, water use has changed. As seen in Figure 7, groundwater withdrawal rates from the Cross Bar Ranch Wellfield have reduced in the early to mid-2000s, from the 25 to 30 mgd range to 15 to 20 mgd range.

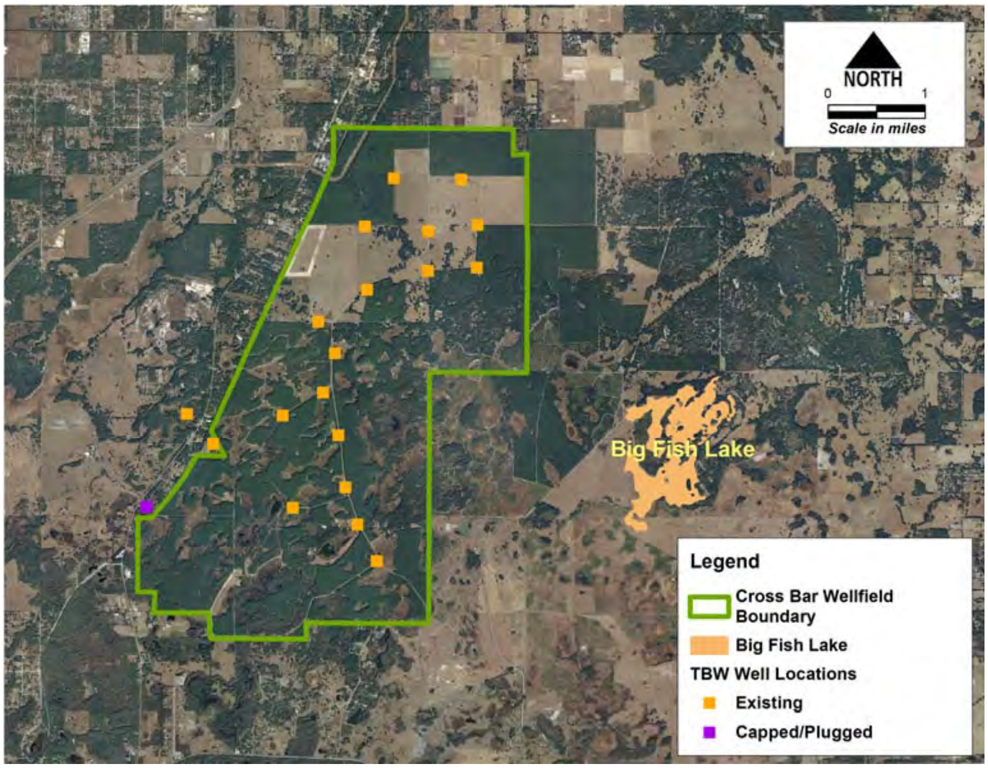

Figure 6. Big Fish Lake and the Cross Bar Ranch Wellfield.

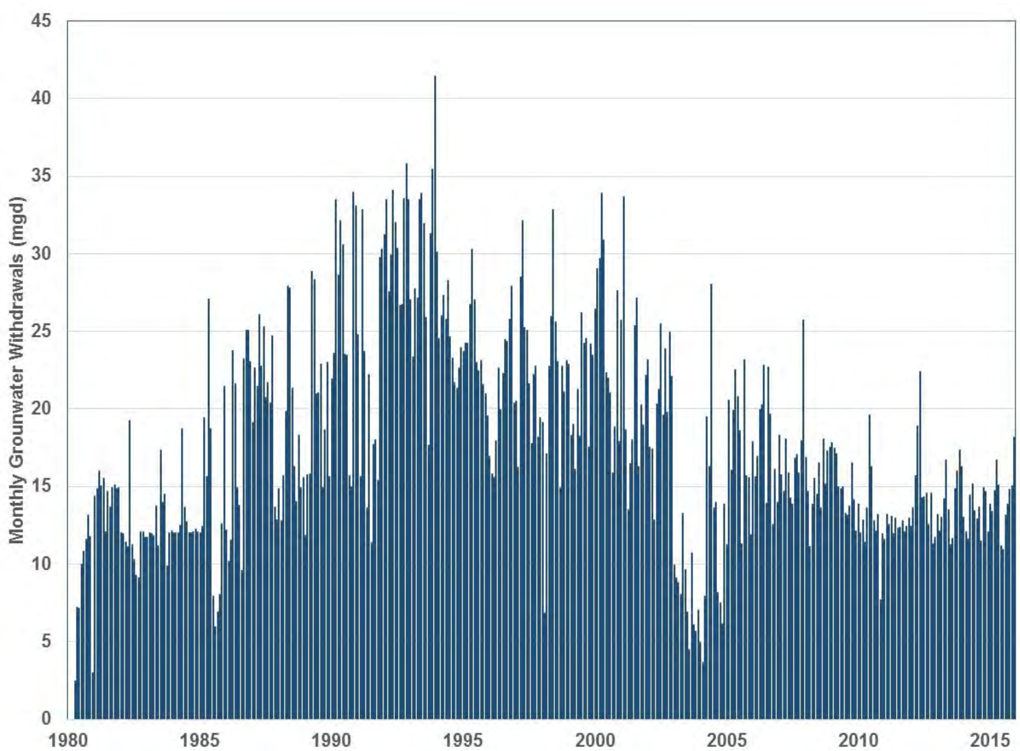

Figure 7. Monthly Cross Bar Ranch Wellfield withdrawals.

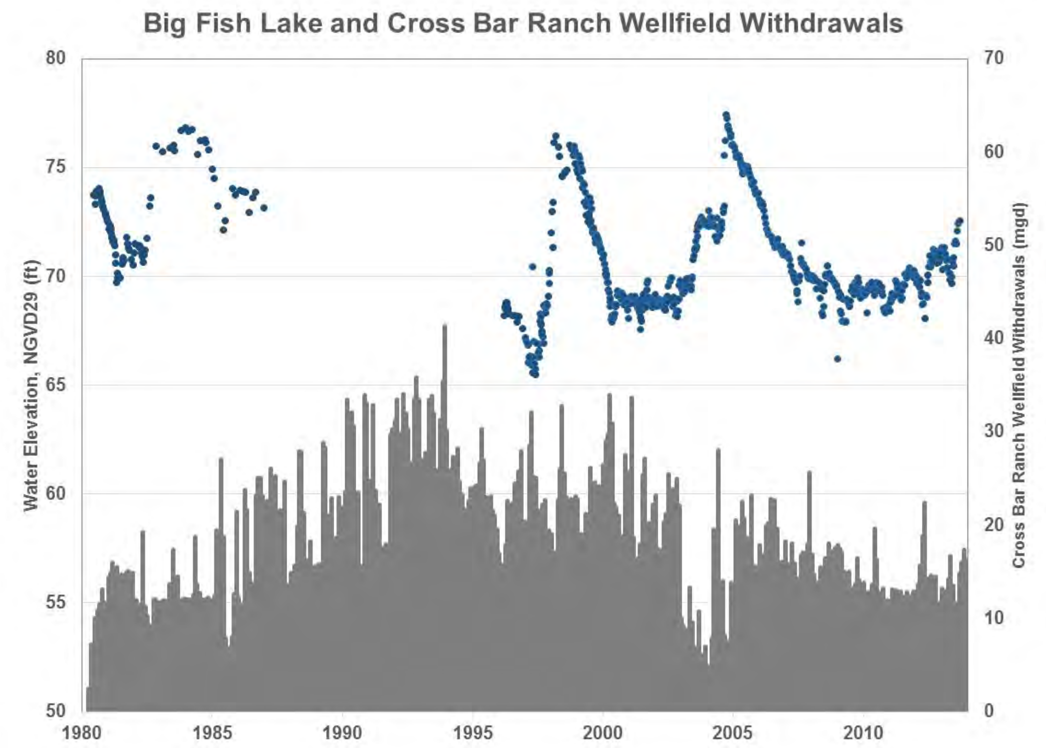

Figure 8. Water levels in Big Fish Lake and groundwater withdrawals at the Cross Bar Ranch Wellfield.

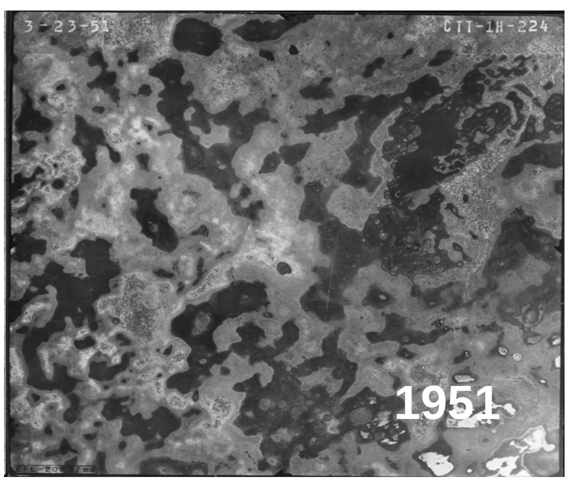

Figure 9. Land use and conditions around Big Fish Lake in 1951(left) and 2011 (right).

Since the summer of 2000, due to concerns of low lake levels, Tampa Bay Water and the property owners began augmenting the lake with water withdrawn from the Floridan aquifer (WUP No. 2005897.003). Figure 10 presents the metered augmentation withdrawals through 2013. The permit originally allowed for 310,000 gpd annual average withdrawals from the Floridan aquifer for augmentation, and was increased to

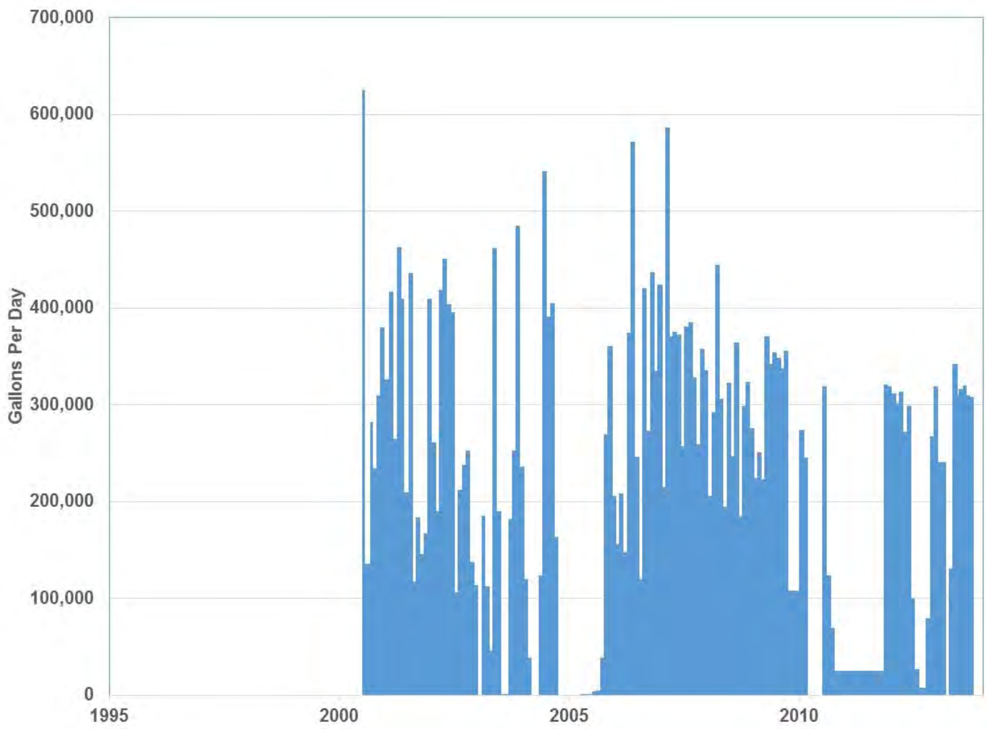

Figure 10. Metered augmentation withdrawals at Big Fish Lake.

1,540,000 gpd annual average withdrawals in 2015 through a newly issued permit (WUP No. 20020500).

C. Purpose of Models

Prior to establishment of Minimum Levels, long-term lake stage percentiles are developed to serve as the starting elevations for the determination of the lake's High Minimum Lake Level and the Minimum Lake Level. A critical task in this process is the delineation of a Historic time period. The Historic time period is defined as a period of time when there is little to no groundwater withdrawal impact on the lake, and the lake's structural condition is similar or the same as present day. The existence of data from a Historic time period is significant, since it provides the opportunity to establish strong predictive relationships between the lake water levels and natural stresses. This relationship can then be used to assess the effect of groundwater withdrawals on lake levels, and to calculate a long-term Historic lake exceedance percentiles such as the P10, P50, and P90 (respectively, the water levels equaled or exceeded ten, fifty, and ninety percent of the time). If data representative of a Historic time period does not exist, or available Historic time period data is considered too short to represent long-term conditions, then a model is developed to approximate long-term Historic data.

In the case of Big Fish Lake, the Cross Bar Ranch Wellfield has potentially affected water levels in the lake since 1980. Other groundwater withdrawals (potentially including other public supply withdrawals) in the area could also affect levels, but the effect of such withdrawals would be much smaller and less consistent. No data from Big Fish Lake exists prior to the initiation of groundwater withdrawals from the Cross Bar Ranch Wellfield. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered essential for estimating long-term Historic percentiles, accounting for changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

The Big Fish Lake water budget model was developed by SDI Environmental Services, Inc. (2014), and was adopted by the District for use in this analysis. The details of the model can be found in SDI Environmental Services, Inc. (2014), and are summarized below. The Big Fish Lake water budget model is a spreadsheet-based tool that includes natural hydrologic processes and engineered alterations acting on the control volume of the lake. The control volume consists of the free water surface within the lake extending down to the elevation of the greatest lake depth. A stage-volume curve was derived for the lake that produced a unique lake stage for any total water volume within the control volume.

The hydrologic processes in the water budget model include:

a. Rainfall and evaporation
b. Augmentation from the Upper Floridan Aquifer
c. Overland flow
d. Inflow and discharge via channels
e. Flow from and into the surficial aquifer
f. Flow from and into the Upper Floridan aquifer

The water budget model uses a daily time-step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels for each lake. The water budget model for Big Fish Lake is calibrated from 1997 through 2013. This period provides the best balance of using available data for all parts of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage area and stage volume estimates were determined by building a terrain model of the lake and surrounding watersheds. Lake bottom elevations and land surface elevations were used to build the model with LP360 (by QCoherent) for ArcGIS, ESRI's ArcMap 10.2, the 3D Analyst ArcMap Extension, Python, and XTools Pro. The overall process involves merging the terrain morphology of the lake drainage basin with the underlying lake basin morphology to develop one continuous three-dimensional (3D) digital elevation model. The 3D digital elevation model was then used to calculate area of the lake and the associated volume of the lake at different elevations, starting at the extent of the lake at its flood stage and working downward to the lowest elevation within the basin.

Creating the stage/volume/surface area model for Big Fish Lake was more difficult than any other lake modeled in the Northern Tampa Bay area as of the date of this report because there is no clear break point for a high level. As seen well in Figure 6, there are dozens of pools of water that become incorporated into Big Fish Lake as the water levels rise. Several attempts were made in which multiple groups of pools were lumped and split, but eventually two large basins were chosen. A north and south basin of the lake was determined, with a connection at approximately 72.0 feet NGVD29. Below this elevation, the basins were modeled separately. A high of 76.8 feet NGVD29 was chosen as the high end for the stage/volume/surface area relationship, although there are three data points in October 2004 (after two hurricanes passed through the area) that are higher than 76.8 feet NGVD29. As can be seen below, the model was not able to be calibrated to these high values, and there is some question as to their measured accuracy due to high water levels in the area at the time.

Precipitation

The Big Fish Lake rain gage on the east side of the lake was used for the model, which covers the period from 1997 to current (Figure 11). Data at this gage is collected by Tampa Bay Water. The median of four other Tampa Bay Water gages on the nearby Cross Bar Ranch wellfield were used to fill in missing data points (Figure 11). The median value from these gages was used to minimize bias.

Lake Evaporation

Lake evaporation was estimated through use of monthly energy budget evaporation data collected by the U.S. Geological Survey (USGS) at Lake Starr in Polk County (Swancar and others, 2000) (Figure 12). The data was collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the Big Fish Lake water budget model when available, and monthly averages for the period of record were used for those months in the model when Lake Starr evaporation data were not available.

A recent study compared monthly energy budget evaporation data collected from both Lake Starr and Calm Lake (Swancar, 2011, personal communications). Calm Lake is located approximately 19 miles to the southwest of Big Fish Lake (Figure 12). The assessment concluded that the evaporation rates between the two lakes were nearly

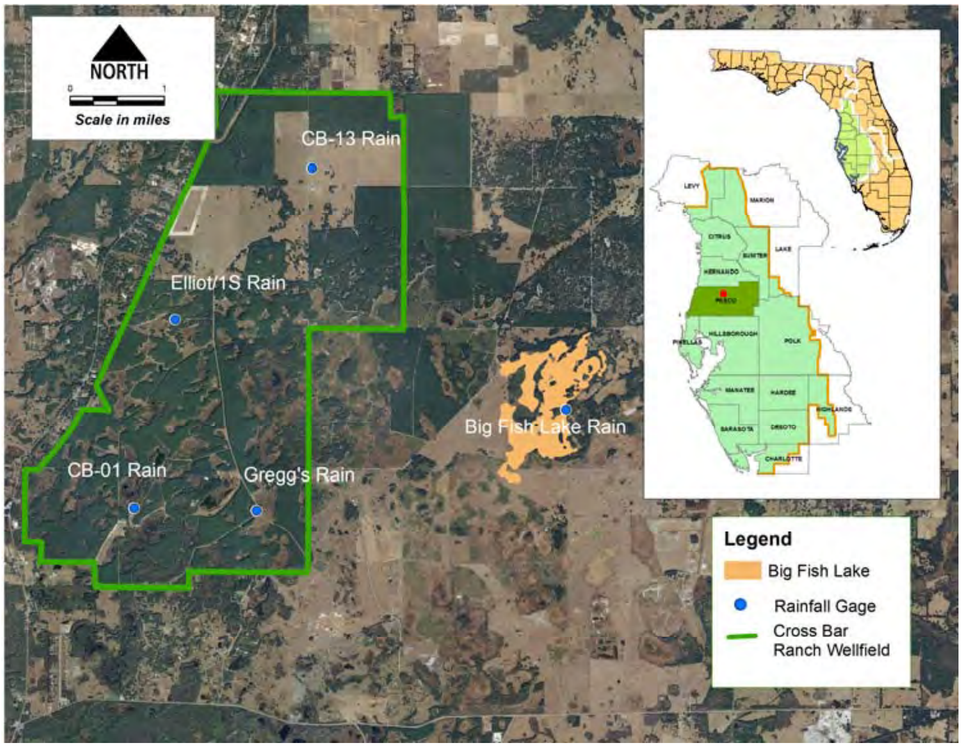

Figure 11. Rain gages used in the Big Fish Lake water budget model.

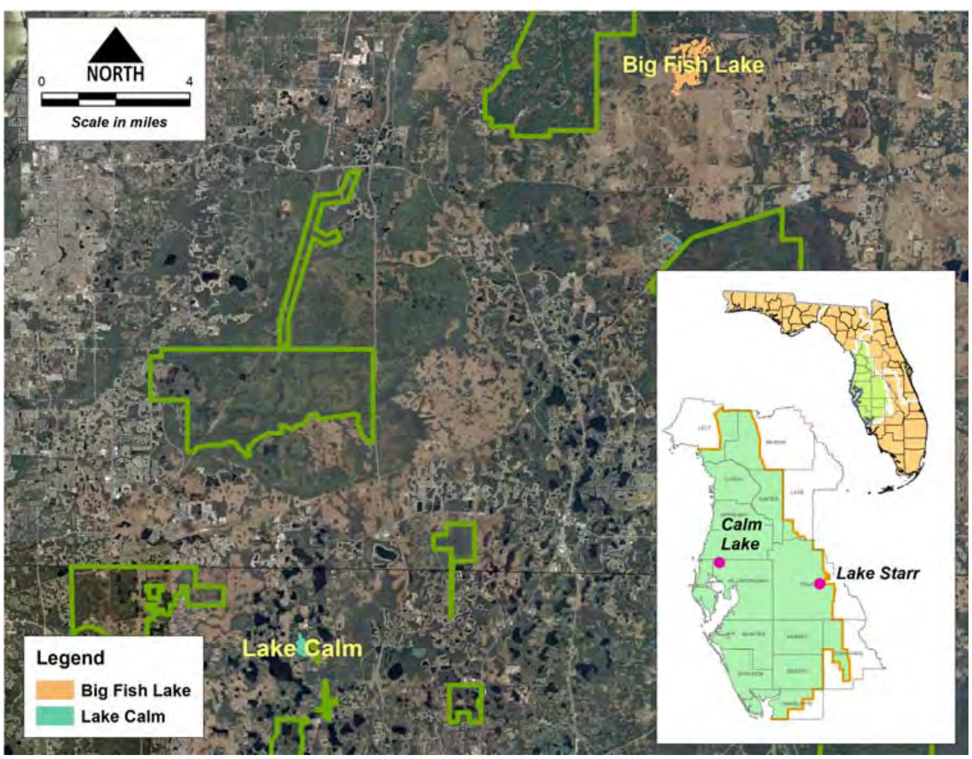

Figure 12. Location of Big Fish Lake, Lake Calm and Lake Starr (see map inset).

the same, with small differences attributed to measurement error and monthly differences in latent heat associated with differences in lake depth.

Jacobs (2007) produced daily potential evapotranspiration (PET) estimates on a 2-square kilometer grid for the entire state of Florida. The estimates began in 1995, and are updated annually. These estimates, available from a website maintained by the USGS, were calculated through the use of solar radiation data measured by a Geostationary Operational Environmental Satellite (GOES). Because PET is equal to lake evaporation over open water areas, using the values derived from the grid nodes over the modeled lake was considered. A decision was made to instead use the Lake Starr evaporation data since the GOES data nodes typically include both upland and lake estimates, with no clear way of subdividing the two. It was thought that using the daily PET estimates based on the GOES data would increase model error more than using the Lake Starr data directly.

Augmentation withdrawn from the Upper Floridan aquifer

When applicable, augmentation quantities withdrawn from the Upper Floridan aquifer were added to the lake on a daily basis, based on the available metered values (Figure 10). Because monthly totals are all that is required for the permit issued by the District, an assumption was made that the monthly total was distributed evenly each day of the month for which augmentation was reported.

Overland Flow

The water budget model was set up to estimate overland flow via a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), and via directly connected impervious area calculations. The free water area of the lake was subtracted from the total watershed area at each time step to estimate the watershed area contributing to surface runoff. The directly connected impervious area (DCIA) is subtracted from the watershed for the SCS calculation, and then added to the lake water budget separately. The curve number (CN) chosen for the watershed of the lake takes into account the amount of DCIA in the watershed that has been handled separately. The modified SCS method was suggested for use in Florida by CH2M HILL (2003), and has been used in several other analyses.

Several slightly varying estimates of watershed boundaries for Big Fish Lake have been performed in the past for different modeling efforts in the area. The watershed of the lake is difficult to determine since the lake consists of a series of pools that become interconnected depending on the stage of the lake, thus the watershed of the pools grows with the stage. The overland flow watershed was estimated to be approximately 997 acres, including the lake (Figure 13).

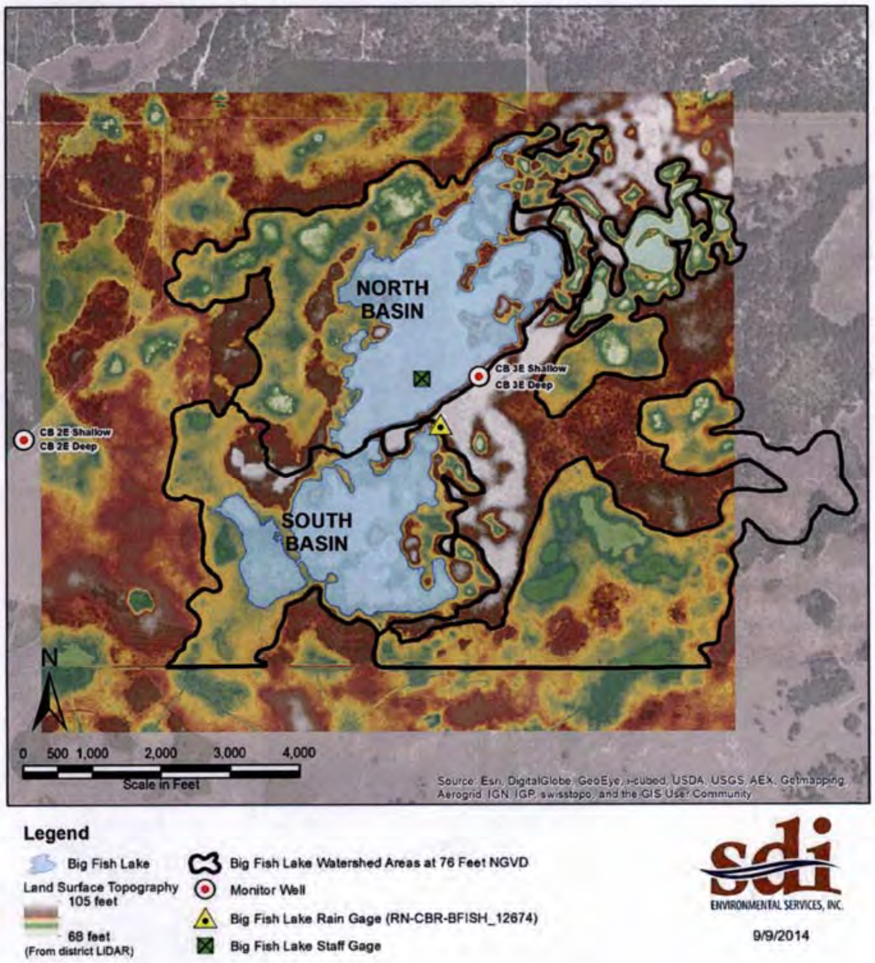

Figure 13. Direct overland flow portion of the Big Fish Lake watershed (from SDI Environmental Services, Inc., 2014).

The SCS CN used for the direct overland flow portion of the watershed is listed in Table 1. Curve Numbers were difficult to assess. The soils in the area of the lake are A, A/D, B/D, C, and D soils. The A/D and B/D soil type means that the characteristics of the soils are highly dependent on how well they are drained. A “D” soil will generally have a higher amount of runoff per quantity of rain than “A” or “B” soils. Because of the proximity of the Cross Bar Ranch Wellfield to the area being modeled, water levels have been historically lowered by the withdrawals, and therefore the soils in the area may have had lower runoff rates during that time (characteristic of “A” or “B” soils). Groundwater withdrawals during the period of calibration were, however, significantly reduced relative to historic withdrawal rates, so the A/D and B/D soils in the area may have begun to exhibit runoff properties more characteristic of “D” soils.

For purposes of this model, taking into account the range of conditions experienced, a weighted Curve Number of 67.4 was calculated using the number of acres of each soil type within the basin times its respective Curve Number divided by total area compromise was used for the CN.

Table 1. Model inputs for the Big Fish Lake water budget model.

Input Variable	Value
Overland Flow Watershed Size in acres (including the lake)	997.0
SCS CN of watershed	67.4
FL Monitor Well Used	CB 3E Deep
Surf. Aq. Monitor Well(s) Used	CB 3E Shallow
Surf. Aq. Hydraulic Conductivity (ft/day)	10
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.001

Inflow and Discharge via Channels from Outside Watersheds

There are no significant inflows or outflows from Big Fish Lake. The lake consists of several basins interconnected at various elevations. The two basins most commonly considered part of the lake are referred to as the North and South basins, and become separated at elevations below approximately 72 feet NGVD29. Several other basins become connected to the lake at various higher elevations. All of the basins are accounted for in the lake stage/volume relationships.

A control elevation of 76.1 feet NGVD29 was previously determined through survey (at which point the lake would flow toward the west). This elevation is rarely reached, but several lake level readings are above this elevation.

Flow from and into the surficial aquifer and Upper Floridan aquifer

Surficial aquifer groundwater inflow and outflow to the lake control volume was estimated using a form of Darcy's Law, represented as Q = TIL, where T is the transmissivity of the surficial aquifer, I is the water level gradient, and L is the lake perimeter. Because of its proximity to the lake, the CB-3E Shallow surficial aquifer monitor well was used for gradient calculations (Figures 3 and 5).

The CB-3E Deep Floridan aquifer monitor well is the closest Upper Floridan aquifer monitor well to Big Fish Lake, and was used to represent the potentiometric surface at the lake (Figure 5). Because the elevation of recent potentiometric surface maps appears to be within one foot between the lake and the well, no adjustments were made to the water levels of this well for modeling purposes. A leakance rate of 0.001 ft/day/ft was determined through the calibration process.

F. Water Budget Model Calibration

The primary reason for the development of the water budget model was to estimate Historic lake stage exceedance percentiles that could be used to support development of Minimum and Guidance Levels for the lake. Model calibration was therefore focused on matching long-term percentiles based on measured water levels, rather than short-term high and low levels.

Measured data from the lake were used for comparison with modeled water levels. Daily values were generated from the model, but only measured lake data points are used for the calibration.

Figure 14 presents the calibration results of the model. Table 2 presents a comparison of the percentiles of the measured data versus the model results. Table 3 presents modeled water budget components for the model calibration period.

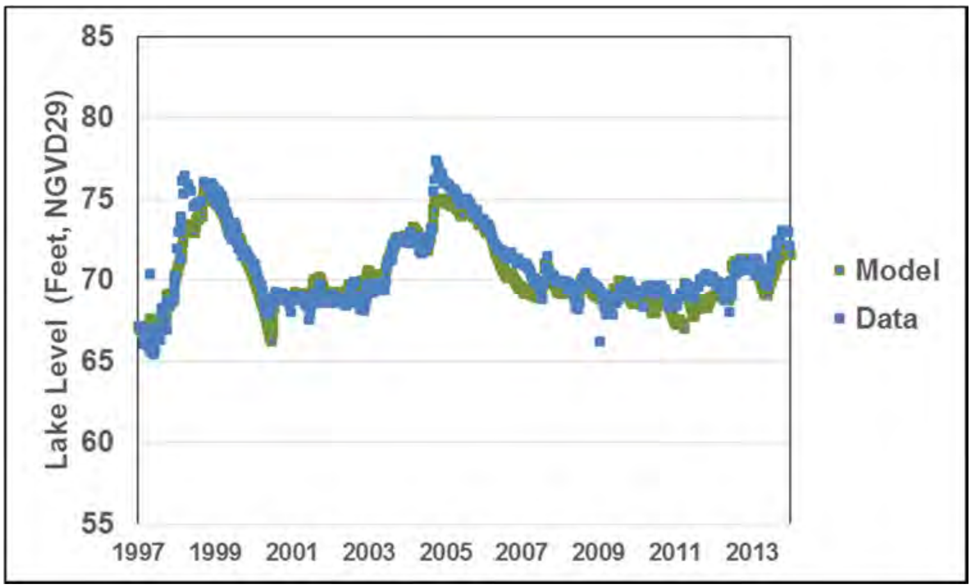

Figure 14. Modeled water levels predicted for the calibrated Big Fish Lake water budget (Model) and measured levels used for the model calibration (Data).

Table 2. Comparison of percentiles of measured lake level data compared to calibration percentiles from the model (all in feet NGVD29).

	Data	Model
P10	74.3	73.7
P50	69.9	69.5
P90	68.4	68.1

Table 3. Big Fish Lake Water Budget (1997-2013)

Inflows	Rainfall	Surficial Aquifer Ground water Inflow	Floridan Aquifer Ground water Inflow	Runoff	DCIA Runoff	Aug.	Inflow via channel	Total
Inches/year	52.0	3.8	0.3	29.1	0	47.0	0	132.2
Percentage	39.3	2.9	0.2	22.0	0	35.6	0	100.0
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**				**Outflow via channel**	**Total**
Inches/year	58.1	22.1	43.7				0	123.9
Percentage	46.9	17.8	35.3				0	100.0

G. Water Budget Model Calibration Discussion

Based on a visual inspection of Figure 15, the model appears to be reasonably well calibrated. There are a few periods when the peaks in the modeled hydrograph are higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with higher and lower lake levels, i.e., the P10 and P90 percentiles. Reduced precision in the higher and lower ranges of the stage-volume relationships for the lake may also have contributed to the percentile differences.

A review of Table 2 shows that the data and model median percentiles (P50) for the lake are within 0.4 feet, the data and model P10 percentiles for the lake are within 0.6 feet, and the data and model P90 percentiles for the lake are within 0.3 feet. Some of the differences at the higher and lower percentiles may be due to less detail in the higher and lower stage-volume relationships. However, because of the short period of record for the lake, and the limited data points at very high elevations, the P10 of the values may be much less accurate than the P50 or lower values.

The water budget component values in the model can be difficult to judge since they are expressed as inches per year over the average lake area for the period of the model run. Leakage rates (and leakance coefficients), for example, represent conditions below the lake only, and may be very different than those values expected in the general area. Runoff also represents a volume over the average lake area, and when the resulting values are divided by the watershed area, they actually represent fairly low runoff rates.

H. Water Budget Model Scenario

Groundwater withdrawals are not directly included in the Big Fish Lake water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Cross Bar Ranch Wellfield are available for the model calibration period, so if a relationship between withdrawal rates and Upper Floridan aquifer potentiometric levels can be established, the effect of changes in groundwater withdrawals can be estimated by adjusting Upper Floridan aquifer levels in the model.

The Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013) is an integrated surface water / groundwater model developed for the northern Tampa Bay area. The INTB model has the ability to account for groundwater and surface-water, as well as the interaction between them. The domain of the INTB application includes the Big Fish Lake area, and represents the most current understanding of the hydrogeologic system in the area.

The INTB was used to determine the drawdown in the surficial aquifer and Upper Floridan aquifer in response to groundwater withdrawals in the area. Drawdown in both aquifers was calculated for two withdrawal rates representing the effects of Tampa Bay Water's regional wellfields before and after cutbacks from approximately 150 mgd to 90 mgd. The pre-cutback period in the model is from 1997 through 2003, while the post-cutback period is 2004 through 2013. The model results allowed the drawdowns associated with all permitted withdrawals to be calculated before and after wellfield cutbacks, assuming changes in all other withdrawals are consistent with the modeled period.

The INTB model was run for each withdrawal scenario from 1996 to 2006 using a daily integration step. Drawdown values in feet were calculated by running the model with and without groundwater withdrawals, and were calculated for each node in the model. The INTB model uses a one-quarter mile grid spacing in the area of the wellfields. Groundwater withdrawal rates from the Cross Bar Ranch Wellfield in each scenario were 22.5 mgd and 16.0 mgd, respectively. Using the drawdowns determined through the INTB model, the Upper Floridan aquifer and surficial monitor well data in the model can be adjusted to reflect changes in groundwater withdrawals.

To estimate lake levels without the influence of groundwater withdrawals, the Upper Floridan aquifer and surficial aquifer wells in the water budget model were adjusted to represent zero withdrawals. For the 1997 to 2013 water budget model period, two periods of adjustment were used to reflect the cutbacks that took place at the Cross Bar Ranch Wellfield. Adjustments to each Upper Floridan aquifer and surficial aquifer well and the associated adjustment periods are found in Table 4.

Table 4. Aquifer water level adjustments to the Big Fish Lake model to represent Historic percentiles

Well	**Adjustment (feet) 1997 through 2003**	**Adjustment (feet) 2004 through 2013**
Upper Floridan aquifer	4.0	2.1
Surficial aquifer	3.8	2.0

Additionally, because Big Fish Lake has experienced a significant amount of augmentation during the modeled period, the augmentation was removed from the model for the scenario runs. This allows the results to represent the hydrology of the lake with no man-made effects (with the exception of permanent structures).

Figure 15 presents measured water level data for the lake along with the model's simulated lake levels under Historic conditions, i.e. in the absence of groundwater withdrawals with structural alterations similar to current conditions. Table 5 presents the Historic percentiles based on the model output.

Historic normal pool elevations are established for lakes, ponds and wetlands to standardize measured water levels and facilitate comparison among wetlands and lakes. The Historic normal pool elevation is commonly used in the design of wetland storm water treatment systems (Southwest Florida Water Management District, 1988). The normal pool can be consistently identified in cypress swamps or cypress-ringed lakes based on similar vertical locations of several indicators of inundation (Hull, et al, 1989; Biological Research Associates, 1996). Historic normal pools have been used as an estimate of the Historic P10 in natural wetlands and lakes, based on observation of many control sites in the northern Tampa Bay area.

Figure 15. Measured lake levels (Data) and Historic water levels predicted with the calibrated Big Fish Lake model (Model).

Table 5. Historic percentiles estimated by the Big Fish Lake water budget model (in feet NGVD29).

Percentile	Elevation
P10	75.9
P50	71.1
P90	69.2

Because Big Fish Lake is in a sand hill setting, rather than a flatwoods setting for which the Historic normal pool concept was developed, there is some question on how well the Historic normal pool applies to Big Fish Lake. The Historic normal pool was determined for Big Fish Lake based on the base of saw palmetto, and was determined to be 76.2 feet NGVD29 (based on the median of 28 palmetto bases, to which 0.25 is added – see Southwest Florida Water Management District, 2005). While the Historic normal pool and natural P10 in lakes and wetlands in the northern Tampa Bay area may differ by several tenths of a foot in many cases, the model's estimate of the Historic P10 for Big Fish Lake is approximately 0.3 feet lower than the field determined Historic normal pool. Therefore, there is no conflict between the Historic P10 calculated and the estimated Historic normal pool.

I. Rainfall Correlation Model

In an effort to extend the period of record of the water levels used to determine the Historic percentiles to be used in the development of the Minimum Levels, a line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 1997). LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data.

In this application, the simulated lake water levels representing Historic conditions were correlated with Long-term rainfall. For the correlation, additional representative rainfall records were added to the rainfall records used in the water budget model (1997-2013). The median of four rainfall gages on the Cross Bar Ranch Wellfield was used from April 4, 1981 through February 4, 1996, and the Big Fish Lake rainfall gage was used from February 5, 1996 through December 31, 1997. The average of the Brooksville NWS and St Leo NWS stations was used from 1930 through April 3, 1981 (Figure 17).

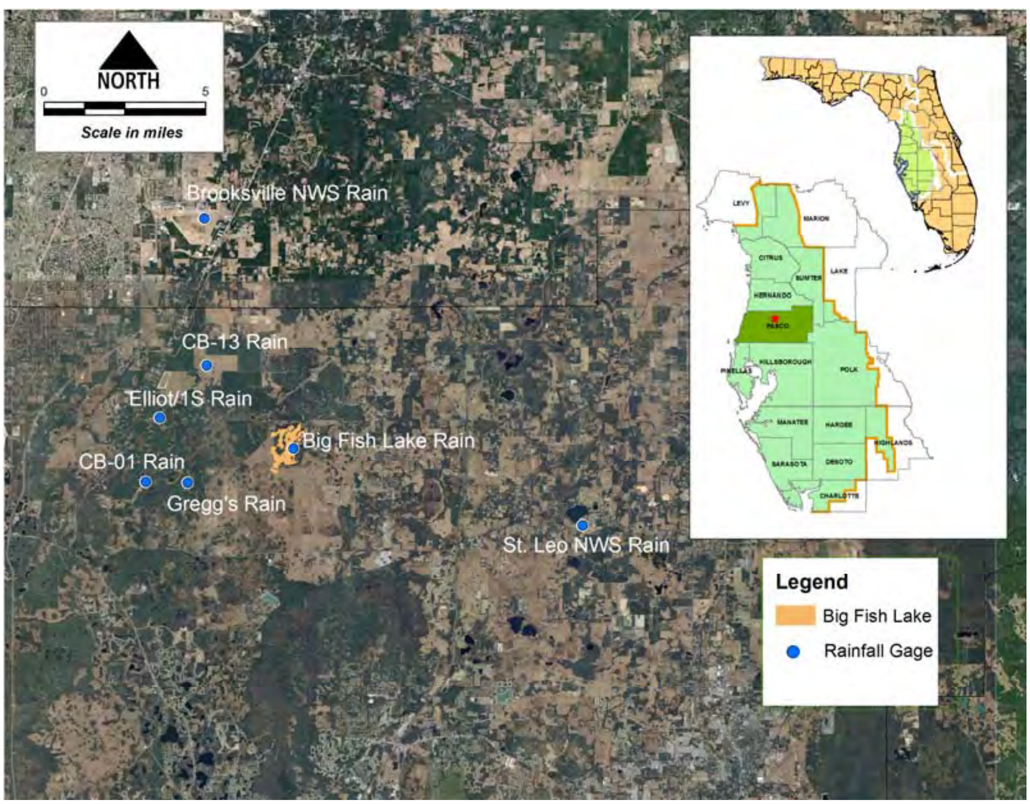

Figure 17. Location of rain stations used for the rainfall correlation model.

Rainfall is correlated to lake water level data by applying a linear inverse weighted sum to the rainfall. The weighted sum gives higher weight to more recent rainfall and less weight to rainfall in the past. In this application, weighted sums varying from 6 months to 10 years are separately used, and the results are compared, with the correlation with the highest correlation coefficient (R^2) chosen as the best model.

Rainfall was correlated to the water budget model results for the entire period used in the water budget model (1997-2013), and the results from 1946-2013 (68 years) were produced. For Big Fish Lake, the 6-year weighted model had the highest correlation coefficient, with an R^2 of 0.60. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2 to 6 year range. The results are presented in Figure 18.

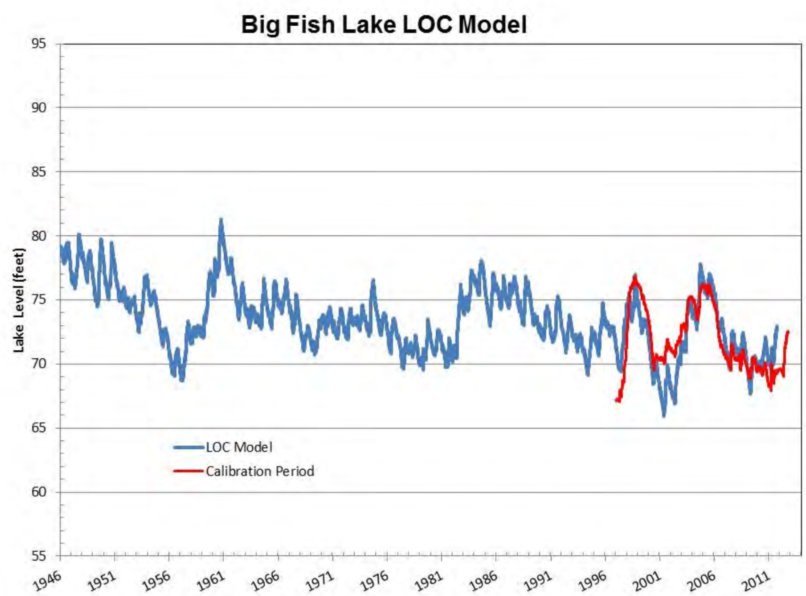

Figure 18. LOC model results for Big Fish Lake.

In an attempt to produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946-1973, while the water budget results are used for the period of 1997-2013. These results are referred to as the "hybrid model." The resulting Historic percentiles for the hybrid model are presented in Table 6. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 5) and those from the hybrid rainfall model (Table 6) for Big Fish Lake are 0.8, 2.2, and 1.2 feet, respectively. These differences are much larger than previously found for lakes in the northern Tampa Bay area within flatwoods settings, perhaps demonstrating the sensitivity that lake levels have in sand hill settings.

Table 6. Historic percentiles as estimated by the hybrid model from 1946 to 2013 (feet NGVD29).

Percentile	Big Fish Lake
P10	76.6
P50	73.3
P90	70.2

J. Conclusions

Based on the model results and the available data, the Big Fish Lake water budget and LOC rainfall models are useful tools for assessing long-term percentiles in the lake. Based on the same information, lake stage exceedance percentiles developed through use of the models appear to be reasonable estimates for Historic conditions.

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APPENDIX B

Technical Memorandum

July 31, 2016

TO: Jerry L. Mallams, P.G., Manager, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
David Carr, Staff Environmental Scientist, Water Resources Bureau
Donna E. Campbell, Environmental Scientist, Water Resources Bureau

Subject: Big Fish Lake Initial Minimum Levels Status Assessment

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A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Big Fish Lake and is proposing revised minimum levels for the lake, in accordance with Section 373.042 and 373.0421, Florida Statutes (F.S). Documentation regarding development of the revised minimum levels is provided by Hancock (2016) and Carr and others (2016).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Big Fish Lake and other waterbodies with established minimum flows or levels in the northern Tampa Bay area, an applicable regional recovery strategy, referred to as the "Comprehensive Plan", has been developed and adopted into District rules (Rule 40D-80.073, F.A.C.). One of the goals of the Comprehensive Plan is to achieve recovery of minimum flow and level water bodies such as Big Fish Lake that are located in the area affected by the Consolidated Permit wellfields (i.e., the Central System Facilities) operated by Tampa Bay Water. This document provides information and analyses to be considered for evaluating the status (i.e., compliance) of the revised minimum levels proposed for Big Fish Lake and any recovery that may be necessary for the lake.

B. Background

Big Fish Lake is located on private property in north-central Pasco County, approximately 2.5 miles west of Bellamy Brothers Boulevard (CR 581) and 2.5 miles north of State Road 52 (Figure 1). The lake lies on or near the watershed divide for the Pithlachascotee and

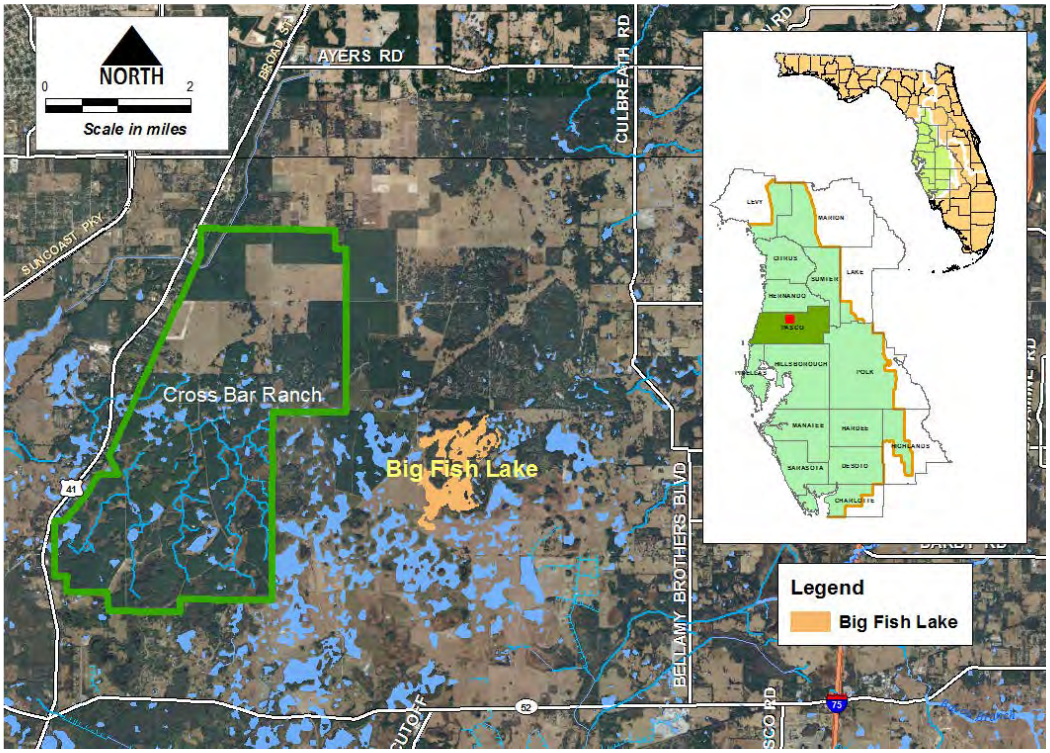

Figure 1. Location of Big Fish Lake in Pasco County, Florida.

Hillsborough Rivers. There are no significant direct surface water inflow or outflows associated with the lake.

During very high rainfall periods, the lake can overflow into a large, relatively flat area surrounding the lake. Big Fish Lake is located approximately 2.5 miles east of the Cross Bar Ranch Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 2). Groundwater withdrawals began at the Cross Bar Ranch Wellfield in 1980 and steadily climbed to approximately 30 million gallons per day (mgd) by the early 1990s (Figure 3). Monthly withdrawal rates since 2005 have averaged from 12 to 18 mgd.

Since the summer of 2000, due to concerns of low lake levels, Tampa Bay Water and the property owners began augmenting the lake with water withdrawn from the Floridan aquifer (WUP No. 2005897.003). The permit is currently being reviewed for renewal. Figure 4 presents the metered augmentation withdrawals through 2013. The permit originally allowed for 310,000 gpd annual average withdrawals from the Floridan aquifer for augmentation, and was increased to 1,540,000 gpd annual average withdrawals in 2015 through a newly issued permit (WUP No. 20020500).

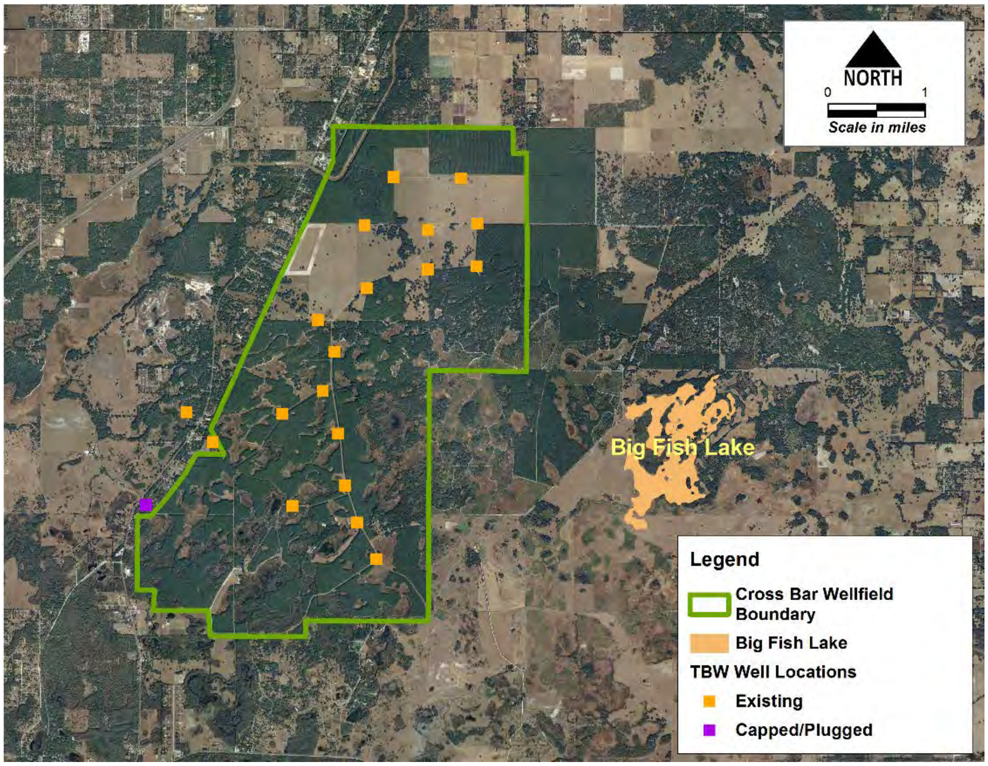

Figure 2. Big Fish Lake and the Cross Bar Ranch Wellfield.

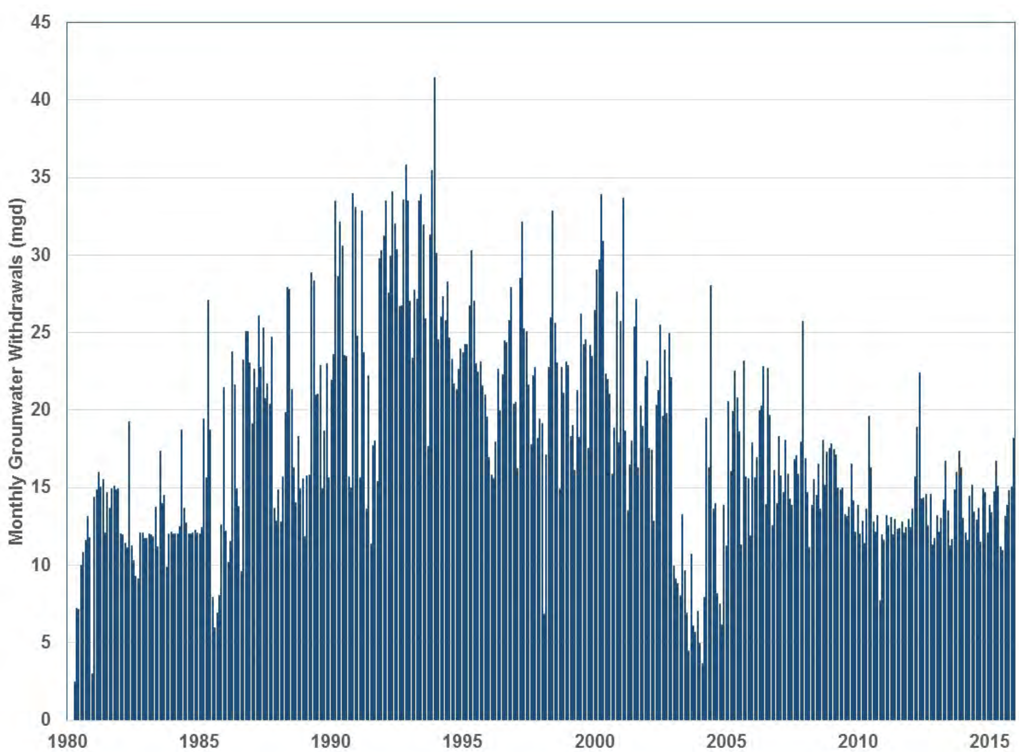

Figure 3. Monthly Cross Bar Ranch Wellfield withdrawals.

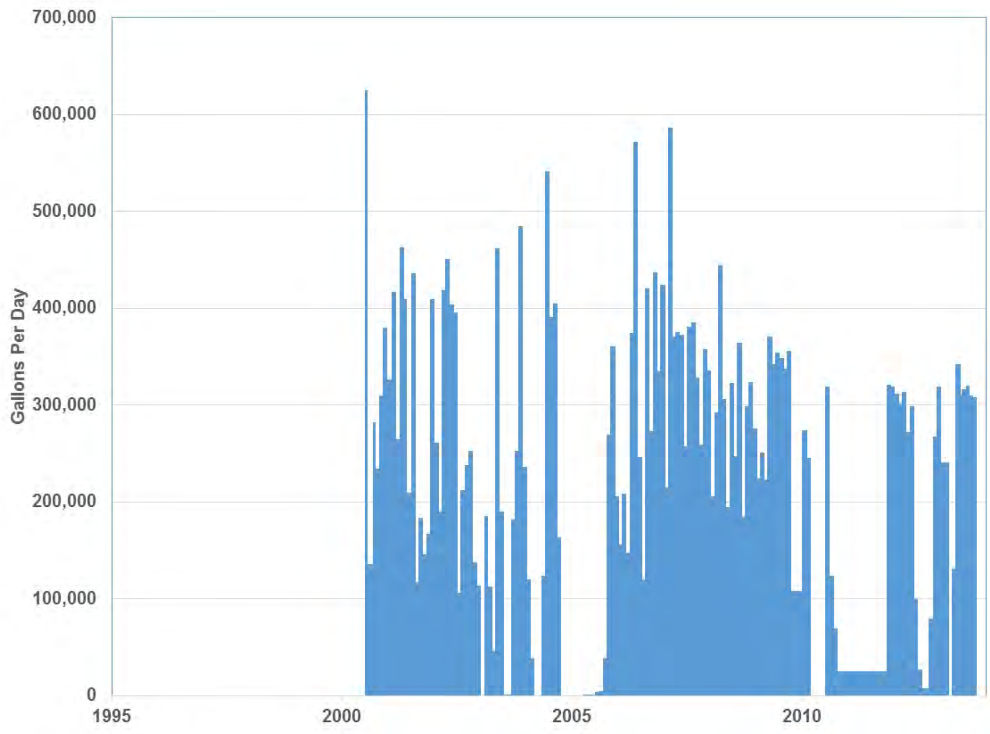

Figure 4. Metered augmentation withdrawals at Big Fish Lake.

C. Revised Minimum Levels Proposed for Big Fish Lake

Revised minimum levels proposed for Big Fish Lake are presented in Table 1 and discussed in more detail by Carr and others (2016). Minimum levels represent long-term conditions that, if achieved, are expected to protect water resources and the ecology of the area from significant harm that may result from water withdrawals. The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. The Minimum Lake Level therefore represents the required 50th percentile (P50) of long-term water levels, while the High Minimum Lake Level represents the required 10th percentile (P10) of long-term water levels. To determine the status of minimum levels for Big Fish Lake or minimum flows and levels for any other water body, long-term data or model results must be used.

Table 1. Proposed Minimum Levels for Big Fish Lake.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	75.4
Minimum Lake Level	72.8

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Big Fish Lake from 2004 through 2015, which was determined to represent the “Current” period. The Current period represents a recent “Long-term” period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. “Long-term” is defined as a period that has been subjected to the full range of rainfall variability that can be expected in the future. As demonstrated in Hancock (2016), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be “Long-term”, a regression analysis using the line of organic correlation (LOC) method was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used in the process to develop the minimum levels for Big Fish Lake (Hancock, 2016). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Big Fish Lake was used for the status assessment (Hancock, 2016). The best resulting correlation for the LOC model created with measured data (2004-2015) was the 7-year weighted period, with a coefficient of determination of 0.87. The resulting lake stage exceedance percentiles are presented in Table 2.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2004 to 2015 data, and the revised minimum levels proposed for Big Fish Lake.

Percentile	**Long Term LOC Model Results 1946 to 2015** Elevation in feet NGVD 29*	**Measured Lake Levels for Current Period (2004 to 2015)** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	76.6	74.8	75.4
P50	72.6	70.7	72.8

* LOC model based on Current Period and extended using rainfall for 1946 to 2015

As an additional piece of information, Table 2 also presents the same percentiles calculated directly from the measured lake level data for Big Fish Lake for the period from 2004 through

2015. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 12 years, rather than the longer-term rainfall conditions represented in the 1946 to 2015 LOC model simulations.

A comparison of the LOC model with the revised minimum levels proposed for Big Fish Lake indicates that the Long-term P10 is 1.2 feet higher than the proposed High Minimum Lake Level, and the Long-term P50 is 0.2 feet below the proposed Minimum Level. The P10 elevation derived directly from the 2004 to 2015 measured lake data is 0.6 feet lower than the proposed High Minimum Lake Level, and the P50 elevation is 2.1 feet lower than the proposed Minimum Lake Level. Differences in rainfall between the shorter 2004 to 2015 period and the longer 1946 to 2015 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Big Fish Lake water levels are below the revised Minimum Lake Level and above the revised High Minimum Lake Level proposed for the lake. These conclusions are supported by comparison of percentiles derived from Long-term LOC modeled lake stage data with the proposed minimum levels.

Minimum flow and level status assessments are completed on an annual basis by the District and on a five-year basis as part of the regional water supply planning process. In addition, Big Fish Lake is included in the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area (40D-80.073, F.A.C). Therefore, the analyses outlined in this document for Big Fish Lake will be reassessed by the District and Tampa Bay Water as part of this plan, and as part of Tampa Bay Water's Permit Recovery Assessment Plan (required by Chapter 40D-80, F.A.C. and the Consolidated Permit (No. 20011771.001)). Tampa Bay Water, in cooperation with the District, will assess the specific needs for recovery in Big Fish Lake and other water bodies affected by groundwater withdrawals from the Central System Facilities. By 2020, if not sooner, an alternative recovery project will be proposed if Big Fish Lake is found to not be meeting its adopted minimum levels. The draft results of the Permit Recovery Assessment Plan are due to the District by December 31, 2018.

F. References

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APPENDIX C

Technical Memorandum

August 29. 2016

TO: Keith Kolasa, Senior Environmental Scientist, Resource Evaluation Section

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Big Fish Lake

1.0 Introduction

Big Fish Lake is located in north-central Pasco County in west-central Florida (Figure 1). Prior to establishment of a Minimum Level (ML), an evaluation of hydrologic changes in the vicinity of the lake is necessary to determine if the water body has been significantly impacted by groundwater withdrawals. The establishment of the ML for Big Fish Lake is not part of this report. This memorandum describes the hydrogeologic setting near the lake and includes the results of two numerical model scenarios of groundwater withdrawals in the area.

2.0 Hydrogeologic Setting

The hydrogeology of the area includes a surficial sand aquifer system; a discontinuous, intermediate clay confining unit, a thick carbonate Upper Floridan aquifer, a low permeable confining unit and a Lower Floridan aquifer. In general, the surficial aquifer system is in good hydraulic connection with the underlying Upper Floridan aquifer because the clay confining unit is generally thin, discontinuous, and breeched by numerous karst features. The surficial sand aquifer is generally a few tens of feet thick and overlies the limestone of the Upper Floridan aquifer that averages nearly 1,000 feet thick in the area (Miller, 1986). In between these two aquifers is the Hawthorn Group clay that varies between a few feet to as much as 25 feet thick. Because the clay unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the Upper Floridan aquifer resulting in moderate-to-high leakage to the Upper Floridan aquifer (SWFWMD, 1996). Thus the Upper Floridan aquifer is defined as a leaky artesian aquifer system.

The base of the Upper Floridan aquifer generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as middle confining unit II (Miller, 1986).

3.0 Evaluation of Groundwater Withdrawal Impacts to Big Fish Lake

A number of regional groundwater flow models have included the area around Big Fish Lake in north-central Pasco County. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000-square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties (SWFWMD, 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002). The most recent and advanced simulation of southern Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2013). The construction and calibration of this model was part of a cooperative effort between the SWFWMD and Tampa Bay Water (TBW), a regional water utility that operates 11 major wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

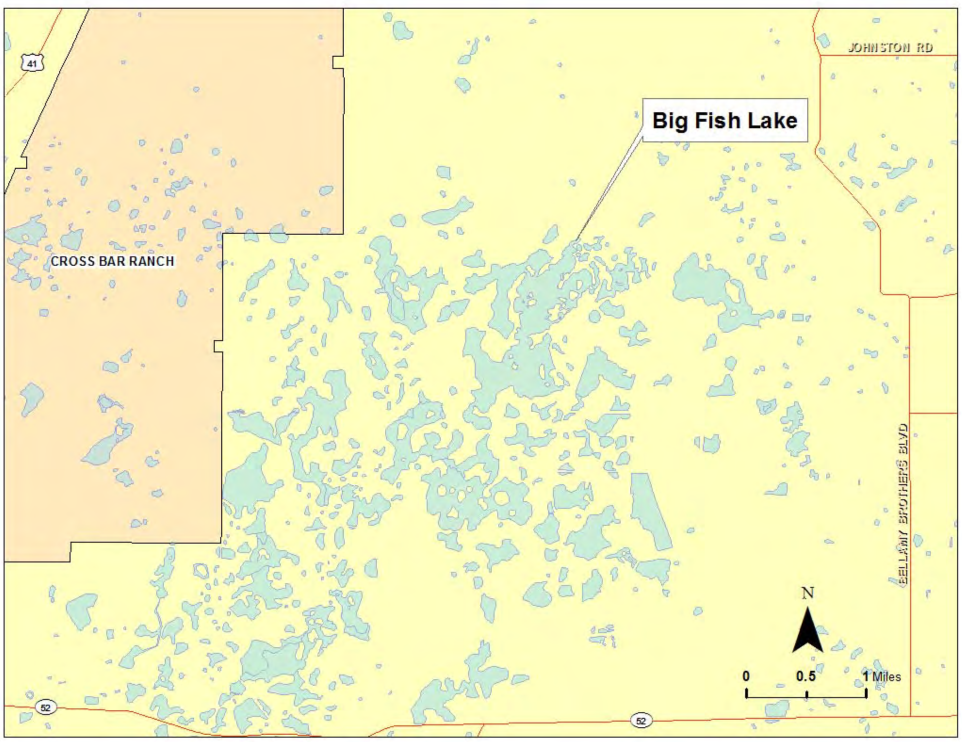

Figure 1. Location of Big Fish Lake.

An integrated model represents the most advanced simulation tool available to the scientific community in water resources investigations. It combines the traditional ground-water flow model with a surface water model and contains an interprocessor code that links both systems. One of the many advantages of an integrated model is that it simulates the entire hydrologic system. It represents the “state-of-art” tool in assessing changes due to rainfall, drainage alterations, and withdrawals.

The model code used to run the INTB simulation is called the Integrated Hydrologic Model (IHM) which combines the HSPF surface water code and the MODFLOW ground-water code using interprocessor software. During the INTB development phase, several new enhancements were made to move the code toward a more physically-based simulation. The most important of these enhancements was the partitioning of the surface into seven major land use segments: urban, irrigated land, grass/pasture, forested, open water, wetlands, and mining/other. For each land segment, parameters were applied in the HSPF model consistent with the land cover, depth-to-water table, and slope. Recharge and ET potential were then passed to each underlying MODFLOW grid cell based on an area weighted-average of land segment processes above it. Other new software improvements included a new ET algorithm/hierarchy plus allowing the model code to transiently vary specific yield and vadose zone storages.

The INTB model contains 172 subbasin delineations in HSPF (Figure 3). There is also an extensive data input time series of 15-minute rainfall from 300 stations for the period 1989-1998, a well pumping database that is independent of integration time step (1-7 days), a methodology to incorporate irrigation flux into the model simulation, construction of an approximate 150,000 river cell package that allows simulation of hydrography from major rivers to small isolated wetlands, and GIS-based definition of land cover/topography. An empirical estimation of ET was also developed to constrain model derived ET based on land use and depth-to-water table relationships.

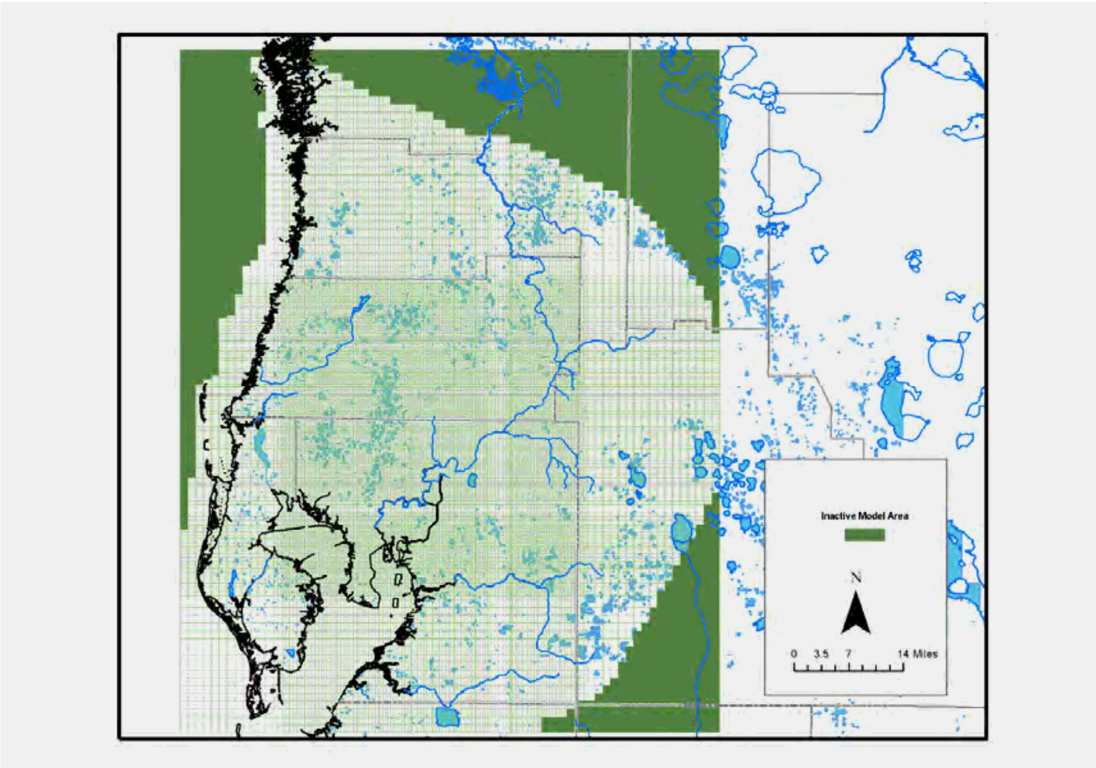

Figure 2. Groundwater grid used in the INTB model

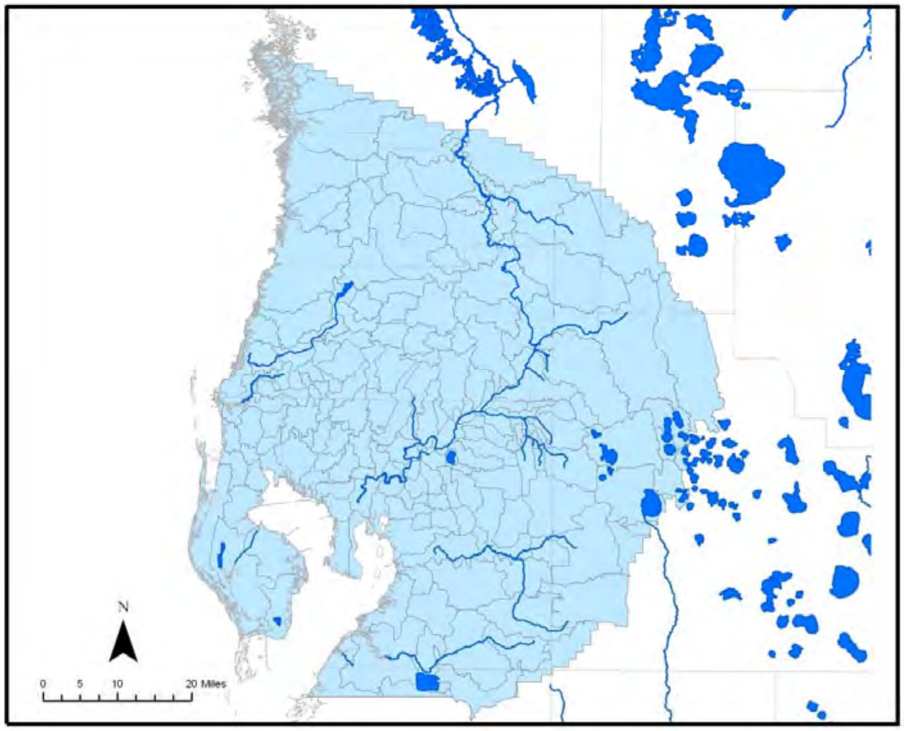

Figure 3. HSPF subbasins in the INTB model.

The MODFLOW gridded domain of the INTB contains 207 rows by 183 columns of variable spacing ranging from 0.25 to one mile. The groundwater portion is comprised of three layers: a surficial aquifer (layer 1), an intermediate confining unit or aquifer (layer 2), and the Upper Floridan aquifer (layer 3). The model simulates leakage between layers in a quasi-3D manner through a leakance coefficient term.

The INTB model is a regional simulation and has been calibrated to meet global metrics. The model is calibrated using a daily integration step for a transient 10-year period from 1989-1998. A model Verification period from 1999 through 2006 has recently been added. Model-wide mean error for all wells in both the surficial and Upper Floridan aquifers is less than 0.2 feet during both the calibration and verification periods. Mean absolute error was less than two feet for both the surficial and Upper Floridan aquifer. Total stream flow and spring flow mean error averaged for the model domain is each less than 10 percent. More information summarizing the INTB model calibration can be found in Geurink and Basso (2013).

3.1 INTB Model Scenarios

Three different groundwater withdrawal scenarios were run with the INTB model. The first scenario consisted of simulating all groundwater withdrawn within the model domain from 1989 through 2000. The second scenario consisted of eliminating all pumping in the Central West-Central Florida Groundwater Basin (Figure 4). Total withdrawals within the Central West-Central Florida Groundwater Basin averaged 239.4 mgd during the 1989-2000 period. TBW central wellfield system withdrawals were simulated at their actual withdrawal rates during this period. The third scenario consisted of reducing TBW central wellfield system withdrawals to their mandated recovery quantity of 90 mgd from the 11 central system wellfields. For TBW only, the 2008 pumping distribution was adjusted slightly upward from 86.9 mgd to 90 mgd to match recovery quantities.

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Big Fish Lake was 3.8 feet and 4.0 feet in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Big Fish Lake was 2.0 feet and 2.1 feet in the Upper Floridan aquifer (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial aquifer based on the INTB model results.

Table 1. INTB model results for Big Fish Lake.

Lake Name	**Predicted Drawdown (feet) in the Surficial Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (feet) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd***
Big Fish	3.8	2.0
Lake Name	**Predicted Drawdown (feet) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (feet) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Big Fish	4.0	2.1

* Average drawdown from model cells intersecting lake

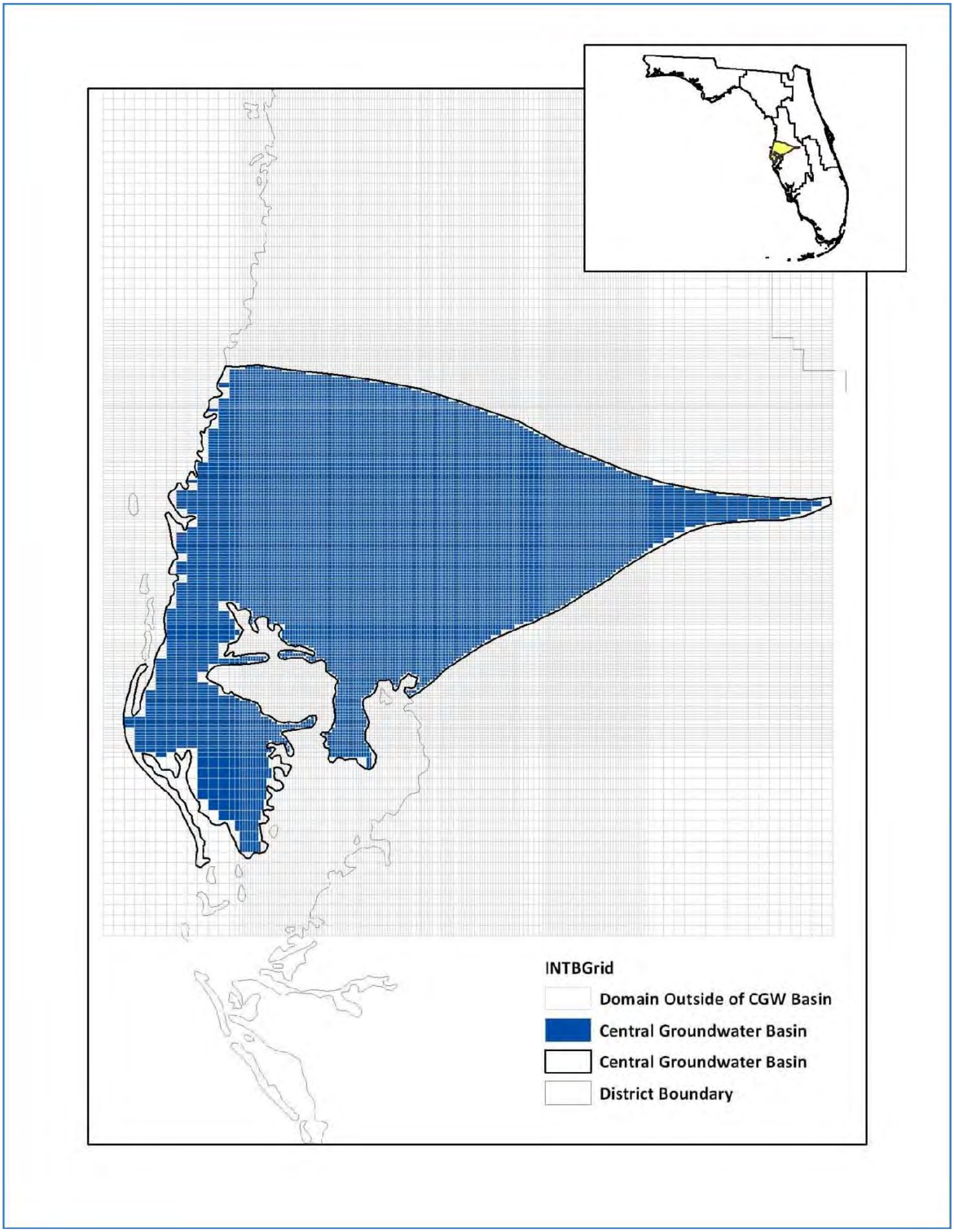

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

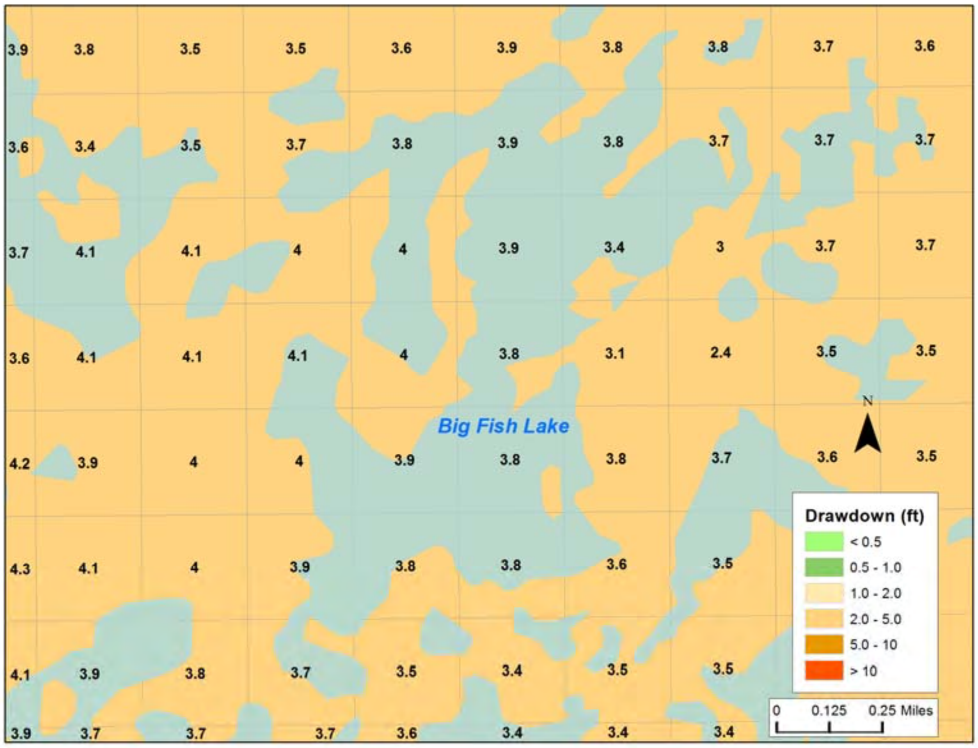

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

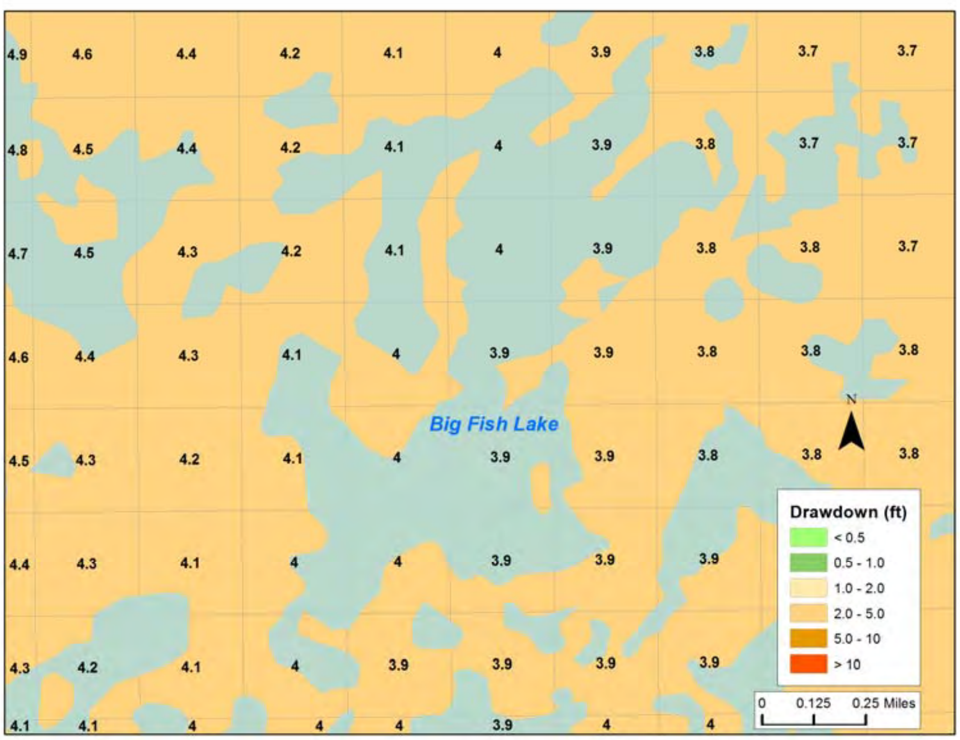

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

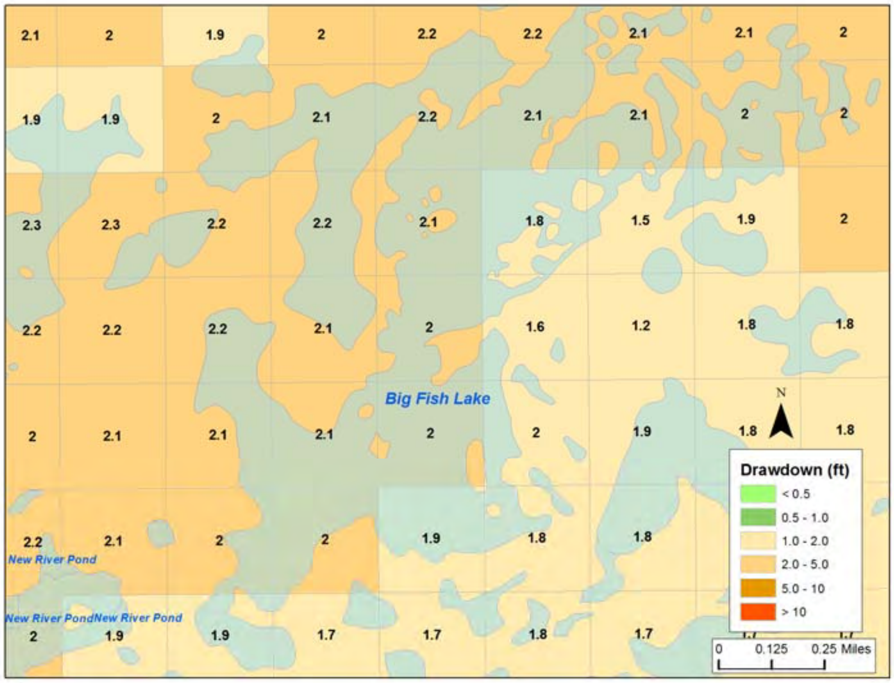

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

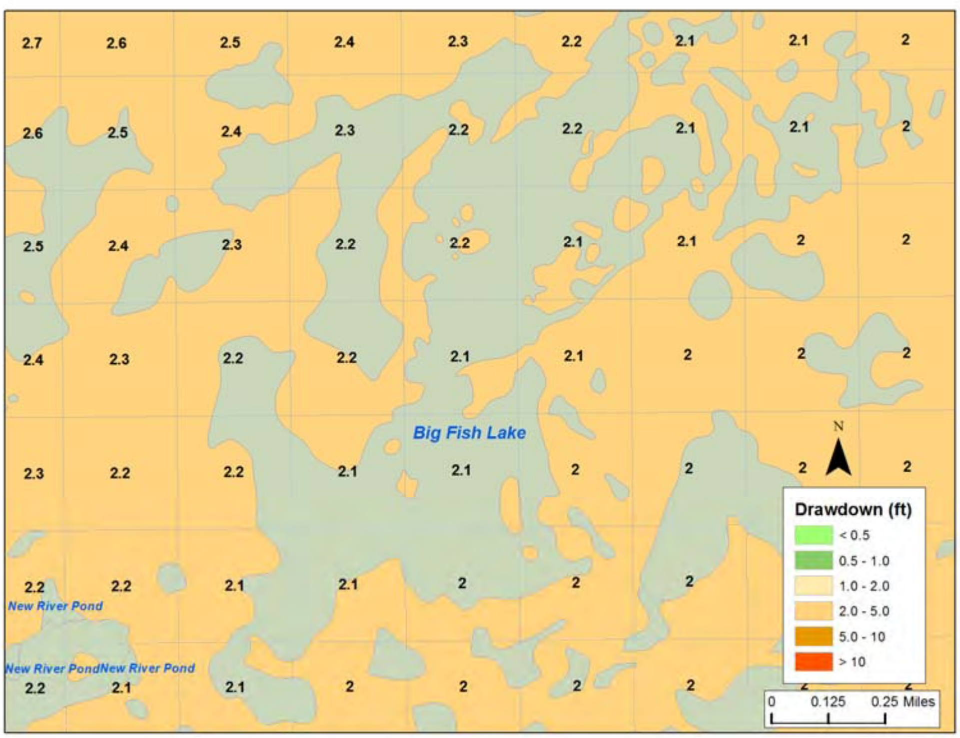

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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