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

February 7, 2018

Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District

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Cover: 2016 Natural Color Imagery of Round Lake (Southwest Florida Water Management District).

Contents

Introduction

Reevaluation of Minimum Flows and Levels

This report describes the development of revised minimum levels for Round Lake in Hillsborough County, Florida. These revised levels were developed based on the re-evaluation of minimum and guidance levels approved by the Southwest Florida Water Management District (District) Governing Board in October 1998 and subsequently adopted into District rules. These revised minimum and guidance levels represent necessary revisions to the currently adopted levels.

Round Lake was selected for re-evaluation 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 lakes were developed. Adopted levels for Round Lake were also re-evaluated 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.

Following Governing Board approval on September 26, 2017, the levels became effective on February 5, 2018.

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 revised 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 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).

Regarding 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, 2007), Hoyer *et al*. (2006), Leeper (2006), 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 recommended 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 1). The specific standards and other information evaluated to support development of revised minimum levels for Round 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 1. 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 the purpose of Minimum Levels development. Those with fringing cypress wetlands greater than 0.5 acres in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (i.e. the Historic P50 is equal to or higher than an elevation 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acres in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 feet below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acres in size are classified as Category 3 Lakes.

According to Chapter 40D-8.624, F.A.C., Round Lake meets the classification as a Category 3 lake, with less than 0.5 acre of fringing cypress wetlands. The Significant Change Standards associated with Category 3 lakes described below will also be developed in a subsequent section of this report.

Lake-specific significant change standards and other available information are developed for establishing Minimum Levels for Category 3 Lakes. The standards are used to identify thresholds for preventing significant harm to cultural and natural system values associated with lakes in accordance with guidance provided in the Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

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.

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 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 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 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 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.

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. Using methods described in Caffrey (2006), mean secchi disk depth (SD) is used to calculate the maximum depth of colonization (MDC) for aquatic plants using regression equation log(MDC) – 0.66log(SD) + 0.30, where all values are represented in meters. The MDC depth is then used to calculate the total acreage at each lake stage that is available for aquatic plant colonization.

Although potential changes in the coverage of herbaceous wetland vegetation and aquatic plants associated with use of the standards is taken into consideration in the development of Minimum Levels, there is no significant change standard to determine a threshold for preventing significant harm to fringing non-cypress wetlands. Based on the Cypress Wetland Standard for Category 1 and 2 lakes, however, a Wetland Offset Elevation was developed for Category 3 Lakes to provide protection for non-cypress fringing wetlands.

The Wetland Offset Elevation is developed to protect lake fringing non-cypress wetlands. Based on the rationale used to develop the Cypress Wetland Standard for Category 1 and 2 Lakes (1.8 feet below the Normal Pool elevation), a Wetland Offset Elevation for Category 3 Lakes was developed. Because Hydrologic Indicators of sustained inundation used to determine the Normal Pool elevation usually do not exist on Category 3 Lakes, another datum, in this case the Historic P50 elevation, was used in the development of the Wetland Offset Elevation. Based on an evaluation of the relationship of the Cypress Wetland Standard with the Historic P50 for hydrologically un-impacted cypress wetlands, the Wetland Offset Elevation for Category 3 Lakes was established at an elevation 0.8 feet below the Historic P50 elevation (Hancock, 2007).

Minimum 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.

Development of Minimum and Guidance Levels for Round Lake

Lake Setting and Description

Watershed

Round Lake is in Northwest Hillsborough County and within the Rocky & Brushy Creek Watershed (Figure 1 & Figure 2). The lake has an immediate watershed/drainage basin area of 53 acres (Figure 3).

In addition to runoff and local drainage, flow between lakes Round and Saddleback occurs via a well-maintained ditch from Saddleback Lake to Linda Vista Circle, and then an 18-inch CMP that passes under the road and on to Round Lake. A high point of 53.7 feet NGVD29 in the pipe as it passes under Linda Vista Circle serves as the control elevation between the lakes. The culvert and ditch system between Round Lake and Saddleback Lake was constructed in the mid-1960s in an attempt to add more water to Round Lake. However, during times when Round Lake is higher than Saddleback Lake, Round Lake can discharge to Saddleback Lake (Figure 4). Refer to Appendix A for additional details.

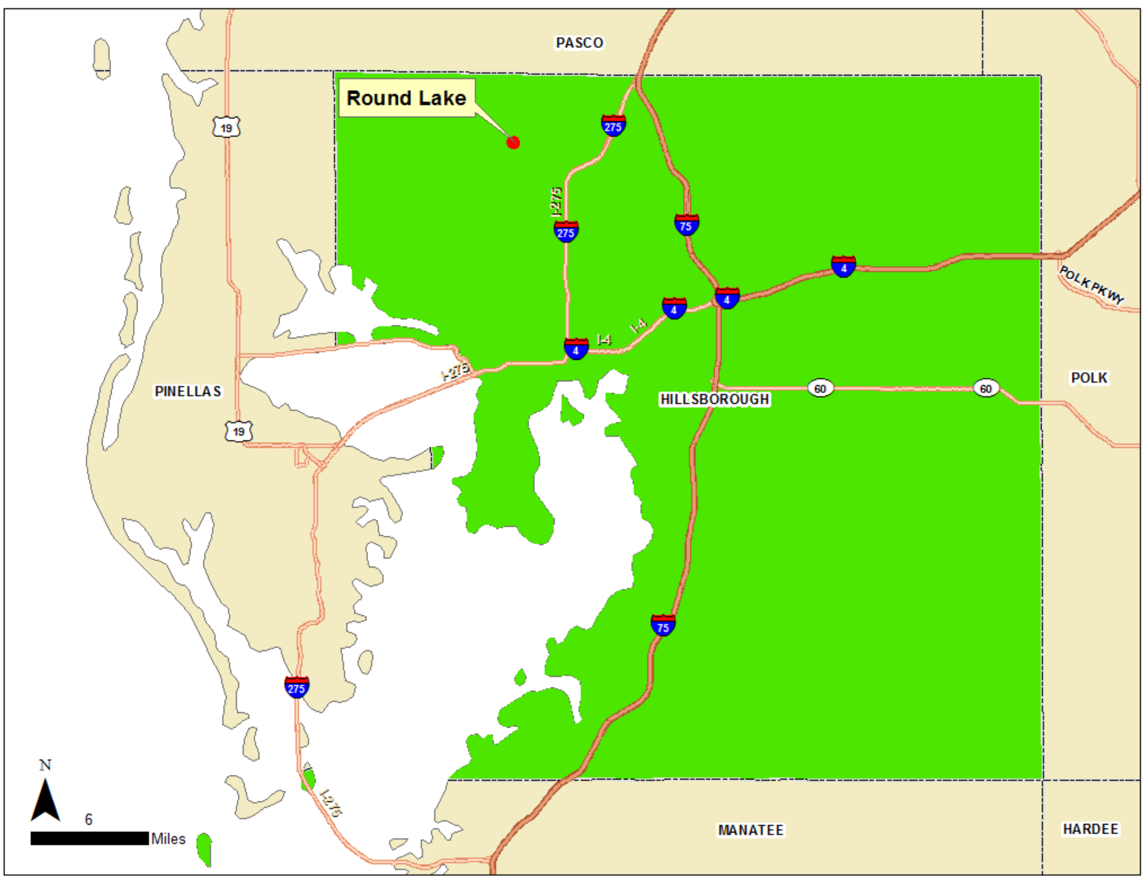

Figure 1. Location of Round Lake in Hillsborough County, Florida.

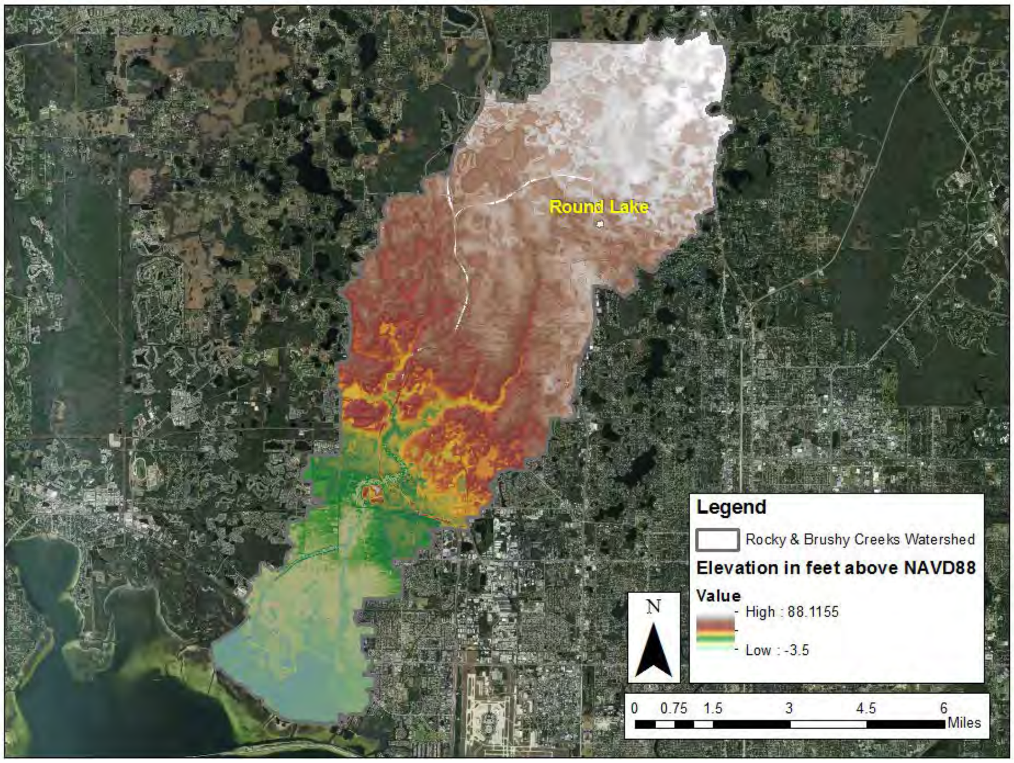

Figure 2. Rocky & Brushy Creek Watershed Delineation and Topography.

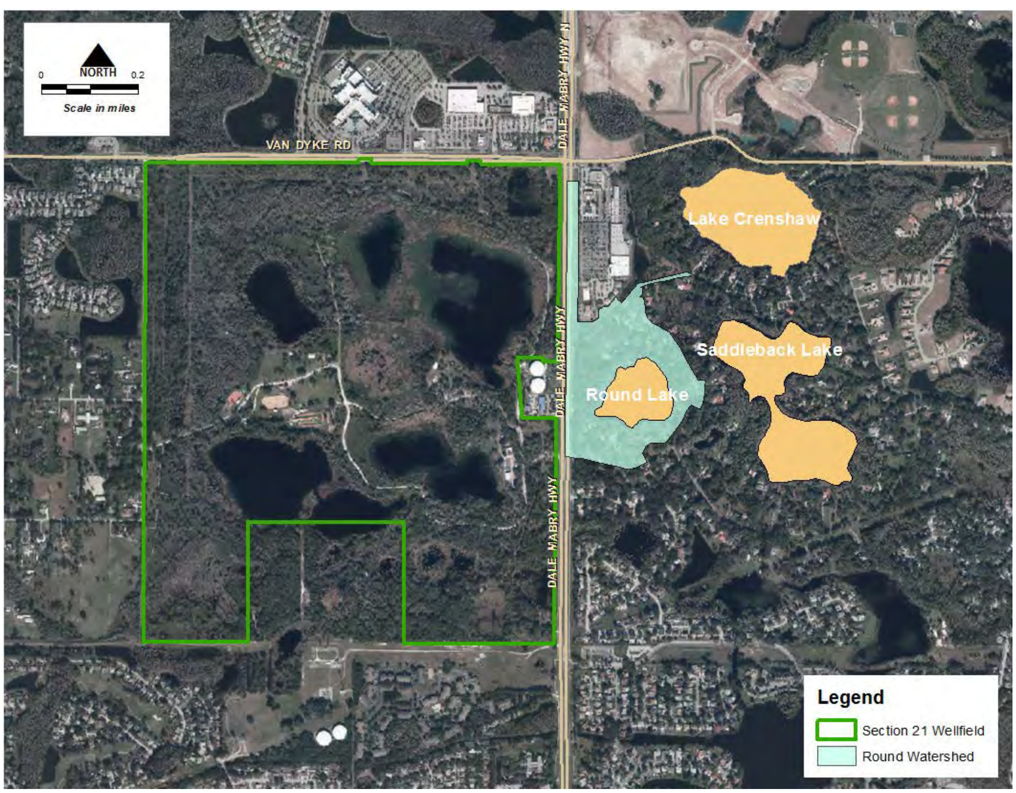

Figure 3. Watershed for Round Lake (2016 Imagery).

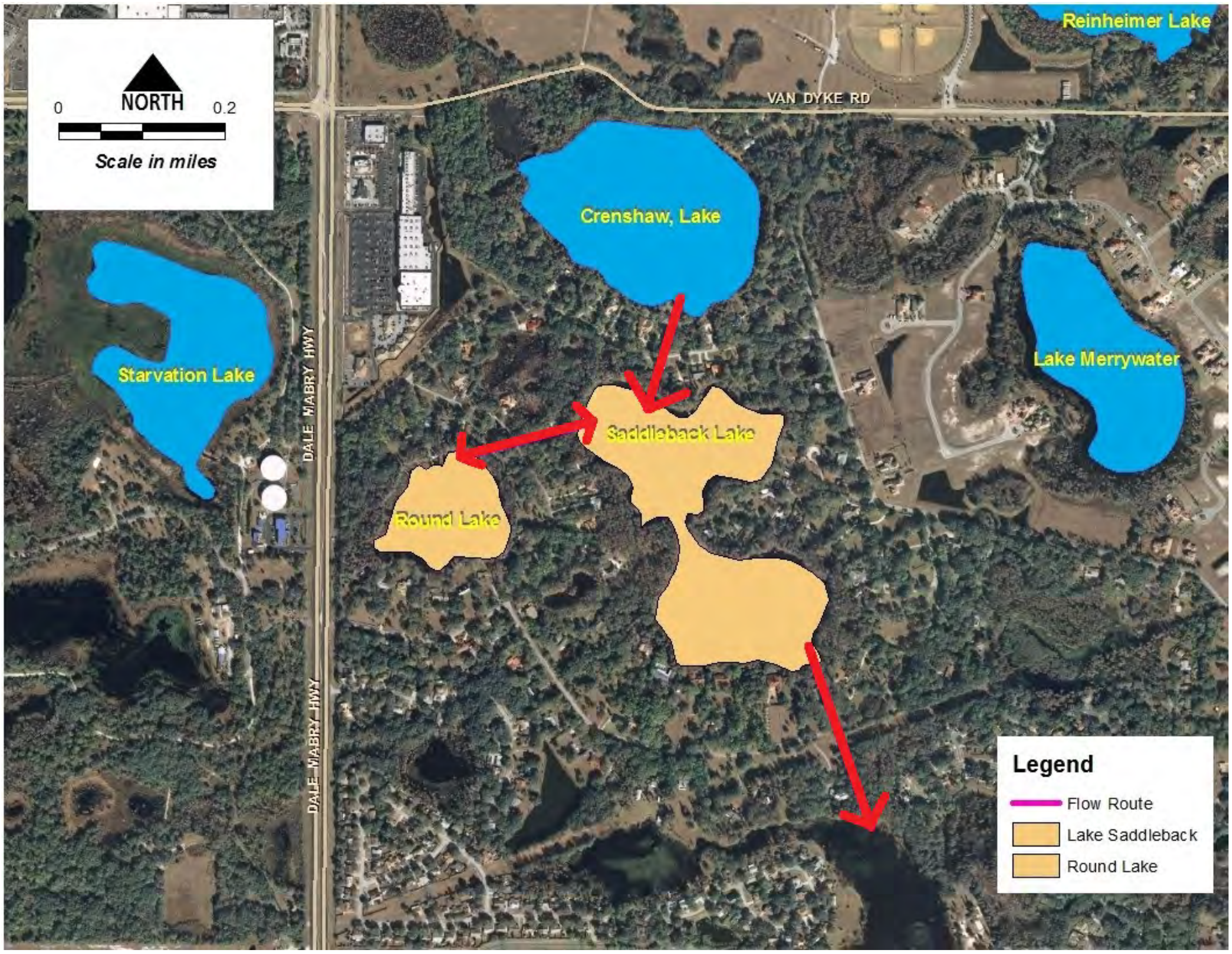

Figure 4. Flow to and from Round Lake.

Site Specific Details

Round Lake is located just east of the Section 21 Wellfield, a Tampa Bay Water public water supply production facility that has been in service since 1963 (Figure 5). Therefore, Round Lake and adjacent lakes have been subjected to the effects of groundwater withdrawals. Monthly withdrawals steadily climbed to nearly 15 million gallons per day (mgd) in 1964 and to over 20 mgd on annual average in 1967. With the development of the South Pasco Wellfield in 1973, withdrawal rates at the Section 21 Wellfield were reduced to approximately 10 mgd on annual average. Withdrawal rates since 2005 have averaged a little over 3 mgd on annual average, with several extended periods with no groundwater withdrawals. Due to the lowering of the lake water levels from the withdrawals, an Upper Floridan aquifer well was installed for routine augmentation, beginning in June 1966, however, the lake did not receive a water use permit until 1996. Refer to Appendix A for additional details.

Figure 5. Round Lake near Section 21 Public Supply Wellfield.

Land Use Land Cover

An examination of the 1950 and 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there have been considerable changes to the landscape in the vicinity during this period; specifically, the dominant land forms. Land use in 1950 was primarily rangeland and upland forests (Figure 6). By 2011, much of the agriculture and upland forest had been replaced by urban land uses (Figure 7). Aerial photography chronicles landscape changes to the immediate lake basin from 1938 to 1984; Figures 8 through 11.

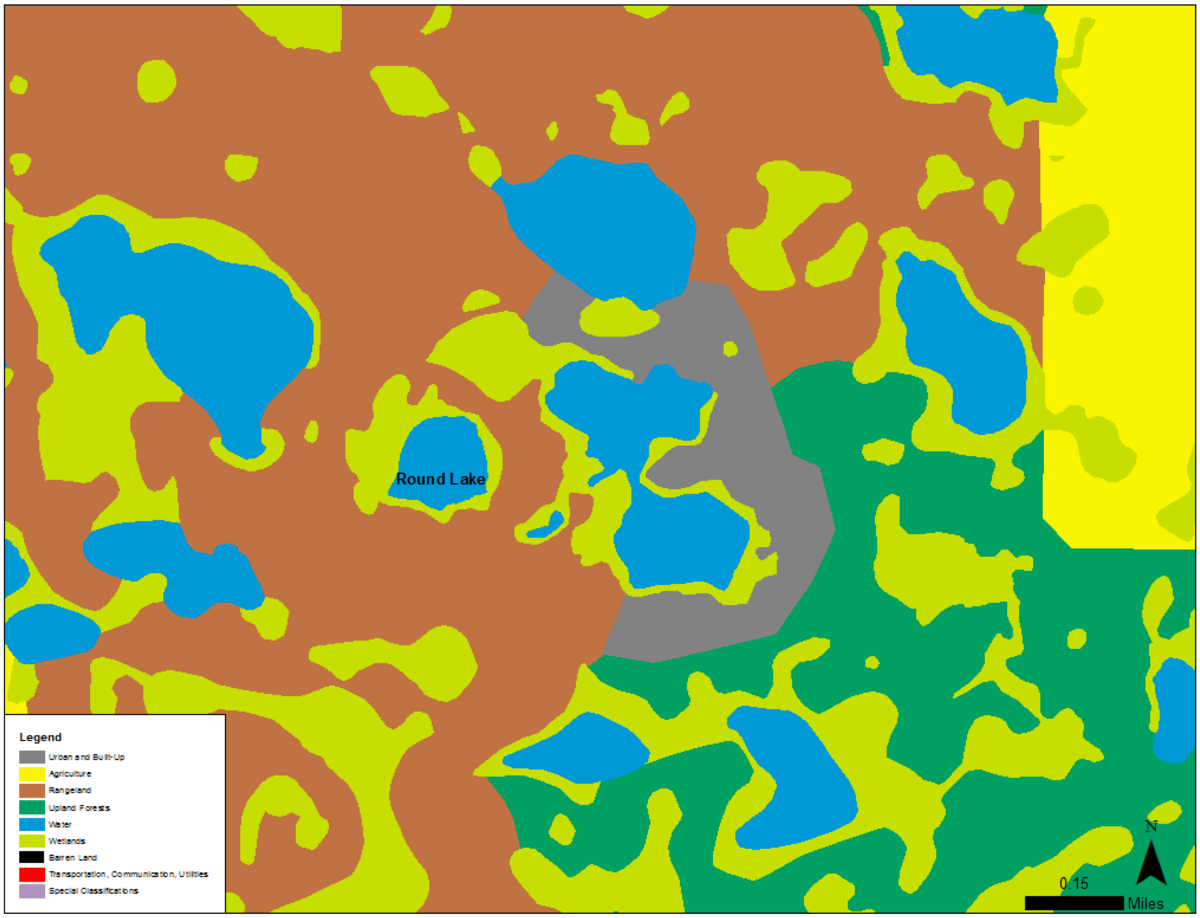

Figure 6. 1950 Land Use Land Cover Map of Round Lake.

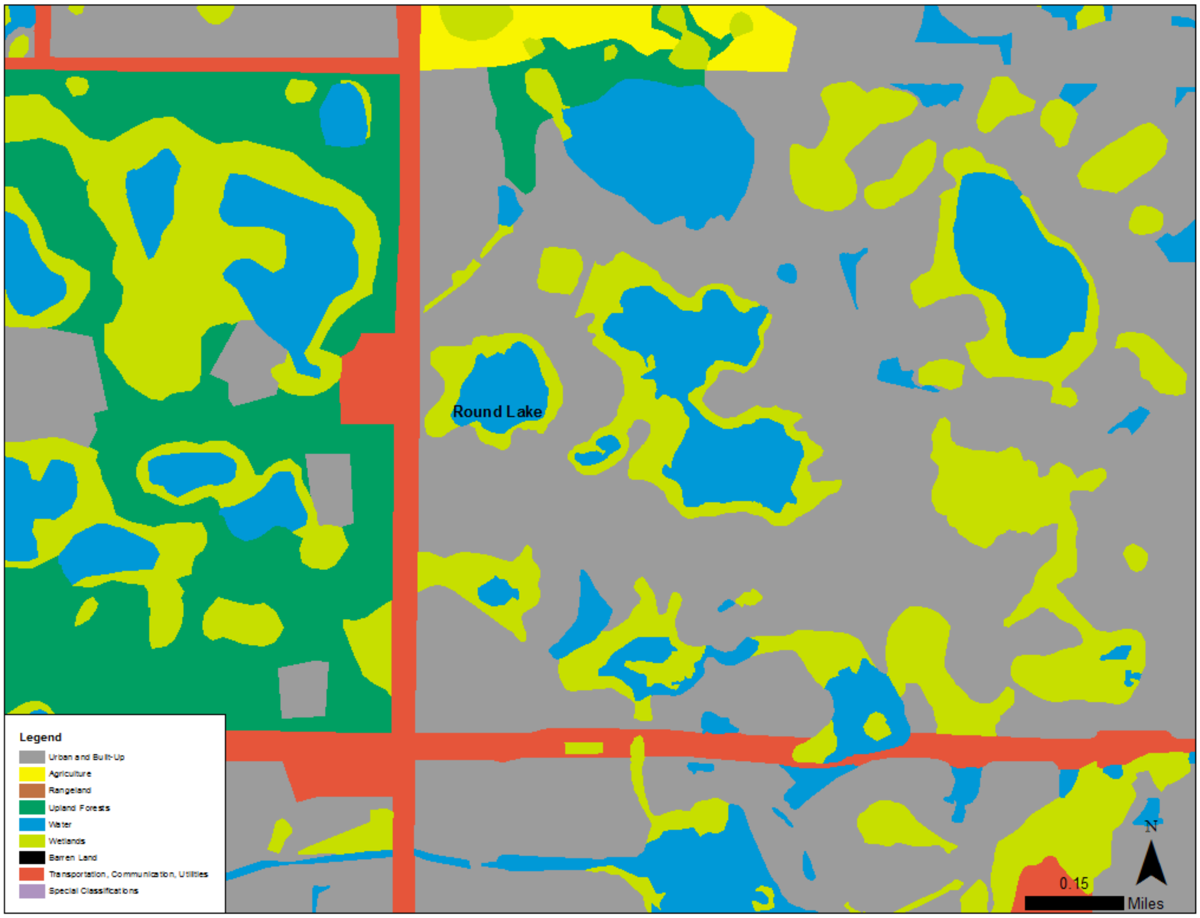

Figure 7. 2011 Land Use Land Cover Map of Round Lake.

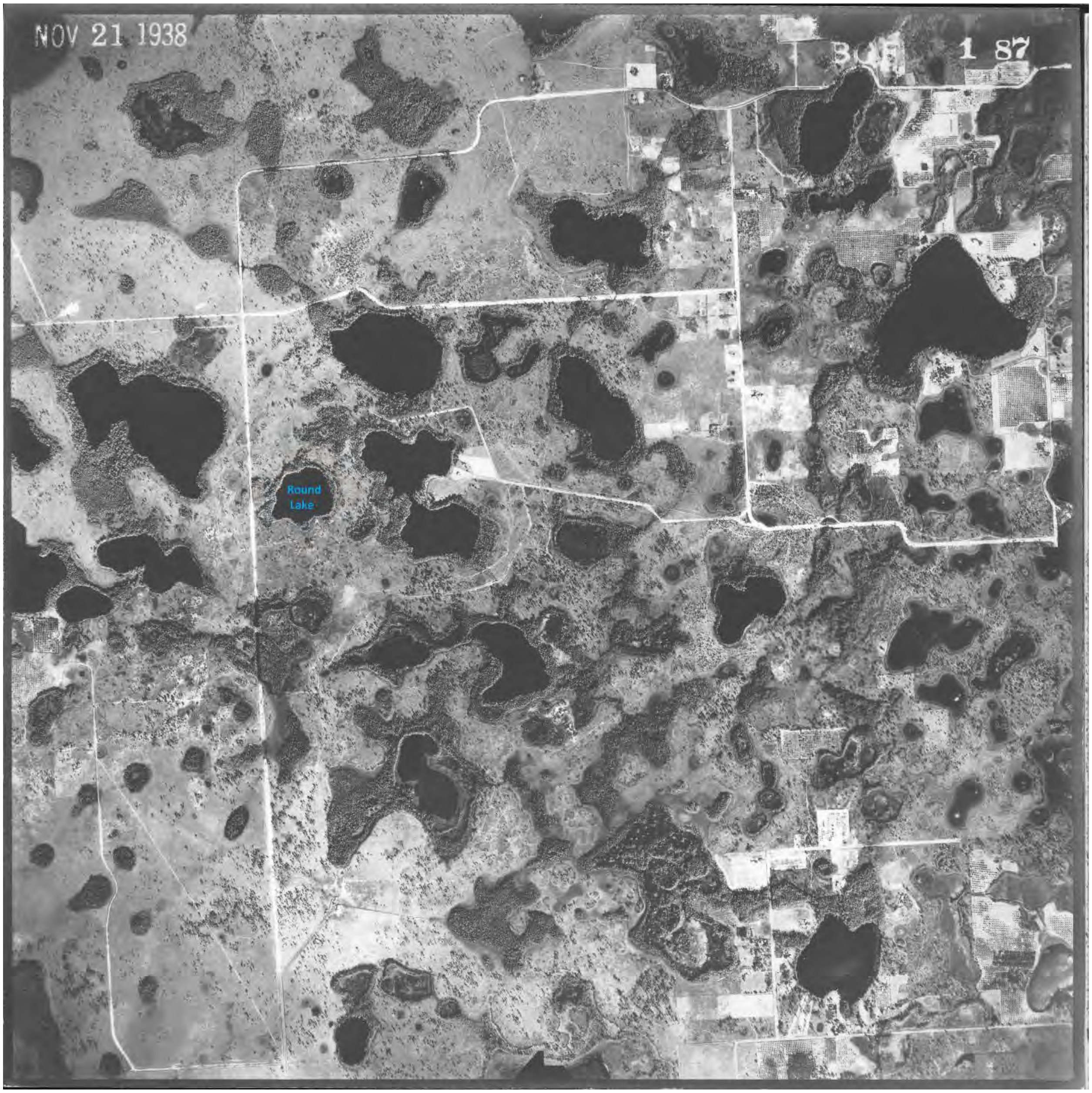

Figure 8. 1938 Aerial Photograph of Round Lake.
Aerial imagery provided by University of Florida George A. Smathers Libraries Aerial Photography: Florida Collection.

Figure 9. 1957 Aerial Photograph of Round Lake.
Aerial imagery provided by University of Florida George A. Smathers Libraries Aerial Photography: Florida Collection.

Figure 10. 1968 Aerial Photograph of Round Lake.
Aerial imagery provided by University of Florida George A. Smathers Libraries Aerial Photography: Florida Collection.

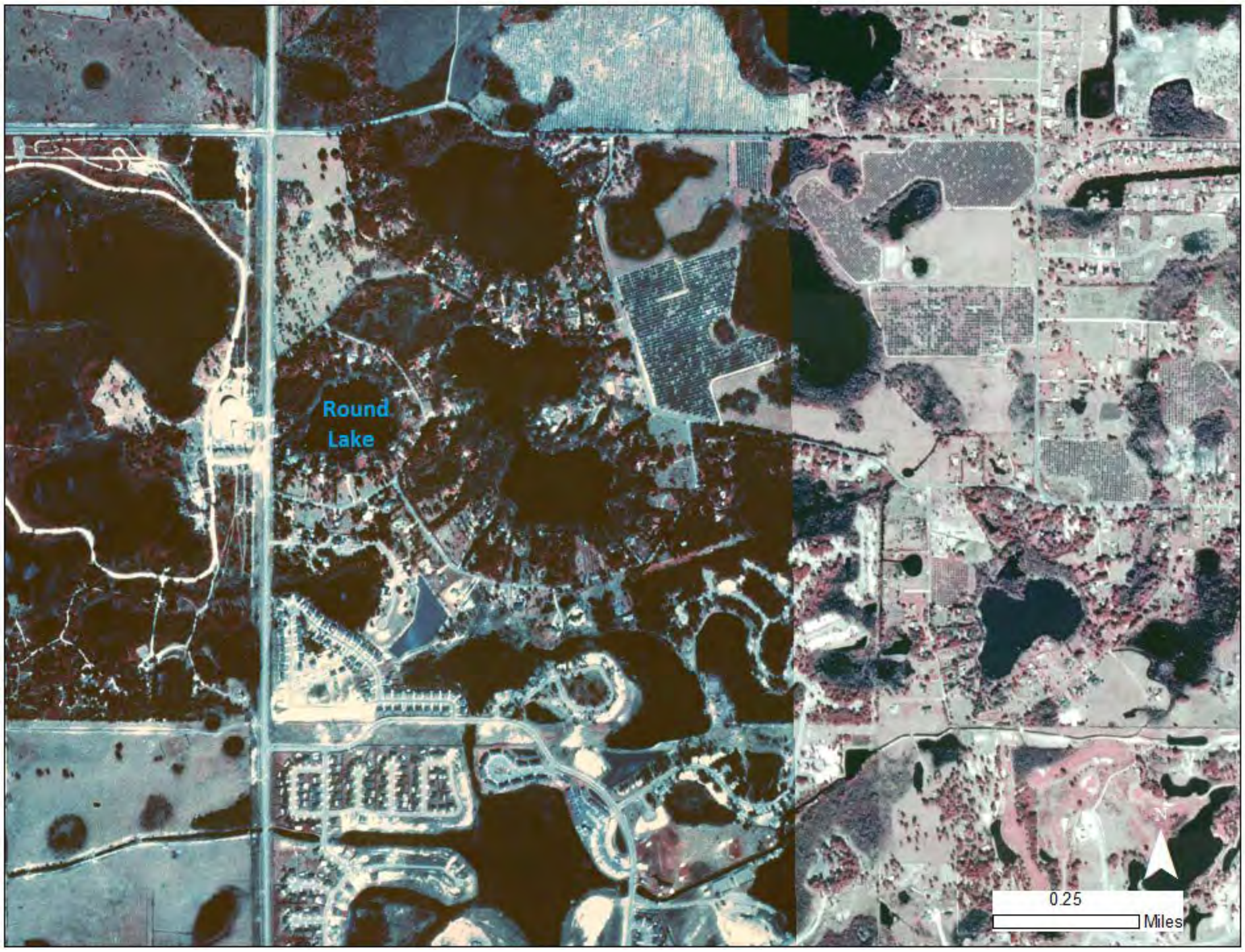

Figure 11. 1984 Aerial Photograph of Round Lake.
(Southwest Florida Water Management District)

Bathymetry Description and History

One-foot interval bathymetric data gathered from 1999 field surveys and modeling resulted in lake-bottom contour lines from 29.6 ft. to 58 ft. (Figure 12). These data revealed that the lowest lake bottom contour (29.6 ft.) is in a hole on the north side of the lake. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

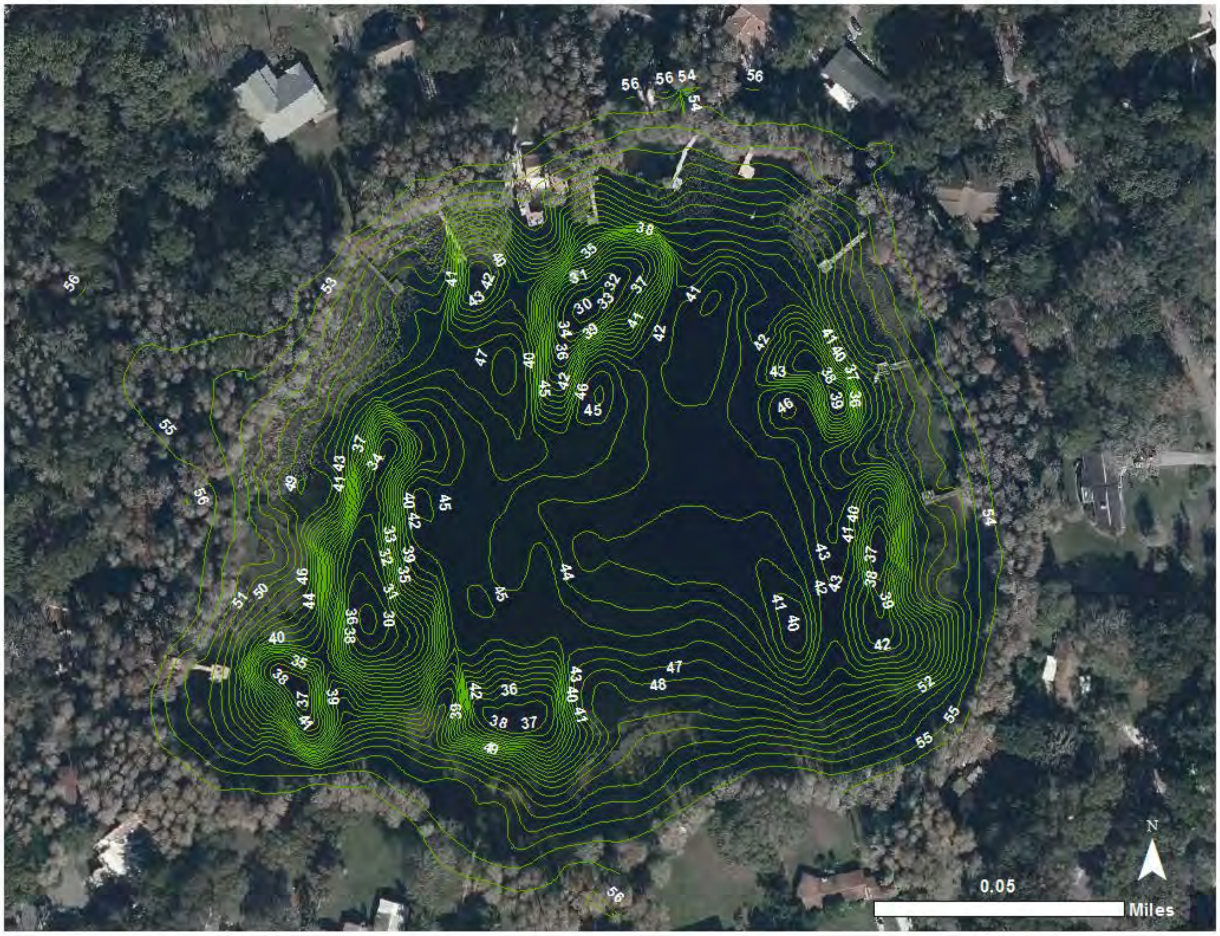

Figure 12. Round Lake 1-foot Contours on a 2016 Natural Color Aerial Photograph.

Water Level (Lake Stage) Record

Lake stage data, i.e., surface water elevations collected are available for Round Lake (SID 19840) from the District's Water Management Information System (Figures 13 & 14). The District continues to monitor the water levels monthly.

Round Lake water elevation data has been collected since January 27, 1965 (Refer to Appendix A for details). The highest lake stage elevation on record was 56.58 ft. and occurred on August 4, 2015. The lowest lake stage elevation on record was 47.74 ft. and occurred on June 7, 1966. Figure 15 shows a dry (1968) and a wet (2016) historic aerial photograph of Round Lake. Round Lake has been regularly augmented with water pumped from the Floridan Aquifer since the mid-1960s, thus aerial imagery doesn't show much noticeable change in water level (Stewart and Hughes 1974, SWFWMD Water Use Permit No. 2011425).

Figure 13. Round Lake Gauge Location SID 19840.

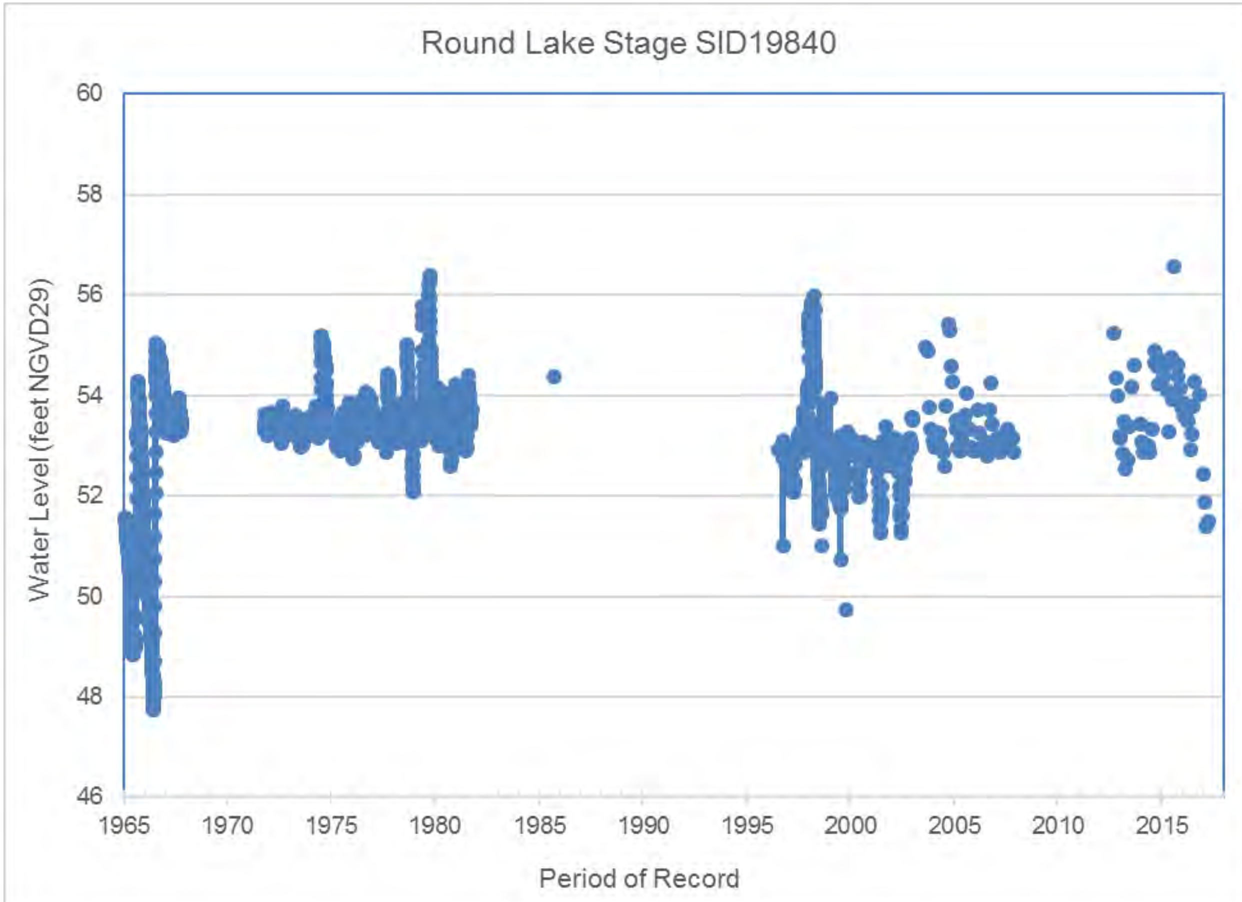

Figure 14. Round Lake Period of Record Stage Data (SID 19840).

Figure 15. A Dry (1968) and a Wet (2016) Historic Aerial Photograph of Round Lake.

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.

In October 2003, the District Governing Board approved Guidance and Minimum levels for Round Lake (Table 2), which were subsequently adopted into Chapter 40D-8, Florida Administrative Code. The levels were set using the methodology for Category 3 Lakes described in SWFWMD (1999a and 1999b). The revised Minimum and Guidance Levels, along with area values for each water level, are listed in Table 3.

Table 2. Minimum and Guidance levels approved in October 2003 for Round Lake

Level	Elevation (feet above NGVD)	Total Lake Area (acres)
Ten Year Flood Guidance Level	56.17	NA
High Guidance Level (P10)	55.60	13.5
High Minimum Level	54.50	11.8
Minimum Level	53.50	10.6
Low Guidance Level	53.50	10.6

Methods, Results and Discussion

The revised Minimum and Guidance Levels proposed in this report were developed for Round Lake using the methodology for Category 3 lakes described in Chapter 40D-8, F.A.C.

Revised levels and the lake surface area for each level are listed in Table 3, 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.

Table 3. Lake Stage Percentiles, Normal Pool, Control Point Elevations, Significant Change Standards, and Revised Minimum and Guidance Levels with associated surface areas for Round Lake.

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Current P10	54.7	11.7
Current P50	53.5	10.4
Current P90	52.8	9.7
Historic P10 (1946 to 2016)	56.6	16.5
Historic P50 (1946 to 2016)	53.9	10.9
Historic P90 (1946 to 2016)	51.1	8.4
Normal Pool and Control Point		
Normal Pool	N/A	N/A
Control Point	53.7	10.6
Significant Change Standards		
Lake Mixing Standard	N/A	N/A
Dock-Use Standard	56.5	16.0
Basin Connectivity Standard	N/A	N/A
Species Richness Standard	52.3	9.3
Aesthetics Standard	51.1	8.4
Recreation/Ski Standard	N/A	N/A
Cypress Standard	N/A	N/A
Wetland Offset Elevation	53.1	9.9
Other		
Lowest Floor Slab Elevation	57.1	17.2
Minimum and Guidance Levels		
High Guidance Level	54.7	11.7
High Minimum Lake Level	54.1	11.1
Minimum Lake Level	53.1	9.9
Low Guidance Level	51.1	8.4

N/A - not appropriate.

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, leakance and groundwater withdrawals.

Stage-area-volume relationships were determined for Round Lake 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 10.4.1 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).

Two elevation data sets were used to develop the terrain model for Round 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. These data were collected using a 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-tenth of a foot elevation change increments (selected stage-area-volume results are presented in Figure 16).

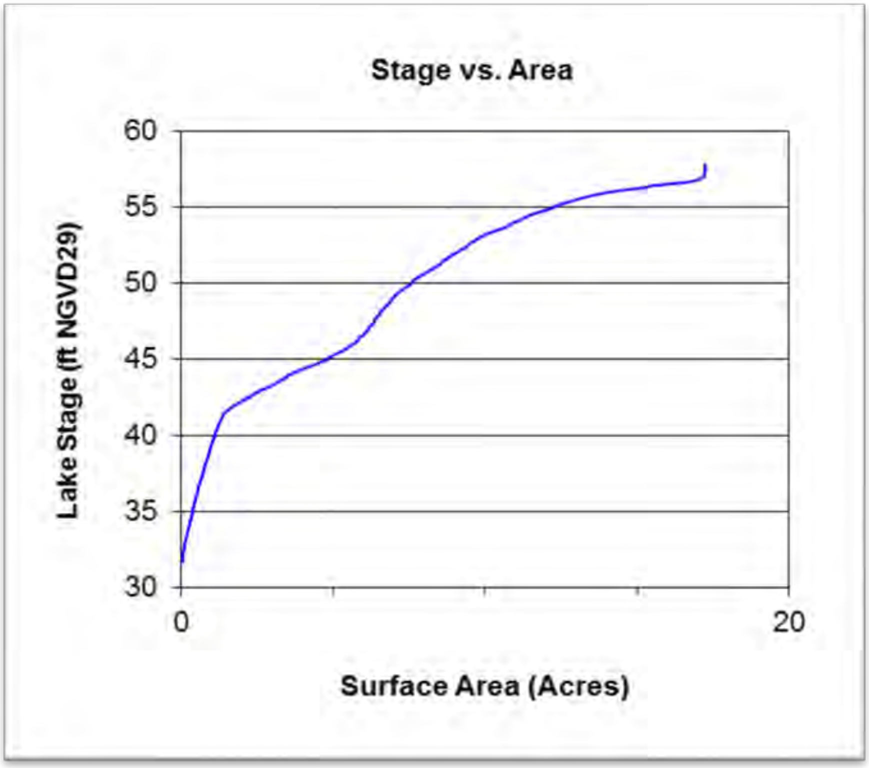

Figure 16. Lake Stage (Ft. NGVD29) to Surface Area (Acres).

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 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).

The initial approach included developing a water budget model which incorporated the effects of precipitation, augmentation, evaporation, overland flow, and groundwater interactions (Appendix A). Using the results of 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 Round Lake and composite regional rainfall.

A combination of model data produced a hybrid model which resulted in a 70-year (1946-2016) 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 56.6 feet. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 53.9 feet. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 51.1 feet. (Figure 17 and Table 3).

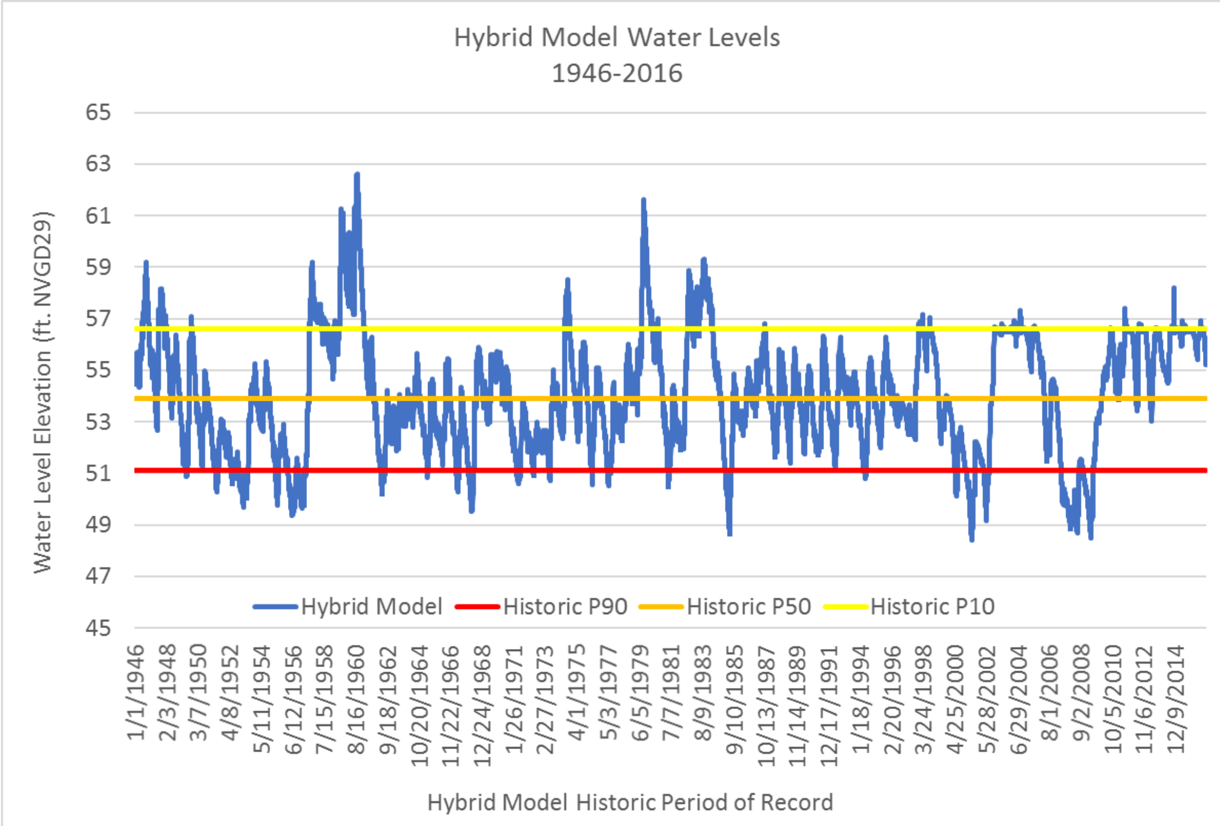

Figure 17. Historic Water Levels (hybrid) Used to Calculate Historic Percentile Elevations Including HP10, HP50, and HP90.

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 inflection points (buttress swelling) and moss collars on the trunks of cypress trees have been shown to be reliable biologic indicators of hydrologic Normal Pool (Carr, et al. 2006). As Round Lake is a Category 3 Lake and does not have sufficient cypress trees with adequate hydrologic indicators, a Normal Pool elevation was not determined.

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. Discharge from Round Lake can occur via the ditch/pipe system between Saddleback and Round, during high levels. Based on survey data, it was determined that the highest spot in the conveyance system is a at 53.7 feet NGVD29 (see Appendix A). The lowest finished floor elevation on Round Lake is at an elevation of 57.13 feet NGVD29. These elevations are from the survey, dated 03/31/2017.

Revised 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. It is established using the best available information, including hydrologic data (modeled or measured Historic P10), hydrologic indicators (Normal Pool elevation), the effectiveness of structural alterations, and other information indicative of previous water levels. If the best available information indicates that a different elevation is more representative of the expected Historic P10, Chapter 40D-8.624(4)(c) allows other information to be used to establish the High Guidance Level.

It was determined in this case that other information should be used to establish the High Guidance Level, rather than the Historic P10 predicted by the water budget and LOC models. Because the Historic P10 exceedance percentile can be significantly affected by drainage and control structures, the accuracy of the Historic P10 derived by the models can, at times, have more error than the lower percentiles (such as the Historic P90 and Historic P50).

In the case of Round Lake, the inflow can become an outflow during very high rainfall periods. Because of this, an adjustment was made in the water budget model to limit how high the lake can get (see Appendix A for a more in-depth explanation). However, because a similar adjustment cannot be made in the LOC model that is based on rainfall and lake level, it was decided that the model-derived Historic P10 may not be representative of the expected Historic P10. For structurally altered lakes, Chapter 40D-8.624(4)(c) allows for establishment of the High Guidance Level at the higher of the Current P10 or Control Point elevation. A review of Table 3 shows that the “Current” P10 (as estimated via the water budget/LOC modeling process) is higher than the

Control Point elevation. Therefore, the High Guidance Level for Round Lake was set at the Current P10 of 54.7 feet NGVD29 (Table 3). The High Guidance Level has been exceeded several times; for example, the highest recorded level was 56.6 feet, occurring on August 4, 2015 (Figure 14).

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. Based on the availability and reliability of Historic data for Round Lake using model results (low elevations are not directly affected by structural alteration like high elevations), the proposed Low Guidance Level was established at the Historic P90 elevation, 51.1 ft. In the gaged period of record, the water elevation has been lower than the Low Guidance Level. For example, the lowest recorded elevation was 47.74 ft. on June 7, 1966 (Figure 14).

Revised Significant Change Standards

As mentioned previously in this report, lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Since Round Lake lacks a lake-fringing cypress swamp greater than 0.5 acres in size, Round Lake was classified as a Category 3 lake.

For Category 3 lakes, the Significant Change Standards are used to identify thresholds for preventing significant harm to environmental values associated with the lake (refer to Table 1) in accordance with guidance provided in the Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.). Other information taken into consideration includes potential changes in the coverage of herbaceous wetland vegetation and aquatic plants.

Category 3 Significant Change Standards including a Lake Mixing Standard, Dock-Use Standard, Basin Connectivity Standard, Species Richness Standard, Herbaceous Wetland Standard, Submerged Aquatic Macrophyte Standard, Aesthetics Standard, and a Recreation/Ski Standard were established for Round Lake, where appropriate. Each standard was evaluated for minimum levels development for Round Lake and presented in Table 3 (ft. NGVD29). Each standard was previously defined in the Lake Classification section of this report.

- The Mixing Standard was not established since the dynamic ratio (basin slope) does not shift from <0.8 to >0.8 ft., thus indicating that there are not potential changes in basin susceptibility to wind-induced sediment re-suspension (see Bachmann *et al.* 2000).
- The Dock-Use Standard was established at 56.5 ft., considering a two-foot draft at the ends of the docks.
- Basin Connectivity Standard was deemed not appropriate as Round Lake has no lobes and the connection between Saddleback and Round is not natural (occurs via ditch and culvert) and no powerboats/water crafts can pass.

- The Species Richness Standard was established at 52.3 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- An Aesthetic-Standard for Round Lake was established at the Low Guidance Level elevation of 51.1 ft.
- The Recreation/Ski Standard was not established since a circular ski corridor with a radius of 418 feet or a rectangular corridor 200 x 2,000 feet was not possible. Thus, Round Lake is classified as a Non-Ski Lake (Figure 18).
- The Wetland Offset was calculated to be 53.1 ft.
- Review of changes in potential herbaceous wetland area associated with change in lake stage (Figure 19), and potential change in area available for aquatic macrophyte colonization (Figure 20) did not indicate that use of any of the identified standards would be inappropriate for minimum levels development.

Figure 18. Circular ski-corridor on Round Lake; Ski Standard not applicable.

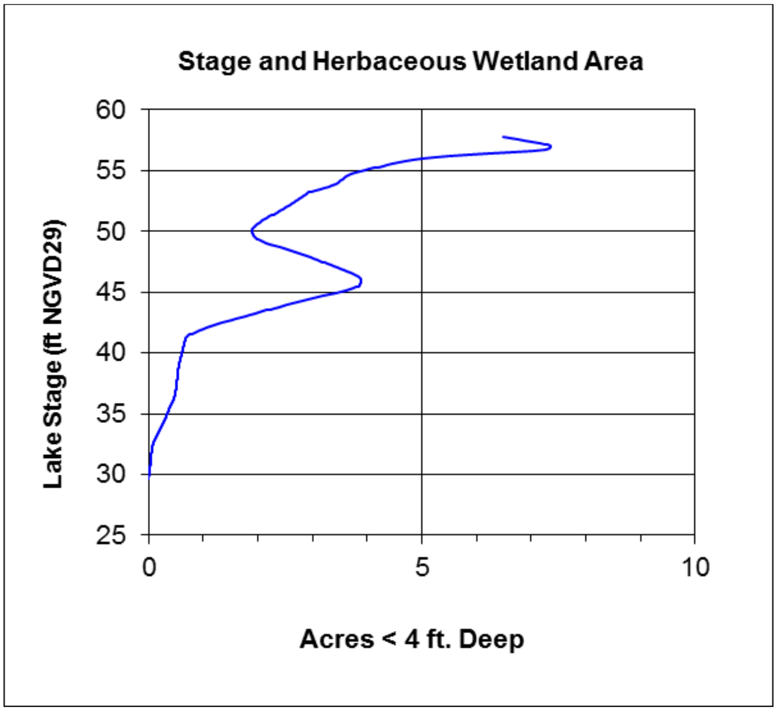

Figure 19. Lake Stage Compared to Available Herbaceous Wetland Area.

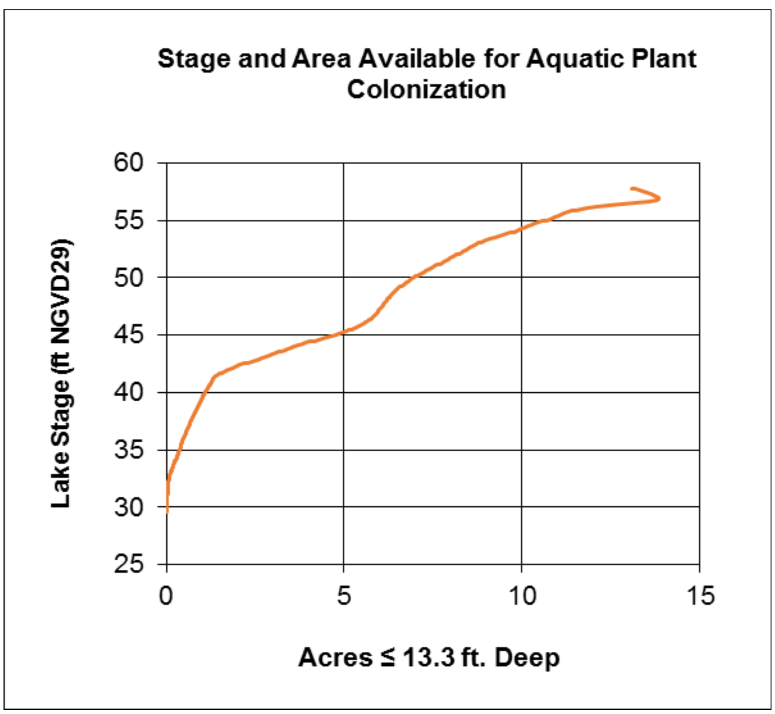

Figure 20. Lake Stage and Area Available for Aquatic Plant Colonization.

Revised Minimum Levels
The Minimum Lake Level (MLL) 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. Following the development of the Significant Change Standards and reviewing other available information, the MLL for Category 3 lakes is established at the most conservative (highest) Standard, below the Historic P50 (HP50). In the case of Round Lake, the revised Minimum Lake Level is 53.1 ft., based off the Wetland Offset.

The High Minimum Lake Level (HMLL) 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, the High Minimum Lake Level may be established using Historic hydrologic data or the region-specific reference lake water regime statistic. Since the Historic P10 data derived from the LOC model was thought to be unreliable for Round Lake, the HMLL was established at the elevation corresponding to the Minimum Lake Level plus the region-specific value (1 foot), thus resulting in a revised HMLL of 54.1 ft.

The revised Minimum and Guidance levels for Round Lake are plotted on the Historic water level record in Figure 21. To illustrate the approximate locations of the lake margin when water levels equal the proposed minimum levels, proposed levels are imposed onto a 2016 natural color aerial photograph in Figure 22.

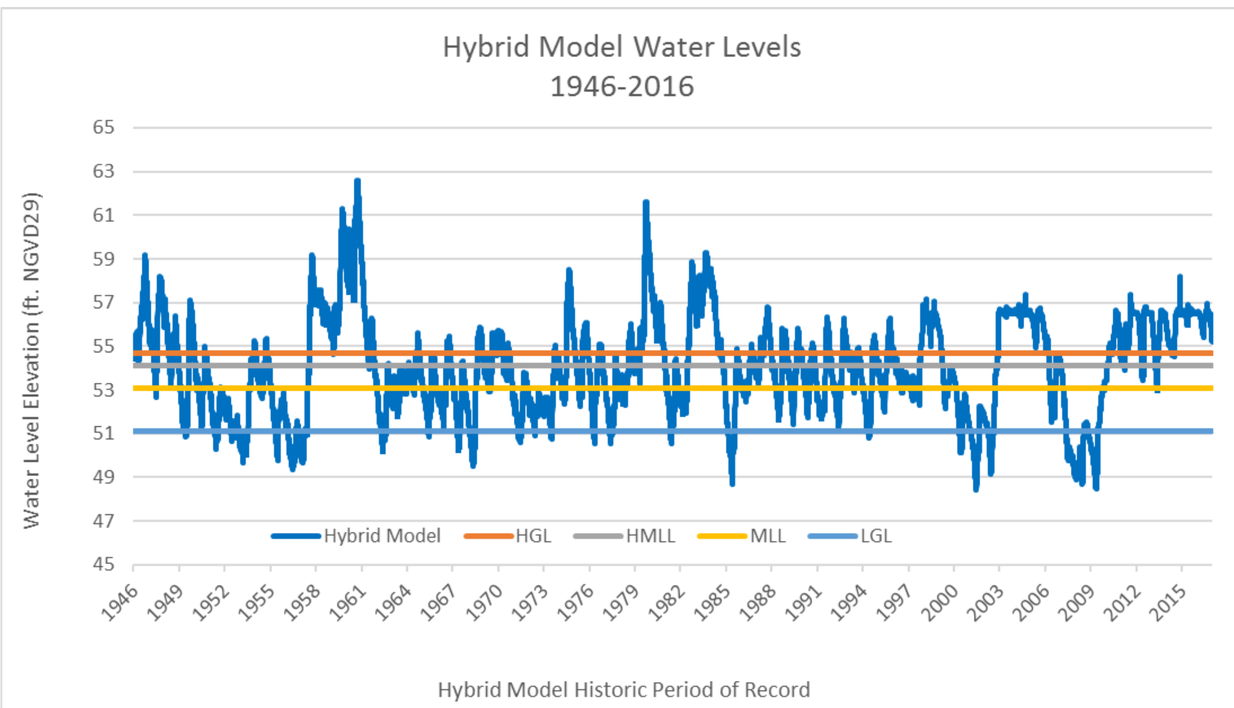

Figure 21. Historic water levels (hybrid) used to calculate the Revised Minimum and Guidance Levels. The revised levels include the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).

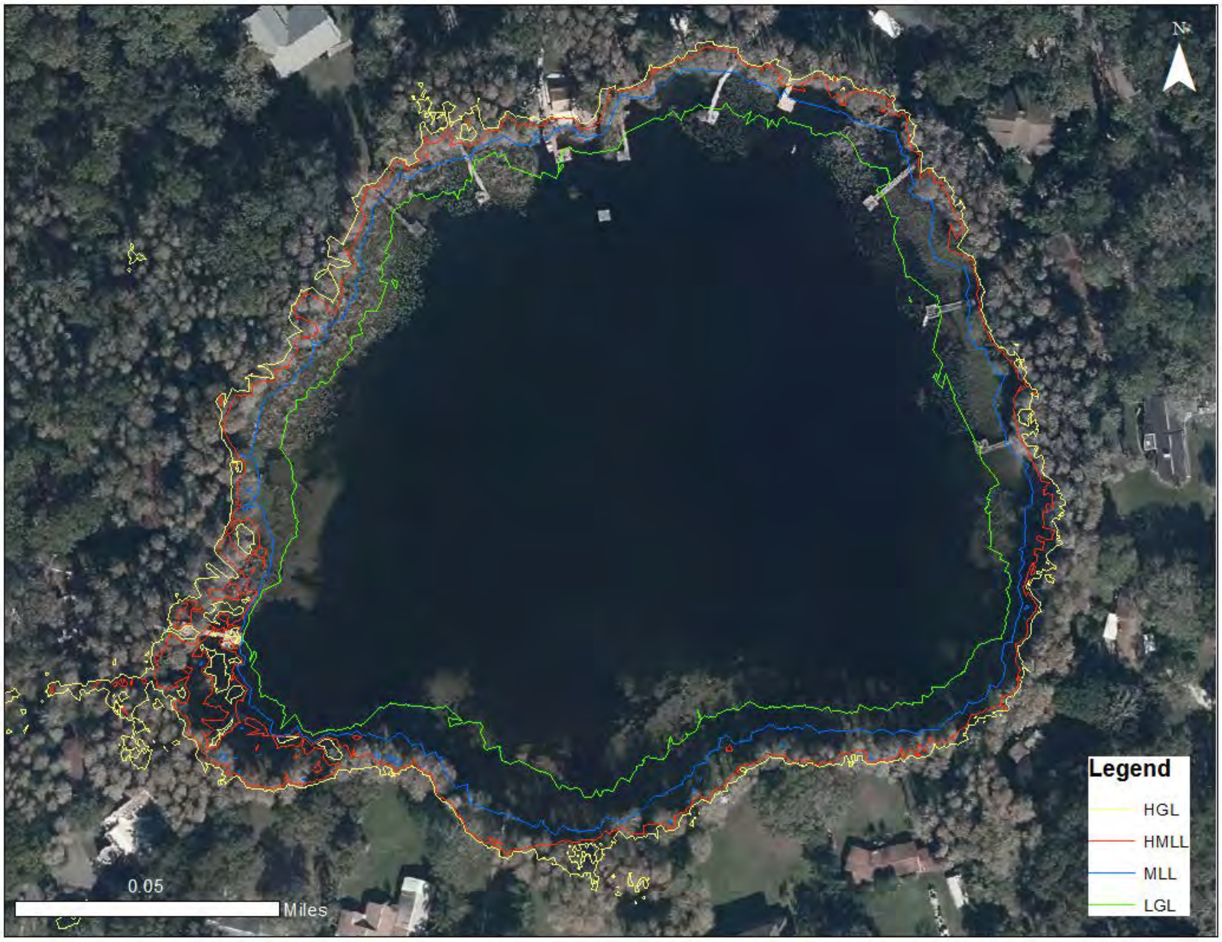

Figure 22. Round Lake Minimum and Guidance Level Contour Lines Imposed Onto a 2016 Natural Color Aerial Photograph (ft. above NGVD29).

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 Round Lake are presented in both datum standards (Table 4). 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 on 1988. The NGVD29 datum conversion to NAVD88 is -0.87 ft. for SID 19840 on Round Lake.

Table 4. Revised Minimum and Guidance Levels for Round Lake in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Feet NGVD29	Elevation in Feet NAVD88 (-0.87 ft.)
High Guidance Level	54.7	53.8
High Minimum Lake Level	54.1	53.2
Minimum Lake Level	53.1	52.2
Low Guidance Level	51.1	50.2

Consideration of Environmental Values

The revised minimum levels for Round 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 Wetland Offset Elevation was used for developing revised Minimum Levels for Round 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, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (Table 1).

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 permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Two environmental values identified in the Water Resource Implementation Rule were not considered relevant to development of revised minimum levels for Round Lake. Estuarine resources were not considered relevant because the lake is not connected to an estuarine resource. Sediment loads were similarly not considered relevant for minimum levels development for the lake, because the transport of sediments as bedload or suspended load is a phenomenon typically associated with flowing water systems.

Comparison of the Revised and Previously Adopted Levels

The revised High Guidance Level is 0.9 feet lower than the previously adopted High Guidance Level, while the Low Guidance Level is 2.4 feet lower than the previously adopted Low Guidance Level (Table 5). The proposed High Minimum Level and Minimum Level for Round Lake are 0.4 feet lower than the currently adopted Levels (Table 5). These differences are associated with the 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, and additional data since the last evaluation. The previously adopted MLL was set using the Aesthetics Standard, while the HMLL was also previously set using the MLL plus the RLWR50 (1.0 feet) for the northern Tampa Bay area.

Table 5. Revised Minimum and Guidance Levels for Round Lake Compared to Previously Adopted Minimum and Guidance Levels.

Minimum & Guidance Levels	Previously Adopted Elevation (Ft., NGVD29)	Revised Elevation (ft., NGVD29)	Difference (ft., NGVD29)
High Guidance Level	55.6	54.7	-0.9
High Minimum Level	54.5	54.1	-0.4
Minimum Level	53.5	53.1	-0.4
Low Guidance Level	53.5	51.1	-2.4

Minimum Levels Status Assessment

To assess if the proposed Minimum and High Minimum Lake Levels are being met, observed stage data in Round Lake were used to create a long-term record using a Line of Organic Correlation (LOC) model, similar to what was used to develop a Historic water level record to establish the Minimum Levels (Appendix A). For the status assessment, the 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, and represent current conditions (referred to as the “Current” period). The Current period for Round Lake was determined to be from 2005 to current, but only quality data from August 2012 through 2016 were available (see Appendix B). The LOC model resulted in a 70-year long-term water level record (1946-2016).

For the status assessment, median P50 and P10 water elevations were compared to the revised Minimum Lake Level and High Minimum Lake Level to determine if long-term water levels were above the revised levels. Results from these assessments indicate that Round Lake water levels that include the positive effects of augmentation are currently at or above the revised Minimum Lake Level and at or above the revised High Minimum Lake Level (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 40D-80.073, F.A.C.). The District plans to continue regular monitoring of water levels in Round Lake and will also routinely evaluate the status of the lakes’ water levels with respect to adopted minimum levels for the lakes included in Chapter 40D-8, F.A.C.

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APPENDIX A

Technical Memorandum

July 10, 2017

TO: Jaime Swindasz, Staff Environmental Scientist, Water Resources Bureau

THROUGH: JP Marchand, Bureau Chief, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Tamera S. McBride, P.G., Senior Hydrogeologist, Water Resources Bureau

Subject: Round and Saddleback Lakes Water Budget Models, Rainfall Correlation Models, 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 Round and Saddleback Lakes in northwest Hillsborough County. Both lakes currently have adopted minimum levels which are scheduled to be re-assessed in FY 2017. This document will discuss the development of the Round and Saddleback Lakes models and use of the models for development of Historic lake stage exceedance percentiles.

B. Background and Setting

Round and Saddleback Lakes are in northwest Hillsborough County, with Round Lake located east of Dale Mabry Highway and approximately 0.5 miles south of Van Dyke Road in Lutz, while Saddleback Lake is directly to the east of Round Lake (Figure 1). The lakes lie within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. In addition to runoff and local drainage, a culvert and ditch system between Round Lake and Saddleback Lake was constructed in the mid-1960s in an attempt to add more water to Round Lakes. However, during times when Round Lake is higher than Saddleback Lake, Round Lake can discharge to Saddleback Lake. Saddleback Lake also receives inflow from Lake Crenshaw to the north via a ditch. Saddleback Lake discharges to the south into a wetland system south of Saddleback Lake, and eventually to the Interceptor Canal. The Interceptor Canal was constructed in 1960 as a flood control system, diverting floodwater from the upper Sweetwater Creek watershed into the Rocky/Brushy Creek watershed (Figure 2).

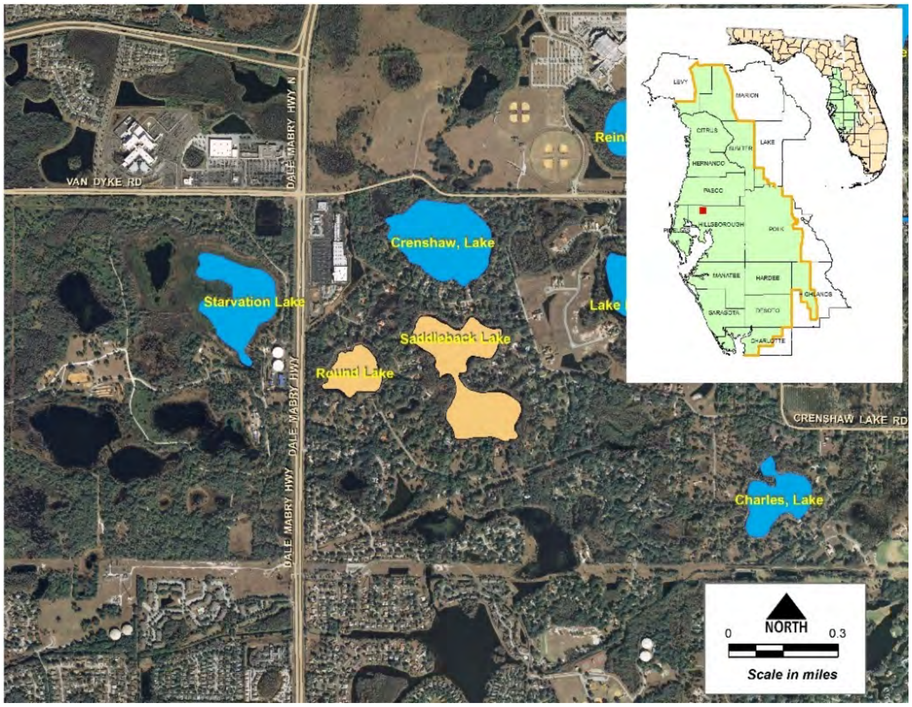

Figure 1. Location of Round and Saddleback Lakes in Hillsborough County, Florida.

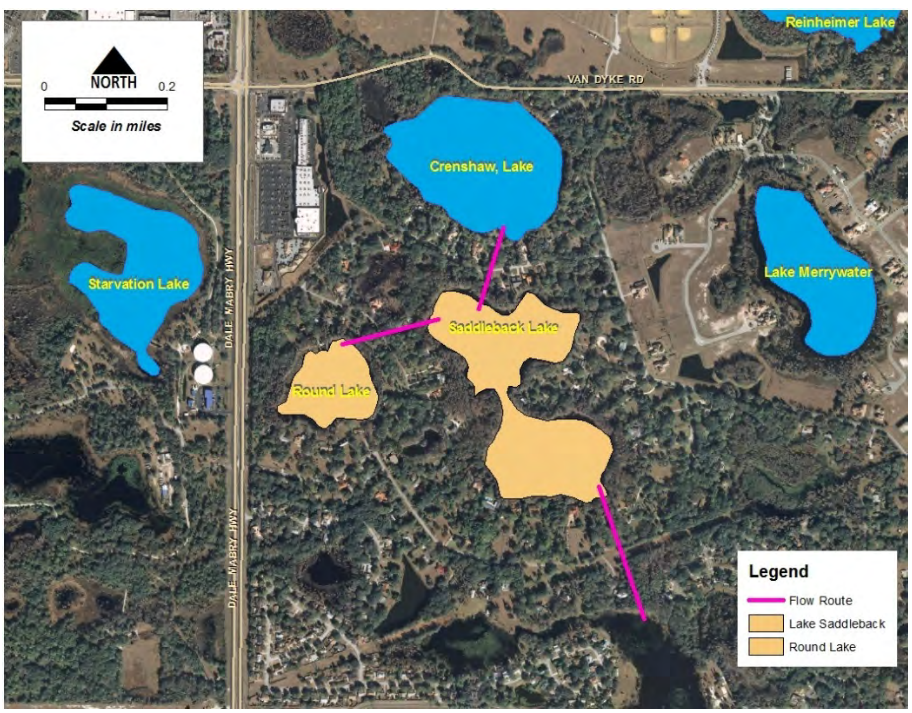

Figure 2. Flow between Round, Crenshaw, and Saddleback lakes and wetland area south of Saddleback Lake.

Physiography and Hydrogeology

The area surrounding the lakes 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 into the lakes is a combination of overland flow and flow through drainage swales and minor flow systems.

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. 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 Round Lake began in January 1965 and at Saddleback Lake in June of 1971 (Figures 3 and 4). Data collection for Saddleback Lake (District SID 19838, Saddleback Lake and USGS SID 2305178, Saddleback Lake Near Lutz FL) occurred weekly in the early part of the record, daily from October 1976 to May 1978, weekly and monthly through 1985, missing from September 1985 to October 1987, weekly through January 1992, mostly missing from January 1992 to March 1993, weekly through December 2003, and monthly through the end of the record. Round lake data (SID 19840) begin in January 1965 and are daily through September 1967, missing through November 1971, weekly through September 1981, missing through September 1996, daily through August 1999, weekly through November 2010, missing through May 2011, and monthly through the end of the record.

Regularly-collected water levels from the Berger Deep Floridan aquifer and Berger Shallow surficial aquifer monitor wells are available beginning November 1964 and June 1973, respectively (Figures 5 and 6). The wells are located approximately 500 feet to the south of Saddleback Lake and 1,800 feet southeast of Round Lake. The data for the Upper Floridan aquifer well are available as weekly at the beginning of the period of record, and become daily in 1974. The available data for the surficial aquifer well are weekly from the beginning of the record, missing between January and September

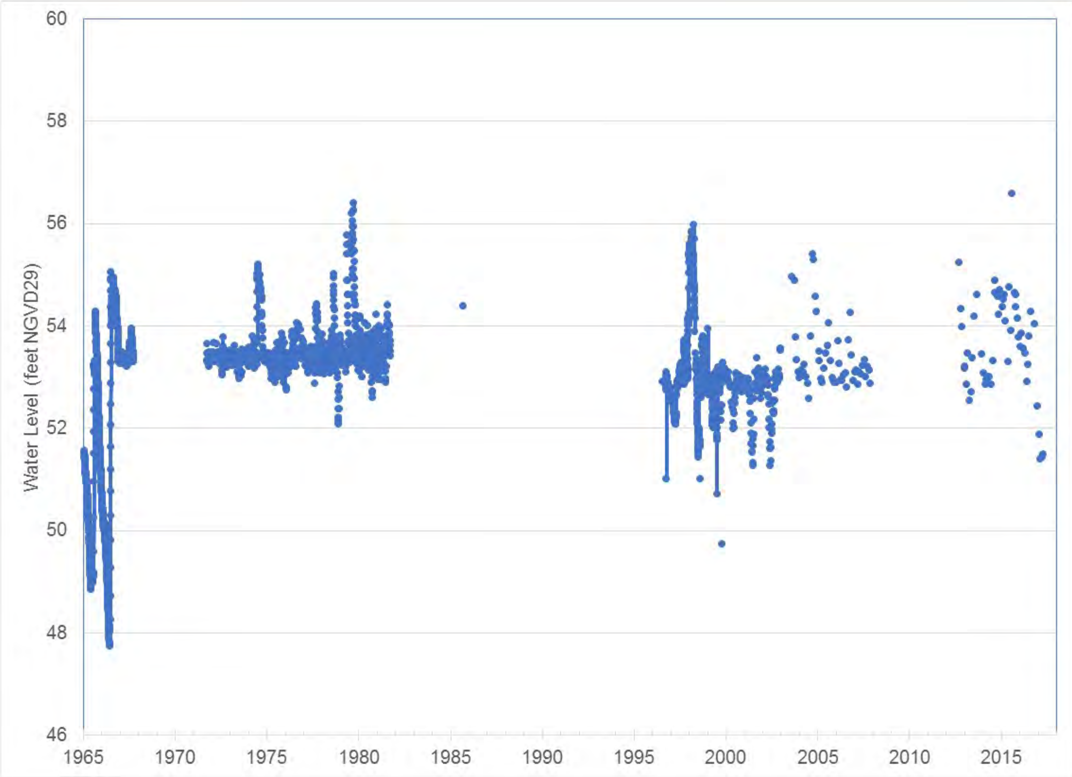

Figure 3. Round Lake water levels (SID 19840).

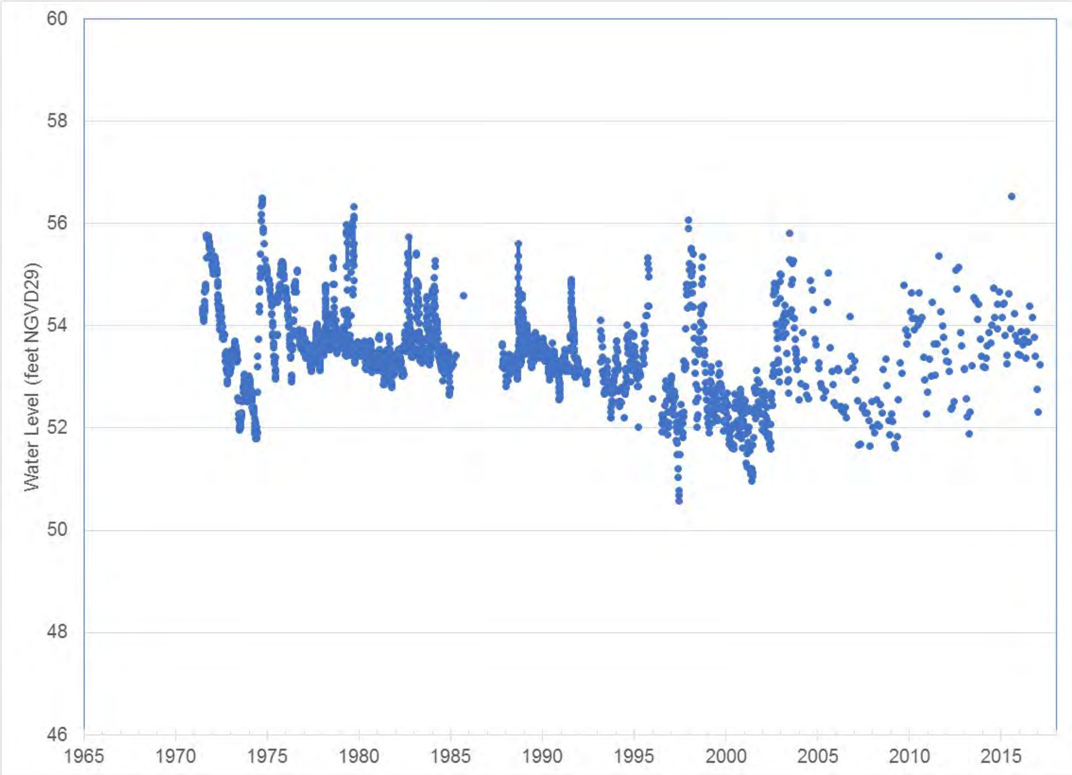

Figure 4. Saddleback Lake water levels (SID 19838 and USGS 2305178).

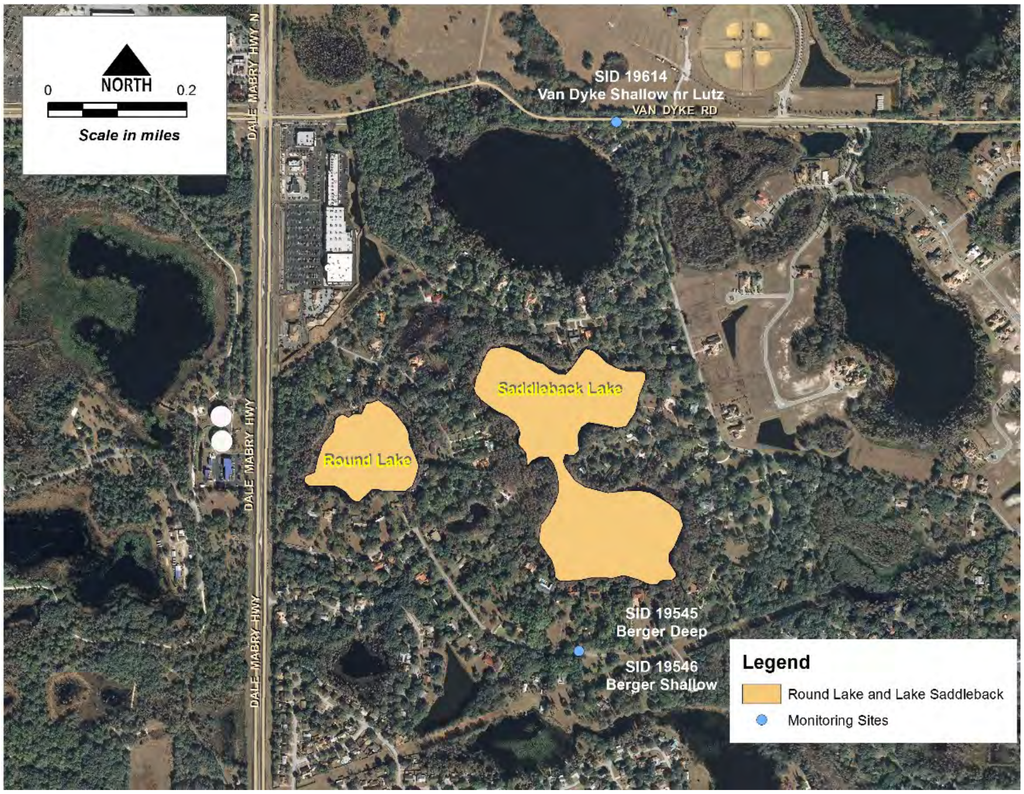

Figure 5. Location of monitor wells near Lakes Round and Saddleback.

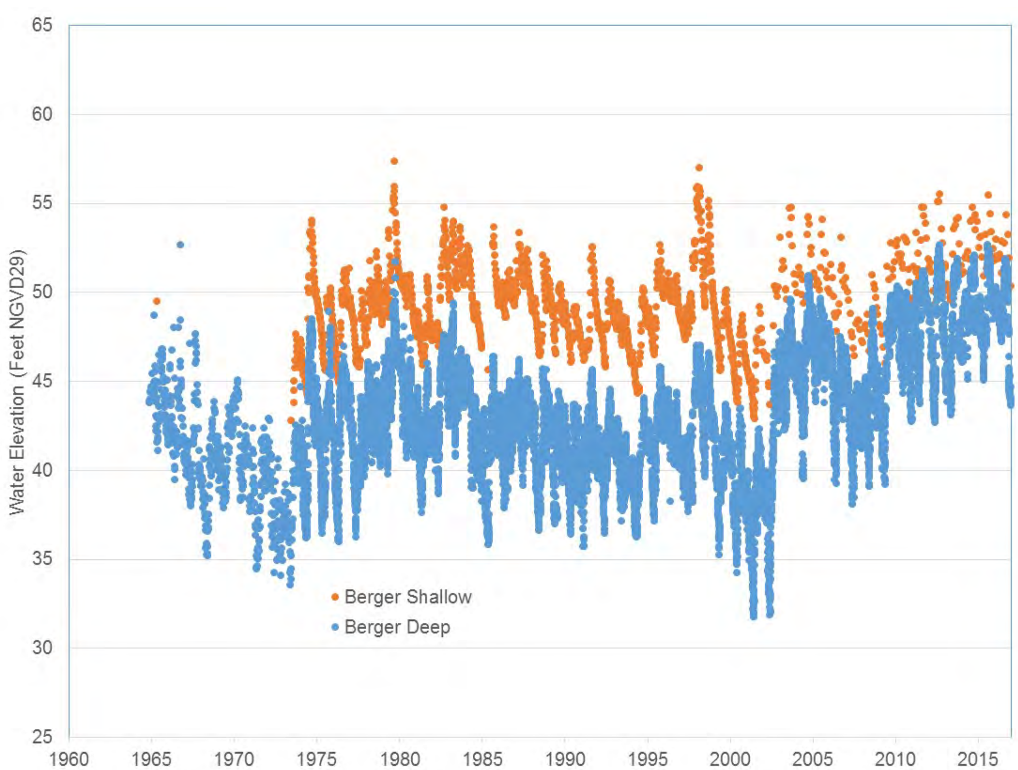

Figure 6. Water levels in the Berger Surficial and Floridan aquifer monitor wells.

1985, and monthly from September 2001 through the end of the data record. Data from the Van Dyke Shallow near Lutz surficial aquifer monitor well are available since October 1964. This well is located approximately 1,800 feet to the northwest of Saddleback Lake (Figure 5). Weekly data are available from this well at the beginning of the period of record, and become daily in 1974 (Figure 7).

Land and Water Use

Round Lake is located less than 500 feet due east of the Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 8).

Saddleback Lake is located approximately 1,600 feet east of the wellfield and Round Lake is located between the wellfield and Saddleback Lake. Groundwater withdrawals began at the Section 21 Wellfield in 1963, with monthly withdrawals steadily climbing to nearly 15 million gallons per day (mgd) in 1964 and to over 20 mgd on annual average in 1967 (Figure 9). With the development of the South Pasco Wellfield in 1973, withdrawal rates at the Section 21 Wellfield were reduced to approximately 10 mgd on annual average. Withdrawal rates since 2005 have averaged a little over 3 mgd on annual average, with several extended periods with no groundwater withdrawals.

Water levels in many lakes in the Section 21 wellfield area dropped significantly since public supply groundwater withdrawals began (Hancock and Basso, 1996). Because water level collection at Lakes Round and Saddleback did not begin until two years after the beginning of withdrawals from the wellfield (Figures 3, 4, and 9), the initial effect of the startup of the wellfield cannot be seen in the data.

According to Stewart and Hughes (1974), water levels in Round Lake and Saddleback Lake dropped precipitously shortly after the commencement of groundwater withdrawals at the Section 21 wellfield. On trial basis, water pumped from the Upper Floridan aquifer (from a Section 21 wellfield production well) was put in Round Lake during the summer of 1965. Based on the success of the trial, the residents of Round Lake constructed an Upper Floridan aquifer well, and routine augmentation began in June 1966. A well was constructed on Saddleback Lake during July 1968, and lake augmentation with Upper Floridan aquifer water began there as well. A review of aerial photography (Figure 10) shows that signs of lowered lake levels after the commencement of groundwater withdrawals at the Section 21 wellfield are obvious in the 1968 photograph as compared to the 1957 photograph. At the time of the 1968 image, Round Lake had been augmented for a few years, while augmentation at Saddleback Lake had either not yet started, or just began. An exposed ring of sandy lake bottom can be seen around Saddleback Lake.

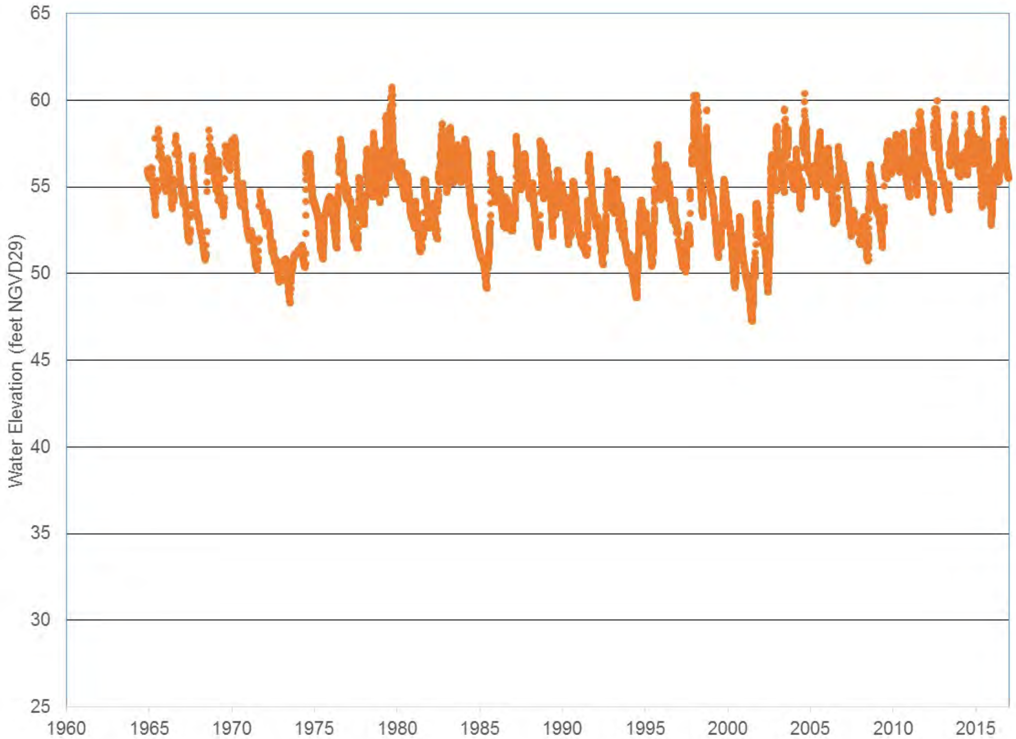

Figure 7. Water levels in the Van Dyke Shallow surficial aquifer monitor well.

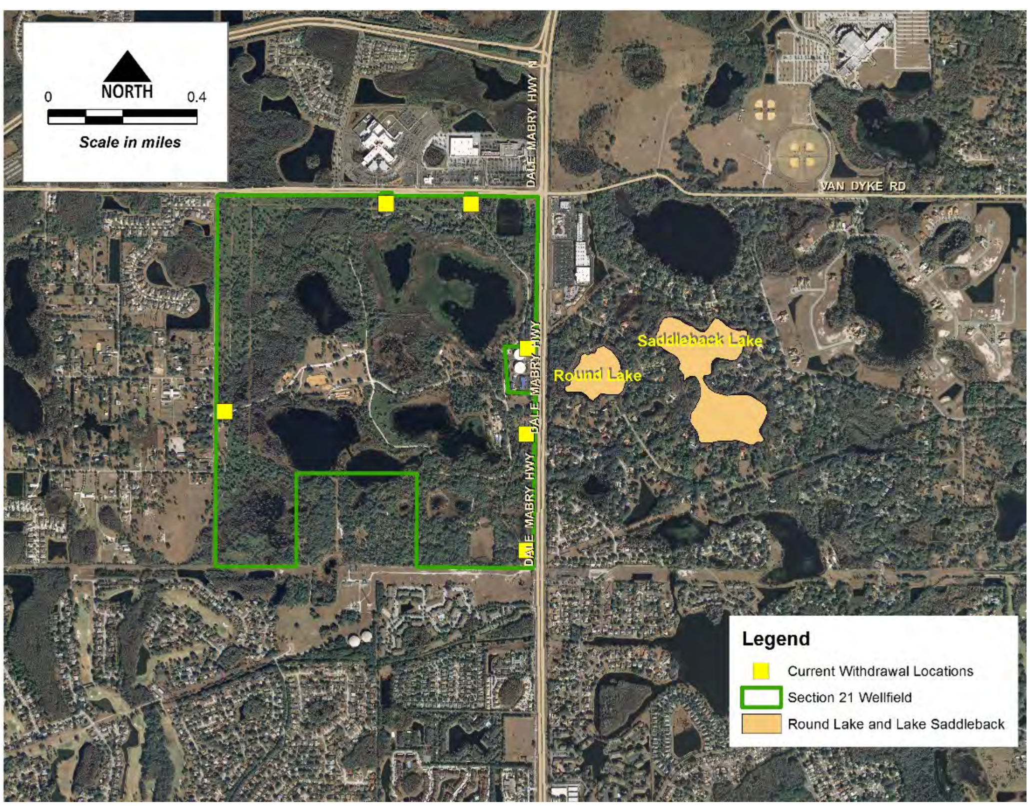

Figure 8. Round Lake, Saddleback Lake, and the Section 21 Wellfield.

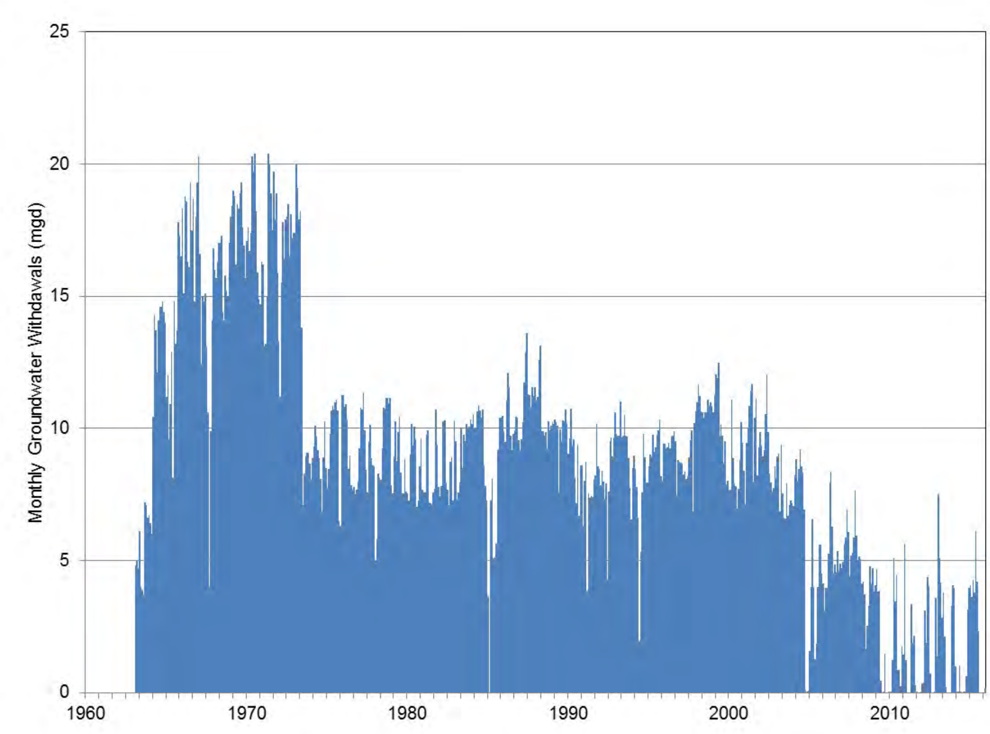

Figure 9. Section 21 Wellfield withdrawals.

Figure 10. Water level changes in Lake Round and Saddleback.

Sinclair (1982) and Tihansky (1999) discuss the observed formation of 64 sinkholes that developed within one month after water levels declined more than 10 feet following the initiation of groundwater withdrawals at the Section 21 Wellfield in 1963. Sinkholes were documented as far as several miles away, and they continued to appear around the wellfield years later. It is possible that a change in leakance properties between Round Lake and Saddleback Lake and the Upper Floridan aquifer (possibly due to karst activity beneath or surrounding the lakes) has persisted since that time.

The relationship between sinkhole formation or karst activity and hydrologic stress in the northwest Hillsborough County area has been well established and thoroughly discussed (Bredehoeft and others, 1965; Sinclair, 1973; Stewart and Hughes, 1974; Sinclair, 1982; Sinclair and others, 1985; Hancock and Basso, 1996; Metz and Sacks, 2002; and, Metz, 2011). Man-induced or natural hydrologic stress can cause sediments in karst formations to unravel or can lower water levels that support overburden covering voids in the limestone aquifer. This can result in sinkholes that appear on the surface, or can result in changes that occur underground and cannot be seen at the surface. These changes, in turn, can result in pathways for water to connect lakes, wetlands, or the surficial aquifer in general, to the underlying Upper Floridan aquifer.

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 period. The Historic 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 period is significant, since it provides the opportunity to establish strong predictive relationships between rainfall, groundwater withdrawals, and lake stage fluctuation that represent the lake's natural state in the absence of groundwater withdrawals. This relationship can then be used to calculate long-term Historic lake stage exceedance percentiles such as the P10, P50, and P90, which are, respectively, the water levels equaled or exceeded ten, fifty, and ninety percent of the time. If measured data representative of a Historic period does not exist, or available Historic 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 Round Lake and Saddleback Lake, the Section 21 Wellfield has potentially affected lake water levels in the lake since early 1963. Other groundwater withdrawals (including other wellfields) in the area could also have affected levels, but the effect of such withdrawals would be smaller and less consistent. No data from either lake exists prior to the commencement of groundwater withdrawals from the Section 21 Wellfield. Therefore, the development of a water budget model coupled with a rainfall correlation model for 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 Round Lake and Saddleback Lake water budget models are spreadsheet-based tools 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 each lake extending down to the elevation of the greatest lake depth. A stage-volume curve was derived for the lakes that produces a unique lake stage for any total water volume within the control volume.

The hydrologic processes in each lake's water budget model include:

a. Rainfall and evaporation
b. Augmentation
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

After the initial development of the Round and Saddleback lakes water budget models, the decision was made to create a water budget model of Lake Crenshaw. Because the three lakes are so close to the Section 21 wellfield, the effect on all three lakes from withdrawals may be significant. Creating a water budget model for Lake Crenshaw allows the effects of withdrawals to also be removed from the lake (in a simulation), which may significantly increase flows to Saddleback Lake.

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 the lake. The water budget model for Round Lake is calibrated from July 1996 through 2016, and the water budget for Saddleback Lake is calibrated from November 2002 through 2016. These periods provide 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. Because the Lake Crenshaw water budget model was created solely for the purpose of improving the Saddleback Lake model, it was also calibrated from November 2002 through 2016.

E. Water Budget Model Components

Lake Stage/Volume

Lake stage area and stage volume estimates were determined by building a terrain model of each 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 10.4.1, 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 the area of each lake and associated volume of each lake at different elevations, starting at the extent of each lake at its flood stage and working downward to the lowest elevation within the basin.

Saddleback Lake consists of two lake lobes joined by a relatively narrow connector. Bathymetric mapping completed for this re-evaluation showed the depth of the connector is lower than the lowest water level record in the period of record data for the lake. If separation had occurred in the past, it would have been a rare, short-duration occurrence. Therefore, lobe separation was not incorporated into the water budget model.

Precipitation

After a review of several rain gages in the area, a composite of several stations was used for each lake's water budget model (Figure 11). The same rainfall record was used for each lake. The goal was to use the closest available data to the lakes, as long as the data appeared to be high quality. The Lake Crenshaw rainfall gage (SID 20005), located about 1,500 feet to the north of Saddleback Lake, has measurements starting at the beginning of the model period (January 1, 1988) through May 30, 2005. The Whalen gage (SID 19492), located approximately 5,800 feet to the east of Saddleback Lake, also has data available through 2005 (when the gage was terminated). The St. Pete Jackson 26A gage (SID 19550), located approximately 5,100 feet to the west of Round Lake, has data available through current, but was not ultimately used for this analysis. All of these rainfall stations are maintained by the District. Also available is NEXRAD (Next Generation Weather Radar) derived rainfall data for the lake from 1995 to current. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration.

After assessment of all available rainfall data, there was a concern with the quality of the later years of the Lake Crenshaw gage when compared to the other gages. The decision was made to use the Lake Crenshaw data for the water budget models from model beginning through 1994 and data for the NEXRAD pixel that overlays the lakes from 1995 to 2016.

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 water

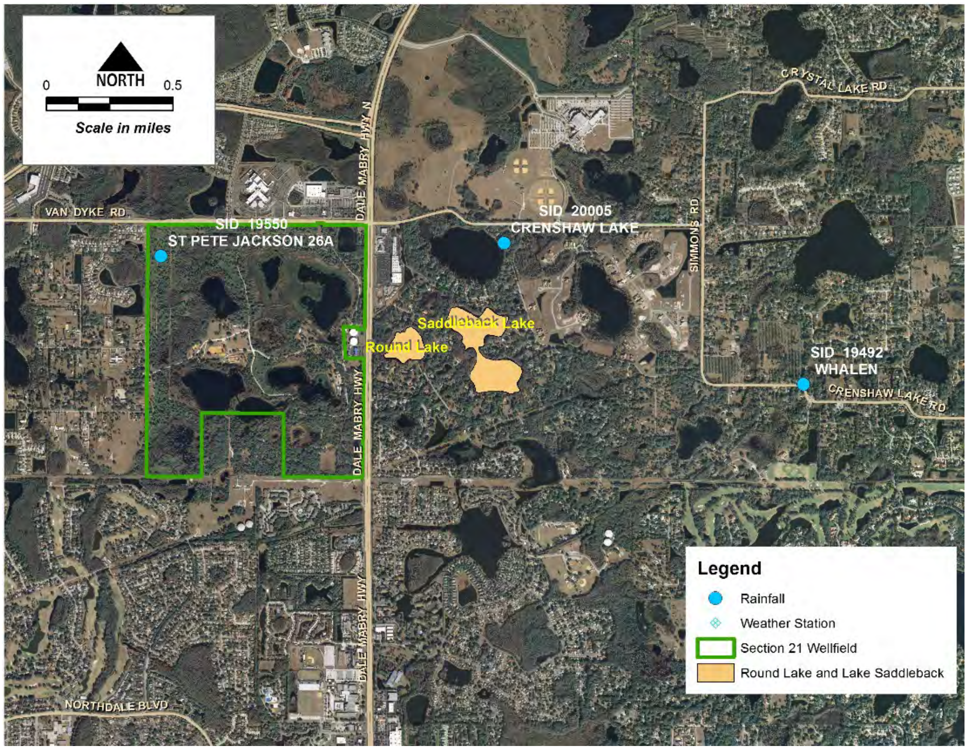

Figure 11. Rain gages considered in the Round Lake and Saddleback Lake water budget models.

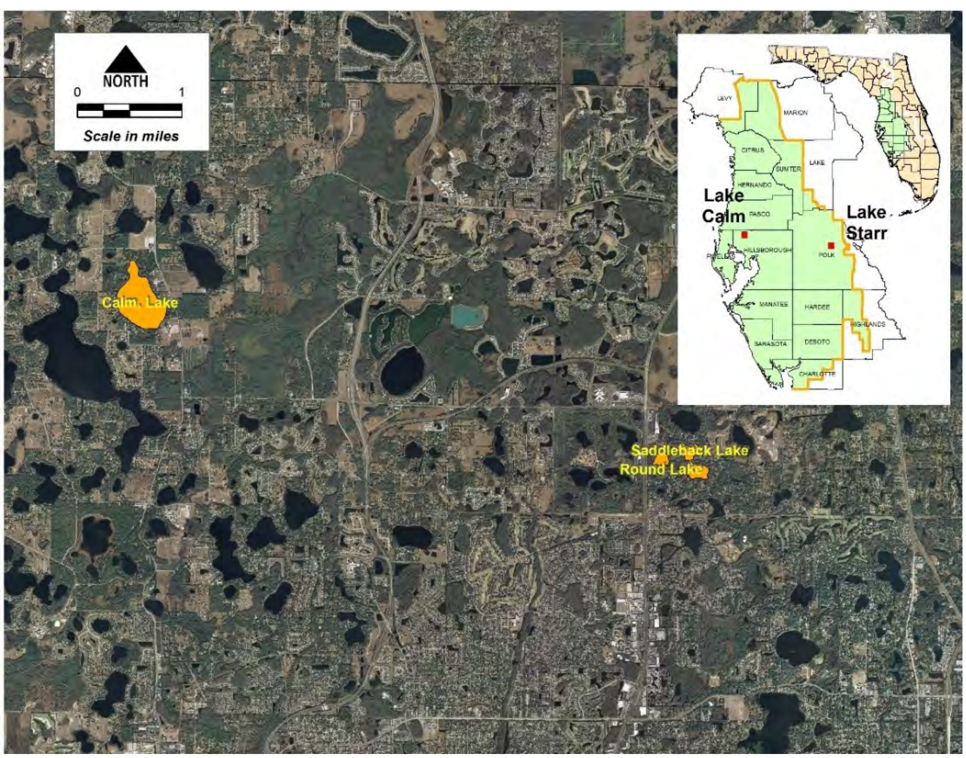

Figure 12. Location of Lakes Round, Saddleback, Calm and Starr (see inset).

budget models when available, and monthly averages for the period of record were used for those months 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 5 miles to the northwest of Round Lake and Saddleback Lake (Figure 12). The assessment concluded that the evaporation rates between the two lakes were essentially 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 using 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 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

Although both Round Lake and Saddleback Lake have been regularly augmented with water withdrawn from the Upper Floridan aquifer since the mid- to late-1960s, the lakes did not receive a water use permit until 1996. Therefore, augmentation quantity data are not available until 1996 for Round Lake. A flow meter was not installed on Saddleback Lake until 2002. Due to these limitations, and because the amount of augmentation added to the lakes was thought to be significant when implemented, the decision was made to begin the Round Lake water budget simulation in 1996 and Saddleback Lake in 2002. Although Lake Crenshaw has had some augmentation historically, there is no evidence augmentation occurred during the simulation period.

When applicable, augmentation quantities withdrawn from the Upper Floridan aquifer were added to each lake daily, based on the available metered values (Figures 13 and 14). Because the District permit only requires reporting of monthly totals (rather than daily, as required the water budget model), for modeling purposes, it was assumed that augmentation was distributed evenly each day in the month that it was reported. From these figures, it is clear that the augmentation applied to Round Lake is much greater than that applied to Saddleback Lake.

Conversion of monthly augmentation to daily could cause model calibration difficulty. Additionally, augmentation was not always reported regularly, which could also cause

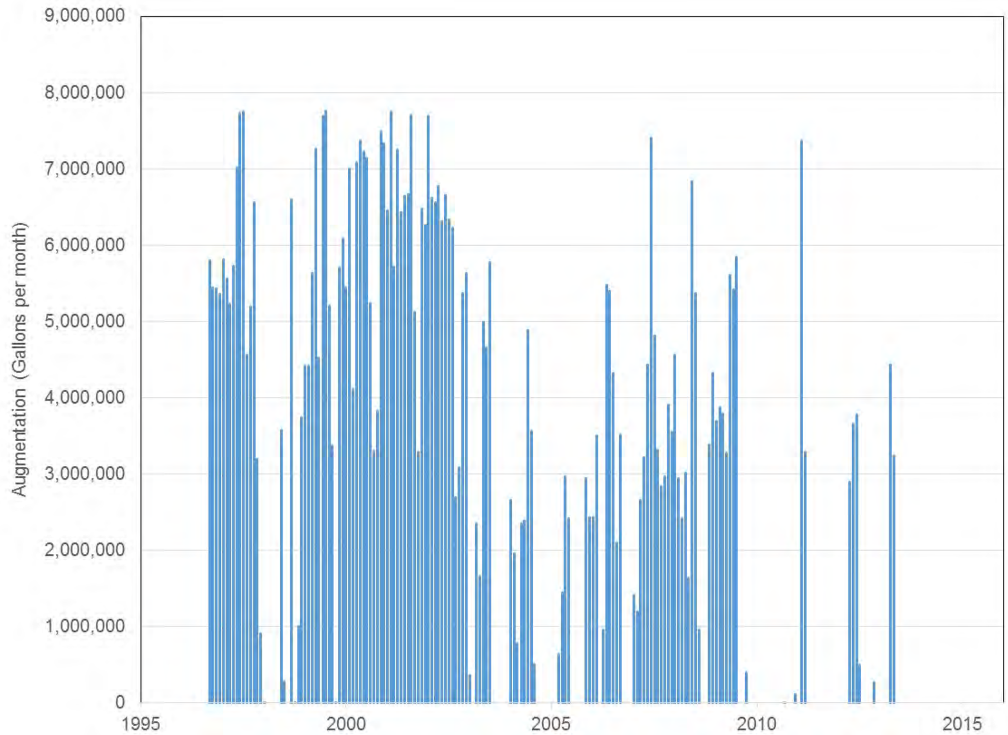

Figure 13. Metered augmentation withdrawals at Round Lake.

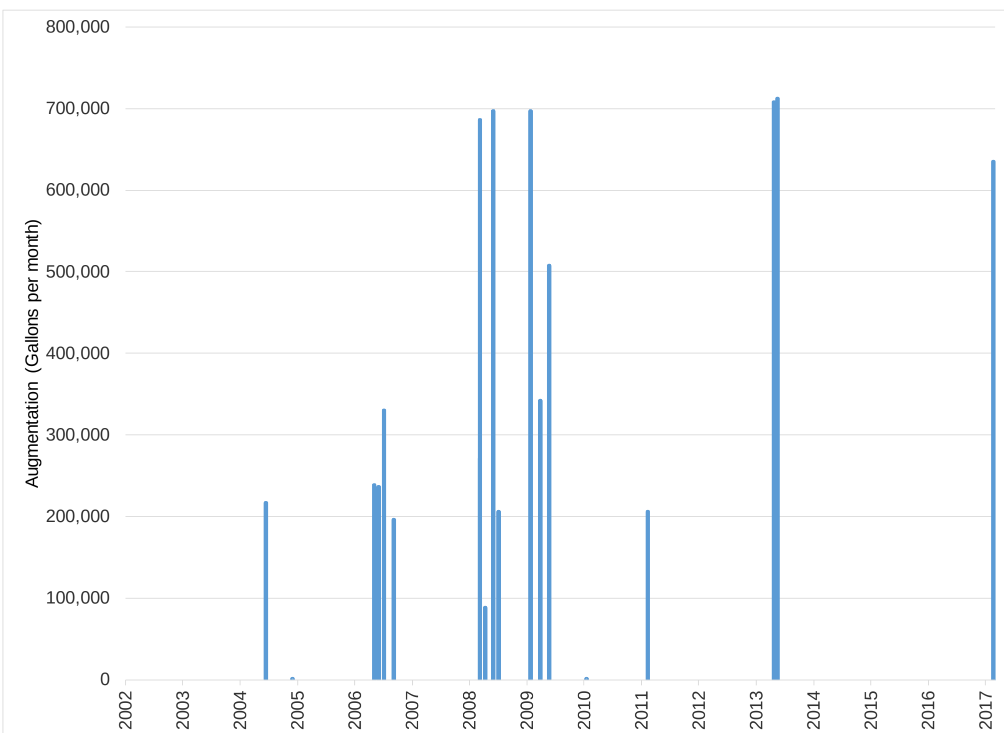

Figure 14. Metered augmentation withdrawals at Saddleback Lake.

calibration issues. For example, if monthly data were missing, augmentation totals for more than one month could have been reported to the District as a monthly total and distributed over one month instead of two. It was impossible to know if the augmentation occurred only during the month that it was reported. While reporting errors and omissions were typically cause for the District to contact the permittee, resolution was not achieved in all cases. Regardless, the best available information was used to represent augmentation in the model. Due to wellfield reductions and higher rainfall in recent years, a significant reduction in reported augmentation quantities can be seen in the data record.

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 each 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. Additionally, the curve number (CN) chosen for the watershed of the lake considers 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. The modification adds a fourth category of antecedent moisture condition (AMC) to the original SCS method (SCS, 1972) to account for Florida's frequent rainfall events.

The topography around Round, Saddleback, and Lake Crenshaw is very flat, so determining watersheds based on relatively subtle divides can be challenging. Several slightly varying estimates of watershed boundaries have been developed in the past for different modeling efforts in the area. One of the most recent set of estimates was developed as part of an effort to model the five main watersheds in northwest Hillsborough County for flood assessment purposes (CH2M HILL Engineers, 2016). The watershed area values developed by CH2M HILL were adopted for the Round, Saddleback, and Lake Crenshaw models (Tables 1 through 3) after an independent check confirming that they are reasonable for water budget modeling purposes.

Round Lake has an immediate watershed from which it receives overland flow (Figure 15), but also receives occasional flow from Saddleback Lake. Saddleback Lake has both an immediate watershed from which it receives overland flow and a contributing watershed to the north from which it can receive channel flow from Lake Crenshaw (Figures 2 and 15). The immediate watershed of Round Lake is approximately 53

Table 1. Model Inputs for the Round Lake water budget model.

Input Variable	Value
Overland Flow Watershed Size (acres)	53.0
SCS CN of watershed	65
Percent Directly Connected	0
FL Monitor Well Used	Berger Deep
Surf. Aq. Monitor Well(s) Used	Berger Shallow
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0041
Outflow K	N/A
Outflow Invert (ft NGVD29)	N/A
Inflow K	0.003
Inflow Invert (ft NGVD29)	53.7

Table 2. Model Inputs for the Saddleback Lake water budget model.

Input Variable	Value
Overland Flow Watershed Size (acres)	135.2
SCS CN of watershed	74
Percent Directly Connected	0
FL Monitor Well Used	Berger Deep
Surf. Aq. Monitor Well(s) Used	Berger Shallow
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.0015
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.0013
Outflow K south	0.009
Outflow Invert (ft NGVD29) south	53.5
Outflow K to Round Lake	0.003
Outflow Invert to Round Lake ft NGVD29)	53.7
Inflow K from Lake Crenshaw	0.0055
Inflow Invert from Lake Crenshaw (ft NGVD29)	54.6

Table 3. Model Inputs for the Lake Crenshaw water budget model.

Input Variable	Value
Overland Flow Watershed Size (acres)	260.7
SCS CN of watershed	70
Percent Directly Connected	0
FL Monitor Well Used	Berger Deep
Surf. Aq. Monitor Well(s) Used	Berger Shallow
Surf. Aq. Leakance Coefficient (ft/day/ft)	0.002
Fl. Aq. Leakance Coefficient (ft/day/ft)	0.00049
Outflow K	0.0055
Outflow Invert (ft NGVD29)	54.6
Inflow K	N/A
Inflow Invert (ft NGVD29)	N/A

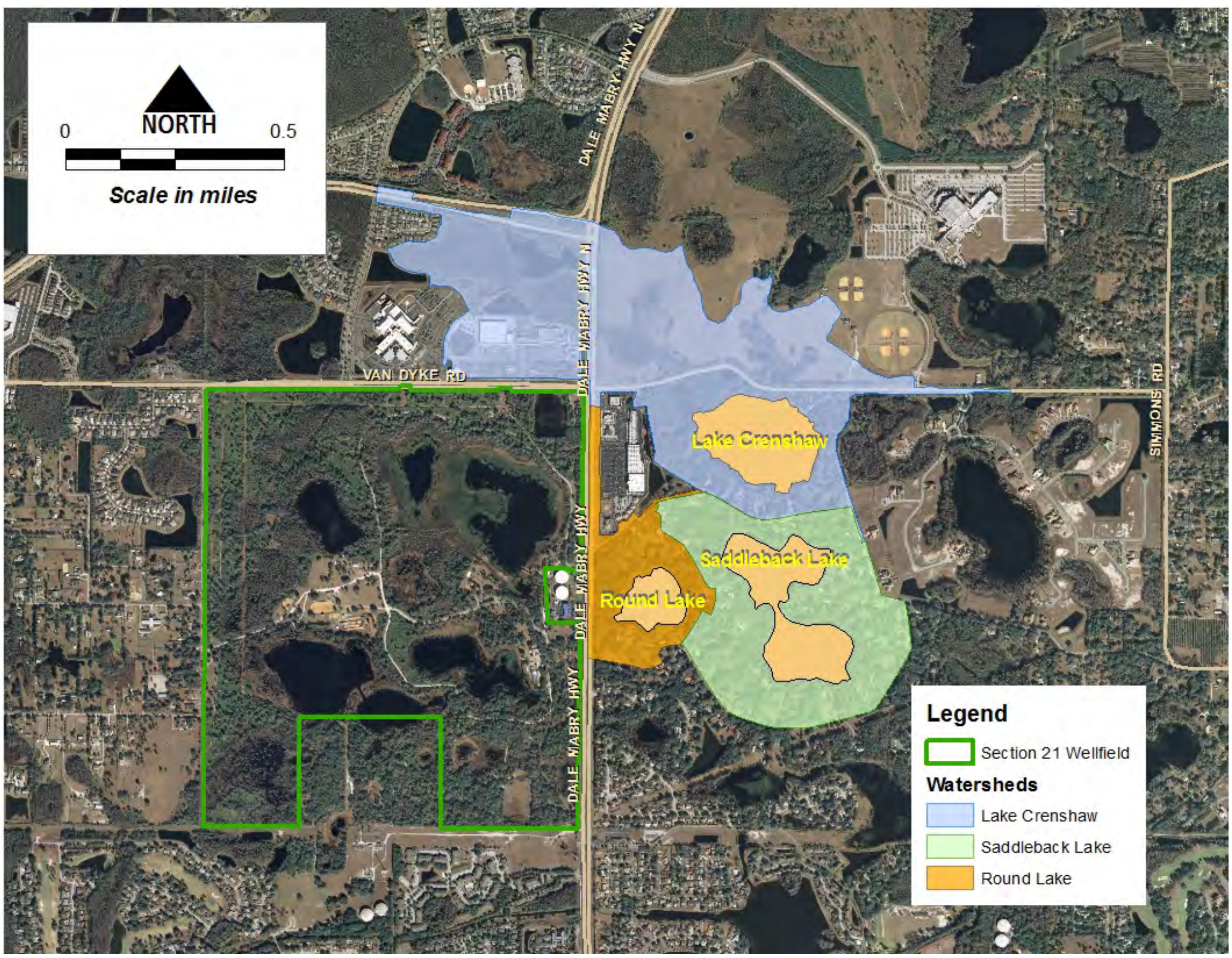

Figure 15. Watersheds of lakes Round, Saddleback, and Crenshaw.

acres. The entire area of the contributing watershed of Saddleback Lake includes the Lake Crenshaw watershed, while the area of direct overland flow watershed is approximately 135 acres (including the lake). The Lake Crenshaw watershed was estimated to be 260.7 acres (including the lake).

Overland flow for each lake can be modeled using the modified SCS method to estimate flow from its contributing watershed. Because Saddleback Lake has an overland flow basin and inflow from the Lake Crenshaw basins, it can be modeled by modeling the overland flow portion of the contributing basin using the modified SCS method, and modeling the contributing basin using lake stage at Lake Crenshaw and a control elevation. However, to account for potential increases in flow from Lake Crenshaw during simulations representing conditions under no groundwater withdrawals, the decision was made to create a water budget of Lake Crenshaw.

The DCIA and SCS CN used for the direct overland flow portions of each watershed are listed in Tables 1, 2, and 3. Curve numbers were difficult to assess. Most of the soils in the area are A/D soils, which 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 “A” soil. Because of the proximity of the wellfields 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 “A” soil). Groundwater withdrawals during a significant part of the calibration period were, however, significantly reduced relative to historic withdrawal rates, so the soils in the area may have begun to exhibit runoff properties more characteristic of “D” soils.

For purposes of the models, considering the range of conditions experienced, a compromise was used for the CN. No direct discharges from impervious areas to the lake were identified, so the DCIA of each watershed is zero.

Inflow and Discharge Via Channels from Outside Watersheds

Inflow and outflow via channels from or to the lake’s watershed (i.e., “channel flow”) is an important component to the water budgets of all three lakes, although the gradients of the channels are relatively flat. Round Lake was modeled with only an inflow via a ditch and culvert system from Saddleback Lake. Saddleback Lake was modeled with an inflow from Lake Crenshaw, and two outflows (one to the northwest toward Round Lake, and one to the south). Lake Crenshaw was modeled with no inflow, but an outflow to Saddleback Lake.

To estimate flow out of each lake, the predicted elevation of the lake from the previous day is compared to the controlling elevation. Control elevations were determined based on professional surveying performed in the area. If the lake elevation is above the controlling elevation, the difference is multiplied by the current area of the lake and an "outflow coefficient." The coefficient represents an estimate of channel and structure efficiency, and produces a rough estimate of volume lost from the lake. This volume is then subtracted from the current estimate of volume in the lake. Calculated outflows (lakes Crenshaw and Saddleback) were assigned to be inflows for the receiving lake water budget models (lakes Saddleback and Round).

Water flows from Lake Crenshaw to Saddleback Lake via a well-maintained ditch, under Little Road through a 42-inch corrugated metal pipe (CMP), and then through another well-maintained ditch to Saddleback Lake. A high point in the ditch north of Little Road (54.6 feet NGVD29) was used as the control elevation since the ditch appears to be well-maintained and stable, and the high point in the 42-inch CMP is nearly a foot lower (53.7 feet NGVD29). Flow from Lake Crenshaw to Saddleback Lake is simulated in the Lake Crenshaw water budget model by calculating daily lake stage. The elevation of Lake Crenshaw for the previous day is compared to the controlling elevation of the ditch system from Lake Crenshaw to Saddleback Lake. If the Lake Crenshaw elevation is above the controlling elevation, the difference is multiplied by the current area of Lake Crenshaw and an outflow coefficient. The resulting daily volumes are then added to the water budget of Saddleback Lake as an inflow.

Saddleback Lake discharges both to the northwest toward Round Lake, and to the south through a ditch. The southern discharge flows under Berger Road via two 36-inch CMPs, and then through a ditch into a wetland south of Saddleback lake. A structure was installed around 1965 in conjunction with construction of a ditch between lakes Saddleback and Round (Figure 16). The operation of this structure was intended to allow Round Lake to be augmented with overflow from Saddleback Lake, as well as allow the outflow from Saddleback Lake to be controlled. The two 36-inch CMPs were equipped with slots into which boards could be installed to adjust the functional elevation of the structure. In the past, the District operated the structure through the addition of boards, but District records indicate boards have not been added to the structure since prior to 2006, about four years after the water budget model start date. Operating records prior to this were not readily available, so it is not known if the boards were in place during the early years of the water budget model. For modeling purposes, it was assumed that the boards were not in place for the entire water budget model calibration period, since they were not installed during most of the model period. Calibration using this assumption appeared reasonable.

A high point in the ditch between Saddleback and Berger Road (53.5 feet NGVD29) was used as the control elevation for the southern outlet of Saddleback Lake since the ditch appears to be well-maintained and stable, and the high point in the 36-inch CMPs under Berger Road is nearly a one-half foot lower (53.1 feet NGVD29).

Figure 16. Operable structure installed on the outlet of Saddleback Lake.

Analysis of available measured data shows lakes Round and Saddleback are rarely connected except during high rainfall periods. Given the relatively flat topography, water can flow both directions between lakes Saddleback and Round. Data show Saddleback Lake flows into Round Lake more often than Round Lake flows into Saddleback Lake; however, both events are relatively infrequent in the data record. For water budget modeling purposes, it was assumed that when the lakes are connected, flow occurs from Saddleback Lake to Round Lake. The flows from Round Lake to Saddleback Lake are relatively low in the long-term water budget of each lake. The flow from Saddleback Lake to Round Lake was estimated by using the model generated outflow from Saddleback Lake, while any outflow from Round Lake to Saddleback Lake was assumed minimal and not incorporated into the model.

Because the Round Lake water budget model begins over five years prior to the Saddleback model, inflow from Saddleback Lake during the period when the Saddleback Lake model does not exist was calculated manually. This occurred only a few times during that period when Saddleback Lake rose above the control elevation of its northwest outlet. The same elevation and outflow coefficient used for the Saddleback Lake model was applied for those calculations.

Flow between lakes Round and Saddleback occurs via a well-maintained ditch from Saddleback Lake to Linda Vista Circle, and then an 18-inch CMP that passes under the road and on to Round Lake. A high point of 53.7 feet NGVD29 in the pipe as it passes under Linda Vista Circle serves as the control elevation between the lakes.

Flow from and into the surficial aquifer and Upper Floridan aquifer

Water exchange between the three lakes and the underlying aquifers is estimated using a leakance coefficient and the head difference between each lake and the aquifer levels. For each model time step, surficial aquifer and Upper Floridan aquifer leakage volumes were calculated independently. Leakance coefficients for each aquifer were determined through calibration.

The Berger Deep well is the closest Upper Floridan aquifer monitor well to both lakes, and was used to represent the potentiometric surface at each lake (Figure 5). A review of potentiometric surfaces for several years concluded that no adjustment to the Berger Deep well was needed to represent the potentiometric surface under the lakes.

The USGS performed a hydrogeologic and water budget assessment of Round Lake and two other lakes in the northwest Hillsborough County area (Metz and Sacks, 2002). As part of that work, two surficial aquifer monitor wells were installed, one 80 feet to the south of the lake, and one 105 feet to the north. Data was collected from the south well from May 1996 to May 1999, while data from the north well was collected from January 1997 to August 1998 (Figure 17). Both wells were then abandoned. As can be seen in the figure, water levels for all three surficial aquifer wells consistently remain well below the lake at similar elevations, and only jump to levels at or above those in the lake during very high rainfall events (the winter of 1997/1998 was an extreme El Niño event). Based on this information, the Berger Shallow well was used to represent the surficial aquifer water levels at all three lakes, again with no adjustments to the levels.

Water Budget Model Approach

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

Upon initial assessment of the water budget results for Round Lake, it was noticed that while District collected data throughout the model period matched well with the model results, the period from 2004 through 2007 did not. Because the data appeared to be shifted upward, the decision was made not to use the data for calibration. The calibration results, however, did not change with or without use of this data.

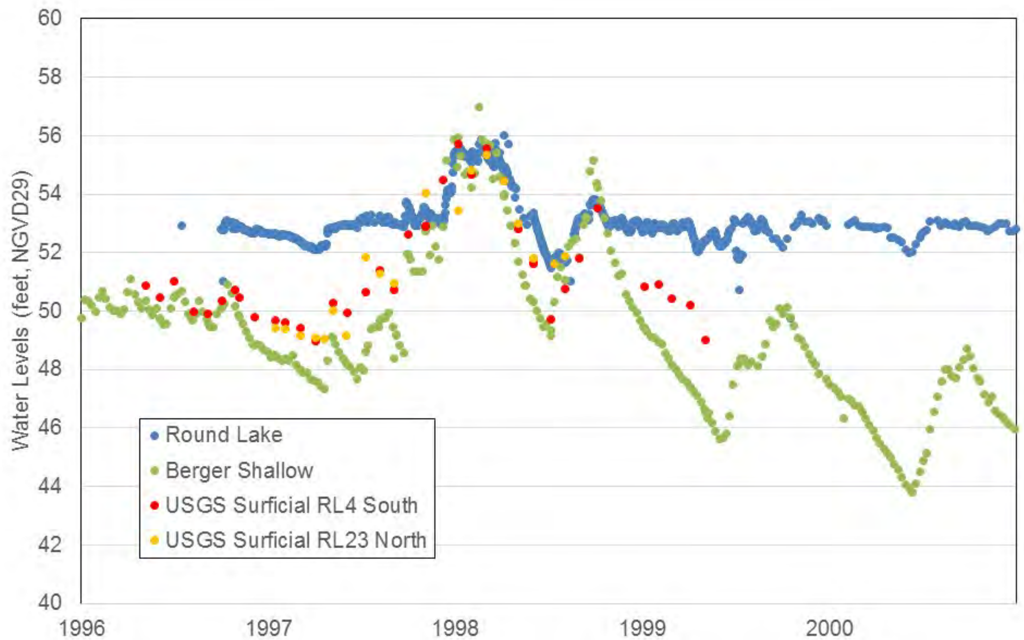

Figure 17. Water levels in Round Lake, the Berger Shallow surficial aquifer monitor well, USGS RL4 South surficial aquifer monitor well, and USGS RL23 North surficial aquifer monitor wells.

Similarly, on Saddleback Lake, it was noticed that during the period from approximately mid-2007 to mid-2008, the modeled water levels dropped significantly, while the measured data did not. Notes in the file of record indicated that the meter on the Saddleback Lake augmentation pump was reported as broken in February 2008 (the length of time it had been broken was not noted), and delinquent meter readings occurred throughout 2007 and 2008. Based on the decline in modeled water levels for this period compared to the higher, steady measured water levels, it is very likely that unreported augmentation occurred during this period. Therefore, the decision was made not to use the period from June 14, 2007 to May 14, 2009 for calibration.

Measured data from each lake were used for comparison with their respective water budget modeled water levels. Daily values were generated from the models, so only actual lake data points are used for the calibration.

F. Water Budget Model Calibration Discussion

Figures 18 through 20 present the calibration results for all three water budget models. Tables 4 through 6 present a comparison of the percentiles of the measured data versus each model's results. Tables 7 through 9 present modeled water budget components for each model's calibration.

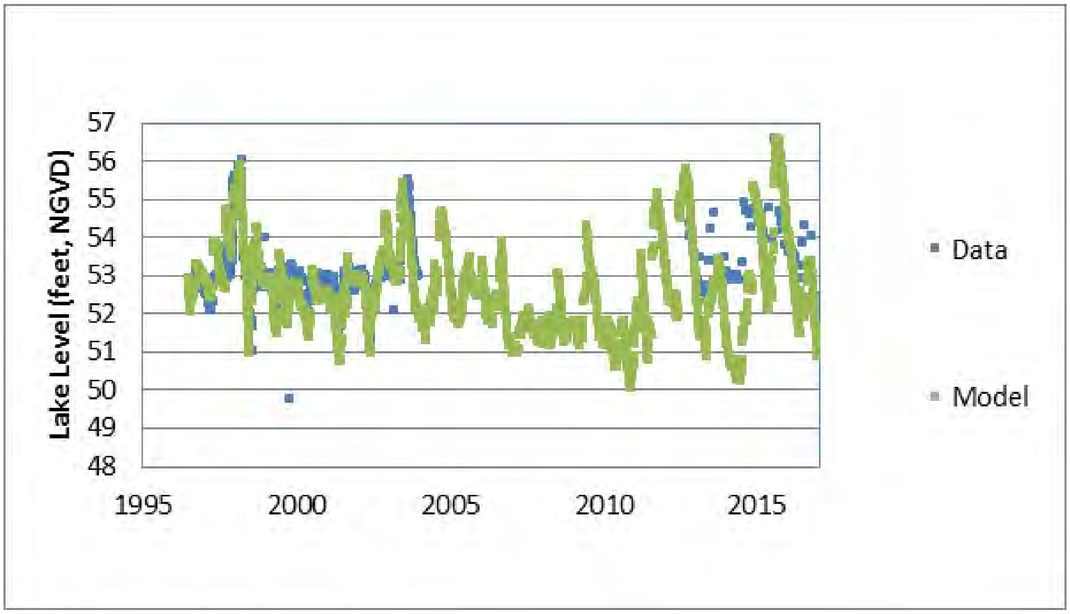

Figure 18. Modeled water levels predicted for the calibrated Round Lake water budget model (Model) and measured levels used for the model calibration (Data).

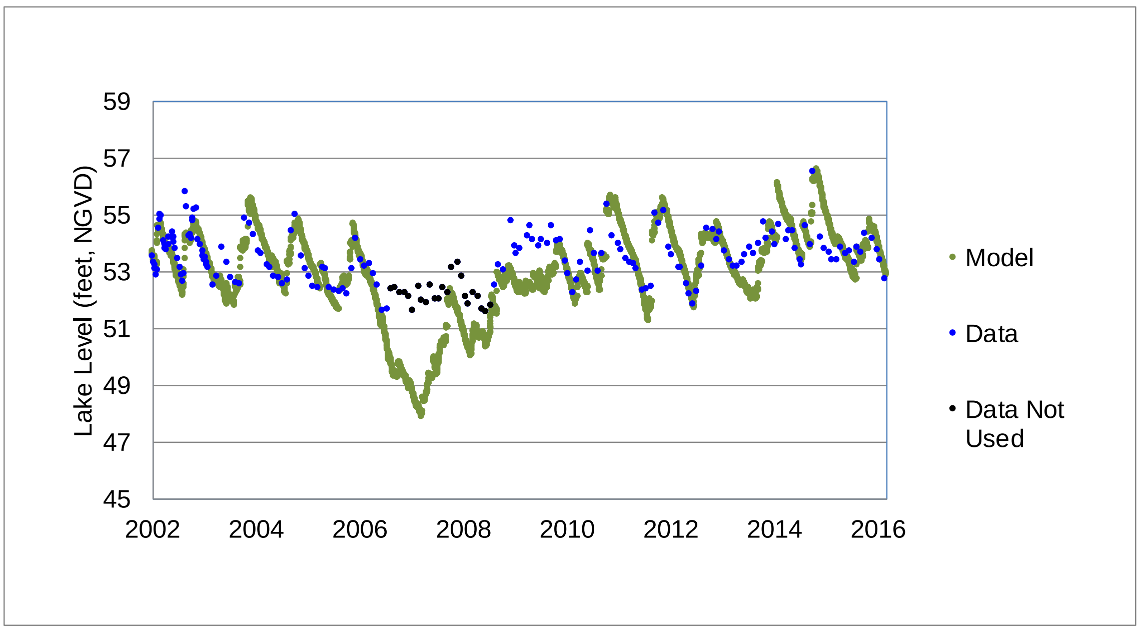

Figure 19. Modeled water levels predicted for the calibrated Saddleback Lake water budget model (Model) and measured levels used for the model calibration (Data).

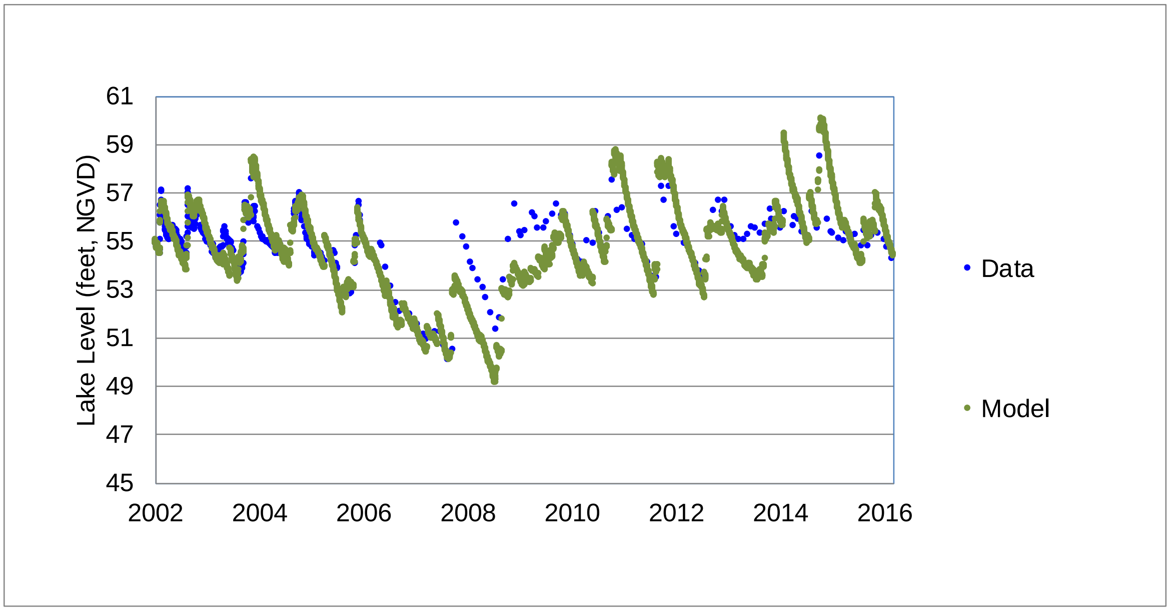

Figure 20. Modeled water levels predicted for the calibrated Lake Crenshaw water budget model (Model) and measured levels used for the model calibration (Data).

Table 4. Comparison of percentiles of measured lake level data compared to calibration percentiles from the Round Lake model (all in feet NGVD29).

	Data	Model
P10	54.6	54.6
P50	52.9	52.9
P90	52.2	52.0

Table 5. Comparison of percentiles of measured lake level data compared to calibration percentiles from the Saddleback Lake model (all in feet NGVD29).

	Data	Model
P10	54.7	54.7
P50	53.6	53.6
P90	52.5	52.4

Table 6. Comparison of percentiles of measured lake level data compared to calibration percentiles from the Lake Crenshaw model (all in feet NGVD29).

	Data	Model
P10	56.3	56.6
P50	55.2	55.2
P90	53.9	53.4

Table 7. Round Lake Water Budget (1996-2016)

Inflows	Rainfall	Surficial Aquifer Ground water Inflow	Floridan Aquifer Ground water Inflow	Runoff	DCIA Runoff	Aug.	Inflow via channel	Total
Inches/year	54.2	1.4	0.0	31.5	0.0	117.3	0.0	216.3
Percentage	25.2	0.7	0.0	14.5	0.0	54.3	0.0	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**				**Outflow via channel**	**Total**
Inches/year	58.0	21.0	138.5				0.0	217.5
Percentage	26,7	9.7	63.6				0.0	100

Table 8. Saddleback Lake Water Budget (2002-2016)

Inflows	Rainfall	Surficial Aquifer Ground water Inflow	Floridan Aquifer Ground water Inflow	Runoff	DCIA Runoff	Aug.	Inflow via channel	Total
Inches/year	56.9	0.1	0.0	34.8	0.0	12.8	17.3	121.8
Percentage	46.7	0.1	0.0	28.5	0.0	10.5	14.2	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**				**Outflow via channel**	**Total**
Inches/year	58.2	11.5	35.0				17.9	122.6
Percentage	47.5	9.3	28.6				14.6	100

Table 9. Lake Crenshaw Water Budget (2002-2016)

Inflows	Rainfall	Surficial Aquifer Ground water Inflow	Floridan Aquifer Ground water Inflow	Runoff	DCIA Runoff	Aug.	Inflow via channel	Total
Inches/year	56.9	0.0	0.0	65.4	0.0	0.0	0.0	122.2
Percentage	46.5	0.0	0.0	53.5	0.0	0.0	0.0	100
Outflows	**Evaporation**	**SURF GW Outflow**	**FL GW Outflow**				**Outflow via channel**	**Total**
Inches/year	58.2	29.4	16,7				18.5	122.7
Percentage	47.4	23.9	13.6				15.1	100

Based on a visual inspection of Figures 18 through 20 and Tables 4 through 9, the models appear to be reasonably well calibrated. A review of Tables 4 and 5 shows that the P10 and P50 for each model matches the measured data to within one tenth of a foot, while the P90 of the Round Lake model is 0.2 feet below that of the measured data, and the P90 of the Saddleback Lake model is 0.1 feet below that of the measured data. The Lake Crenshaw water budget model (used solely to estimate unimpacted flow into Saddleback Lake to facilitate calculation of Historic percentiles for Saddleback Lake) was calibrated to within one-tenth of a foot for the P50, while the P10 is 0.3 feet higher than that of the measured data, and the P90 of the model is 0.6 feet lower than that of the measured data (Table 6).

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.

As part of the Metz and Sacks (2002) project mentioned previously, a water budget was constructed for Round Lake from June 1996 to May 1999. While the results cannot be directly compared to the Round Lake water budget model presented here due to the difference in time periods assessed and the more lumped parameters in the USGS model, it can be seen from Table 10 that the results are comparable.

Table 10. Comparison of USGS water budget (Metz and Sacks, 2002) and District water budget for Round Lake.

	Change in Storage	Rainfall	Evaporation	SW Inflow	Augmentation	Net GW Flow
	-3.1	54.2	58.0	1.9	159.4	-136.3
	-0.1	61.0	52.0	3.8	165.3	-181.7

It can be seen that Round Lake is augmented much more heavily than Saddleback Lake, and the leakage from Round Lake to the Upper Floridan aquifer is much greater than the other two lakes (and greater than any other lake water budget model constructed for northwest Hillsborough County area lakes). The leakage below Saddleback Lake is more typical of other lakes modeled in the area, while the leakage below Lake Crenshaw is lower than most others modeled in the area.

G. Water Budget Model Results

Groundwater withdrawals are not directly included in the water budget models, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. Metered groundwater withdrawal rates from the Section 21 Wellfield are available throughout the period of the calibrated model, 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 model developed for the northern Tampa Bay area. The INTB model can account for groundwater and surface water, as well as the interaction between them. The domain of the INTB application includes the area of Round and Saddleback lakes, 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 before 2005, while the post-cutback period is 2005 through 2016. 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 for 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 around the wellfields. Groundwater withdrawal rates from the Section 21 Wellfield in each scenario were 8.9 mgd and 4.2 mgd, respectively.

Results from the INTB modeling scenarios showed that there is a fairly linear relationship between Upper Floridan aquifer drawdown and withdrawal rates at the wellfields. Because of the leaky nature of the confining unit around the lakes, and because the water table in the model is not active, the relationship between groundwater withdrawals in the Upper Floridan and water levels in the surficial aquifer was also of interest. 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 models were adjusted to represent zero withdrawals. For the water budget model periods, two periods of adjustment were used to reflect the cutbacks that took place at the Section 21 wellfield. The adjustments to each Upper Floridan aquifer and surficial aquifer well are found in Tables 11 through 13. Additionally, since Round and Saddleback lakes were augmented with groundwater during the water budget model period, reported augmentation quantities were removed from the water budget models for calculation of Historic percentiles.

Table 11. Aquifer water level adjustments to the Round Lake Model to represent Historic percentiles.

Well	Adjustment (feet) July 1996 to 2004	Adjustment (feet) 2005 to 2016
Upper Floridan aquifer	12.8	5.7
Surficial aquifer	3.5	1.5

Table 12. Aquifer water level adjustments to the Saddleback Lake Model to represent Historic percentiles.

Well	Adjustment (feet) November 2002 to 2004	Adjustment (feet) 2005 to 2016
Upper Floridan aquifer	9.8	4.6
Surficial aquifer	3.8	1.6

Table 13. Aquifer water level adjustments to the Lake Crenshaw Model to represent Historic percentiles.

Well	Adjustment (feet) November 2002 to 2004	Adjustment (feet) 2005 to 2016
Upper Floridan aquifer	10.1	4.3
Surficial aquifer	3.0	1.1

Figures 21 through 23 present measured water level data for each lake along with the water budget model-simulated lake levels in the lake under Historic conditions (i.e., in the absence of groundwater withdrawals with structural alterations similar to current conditions). Tables 14 through 16 present the Historic percentiles based on the output of each lake model.

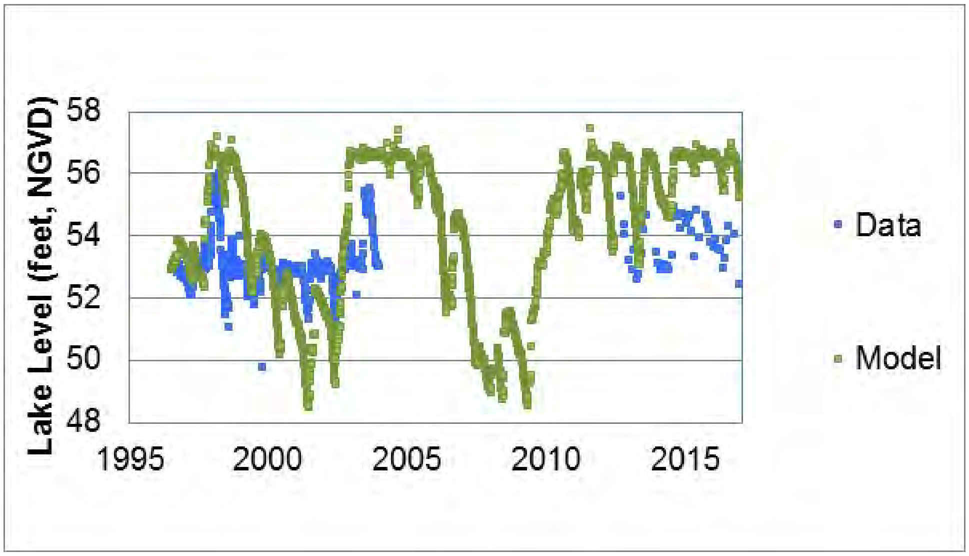

Figure 21. Measured lake levels (Data) and Historic water levels predicted with the calibrated Round Lake model (Model) (Modeled with limiter of 56.5 feet NGVD29).

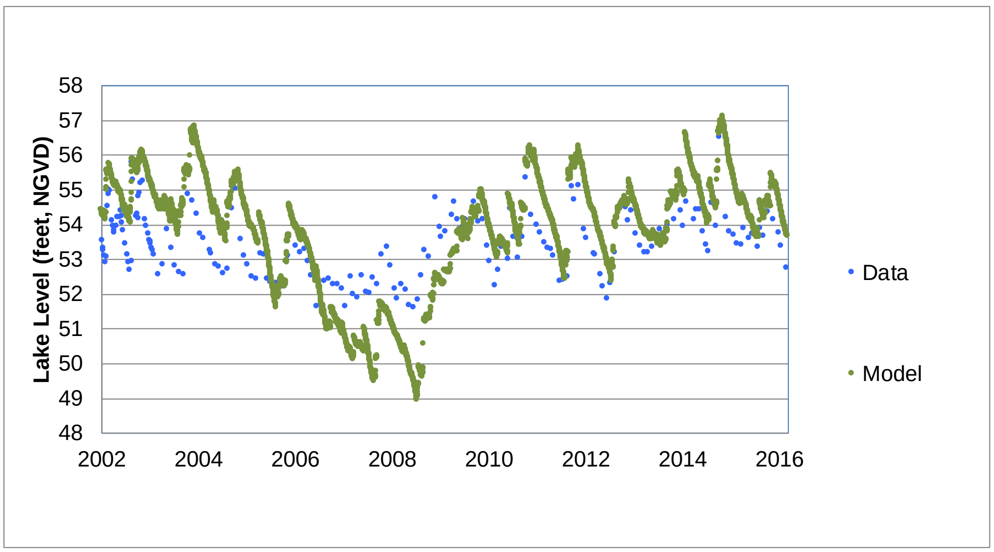

Figure 22. Measured lake levels (Data) and Historic water levels predicted with the calibrated Saddleback Lake model (Model).

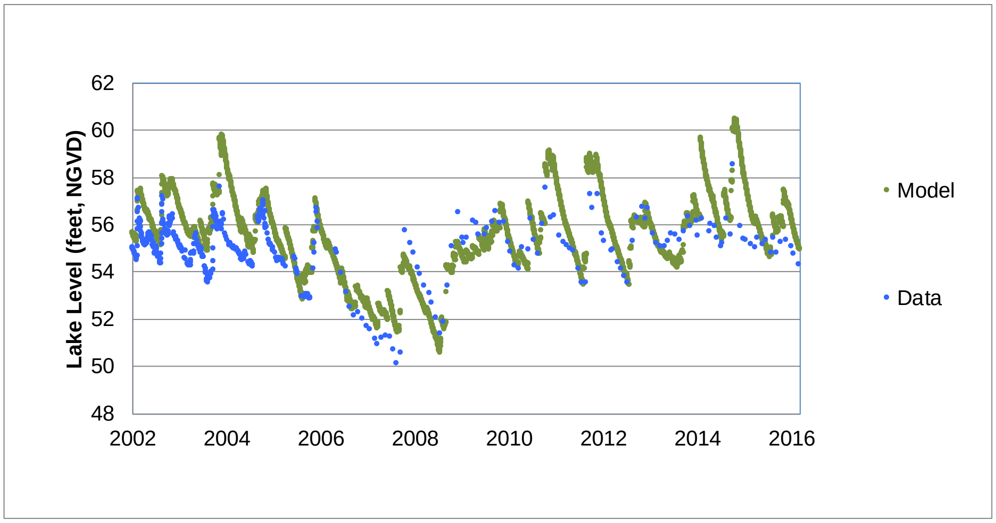

Figure 23. Measured lake levels (Data) and Historic water levels predicted with the calibrated Lake Crenshaw model (Model).

Table 14. Historic percentiles estimated using the Round Lake water budget model (in feet NGVD29).

Percentile	Elevation
P10	56.5
P50	54.9
P90	50.3

Table 15. Historic percentiles estimated using the Saddleback Lake water budget model (in feet NGVD29).

Percentile	Elevation
P10	55.6
P50	54.2
P90	51.0

Table 16. Historic percentiles estimated using the Lake Crenshaw water budget model (in feet NGVD29).

Percentile	Elevation
P10	57.7
P50	55.5
P90	52.8

Upon inspection of the initial run of the Round Lake model with augmentation and groundwater withdrawal effects removed, it was noticed that water levels in the model often exceeded 58 feet NGVD29. Because the culvert and ditch system connecting Round and Saddleback lakes is simulated as a discharge from Saddleback Lake and an inflow to Round Lake, water cannot flow out of Round Lake. In reality, water would begin to discharge to Saddleback Lake through the ditch system when Round Lake is at high elevations, and ultimately discharge out the southern outlet of Saddleback Lake when the controlling elevation is exceeded. An inspection of the period of record measured data of both lakes shows that neither lake has exceeded 56.5 feet NGVD29. Because the high levels in the Round Lake simulation exceeded this value for long periods of time, there was a concern that the P50 could be unrealistically elevated. The decision was made to limit simulated Round Lake elevations that exceeded 56.5 feet by returning the water elevation to 56.5 feet whenever the previous day's predicted value exceeds it. The result is a more reasonable simulation of expected water levels given the structural alterations of the lakes.

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.

Historic normal pools were determined for Saddleback Lake based on inflection points of remaining cypress trees. Historic normal pool was not determined for Round Lake since it was determined that no cypress wetlands of one-half acre in size or more still exist around the lake. The Historic normal pool for Saddleback Lake was determined to be 56.8 feet NGVD29. 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 Saddleback Lake is approximately one foot below the field determined Historic normal pool. However, because the structural control on the lake was determined to be at 53.5 feet NGVD29, the lake is considered structurally altered, and no longer capable of regularly reaching the historic normal pool. Therefore, in this case, the natural water levels experienced prior to the wellfield establishment may not quite be able to be achieved, likely due structural alterations of the lake's outlet.

I. Rainfall Correlation Model

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 models 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. The gages, periods of data used, and the location of stations used in the LOC are shown in Table 17 and Figure 24. Although the Hillsborough River State Park and Tarpon Springs Sewage Plant gates are 16 and 17 miles away, respectively, they are one of only a few rain gages in the vicinity with data preceding 1965.

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.

Table 17. Rainfall gages used for Round and Saddleback Lakes LOC models.

Rainfall Data Source	Period	Distance from Lakes (miles)
Hillsborough River Sate Park	Jan. 1, 1929 to Jan. 27, 1949	17 east
Tarpon Springs Sewage Plant (infilled with Hillsborough River State Park and Saint Leo)	Jan. 28, 1949 to July 31, 1965	16 west
Section 21 Lutz Wellfield	Aug. 1, 1965 – 1971	0.5 northwest
Lake Crenshaw (infilled with Section 21 Lutz Wellfield)	1972 – 1994	0.3 northeast
NEXRAD	1995 – 2016	Pixel over lakes

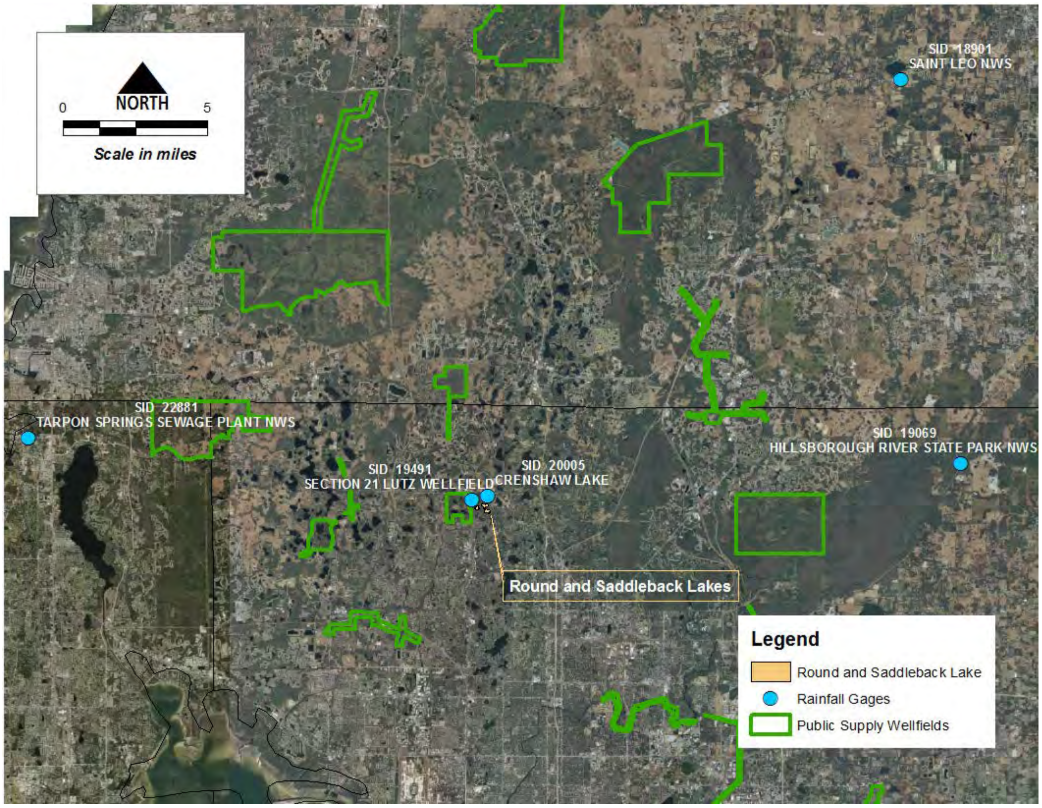

Figure 24. Location of rain stations used for the rainfall correlation model.

Rainfall was correlated to the water budget model results for the entire period used in the water budget model for Saddleback Lake (November 2002 to 2016) and the Round Lake model (July 1996 through 2016), and the results from 1946-2016 (70 years) were produced for both lakes. For Saddleback Lake, the 2-year weighted model had the highest correlation coefficient, with an R^2 of 0.74. For Round Lake, the 2-year weighted model also had the highest correlation coefficient, with an R^2 of 0.66. Previous correlations for lakes in the northern Tampa Bay area have consistently had best correlation coefficients in the 2- to 5-year range. The results are presented in Figures 25 and 26.

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 through October 2002 for Saddleback Lake and 1946 through June 1996 for Round Lake, while the water budget results are used for the water budget model period. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Tables 18 and 19.

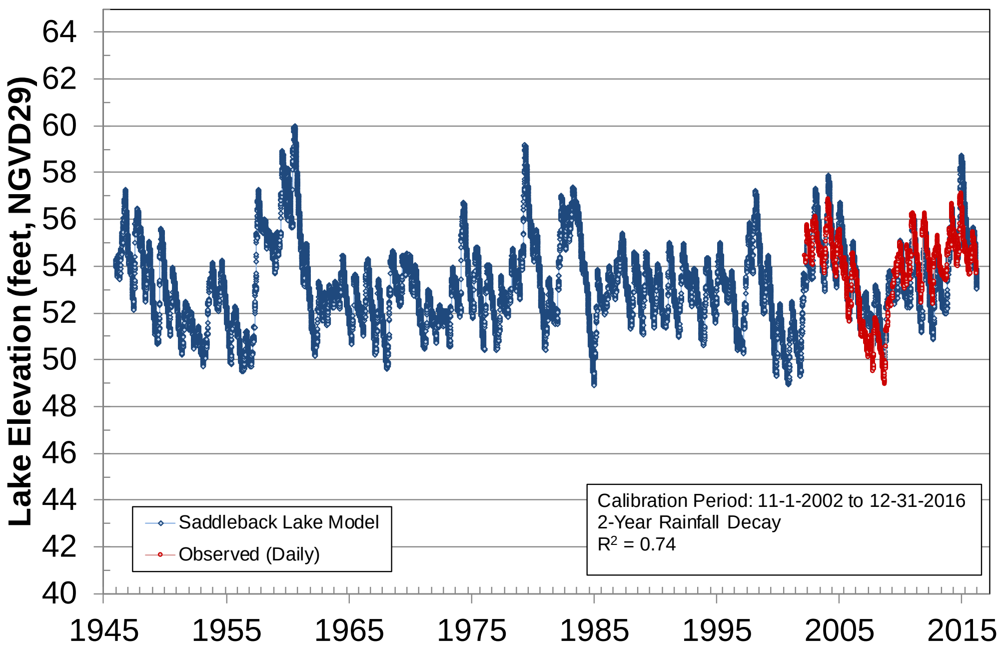

Figure 25. LOC model results for Saddleback Lake.

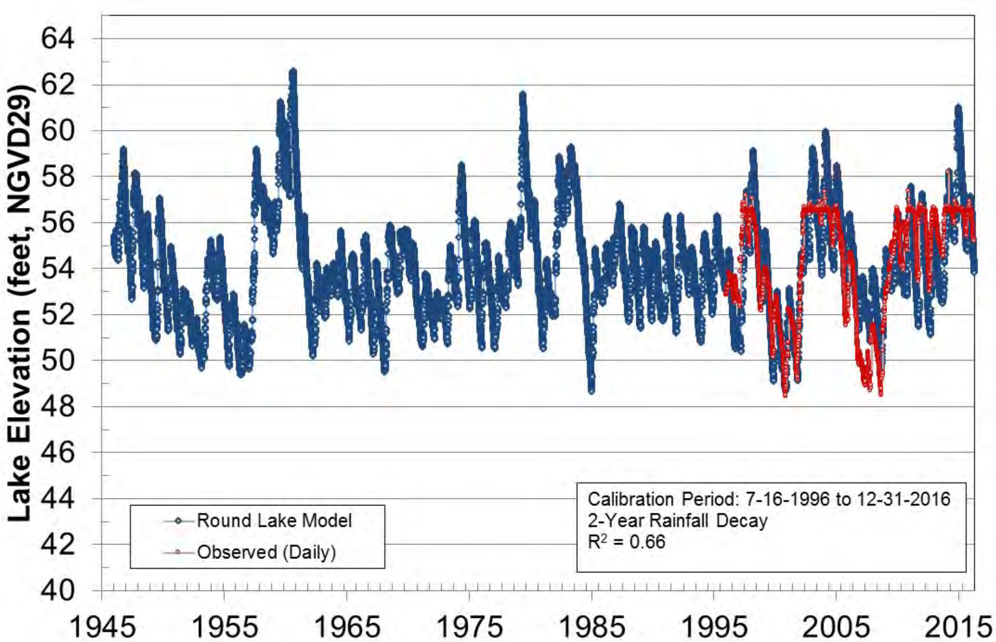

Figure 26. LOC model results for Round Lake.

Table 18. Round Lake Historic percentiles as estimated by the hybrid model from 1946 to 2016 (feet NGVD29).

Percentile	Lake Round
P10	56.6
P50	53.9
P90	51.1

Table 19. Saddleback Lake Historic percentiles as estimated by the hybrid model from 1946 to 2016 (feet NGVD29).

Percentile	Saddleback Lake
P10	55.6
P50	53.1
P90	50.8

Note that the difference between the P10, P50, and P90 percentiles derived from the water budget model (Tables 14 and 15) and those from the hybrid rainfall model (Tables 18 and 19) for Round Lake are 0.1, 1.0, and 0.8 feet, respectively, and for Saddleback Lake are 0, 1.1, and 0.2 feet, respectively. Differences between the two models likely resulted, since percentiles calculated from the LOC model incorporate a much longer rainfall period (and rainfall variation) than the water budget model.

The accuracy of the Historic P10 can, at times, have more error than the lower percentiles (such as the Historic P90 and Historic P50), because the Historic P10 exceedance percentile can be significantly affected by drainage and control structures. In the case of Round Lake, the inflow can become an outflow during very high rainfall periods. Because of this, an adjustment was made in the water budget model to limit how high the lake can get; however, a similar adjustment cannot be made in the LOC since water level predictions are based only on rainfall. It appears that the water budget model for Saddleback Lake reasonably simulated the effects of structural alterations; however, this effect was not represented as well in the LOC model in which water level predictions are based only on rainfall. Due to these reasons, the modeled Historic P10 of the LOC models for both Round and Saddleback lakes are relatively high, especially given current structural alterations. This should be considered when these values are used to determine the High Minimum Lake Level.

J. Conclusions

Based on the model results and the available data, the Round Lake and Saddleback 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 10, 2017

TO: JP Marchand, Bureau Chief, Water Resources Bureau

FROM: Michael C. Hancock, P.E., Senior Prof. Engineer, Water Resources Bureau
Tamera S. McBride, P.G., Senior Hydrogeologist, Water Resources Bureau
Jaime Swindasz, Staff Environmental Scientist, Water Resources Bureau

Subject: Round Lake Initial Minimum Levels Status Assessment

A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Round 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 and McBride (2017) and Swindasz and others (2017).

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 Round 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 Round 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 of the revised minimum levels proposed for Round Lake and any recovery that may be necessary for the lake.

B. Background

Round Lake is in northwest Hillsborough County, east of Dale Mabry Highway and approximately 0.5 miles south of Van Dyke Road in Lutz (Figure 1). The lake lies within the Brushy Creek watershed. Brushy Creek is a tributary to Rocky Creek. Water inflow from

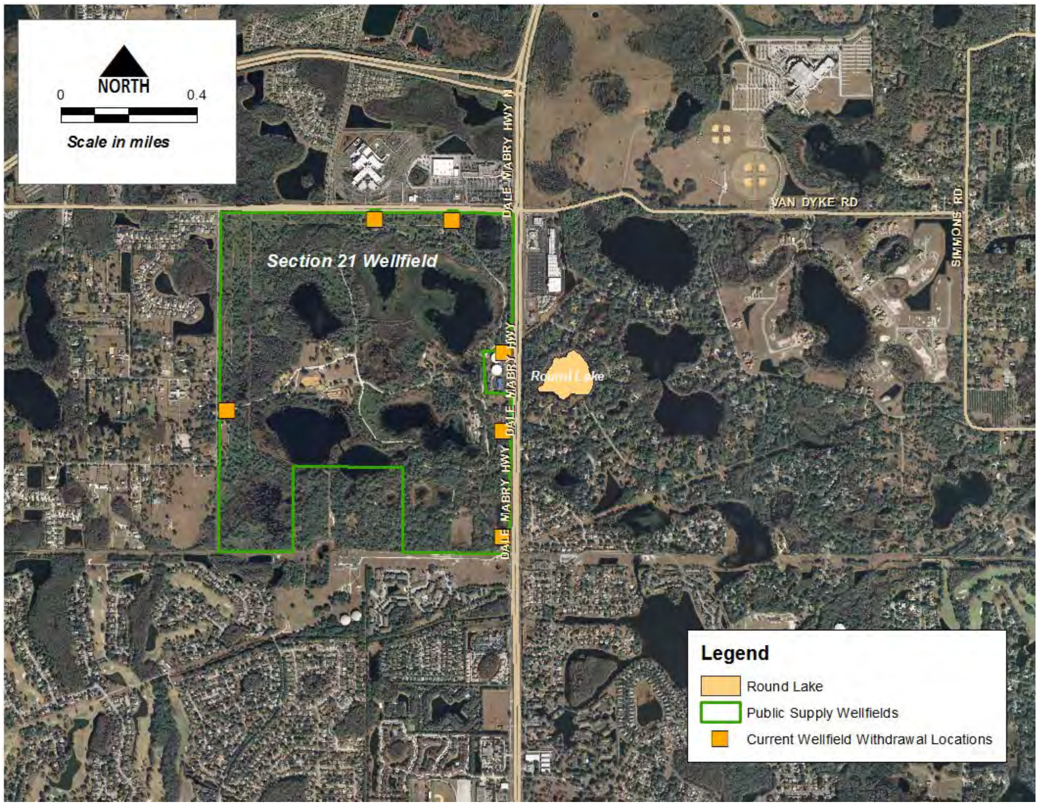

Figure 1. Location of Round Lake in Hillsborough County, Florida.

Saddleback Lake to the west (Figure 2) occurs during high flow periods, although the topography is very flat, and flows are often negligible. With few exceptions, there are no discharges from Round Lake.

Round Lake is located due east of Section 21 Wellfield, one of eleven regional water supply wellfields operated by Tampa Bay Water (Figure 1). Groundwater withdrawals began at the Section 21 Wellfield in 1963. Monthly average withdrawals steadily climbed to nearly 15 million gallons per day (mgd) in 1964 and to over 20 mgd in 1967 (Figure 3). With the development of the South Pasco Wellfield in 1973, annual average withdrawal rates at the Section 21 Wellfield were reduced to approximately 10 mgd. Monthly withdrawal rates since 2005 have averaged less than 3 mgd, with several extended periods when the wellfield was shut down completely.

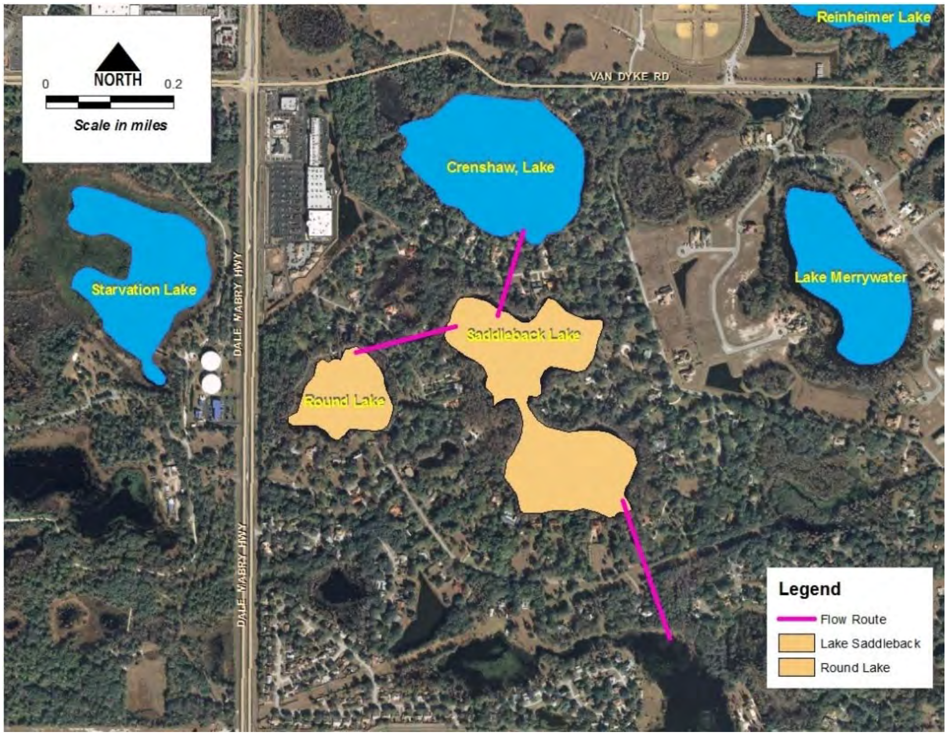

Figure 2. Flow between Round, Crenshaw, and Saddleback lakes and wetland area south of Saddleback Lake.

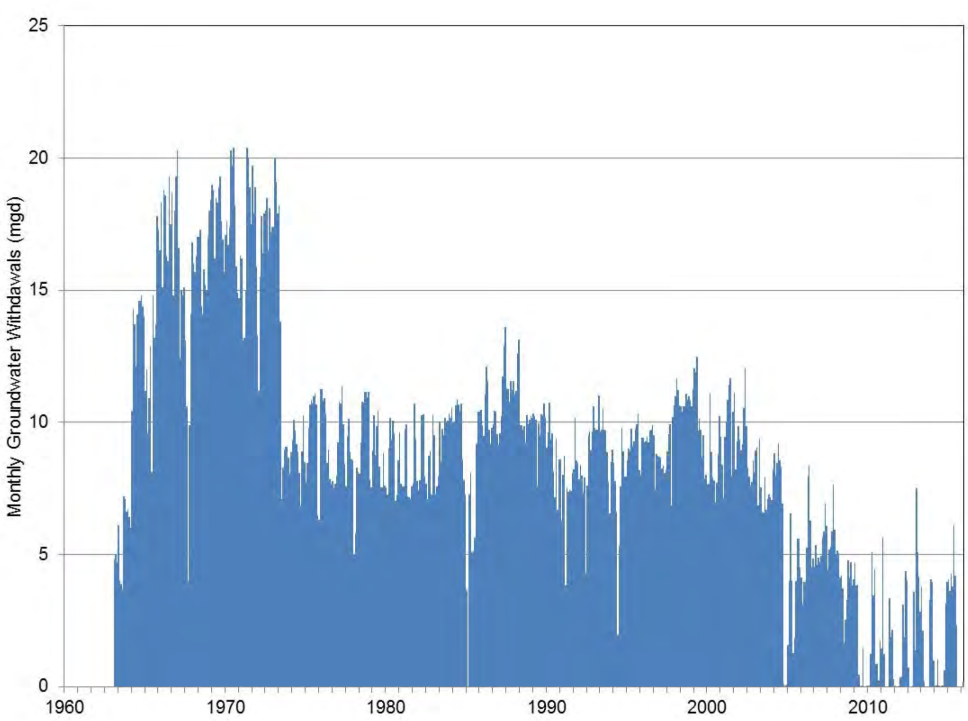

Figure 3. Section 21 Wellfield withdrawals.

Round Lake has been regularly augmented with water withdrawn from the Upper Floridan aquifer since the mid- to late-1960s; however, the lake did not receive a water use permit until 1996. Therefore, augmentation quantity data are not available until 1996 for Round Lake. The current permit for Round Lake allows up to 215,000 gallons per day annual average or 256,000 gallons per day peak month of augmentation.

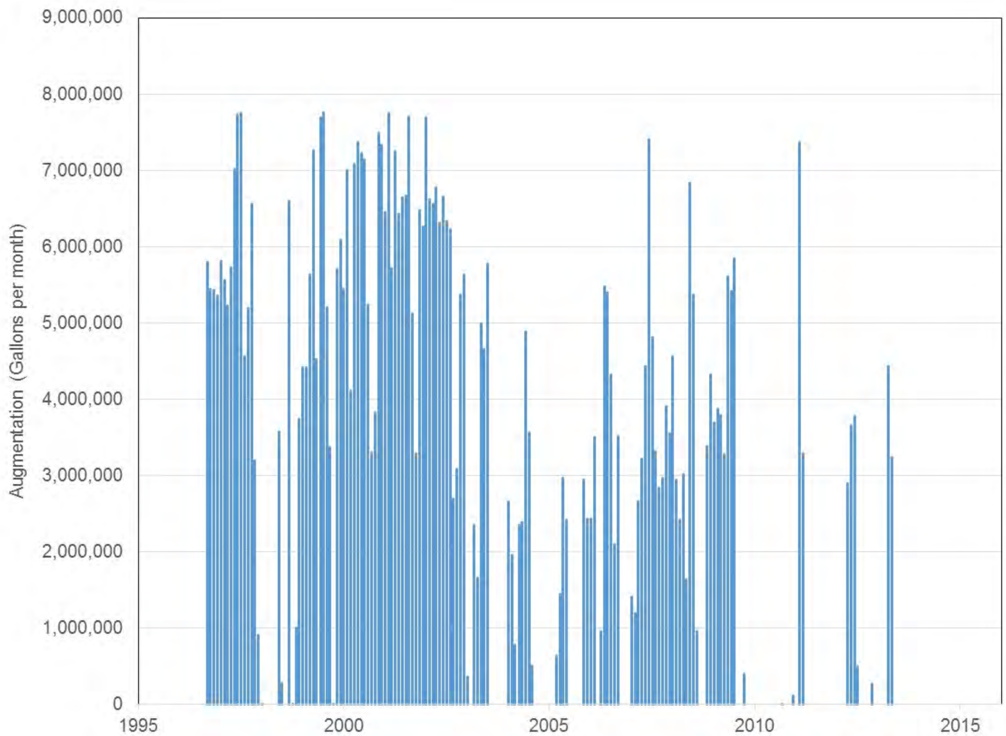

Figure 4. Metered augmentation withdrawals at Round Lake.

C. Revised Minimum Levels Proposed for Round Lake

Revised minimum levels proposed for Round Lake are presented in Table 1 and discussed in more detail by Swindasz and others (2017). 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 Round 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 Round Lake.

Proposed Minimum Levels	**Elevation in Feet** NGVD 29
High Minimum Lake Level	54.1
Minimum Lake Level	53.1

D. Status Assessment

The lake status assessment approach involves using measured lake stage data representing the “Current” period for Round Lake. The “Current” period for Round Lake was determined to be 2005 through 2016, however, as discussed in Hancock and McBride (2017), the only competent data for Round Lake during this period is from 2012 to 2016. 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 and McBride (2017), groundwater withdrawals during this period were relatively consistent; however, it is crucial to note that the lake was actively augmented during the Current period and the resulting levels were used to assess status.

To create a data set that can reasonably be considered “Long-term”, a regression analysis was performed on the lake level data from the Current period and daily rainfall data using the line of organic correlation (LOC) method. 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 to develop the minimum levels for Round Lake (Hancock and McBride, 2017). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing 70 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 Round Lake was used for the status assessment (Hancock and McBride, 2017). The best resulting correlation for the LOC model created with measured data (2012-2016) was the 6-month weighted period, with a coefficient of determination of 0.69. The resulting lake stage exceedance percentiles are presented in Table 2.

As an additional piece of information, Table 2 also presents the percentiles calculated directly from the measured lake level data for Round Lake for the period from 2012 through 2016. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 4 years, rather than the longer-term rainfall conditions represented in the 1946 to 2016 LOC model simulation.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2012 to 2016 data, and the revised minimum levels proposed for Round Lake.

Percentile	**Long Term LOC Model Results 1946 to 2016** Elevation in feet NGVD 29[1, 2]	**Measured Lake Levels for Current Period (2012 to 2016)** Elevation in feet NGVD 29[2]	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	54.7	54.7	54.1
P50	53.5	53.9	53.1

[1]LOC model based on Current Period and extended using rainfall for 1946 to 2016
[2]Current Period includes active lake augmentation

A comparison of the LOC model with the revised minimum levels proposed for Round Lake indicates that the Long-term P10 is 0.6 feet above the proposed High Minimum Lake Level, and the Long-term P50 is 0.4 feet above the proposed Minimum Lake Level. The P10 elevation derived directly from the 2012 to 2016 measured lake data is 0.6 feet higher than the proposed High Minimum Lake Level, and the P50 elevation is 0.8 feet higher than the proposed Minimum Lake Level. Current period data used to determine the Long-term LOC and the measured lake level statistics *include* augmentation that raised lake levels. Differences in rainfall between the shorter 2012 to 2016 period and the longer 1946 to 2016 period used for the LOC modeling analyses likely contribute to the differences between model derived and measured lake stage exceedance percentiles.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Round Lake water levels that include the positive effects of augmentation are above the revised Minimum Lake Level and 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, Round 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 status of Round 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 Round 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 Round 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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Swindasz. J. and others. 2017. Proposed Minimum and Guidance Levels for Round Lake in Hillsborough County, Florida. Southwest Florida Water Management District. Brooksville, Florida.

Draft Technical Memorandum

February 10, 2017

TO: Michael Hancock, P.E., Senior Hydrogeologist, Resource Evaluation Bureau
Tamera S. McBride, P.G., Senior Hydrogeologist, Water Resources Bureau

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

Subject: Evaluation of Groundwater Withdrawal Impacts to Round Lake

1.0 Introduction

Round Lake is located in northwest Hillsborough 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 Round 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. Underlying the middle confining unit II is the Lower Floridan aquifer (Miller, 1986).

3.0 Evaluation of Groundwater Withdrawal Impacts to Round Lake

A number of regional groundwater flow models have included the area around Round Lake in northwest Hillsborough 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, 2012). 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

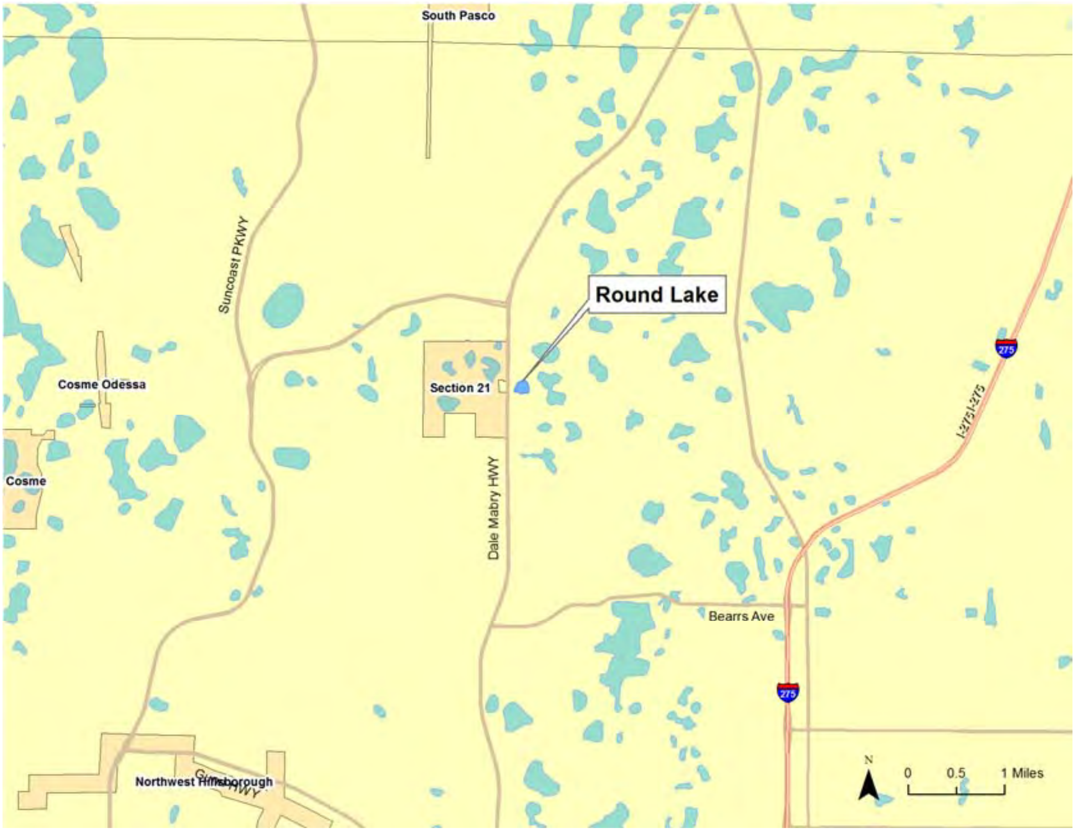

Figure 1. Location of Round Lake.

wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

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

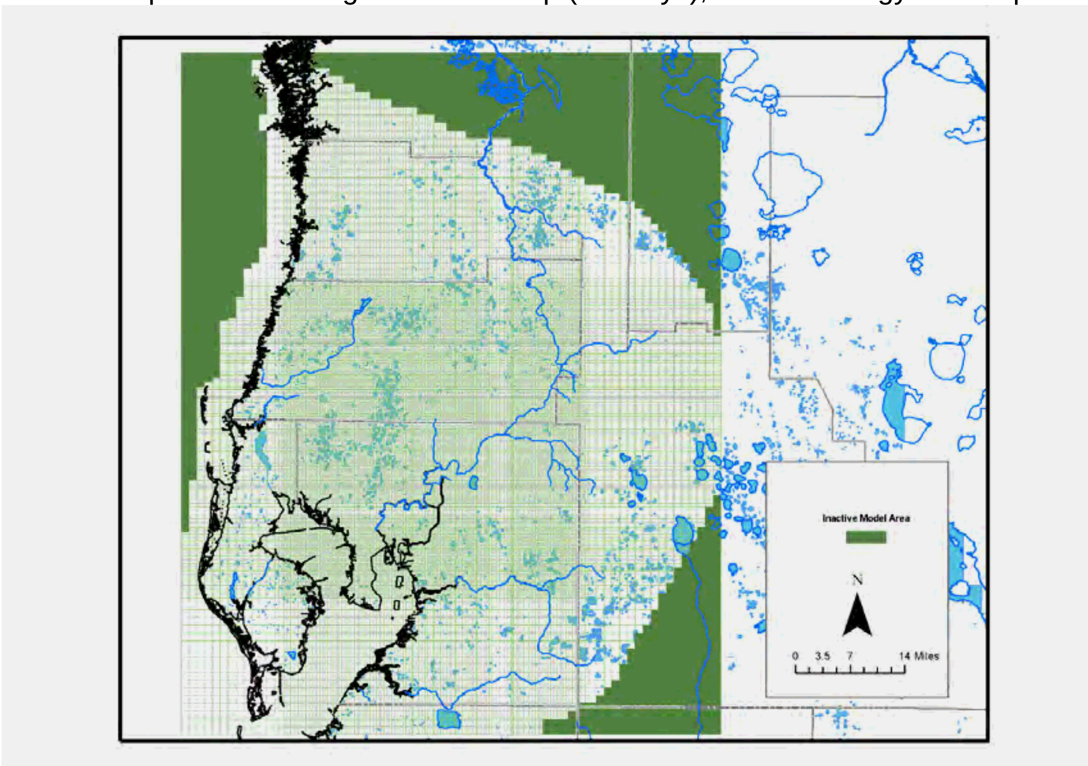

Figure 2. Groundwater grid used in the INTB model

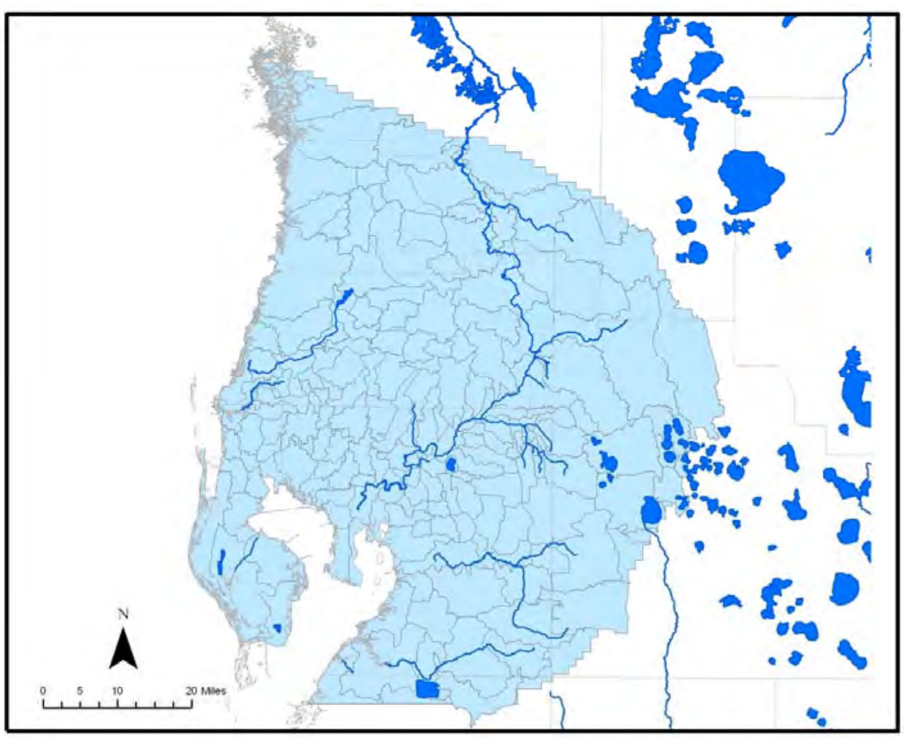

Figure 3. HSPF subbasins in the INTB model.

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.

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 beenc 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 was also 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 (2012).

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 Round Lake was 3.5 ft, and 12.8 ft 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 Round Lake was 1.5 ft and 6.0 ft in the Upper Floridan aquifer (Figure 6 and 7). Table 1 presents the predicted drawdown in the surficial and the Upper Floridan aquifer based on the INTB model results.

Table 1. INTB model results for Round Lake.

Lake Name	**Predicted Drawdown (ft) in the Surficial Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd***
Round	3.5	1.5
Lake Name	**Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals***	**Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd***
Round	12.8	6.0

* Average drawdown from model cells intersecting lake

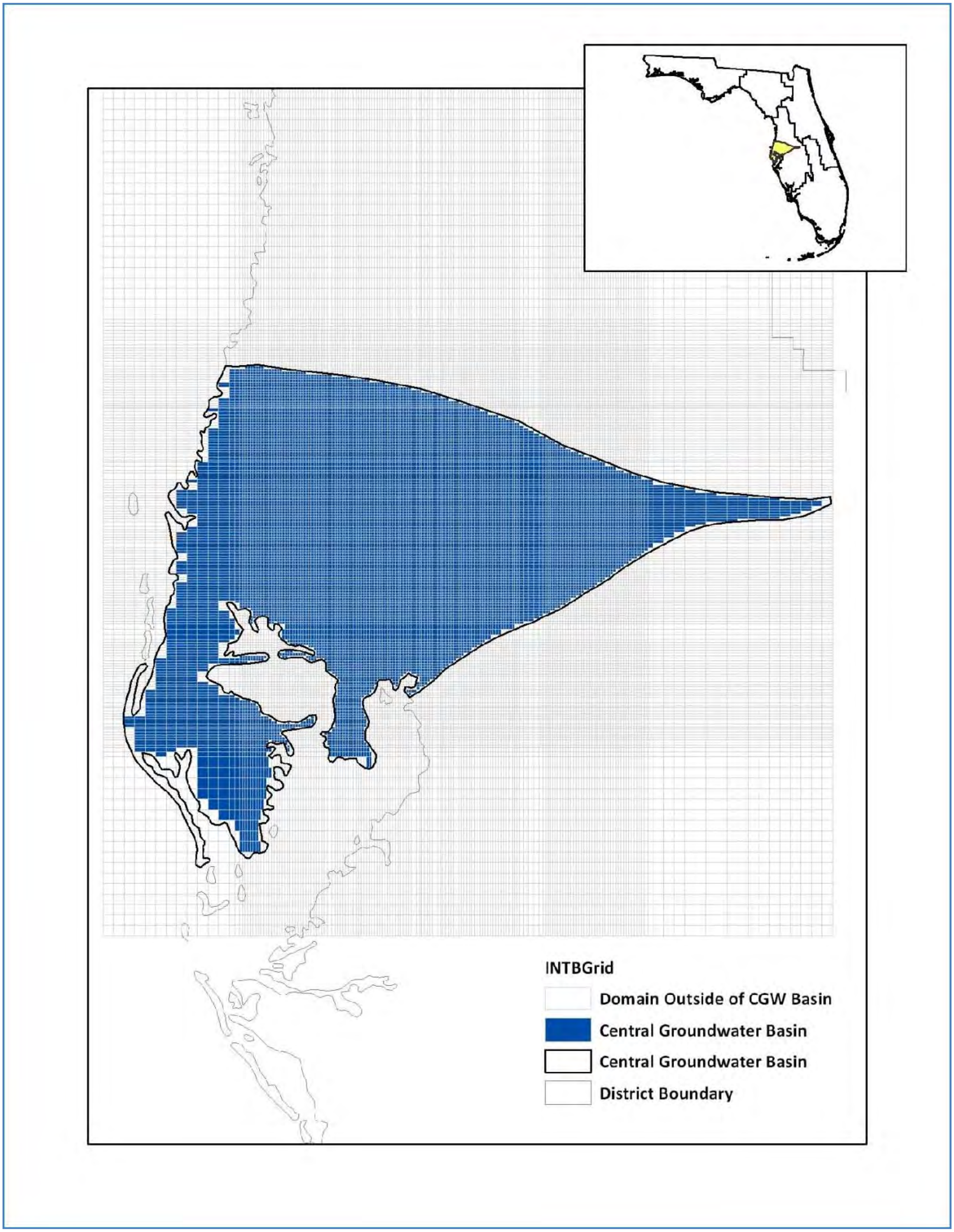

Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.

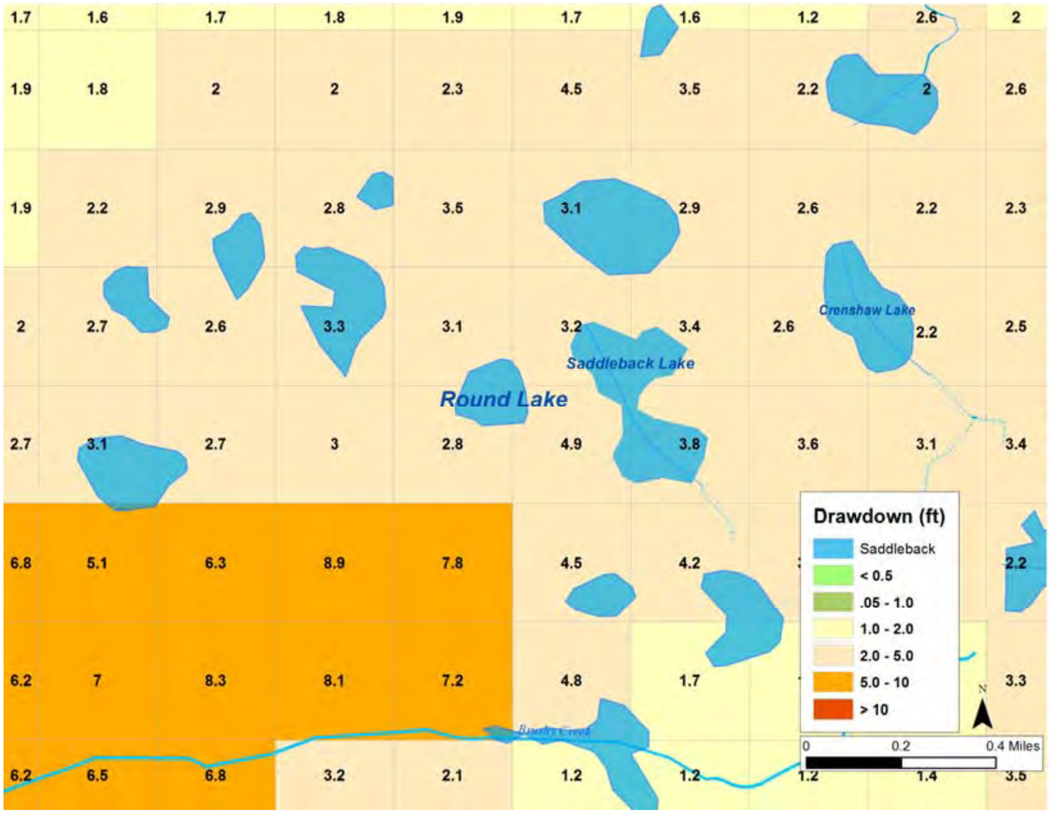

Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.

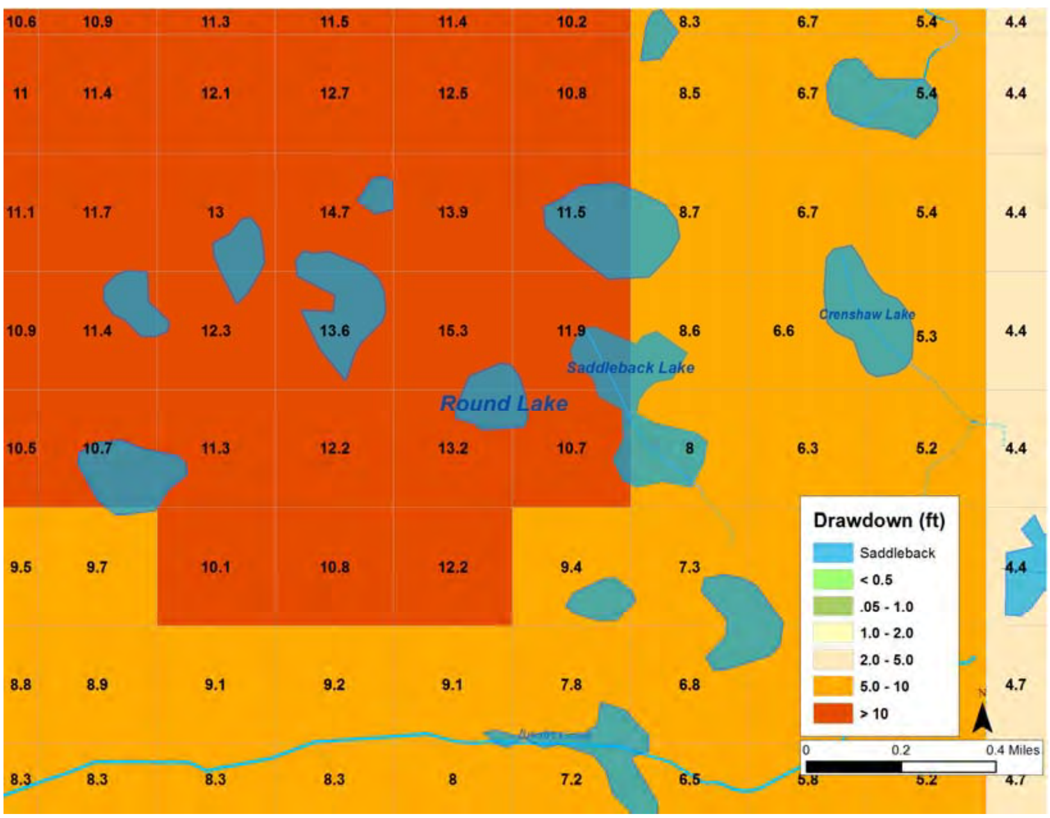

Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.

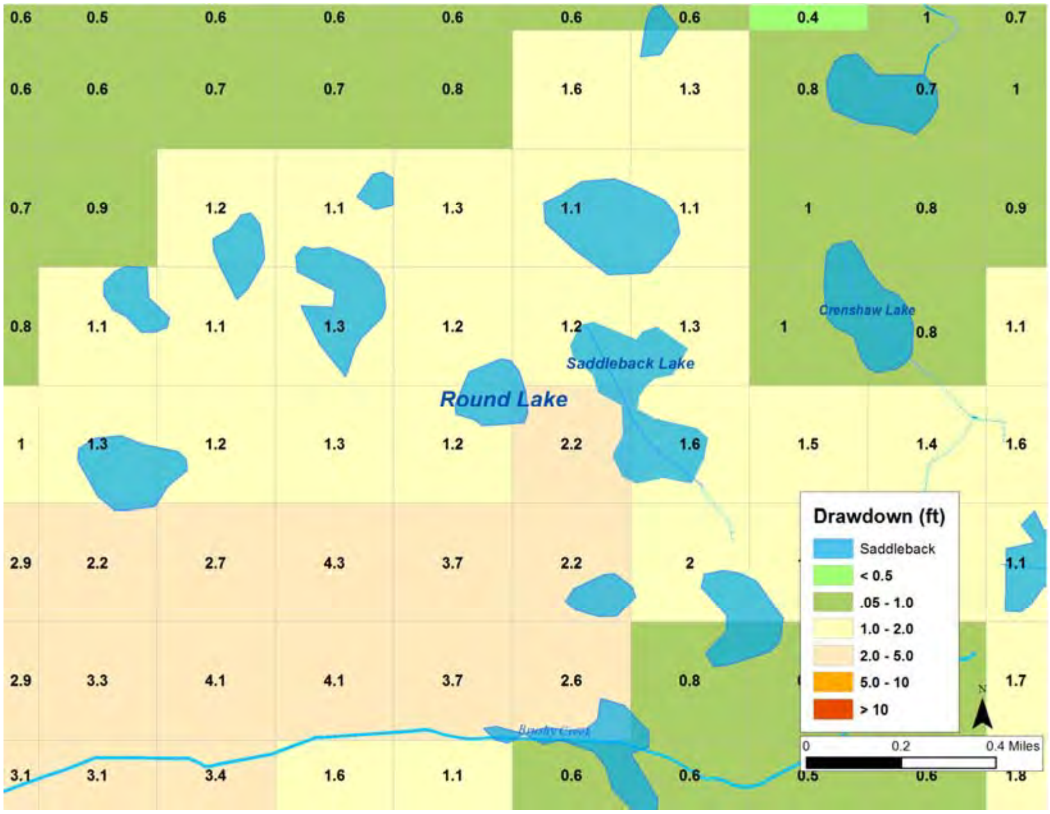

Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.

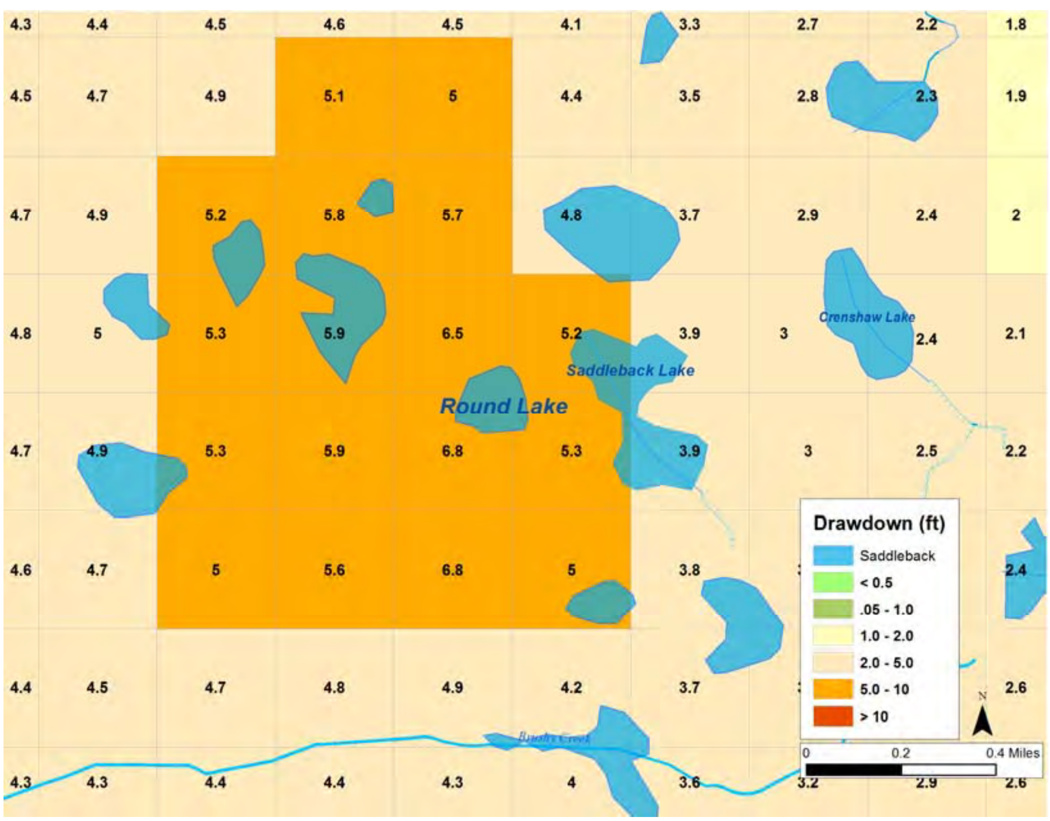

Figure 8. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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