Minimum and Guidance Levels for Lake Eva (Haines City) in Polk County, Florida

February 5, 2018

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

Minimum and Guidance Levels for Lake Eva (Haines City) in Polk County, Florida

February 5, 2018

Resource Evaluation Section
Water Resources Bureau
Southwest Florida Water Management District
2379 Broad Street
Brooksville, Florida 34604-6899

Contributors:
Mark Hurst
Jason Patterson
Don Ellison
Mark Barcelo
David Carr
Donna Campbell

Cover: 2014 Natural Color Imagery of Lake Eva (Southwest Florida Water Management District files).

Contents

Introduction

Evaluation of Minimum Flows and Levels

This report describes the development of minimum and guidance levels for Lake Eva located in the city of Haines City in Polk County, Florida. These levels were developed based on evaluation of historic lake water levels, including water budget models, and the applicable significant change Standards, as discussed in detail in this report.

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 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).

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

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

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

- adjust measured flow or water level historical records to account for existing changes/alterations;
- model or simulate flow or water level records that reflect long-term conditions that would be expected based on existing changes/alterations and in the absence of measurable withdrawal impacts;
- develop or identify significant harm standards, thresholds and other criteria;
- aid in the characterization or classification of lake types or classes based on the changes/alterations;
- evaluate the status of water bodies with proposed or established MFLs (i.e., determine whether the flow and/or water level are below, or are projected to fall below the applicable minimum flow or level); and
- support development of lake guidance levels (described in the following paragraph).

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

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

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

Categorical significant change standards and other available information are developed to identify criteria that are sensitive to long-term changes in hydrology and can be used for establishing minimum levels. For all lake categories, the most sensitive, appropriate criterion or criteria are used to develop 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 minimum levels for Lake Eva 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	Lake Mixing Standard, Cypress Standard, Herbaceous Wetland Information, Submersed Aquatic Macrophyte Information
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 based 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. According to Chapter 40D-8.624, F.A.C., Lake Eva meets the classification as a Category 3 lake: one that has "no lake-fringing cypress swamp(s) greater than 0.5 acre in size." Therefore, the appropriate significant change Standards were determined for Lake Eva and used in the Minimum Levels development. The change Standards and other information associated with Category 3 lakes are described below and will be developed in a subsequent section of this report.

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 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 ft., or a rectangular ski corridor 200 ft. in width and 2,000 ft. in length, and use of Historic lake stage data or region-specific reference lake water regime statistics where Historic lake data are not available.

The 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.

In addition to the Standards, 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 ft.). 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. Note however, that as no water transparency data are available for Lake Eva, macrophyte colonization was not determined.

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. (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 (P10) 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 (P50).

- 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 (P90) on a long-term basis.

The District is in the process of converting (relative to mean sea level) 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 were collected or reported relative to NAVD88 and converted to elevations relative to NGVD29. Datum conversions were derived using District survey data and the Corpscon 6.0 software distributed by the United States Army Corps of Engineers.

Development of Minimum and Guidance Levels for Lake Eva

Lake Setting and Description

Watershed

Lake Eva is located in northeast Polk County (Sections 29 and 32, Township 27 South, Range 27 East) in the Lake Eva Outlet Watershed within the Peace River Primary Drainage Basin (USGS Drainage Basins-HUC) (Figures 1). The lake has a drainage area of 620.2 acres (including the lake area of 165.4 acres) (Figure 2). There are no significant inflows or outflows associated with the lake, except for a culvert under Peninsular Drive at the lowest topographic point in the southwest area of the lake. However, it appears water rarely, if ever, flows in or out of the lake through the culvert.

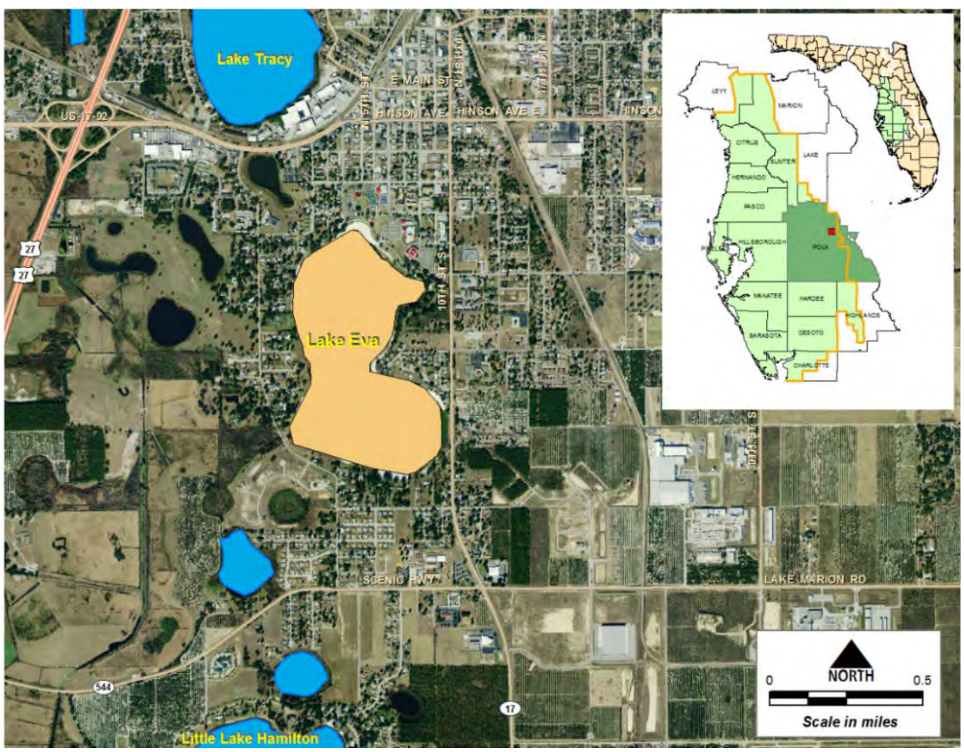


Figure 1. Location of Lake Eva in Polk County, Florida.

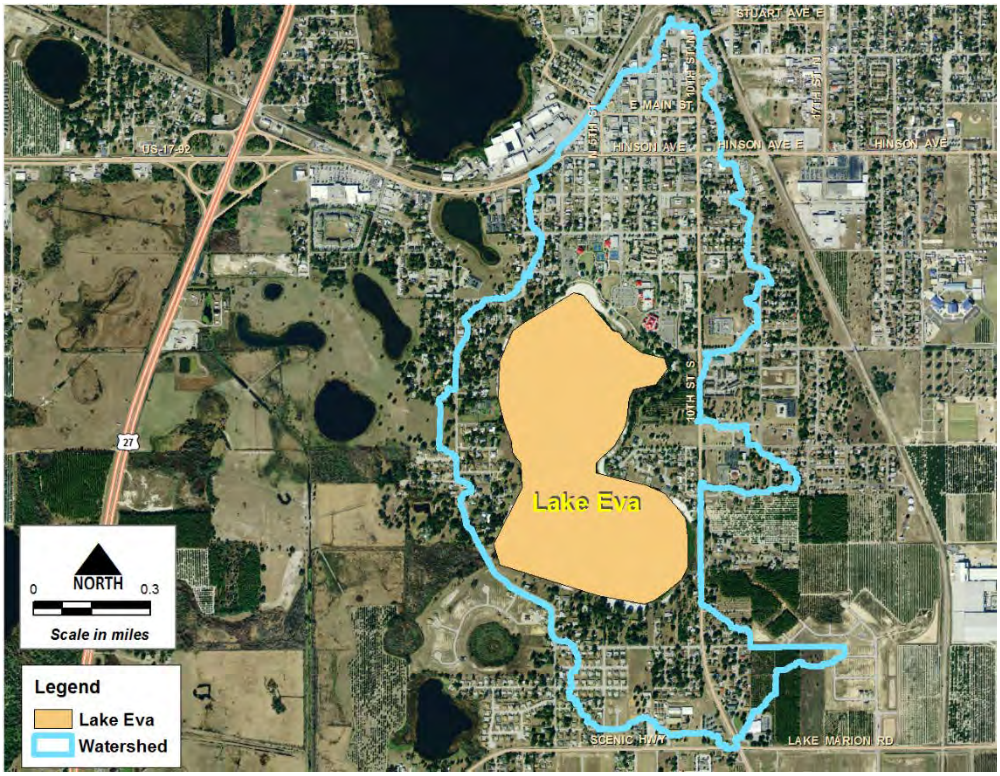


Figure 2. Lake Eva Drainage Basin.

Site Specific Details

The lake is located on the western edge of the Lake Wales Ridge, and land surface elevations north and west of the lake do not increase as steeply as east and south of the lake. For example, within a quarter mile of the eastern and southern boundaries of the lake, land surface elevations can increase by 75 ft. or more. The rate of rise to the north and west is generally much more gradual. Specifically, ground elevations in the Lake Eva basin and surrounding uplands range from approximately 121 ft. to 225 ft., with the highest elevations on the east side of the lake and the lowest on the west side.

There are no major natural surface water systems draining into the basin, although there are direct stormwater discharges to the lake. There are currently no permitted surface water withdrawals from the lake; however, there are numerous permitted groundwater withdrawals in the vicinity, including major groundwater withdrawals associated with operation of the city of Haines City Public Supply wells (SWFWMD Water Use Permit No. 20008522.010).

Land Use Land Cover

The uplands surrounding Lake Eva are almost entirely residential, with the exception of a public park on the north shore and a small citrus grove on the east shore.

An examination of 1941 aerial photography and more current 2011 Florida Land Use, Cover and Forms Classification System (FLUCCS) maps revealed that there have been considerable changes to the landscape in the vicinity of Lake Eva during this period, primarily from agriculture to residential / urban. Specifically, land use in 1941 was primarily citrus groves, but by 2011 most of the groves had been replaced by residential development (Figure 3). Figures 4 through 7 aerial photography chronicle landscape changes in the immediate lake basin from 1941 to the present.

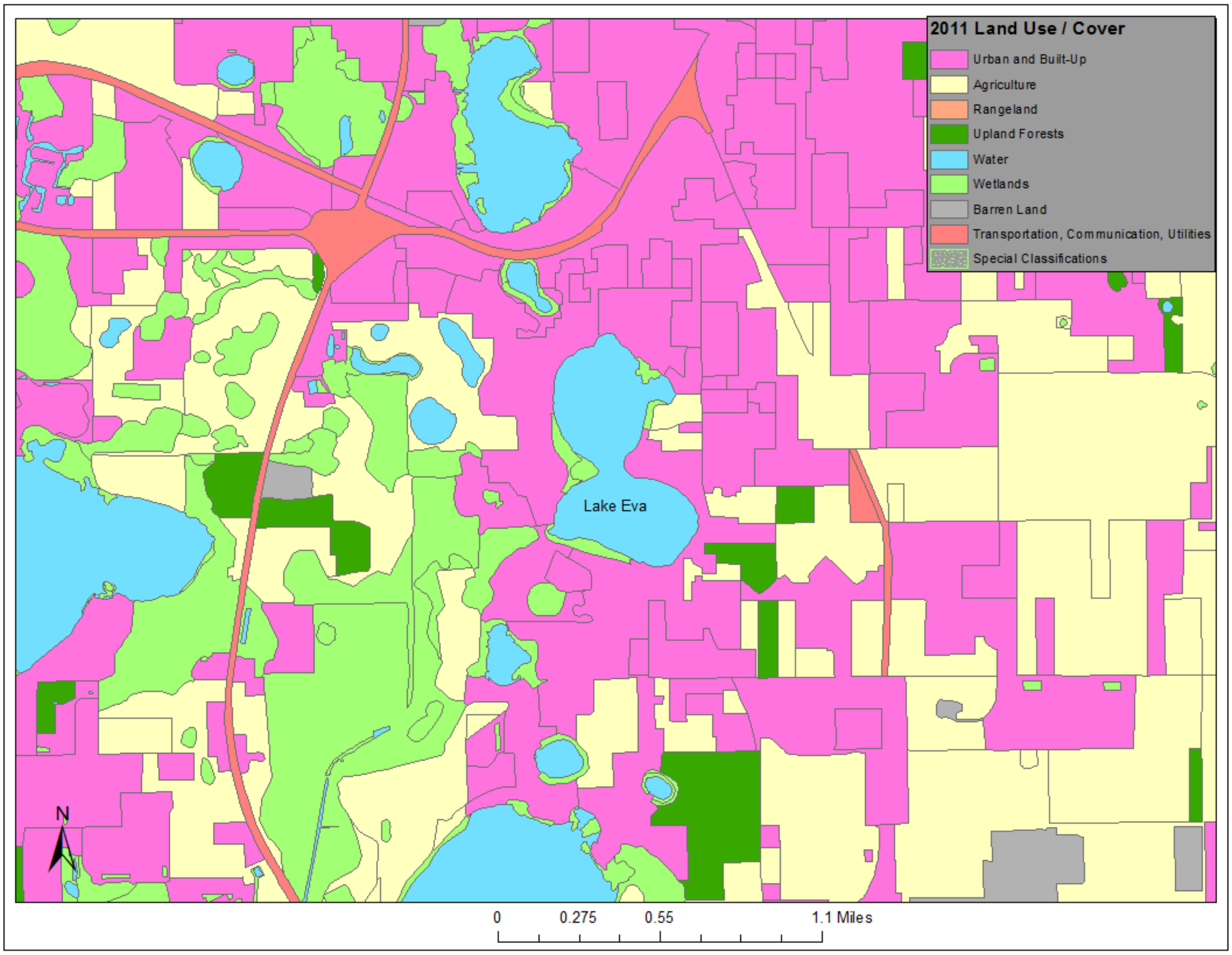


Figure 3. 2011 Land Use Land Cover Map of the Lake Eva Vicinity.

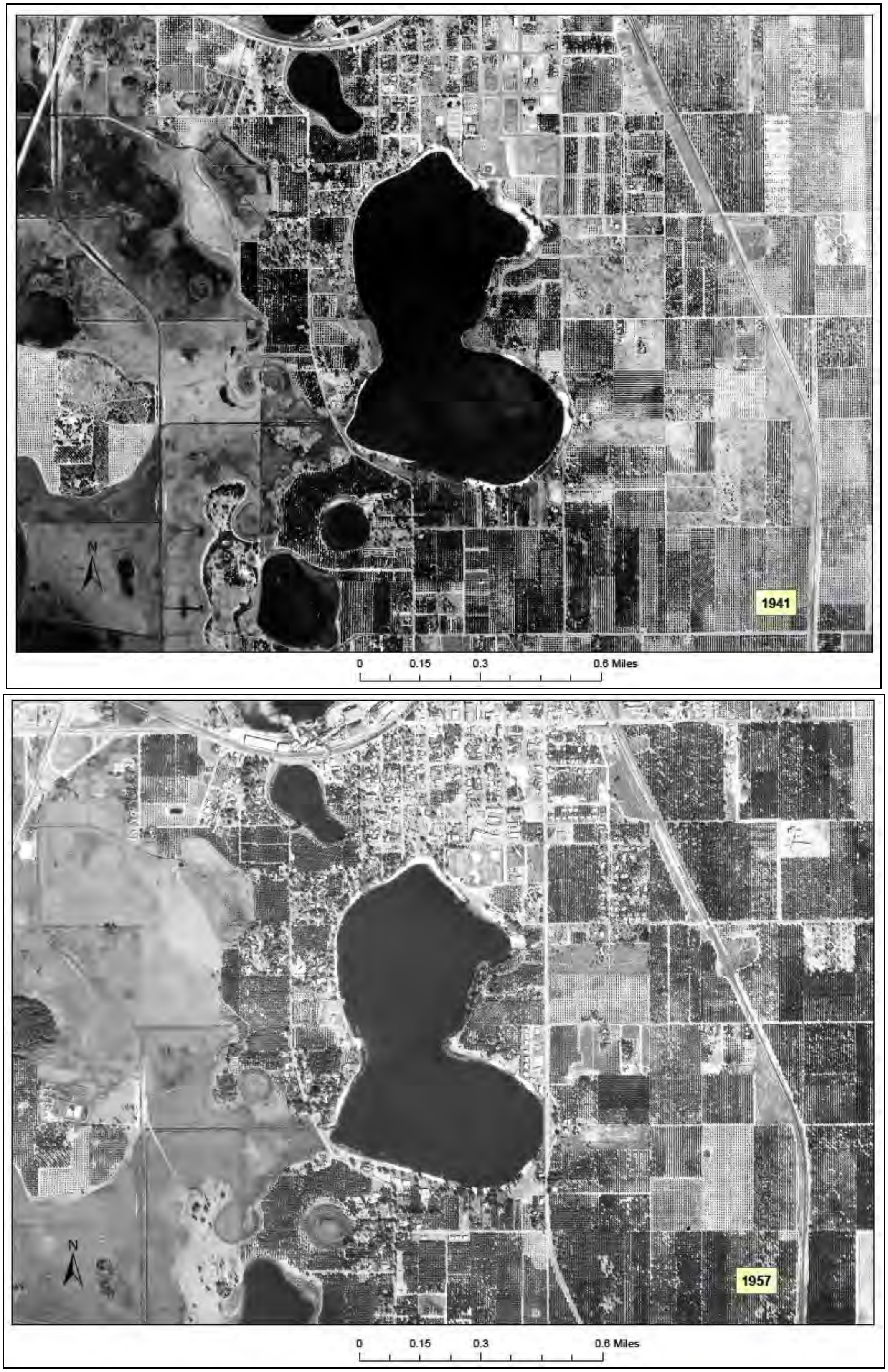


Figure 4. 1941 and 1957 Aerial Photographs of Lake Eva.

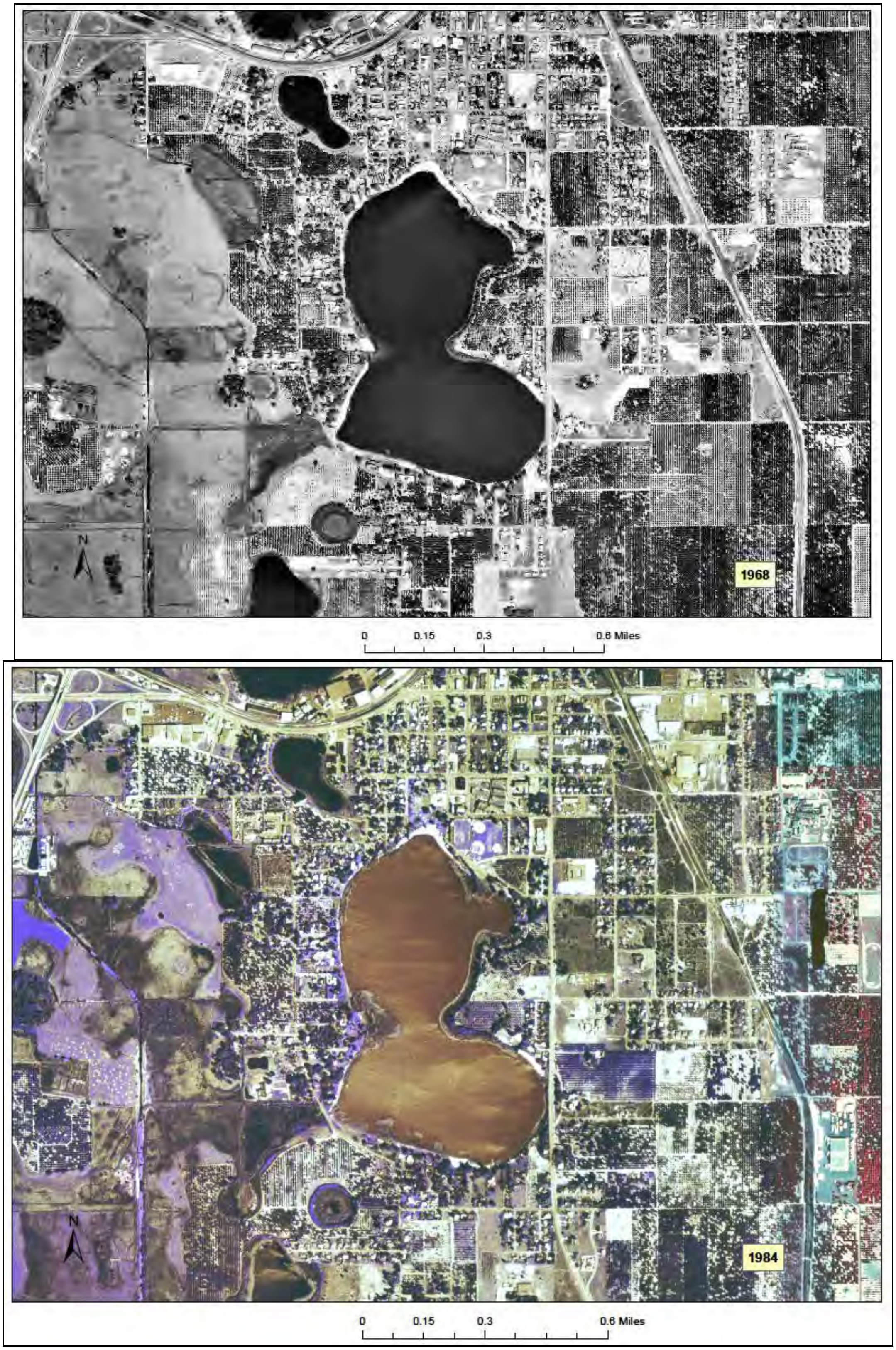


Figure 5. 1968 and 1984 Aerial Photographs of Lake Eva.

Figure 6. 2005 and 2014 Aerial Photographs of Lake Eva.

Figure 7. 2015 Aerial Photograph of Lake Eva.

Physiography and Hydrogeology

Lake Eva is situated on the western edge of a north-south oriented ridge (the Lake Wales Ridge) that is approximately 100 miles long and ranges from four to ten miles wide. White (1970) classified the area of central Florida containing Lake Eva as the Central Highlands physiographic region. Brooks (1981) characterized the two areas surrounding Lake Eva as the Lake Wales Ridge subdivision of the Central Lake Physiographic District and the Winter Haven Karst subdivision of the Central Lake District (Figure 8). As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as the Northern Lake Wales Ridge region, and described as having well-drained, sandy soils with mostly alkaline, clear water lakes with low to moderate nutrient levels (Griffith *et al.* 1997).

The Lake Wales Ridge area is predominantly well-drained and has internal drainage caused by numerous karst features; hence, it is the principal recharge area of the Floridan aquifer. Dissolution of the underlying limestone creates the relief seen in the Lake Wales Ridge. The Lake Wales Ridge Complex is a remnant of a broader upland that has been eroded and lowered by sea level fluctuations, fluvial erosion, and aeolian redistribution of sediments (Green et al., 2012). The lake straddles the western portion of the Lake Wales Ridge that slopes downward to the east and west. Elevations within the immediate watershed range from the lake edge at about 122 ft. to 221 ft. NAVD 88 on the south side of the lake. Drainage into the lake is a combination of overland flow, flow through a stormwater drainage system, as well as percolation from the surficial aquifer. The area adjacent to the western side of the lake is categorized as the Winter Haven Karst in the Central Lake Physiographic District (Brooks, 1981); a region of sandhills with large circular lakes.

The hydrogeology of the area includes a sand surficial aquifer; a clay confining unit perforated by karst features (sinkholes); and the thick carbonate Upper Floridan aquifer (Spechler and Kroening, 2007). The majority of lakes in the study area are sinkhole lakes that originated through collapse of solution-enlarged features in the underlying Floridan aquifer (Barcelo and others, 1990). Lake Eva is considered a sinkhole lake. Sinkholes can provide more direct avenues for water from the surficial aquifer to recharge the underlying Upper Floridan aquifer. Lateral movement of water through the surficial aquifer can be affected by individual lake basins because of the rolling topography, but there is also a sub-regional component to flows. The surficial aquifer is recharged by area rainfall; however, much of the rain that falls drains into lakes or is lost to evapotranspiration. Other sources of recharge that are applied to land include wastewater, reclaimed water, septic effluent, and irrigation of agricultural land or landscape areas (Spechler and Kroening, 2007). In elevated areas, such as the Lake Wales Ridge, the water table generally is a subdued reflection of land-surface topography (Yobbi, 1996). The Intermediate confining unit (more recently referred to as the Hawthorn aquifer system) consists mostly of interbedded clay, silt, phosphate, and sand, and serves as a confining unit under Lake Eva.

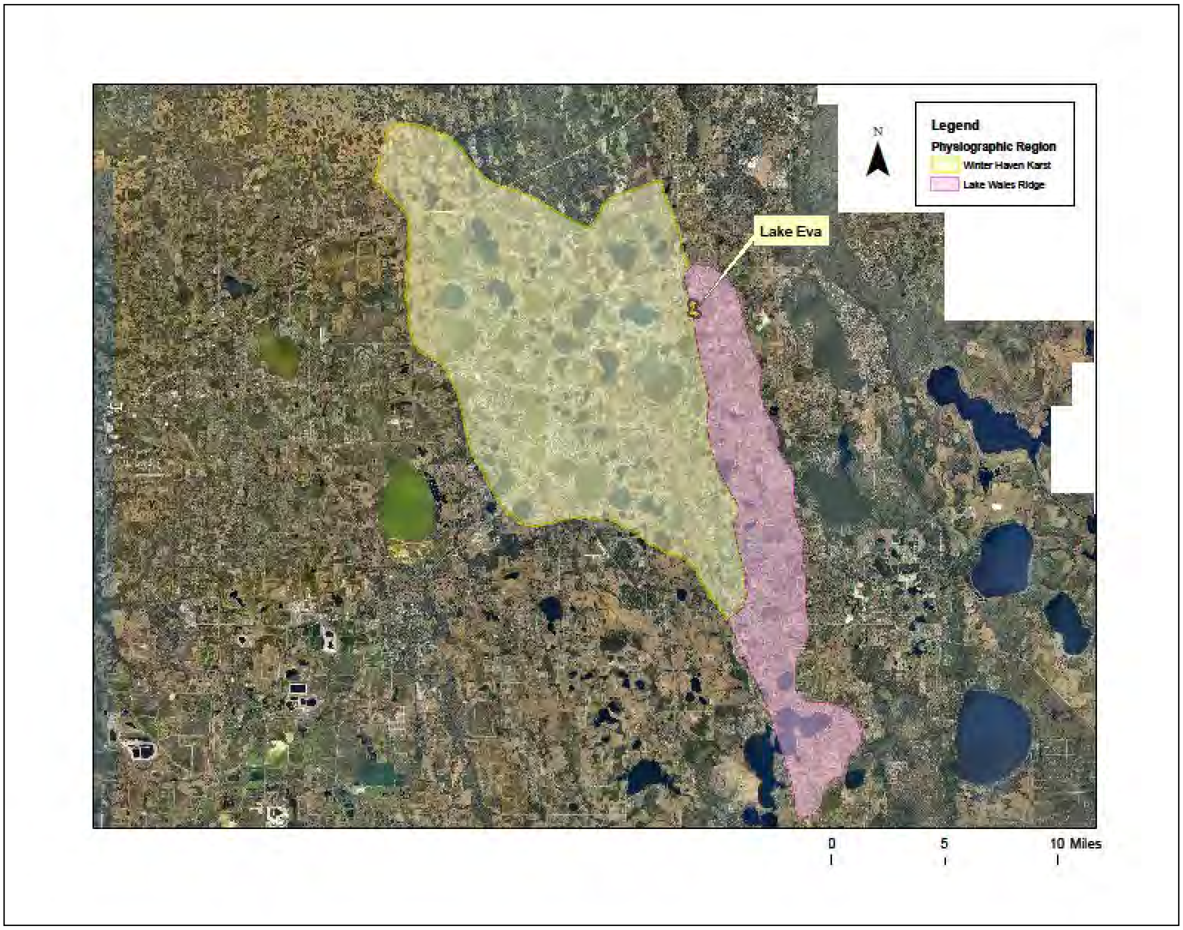


Figure 8. Physiographic Regions of the Lake Eva Area.

Bathymetry Description and History

One-foot interval bathymetric data gathered from recent field surveys resulted in lake-bottom contour lines down to 104 ft. (Figure 9). These data revealed that this lowest lake bottom contour located near the center of the north lobe of the lake is the deepest area at approximately 16 ft. deep. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report.

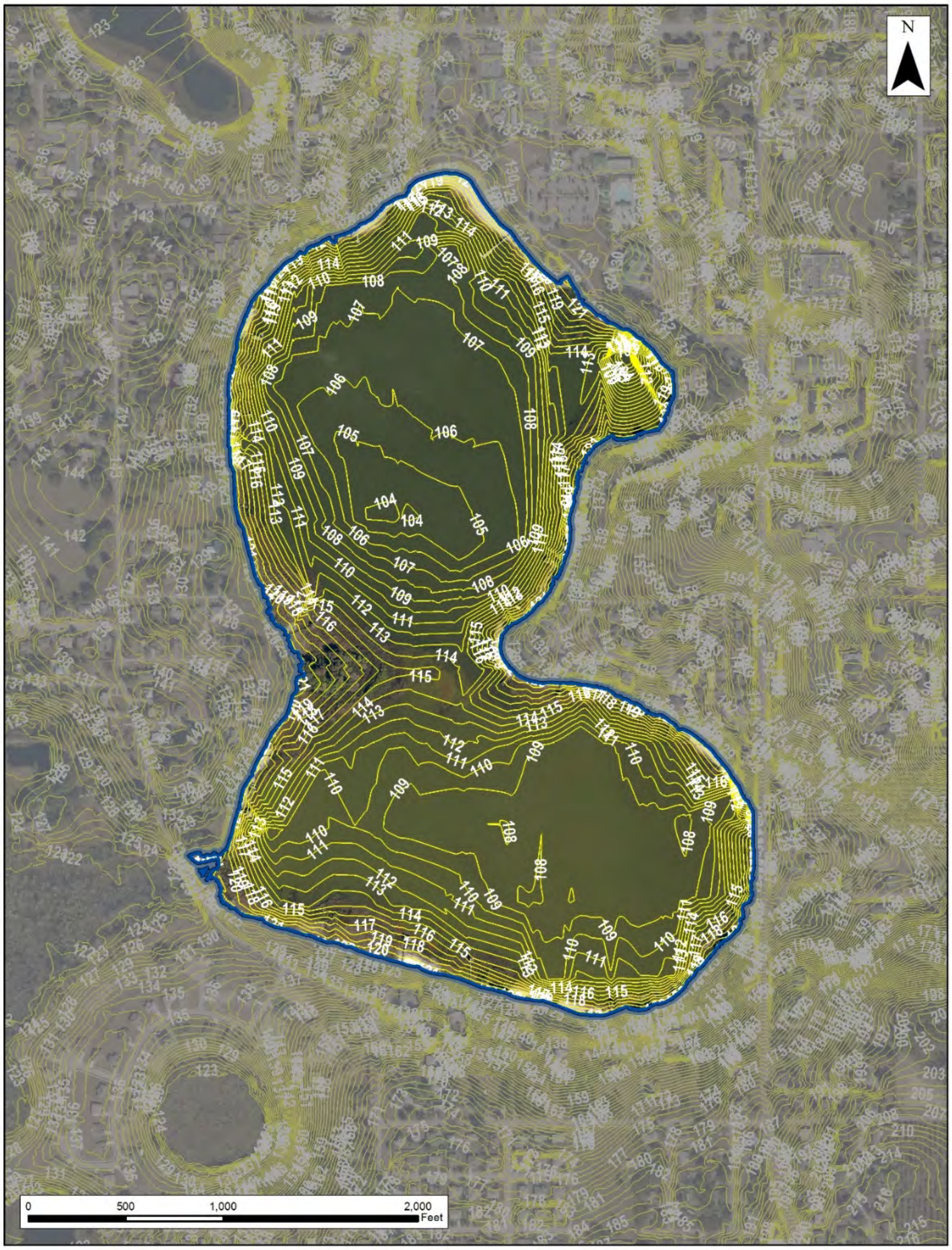


Figure 9. Lake Bottom Contours on a 2014 Aerial Photograph

Water Level (Lake Stage) Record

Lake stage data, i.e., recorded surface water elevations, are available for Lake Eva from the District's Water Management Information System (SID 17731) (Figure 10). Water level data collection at Lake Eva was collected weekly from July 1988 until May 1992. Data collection did not occur at the lake between May 1992 and February 2006. From

March 2006 through March 2013 data collection frequency was weekly. Data collection frequency at Lake Eva has been daily since March 2013 (Figure 11). The highest lake stage elevation on record was 120.28 ft. and occurred in March 21, 2006. The lowest lake stage elevation on record was 114.08 ft. and occurred on May 24, 2012. Figure 12 shows the extent of Lake Eva during a relatively wet year (2006) and a relatively dry year (2010).

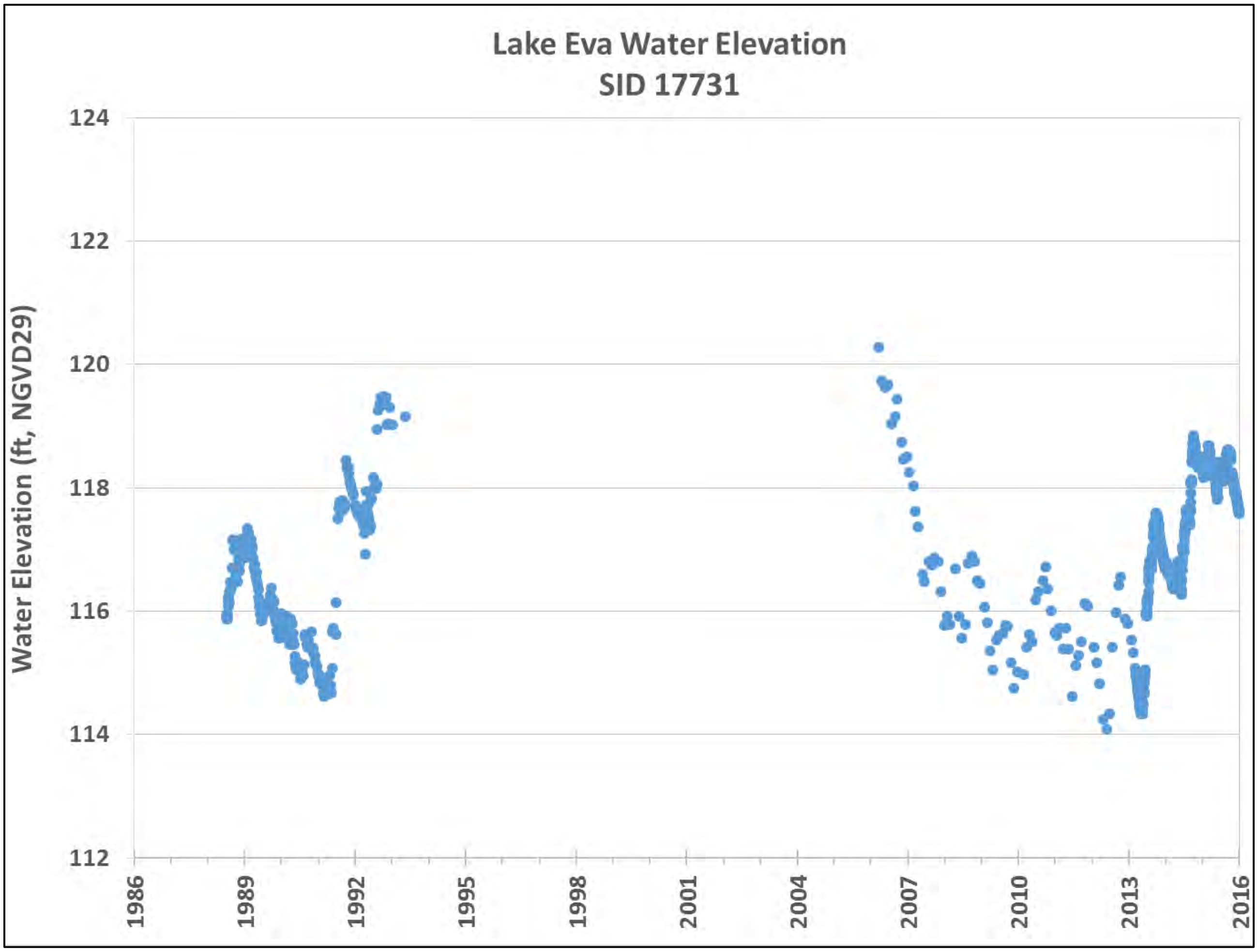
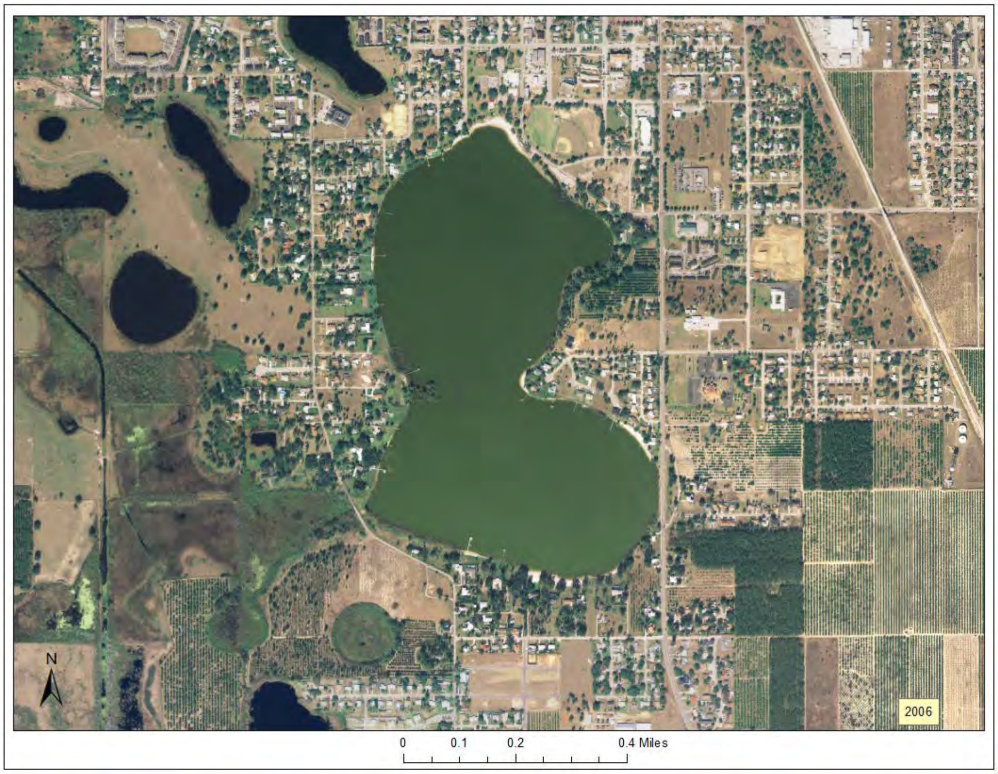


Figure 10. Lake Eva Period of Record Stage Data (SID 17731)

Figure 11. Lake Eva Gauge SID 17731 (NAVD88 datum) on March 3, 2016



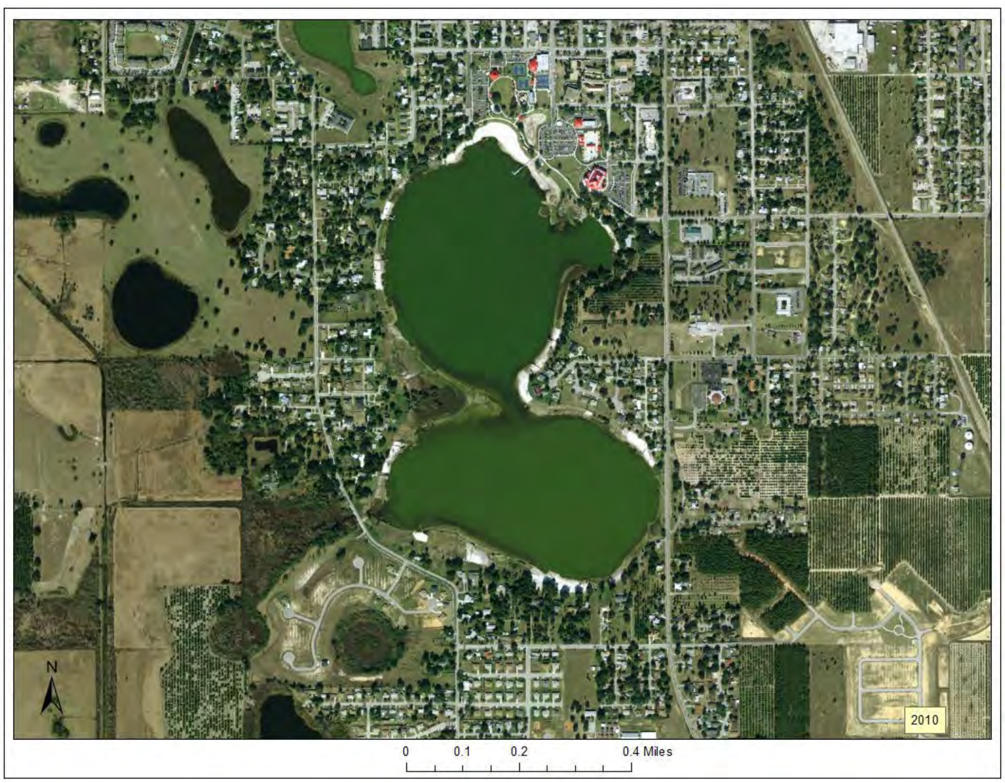


Figure 12. High Water Level (2006) and Low Water Level (January 2010) Historic Aerial Photographs of Lake Eva.

Currently Adopted Guidance Levels

There are no previously adopted minimum or guidance levels for Lake Eva.

Methods, Results and Discussion

Historical and Current Management Levels

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

The Minimum and Guidance Levels in this report were developed for Lake Eva using the methodology for Category 3 lakes described in Chapter 40D-8, F.A.C. These levels, along with lake surface area for each level are listed in Table 2, along with other information used for development of the levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

Bathymetry

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

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

Table 2. Lake Stage Percentiles, Normal Pool and Control Point Elevations, Significant Change Standards, and Minimum and Guidance Levels with associated surface areas for Lake Eva.

Levels	**Elevation in Ft. NGVD 29**	**Lake Area (acres)**
Lake Stage Percentiles		
Historic P10 (1946 to 2016)	120.8	177.11
Historic P50 (1946 to 2016)	118.3	160.20
Historic P90 (1946 to 2016)	116.2	146.31
Normal Pool and Control Point		
Normal Pool	NA	
Control Point	ND	
Significant Change Standards		
Recreation/Ski Standard	114.1	129.63
Dock-Use Standard	120.1	170.98
Wetland Offset Elevation	117.5	155.12
Aesthetics Standard	116.2	146.31
Species Richness Standard	115.5	141.36
Basin Connectivity Standard	118.1	158.95
Lake Mixing Standard	110.2	86.67
Minimum and Guidance Levels		
High Guidance Level	120.8	177.11
High Minimum Lake Level	119.2	165.70
Minimum Lake Level	118.1	158.95
Low Guidance Level	116.2	146.31

NA - not appropriate; ND – not determined

Two elevation data sets were used to develop the terrain model for Lake Eva. 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). The with an LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20) mounted to a boat hull, a Lowrance LMS-350A sonar-based depth finder and the Trimble GPS Pathfinder Pro XR/Mapping System (Pro XR GPS Receiver, Integrated GPS/MSK Beacon Antenna, TDC1 Asset Surveyor and Pathfinder Office software).

The DEM created from the combined elevation data sets was used to develop topographic contours of the lake basin and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the

ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments. Selected stage-area-volume results are presented in Figure 13.

Development of Exceedance Percentiles

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

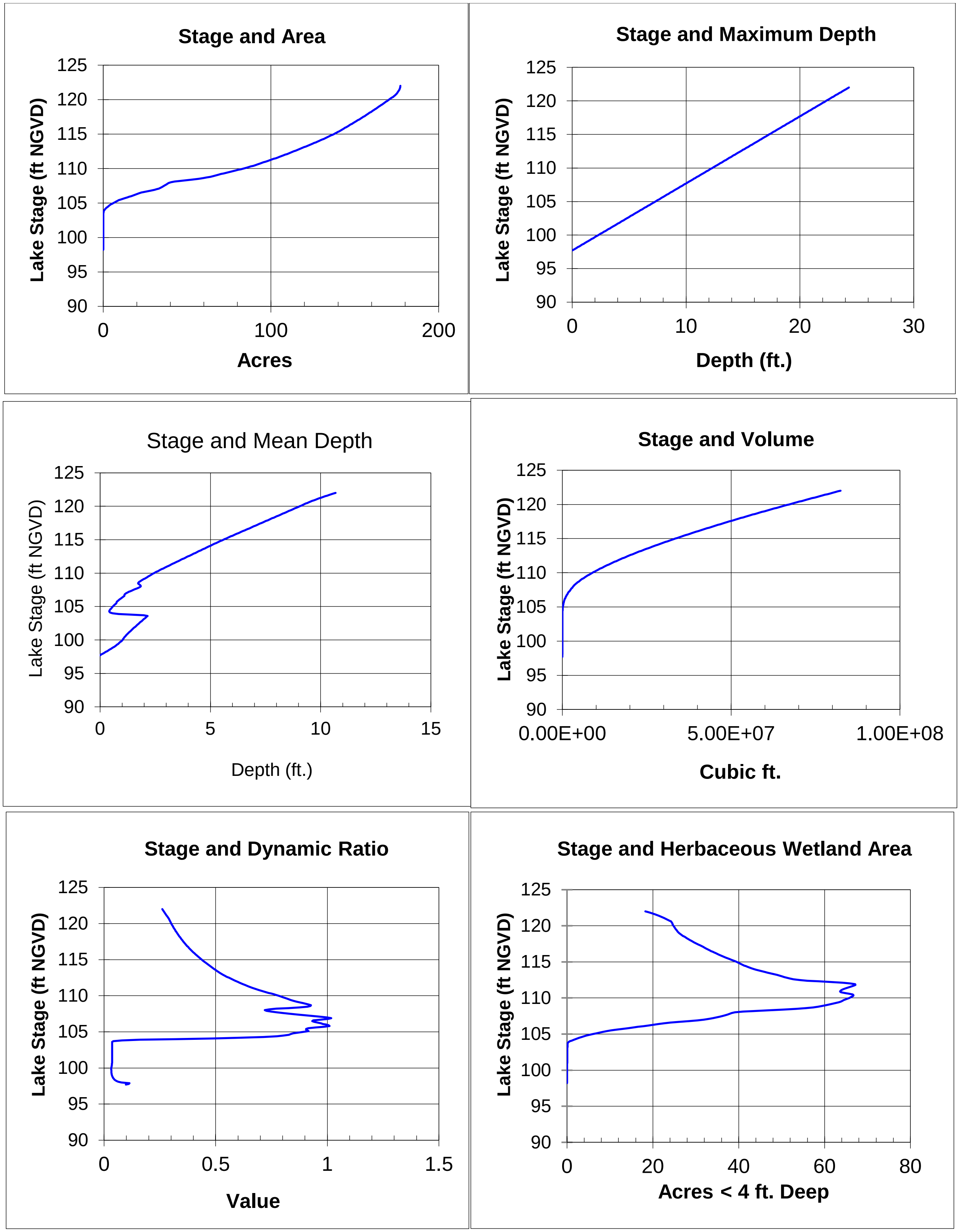


Figure 13. Surface area, volume, mean depth, maximum depth and dynamic ratio (basin slope) as a function of lake stage.

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 creating a water budget model which incorporated the effects of precipitation, 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 Lake Eva and composite regional rainfall.

A combination of model data produced a hybrid model which resulted in a 71 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 120.8 ft. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 118.3 ft. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 116.2 ft. (Figure 14 and Table 3).

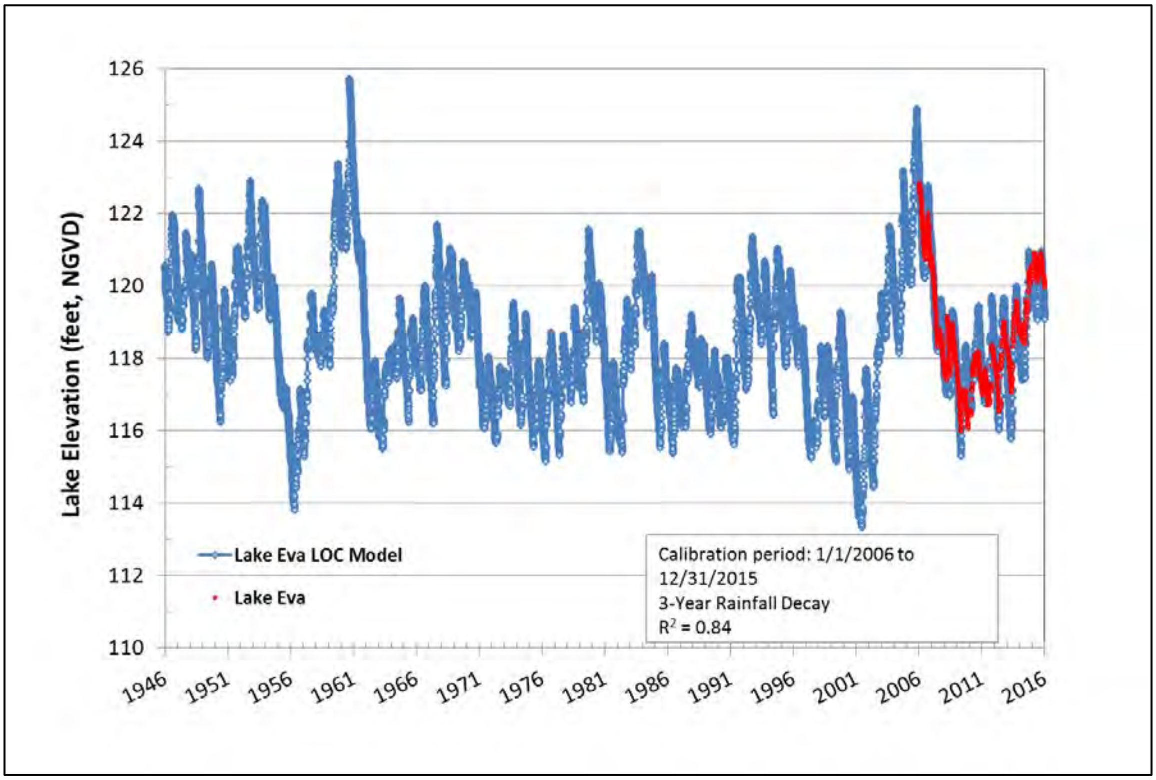


Figure 14. Historic Water Levels (hybrid) Used to Calculate Percentile Elevations Including P10, P50, and P90.

Table 3. Historic percentiles as estimated using the hybrid model from 1946 to 2016.

Percentile	Lake Eva
P10	120.8
P50	118.3
P90	116.2

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 Lake Eva does not have enough 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. The highest fixed spot in the outflow conveyance system is a low area in the southwest area of the lake at approximately 122 ft. However, due to the lack of complete historic water level data and survey information for this low area, it was not considered the Control Point for Lake Eva. The lowest building floor elevation was determined by survey to be 126.5 ft.

Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the *expected* Historic P10 of the lake, and is established using Historic data if it is available, or is estimated using the Current P10, the Control Point elevation, and the Normal Pool elevation. Based on the availability of Historic data developed for Lake Eva, the High Guidance Level was established at the Historic P10 elevation of 120.8 ft. The existing water level record does not show that the High Guidance Level has ever been exceeded. However, the lake level may have exceeded that elevation during the time when lake levels were not recorded. The highest recorded level was 120.28 ft. on March 21, 2006 (see Figure 10 above).

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate Historic or current data are not available. These statistics represent differences between P10, P50, and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals, i.e., reference lakes. Reference lake water regime statistics include the RLWR 50, RLWR 90 and RLWR 5090, which are, respectively, median differences between P10 and P50, P10 and P90, and P50 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Lake Eva, the Low Guidance Level was established at the Historic P90 elevation, 116.2 ft.

Significant Change Standards

The stage-volume relationship was developed, and Category 3 significant change standards were established for Lake Eva, including a Lake Mixing Standard, a Dock-Use Standard, a Basin Connectivity Standard, a Species Richness Standard, an Aesthetics Standard, and a Recreation/Ski Standard. An additional standard is developed to protect lake fringing wetlands (Wetland Offset). Herbaceous Wetland information was also evaluated. Each standard was previously defined in the Lake Classification section of this report. Each standard was evaluated for minimum levels development for Lake Eva and are presented in Table 2 above.

- The Mixing Standard was established at elevation 110.20 ft. due to the dynamic ratio (basin slope) shifting from <0.8 to >0.8 ft., indicating that potential changes in basin susceptibility to wind-induced sediment re-suspension.
- The Dock-Use Standard was established at elevation 120.1 ft., considering a two-foot draft at the ends of the docks (Table4).
- The Basin Connectivity Standard was set at elevation 118.1 ft. This is the elevation the lake would need to rise to allow enough clearance for boats to pass between the north and south lobes of the lake.
- The Species Richness Standard was established at elevation 115.5 ft., based on a 15% reduction in lake surface area from that at the Historic P50 elevation.
- An Aesthetic-Standard for Lake Eva was established at the Low Guidance Level elevation of 116.2 ft.
- The Recreation/Ski Standard was calculated at elevation 114.1 ft. based on a ski elevation of 112.0 ft.

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 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, draft report, 2007) and established for Lake Eva at 117.5 ft.

Review of changes in potential herbaceous wetland area associated with change in lake stage did not indicate that use of any of the identified standards would be inappropriate for minimum levels development (Figure 13).

Table 4. Summary statistics and elevations associated with docks on Lake Eva.

Summary Statistics	Statistics Values or Elevations of Sediments at Waterward End of Docks	Elevations of Dock Platforms
N (number of docks)	22	22
10th Percentile (P90)	112.3	121.1
Median or 50th Percentile	115.0	122.7
90th Percentile (P10)	116.0	124.6
Maximum	118.9	125.2
Minimum	110.8	120.8

Minimum Levels

The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis (P50). For a Category 3 lake the Minimum Lake Level is established utilizing a process that considers applying professional experience and judgement, and the seven Standards listed previously. The Minimum Lake Level for Lake Eva is established at the Basin Connectivity Standard elevation of 118.1 ft.

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 (P10). For Category 3 lakes, the High Minimum Lake Level is developed using the Minimum Lake Level, Historic data, or reference lake water regime (RLWR) statistics. If Historic Data are available, the High Minimum Lake Level is established at an elevation corresponding to the Minimum Lake Level plus the difference between the Historic P10 and Historic P50. If Historic data are not available, the High Minimum Lake level is set at an elevation corresponding to the Minimum Lake Level plus the region-specific RLWR 50. The RLWR statistics include the RLWR 50, RLWR 5090 and RLWR 90, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the limited availability of Historic data for Lake Eva, it was difficult to estimate a Historic P10 for the lake using the LOC and water budget models. Therefore, the High Guidance level was established using the RLWR 50. The appropriate RLWR 50, the median difference between the P10 and P50 for lakes along the Highlands and Lake Wales Ridge area is 1.1 ft. This offset was applied to the Minimum Lake Level of 118.1 ft. to produce a reasonable High Minimum Lake Level of 119.2 ft.

Minimum and Guidance levels for Lake Eva are plotted on the Historic water level record in Figure 15. To illustrate the approximate locations of the lake margin when water levels equal the minimum levels, these levels are imposed on a 2014 natural color photograph in Figure 16.

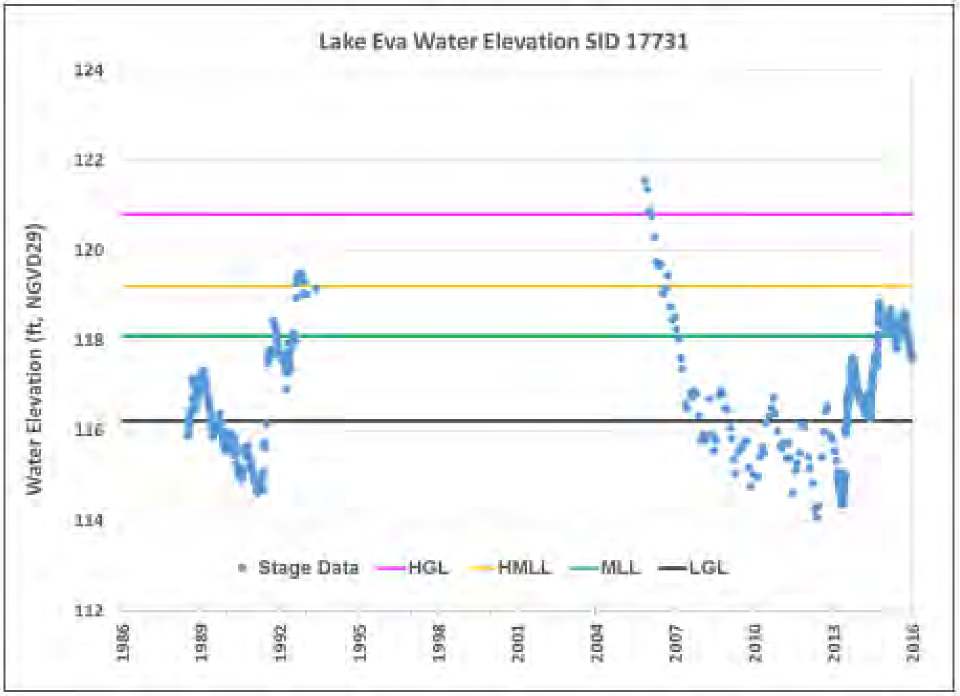


Figure 15. Historic water levels (hybrid) used to calculate the Minimum and Guidance Levels. The levels include the High Guidance Levels (HGL), High Minimum Lake Levels (HMLL), Minimum Lake Levels (MLL), and Low Guidance Levels (LGL).

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 MFLs for Lake Eva are presented in both datum standards (Table 5). 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 was converted to NAVD88 using the Corpscon conversion of -0.92 ft.

Table 5. Minimum and Guidance Levels for Lake Eva in NGVD29 and NAVD88.

Minimum and Guidance Levels	Elevation in Ft. NGVD29	Elevation in Ft. NAVD88
High Guidance Level	120.8	119.88
High Minimum Lake Level	119.2	118.28
Minimum Lake Level	118.1	117.18
Low Guidance Level	116.2	115.28

Figure 16. Lake Eva Minimum and Guidance Level Contour Lines Imposed on a 2014 Natural Color Aerial Photograph.

Consideration of Environmental Values

The minimum levels for Lake Eva 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 Minimum Levels for Lake Eva 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 (refer to Table 1).

Minimum Levels Status Assessment

To assess whether the Minimum Lake Level is being met, observed stage data in Lake Eva were used to create a long-term record using a modified version of the LOC model developed for predicting long-term lake levels (Appendix A). For the status assessment, the "current" lake stage data used to create the LOC must be from a period representing a time when groundwater withdrawals and structural alterations are reasonably stable. Water level data collection at Lake Eva was collected weekly from July 1988 until May 1992. Data collection did not occur at the lake between May 1992 and February 2006. From March 2006 through March 2013 data collection frequency was weekly. Data collection frequency at Lake Eva has been daily since March 2013. Using the current stage data, the LOC model was created. Utilizing rainfall data in the LOC model resulted in a 70-year long-term water level record (1946-2015).

For the status assessment, cumulative median (P50) and cumulative P10 water surface elevations were compared to the Minimum Lake Level and High Minimum Lake Level to determine whether long-term water levels were above these levels. Results from these assessments indicate that Lake Eva water levels are currently below the Minimum Lake Level and below the High Minimum Lake Level for the lake. These conclusions are supported by comparison of percentiles derived from LOC-modeled lake stage data with the minimum levels. (See Appendix B).

The lake lies within the region of the District covered by an existing recovery strategy for the Southern Water Use Caution Area (Rule 40D-80.074, F.A.C.). The District plans to continue regular monitoring of water levels in Lake Eva and will also routinely evaluate the status of the lake's water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C.

Documents Cited and Reviewed

Bachmann, R.W., Hoyer. M.V., and Canfield, D.E. Jr. 2000. The potential for wave disturbance in shallow Florida lakes. Lakes and Reservoir Management 16: 281-291.

Barcelo, M.D., Slonena, D.L., Camp, S.C., and Watson. J.D, 1990. Ridge II, A Hydrogeologic Investigation of the Lake Wales Ridge: Southwest Florida Water Management District, 14 p.

Basso, R. and Schultz, R. 2003. Long-term variation in rainfall and its effect on Peace River flow in west-central Florida. Southwest Florida Water Management District, Brooksville, Florida.

Bedient, P., Brinson, M., Dierberg, F., Gorelick, S., Jenkins, K., Ross, D., Wagner, K., and Stephenson, D. 1999. Report of the Scientific Peer Review Panel on the data, theories, and methodologies supporting the Minimum Flows and Levels Rule for northern Tampa Bay Area, Florida. Prepared for the Southwest Florida Water Management District, the Environmental Confederation of Southwest Florida, Hillsborough County, and Tampa Bay Water. Southwest Florida Water Management District. Brooksville, Florida.

Brooks, H. K. 1981. Physiographic divisions of Florida: map and guide. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville, Florida.

Carr, D.W. and Rochow, T.F. 2004. Technical memorandum to file dated April 19, 2004. Subject: comparison of six biological indicators of hydrology in isolated *Taxodium acsendens* domes. Southwest Florida Water Management District. Brooksville, Florida.

Carr, D. W., Leeper, D. A., and Rochow, T. F. 2006. Comparison of Six Biologic Indicators of Hydrology and the Landward Extent of Hydric Soils

Caffrey, A.J., Hoyer, M.V. and Canfield, D.E., Jr. 2006. Factors affecting the maximum depth of colonization by submersed aquatic macrophytes in Florida lakes. University of Florida Institute of Food and Agricultural Sciences Department of Fisheries and Aquatic Sciences. Gainesville, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Dierberg, F. E. and Wagner, K. J. 2001. A review of “A multiple-parameter approach for establishing minimum levels for Category 3 Lakes of the Southwest Florida Water Management District” June 2001 draft by D. Leeper, M. Kelly, A. Munson, and R. Gant. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Emery, S., Martin, D., Sumpter, D., Bowman, R., Paul, R. 2009. Lake surface area and bird species richness: analysis for minimum flows and levels rule review. University of South Florida Institute for Environmental Studies. Tampa, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida

Enfield, D. B., Mestas-Nunez, A. M., and Trimble, P. J. 2001. The Atlantic multi-Decadal oscillation and its relation to rainfall and river flow in the continental U. S. Geophysical Research Letters 28: 2077-2080.

Flannery, M.S., Peebles, E.B. and Montgomery, R.T. 2002. A percent-of-flow approach for Managing reductions in freshwater flows from unimpounded rivers to southwest Florida estuaries. Estuaries 25: 1318-1332.

Green, R.C., W.L. Evans III, C.P. Williams, C. Kromhout, and S.W. Bassett. 2012. Text to Accompany Geologic Map of the U.S.G.S. Tarpons Springs 30 x 60 Minute Quadrangle, Central Florida Department of Environmental Protection, Florida Geological Survey.

Griffith, G., Canfield, D., Jr., Horsburgh, C., Omernik, and J. Azevedo, S. 1997. Lake regions of Florida (map). United States Environmental Protection Agency, University of Florida Institute of Food and Agricultural Sciences, Florida Lakewatch, Florida Department of Environmental Protection, and the Florida Lake Management Society.

Hancock, M. 2006. Draft memorandum to file, dated April 24, 2006. Subject: a proposed interim method for determining minimum levels in isolated wetlands. Southwest Florida Water Management District. Brooksville, Florida.

Hancock, M. 2007. Recent development in MFL establishment and assessment. Southwest Florida Water Management District, draft 2/22/2007. Brooksville, Florida.

Hancock, M.C., Leeper, D.A., Barcelo, M.D. and Kelly, M.H. 2010. Minimum flows and levels development, compliance, and reporting in the Southwest Florida Water Management District. Southwest Florida Water Management District. Brooksville, Florida.

Helsel, D. R. and Hirsch, R. M. 1992. Statistical methods in water resources. Studies in Environmental Science 45. Elsevier. New York, New York.

Hoyer, M.V., Israel, G.D. and Canfield, D.E., Jr. 2006. Lake User's perceptions regarding impacts of lake water level on lake aesthetics and recreational uses. University of Florida Institute of Food and Agricultural Sciences Department of Fisheries and Aquatic Sciences and Department of Agricultural Education and Communication. Gainesville, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Kelly, M. 2004. Florida river flow patterns and the Atlantic Multidecadal Oscillation. Southwest Florida Water Management District. Brooksville, Florida.

Leeper, D. 2006. Proposed methodological revisions regarding consideration of structural alterations for establishing Category 3 Lake minimum levels in the Southwest Florida Water Management District, April 21, 2006 peer-review draft. Southwest Florida Water Management District. Brooksville, Florida.

Leeper, D., Kelly, M., Munson, A., and Gant, R. 2001. A multiple-parameter approach for establishing minimum levels for Category 3 Lakes of the Southwest Florida Water Management District, June14, 2001 draft. Southwest Florida Water Management District, Brooksville, Florida.

Mace, J. 2009. Minimum levels reevaluation: Gore Lake Flagler County, Florida. Technical Publication SJ2009003. St. Johns River Water Management District. Palatka, Florida.

Neubauer, C.P., Hall, G.B., Lowe, E.F., Robison, C.P., Hupalo, R.B., and Keenan, L.W. 2008. Minimum flows and levels method of the St. Johns River Water Management District, Florida, USA. Environmental Management 42: 1101-1114.

Poff N.L., B. Richter, A.H. Arthington, S.E. Bunn, R.J. Naiman, E. Kendy, M. Acreman, C. Apse, B.P. Bledsoe, M. Freeman, J. Henriksen, R.B. Jacobson, J. Kennen, D.M. Merritt, J. O'Keeffe, J.D. Olden, K. Rogers, R.E. Tharme & A. Warner. 2010. The Ecological Limits of Hydrologic Alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* 55:147-170.

Poff, N.L. and Zimmerman, K.H. 2010. Ecological responses to altered flow regimes: a literature review to inform science and management of environmental flows. Freshwater Biology 55: 194-205.

Postel, S. and Richter, B. 2003. Rivers for life: Managing water for people and nature. Island Press. Washington, D.C.

Schultz, Richard, Michael Hancock, Jill Hood, David Carr, and Theodore Rochow. Memorandum of file, dated July 21, 2004. Subject: Use of Biologic Indicators for Establishment of Historic Normal Pool. Southwest Florida Water Management District. Brooksville, Florida.

Spechler, R.M. and S.E. Kroening. 2007. Hydrology of Polk County. Scientific Investigations Report 2006-5320. U.S. Geological Survey. Reston, Virginia.

Wagner and Dierberg (2006) A Review of a Multiple-Parameter Approach for Establishing Minimum Levels for Category 3 Lakes of the Southwest Florida Water Management District. SWFWMD, Brooksville, Fl.

Wantzen, K.M., Rothhaupt, K.O., Morti, M. Cantonati, M.G. Toth, L.G. and Fisher, P. (editors). 2008. Ecological effects of water-level fluctuations in lakes. Development in Hydrobiology, Volume 204. Springer Netherlands.

White, W. A. 1970. The geomorphology of the Florida peninsula. Geological Bulletin, No. 51. Bureau of Geology, Florida Department of Natural Resources. Tallahassee, Florida.

Yobbi, D.K., 1996. Analysis and Simulation of Ground-Water Flow in Lake Wales Ridge and Adjacent Areas of Central Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4254, 82 p.

APPENDIX A

Draft Technical Memorandum

August 17, 2016

TO: Mark Hurst, Senior Environmental Scientist, Water Resources Bureau

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

FROM: Jason G. Patterson, Hydrogeologist. Water Resources Bureau
Michael Hancock, P.E., Senior Professional Engineer, Water Resources Bureau
Mark Barcelo, P.E., Chief Professional Engineer, Water Resources Bureau

Subject: Lake Eva Water Budget Model, Rainfall Regression Model, and Historic Percentile Estimations

---

A. Introduction

Water budget and rainfall regression models were developed to assist the Southwest Florida Water Management District (District) in the assessment of minimum levels for Lake Eva, located in east-central Polk County, within the City of Haines City. A proposed minimum level for Lake Eva is scheduled to be established in FY 2016. This document will discuss the development of the Lake Eva models and use of the models for development of Historic lake stage exceedance percentiles using those models.

B. Background and Setting

Lake Eva is located in east-central Polk County, west of US Highway 27 between Scenic Highway and Hinson Avenue in the City of Haines City (Figure 1). The lake is within the Peace Creek watershed, as identified by ADA Engineering (2012) and Atkins (2013) for watershed management program modeling. There are no major natural surface water systems draining into the basin, although there are direct stormwater discharges to the lake. There are currently no permitted surface water withdrawals from the lake; however, there are numerous permitted groundwater withdrawals in the vicinity.

Physiography and Hydrogeology

Lake Eva is situated on the western edge of a north-south oriented ridge (the Lake Wales Ridge) that is approximately 100 miles long and ranges from four to ten miles

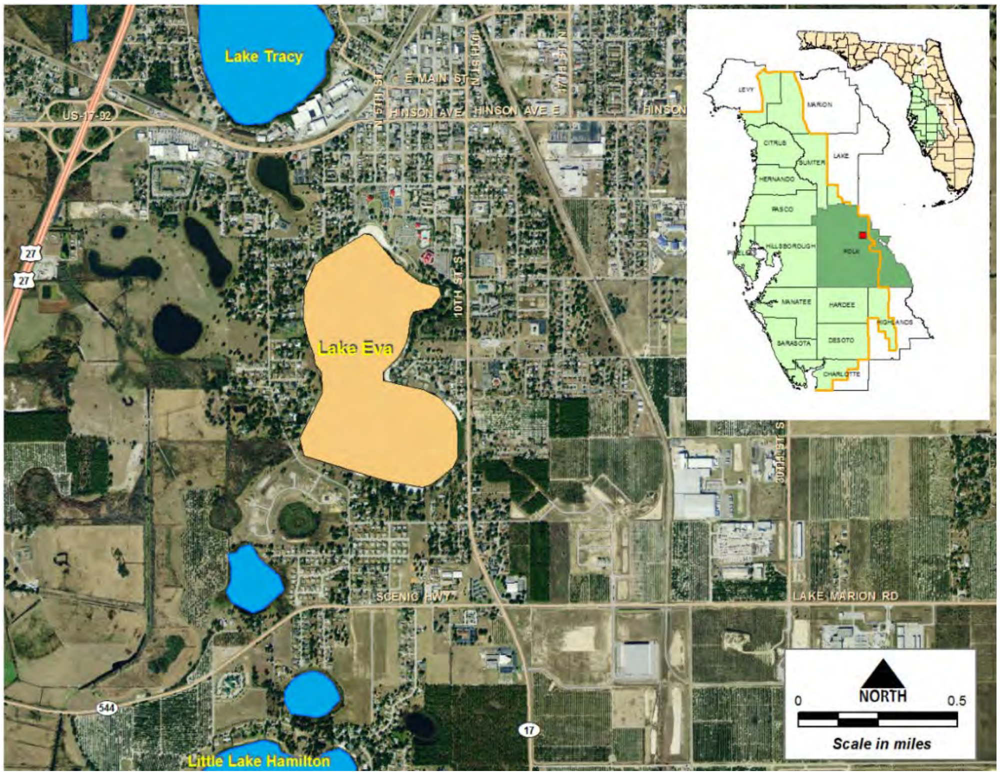


Figure 1. Location of Lake Eva in Polk County, Florida

wide. The area surrounding the lake is categorized as the Iron Mountains in the Central Lake Physiographic District (Brooks, 1981). It is a sub-region of the Lake Wales Ridge and contains very high sand hills underlain by sand, gravel, and clayey sand that are deeply weathered. The Lake Wales Ridge area is predominantly well-drained and has internal drainage caused by numerous karst features; hence, it is the principal recharge area of the Floridan aquifer. Dissolution of the underlying limestone creates the relief seen in the Lake Wales Ridge. The Lake Wales Ridge Complex is a remnant of a broader upland that has been eroded and lowered by sea level fluctuations, fluvial erosion, and aeolian redistribution of sediments (Green et al., 2012). The lake straddles the western portion of the Lake Wales Ridge that slopes downward to the east and west. Elevations within the immediate watershed range from the lake edge at about 122 feet to 221 feet NAVD 88 on the south side of the lake. Drainage into the lake is a combination of overland flow, flow through a stormwater drainage system, as well as percolation from the surficial aquifer. The area adjacent to western side of the lake is categorized as the Winter Haven Karst in the Central lake Physiographic District (Brooks, 1981); a region of sandhills with large circular lakes.

The hydrogeology of the area includes a sand surficial aquifer; a clay confining unit perforated by karst features (sinkholes); and the thick carbonate Upper Floridan aquifer (Spechler and Kroening, 2007). The majority of lakes in the study area are sinkhole lakes that originated through collapse of solution-enlarged features in the underlying Floridan aquifer (Barcelo and others, 1990). Lake Eva is considered to be a sinkhole lake. Sinkholes can provide more direct avenues for water from the surficial aquifer to recharge the underlying Upper Floridan aquifer. Lateral movement of water through the surficial aquifer can be affected by individual lake basins because of the rolling topography, but there is also a sub-regional component to flows. The surficial aquifer is recharged by area rainfall; however, much of the rain that falls drains into lakes or is lost to evapotranspiration. Other sources of recharge that are applied to land include wastewater, reclaimed water, septic effluent, and irrigation of agricultural land or landscape areas (Spechler and Kroening, 2007). In elevated areas, such as the Lake Wales Ridge, the water table generally is a subdued reflection of land-surface topography (Yobbi, 1996). The Intermediate confining unit (more recently referred to as the Hawthorn aquifer system) consists mostly of interbedded clay, silt, phosphate, and sand is present at Lake Eva and serves as a confining unit.

Stratigraphy near Lake Eva are described by Lithologic Logs W-3799 and W-12269. W-3799 is approximately one-half mile north of Lake Eva and W-12269 is approximately 2.3 miles northeast of the lake. The surficial aquifer at both sites consist of undifferentiated, unconsolidated quartz sand and clayey quartz sand deposits. The surficial aquifer is present at W-3799 from land surface datum (LSD) to 80 feet below LSD and at W-12269 from LSD to 100 feet below LSD. The stratigraphy at both sites is typical of the area, as the surficial aquifer generally thickens toward the east, especially along the southern part of the Lake Wales Ridge where the thickness can exceed 200 feet. The surficial aquifer is considered the uppermost water-bearing unit and is recharged primarily by the infiltration of rainfall. Most rainfall within the area of Lake Eva drains into streams or lakes or is lost to evapotranspiration. The remaining rainfall recharges the surficial aquifer by percolating through unsaturated surficial deposits (Spechler and Kroening, 2007).

Spechler and Kroening (2007) report that the intermediate confining unit, or Hawthorn aquifer system is present throughout much of Polk County and is locally absent or thin in the extreme northwestern part of Polk County. The Hawthorn aquifer system was present at the W-3799 and W-12269 sites. It was primarily composed of clayey/sandy limestones and sandy clays grading to clayey dolomites. The unit typically displays low to moderate porosity values with low permeability values.

Below the Hawthorn aquifer system lies the limestone of the Upper Floridan aquifer system that ranges from approximately 300 feet thick in eastern Polk County to more than 1,200 feet thick in the southwestern part of the county (Spechler and Kroening, 2007). The Floridan aquifer system, the principal source of water for this area, extended from 110 feet below LSD to 600 feet below LSD at the W-3799 site and from

120 feet below LSD to 425 feet below LSD at the W-12269 site. The Floridan aquifer system here consisted mainly of calcarenitic limestone with some dolomite lenses.

Data

Water level data collection at Lake Eva was collected weekly from July 1988 until May 1992. Data collection did not occur at the lake between May 1992 and February 2006. From March 2006 through March 2013 data collection frequency was weekly. Data collection frequency at Lake Eva has been daily since March 2013 (Figure 2).

Lake Alfred Deep at Lake Alfred Upper Floridan aquifer monitor well (SID 25227) was used for the water budget model for Lake Eva (Figure 3 and 4). The well is located approximately 5.5 miles west of Lake Eva. Data at Lake Alfred Deep at Lake Alfred was collected every other week from 1971 until December 2011 when data collection became monthly. Data gaps were infilled linearly for the duration of the water budget model.

Surficial aquifer monitor wells RIDGE WRAP P-5 (SID 26374) and PRIM Pc-01 Water Tower (SID 728010) were used to construct the water budget model for Lake Eva (Figures 3 and 4). From January 1, 2006 until May 20, 2009, the RIDGE WRAP P-5 well was used. The well is located approximately 2.9 miles north of Lake Eva and is located along the western portion of the Lake Wales Ridge. Data for RIDGE WRAP P-5 begin in November 1991 and data collection frequency are monthly. Data gaps were linearly infilled. The PRIM Pc-01 Water Tower well data begin on May 21, 2009. The well is located approximately 3.5 west-southwest of Lake Eva and data collection frequency are daily. Only two data gaps are in the data set and both were linearly infilled. The first data gap was from October 30, 2009 to November 29, 2009 (31 days) and the second was from April 13, 2013 to April 30, 2013 (17 days).

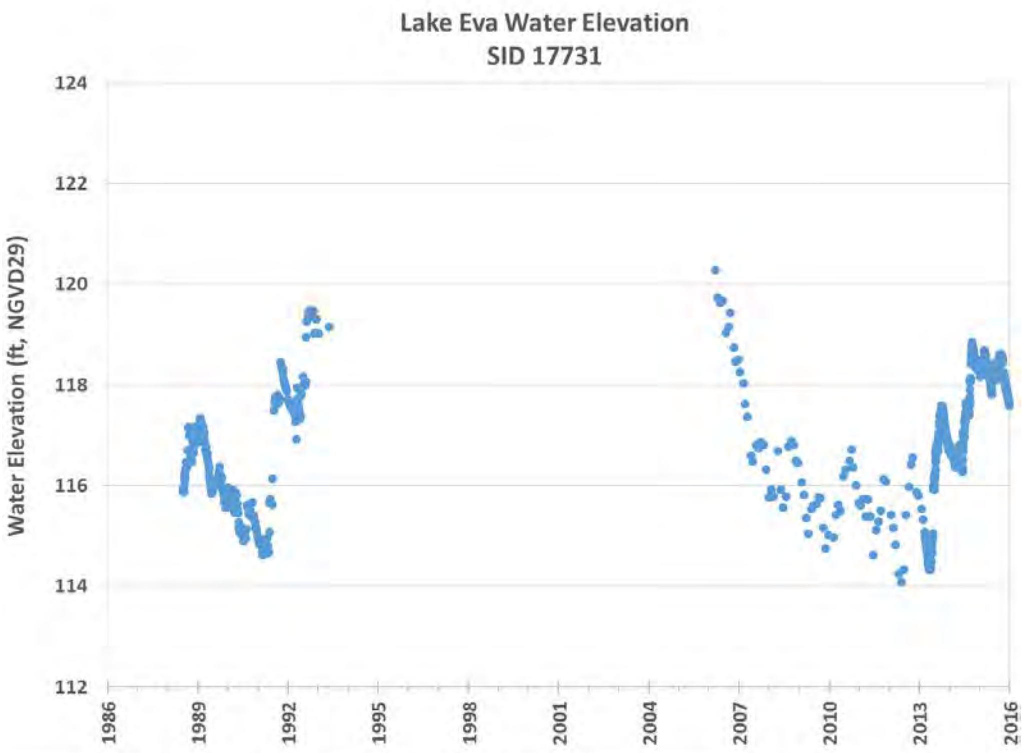


Figure 2. Lake Eva water levels

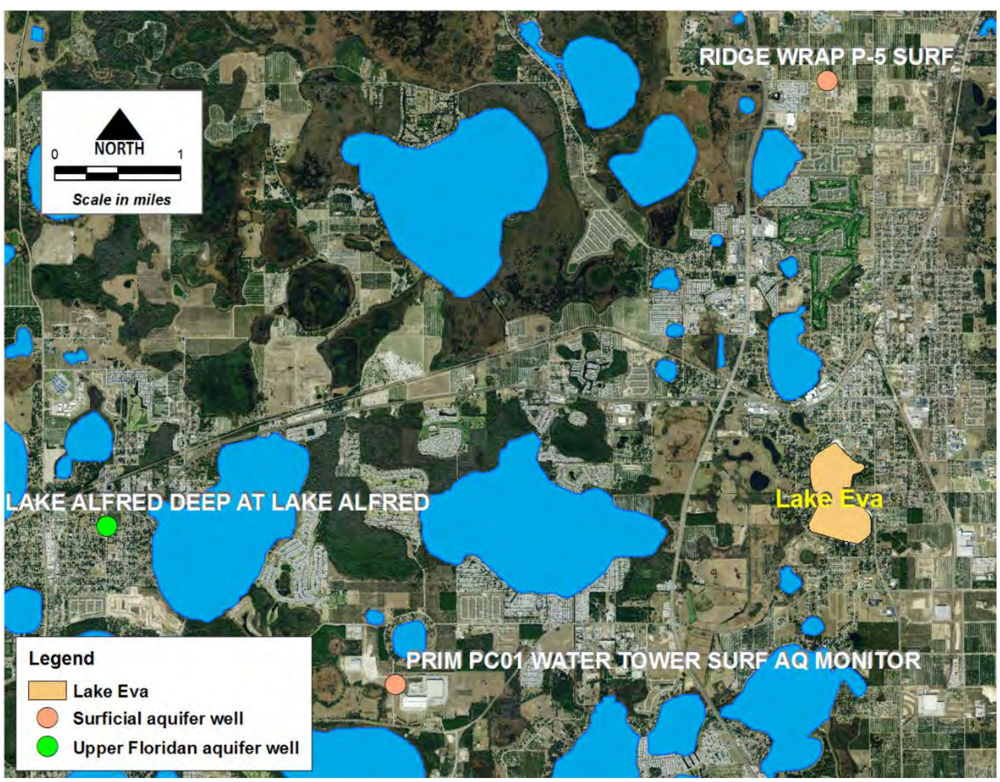


Figure 3. Location of monitoring wells near Lake Eva

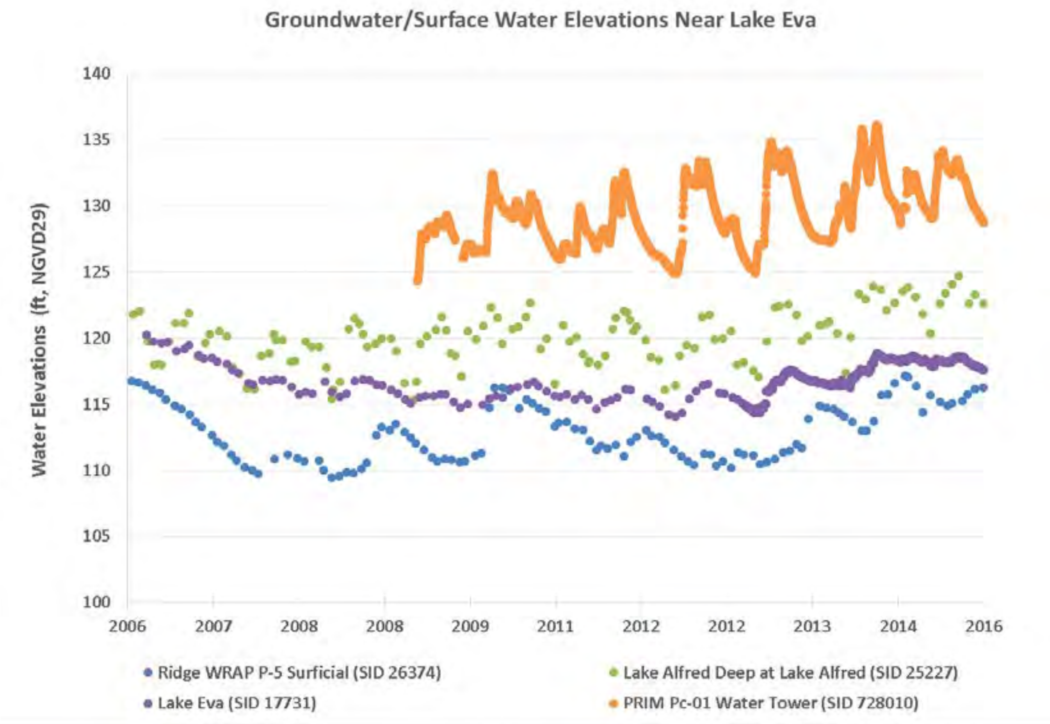


Figure 4. Water levels in monitoring wells near Lake Eva

Land and Water Use

Land and water use in the area of Lake Eva has changed over the years. Figure 5 shows the land use around Lake Eva in 1941 and Figure 6 shows 2011 land use/land cover with 2012 aerial imagery. Much of the land use in 1941 consisted of citrus groves, agriculture and some residential development on the west and north side of the lake. Today, land use and water use have changed (Figures 5 through 7, and Table 1). Land use has become more urban, replacing much of the citrus, however, agricultural land use is abundant to the east and south of the lake. The estimated total groundwater use average from 2008 to 2012 within one mile of the lake is approximately 3.8 million gallons per day (mgd), of which approximately 99 percent is for public supply. Within 5 miles of the lake, the estimated total groundwater use average from 2008 to 2012 is approximately 16.6 mgd, of which 54 percent is agricultural use and 40 percent is for public supply. Commercial/industrial, mining/dewatering and recreation uses are approximately 6 percent of the estimated total groundwater use average for the same time period.

Figure 5. Land use around Lake Eva in 1941

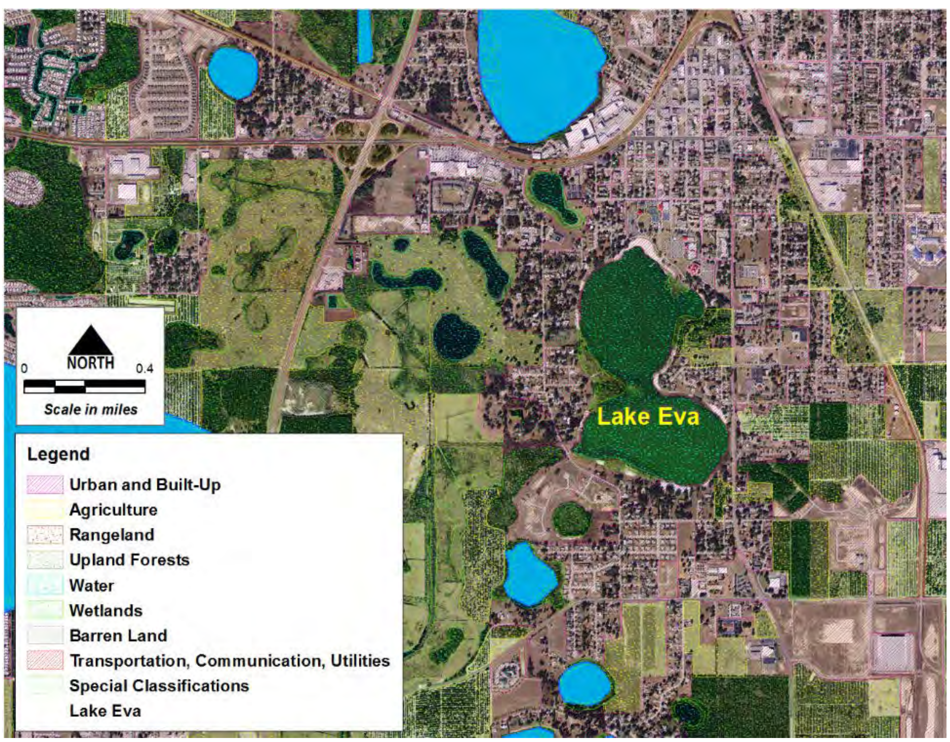


Figure 6. Land use/land cover in 2011 shown on 2012 aerial imagery

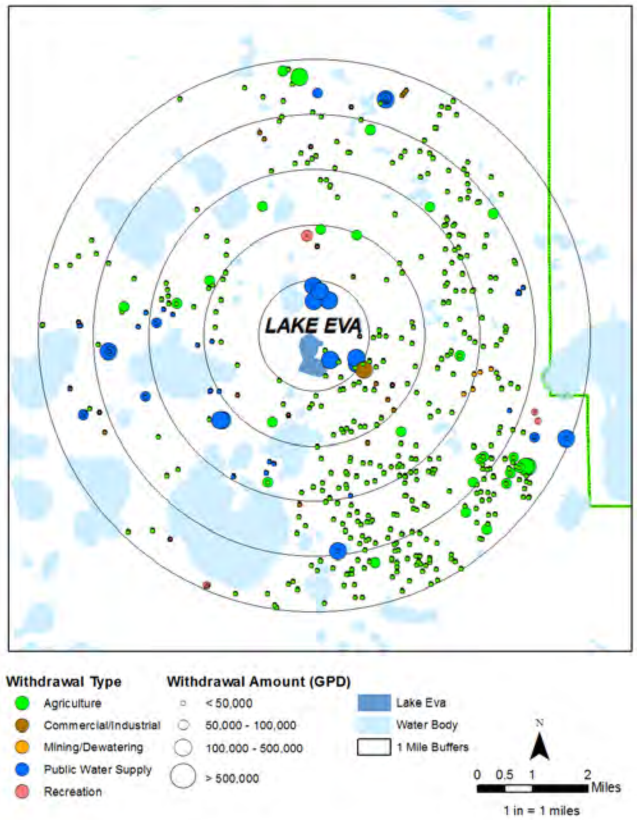


Figure 7. Lake Eva and average groundwater and surface water withdrawal amounts over the period 2008-2012

Table 1. Water Use in the Lake Eva area (2008-2012 average)

Water Use Within 1 Mile of Lake Eva (GPD)			
Use Type	**SW**	**GW**	**Total**
Agriculture	-	36,597	36,597
Commercial/Industrial	-		
Mining/Dewatering	-		
Public Supply	-	3,771,530	3,771,530
Recreation	-	3,635	3,635
Total	-	3,811,762	3,811,762
Water Use Within 5 Miles of Lake Eva (GPD)			
Use Type	**SW**	**GW**	**Total**
Agriculture	92,911	8,967,906	9,060,817
Commercial/Industrial	-	258,617	254,617
Mining/Dewatering	8,604	2,489	11,093
Public Supply	219	6,660,937	6,661,156
Recreation	36,627	622,063	658,690
Total	138,361	16,512,012	16,646,373

Figure 8 presents total estimated and measured groundwater withdrawals in Polk County since the 1930s (updated from Southwest Florida Water Management District, 2006). Significant groundwater withdrawals began in the area throughout the 1940s and 1950s, and peaked in late 1960s and early 1970s. Groundwater withdrawals in Polk County have been relatively stable since the early to mid-1990s, although this period includes both extreme dry (2000) and wet (2004/2005) conditions. Since 1994, estimated groundwater withdrawals in Polk County averaged about 218 mgd and ranged from 172 mgd in 2011 to 274 mgd in 2000.

Figure 9 shows that the most recent 5-year period reflects reduced withdrawal amounts compared to earlier years shown in this figure. This is especially evident for agriculture and mining/dewatering uses. Public supply withdrawals, however, increased and peaked in 2006, but have returned to previous withdrawal levels. Factors that have been cited for declines in agricultural use include uncertainties associated with citrus greening and canker and increased urbanization, which is reflected in reductions in citrus acres in the county. The economic recession that began in the mid 2000's is often cited as a potential influence in the more recent reductions in public supply withdrawals. Because permitted groundwater withdrawal quantities have remained fairly constant (with the exception of changes in how agriculture is permitted in the Southern Water Use Caution Area (SWUCA) since 2003), the permanancy of these declines is uncertain. However, the District continues to work with users to develop alternative supplies to meet water demands.

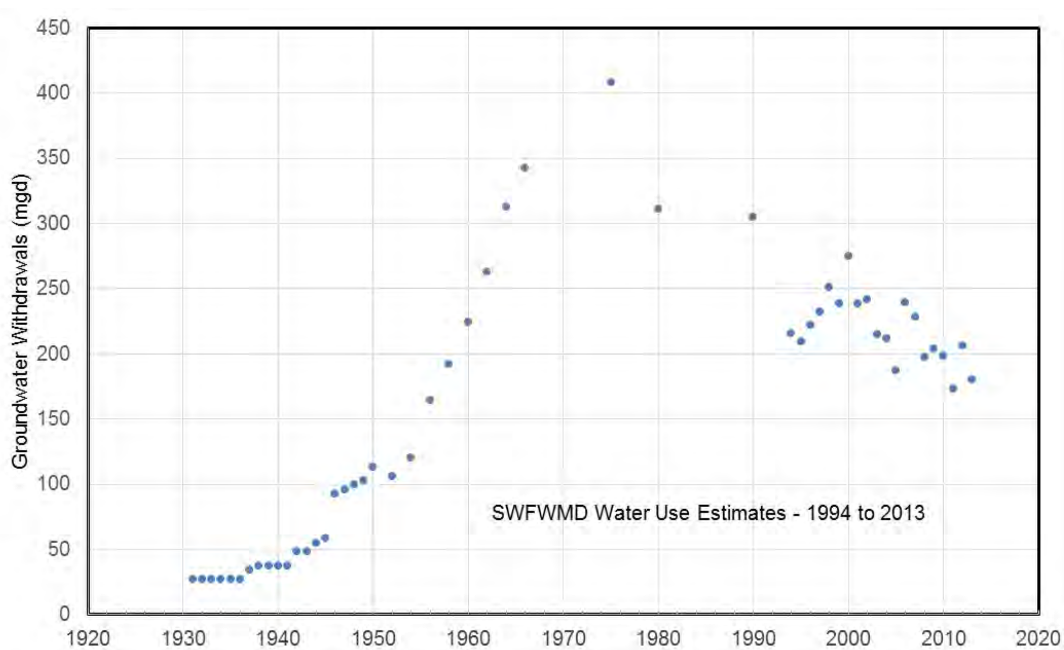


Figure 8. Total groundwater withdrawals in Polk County

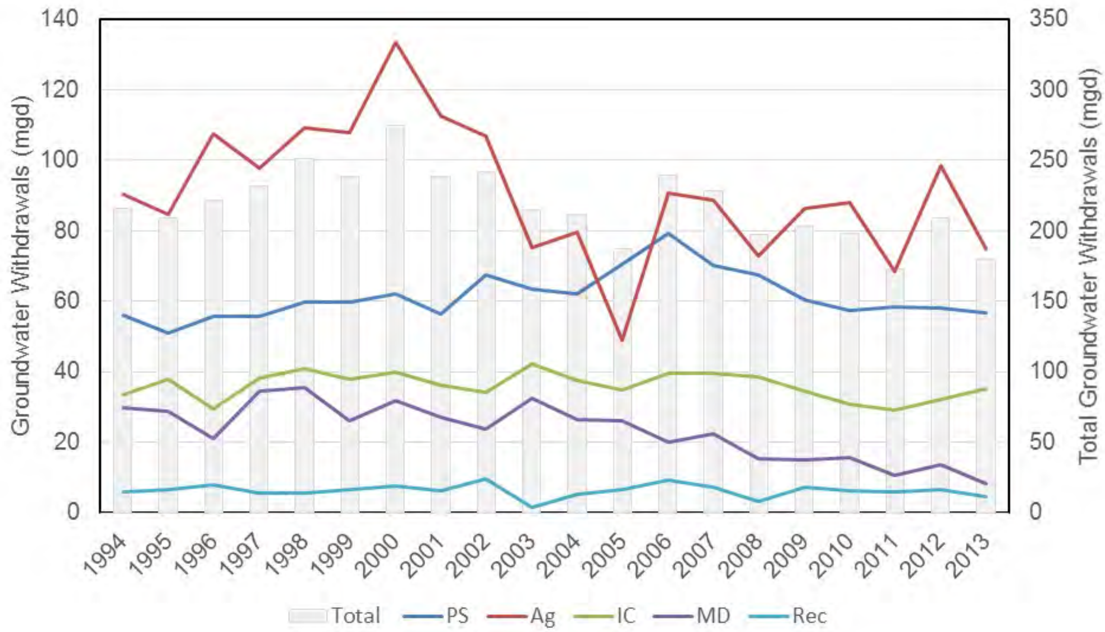


Figure 9. Estimated groundwater use in Polk County by use type (1994-2013)

Though there have been periods of higher and lower pumping since the early 1990s, groundwater levels have been reasonably stable, especially in the more northern portions of the County. Figure 10 presents long-term water levels for three key wells in the region. Water levels in the ROMP 60 and Coley Deep wells indicate slight increases in the annual average levels over this time period.

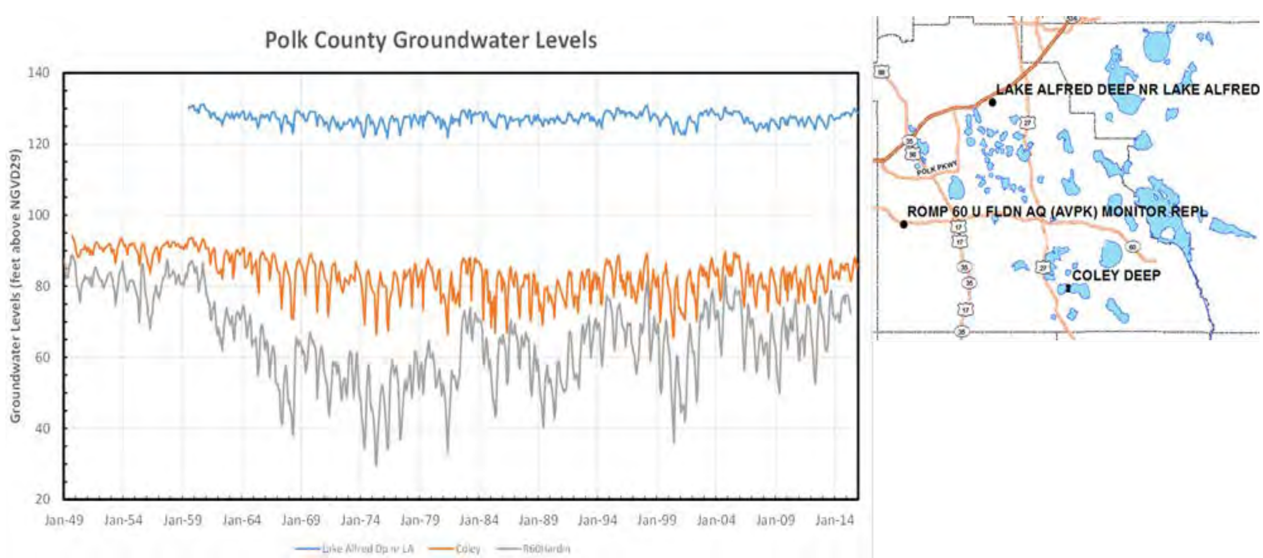


Figure 10. Long-term groundwater levels in Polk County

C. Purpose of Models

Prior to establishment of Minimum Levels, long-term lake stage percentiles are developed to serve as the starting elevations for the determination of the lake's High Minimum Lake Level and the Minimum Lake Level. A critical task in this process is the delineation of a Historic time period. The Historic time period is defined as a period of time when there is little to no groundwater withdrawal impact on the lake, and the lake's structural condition is similar or the same as present day. The existence of data from a Historic time period is significant, since it provides the opportunity to establish strong predictive relationships between rainfall, groundwater withdrawals, and lake stage fluctuation that represent the lake's natural state in the absence of groundwater withdrawals. This relationship can 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 data representative of a Historic time period do not exist, or available Historic time period data is considered too short to represent long-term conditions, then a model is developed to approximate Long-term Historic data.

In the case of Lake Eva, withdrawals throughout the area have potentially affected water levels in the lake since the early 1940s. No data from Lake Eva exist prior to the initiation of groundwater withdrawals. Therefore, the development of a water budget model coupled with a rainfall correlation model of the lake was considered essential for estimating long-term Historic percentiles, accounting for changes in the lake's drainage system, and simulating effects of changing groundwater withdrawal rates.

D. Water Budget Model Overview

The Lake Eva water budget model is a spreadsheet-based tool that includes natural hydrologic processes and engineered alterations acting on the control volume of the lake. The control volume consists of the free water surface within the lake extending down to the elevation of the greatest lake depth. Using LiDAR and bathymetry data, a stage-volume curve was derived for the lake that produced a unique lake stage for any total water volume within the control volume.

The hydrologic processes in the water budget model include:

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

The water budget model uses a daily time step, and tracks inputs, outputs, and lake volume to calculate a daily estimate of lake levels. The water budget model for Lake Eva was calibrated for the period from 2006 to 2015. This period provides the best balance of using available data for all components of the water budget and the desire to develop a long-term water level record.

E. Water Budget Model Components

Lake Stage/Volume

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

Precipitation

After a review of several rain gages in the area, rainfall data from NEXRAD (Next Generation Weather Radar) was used for the water budget model (Figure 11).

Data for Lake Alfred Experimental Station NWS are available for the earliest date necessary to complete the LOC model (January 1930) through August 2000. In June 1993, data for the Lake Henry rainfall station are available and collected to present date. Data from Lake Alfred Experimental Station NWS and Lake Henry rainfall station had some periods of missing values in the time series data. Data gaps were infilled using rainfall data collected at Winter Haven NWS, Mountain Lake NWS and Lakeland NWS.

For the period January 1, 1995 through December 31, 2015, an average of data for four NEXRAD pixels coinciding with the lake were used for the LOC model. NEXRAD is a network of 160 high-resolution Doppler weather radars controlled by the NWS, Air Force Weather Agency, and Federal Aviation Administration. The NEXRAD data were used for the water budget model because it resulted in a better calibration of the water budget model than using the average or individual results of the gages used for the earlier model period. NEXRAD data are expected to be available in the future, so they can be used for future status assessments.

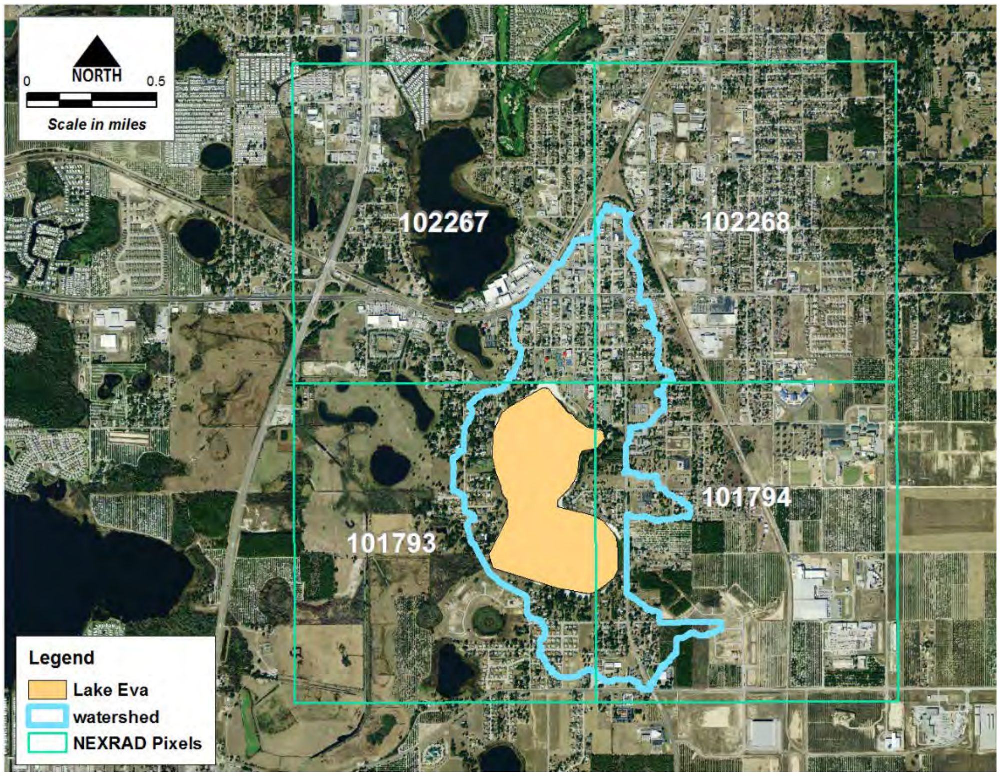


Figure 11. NEXRAD grids assessed in the Lake Eva water budget model

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 et al., 2000) (Figure 12). Lake Starr is located approximately 9.3 miles to the south-southwest of Lake Eva. The data were collected from August of 1996 through July of 2011. Monthly Lake Starr evaporation data were used in the water budget model when available, and monthly averages for the period of record were used for those months when Lake Starr evaporation data were not available.

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 the USGS, were calculated through the use of solar radiation data measured by a Geostationary Operational Environmental Satellite (GOES). Because PET is equal to lake evaporation over open water areas, using the values derived from the grid nodes over the modeled lake was considered. A decision was made to instead use the Lake Starr evaporation data since the GOES data nodes typically include both upland and lake estimates, with no clear way of subdividing the two. It was thought that using the daily PET estimates based on the GOES data would increase model error more than using the Lake Starr data directly.

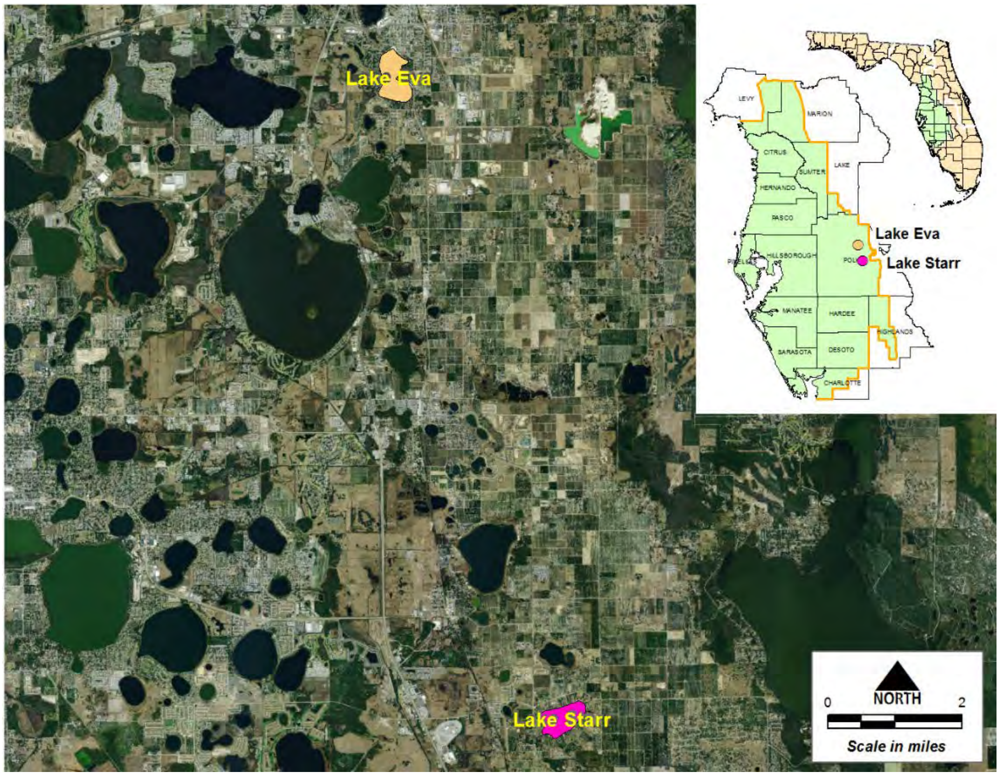


Figure 12. Location of Lake Eva and Lake Starr

Overland Flow

The water budget model was set up to estimate overland flow via a modified version of the U.S. Department of Agriculture, Soil Conservation Service (SCS) Curve Number method (SCS, 1972), and via directly connected impervious area calculations. The free water area of the lake was subtracted from the total watershed area at each time step to estimate the watershed area contributing to surface runoff. The directly connected impervious area (DCIA) is subtracted from the watershed area 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 only represents the portion of the watershed not accounted for with DCIA.

The modified SCS method was described and 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 lake is located on the western edge of the Lake Wales Ridge and land surface elevations north and west of the lake do not increase as steeply as land surface to the east and south of the lake. For example, within a quarter mile of the eastern and southern boundaries of the lake, land surface elevations can increase by 75 feet or more. The rate of rise to the north and west is generally much more gradual.

Several slightly varying estimates of watershed boundaries have been performed 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 Peace Creek for the Watershed Management Program (ADA Engineering 2012 and Atkins 2013). These watershed area values were adopted for the Lake Eva model (Table 2) after an independent check confirming that they are reasonable for modeling purposes (Figure 13). Lake Eva has no significant inflow from other lakes, so the entire watershed is as shown in Figure 13, which consists of 620.2 acres (including the lake area of 165.4 acres).

The DCIA and SCS CNs used for the direct overland flow portion of the watershed are listed in Table 2. The soils in the immediate lake watershed are mostly “A” soils, with some small areas of “A/D,” soils at the southwest portion of the lake. The land use within the lake watershed is 46 percent medium density residential, 21 percent institutional, 18 percent commercial and services and the remaining land use accounting for less than 15 percent. A curve number (model calibration parameter) of 61 was used in the model and was considered reasonable given the local soil types, land use types and hydrologic conditions. The DCIA parameter was used in addition to the curve number parameter to account for connected impervious areas that provide direct runoff to the lake through storm water systems. While there are no significant natural surface water inflows to the lake, there are several directly connected drains for street and residential storm water, with no observed retention ponds. It was estimated that 11 percent of the watershed (model calibration parameter) is directly connected impervious area, which was considered reasonable given current land use types.

Table 2. Model inputs for the Lake Eva water budget model

Input Variable	Value
Overland Flow Watershed Size (acres)	620.2
SCS CN for watershed	61
Percent Directly Connected Area	11%
Upper Floridan Aquifer Monitor Well Used	Thornhill Ranch Deep
Surficial Aquifer Monitor Well Used	Ridge WRAP P-5 Surficial Ridge WRAP P-7 Surficial
Upper Floridan Aquifer Leakance Coefficient (ft/day/ft)	0.0003
Surficial Aquifer Leakance Coefficient (ft/day/ft)	0.002
Outflow K	N/A
Outflow Invert (ft NGVD 29)	N/A
Inflow K	N/A
Inflow Invert (ft NGVD 29)	N/A

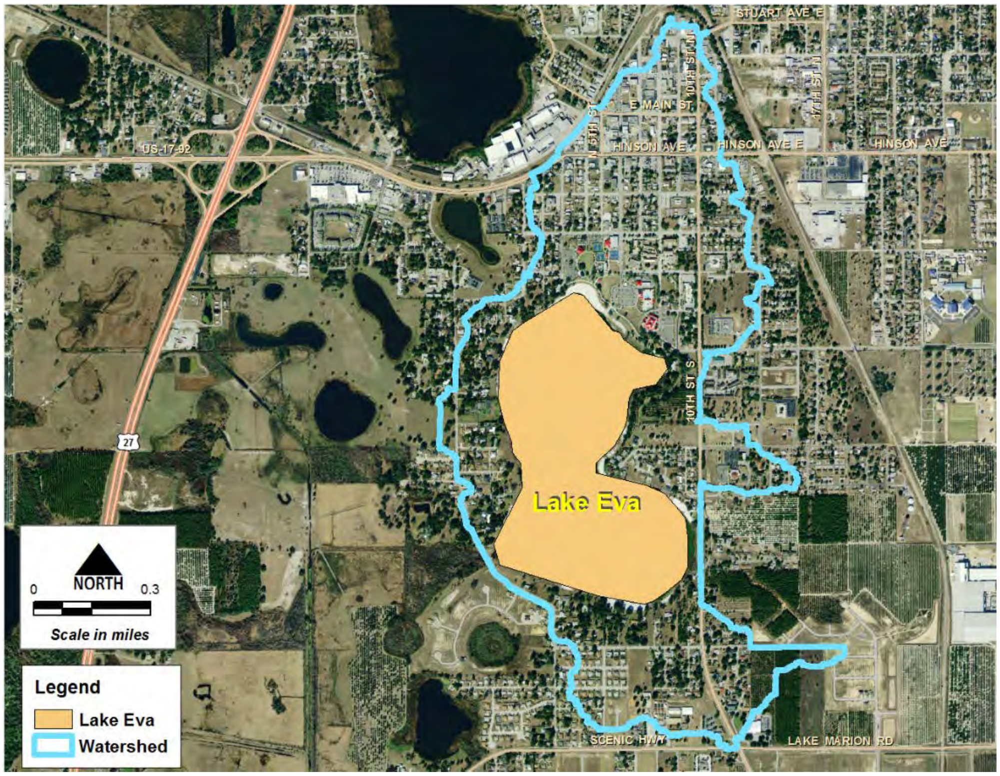


Figure 13. The Lake Eva watershed

Inflow and Discharge via Channels from Outside Watersheds

Lake Eva is a closed basin lake with no significant inflows or outflows. LiDAR-derived contours show that Lake Eva would only connect to a wetland located southwest of the lake when the lakes stages exceed approximately 122 NGVD 29. LIDAR (Light Detection and Ranging) is a remote sensing method that measures variable distances to create three-dimensional information about the shape of the Earth's surface. Period of record water level data do not have values that exceed the overflow level into the wetland (Figure 14). It should be noted, however, that the overflow elevation is estimated and overflow events may not be captured in the data due to measurement frequency. In general, it is reasonable to assume that overflow from Lake Eva into the wetland rarely occurs.

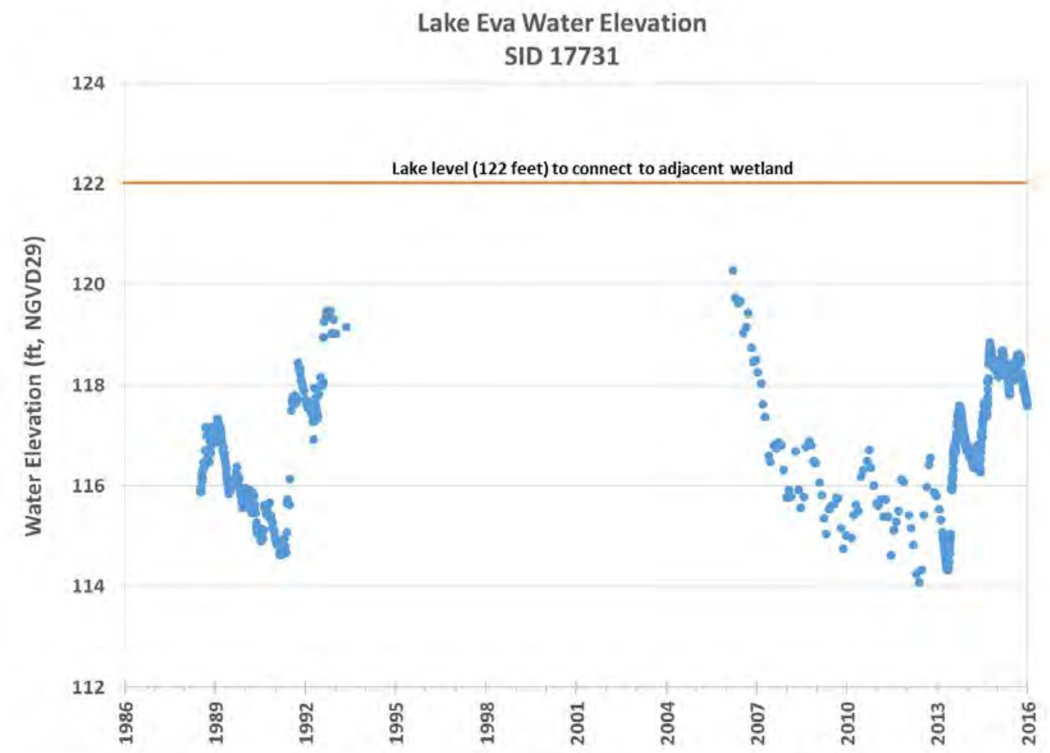


Figure 14. Water Elevation of Lake Eva

<u>Flow from and into the surficial aquifer and Upper Floridan aquifer</u>

Water exchange between Lake Eva and the underlying aquifers is estimated using a vertical leakance coefficient and the head difference between the lake and the aquifer levels. For each day of the simulation period, surficial aquifer and Upper Floridan aquifer leakage volumes were calculated independently. Leakance coefficients for each aquifer were then determined through calibration.

Lake Alfred Deep at Lake Alfred Upper Floridan Monitor Well

The Lake Alfred Deep at Lake Alfred Upper Floridan aquifer well was used to represent the Upper Floridan aquifer potentiometric surface at the lake (Figures 3 and 4). During the water budget model calibration period data was collected every other week from January 2006 to November 2011 and monthly from December 2011 to December 2015. Missing data was infilled linearly. The well is located approximately 5.5 miles to the west of Lake Eva. Due to the distance from the well to the lake, an offset of 15 ft was subtracted to the data collected at the well. The offset was calculated by averaging the potentiometric surfaces in the Upper Floridan aquifer at the well and lake and taking the difference of the averages. The potentiometric surfaces were generated by the United States Geological Survey (USGS) on a biannual schedule of May and September in order to represent the wet and dry condition for each year. The USGS created potentiometric surfaces within the District annually from 2000 to 2011. Since the water budget model for Lake Eva extends back to 2006, only the 2006 through 2011 potentiometric surface maps were used to calculate the offset.

RIDGE WRAP P-5 and PRIM Pc-01 Water Tower Surficial Aquifer Monitor Wells

The RIDGE WRAP P-5 surficial aquifer monitor well data are monthly. The well is located approximately 2.9 miles north of Lake Eva along the western portion of the Lake Wales Ridge (Figures 3 and 4). Due to the distance of the well to the lake, a monthly offset ranging from 2.2 feet in July to 4.4 feet in December was applied to the well. The offset was calculated by averaging the monthly water levels at the well and the lake and taking a difference of the averages. Data collection at this well begin in 1991. Linear infilling was used to infill missing data to create daily values needed for the water budget model. The RIDGE WRAP P-5 surficial aquifer well was used in the water budget model from January 2006 to May 2009.

The PRIM Pc-01 Water Tower surficial aquifer monitor well data are daily. The well is located approximately 3.5 miles west-southwest of Lake Eva within the Polk Uplands region. Due to the distance of the well to the lake, a monthly offset ranging from 10.9 feet in January to 16.1 feet in July was applied to the well. The offset was calculated by averaging the monthly water levels at the well and the lake and taking the difference of the averages. Data collection at this well begin in 2009. Linear infilling was used to infill two relatively small data gaps to create a complete data set of daily values needed for the water budget model. The PRIM Pc-01 Water Tower surficial aquifer monitor well was used in the water budget model from May 2009 to December 2015.

F. Water Budget Model Calibration

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

Figure 15 presents the calibration results of the model. Table 3 presents a comparison of the percentiles of the measured data versus the model results. Table 4 presents the modeled water budget components for the calibration period.

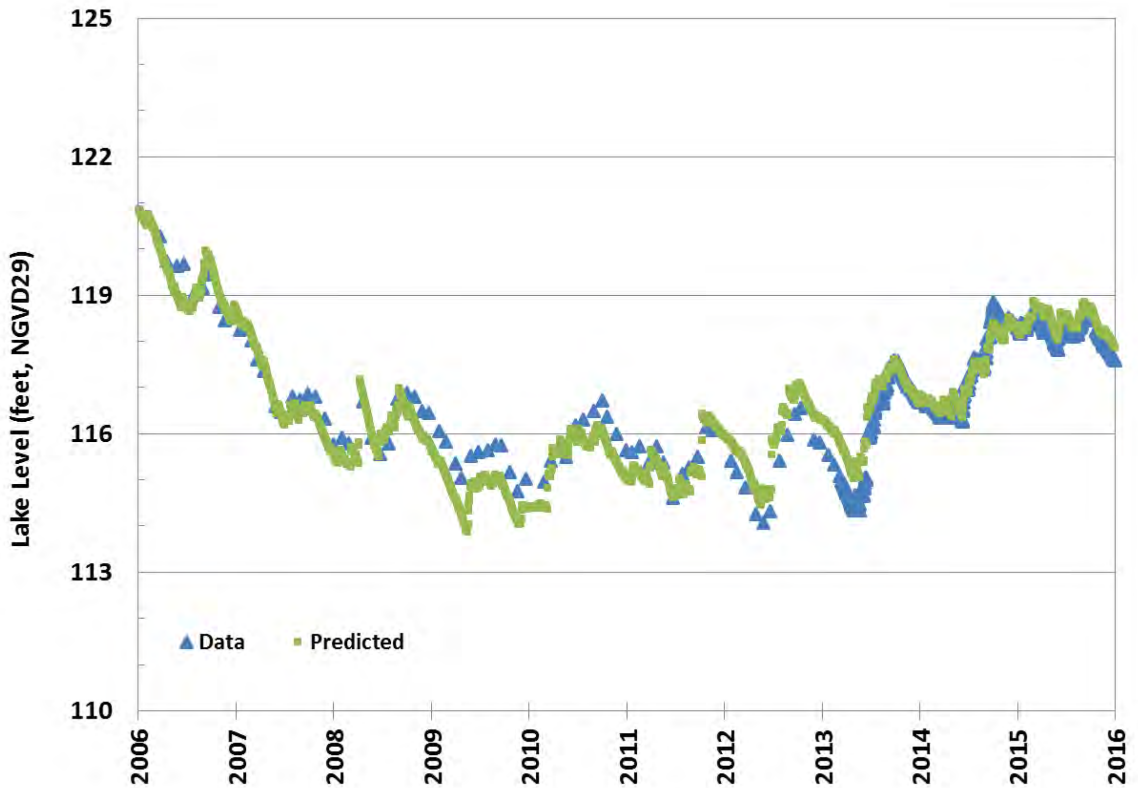


Figure 15. Modeled water levels predicted for the calibrated Lake Eva water budget (Predicted) and measured levels used for the model calibration (Data)

Table 3. Comparison of percentiles of measured lake level data compared to calibration percentiles from the model (all in feet NGVD 29)

	Data	Model
P10	118.5	118.6
P50	117.5	117.5
P90	115.3	115.6

Table 4. Lake Eva Water Budget (2006-2015)

Inflows	Rainfall	Surficial Aquifer Ground-water Inflow	Floridan Aquifer Ground-water Inflow	Runoff	DCIA Runoff	Inflow via channel	Total
In/yr	49.2	3.0	0.0	8.7	17.4	0.0	78.4
%	62.7	3.9	0.1	11.1	22.2	0.0	100.0
Outflows	**Evap-oration**	**Surficial Aquifer Ground-water Outflow**	**Floridan Aquifer Ground-water Outflow**			**Outflow via channel**	**Total**
In/yr	59.3	7.7	15.0			0.0	82.0
%	72.3	9.4	18.3			0.0	100.0

G. Water Budget Model Calibration Discussion

Based on visual inspection of Figure 15 the model appears to be reasonably well calibrated. There are a few periods when the peaks or lows in the modeled hydrograph are slightly higher or lower than the measured values, and these differences contributed to minor differences between the modeled and measured percentiles associated with the P90 percentile. Data limitations in the extreme ranges of the topography/bathymetry used to develop stage-volume estimates may also have contributed to the percentile difference.

A review of Table 3 shows no differences in medians (P50) between the data and model for the lake. The difference in measured and water budget model predicted P10 percentiles is 0.1 and P90 percentiles is 0.2 (with model being higher for both). This minor difference could be attributed to inaccuracies in rainfall estimates caused by the distance between rainfall gages and the lake during certain time periods or data collection frequency or issues.

The water budget model results are best viewed in terms of inches per year over the average lake area for the period of the model run, which can be difficult to comprehend at first. For example, runoff for the entire watershed is applied to the smaller lake area, which makes the value appear high until the differences in application area are considered. Leakage rates (and leakance coefficients), as another example, represent conditions below the lake base only, and may not be representative of the entire watershed. Professional judgement and decisions were used to match the modeled lake levels with observed data and arrive at the ultimate goal of developing a calibrated model. Even though data gaps as well as uncertainties in the values of model parameters have caused some differences between the model and observed data, the model is reasonably well calibrated and can be used to estimate the long term historic percentiles.

H. Water Budget Model Results

Groundwater withdrawals are not directly included in the Lake Eva water budget model, but are indirectly represented by their effects on water levels in the Upper Floridan aquifer. When 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.

Determining the amount of Upper Florida Aquifer drawdown that has occurred due to groundwater withdrawals involved the use of a regional groundwater model and analysis of water level data. The East-Central Florida Transient (ECFT) groundwater model (Sepulveda, et al., 2012 and CFWI, 2014) was used to quantify changes in water levels in response to changes in groundwater withdrawals. This was accomplished using a series of model runs whereby recent withdrawals and irrigation amounts were reduced by 25 percent, 50 percent, and 75 percent. This approach enabled the model to be used within the range of withdrawals that were used during the calibration phase. For the reassessment of minimum levels, the reduced pumping scenarios used a Reference Condition as a basis for comparing model reduction scenarios. The Reference Condition was based on the amount of groundwater withdrawals needed to meet the demands for water that existed as of 2005. Pumping amounts for each year and month of the 12 year transient model run were varied according to rainfall that occurred during each month. As a result of the model scenarios it was estimated that modeled groundwater withdrawals have lowered Upper Floridan aquifer water levels about 6.6 feet beneath Lake Eva.

In addition to the reduced pumping scenarios, an assessment of long-term changes in groundwater levels was performed as a means of gaging model results. Because there is no well at the Lake Eva location, the assessment focused on changes occurring at the Lake Alfred Deep well near Lake Alfred, Coley Deep, ROMP 60 and the ROMP 73 sites. Water levels for the ROMP 73 well were extended back to the 1950s using available data from the other well sites. One issue associated with this type of analysis is that the water level data do not extend back in time when pumping was zero, whereas the change represented by the model reflects a period of no pumping. Average annual water level changes represented by the data were based on comparison of recent (1990 to 2014) levels to the period prior to and including 1960. For the Lake Alfred well, model results were 2.2 feet compared to 2.9 feet when looking at the data and for the Coley Deep well, the model indicated 7.4 feet compared to a change of 9.2 feet when looking at the data. These results are generally consistent, especially considering the data shows slightly more change which is likely due to the differences in rainfall recharge between the two periods that is not represented in the model. Results for the ROMP 60 and ROMP 73 well sites were less certain and likely influenced by their locations relative to model boundaries.

For use in the water budget model, it was recommended that 6 feet of drawdown be used. This accounts for increases in pumping amounts that have occurred within one mile of the lake during and beyond the period used for the model. With respect to the surficial aquifer, the relationship between the Leakance coefficient and the ratio of surficial aquifer to Upper Florida aquifer drawdowns established for previous modeling efforts was used. From the water budget model, the Leakance coefficient was 0.0003 feet/day/feet which resulted in a ratio of surficial to Upper Florida drawdown of 0.3. The resulting recovery in the surficial aquifer was then estimated as the product of this ratio and the estimated Upper Florida aquifer recovery amount (6 feet) of 1.8 feet.

Figure 16 presents the results of the calibrated water budget model for Lake Eva with and without the effects of groundwater withdrawals. Table 5 presents the percentiles based on the model output.

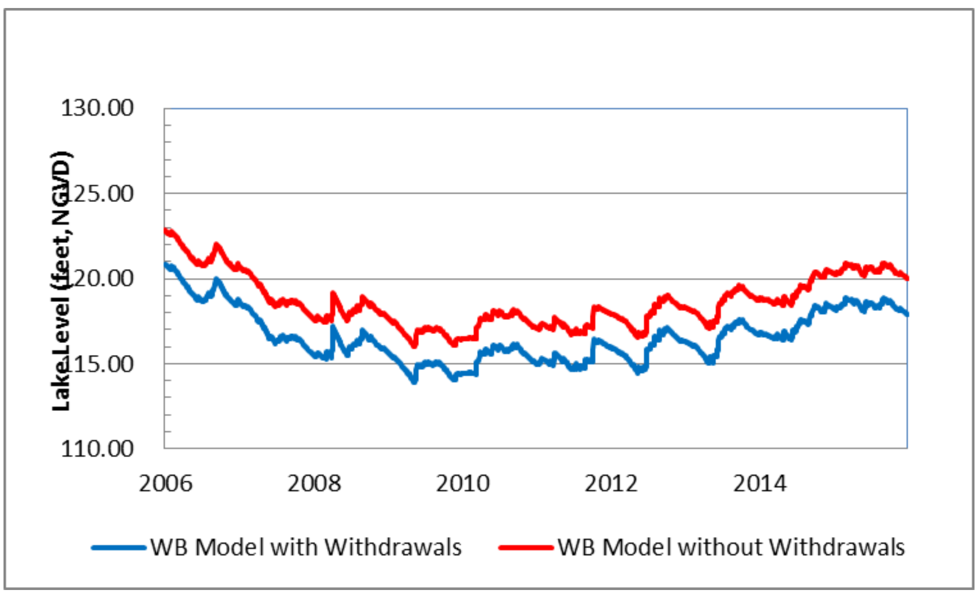


Figure 16. Calibrated Water Budget Model for Lake Eva with and without the effects of withdrawals

Table 5. Historical lake level percentiles determined using the water budget model (feet NGVD 29)

Percentile	Elevation
P10	120.7
P50	119.4
P90	117.7

J. Rainfall Regression Model

In an effort to extend the period of record of water levels used to determine the Historic percentiles to be used in the development of the Minimum Levels, a line of organic correlation (LOC) was performed using the results of the water budget model and long-term rainfall data. 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). 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. By using this technique, the limited years of calibrated model water levels can be projected back to create a simulated data set representing over 60 years of lake levels, based on the relationship between modeled water levels and actual rainfall.

In this application, the simulated lake water levels representing Historic conditions were correlated with long-term rainfall data. For the rainfall regression analysis, additional representative rainfall records were added to the rainfall data used in the water budget model (2014-2015), extending the rainfall record back to 1946. The record consisted of daily rainfall measurements from the closest rainfall gage and missing daily data values were infilled from the next closest gage with available data until all days were populated with rainfall data. The main gages used to build the Long-term rainfall series (Figure 17) were Lake Alfred Experimental Station NWS (SID 17616) and Lake Henry rain gage (SID 25170). Missing days were infilled with gaged rainfall at Winter Haven NWS (SID 24534), Mountain Lake NWS (SID 25147) and Lakeland 2 NWS (SID 18048).

Rainfall data were 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 were separately used, the results were compared, and the weighted rainfall series with the highest coefficient of determination (R2) was chosen as the best model.

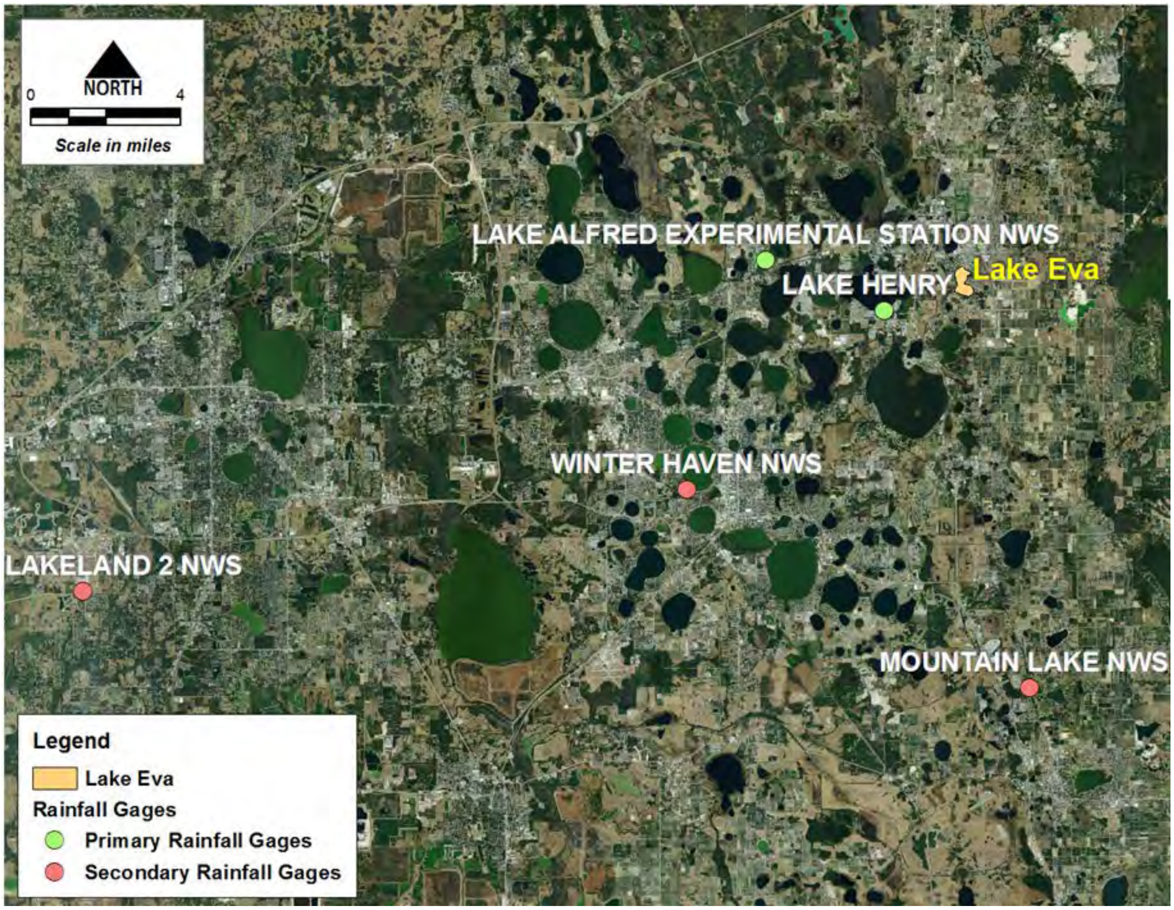


Figure 17. Rainfall Gages used for LOC Model

As discussed in Section B earlier in this memorandum, assessment of Polk County-wide withdrawals and Upper Floridan aquifer levels provided strong evidence that groundwater withdrawal patterns appear to have changed sometime in the early to mid-1990s and have remained reasonably consistent since that time. The results of the LOC are also consistent with this conclusion. The goal of this step in the analysis is to develop a LOC model that simulates Long-term water levels with the effects of groundwater pumping removed and to represent the current structural operating schedule affecting the lake (Figure 16). Given the diverse and dispersed nature of groundwater withdrawals affecting the lake, it was difficult to determine a multi-period correction for groundwater impacts. The water budget model results used in the LOC model were limited to a period of relatively consistent groundwater impacts from 2006 to 2015. For this assessment, the final 3-year weighted model had the highest coefficient of determination, with R^2 of 0.84. The results are presented in Figure 18.

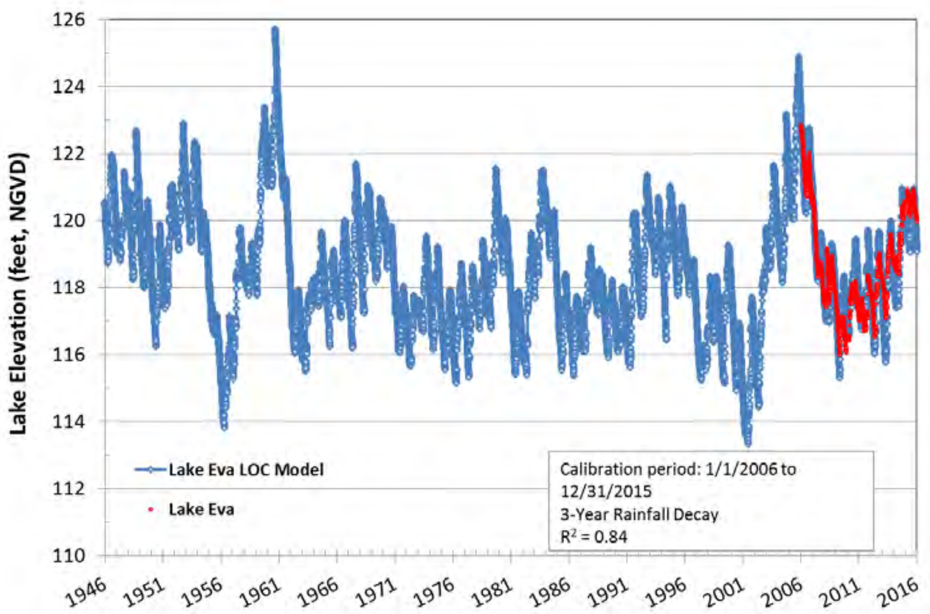


Figure 18. LOC model results for Lake Eva

In an attempt to produce Historic percentiles that apply significant weight to the results of the water budget models, the rainfall LOC results for the period of the water budget model are replaced with the water budget model results. Therefore, the LOC rainfall model results are used for the period of 1946-2015, while the water budget results are used for the period of 2006-2015. These results are referred to as the “hybrid model.” The resulting Historic percentiles for the hybrid model are presented in Table 6. Note that the difference between the P10, P50, and P90 percentiles from the water budget model (Table 5) and those from the hybrid rainfall model (Table 6) for Lake Eva are 0.1 for the P10 (with the hybrid model being higher), 1.1 and 1.5 for the P50 and P90, respectively (with the water budget model being higher).

Table 6. Historic percentiles as estimated using the hybrid model from 1946 to 2015 (feet NGVD 29).

Percentile	Lake Eva
P10	120.8
P50	118.3
P90	116.2

J. Conclusions

Based on the model results and the available data, the Lake Eva 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.

K. References

ADA Engineering. December 3, 2012. Draft Peer Review of Floodplain Results Presented in Justification Report, Peace Creek Watershed Management Program.

Atkins. March 2013. Peace Creek Watershed Justification Report. East Central Florida Transient Model Documentation: In support of the 2014 Draft CFWI Regional Water Supply Plan.

Barcelo, M.D., Slonena, D.L., Camp, S.C., and Watson. J.D, 1990. Ridge II, A Hydrogeologic Investigation of the Lake Wales Ridge: Southwest Florida Water Management District, 14 p.

Brooks, H.K. 1981. Physiographic divisions of Florida: map and guide. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida.

Central Florida Water Initiative Hydrologic Analysis Team. August 29, 2014.

CH2MHILL. 2003. Local Runoff Prediction for the Lower Hillsborough River and Tampa Bypass Canal Watersheds. Draft Technical Memorandum. Prepared for Tampa Bay Water. Clearwater, Florida.

Green, R.C., W.L. Evans III, C.P. Williams, C. Kromhout, and S.W. Bassett. 2012. Text to Accompany Geologic Map of the U.S.G.S. Tarpons Springs 30 x 60 Minute Quadrangle, Central Florida Department of Environmental Protection, Florida Geological Survey.

Helsel D.R. and R.M Hirsch. 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic Analysis and Interpretation. Chapter A3. U.S. Geological Survey.

Jacobs, J. 2007. Satellite-Based Solar Radiation, Net Radiation, and Potential and Reference Evapotranspiration Estimates over Florida: Task. 4. Calculation of Daily PET and Reference ET from 1995 to 2004. University of New Hampshire.

O'Reilly, A.M., Roehl, E.A., Jr., Conrads, P.A., Daamen, R.C., and Petkewich, M.D. 2014. Simulation of the Effects of Rainfall and Groundwater Use on Historical Lake Water Levels, Groundwater Levels, and Spring Flows in Central Florida: U.S. Geological Survey Scientific Investigations Report 2014–5032, 153 p., http://pubs.usgs.gov/sir/2014/5032/.

Sepulveda, N., C.R. Tiedeman, A.M. O'Reilly, J.B. Davis, and P. Burger. 2012. Groundwater Flow and Water Budget in the Surficial and Floridan Aquifer Systems in East-Central Florida: U.S. Geological Survey Open-File Report 2012-1132, 195 p., http://pubs.usgs.gov/of/2012/1132/.

Soil Conservation Service. 1972. National Engineering Handbook. August 1972.

Southwest Florida Water Management District. 2006. Southern Water Use Caution Area Recovery Strategy.

Spechler, R.M. and S.E. Kroening. 2007. Hydrology of Polk County. Scientific Investigations Report 2006-5320. U.S. Geological Survey. Reston, Virginia.

Swancar, A., T.M. Lee, and T.M. O'Hare. 2000. Hydrogeologic Setting, Water Budget, and Preliminary Analysis of Ground-Water Exchange at Lake Starr, a Seepage Lake in Polk County, Florida. Water-Resources Investigations Report 00-4030. U.S. Geological Survey. Tallahassee, Florida.

Yobbi, D.K., 1996. Analysis and Simulation of Ground-Water Flow in Lake Wales Ridge and Adjacent Areas of Central Florida: U.S. Geological Survey Water-Resources Investigations Report 94-4254, 82 p.

Appendix B

Draft Technical Memorandum

August 18, 2016

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

FROM: Jason G. Patterson, Hydrogeologist, Water Resources Bureau
Mark Hurst, Senior Environmental Scientist, Water Resources Bureau

Subject: Lake Eva Initial Minimum Levels Status Assessment

A. Introduction

The Southwest Florida Water Management District (District) is reevaluating adopted minimum levels for Lake Eva 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 Patterson and Hancock (2016) and Hurst and others (2016).

Section 373.0421, F.S. requires that a recovery or prevention strategy be developed for all water bodies that are found to be below their minimum flows or levels, or are projected to fall below the minimum flows or levels within 20 years. In the case of Lakes and other waterbodies with established minimum flows or levels in the Southern Water Use Caution Area (SWUCA), an applicable regional recovery strategy, referred to as the SWUCA Recovery Strategy, has been developed and adopted into District rules (Rule 40D-80.074, F.A.C.). One of the goals of the SWUCA Recovery Strategy is to achieve recovery of minimum flow and level water bodies such as Lake Eva. This document provides information and analyses to be considered for evaluating the status of the revised minimum levels proposed for Lake Eva and any recovery that may be necessary for the lake.

B. Background

Lake Eva is located in east-central Polk County, west of US Highway 27 between Scenic Highway and Hinson Avenue in the City of Haines City (Figure 1). The lake is within the Peace Creek watershed.

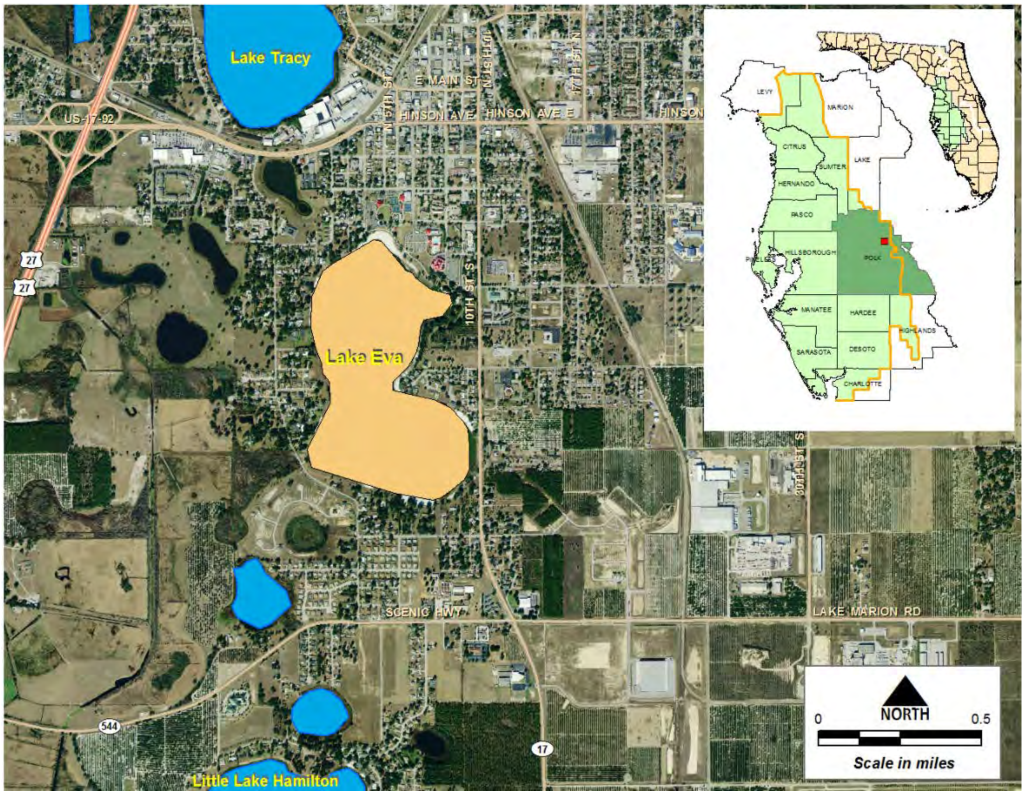


Figure 1. Location of Lake Eva in Polk County, Florida

C. Minimum Levels Proposed for Lake Eva

Minimum levels proposed for Lake Eva are presented in Table 1 and discussed in more detail by Hurst and others (2015). 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 Lake Eva 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 Lake Eva.

Proposed Minimum Levels	Elevation in Feet NGVD 29
High Minimum Lake Level	119.2
Minimum Lake Level	118.1

D. Status Assessment

The lake status assessment approach involves using actual lake stage data for Lake Eva from 2014 through 2015, which was determined to represent the "Current" period. The Current period represents a recent "Long-term" period when hydrologic stresses (including groundwater withdrawals) and structural alterations are reasonably stable. For Lake Eva, structural alterations near the lake occurred in 2014 and have affected the water table at the lake. It is anticipated that the structural alterations will remain stable, and therefore 2014 through 2015 are considered to represent the "Current" period. "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 Patterson and Hancock (2016), groundwater withdrawals during this period were relatively consistent. To create a data set that can reasonably be considered to be "Long-term", a line of organic correlation (LOC) analysis was performed on the lake level data from the Current period. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 2002). The LOC is preferable for this application since it produces a result that best retains the variance (and therefore best retains the "character") of the original data. This technique was used to develop the minimum levels for Lake Eva (Patterson and Hancock, 2016). By using this technique, the limited years of Current lake level data can be projected back to create a simulated data set representing over 60 years of lake levels, based on the current relationship between lake water levels and actual rainfall.

The same rainfall data set used for setting the minimum levels for Lake Eva was used for the status assessment. The best resulting correlation for the LOC model created with measured data was the 3-year weighted period (the best correlation for the LOC analyses created with Historic data to set the Lake Eva MFL was 6 years), with a coefficient of determination of 0.91. The resulting lake stage exceedance percentiles are presented in Table 2.

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

2014 through 2015. A limitation of these values is that the resulting lake stage exceedance percentiles are representative of rainfall conditions during only the past 2 years, rather than the longer-term rainfall conditions represented in the 1946 to 2014 LOC model simulations.

Table 2. Comparison of lake stage exceedance percentiles derived from the lake stage/LOC results, exceedance percentiles of the 2014 to 2015 data, and the revised minimum levels proposed for Lake Eva.

Percentile	**Lake Stage/LOC Model Current Withdrawal Scenario Results** Elevation in feet NGVD 29	**2014 to 2015 Data** Elevation in feet NGVD 29	**Proposed Minimum Levels** Elevation in feet NGVD 29
P10	118.8	118.5	119.2
P50	116.9	118.2	118.1

A comparison of the LOC model with the minimum levels proposed for Lake Eva indicates that the Long-term P10 is 0.4 feet below the proposed High Minimum Lake Level, and the Long-term P50 is 1.2 feet below the proposed Minimum Lake Level. The P10 elevation derived directly from the 2014 to 2015 lake data is 0.7 feet below the proposed High Minimum Lake Level and the P50 elevation is 0.1 feet above the proposed Minimum Lake Level. Differences in rainfall between the shorter 2014 to 2015 period and the longer 1946 to 2015 period used for the LOC modeling analyses likely contribute to the differences between derived and measured lake stage exceedance percentiles. Additionally, differences between actual withdrawal rates and those used in the models may have contributed to some of the differences in the percentiles.

E. Conclusions

Based on the information presented in this memorandum, it is concluded that Lake Eva water levels are currently below the Minimum Lake Level and the High Minimum Lake Level proposed for the lake. These conclusions are supported by comparison of percentiles derived from 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.

F. References

Hurst, M., J. Patterson, M. Hancock, M. Barcelo and T. McBride. 2016. Proposed Minimum and Guidance Levels for Lake Eva in Polk County, Florida. Southwest Florida Water Management District. Brooksville, Florida.

Patterson, J., M. Hancock, M. Barcelo. 2016. Technical Memorandum to Mark Hurst, Subject: Lake Eva Water Budget Model, Rainfall Correlation Model, and Historic Percentile Estimations. Southwest Florida Water Management District. Brooksville, Florida.

Helsel D.R. and R.M Hirsch. 2002. Statistical Methods in Water Resources. Techniques of Water-Resources Investigations of the United States Geological Survey. Book 4, Hydrologic Analysis and Interpretation. Chapter A3. U.S. Geological Survey.