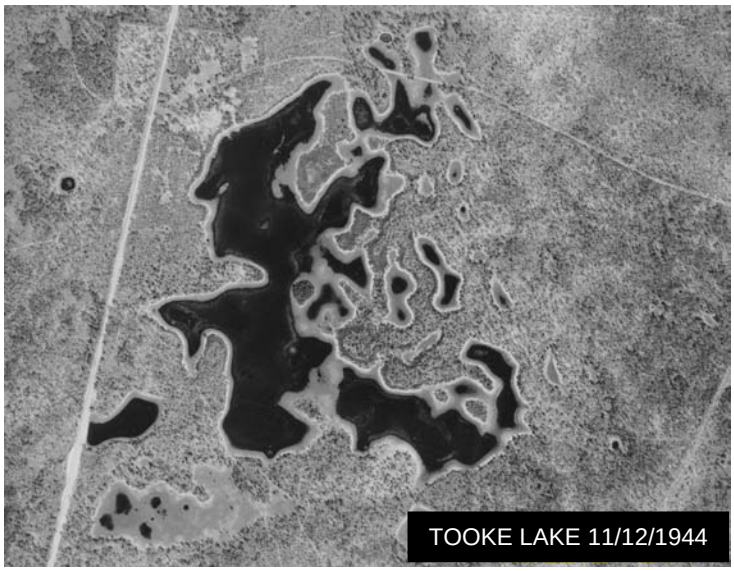
Minimum and Guidance Levels
For Tooke Lake in Hernando County, Florida



February 21, 2013

Resource Evaluation Section
Water Resources Bureau
Southwest Florida
Water Management District

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2379 Broad Street
Brooksville, Florida 34604-6899

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Cover Page: A comparison of 1944 and 2006 aerial photographs of Tooke Lake. The 1944 imagery was collected on November 12, 1944 by the United States Department of Agriculture. The 2006 imagery was collected on March 7, 2006 by the District.

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Minimum and Guidance Levels for Tooke Lake

Section 373.042, Florida Statutes (F.S.). directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels for lakes, wetlands, rivers and aquifers. Section 373.042(1)(a), F.S., states that the 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 level of an aquifer or surface water body as "the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." Minimum flows and levels are established and used by the Southwest Florida Water Management District (SWFWMD) 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.

Development of minimum flows and levels are key components in supporting resource protection, recovery and regulatory compliance by establishing standards below which significant harm will occur in specific water bodies. Section 373.0421, F.S., requires the development of a recovery or prevention strategy for water bodies if 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." Section 373.0421 (2), F.S., requires that recovery or prevention strategies be developed to: "(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level." Periodic re-evaluation and, as necessary, revision of established minimum flows and levels are required by Section 373.0421(3), F.S.

Section 373.0421, F.S., requires that minimum flows and levels be established based upon the best available information with consideration 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 caveat that these considerations shall not allow significant harm caused by withdrawals. The Florida Water Resources Implementation Rule (Rule 62-40.473, Florida Administrative Code (F.A.C.)), provides additional guidance for the establishment of minimum flows and levels, requiring that "consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows, and environmental values associated with coastal, estuarine, aquatic and wetland 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." The Water Resource Implementation Rule also indicates that "minimum 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."

The SWFWMD has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers and aquifers, subjected the methodologies to independent, scientific peer-review, and incorporated the methods into Chapter 40D-8, F.A.C. For lakes, methodologies 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 without at least 0.5 acre of fringing cypress wetlands are classified as Category 3 Lakes. Rule 40D-8.624, F.A.C., provides for the establishment of Guidance Levels, which serve as advisory information for the SWFWMD staff, 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 provided in Southwest Florida Water Management District (1999a), Leeper *et al.* (2001) and Leeper (2006). Peer-review findings regarding the lake level methods are available in Bedient *et al.* (1999), Dierberg and Wagner (2001) and Wagner and Dierberg (2006).

Two Minimum Levels and two Guidance Levels have typically been established for lakes, and upon adoption by the SWFWMD Governing Board, incorporated into Rule 40D-8.624, F.A.C. The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD), are described below.

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

In accordance with Chapter 40D-8, F.A.C., Minimum and Guidance Levels were developed for Tooke Lake (Table 1), a Category 3 lake located in Hernando County, Florida. The District has not previously adopted management water levels on this lake. The levels were established using best available information, including field data that were obtained specifically for the purpose of minimum levels development. The data and analyses used for development of the levels are described in the remainder of this report. Following a public input process, District staff anticipates recommending that the Governing Board approve the levels to be adopted in Rule 40D-8.624, F.A.C.

All elevation values included within this report are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD 29). In some circumstances data were collected as North American Vertical Datum of 1988 (NAVD 88) and converted to NGVD 29. All conversions were derived using Corpscon 6.0, a computer software program that performs vertical conversions to and from NGVD 29 and NAVD 88.

Table 1. Minimum and Guidance Levels for Tooke Lake.

Minimum and Guidance Levels	Elevation in Feet NGVD 29
High Guidance Level	21.2
High Minimum Lake Level	20.4
Minimum Lake Level	16.3
Low Guidance Level	14.2

Data and Analyses Supporting Development of Minimum and Guidance Levels

Lake Setting and Description

Tooke Lake is located in Hernando County, Florida (Section/Township/Range 13&24/22/17), (Figure 1). White (1970) classified the physiographic area as the Northern Gulf Coastal Lowlands bordered to the west by coastal swamps and to the east the Brooksville Ridge (Figure 2). This area is categorized as the Weeki Wachee Dune Field in the Ocala Uplift Physiographic District which features distinctive, low rolling limestone plains with a sand pine, longleaf pine, and turkey oak landscape (Brooks 1981). As part of the Florida Department of Environmental Protection's Lake Bioassessment Regionalization Initiative, the area has been identified as the Weeki Wachee Hills region. Griffith *et al.* (1997) describe the region as one of mostly clear water, circumneutral-pH lakes that have moderately low alkalinity and nutrients.

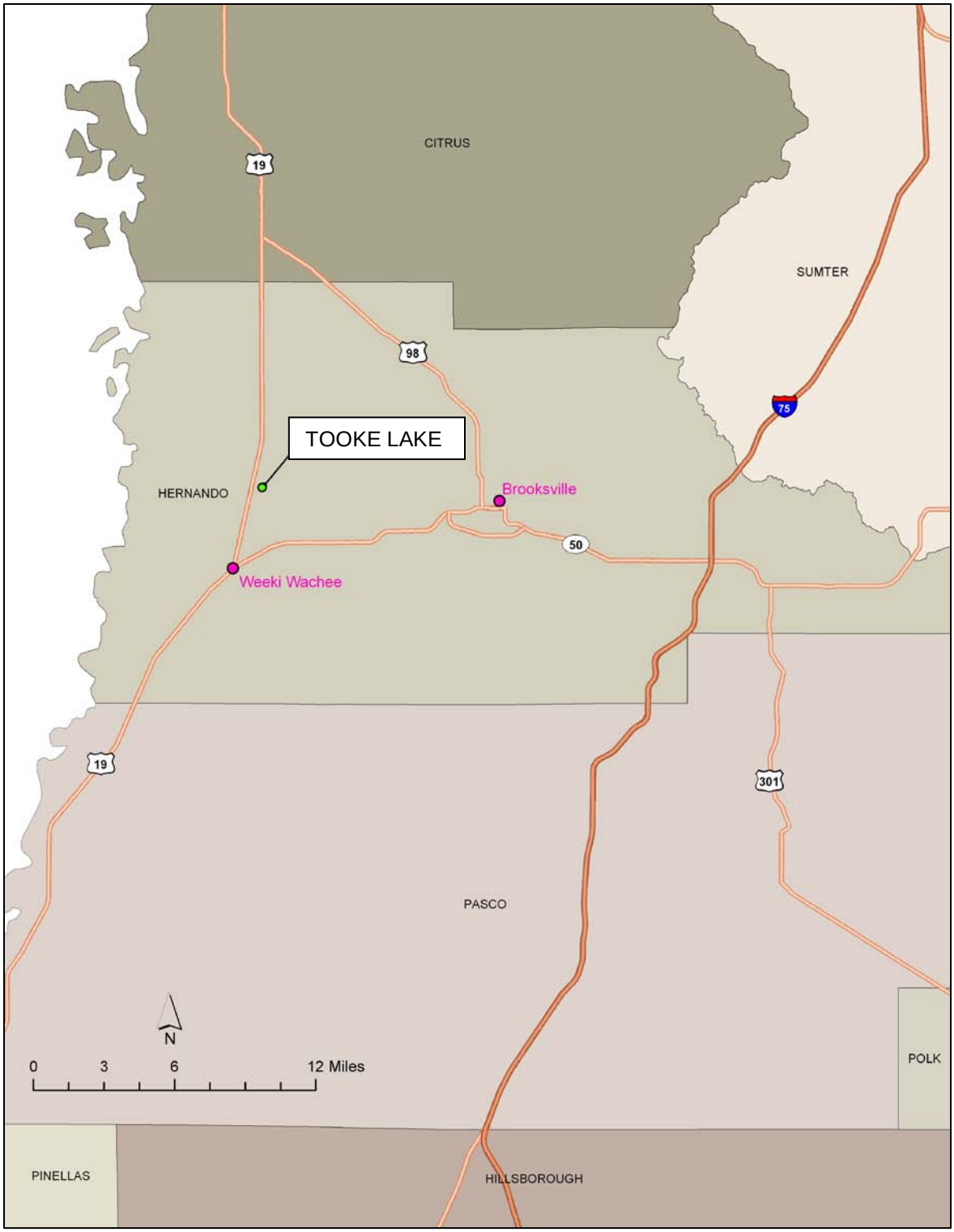

Figure 1. Location of Tooke Lake in Hernando County, Florida.

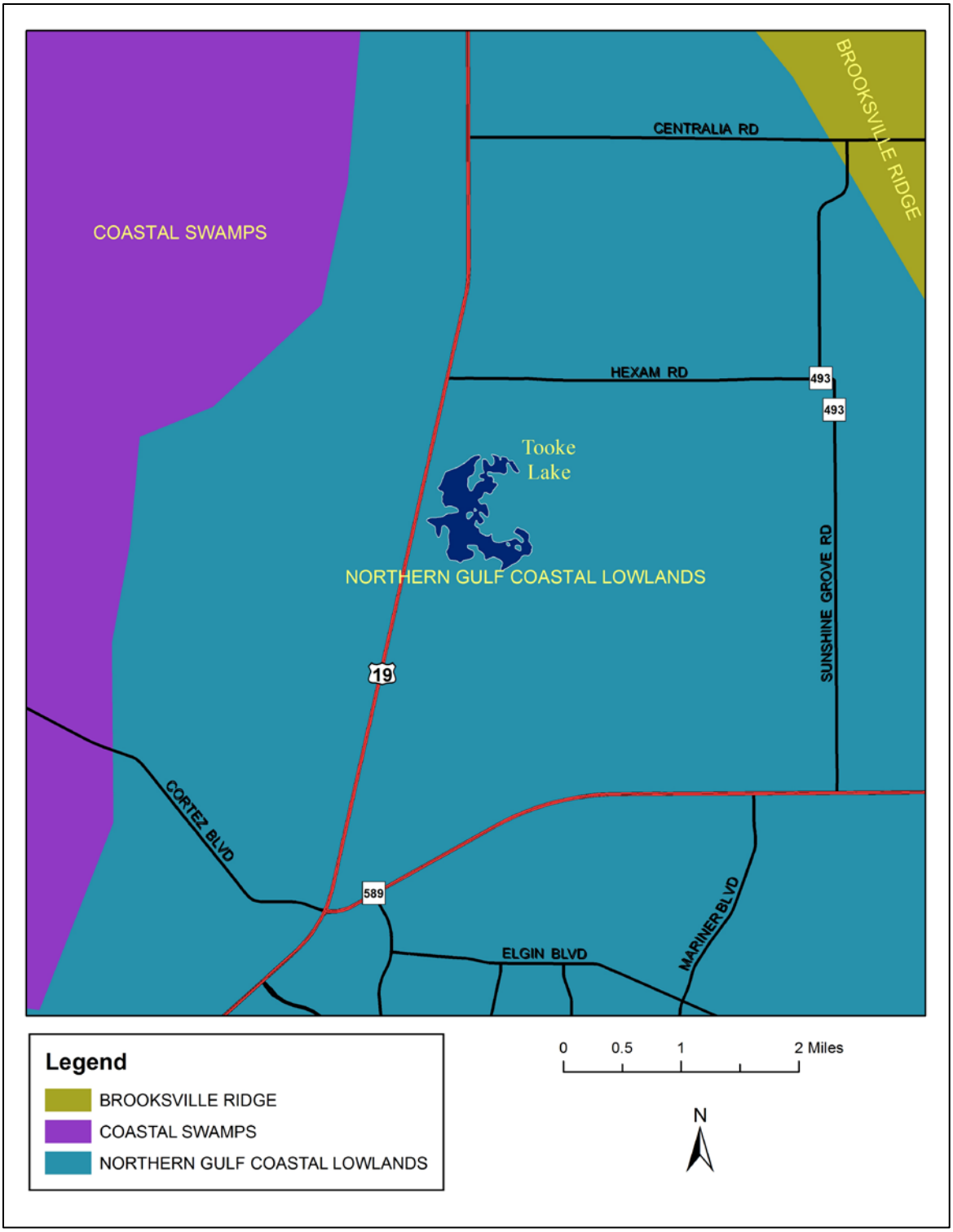

Figure 2. Physiographic regions of the Tooke Lake area.

Most of the land surrounding Tooke Lake is residential development (Figure 3), however, a portion remains as a natural sandhill community of longleaf pine-xeric oak. The soils surrounding the lake are Basinger, Tavares and Candler fine sands (Hyde *et al.* 1977). There is no public access to Tooke Lake.

Tooke Lake watershed is approximately 24.5 square miles in size and located within the Weeki Wachee Drainage Basin in the larger Upper Coastal Rivers watershed (SWFWMD 2009). There are no surface water withdrawals from the lake. There is one water supply well permit and many small landscape wells in the vicinity. Figure 4 shows all permitted groundwater withdrawal wells within one, two and three mile radii of the lake. Monthly average water withdrawals are generally less than 4 million gallons per day (mgd) within a three mile radius of Tooke Lake (Basso 2012).

The 1956 (photo-revised 1981) United States Geological Survey 1:24,000 Tooke Lake quadrangle map indicates the lake edge elevations is 20 ft. The "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969) lists Tooke Lake as 236 acres, which agreed with the 240 acres calculated by contour map analyses. A topographic map of the Tooke Lake basin was generated to illustrate the contours in the lake less than or equal to 20 ft (Figure 5).

Currently Adopted Minimum and Guidance Levels

The Southwest Florida Water Management 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 an initiative for establishing lake management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes had been established. Tooke Lake does not currently have Adopted Minimum and Guidance Levels.

Summary Data Used for Development of Minimum and Guidance Levels

Minimum and Guidance Levels for Tooke Lake were developed using the methodology for Category 3 Lakes described in Rule 40D-8.624, F.A.C. The levels and additional information are listed in Table 2, along with lake surface areas for each level or feature/standard elevation. Detailed descriptions of the development and use of these data are provided in the subsequent sections of this report.

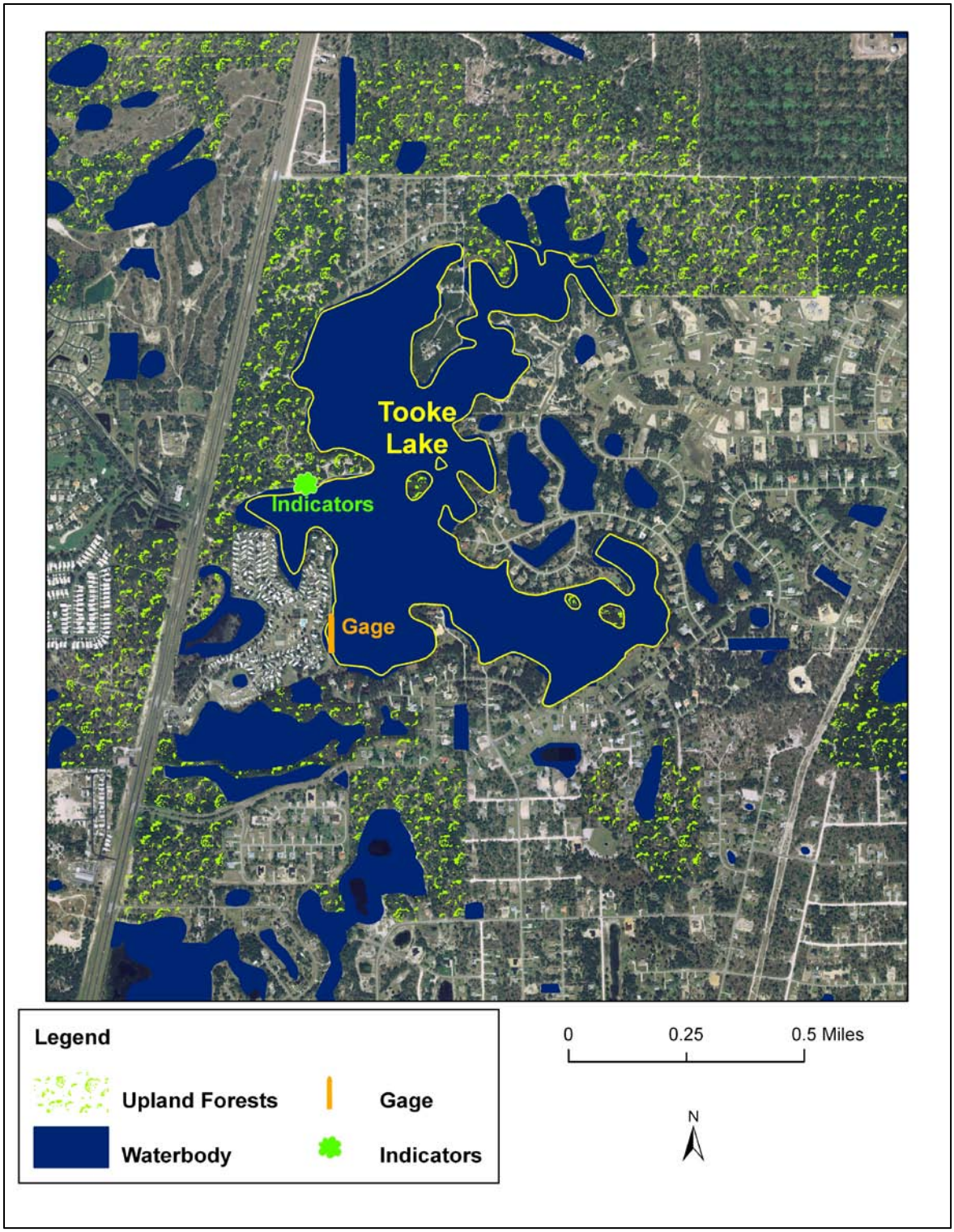

Figure 3. Location of the water level gage and hydrologic indicators at Tooke Lake.

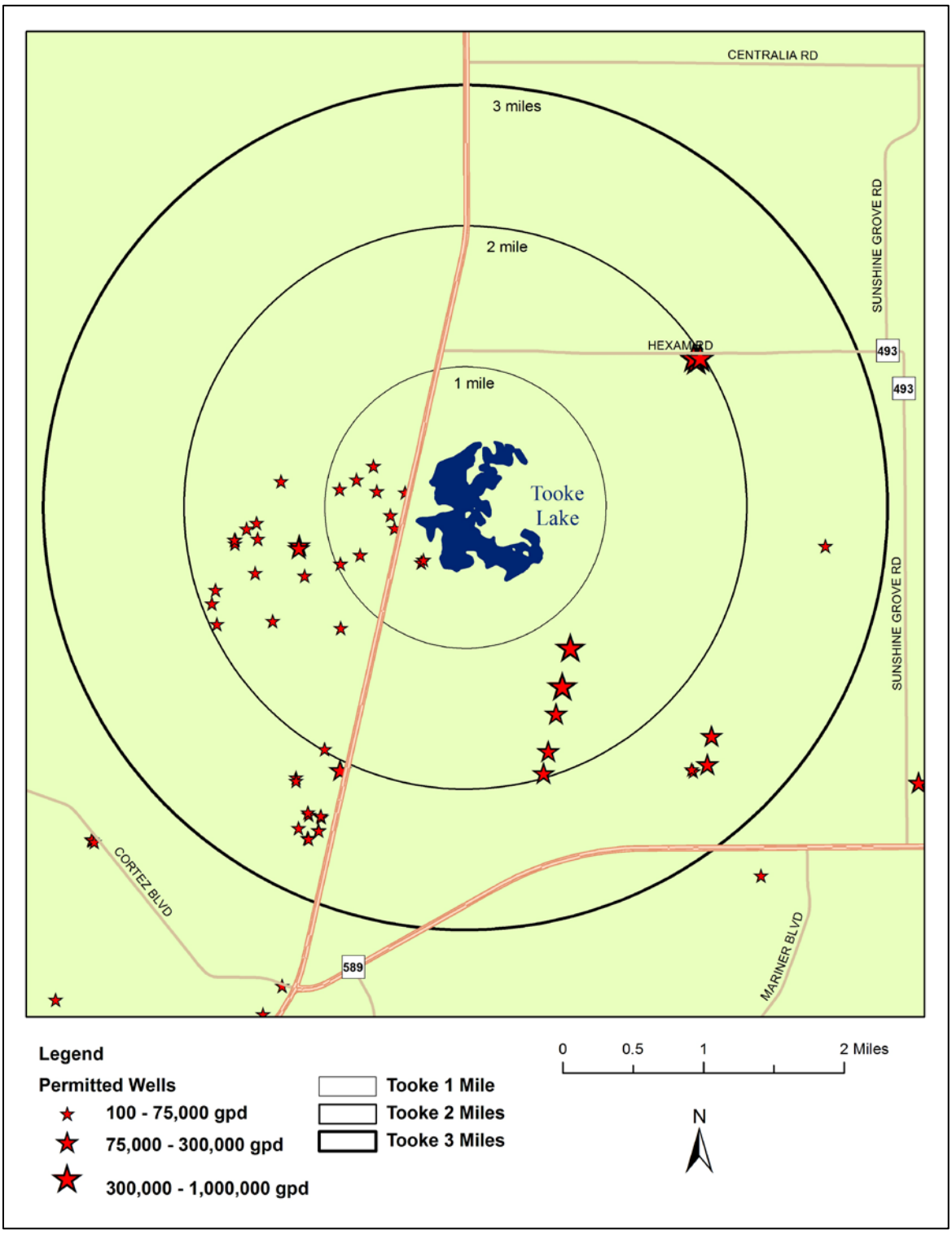

Figure 4. Permitted groundwater wells shown in average gallons per day withdrawals within a one mile, two mile and three mile radius of Tooke Lake.

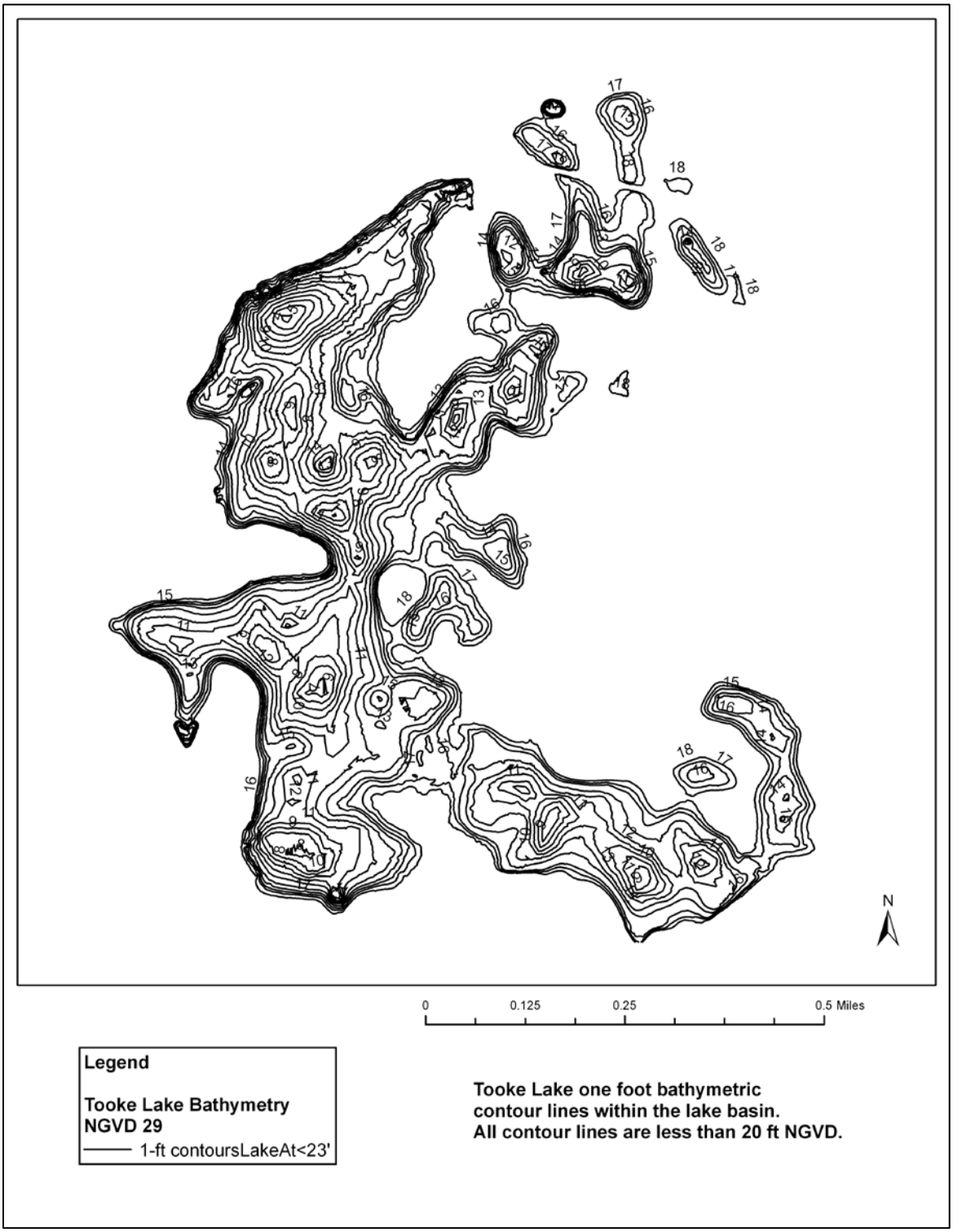

Figure 5. One-foot topographic contours of the Tooke Lake basin at and below 20 ft NGVD.

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

Levels	Elevation in Feet NGVD 29	Lake Area (acres)
Lake Stage Percentiles		
Period of Record (POR) P10 (1999 to 2012)	17.2	170
Period of Record (POR) P50 (1999 to 2012)	13.8	88
Period of Record (POR) P90 (1999 to 2012)	12.6	53
Historic P10 * (1946 to 2010)	21.2	298
Historic P50 * (1946 to 2010)	17.1	188
Historic P90 * (1946 to 2010)	14.2	100
Normal Pool and Control Point		
Normal Pool	21.5	289
Control Point	24.0	TOB
Significant Change Standards		
Basin Connectivity Standard	22.5	318
Recreation/Ski Standard	17.9	170
Wetland Offset Elevation	16.3	148
Lake Mixing Standard	16.2	146
Species Richness Standard	16.1	144
Aesthetics Standard	14.2	100
Dock-Use Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	21.2	298
High Minimum Lake Level	20.4	248
Minimum Lake Level	16.3	148
Low Guidance Level	14.2	146

NA - not appropriate; TOB - greater than the top of lake bank 23.0.
* - Long term Historic percentiles based on modeled (1946-2010) and measured (1999-2012) data.

Lake Stage Data and Exceedance Percentiles

Lake stage data, *i.e.,* surface water elevations for Tooke Lake relative to NGVD 29 were obtained from the District's Water Management Information System (WMIS) data base (site identification number 20698). The period of record (POR) for the data extends from April 1999 through July 2012. See figure 3 for the current location of the SWFWMD lake water level gage. Using the available lake stage data, monthly mean lake stage were calculated and graphed (Figure 6).

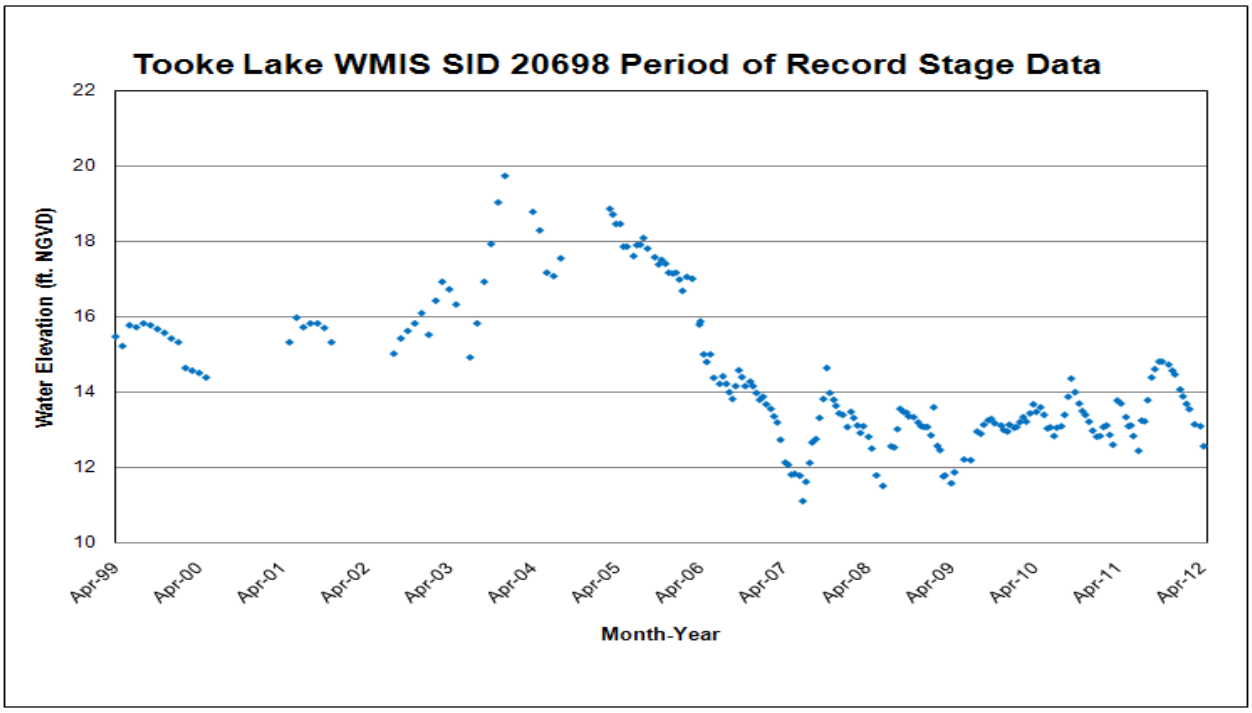

Figure 6. Tooke Lake (WMIS SID 20698) period of record monthly mean stage data - April 1999 through July 2012.

The highest water elevation recorded was 19.73 ft and occurred in December 1, 2003. The lowest water elevation recorded was 11.1 ft and occurred on June 27, 2007. The vertical range between the recorded high (19.7 ft) and low (11.1 ft) lake stage is 8.6 ft. The horizontal distance between the POR high and low around much of the lake is approximately 150 ft (Figure 7). Consequently, for every 17 ft horizontal distance there is one foot drop (17:1 ft ratio). A 58:1 foot ratio commonly occurs between the POR high and low water level elevations (500 foot horizontal distance). A small vertical fluctuation in water level will result in a notable substantial change in the lake shoreline. Tooke Lake is typical of the many gradually sloped, shallow lakes/deep marshes that are common in western Hernando County.

For the purpose of Minimum Levels determination, lake stage data are classified 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. Lake stage data are not classified as “Current” for periods when there were measurable, stable impacts due to water withdrawals, and impacts due to structural alterations were stable. Tooke Lake is not classified as a structurally altered lake. A review and analysis of available water-use information, well data and withdrawal impact simulations was conducted using the SWFWMD Northern District groundwater flow model (Basso 2012). Based on this, groundwater withdrawal impacts to the lake are minimal. Additionally, based on the groundwater model results, the historic period for Tooke Lake could

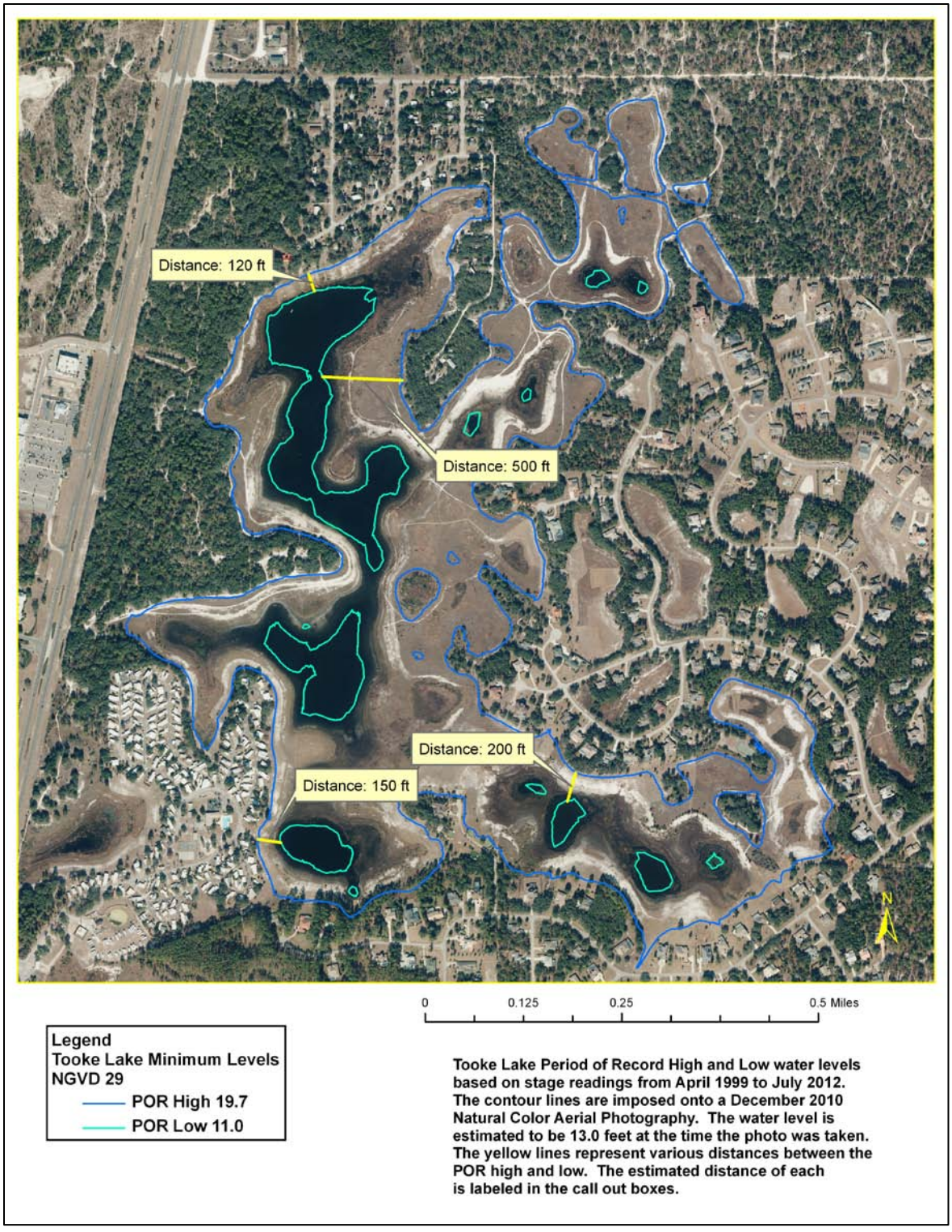

Figure 7. Approximate location of the lake basin contours associated with the lake stage period of record high (19.7 ft) and low (11.0 ft) for Tooke Lake. The background imagery was collected in December 2010.

reasonably extend to present day. However, for the purpose of establishing the rainfall regression model in a conservative manner the historic period was defined as the period pre-dating 1990.

Because available data for Tooke Lake starts in 1999 there are no available historic lake data available. To recreate historic data, the model effort used two regression models. The first regression model was between the lake stage and a nearby Floridan well (Weeki Wachee FLDN WMIS Site ID 20584) that has a long period of data that predates 1990. The regression between the lake and the well was based on the 2006 through March 2012 time period. Results from this model that predate 1995 represent historic lake stage records for Tooke Lake. The historic data from the first regression model served as the basis for the development of the final rainfall lake stage regression model. To accomplish this, a composite rainfall data set was developed for the time period of 1946 to present using data from two rainfall data collection sites. The rain gage sites included the Weeki Wachee National Weather Service (NWS) site, and Brooksville Chinsegut Hill NWS site (WMIS Site ID's 20915 and 20573 respectively). The rainfall regression model was based on historic data from 1975 to 1990. The resulting lake level rainfall model had a correlation coefficient of determination (r^2) equal to 0.805. The model was then applied to predict the lake stage for the long term Historic time period of the 1946 to 2010. This sixty-four-year period was considered sufficient for incorporating the range of lake stage fluctuations that would 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). These actual lake stage measurements and the final rainfall regression model representing un-impacted conditions are graphed in Figure 8a and 8b.

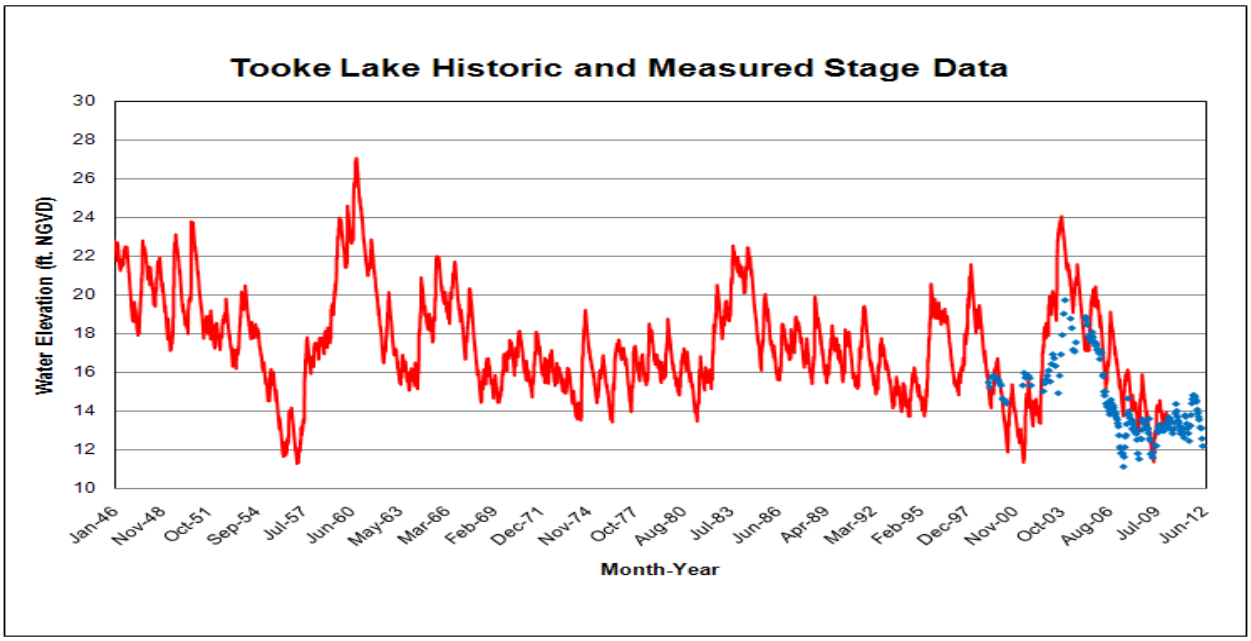

Figure 8a. January 1946 – February 2010 modeled long term historic lake stage (red line) and April 1999 – May 2012 measured lake stage (blue markers) as monthly means.

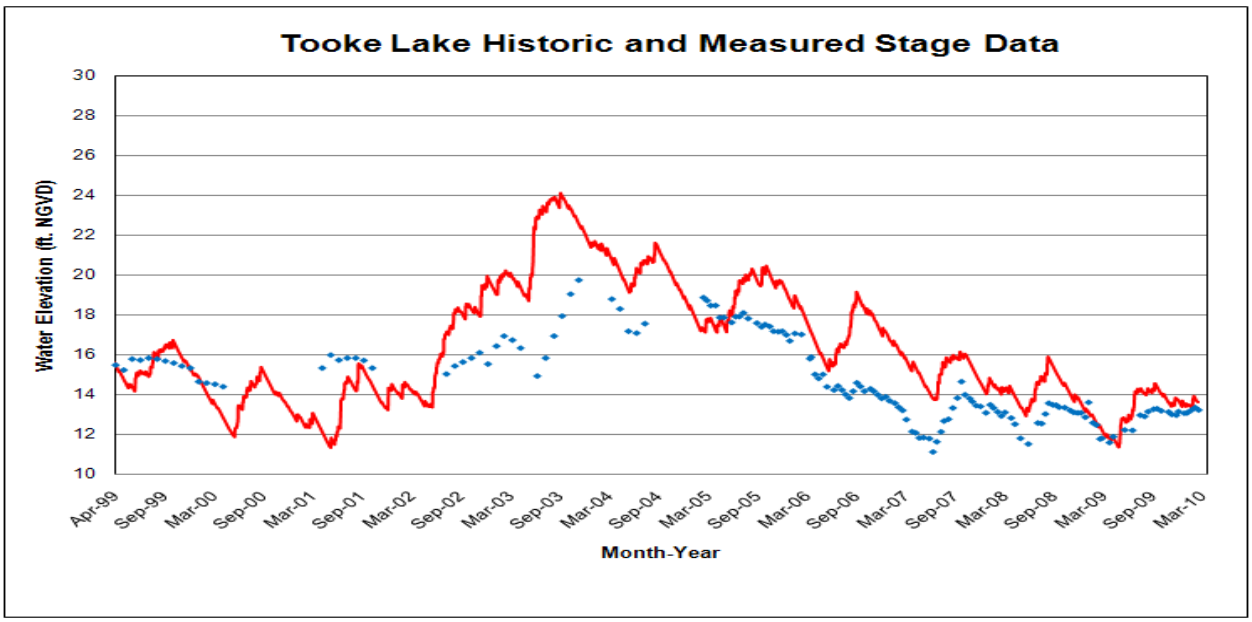

Figure 8b. April 1999 – February 2010 modeled long term historic lake stage (red line) and measured lake stage (blue markers).

The highest predicted historic water levels were generally near 22 ft (compared to the recorded high of 19.7 ft) and occurred four times; each time lasting several years in succession (Figure 9). Predicted historic low water levels were generally near 11 ft (similar to the record low of 11.1) and also occurred four times and generally occurred in one month intervals. The historic periods of high and low water levels since 1946 on a 2010 aerial photograph and reports specific dates associated with the extreme high and low water levels.

The final modeled historic lake stage data set was used to calculate the Historic P10, P50, and P90 lake stage percentile elevations (Figure 10, Table 2). The **Historic P10** elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the historic period, was **21.2 ft.** The **Historic P50** elevation, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was **17.1 ft**. The **Historic P90** elevation, the elevation the lake water surface equaled or exceeded 90 percent of the time during the historic period, was **14.2 ft**.

Figure 9. Periods of historic high and low water levels for Tooke Lake. These levels are based on stage data since 1946 as associated with conditions observed on a December 2010 aerial imagery.

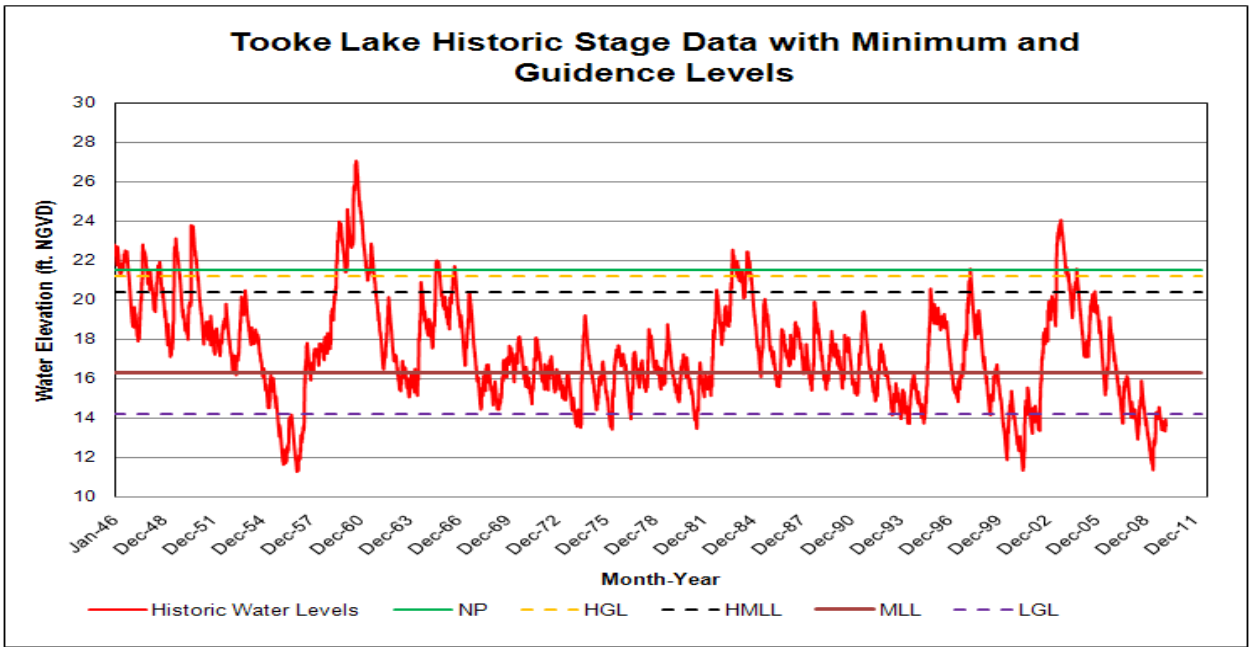

Figure 10. Tooke Lake modeled long term Historic Lake Stage and measured lake stage (both as monthly means) used to calculate the Historic P10, P50, and P90 Lake Stage Percentile Elevations for Tooke Lake from January 1946 through February 2010. The long term Historic P10, P50, and P90 are depicted as horizontal lines. Lake stage elevations are in feet above NGVD 29.

Normal Pool Elevation, Control Point Elevation and Structural Alteration Status

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, including biological and physical features. Based on ground elevations measured in September 2011 at the bases of saw palmetto (*Serenoa repens*) along the west shore of the lake (Figure 3), the **Normal Pool** elevation was established at **21.5 ft**. The Normal Pool is slightly lower in elevation than the lowest floor slab (21.9 ft).

The **Control Point** elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system (*e.g.,* weir, ditch, culvert, or pipe) that is the principal control of water level fluctuations in the lake. Based on review of one-foot contour interval aerial maps and field survey data collected in October 2011, it was determined that Tooke Lake has a natural "saddle" that would connect the lake to the swale along U.S. Highway 19 if the lake stage was sufficiently high. The **Control Point** was established at the lowest elevation of this saddle at **24.0 ft.** This control point was exceeded only once (1960) based on the predicted historic lake levels record. Unusually high water levels occurred in 1958-59 (similar to those high water levels that occurred in 2003) which preceded the peak level of 27 ft estimated for 1960. During the 1960 hurricane season, 27 inches fell in a four day period (SWFWMD 2011), followed

by hurricane Donna which was associated with up to 14 inches of rain in a three day period in September 1960 (SWFWMD 2002).

Guidance Levels

The **High Guidance Level** 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 expected Historic P10 of the lake and is established using historic lake stage data if it is available, or is estimated using the Current P10, the control point, and the normal pool elevation. Based on the availability of the long term historic data record, the **High Guidance Level** was established at **21.2 ft** (Figure 11, Table 2). This elevation is very similar to the Normal Pool elevation estimated at 21.5 ft.

The **Low Guidance Level** is provided as an advisory guideline for water dependent structures, information for lake shore 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 level is established using historic or current lake stage data, and in some cases, reference lake water regime statistics, which were simply differences between selected lake stage percentiles for a set of reference lakes. Based on the availability of the long term historic data set for Tooke Lake, the **Low Guidance Level** was established at **14.2 ft** (Figure 11, Table 2).

Lake Classification

Lakes are classified as Category 1, 2, or 3 for the purpose of Minimum Levels development. Those with fringing cypress wetlands greater than 0.5 acres in size where water levels currently rise to an elevation expected to fully maintain the integrity of the wetlands (*i.e.*, the Historic P50 is equal to or higher than an elevation 1.8 ft below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acres in size that have been structurally altered such that the Historic P50 elevation is more than 1.8 ft below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with cypress wetlands less than 0.5 acres in size are classified as Category 3 Lakes. Because Tooke Lake does not have fringing cypress wetlands, it is classified as a Category 3 Lake.

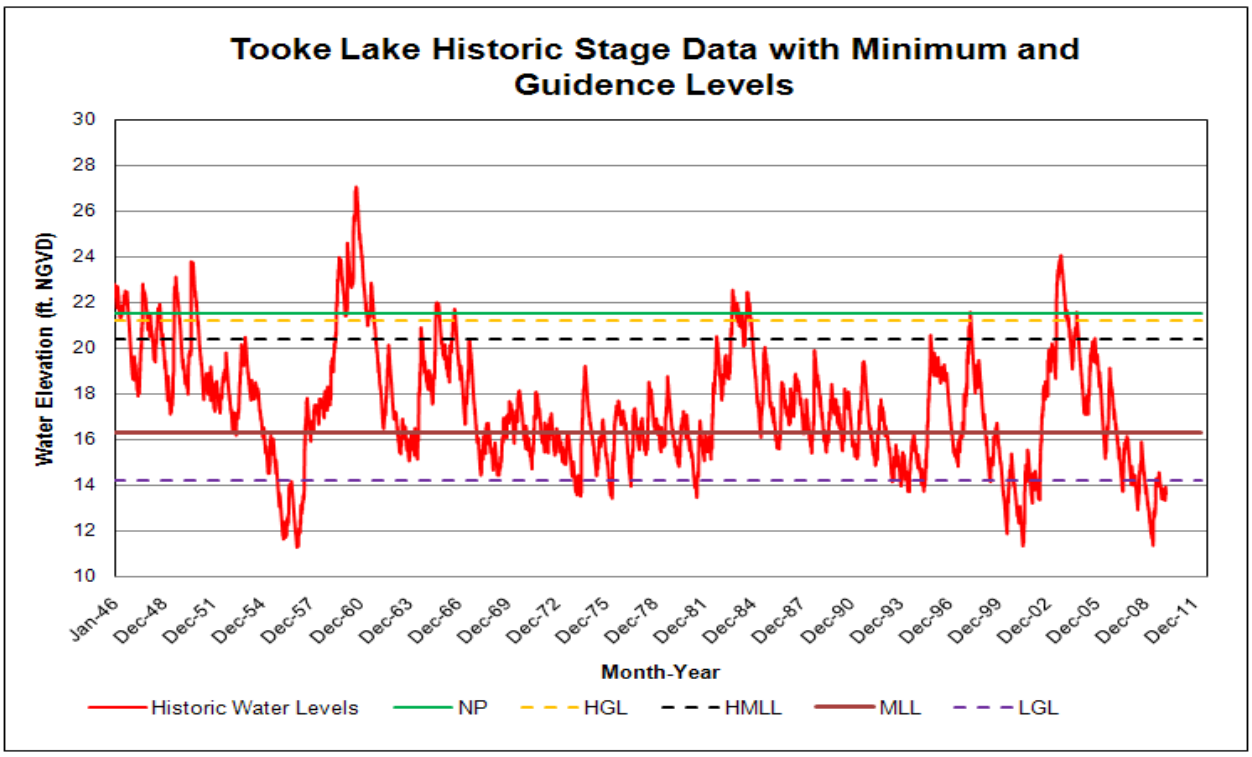

Figure 11. Monthly mean lake stage and Minimum and Guidance Levels for Tooke Lake. Levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL), and the Low Guidance Level (LGL).

Significant Change Standards and Other Information for Consideration

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

Six significant change standards are developed for **Category 3** Lakes, including an Aesthetics Standard, a Species Richness Standard, a Recreation/Ski Standard, a Dock-Use Standard, a Basin Connectivity Standard, and a Lake Mixing Standard. A Wetland Offset Elevation is also developed and used along with the significant change standards to identify desired median lake stage elevations that if achieved, are intended to preserve various natural system and human-use lake values.

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 lake-use. The standard is based

on the elevation of lake sediments at a critical high-spot between lake sub-basins (lobes), clearance water depths for movement of aquatic biota or powerboats and other watercraft, and use of Historic lake stage data or region-specific reference lake water regime statistics. The Tooke Lake basin includes two lobes ("north" and "south" lobes) that become separated from the main lake basin during periods of low water levels. A review of the LIDAR elevation data indicates that the **Critical High Spot** connecting the north and south lobes to the main lake pool is at **17.6 ft**. The **Basin Connectivity Standard** for Tooke Lake is established at **22.5 ft**, based on the sum of the elevation that ensures connectivity (17.6 ft), a two-foot clearance value for movement of biota and use of powerboats on the lake, and the difference between the Historic P50 and Historic P90 (2.9 ft). The Connectivity Standard corresponds to the historic P6 (HP6). Because it is considerably higher than the HP50 (Table 2), it is deemed inappropriate for development of a Minimum Lake Level for Tooke Lake.

The **Wetland Offset** is developed to protect herbaceous wetlands associated with a lake. The standard is based on a review (Hancock 2006) of the minimum level methods used for cypress-dominated wetlands, and specifies that up to an 0.8 foot decrease in the Historic P50 elevation (i.e., the Wetland Offset) would not likely be associated with significant changes in herbaceous wetlands occurring within lake basins. Because herbaceous wetlands are common within the Tooke Lake basin, the Wetland Offset was determined by subtracting 0.8 ft from the Historic P50 elevation. The **Wetland Offset** for Tooke Lake is established at **16.3 ft** and was equaled or exceeded 63 percent of the time, based on the Historic, composite water level record. The standard elevation is the nearest standard below the HP50 (Table 2) and corresponds to the Historic P63.

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 Florida lakes, the standard is established at the lowest elevation associated with less than a 15 percent reduction in lake surface area relative to the lake area at the Historic P50 elevation. The **Species Richness Standard** for Tooke Lake is established at **16.1 ft** (see Figure 12 for a plot of lake surface area relative to lake stage). The Species Richness Standard was equaled or exceeded 66 percent of the time, based on the long term Historic, composite water level record. The standard elevation is lower than the HP50 (Table 2) and corresponds to the Historic P66.

The **Recreation/Ski Standard** for Tooke Lake 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 five-foot deep ski corridor delineated as a circular area with a radius of 418 ft, or a rectangular ski area 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. The **Recreation/Ski Standard** for Tooke Lake is established at **17.9 ft**, based on the sum of the elevation at which the lake could contain an area suitable for safe skiing (15.0 ft) and the difference between the Historic P50 and Historic P90 (2.9 ft). The

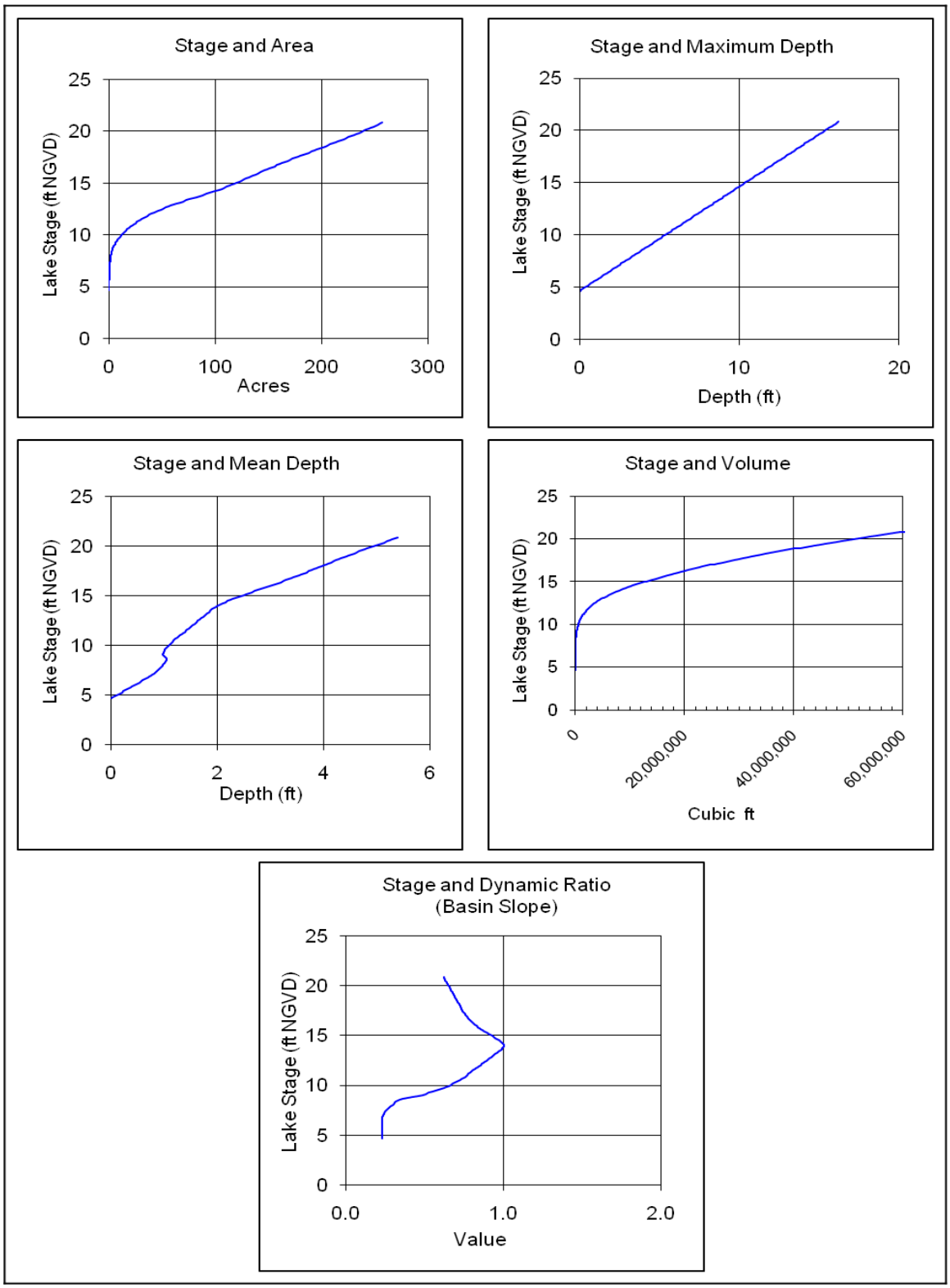

Figure 12. Surface area, maximum depth, mean depth, volume, dynamic ratio (basin slope) in Tooke Lake as a function of lake stage (water surface elevation).

Recreation/Ski Standard was equaled or exceeded 39 percent of the time, based on the long term composite Historic water level record. Because the standard therefore corresponds to the Historic P39, is higher than the HP50 and the lake is not considered to be structurally altered, the standard was deemed appropriate for the development of a Minimum Lake Level for Tooke Lake.

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 becoming degraded below 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**, which is **14.2 ft** for Tooke Lake. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard ninety percent of the time during the historic long term period.

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 clearance water depth value for boat mooring, and use of Historic lake stage data or region-specific reference lake water regime statistics. Development of the Dock Use Standard was not appropriate for Tooke Lake because only 8 non-floating docks (in usable condition) exist on the lake.

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 (Figure 12). The **Mixing Standard** for Tooke Lake is established at **16.2 ft.** The Mixing Standard was equaled or exceeded 64 percent of the time, based on the long term Historic, composite water level record. The standard elevation is the second lowest standard below the HP50 (Table 2) and corresponds to the Historic P64.

Information on **herbaceous wetlands** is taken into consideration when developing minimum lake levels. This is accomplished by determining the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (*i.e*., basin area with a water depth of four or less feet) (Figure 13). 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 (*i.e*., basin area with a water depth of 5.5 ft or less) (Figure 13). Review of changes in potential herbaceous wetland area or area available for submersed aquatic plant colonization in relation to change in lake stage did not indicate that use of any of the significant change standards would be inappropriate for establishment of the Minimum Lake Level for Tooke Lake.

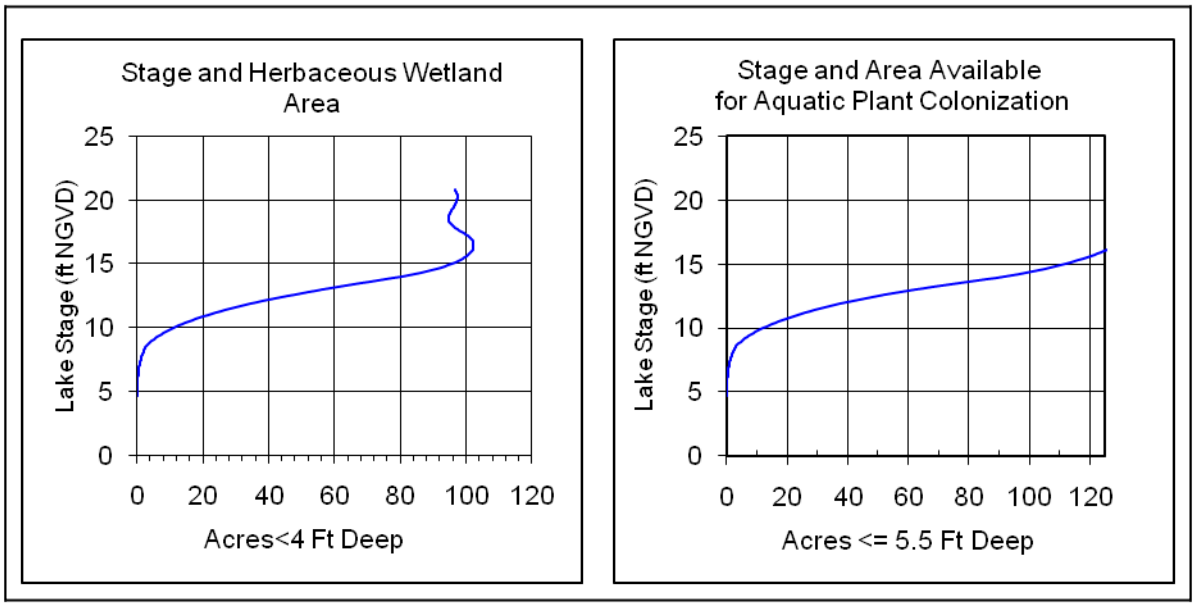

Figure 13. Potential herbaceous wetland area and area available for submersed Macrophyte colonization in Tooke Lake as a function of lake stage (water surface elevation).

Minimum Levels

Minimum Lake Levels are developed using specific lake-category significant change standards and other available information or unique factors, including: substantial changes in the coverage of herbaceous wetland vegetation and aquatic macrophytes; elevations associated with residential dwellings, roads or other structures; frequent submergence of dock platforms; faunal surveys; aerial photographs; typical uses of lakes (*e.g.,* recreation, aesthetics, navigation, and irrigation); surrounding land-uses; socio-economic effects; and public health, safety and welfare matters. Minimum Levels development is also contingent upon lake classification*, i.e.,* whether a lake is classified as a Category 1, 2 or 3 lake.

The Minimum Lake Level (MLL) is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For Category 3 Lakes such as Tooke Lake, the Minimum Lake Level is typically established at the elevation corresponding to the most conservative significant change standard, *i.e*., the standard with the highest elevation, except where that elevation is above the Historic P50 (Table 2) elevation. Based on elevations associated with appropriate standards developed for Tooke Lake, the **Minimum Lake Level** was established at the **Wetland Offset (16.3 ft).** The Wetland Offset is 0.8 ft below the historic P50 and is similar to the **Mixing Standard (16.2 ft)** and **Species Richness Standard (16.1 ft).** Establishing the purposed MLL level a the Wetland Offset elevation is expected to afford protection to the natural system and human-use values associated with all appropriate significant

change standards identified for the lake while also providing protection for herbaceous wetlands occurring within the basin.

The **High Minimum Lake Level (HMLL)** is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For Category 3 lakes, the High Minimum Lake Level is developed using the Minimum Lake Level, Historic data or reference lake water regime 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 RLWR50, which is the difference between the Historic P10 and P50 for a set of reference lakes. Based on the availability of long term composite Historic data for Tooke Lake, the **HMLL** is established at **20.4 ft** by adding the difference between the Historic P50 and Historic P10 (4.1 ft) to the Minimum Lake Level.

The Minimum and Guidance levels for Tooke Lake are shown in Figure 11 along with monthly mean surface water levels. The levels are also shown as contour lines on historic aerial photographs (Figures 14 – 17). The most recent (2010) and oldest (1944) aerial photographs available are represented in Figures 14 and 17 (respectively). Figure 15 presents a 2007 aerial which illustrates water levels near the historic extreme low. Figure 16 presents a 1984 aerial which illustrates water levels near the extreme high. Unfortunately, aerial photography is not available that would show the extreme water levels in 1960.

Staging of the lake at Minimum levels wouldn't be expected to flood any man-made features within the immediate lake basin. The High Minimum Lake Level (20.4 ft) is approximately 1.5 ft lower than the lowest floor slab (21.9 ft) within the lake basin. The High Minimum Lake Level is also approximately 0.5 ft lower than the lowest spot on the paved roads (20.9 ft) adjacent to the lake. A period of record high of 19.6 ft was measured in December 2003 during a three-year period of unusually high rainfall including the heavy rains associated with the 2001 "El Niño" event. This period of record high was 0.8 ft lower than the High Minimum Lake Level.

Compliance Evaluation

Compliance with the Minimum Lake Level and High Minimum Lake Level was evaluated using the rainfall model that was used to develop the long term Historic lake stage exceedance percentiles (Ellison 2012). The model was used to evaluate whether measured lake stage values fall within prediction intervals established for the calibration window or time period used for model development. Water levels in Tooke Lake were determined to be in compliance with both the Minimum Lake Low Level and High Minimum Level based on rainfall data available through July 2011.

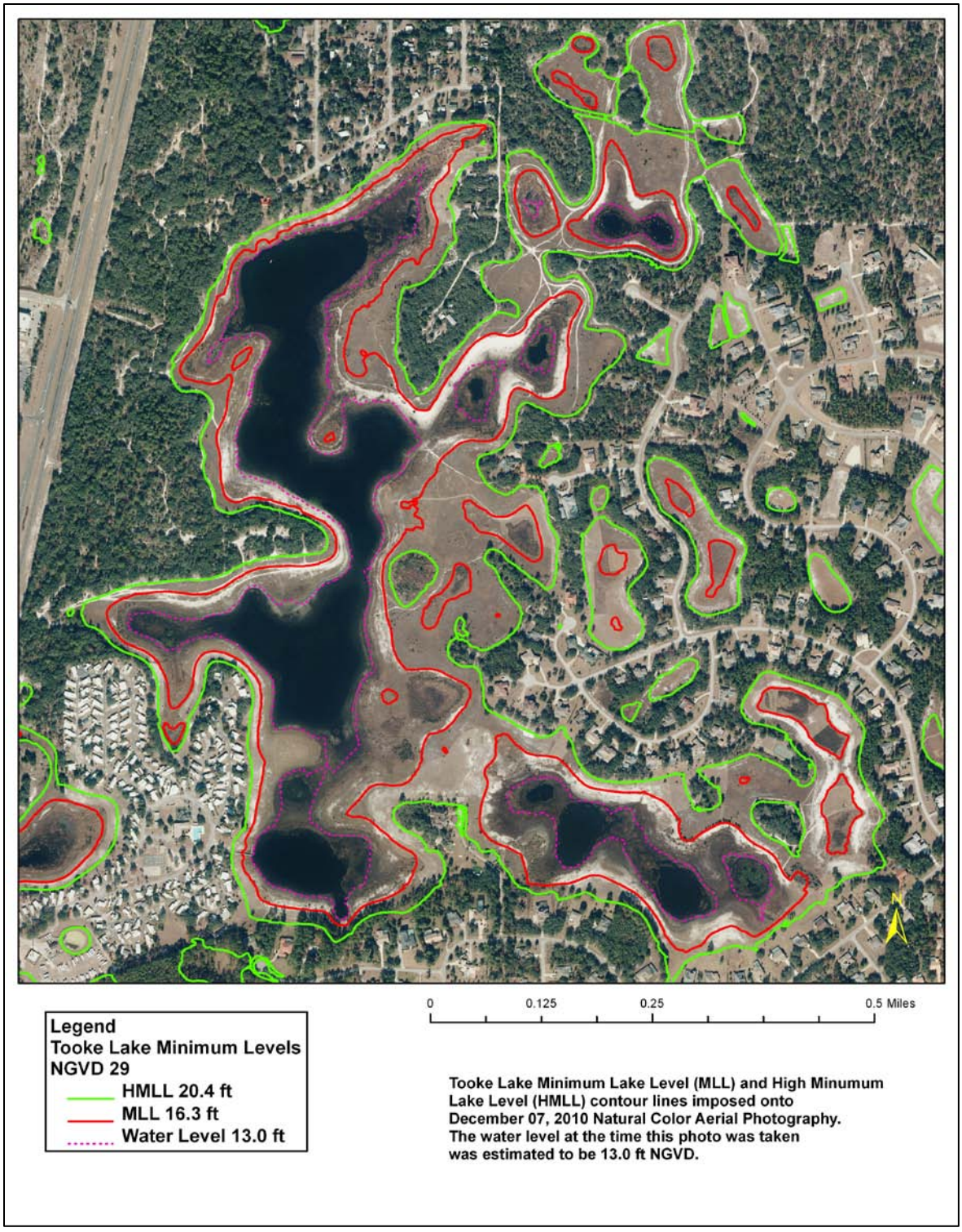

Figure 15. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Tooke Lake relative to conditions on December 07, 2010. Based on gage readings, the estimated lake stage was 13.0 ft on the date of the imagery.

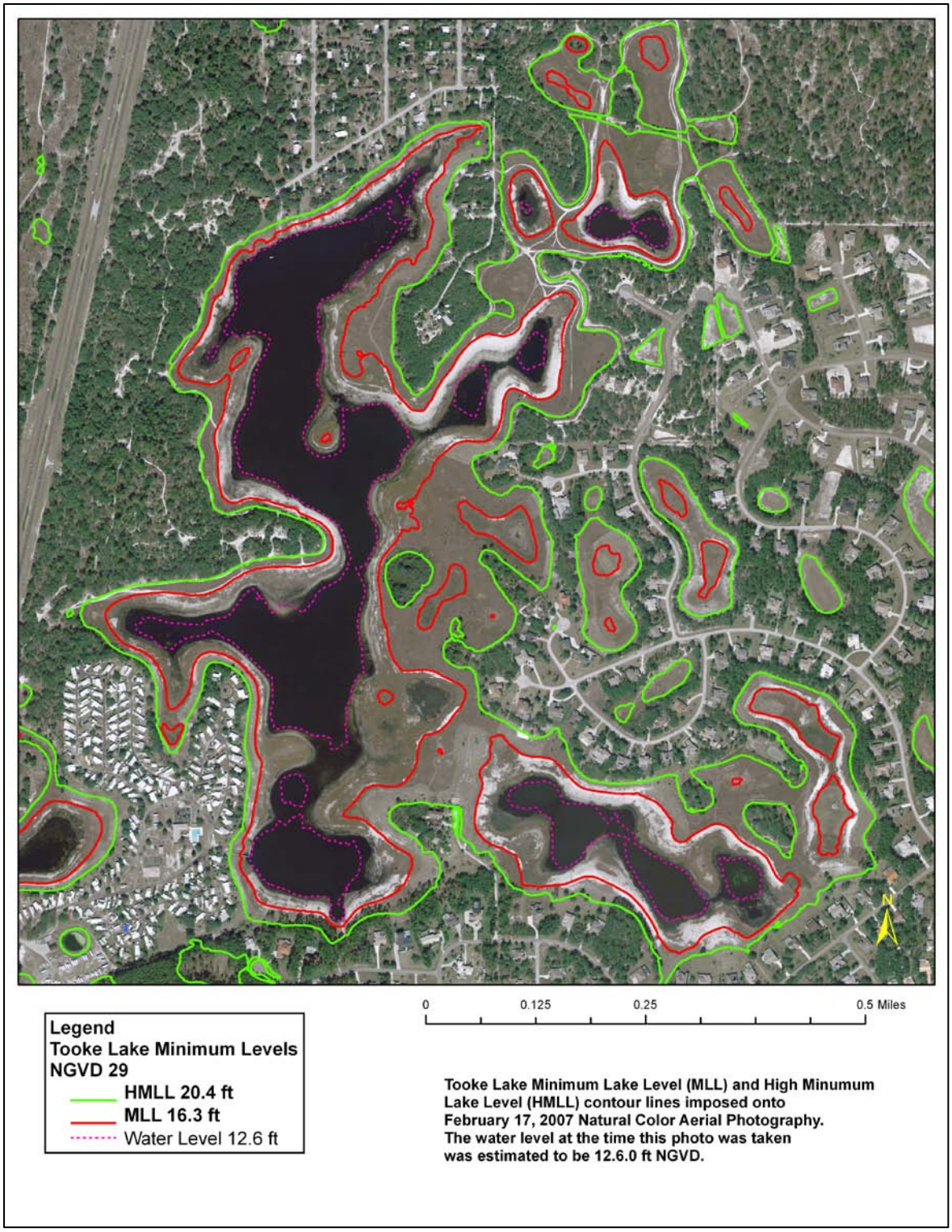

Figure 16. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Tooke Lake relative to conditions on February 17, 2007. Based on gage readings the estimated lake stage was 12.6 ft on the date of the imagery.

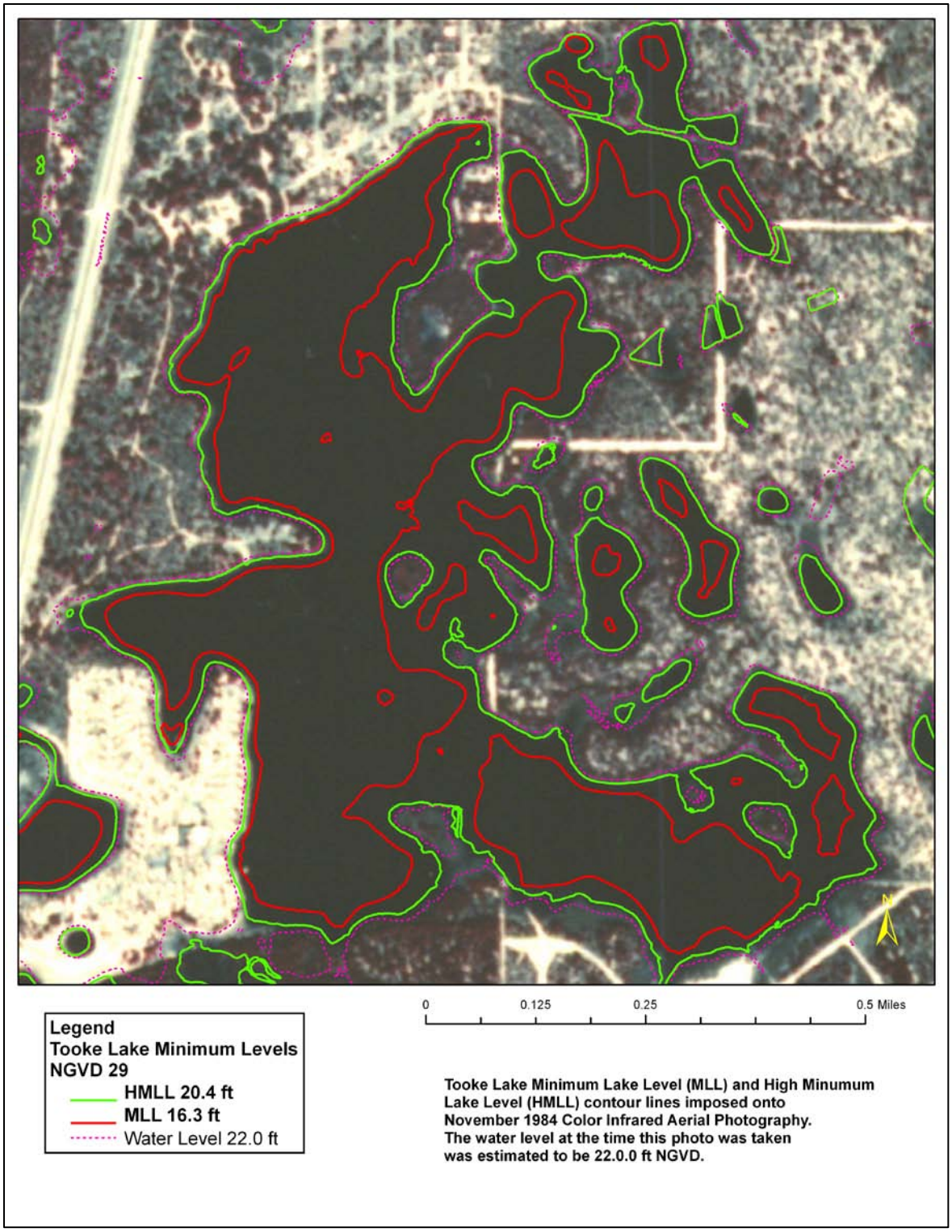

Figure 17. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Tooke Lake relative to conditions on November 1984. Based on interpretation of contour lines at the lake edge at the time of this imagery, the lake stage was estimated at 22.0 ft.

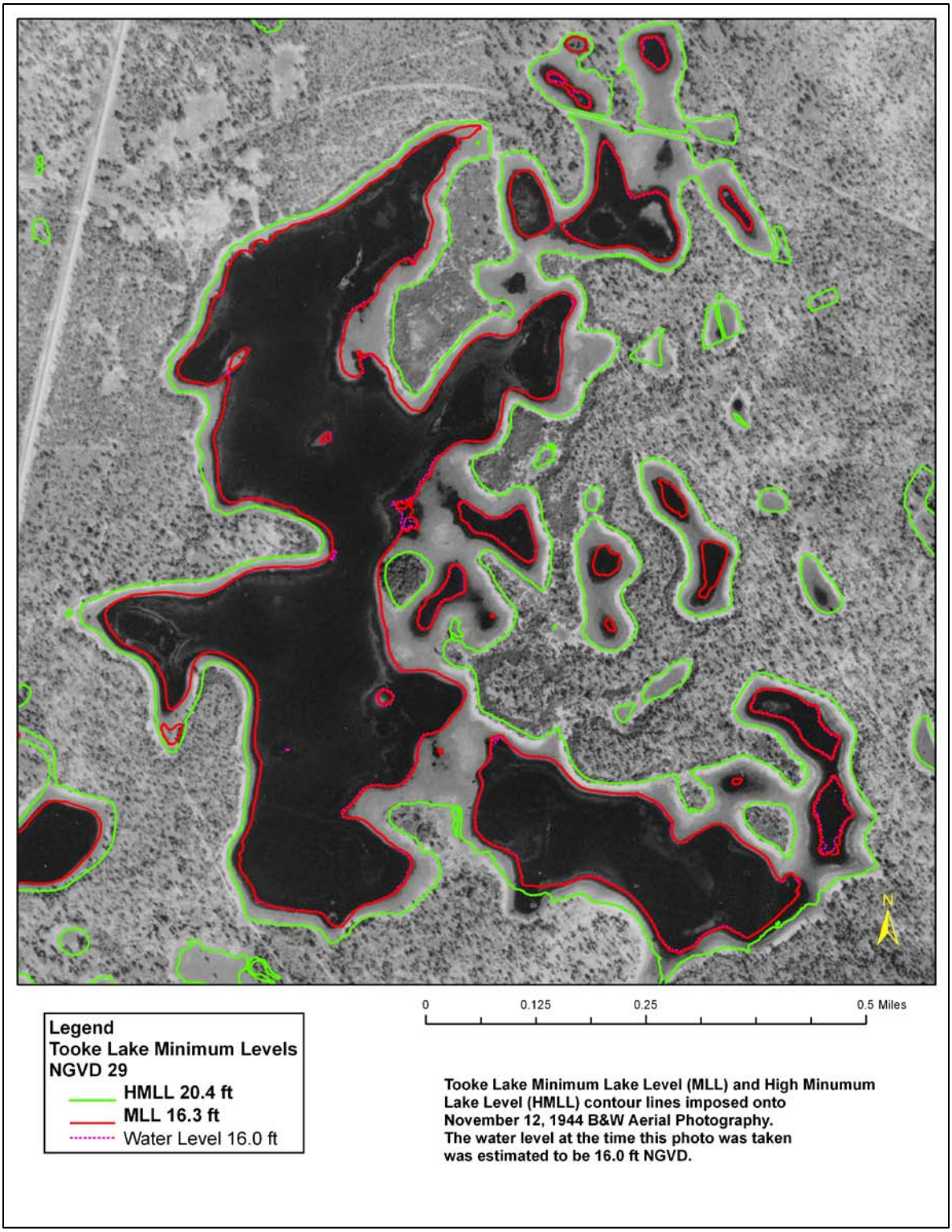

Figure 18. Approximate location of water level (i.e., shoreline) associated with the Minimum Lake Level (MLL) and High Minimum Lake Level (HMLL) for Tooke Lake relative to conditions on November 12, 1944. Based on interpretation of contour lines at the lake edge at the time of this imagery, the lake stage was estimated at 16.0 ft.

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