Minimum and Guidance Levels for Lake Bonnie in Polk County, Florida

February 18, 2008

Ecologic Evaluation Section
Resource Projects Department

Southwest Florida
Water Management District

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Brooksville, Florida 34604-6899

On the cover: Aerial photograph of Lake Bonnie in 2004 (Southwest Florida Water Management District (2004a).

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Minimum and Guidance Levels for Lake Bonnie

State law (Section 373.042, Florida Statutes; hereafter 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. As currently defined by statute, 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", and the minimum level of an aquifer or surface water body is "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 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 a minimum flow or level does not in itself protect a water body from significant harm; however, resource protection, recovery and regulatory compliance can be supported once the flow or level standards are established. State law governing implementation of minimum flows and levels (Chapter 373.0421, F.S.) requires 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". Recovery or prevention strategies are 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 also required by state law.

Minimum flows and levels are to 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 (Section 373.0421, F.S.). The Florida Water Resources Implementation Rule (Rule 62-40.473, Florida Administrative Code; hereafter 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 Southwest Florida Water Management District 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 its Water Level and Rates of Flow Rule (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. Chapter 40D-8, F.A.C. also provides for the establishment of Guidance Levels, 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 provided in Southwest Florida Water Management District (1999a, b), 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).

In recent years, two Minimum Levels and three Guidance Levels have typically been established for lakes, and upon adoption by the District Governing Board, incorporated into Chapter 40D-8, 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 Ten Year Flood Guidance Level is provided as an advisory guideline for lakeshore development. It is the level of flooding expected on a frequency of not less than the ten-year recurring interval, or on a frequency of not greater than a ten percent probability of occurrence in any given year.

- 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 October 2007, the District Governing Board approved rule amendments pertaining to the elimination of Ten Year Flood Guidance Levels and references to the levels from Chapter 40D-8, F.A.C. Work related to the development of ten-year flood levels and other flood-recurrence levels is currently conducted through the District Watershed Management Program, and information pertaining to flood levels is included in watershed management plans that result from program activities.

In accordance with Chapter 40D-8, F.A.C., proposed Minimum and Guidance Levels were developed and revised for Lake Bonnie, a Category 3 Lake located in Polk County, Florida (Southwest Florida Water Management District 2005a, 2007). The levels were established using best available information, including data that were obtained specifically for the purpose of minimum levels development. Following a public input process, the District Governing Board approved adoption of the proposed levels on October 30, 2007 and the levels (Table 1) were subsequently incorporated into Chapter 40D-8, F.A.C. The data and analyses used for development of the adopted levels are described in the remainder of this report.

Table 1. Minimum and Guidance Levels for Lake Bonnie.

Minimum and Guidance Levels	Elevation (feet above NGVD)
High Guidance Level	105.9
High Minimum Lake Level	105.8
Minimum Lake Level	102.1
Low Guidance Level	99.8

Data and Analyses Supporting Development of Minimum and Guidance Levels for Lake Bonnie

Lake Setting and Description

Lake Bonnie is located in Polk County, Florida (Section 31, Township 29 South, Range 28 East) in the Peace River Basin of the Southwest Florida Water Management District (Figure 1). White (1970) classified the region of central or mid-peninsular Florida containing Lake Bonnie as the Lake Wales Ridge physiographic region. Brooks (1981) categorized the area surrounding the lake as the Iron Mountains subdivision of the Lake Wales Ridge in the Central Lake Physiographic District, and described the region as an area of residual sandhills underlain by sand, gravel, and clayey sand. 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 lake region and described as an area of alkaline, low to moderate nutrient, clearwater lakes (Griffith *et al.* 1997).

The lake, which lies in the Lake Weohyakapka watershed, has a drainage area of 0.8 square miles (Southwest Florida Water Management District 1996). There are no major, natural surface water systems draining into the basin, although a stormwater system directs runoff into the basin from developed areas west of the lake and a cut through the sand ridge on the east side of the lake could permit surface inflow or outlflow (Figure 2). The basin has no natural outlets, and based on historical photography (Figures 3-12) from the 1940s through 2006 and a soil survey map from 1927 (Figure 13) this appears to have been the case for the past 80 years. There are no surface water withdrawals from the lake currently permitted by the District. There are, however, 27 permitted groundwater withdrawal sites within one mile of the lakeshore (Figure 14). The sites are permitted for a total daily average withdrawal of 901,300 gallons per day.

Uplands surrounding Lake Bonnie are used primarily for residential development and citrus production, and lands to the east of the basin have been extensively altered as a result of sand-mining operations (Figure 15). Native vegetation, including live oak (*Quercus virginiana*), saw palmetto (*Serenoa repens*), cordgrass (*Spartina bakeri*), prickly-pear cactus (c.f. *Opuntia humifusa*) and pine (*Pinus* sp.) occur at higher elevations within the basin. Aquatic and semi-aquatic plants, including cattail (*Typha* sp.) and willow (*Salix* sp.) are sparsely distributed on the lake bottom.

No information on the surface elevation or size of Lake Bonnie is included in the "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969, Shafer *et al.* 1986). The 1952 (photorevised 1972) United States Geological Survey 1:24,000 Lake Wales quadrangle map shows the lake's surface at 106 feet above mean sea level. The revised 1993 version of the map does not include an elevation for the lake, but does show a small area of standing water within the basin (Figure16). A topographic map of the basin generated in support of minimum levels development (Figure 17), indicates that approximately 12.3 acres of the basin is inundated when the lake is staged at 106

feet above NGVD. At lake stages below 103 feet above NGVD, only small areas of the basin are inundated, and the basin is dry when the water surface recedes below 99.8 feet above NGVD.

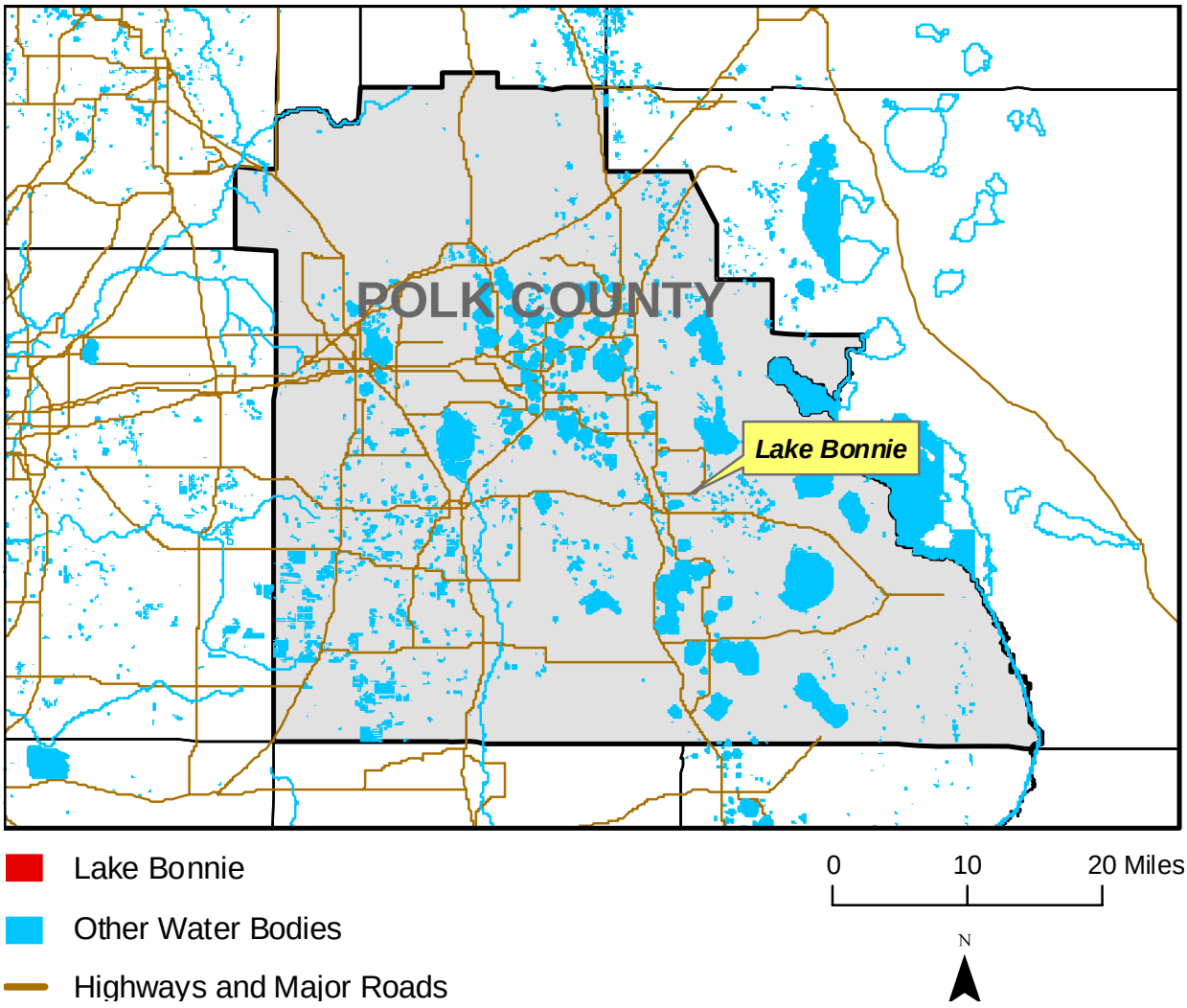


Figure 1. Location of Lake Bonnie, other regional water bodies, and highways/major roads in and around Polk County, Florida.

Figure 2. Aerial photograph of Lake Bonnie in 2006 (image source: 3001, Inc. 2006), showing the location of the District water level gauge, a lift station, sites where hydrologic indicators of normal pool were measured and the names of selected roads in the lake vicinity.

Figure 3. Aerial photography of Lake Bonnie in 2005 (image source: Woolpert, Inc. 2005b).

Figure 4. Aerial photography of Lake Bonnie in 2004 (image source: EarthData International 2004).

Figure 5. Aerial photography of Lake Bonnie on October 21, 2004 (Southwest Florida Water Management District 2004a).

Figure 6. Aerial infrared photography of Lake Bonnie in 1999 (image source: Southwest Florida Water Management District 2002a).

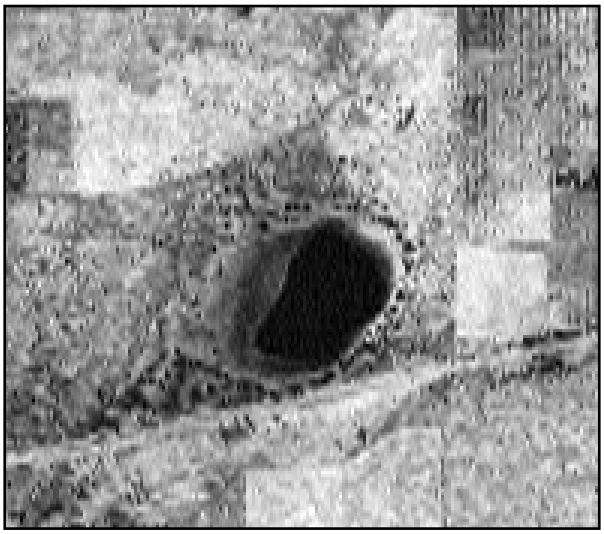
Figure 7. Aerial infrared photography of Lake Bonnie on March 4, 1998 (image source: Southwest Florida Water Management District 1998).

Figure 8. Aerial infrared photography of Lake Bonnie in 1994 (image source: Southwest Florida Water Management District date unknown).

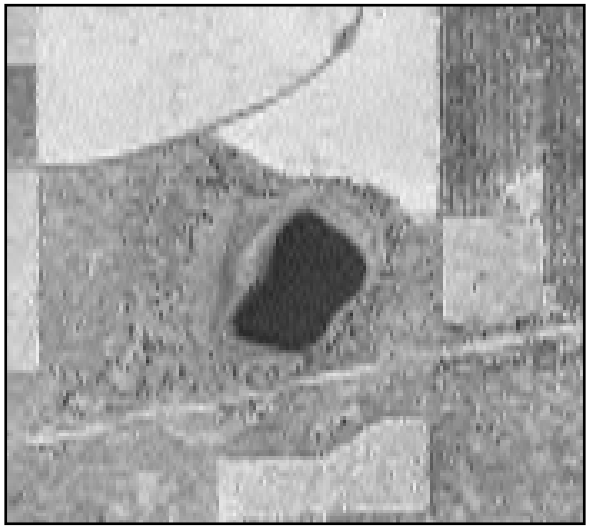
Figure 9. Aerial photography of Lake Bonnie in January 1987 (image source: Southwest Florida Water Management District 1987).

Figure 10. Aerial photography of Lake Bonnie in 1984 (image source: United States Geological Survey 2004).

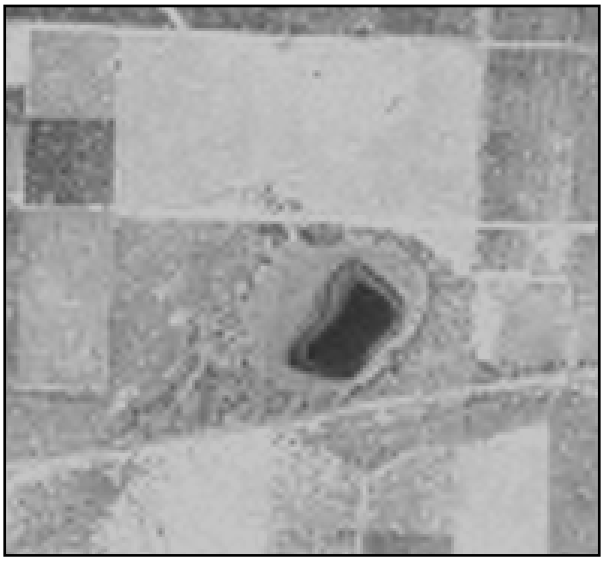
Figure 11. Aerial photograph of Lake Bonnie in March 1971 (image source: Woolpert 2005a).



March 1, 1941



January 7, 1952



January 27, 1958

February 9, 1968

Figure 12. Aerial photography of Lake Bonnie in 1941, 1952, 1958 and 1968 (image sources: United States Department of Agriculture 1941, 1952. 1958 and 1968).

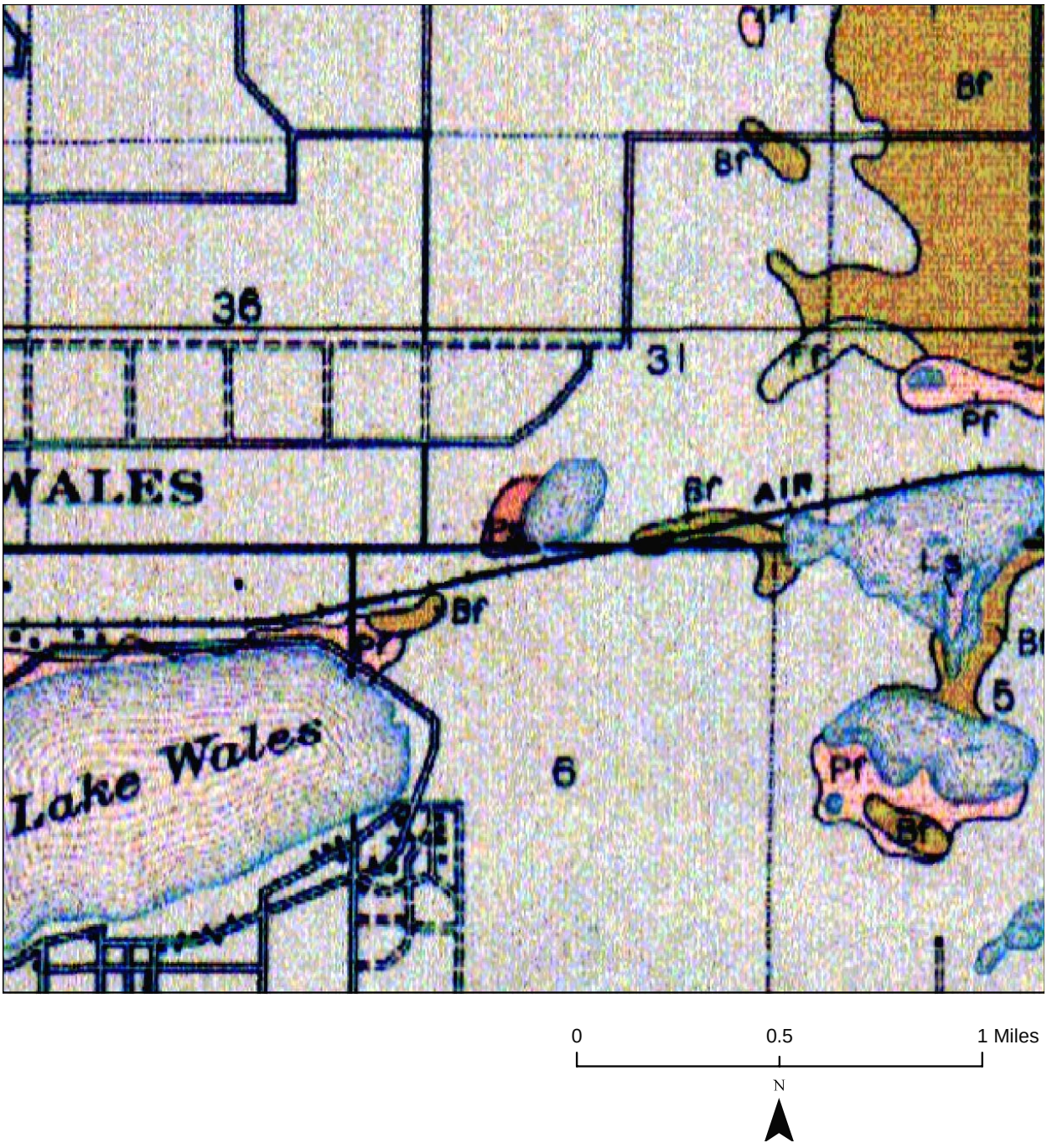


Figure 13. United States Department of Agriculture soil survey map of the Lake Bonnie area in 1927 (image source: Jones, Edmunds & Associates 2005).

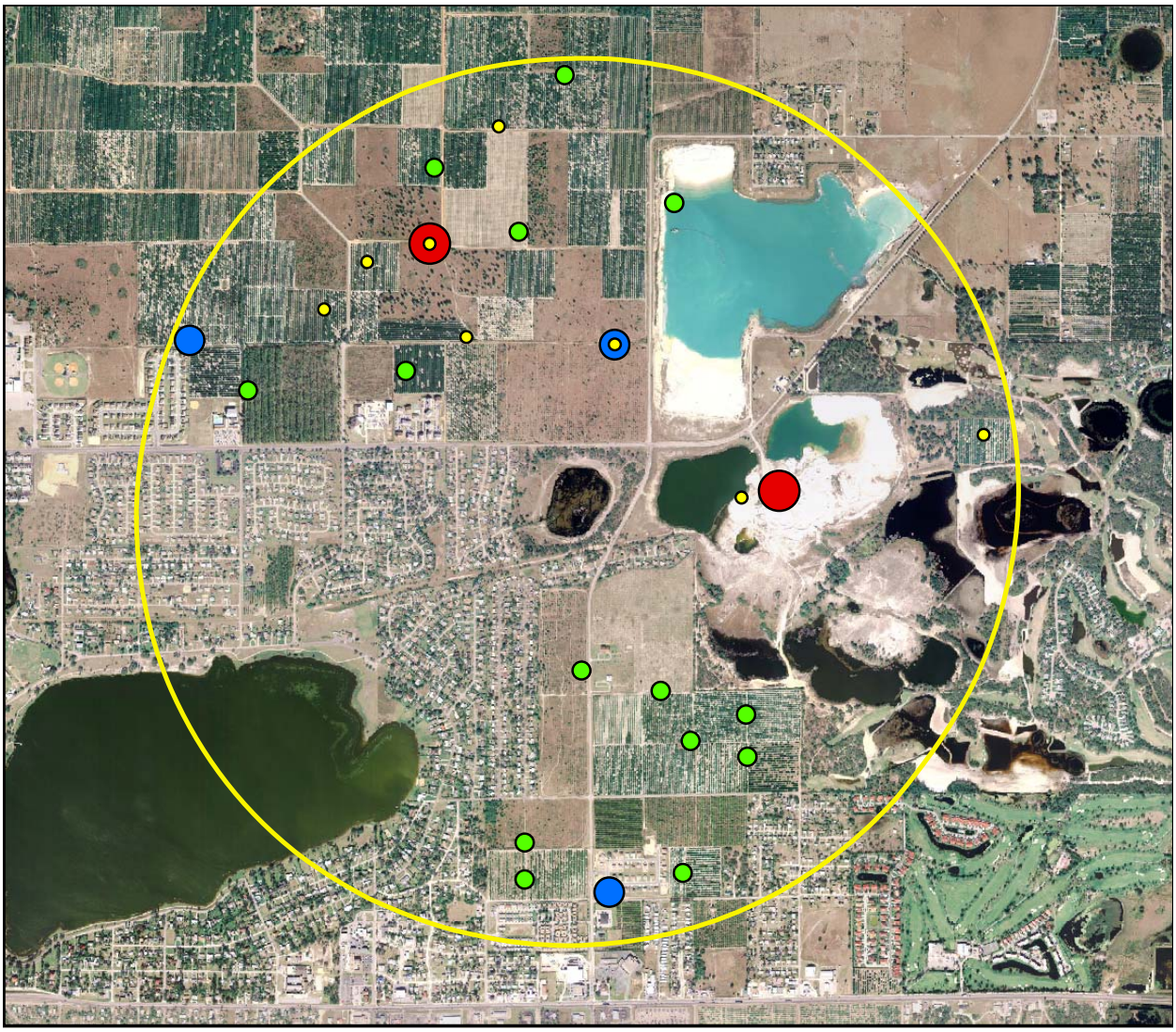


Figure 14. Permitted daily average groundwater withdrawal quantities (gallons per day as of June 2007) within one mile of the Lake Bonnie shoreline as delineated by the yellow line surrounding the lake (photographic image source: 3001, Inc. 2006).

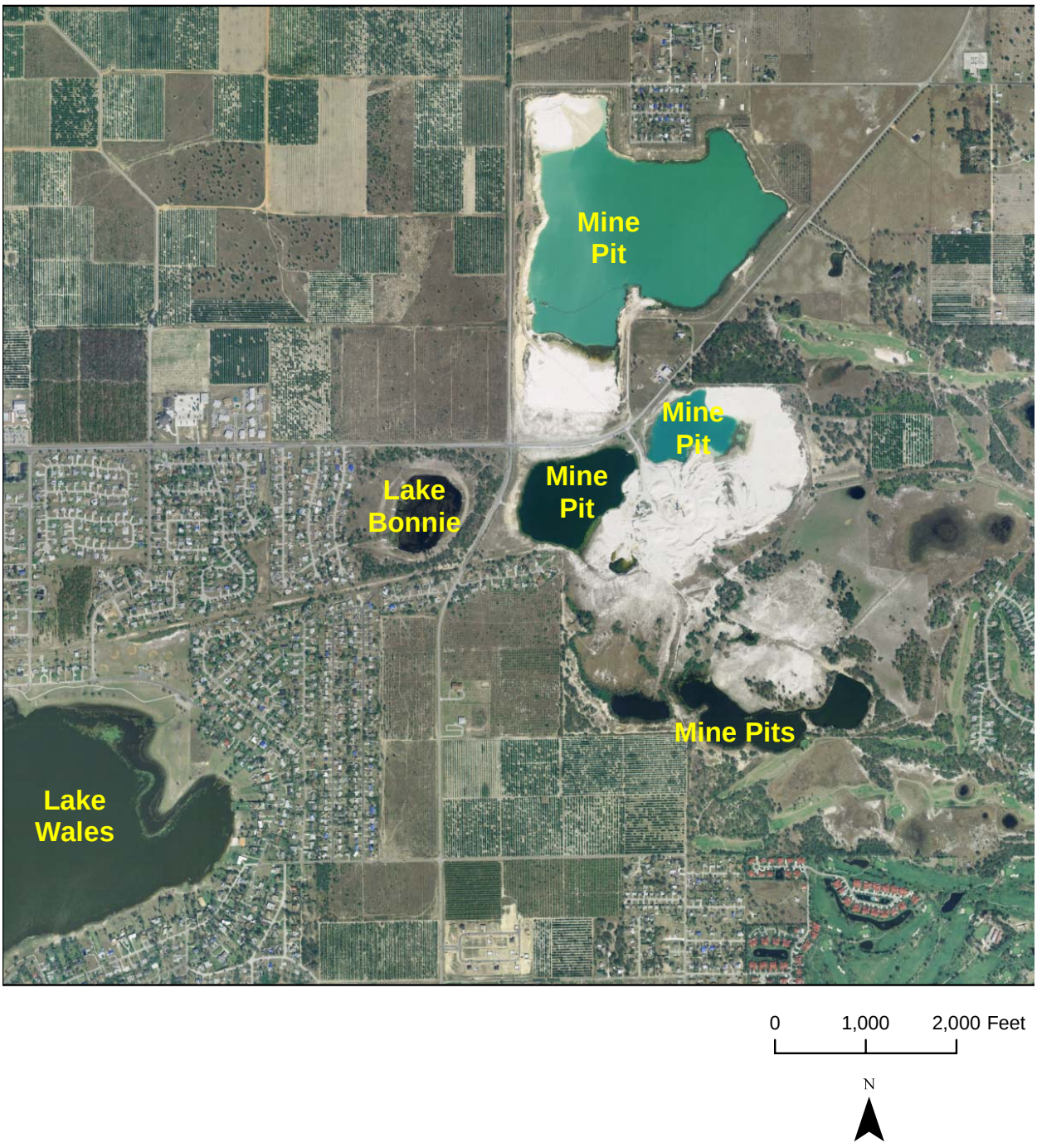


Figure 15. Aerial photography of the Lake Bonnie vicinity in 2005 (photographic image source: Woolpert, Inc. 2005b) showing residential, citrus production and mining land-uses.

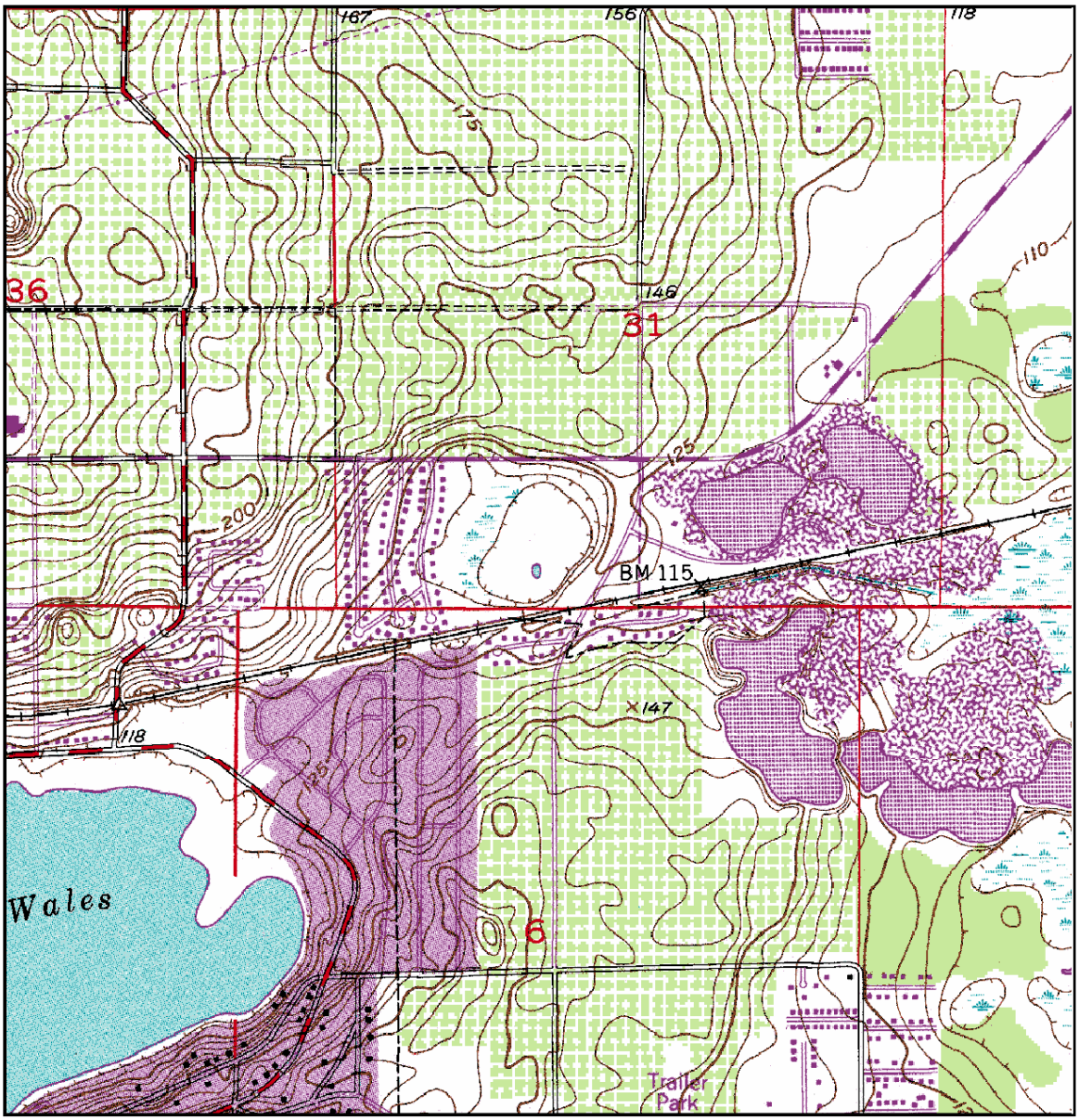


Figure 16. United States Geological Survey five-foot ground elevation contours (feet above NGVD 1929) in the vicinity of Lake Bonnie (image source: Southwest Florida Water Management District 2002b).

Elevation contours were developed based on spot and contour line elevation data from a 1987 District aerial photography with contours map (Sheeet No. 31-29-28).

0 250 500 Feet

N

Figure 17. One-foot ground elevation contours (feet above NGVD) within the Lake Bonnie basin (photographic image source: 3001, Inc. 2006).

Previously Adopted 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 establishing management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes had been established.

Management levels for Lake Bonnie (Table 2, currently referred to as Guidance Levels) were approved by the Governing Board in August 1991 and incorporated into District rules (Chapter 40D-8, F.A.C.). A Maximum Desirable Level of 112.50 feet above NGVD was also developed but was not adopted by rule. The levels were developed using a methodology that differs from the current District approach for establishing Minimum and Guidance Levels, and do not, therefore, necessarily correspond with levels developed using current methods. Following the October 2007 adoption of Minimum and Guidance Levels for Lake Bonnie that were developed using current methodologies, the previously adopted Guidance Levels were removed from Chapter 40D-8., F.A.C.

Annually since 1991, a list of stressed lakes has been developed to support the District's water-use permitting program. As described in the District's Consumptive Use of Water Rule (Chapter 40D-2, F.A.C.), "a stressed condition for a lake is defined to be chronic fluctuation below the normal range of lake level fluctuations". For lakes with adopted High, Low and Extreme Low Levels, chronic fluctuation below the Low Level is considered a stressed condition. For lakes without adopted levels, the evaluation of stressed condition is conducted on a case-by-case basis. Lake Bonnie is included on the most recent Stressed Lakes List (Gant 2007), based on the Guidance Levels previously adopted for the lake, and was also classified as a stressed lake from 1992 through 2006 (Gant 1999a, 1999b, 2000, 2002, 2003, 2004, 2005, 2006). Based on adoption of Minimum Levels for the lake in October 2007, Lake Bonnie will not be included in future Stressed Lakes List evaluations. Evaluation of water level fluctuations within the basin will instead be incorporated in annual determinations of compliance with adopted Minimum Levels.

Table 2. Previously adopted Guidance Levels and associated surface areas for Lake Bonnie.

Level	Elevation (feet above NGVD)	Lake Area (acres)
Ten Year Flood Guidance Level	113.30	26.2
High Level	113.00	25.0
Low Level	110.00	14.5
Extreme Low Level	108.00	13.3

Summary Data Used for Minimum and Guidance Levels Development

Currently adopted Minimum and Guidance Levels were developed for Lake Bonnie using the methodology for Category 3 lakes described in Chapter 40D-8, F.A.C. The levels and additional parameters are listed in Table 3, along with surface areas for each parameter elevation. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

Table 3. Minimum and Guidance Levels, lake stage percentiles, Normal Pool, Control Point elevation, and significant change standards and associated surface areas for Lake Bonnie.

Levels	Elevation (feet above NGVD)	Lake Area (acres)
Lake Stage Exceedance Percentiles		
Period of Record P10	108.3	13.5
Period of Record P50	105.3	12.0
Period of Record P90	102.5	2.9
Historic P10	105.9	12.2
Historic P50	102.2	2.1
Historic P90	99.8	0
Normal Pool and Control Point		
Normal Pool	114.8	32.1
Control Point	NA	NA
Significant Change Standards		
Basin Connectivity Standard	107.4	13.0
Species Richness Standard	102.1	1.9
Wetland Offset Elevation	101.4	0.7
Aesthetics Standard	99.8	0
Lake Mixing Standard	NA	NA
Cypress Standard	NA	NA
Recreation/Ski Standard	NA	NA
Dock-Use Standard	NA	NA
Minimum and Guidance Levels		
High Guidance Level	105.9	12.2
High Minimum Lake Level	105.8	12.2
Minimum Lake Level	102.1	1.9
Low Guidance Level	99.8	0

NA = not applicable

Lake Stage Data and Percentiles

Lake stage data, *i.e.,* surface water elevations, are available for Lake Bonnie (District Universal Identification Number STA 1185 4634) from the District Water Management Database for the period from October 2004 through June 2007 (Figure 18). The highest recorded water surface elevation for the lake, 109.28 feet above NGVD, was measured on November 8, 2005. Field observations by District staff, and historic aerial photography indicate that the lake has repeatedly dried, exposing lower portions of the basin, which occur at elevations ranging from 103 feet above NGVD down to approximately 99.8 feet above NGVD.

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 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 categorized as "Current" for periods when there were measurable, stable impacts due to water withdrawals, and impacts due to structural alterations were stable.

Based on water-use estimates and analysis of lake stage and regional ground water fluctuations, hydrologic data collected prior to the mid-1960s for many lakes in the Lake Wales Ridge area may be classified as Historic data, and data collected since that period may be classified as Current data (Ellison 2002). Available lake stage data for Lake Bonnie were, therefore, classified as Current data. However, the short period of record for the data limited its usefulness for characterization of water level fluctuation within the basin.

To approximate water level fluctuations for Lake Bonnie, a Historic composite sixty-year record of monthly mean lake surface elevations was developed and used to calculate Historic lake stage exceedance percentiles. The 60-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, Kelly 2004).

Modeled monthly mean lake stage values for the composite data set were developed using a linear fitting procedure known as the line or organic correlation (see Helsel and Hirsch 1992). The procedure was used initially to describe the linear relationship between available monthly mean lake stage data for Lake Bonnie and Crooked Lake (District Universal Identification Number STA 322 323), a large lake located about five miles south of Lake Bonnie in Polk County. This "initial" line of organic correlation equation was developed based on lake stage data collected from October 2004 through June 2007, and was used to estimate monthly water surface elevations for Lake Bonnie for the period from January 1946 through December 2005 (unpublished District data). A long-term data set of monthly mean water surface elevations for Lake Bonnie was then

created for the 1946-2005 period using the modeled water surface elevations and available lake stage records for the lake.

A second line of organic correlation equation was then developed to describe the relationship between monthly water surface elevations for Lake Bonnie derived from the initial regression analyses and regional rainfall, as measured at the Mountain Lake rainfall station (District Universal Identification Number RNF 280 280), a long-term rainfall gauging station about 3 miles northwest of Lake Bonnie in Polk County. The modeled lake stage data that were used for the second regression analyses were from the period prior to January 1965 and were assumed to be representative of Historic conditions, *i.e.,* reflective of a period when there were no measurable impacts due to water withdrawals, and impacts due to structural alterations were similar to existing conditions. Rainfall values used for the analysis consisted of weighted forty-eight month cumulative totals that were derived using a linear-decay series to weight monthly rainfall values for the forty-eight month periods. The line of organic correlation equation developed for the modeled lake stage and rainfall data collected from January 1946 through December 1964 was used to estimate water surface elevation values for Lake Bonnie for the period from January 1946 through December 2005 (unpublished District data). A Historic, composite data set of monthly mean water surface elevations for Lake Bonnie was then developed using the modeled water surface elevations derived from the initial and second regression analyses (Figure 19).

Based on the Historic composite data set, the Historic P10 elevation, which is the elevation the lake water surface equaled or exceeded ten percent of the time during the Historic period, was 105.9 feet above NGVD. The Historic P50, the water surface elevation that was equaled or exceeded fifty percent of the time during the Historic period, was 102.2 feet above NGVD. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 99.8 feet above NGVD. The Historic P10, P50 and P90 elevations are respectively 2.4, 3.1 and 2.7 feet lower than the corresponding period of record lake stage exceedance percentiles.

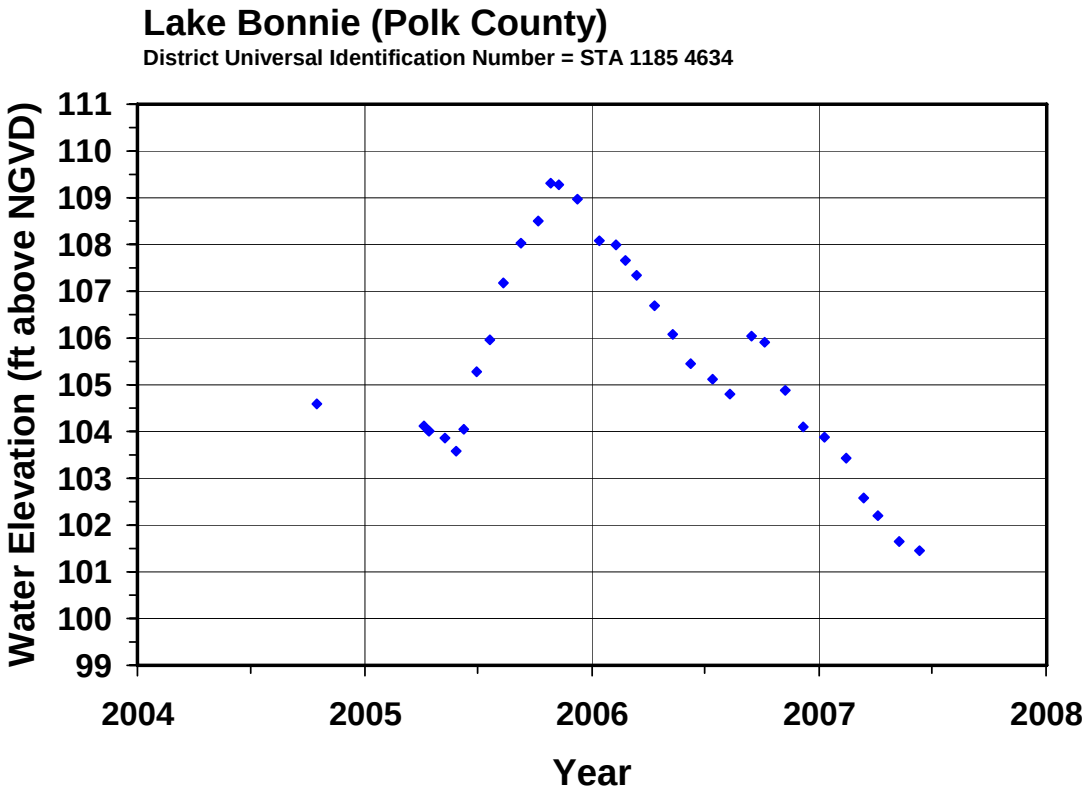


Figure 18. Measured water surface elevations in Lake Bonnie through June 2007.

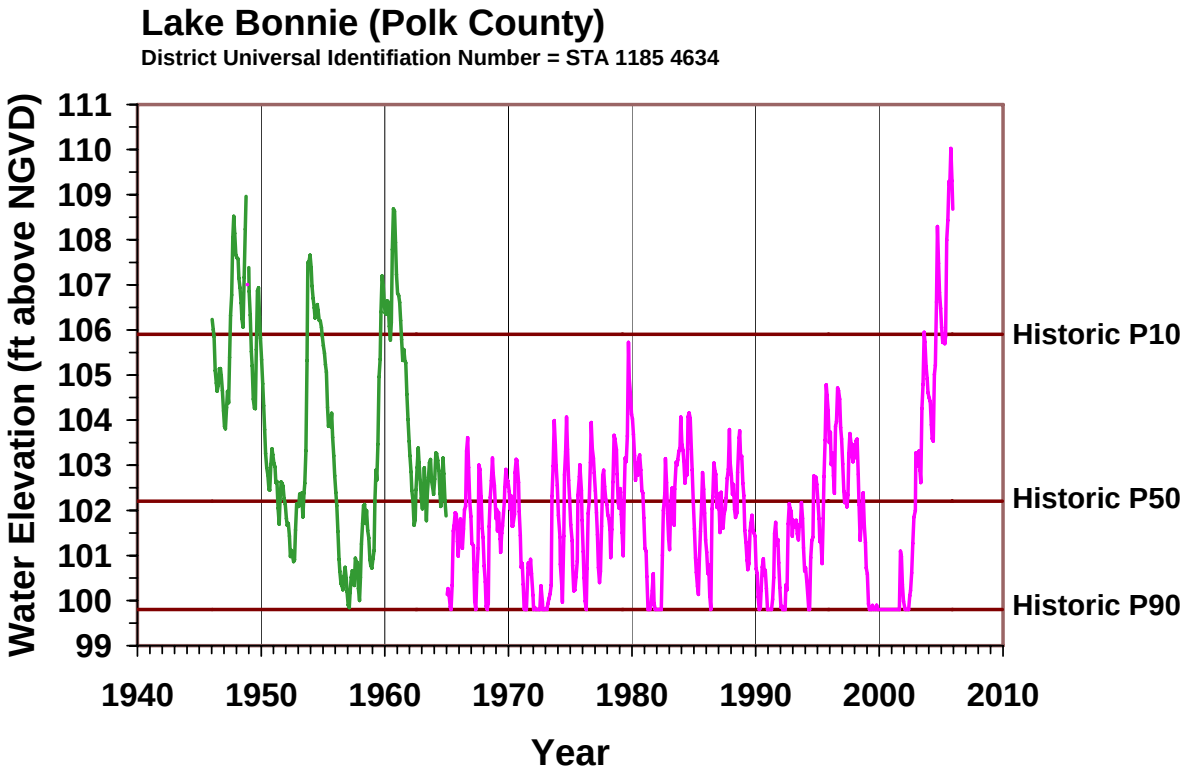


Figure 19. Historic composite monthly-mean water surface elevations for Lake Bonnie from January 1946 through December 2005, and Historic lake-stage exceedance percentiles. Composite data includes values based on water level (green) and rainfall (fuchsia) models. For graphing purposes, modeled water surface elevations were truncated at 99.8 feet above NGVD, the lowest ground elevation within the lake basin.

Normal Pool, Control Point Elevation and Determination of Structural Alteration Status

The Normal Pool elevation, a reference elevation used for development of minimum lake and wetland levels, is established using elevations of Hydrologic Indicators of sustained inundation, including biological and physical features. For development of Minimum Lake Levels, the Normal pool elevation is considered an approximation of the Historic P10. Based on ground elevations that were measured in March 2002 and October 2004 at the base of 19 saw palmetto (*Serenoa repens*) shrubs along the lake shoreline, the Normal Pool elevation for Lake Bonnie was established at 114.8 feet above NGVD (Figure 2, Table 4). The distribution of sand cordgrass (*Spartina bakeri*), a species that is commonly found along lake margins and in shallow inundated areas, at elevations higher than 113 feet above NGVD (unpublished District data) provided additional evidence of high-water levels in the lake basin. The palmetto and cordgrass indicators were, however, found to occur at much higher elevations than the seasonal high water table elevation of 102.4 feet above NGVD that was identified for the lake basin in 2004 in support of an Environmental Resource Permit concerning development of the surrounding uplands (see Southwest Florida Water Management District 2004b).

For development of Minimum and Guidance levels, lakes are classified as open or closed basin lakes. Open basin lakes are systems that are connected to, or are part of an ordered surface water conveyance system, *i.e*., they have outlets or inlets for conveyance of surface water. Closed basin lakes are those that are not part of an ordered conveyance system. Based on review of available survey data (Southern Cross Engineering, Inc. 1999, Southwest Florida Water Management District 1987, 2004d, 2005b) for the basin, Lake Bonnie was classified as a closed-basin lake.

The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system (*e.g.,* a weir, canal or culvert) that is the principal control of water level fluctuations in the lake. A Control Point may be established at the invert or crest elevation associated with a water control structure at a lake outlet, or at a high, stable point in a lake-outlet canal, ditch or wetland area. The invert or crest elevation is the lowest point on the portion of a water control structure that provides for conveyance of water across or through the structure. Because Lake Bonnie is a closed-basin lake, a Control Point elevation was not established.

Structural alteration status is determined to support development of the High Guidance Level. In addition to identification of outlet conveyance system modifications, comparison of the Control Point elevation with the Normal Pool is typically used to determine if a lake has been structurally altered. If the Control Point elevation is below the Normal Pool, the lake is classified as a structurally altered system. If the Control Point elevation is above the Normal Pool or the lake has no outlet, then the lake is not considered to be structurally altered. Although the Lake Bonnie basin has been modified from it's natural state (a stormwater system directs runoff into the basin and the sand ridges surrounding the basin are breached in numerous spots), based on available survey data and flood-stage frequency information (Southwest Florida Water

Management District 1992, Arnold 2004a, b, 2005), Lake Bonnie was determined not to be Structurally Altered.

Table 4. Summary statistics for hydrologic indicator measurements (ground elevations at the base of individual saw palmetto, *Serenoa repens*, shrubs) used for establishing the Normal Pool Elevation for Lake Bonnie. Elevations were measured by District staff in March 2003 and October 2004.

Hydrologic Indicator	Statistic	Statistic Value (N) or Elevation (feet above NGVD)
Base of saw palmetto shrubs	N	19
	Median	114.8
	Mean (SD)	114.6 (1.0)
	Minimum	113.1
	Maximum	117.3

Guidance Levels

The Ten Year Flood Guidance Level was developed as advisory information for lakeshore development and is the level of flooding expected on a frequency of not less than the ten-year recurring interval, or on a frequency of not greater than a ten percent probability of occurrence in any given year. The previously adopted Ten Year Flood Guidance Level for Lake Bonnie, 113.3 feet above NGVD, was developed in the early 1990s (Southwest Florida Water Management District 1992, 1996). Although the District does not plan to incorporate a new Ten Year Flood Guidance Level for Lake Bonnie into District rules, recent review of flood-recurrence levels for the lake indicates that the previously adopted Ten Year Flood Guidance Level NGVD could be modified. Based on a probability analysis of annual peak stages for a sixty-three year simulated water level record that was developed using the Hydrologic Simulation Program Fortran, the ten year flood recurrence level for Lake Bonnie was determined to be 108.7 feet above NGVD (Arnold 2004a, b, 2005).

In October 2007, the District Governing Board approved rule amendments to remove all adopted Ten Year Flood Guidance Levels from Chapter 40D-8, F.A.C. The intent of this action was not to discontinue development of regional and site-specific flood stage information, but rather to promote organizational efficiency by eliminating unnecessary rules. Flood stage levels continue to be developed under the District's Watershed Management Program, but ten year flood recurrence levels are not incorporated into Chapter 40D-8, F.A.C. In accordance with this policy, Chapter 40D-8, F.A.C. does not currently include a Ten Year Flood Guidance Level for Lake Bonnie.

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 and the normal pool elevation. Based on the availability of the composite Historic water level record for Lake Bonnie, the High Guidance Level was established at the Historic P10 elevation, 105.9 feet above NGVD.

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, and is established using Historic or Current data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate historic or current data are not available. These statistics represent differences between P10, P50 and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals (*i.e*., reference lakes). Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of the composite Historic water level record for Lake Bonnie, the Low Guidance Level was established at the Historic P90 elevation, 99.8 feet above NGVD.

Lake Classification

Lakes are classified as Category 1, 2 or 3 for the purpose of Minimum Levels development. Systems with fringing cypress wetlands greater than 0.5 acres in size where water levels regularly rise to an elevation expected to fully maintain the integrity of the wetlands (*i.e.,* the Historic P50 is not more than 1.8 feet below the Normal Pool elevation) are classified as Category 1 Lakes. Lakes with fringing cypress wetlands greater than 0.5 acres in size that have been structurally altered such that the Historic P50 is more than 1.8 feet below the Normal Pool elevation are classified as Category 2 Lakes. Lakes without fringing cypress wetlands or with less than 0.5 acres of fringing cypress wetlands are classified as Category 3 Lakes. Based on the lack of lake-fringing cypress wetlands within the lake-basin, Lake Bonnie was classified as a Category 3 lake.

Significant Change Standards and Other Information for Consideration

Lake-specific significant change standards and other available information are developed for establishing Minimum Levels. The standards are used to identify thresholds for preventing significant harm to cultural and natural system values associated with lake ecosystems, in accordance with guidance provided in the Florida Water Resources Implementation Rule (Chapter 62-40.473, F.A.C.). Other information

taken into consideration for Minimum Levels development includes potential changes in the coverage of herbaceous wetland and submersed aquatic plants.

For Category 1 or 2 lakes, a significant change standard is established at the elevation 1.8 feet below the Normal Pool elevation. This standard, operationally referred to as the Cypress Standard, is used to identify a desired median lake stage that may be expected to preserve the ecological integrity of lake-fringing cypress wetlands. Because Lake Bonnie is a Category 3 Lake, a Cypress Standard was not developed for the basin.

For Category 3 lakes, six significant change standards, including a Basin Connectivity Standard, a Species Richness Standard, an Aesthetics Standard, a Lake Mixing Standard, a Recreation/Ski Standard, and a Dock-Use Standard are developed. These standards identify desired median lake stages 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 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 region-specific reference lake water regime statistics. The Basin Connectivity Standard was established at 107.4 feet above NGVD, based on the elevation that ensures connectivity between the lake sub-basins (103.0 feet above NGVD), a two-foot water depth in the area of connectivity to allow for movement of boats between the sub-basins, and the 2.4 foot difference between the Historic P50 and Historic P90 elevations. Based on the Historic composite data record, the Basin Connectivity Standard was equaled or exceeded three percent of the time, *i.e*., the standard elevation corresponds to the Historic P03.

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. For Lake Bonnie, the Species Richness Standard was established at 102.1 feet above NGVD. Based on the Historic composite data record, the Species Richness Standard was equaled or exceeded fifty-two percent of the time, *i.e*., the standard elevation corresponds to the Historic P52.

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to limit potential change in 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, which for Lake Bonnie occurs at an elevation of 99.8 feet above NGVD. 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 period defined by the Historic composite data set.

The Lake Mixing Standard is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment resuspension. 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. Based on review of dynamic ratio values for lake stage elevations below the Historic P50 (*i.e.*, below 102.2 feet above NGVD, see Figure 20), a Lake Mixing Standard was not established for Lake Bonnie.

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 five-foot deep ski corridor delineated as a circular area with a radius of 418 feet, or a rectangular ski area 200 feet in width and 2,000 feet in length, and use of Historic lake stage data or region-specific reference lake water regime statistics. Based on the morphology of the basin, a Recreation/Ski Standard was not developed for Lake Bonnie.

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. Because there are no docks within the basin, a Dock-Use Standard was not developed for Lake Bonnie.

Herbaceous Wetland Information is taken into consideration to determine the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (*i.e*., basin area with a water depth of four or less feet). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also considered, based on water transparency values. Review of herbaceous wetland area in relation to change in lake stage did not indicate that use of any of the available significant change standards would be inappropriate for minimum levels development although it should be noted that use of the Aesthetics Standard would result in establishment of the Minimum Lake Level at the elevation of the lowest point within the lake basin. Changes in the area available for aquatic plant colonization associated with changes in lake stage could not be evaluated for Lake Bonnie due to the lack of water transparency information.

Because herbaceous wetlands are common within the Lake Bonnie basin, it was determined that an additional measure of wetland change should be considered for minimum levels development. Based on a recent review (Hancock 2006) of the development of minimum level methods for cypress-dominated wetlands, it was determined that up to an 0.8 foot decrease in the Historic P50 elevation would not likely

be associated with significant changes in the herbaceous wetlands occurring within lake basins. A Wetland Offset elevation of 101.4 feet above NGVD was therefore established for Lake Bonnie by subtracting 0.8 feet from the Historic P50 elevation. The standard elevation was equaled or exceeded sixty-eight percent of the time during the Historic period defined by the Historic composite data record, *i.e*., the standard elevation corresponds to the Historic P68.

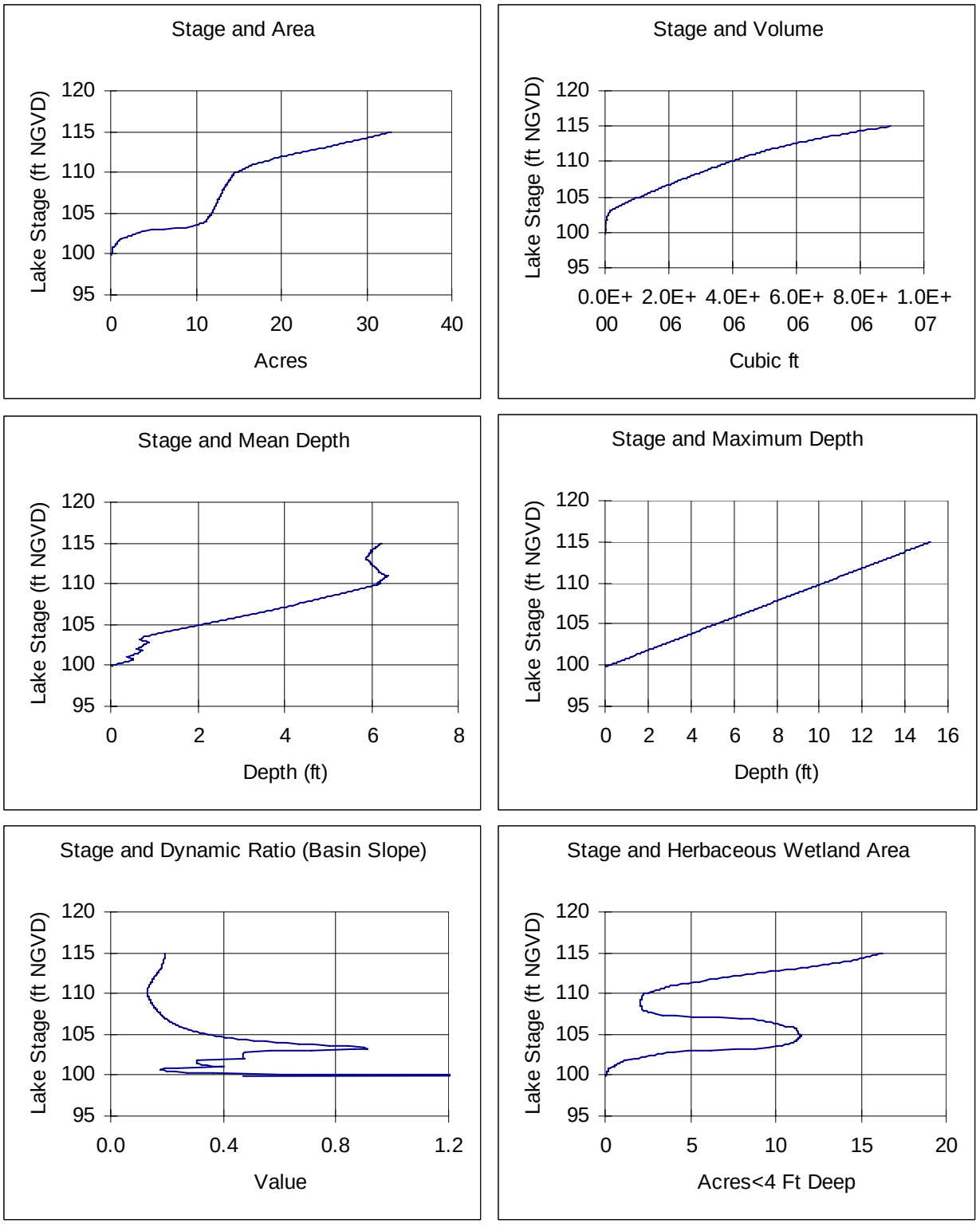


Figure 20. Lake Bonnie surface area, volume, mean depth, maximum depth, dynamic ratio (basin slope) and potential herbaceous wetland area versus lake stage.

Minimum Levels

Minimum Lake Levels, including the Minimum Lake Level and High Minimum Lake Level, are developed using specific lake-category significant change standards and other available information or unique factors, including: potential 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, 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 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, the Minimum Level may be 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 elevation, in which case, the Minimum Level is established at the Historic P50 elevation. Because the Basin Connectivity Standard for Lake Bonnie is higher than the Historic P50 elevation, the Minimum Level could have been established at the Historic P50 elevation, 102.2 feet above NGVD. However, because the Basin Connectivity Standard for the lake corresponds to the Historic P03 elevation, and because establishment of the Minimum Lake Level at the Historic P50 elevation would mean that any withdrawal impact, no matter how small, would not be permitted, it was determined that it would not be appropriate to use the Basin Connectivity Standard for establishing the Minimum Lake Level.

The Minimum Lake Level was, instead, established at the elevation corresponding to the Species Richness Standard (102.1 feet above NGVD), the highest of the other available significant change standards. Because the Species Richness Standard is higher than the other available significant change standards and the Wetland Offset elevation, it may be expected to be protective of lake values represented by the other standards, as well as the herbaceous wetlands within the basin. The 0.1-foot decrease in the median lake stage associated with use of the Species Richness Standard for development of the Minimum Lake Level (the standard elevation is 0.1 feet lower than the Historic P50) would also not be expected to significantly impact values associated with the Basin Connectivity Standard. Assuming a 0.1 foot reduction in water levels over the range of lake levels in the Historic composite water level record, the amount of time that the lake surface would have equaled or exceed the Basin Connectivity Standard would have been decreased by less than one percent, as compared to the time the standard was equaled or exceeded based on the unmodified Historic composite record.

The High Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. For 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. Based on the availability of the Historic composite water level record, the High Minimum Lake Level for Lake Bonnie was established at 105.8 feet above NGVD, by adding the 3.7 foot difference between the Historic P50 and Historic P10 elevations to the Minimum Lake Level.

The Minimum and Guidance levels for Lake Bonnie are shown in Figure 21 along with monthly mean water surface elevations based on period of record water level measurements. Staging of the lake at the Minimum Levels would not be expected to flood any man-made features within the immediate lake basin (see Figure 22 for the approximate lake margins when the water surface is at the Minimum Levels). Based on a 1987 one-foot contour interval aerial map for the region (Southwest Florida Water Management District 1987) and other available field-survey data, the High Minimum Lake Level is approximately 9.5 feet lower than the lowest residential building along the lakeshore and is approximately 7.2 feet lower than the lowest spot on the paved roads encircling the lake (Table 5).. The High Minimum Lake Level is also and about 5.7 feet lower than a concrete slab associated with a lift station in the southwest corner of the basin.

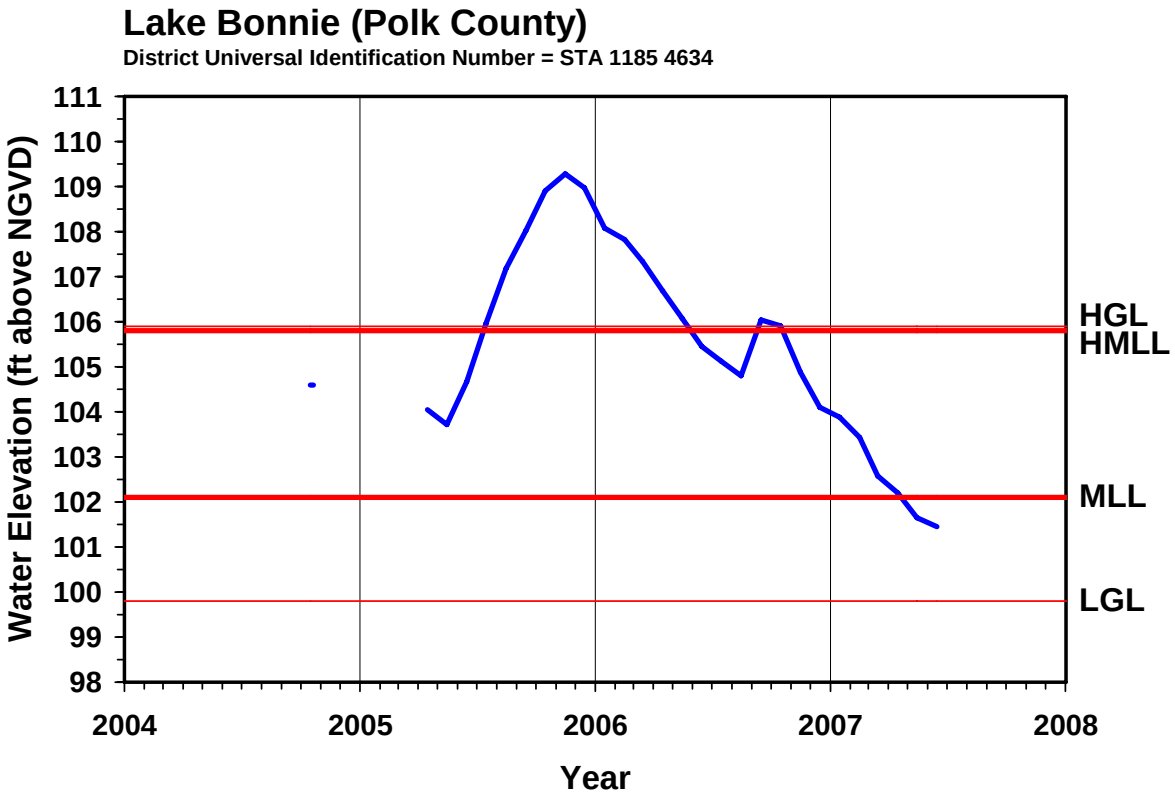


Figure 21. Mean monthly surface water elevation of Lake Bonnie through June 2007 based on measured lake stage records (blue line), and Guidance and Minimum Levels (red lines). Guidance and Minimum Levels include the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL) and Low Guidance Level (LGL).

Table 5. Elevations of selected man-made features occurring at relatively low elevations within the immediate Lake Bonnie basin.

Lake Basin Features	Elevation (feet above NGVD)
Low Road (Road)	113 – 114
Low Floor Slab (residential dwelling)	115.7
Low Floor Slab (attached screened room)	115.3
Low Other (lift station on concrete slab)	~111.5

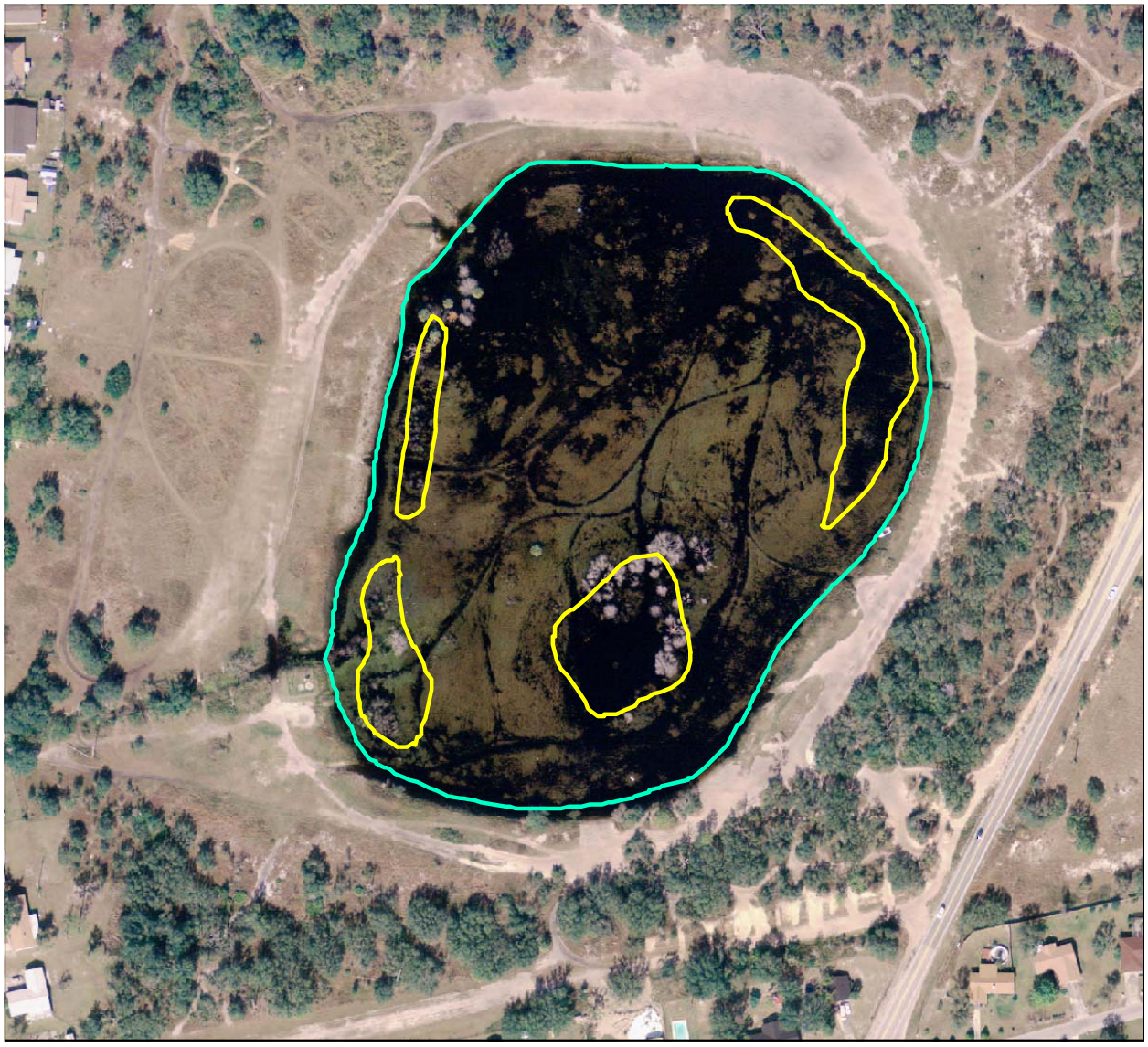


Figure 22. Approximate location of the Minimum Lake Level and High Minimum Lake Level for Lake Bonnie (photographic image source: 3001, Inc. 2006).

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