# Revised Minimum and Guidance Levels Based on Reevaluation of Levels Adopted for Lake Padgett in Pasco County, Florida

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Resource Evaluation Section
Water Resources Bureau

Southwest Florida Water Management District

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**Cover:** Lake Padgett shoreline on December 3, 2013 (Southwest Florida Water Management District files).

# Executive Summary

This report describes the development of revised minimum and guidance levels for Lake Padgett in Pasco County, Florida based on reevaluation of levels in District rules (Rule 40D-8.624, Florida Administrative Code; F.A.C.) that were adopted in December 2004. Following Board approval on June 23, 2015, the revised levels were adopted into rule on September 1, 2015 and became effective on September 21, 2015.

Minimum levels are the levels at which further water withdrawals would be significantly harmful to the water resources of the area (Section 373.042(1)(b), Florida Statutes; F.S.). Minimum levels adopted by the District for lakes, wetlands and aquifers, and minimum flows adopted for rivers, springs and estuaries are used to support water resource planning and permitting activities. Guidance levels are adopted for lakes and used as advisory guidelines for construction of lakeshore development, water dependent structures, and operation of water management structures.

Section 373.0421(3), F.S., requires the periodic reevaluation and, as needed, the revision of established minimum flows and levels (MFLs). Minimum levels for Lake Padgett were selected for reevaluation based on the recent development of modeling tools for simulating natural water level fluctuations in lake basins that were not available when the currently adopted levels for the lake were developed. The reevaluation of Minimum levels for Lake Padgett involved use of improved modeling methods, additional lake stage data, an updated normal pool evaluation and new MFLs status assessment tools. The reevaluation was also completed to support ongoing assessment of the status of minimum flows and levels water bodies and the need for additional recovery in the northern Tampa Bay Water Use Caution Area, a region of the District where strategies are being implemented to support recovery to MFLs thresholds. The revised levels summarized in this report for Lake Padgett represented necessary revisions to the previously adopted levels.

The revised levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (and as elevations in feet above the North American Vertical Datum of 1988), are listed in Table ES-1 along with descriptions for the levels included in District rules (Rule 40D-8.624, F.A.C). The revised Minimum Levels were developed using current District methods for establishing minimum levels for Category 1 Lakes, which are lakes that are contiguous with at least 0.5 acres of cypress-dominated wetlands. The revised Minimum Levels were also developed with consideration of and are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.).

The revised High Guidance Level and Low Guidance Level for Lake Padgett are respectively, 0.5 feet higher and 0.1 feet lower than the previously adopted guidance levels. These differences are associated with application of a new modeling approach for characterization of historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions.

The revised High Minimum Lake Level for Lake Padgett is 0.5 feet lower than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 0.9 feet lower than the previously adopted Minimum Lake Level. These differences are primarily due to differences in normal pool elevations that were previously and recently determined for the lake.

The revised minimum levels established for Lake Padgett are currently being met and are expected to be met for the next 20-year planning period.

**Table ES-1. Minimum and Guidance Levels for Lake Padgett and level descriptions**.

| Minimum and Guidance Levels | Elevation (feet above NGVD29[a]) | Elevation (feet above NAVD88[b]) | Level Descriptions |
|---|---|---|---|
| High Guidance Level | 71.0 | 70.2 | Advisory guideline for construction of lake shore development, water dependent structures, and operation of water management structures. The High Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ten percent of the time on a long-term basis. |
| High Minimum Lake Level | 70.0 | 69.2 | Elevation that a lake's water levels are required to equal or exceed ten percent of the time on a long-term basis. |
| Minimum Lake Level | 68.6 | 67.8 | Elevation that the lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. |
| Low Guidance Level | 68.3 | 67.5 | 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. |

[a] National Geodetic Vertical Datum of 1929
[b] North American Vertical Datum of 1988

# Acknowledgements

The authors would like to thank a number of other District staff for supporting completion of this report. Jason Patterson completed an assessment of groundwater withdrawal impacts on Lake Padgett. Richard Gant, Keith Kolasa and David Carr assisted with field work for the project. Christina Uranowski and Ron Basso offered constructive comments on earlier versions of the project report.

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# Introduction

## Reevaluation of Minimum Flows and Levels

This report describes the development of revised minimum and guidance levels for Lake Padgett in Pasco County, Florida. The levels were developed based on the reevaluation of minimum and guidance levels approved by the Southwest Florida Water Management District Governing Board for the lake in August 2004 and adopted into District rules in December 2004 (see Leeper 2003, Appendix A). The revised minimum and guidance levels represented necessary revisions to the currently adopted levels.

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

Following Board approval on June 23, 2015, the revised levels were adopted into rule on September 1, 2015 and became effective on September 21, 2015.

## Minimum Flows and Levels Program Overview

### Legal Directives

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

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

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

The Florida Water Resource Implementation Rule, specifically Rule 62-40.473, Florida Administrative Code (F.A.C.), provides additional guidance for the establishment of MFLs, requiring that "…consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including: a) Recreation in and on the water; b) Fish and wildlife habitats and the passage of fish; c) estuarine resources; d) Transfer of detrital material; e) Maintenance of freshwater storage and supply; f) Aesthetic and scenic attributes; g) Filtration and absorption of nutrients and other pollutants; h) Sediment loads; i) Water quality; and j) Navigation."

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

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

### *Programmatic Description and Major Assumptions*

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

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

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

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

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

### *Consideration of Changes and Structural Alterations and Environmental Values*

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

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

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

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

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

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

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

**Table 1. Environmental values identified in the state Water Resource Implementation Rule for consideration when establishing minimum flows and levels and associated significant change standards and other information used by the District for consideration of the environmental values.**

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

NA[1] = Not applicable for consideration for most priority lakes;

NA[2] = Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

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

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

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

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

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

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

# Lake Setting and Description

## Location

Lake Padgett is located in the census-designated place of Land O' Lakes, Florida within south-central Pasco County in the Tampa Bay Planning Region of the Southwest Florida Water Management District (Figure1). The lake extends into portions of Sections 24 and 25, Township 26 South, Range 18 East and is generally centered around 28°12'14'' latitude and -82°27'31" longitude (Figure 2).

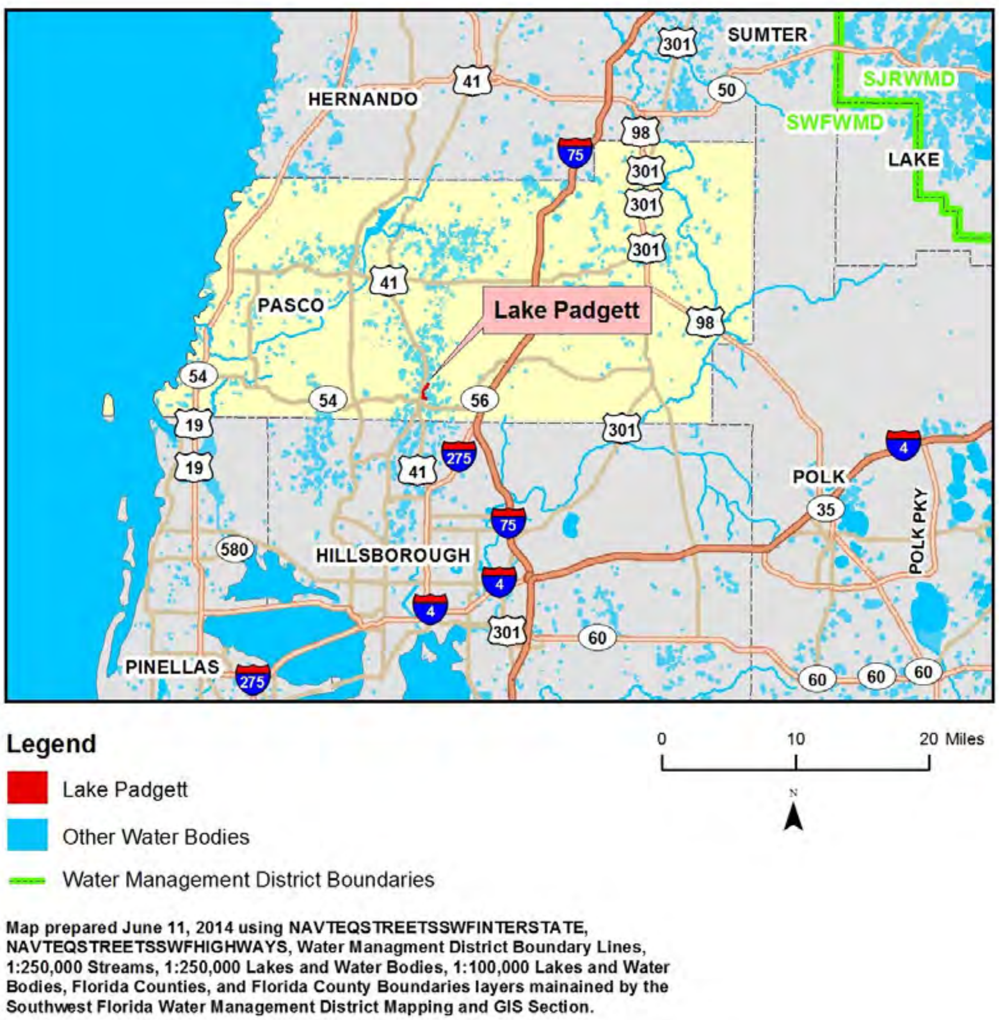



**Figure 1. Location of Lake Padgett in Pasco County, Florida within the Southwest Florida Water Management District (SWFWMD). A portion of the boundary between the SWFWMD and the St. Johns River Water Management (SJRWMD) is also shown.**

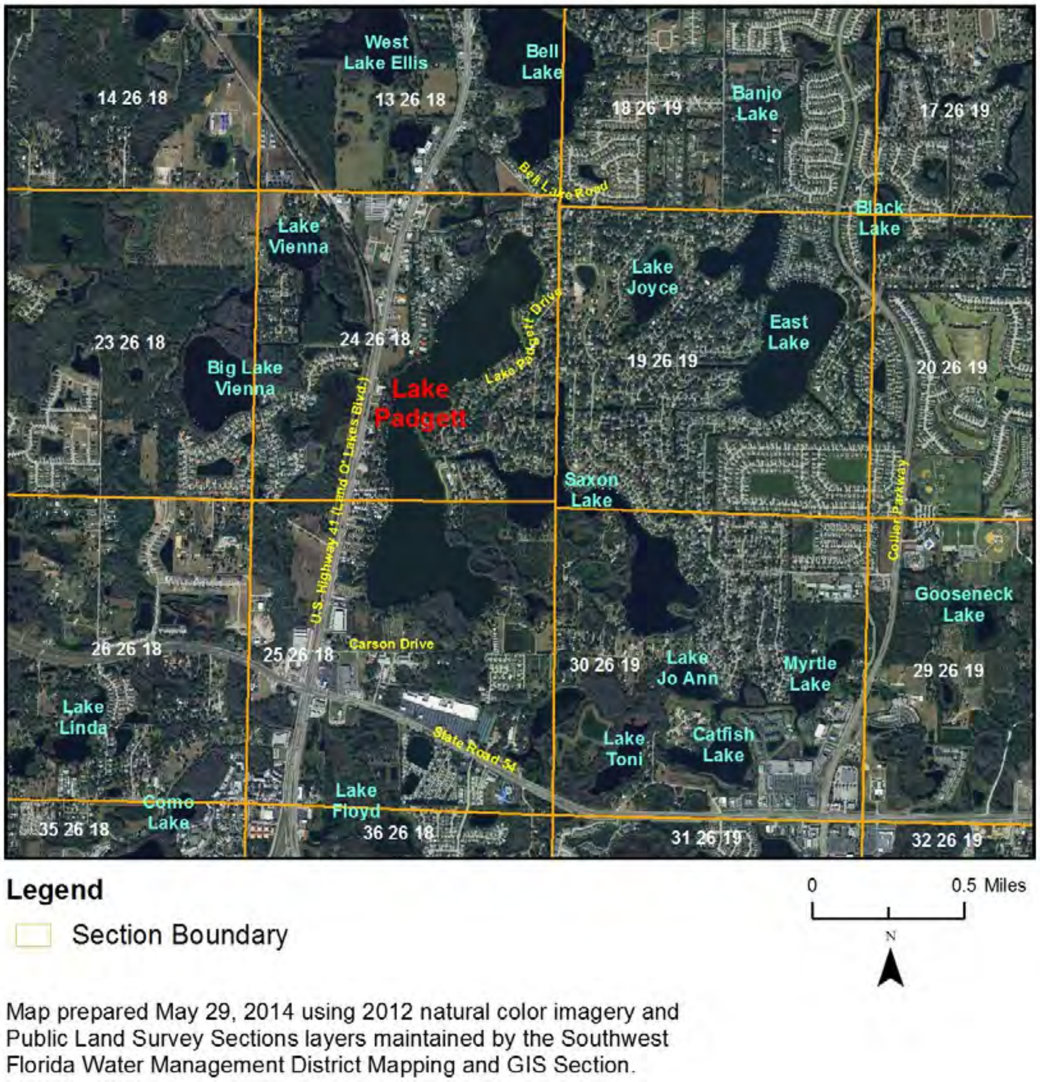



**Figure 2. Lake Padgett, other nearby lakes, roads and gridded Public Land Survey sections labeled with numeric section, township (south) and range (east) information.**

## Physiography and Hydrogeology

White (1970) classified the region of west-central Florida containing Lake Padgett as the Northern Gulf Coastal Lowlands physiographic region. Brooks (1981) categorized the area around and including the lake as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District, and described the region as a “plain with elevations ranging between 50 and 80 feet that contains numerous small lakes overlying moderately thick limestone with karst features. As part of the Florida Department of Environmental Protection’s Lake Bioassessment/ Regionalization Initiative, the area has also been identified as the Land-O-Lakes lake region and described as an area of neutral to slightly alkaline, low to moderate nutrient, clear-water lakes interspersed in sandy uplands (Griffith *et al.* 1997).

The hydrogeology of the area includes a surficial sand aquifer system, a discontinuous, intermediate clay confining unit, the thick carbonate Upper Floridan aquifer (UFA) and the lower Floridan aquifer (LFA). The surficial aquifer system is generally a few tens of feet thick and overlies the limestone of the UFA, which averages nearly 1,000 feet in thickness within the area (Miller 1986). The Hawthorn Group clay lies between the surficial aquifer and the LFA and varies from a few feet to as much as 25 feet in thickness. Because this clay confining unit is breached by buried karst features and has previously been exposed to erosional processes, preferential pathways locally connect the overlying surficial aquifer to the UFA, resulting in moderate-to-high leakage to the UFA (SWFWMD 1996). The UFA in the vicinity of Lake Padgett may therefore be characterized as a leaky artesian aquifer system. The base of the UFA generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit, which is generally referred to as middle confining unit II, is regionally extensive and separates the UFA from the Lower Floridan aquifer (Miller 1986).

## Bathymetry and Basin/Watershed Description and History

The "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969, Shafer *et al.* 1986) lists the size of Lake Padgett as 200 acres. A topographic map of the basin generated in support of minimum levels development (Figure 3) indicates that the lake extends over 183.2 acres when the water surface is at the elevation of 69 feet above NGVD29 included on the 1974 (photorevised 1987) United States (U.S.) Geological Survey 1:24,000 Lutz, Fla. quadrangle map. At this elevation, mean and maximum water depths in the lake are 9.3 and 29.4 feet, respectively. Additional morphometric or bathymetric information for the lake basin is discussed in the Methods, Results and Discussion section of this report and is also available in Henderson (1983) and Florida Lakewatch (2005).

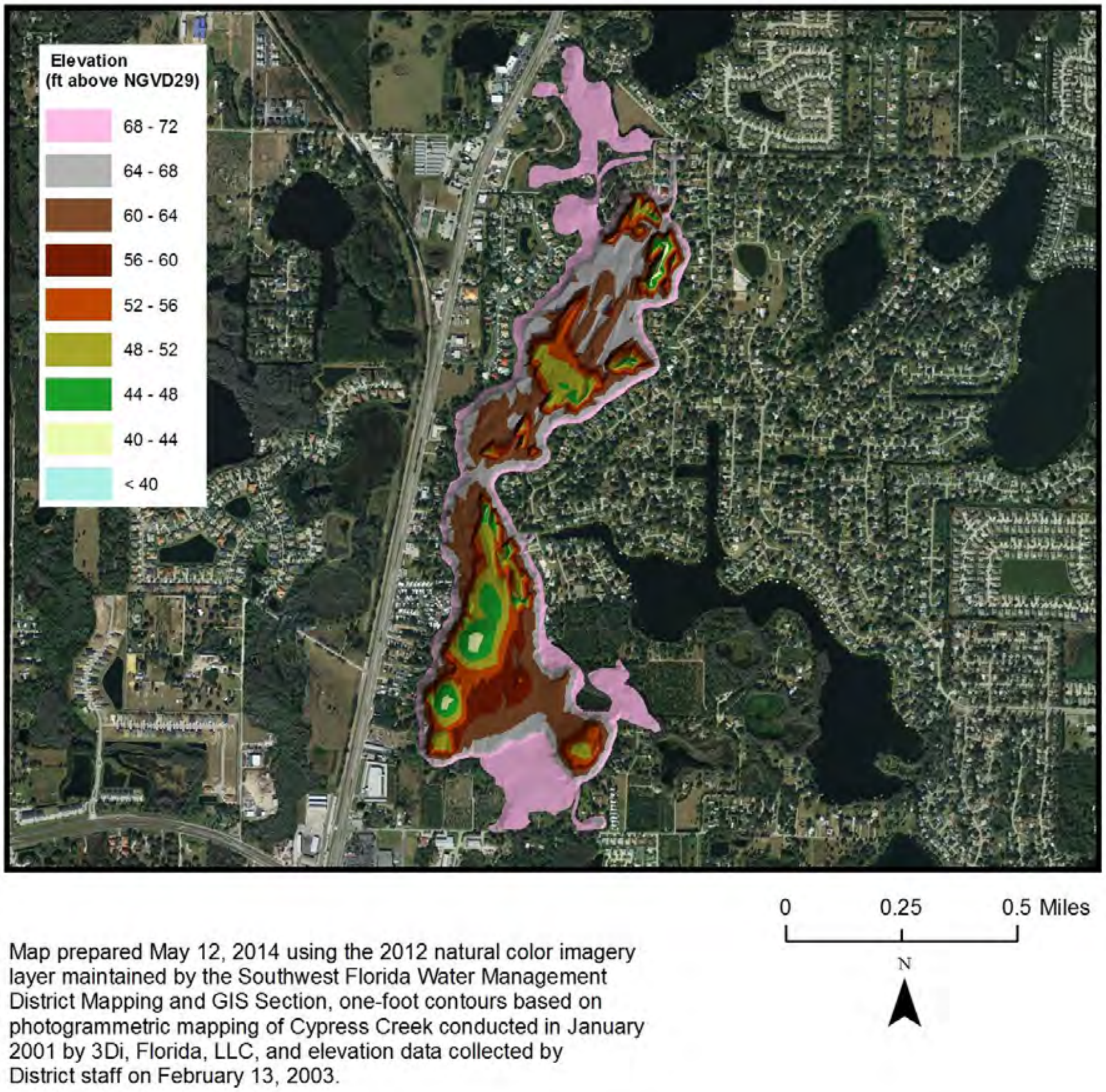



**Figure 3. Land/lake-bottom elevations within the immediate Lake Padgett basin from the deepest portion of the basin up to an elevation of 72 feet above NGVD29.**

The Lake Padgett basin/watershed has been extensively altered as a result of drainage modifications, agricultural activities, including citrus production and livestock grazing or pastureland use, and residential/urban development. Agricultural activities and constructed roads are evident in the immediate lake basin in aerial photographs from the 1930s through current times (Figures 4 through 9). Henderson (1983) reports that a canal/culvert system connecting Lake Saxon and Lake Padgett was constructed in association with the accelerated residential development that started around 1967. Aerial photographs from the 1970s and 1984 illustrate changes that were made to the outlet canal at the southeast margin of the lake (Figures 8 and 9). Residential and commercial development currently encircles most of the lake. Public access to the lake is limited, although the Lake Padgett Estates Civic Homeowners Association maintains a park and boat ramp along the lake's eastern shore.

Based on review the Florida Land Use, Cover and Forms Classification System (FLUCCS) layer maintained by the District Mapping and GIS Section, most of the land in the vicinity of Lake Padgett may be classified as Urban and Built Up (data not shown). However, substantial wetlands areas remain within the immediate lake basin along the southeastern and northwestern margins of the lake (Figure 10). Common obligate or facultative wet (as defined by Rule 62-340.200, F.A.C.) trees include cypress (*Taxodium* sp.) and red maple (*Acer rubrum*). Common shrubs and herbaceous wetland/aquatic plants include hydrilla (*Hydrilla verticillata*), cattail (*Typha* sp.), pickerelweed (*Pontederia cordata*), spatterdock (*Nuphar luteum*), maidencaine (*Panicum hemitomon*), pennywort (*Hydrocotyle umbellata*), eelgrass (*Vallisneria* sp.), wax myrtle (*Myrica cerifera*), swamp fern (*Blechnum serrulatum*) and other ferns

The lake lies within the Lake Hanna Outlet drainage basin in the Hillsborough River watershed, as delineated for the U.S. Geological Survey Hydrologic Unit Classification system (Figure 11). The drainage basin is also known as Thirteen-Mile Run and ultimately discharges to Cypress Creek, a tributary of the Hillsborough River, which drains into Tampa Bay. The District maintains a number of water control structures within or adjacent to the Lake Hanna Outlet drainage basin, downstream from Lakes Kell, Keene, Hanna and Stemper.

The drainage area for Lake Padgett (including upstream lake basins) has been reported at 6.6 square miles (USGS 1966, Florida Board of Conservation 1969, Foose (1981) and ~5.4 square miles by Henderson (1983). The immediate sub-basin around the lake extends over 482 acres (Parsons 2011) to 489 acres (SWFWMD GIS layer), or approximately 0.75 square miles. Surface water inputs to the lake include direct precipitation on the lake surface, runoff from immediately adjacent upland areas, inflow from Bell Lake to the north, Saxon Lake to the east, and to a lesser extent from an unnamed pond northwest of the lake on the west side of U.S. Highway 41 (Figure12).

Seven oval concrete culverts adjacent to wetland areas along the southeastern lakeshore provide conveyance from the lake under Carson Drive, and ultimately, through additional wetlands and lakes, to Cypress Creek. The culverts are approximately 1.7 feet high x 2.5 feet wide, 32 or 33 feet in length, and may be grouped into two sets; a “western” set of five culverts located adjacent to a forested wetland along the south shore of the lake and an “eastern” set of two culverts located at the southern terminus of an outlet canal along the southeastern lakeshore (Figure 13). The invert or flowline elevations for the western culverts range from approximately 68.1 to 69.3 feet above NGVD, based on a District survey completed in 2003 (Southwest Florida Water Management District 2003). Surveyed invert elevations at the high ends of the eastern culverts are reported as 68.6 and 68.7 feet above NGVD29 in the survey, which also identified an elevation of 68.7 feet above NGVD29 for a high spot in a ditched area of conveyance through the wetland south of Carson Drive. Field observations from 2009 suggest that the flowline elevation for the eastern set of culverts may be higher than the invert elevations reported for the ends of the culverts. The flowline appears to be located at higher areas in the culverts under Carson Road associated with angled positioning of the multiple pipes that comprise each culvert, and was estimated at 69.0 to 69.2 feet above NGVD29 (Arnold 2009). Flow through both of the eastern culverts was observed during a site visit in January 2014 (see Figure 13), when the water surface elevation at the lake gage was 68.98 feet above NGVD29 (personal observation) and no higher controlling elevations between the lake and the culverts were identified.

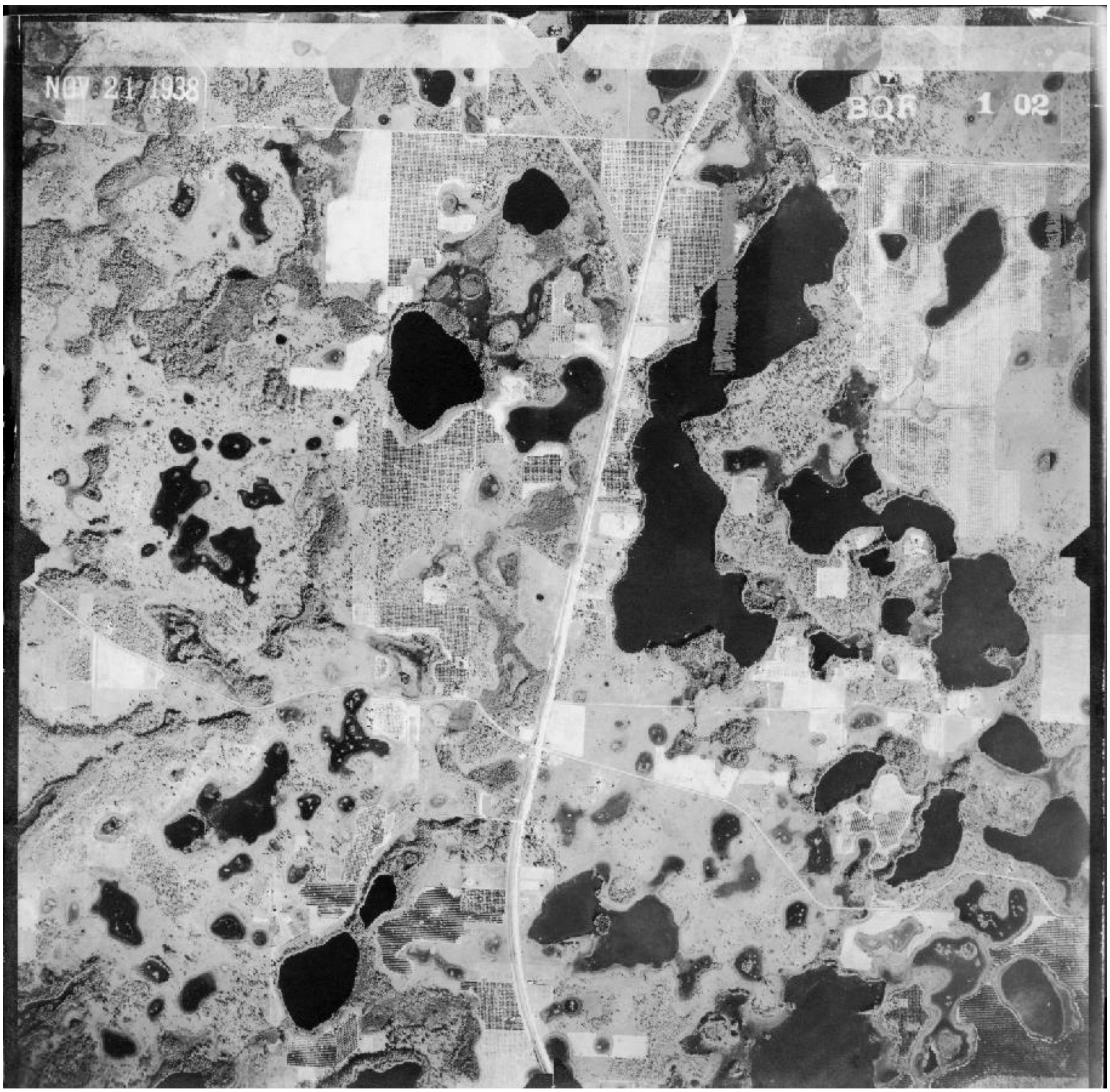



**Figure 4. Aerial photograph of Lake Padgett in 1938 (United States Department of Agriculture 1938). Note the anomalous shaded band in the northern portion of the lake and on the adjacent northwestern shoreline area.**

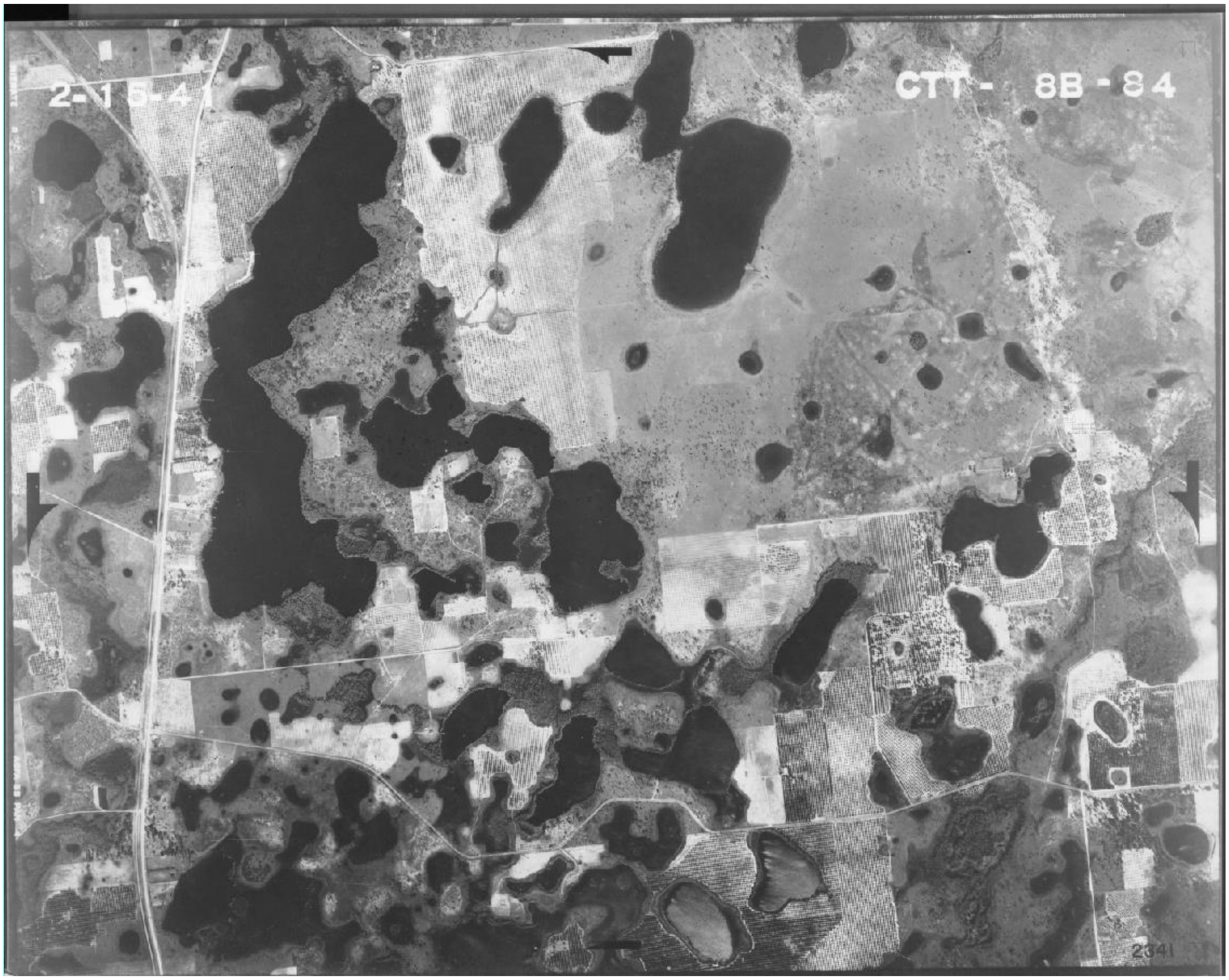



**Figure 5. Aerial photograph of Lake Padgett in 1941 (United States Department of Agriculture 1941b).**

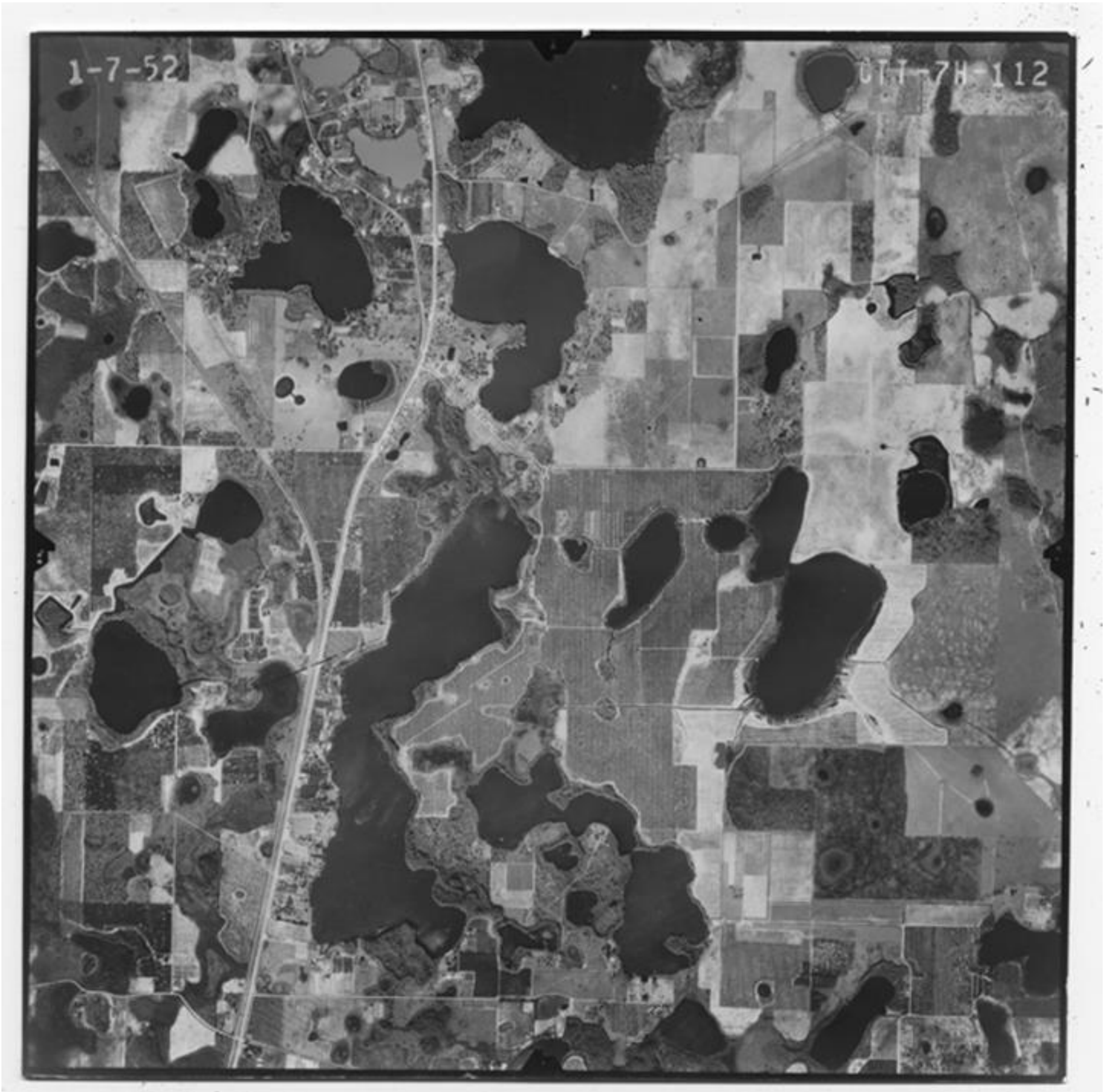



**Figure 6. Aerial photographs of Lake Padgett in 1952 (United States Department of Agriculture 1952b).**


**Figure 7. Aerial photographs of Lake Padgett in 1957 (United States Department of Agriculture 1957a).**


**Figure 8. Aerial photograph of Lake Padgett in the 1970s.**

Map prepared May 25, 2014 using the1984 NHAP 1.5M Color Infrafred Aerial Photography layer maintained by the Southwest Florida Water Management District Mapping and GIS Section.

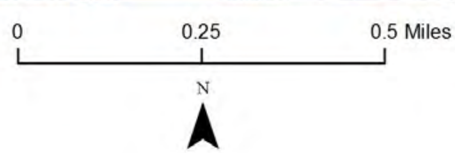
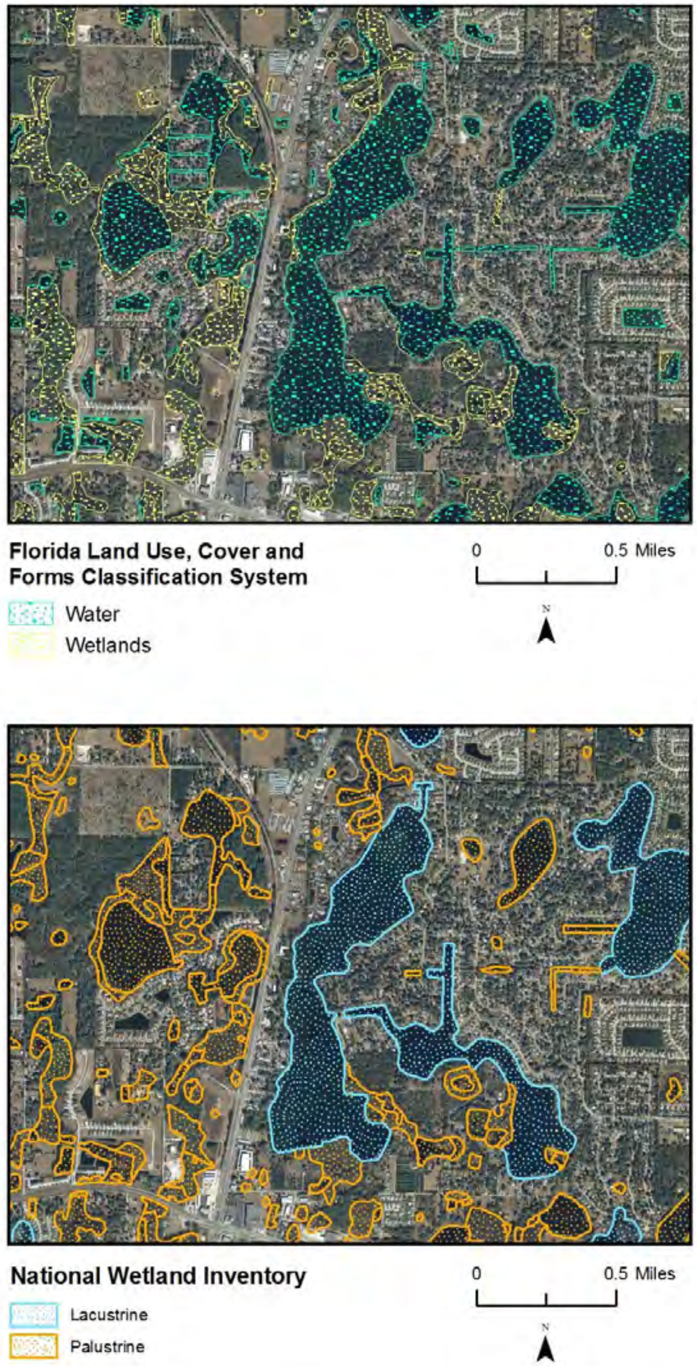



**Figure 9. Aerial photograph of Lake Padgett in 1984 based on United States Geological Survey National High Altitude Photography (NHAP).**




Maps prepared May 12, 2014 using 2011 natural color imagery (both panels) LULUC2010 (upper panel), and SDECREATOR.NATIONAL WETLANDSINVENTOR (lower panel) layers maintained by the Southwest Florida Water Management District Mapping and GIS Section.

**Figure 10. Lake and wetland areas in the Lake Padgett vicinity based on 2010 Florida Land Use, Cover and Forms Classification System Classification data (upper panel) and 2000 National Wetland Inventory information (lower panel).**

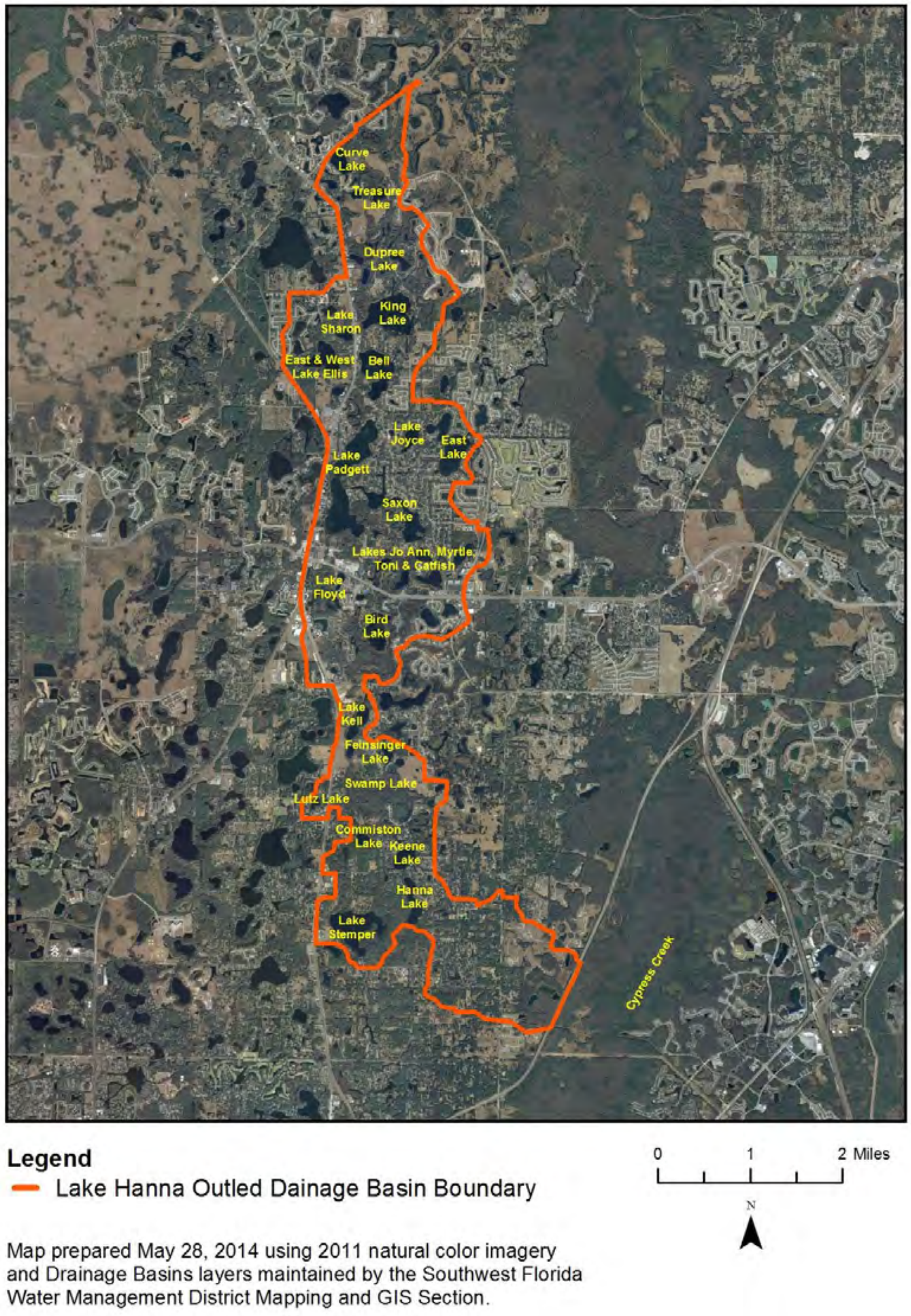



**Figure 11. Lake Hanna Outlet Drainage Basin, which contains Lake Padgett, as delineated in 2004 by the Florida Department of Environmental Protection based on U.S. Geological Survey 1:24,000 quadrangle maps and the Survey's Hydrologic Unit Classification coding system.**

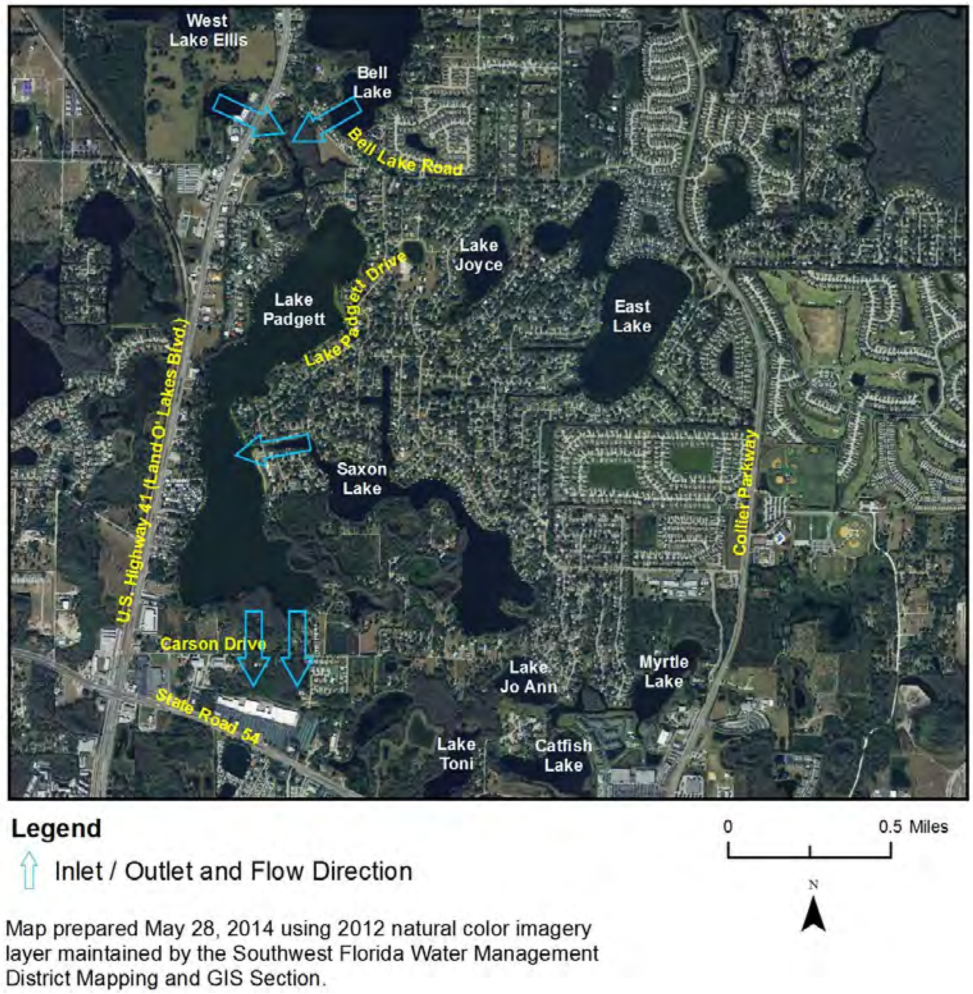



**Figure 12. Lake Padgett surface water inlets and outlets.**

**Figure 13. Northern, upstream ends (left panel) and southern, downstream ends (right panel) of two culverts at the Lake Padgett outlet at Carson Drive on January 24, 2013 (District files).**

## Hydrology

### *Climate and Rainfall*

The climate of west-central Florida, where Lake Padgett occurs, may be characterized as humid subtropical, with warm wet summers and mild winter conditions. Local weather patterns are strongly influenced by the Gulf of Mexico, which moderates winter and summer temperatures. Daily temperatures average about 72° Fahrenheit (F) on an annual basis and typically range from 49° F in January to 91° F in July and August, based on summary information reported for three National Weather Service stations within the Hillsborough River Basin (SWFWMD 1999c).

Area-weighted regional records tabulated by the District using NEXRAD (Next-Generation Radar) and other data obtained from the National Weather Service indicate that annual rainfall in Pasco County ranged from 31.3 to 75.7 inches and averaged 53.9 inches for the 99-year period from 1915 through 2013 (Figure 14, upper panel). On an annual basis, rainfall for this period was typically highest during the months of June through September (Figure 14, lower panel), likely as a result of the significant rainfall events that may be associated with convective and tropical storms that occur during these wet-season months. Evapotranspiration for the area has been reported at approximately 39 inches per year (Hutchinson 1984) and annual evaporation rates of 47 to 59 inches are reported for shallow, central Florida lakes (*e.g.,* see Henderson 1983, Schiffer 1998, Swancar *et al.* 2000, Metz and Sacks 2003). Cherry *et al.* (1970) note that evaporation in the region is highest in May and June, prior to and during the early phase of the summer wet season.

No statistically significant linear trend is evident for the 99-year Pasco County rainfall record, based on ordinary least squares regression analysis. Shorter-term trends are, however, apparent in the record, especially when annual values are aggregated as moving-average values (see Figure 14, upper panel). A plot of annual departure from the long-term average annual rainfall in Pasco County provides another means for identifying periods of above or below average area rainfall. Many years in the 1940s, for example, were relatively wet, as was the four-year period from 1957 through 1960, during which annual average rainfall ranged up to 21.8 inches above the long-term average (Figure 15). Below-average annual rainfall has been common in Pasco County during many of the past twenty-five years (1989 through 2013) (Figure 15).

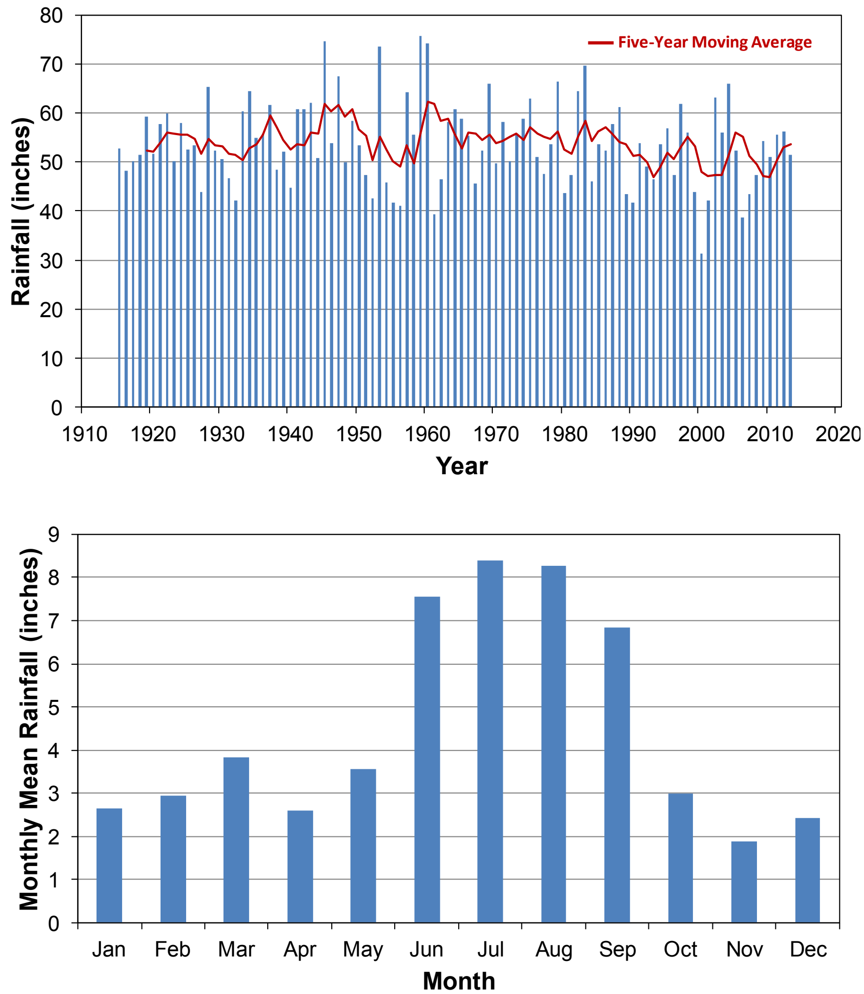



**Figure 14. Area-weighted annual (upper panel) and monthly mean (lower panel) rainfall for Pasco County between 1915 and 2013 (data source: Southwest Florida Water Management District Rainfall Data Summaries web page at http://www.swfwmd.state.fl.us/data/hydrologic/rainfall_data_summaries.**

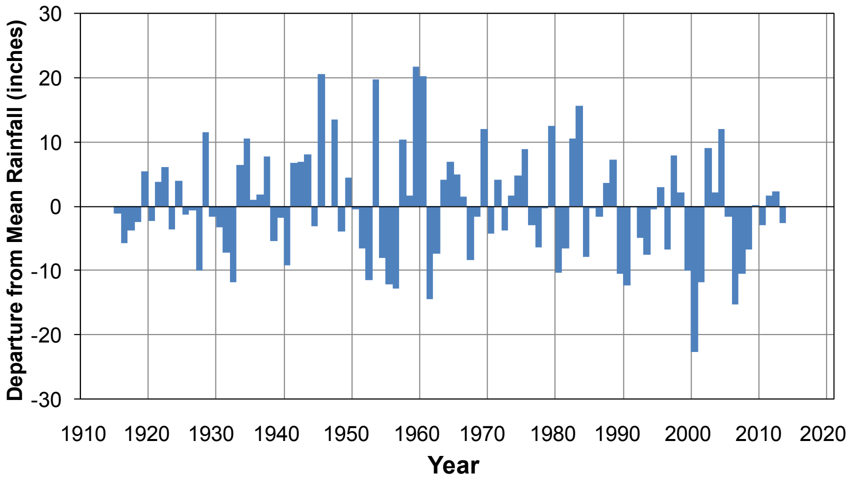



**Figure 15. Annual departure from the mean annual rainfall of 54.0 inches for Pasco County from 1915 through 2013 (data source: same as for Figure 14).**

### *Water Level (Lake Stage) Record*

Daily lake stage data, i.e., surface water elevations are available for Lake Padgett from the District Water Management Information System for the period from January 6, 1965 through the present time. These data were observed, i.e., measured by the U.S. Geological Survey and the District at a site along the western lakeshore identified as Lake Padgett near Lutz (SID 19127) and by the District at a second site on the northwestern lakeshore identified as Lake Padgett (SWFMWD) (SID 19130) (Figure 16). Data were collected at site SID 19127 from January 6, 1965 through August 23, 2004 and from July 8, 1985 through the present time at site SID 19130. Comparison of these records show good agreement for the period of overlapping data collection.

The available daily stage record, from January 6, 1965 through March 30, 2015 (Figure 17), is not continuous for either site. The record for site 19127 includes a period in the latter half of the 1960s when water surface elevation records were especially sparse; within this period, records from November 1966 through September 1969 collected by the U.S. Geological Survey were previously, but are no longer stored in the District Water Management Information System. However, because the data were used and published in an earlier U.S. Geological Survey study on Lake Padgett (Henderson 1983) and represent conditions prior to initiation of ground water withdrawals at the nearby South Pasco Wellfield, the District is continuing the use of this data for this study.

The highest surface water elevation for the lake in the record, 71.90 feet above NGVD29, occurred on September 9, 1988. This elevation is lower than a peak flood elevation of 73.6 feet above NGVD29 reported for October 1, 1960 by the Florida Department of Transportation (Florida Department of Transportation 1961). The low of record, 66.27 feet above NGVD29, was recorded on June 18, 2001.


**Figure 16. Locations of the current (SID or Site Identification Number19130) and former (SID19127) water-level gage sites in Lake Padgett.**

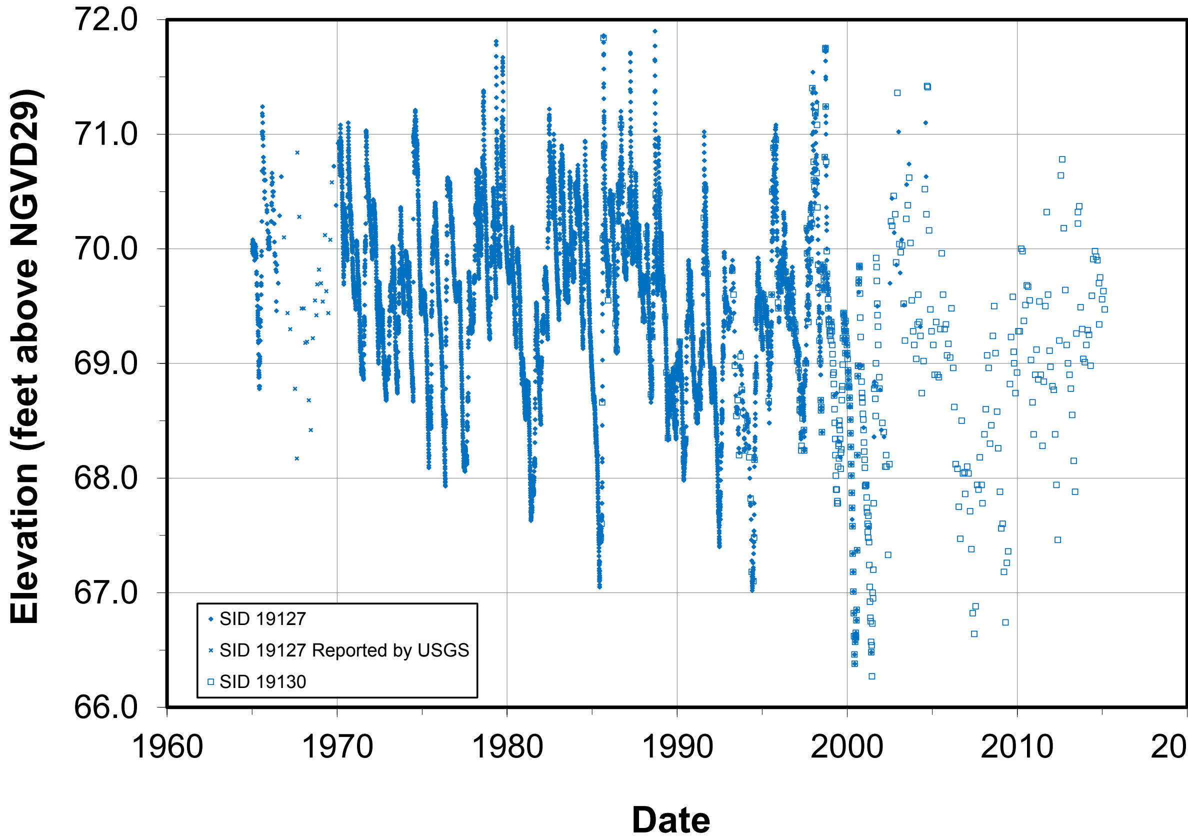



**Figure 17. Observed water surface elevations for Lake Padgett from January 6, 1965 through March 30 23, 2015 at two gauge sites (SID 191927 and SID 19130), including records from the late 1960s for SID 19127 that were reported by the U.S. Geological Survey (USGS) but are not currently included in in the District Water Management Information System.**

### *Water Use in the Lake Area and Evaluation of Withdrawal Impacts*

Surface water withdrawals from Lake Padgett may have occurred historically, and there may be small withdrawals from the lake that fall below District permitting thresholds, but there are currently no permitted surface withdrawals at the lake. There are, however, numerous permitted groundwater withdrawals in the area that may affect Lake Padgett water levels (Figure 18).

Some of these withdrawals are part of eleven public water supply wellfields collectively referred to as the Central System Facilities. The Central System Facilities are operated by the regional water supplier Tampa Bay Water and include wellfields in Pasco, northeastern Pinellas and northern Hillsborough counties (see Figures 19 and 20). In the early 1930's the first facility wellfield, the Cosme-Odessa Wellfield, which is located in Hillsborough County 9 miles southwest of Lake Padgett, began operation. In the late 1950s and during subsequent decades, additional wellfields that comprise the current Central System Facilities became operational. The South Pasco Wellfield, located 2.5

miles southwest of Lake Padgett, is the closest Central System Facility to the lake. Production at South Pasco Wellfield began in 1973. Combined withdrawals for all facility wellfields peaked at 210.8 million gallons per day (mgd) in May 2000 and averaged 153.5 mgd during the five years from 1997 through 2001, but has decreased markedly since then, averaging less than 90 mgd on an annual basis since 2008.

An analysis of water use based on metered and estimated quantities (SWFWMD 2013) for all water users in the area indicates that mean monthly water use within 1, 2, and 3 miles of Lake Padgett was 0.2, 1.0 and 1.5 mgd, respectively, for the 20-year period from 1992 through 2011 (Figure 21). Mean monthly water use for the same period increased to 13, 72.6 and 192.0 mgd, respectively at distances within 5, 10 and 20 miles from the lake. For comparative purposes, total withdrawals for the Central System Facilities averaged 121.9 mgd from 1992 through 2011.

As summarized in the Tampa Bay Planning Region portion of the District Water Management Plan (SWFWD 2011), investigations of interactions between water use, other factors and the water resources of the northern Tampa Bay area have been completed by the District and many others during the past half century. Much of this work, in particular the information compiled for the District's water resource assessment project for the area (e.g., see SWFWMD 1996b), contributed to the 1989 establishment and 2007 expansion of the Northern Tampa Bay Water Use Caution Area (NTBWUCA), which includes Pinellas County, a northern portion of Hillsborough County and Pasco County, where Lake Padgett is located (refer to Figure 19). Water Use Caution Areas are areas where "…regional action is necessary to address cumulative water withdrawals that are causing or may cause adverse impacts to the water and related land resources or the public interest…" (Rule 40D-2.801, F.A.C.).

In an effort to address and better manage regional resource concerns, the District issued a consolidated water use permit to Tampa Bay Water in December 1998 for withdrawals at the Central System Facilities, entered with Tampa Bay Water and its member governments into what was referred to as the Partnership Agreement, and adopted MFLs for a number of lakes, wetlands and aquifers in the Northern Tampa Bay Region. The Partnership Agreement included a phased reduction in annual average groundwater pumping from 158 mgd to 90 mgd at the Central System Facilities by 2008. In accordance with the agreement, the District developed a recovery strategy for the northern Tampa Bay area and adopted a regulatory portion of the strategy into District rules (Chapter 40D-80, F.A.C.) that became effective in 2000 and were in place through 2010, when the Partnership Agreement expired.

Implementation of the original Northern Tampa Bay area recovery strategy contributed to increasing water levels and flows and improving the condition of many wetlands, lakes, streams, springs and aquifer levels, but the need for additional recovery of some systems remained. To address this need, the District adopted a second phase of the area recovery strategy in 2010. This second recovery phase is referred to as the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area Recovery and Prevention Strategy, or simply the

“Comprehensive Plan.” The Comprehensive Plan addresses recovery of MFLs water bodies and avoidance and mitigation of unacceptable adverse impacts to wetlands, lakes streams springs and aquifer levels associated with Central System Facilities and other area facilities, which are collectively referred to in rule as the “90 MGD Facilities” (Rule 40D-80.873, F.A.C.). Adoption of the second phase of the area recovery plan was followed in January 2011 by renewal of the consolidated permit addressing withdrawals from the Central System Facilities by Tampa Bay Water through January 2021.

Continued implementation of the Comprehensive Plan has resulted in a dramatic reduction in total groundwater withdrawals from Tampa Bay Water’s wellfield network. To compensate for the required reductions in groundwater withdrawals at the Central System Facilities, increased reliance has been placed on surface water withdrawals and a sea-water desalination facility for water supply. In keeping with the intent of the Comprehensive Plan, Tampa Bay Water now obtains surface water supplies from the Tampa Bypass Canal, the Hillsborough and Alafia Rivers, and maintains and operates a 25 mgd capacity seawater desalination plant on the eastern shore of Tampa Bay.

As part of the development of methods for establishing minimum lake levels, the Southwest Florida Water Management District (1999a) evaluated effects of groundwater withdrawals at the wellfields now known as the Central System Facilities on water levels in northern Tampa Bay area lakes. The analyses included development of hydrologic statistics referred to as Reference Lake Water Regime Statistics that could be used to characterize water level fluctuations for withdrawal-impacted lakes that could be expected in the absence of existing withdrawal effects. Through consideration of measured Floridan aquifer water levels, evaluation of drawdowns in the potentiometric surface of the aquifer associated with wellfield withdrawals and modeled with the Integrated Northern Tampa Bay Groundwater Flow Model (SWFWMD 1993), and comparison of area lake water level hydrographs relative to distances from lakes known to be affected by the wellfield withdrawals, Lake Padgett was identified as one of the reference lakes used for development of the Northern Tampa Bay Reference Lake Water Regime Statistics. Results from the analyses indicated Lake Padgett and the other identified reference lakes were minimally affected by groundwater withdrawals. This finding of minimal withdrawal impact on lake levels was later used by the District during development of the currently adopted minimum and guidance levels for Lake Padgett (SWFWMD 2003).

Recent simulations developed by the District using the Integrated Northern Tampa Bay (INTB) model, a new more advanced numerical groundwater flow model (Geurink, 2013), suggest that regional groundwater withdrawals contribute to drawdown in the surficial and Upper Floridan aquifers in the vicinity of Lake Padgett (Patterson 2014; included as Appendix B). Comparison of simulated groundwater levels within the INTB model domain based on average withdrawals that occurred from 1989 through 2000 (239.4 mgd) with groundwater levels based on a simulation with all groundwater pumping eliminated indicated that withdrawals lower Surficial Aquifer water levels 1.2 feet and UFA water levels 2.2 feet in the vicinity of Lake Padgett.

However, statistical modeling of Lake Padgett water levels and area rainfall as described in the Classification of Lake Stage Data and Development of Exceedance Percentiles section of this report and in Ellison (2016), which is included as Appendix C to this report, indicates that water level fluctuations in the lake are closely associated with rainfall variation, confirming the earlier District finding that impacts from groundwater withdrawals are minimal for most of the period of record at Lake Padgett.

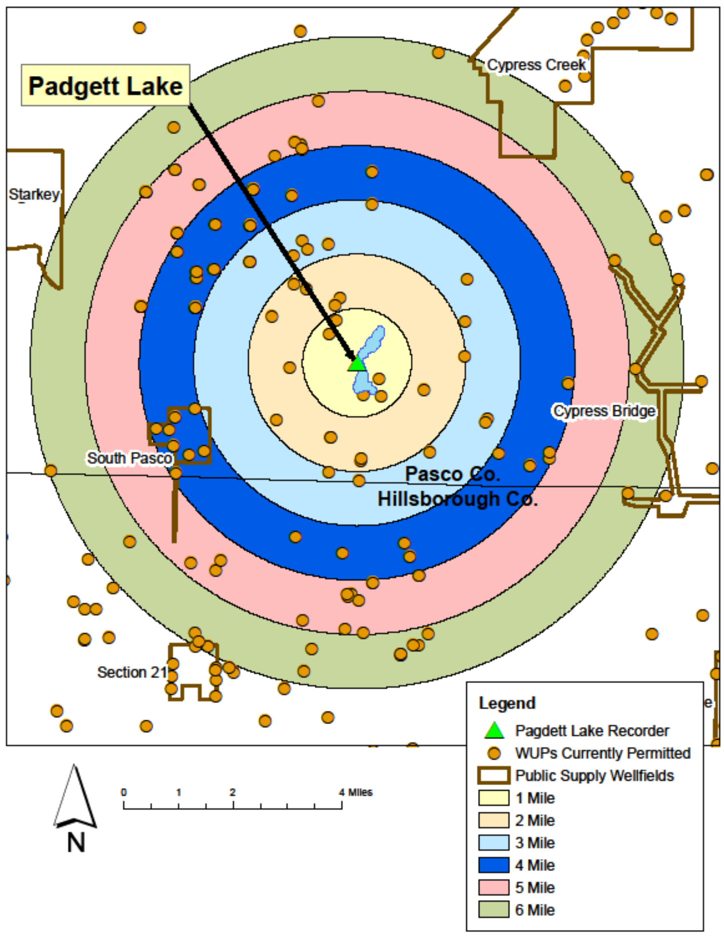



**Figure 18. Permitted water use permit (WUP) withdrawal sites within one to six miles of Lake Padgett. Central System Facility wellfields (Public Supply Wellfields) near the lake are also shown.**

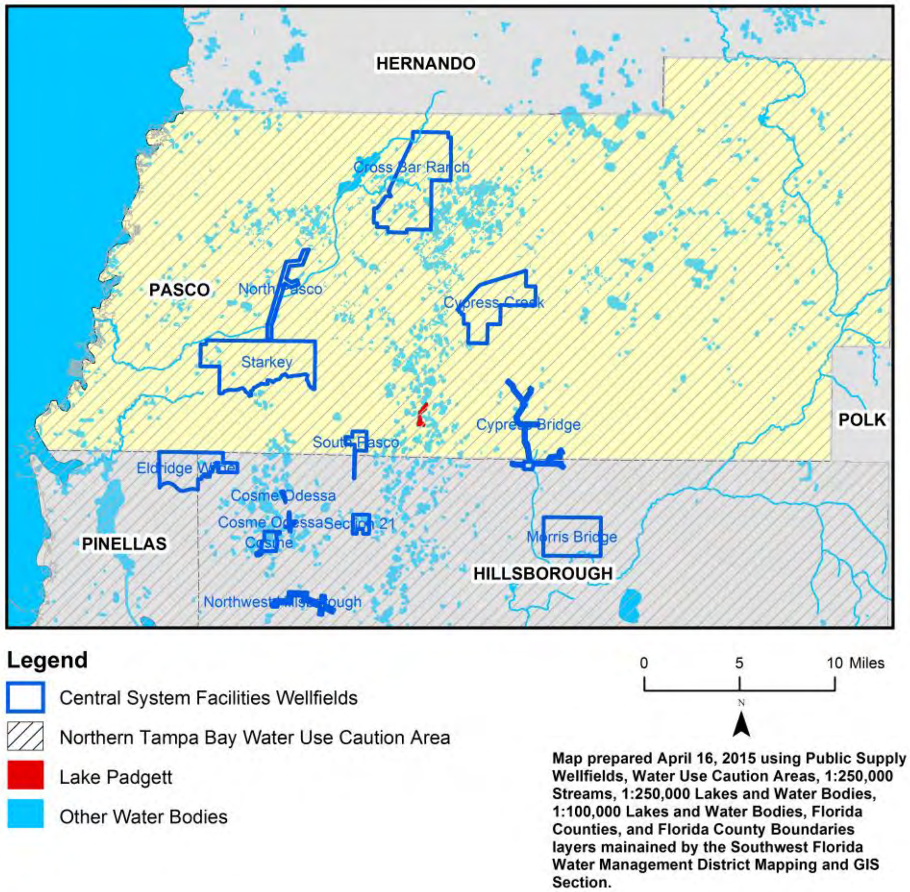



**Figure 19. Location of Tampa Bay Water's Central System Facilities wellfields, Northern Tampa Bay Water Use Ca**

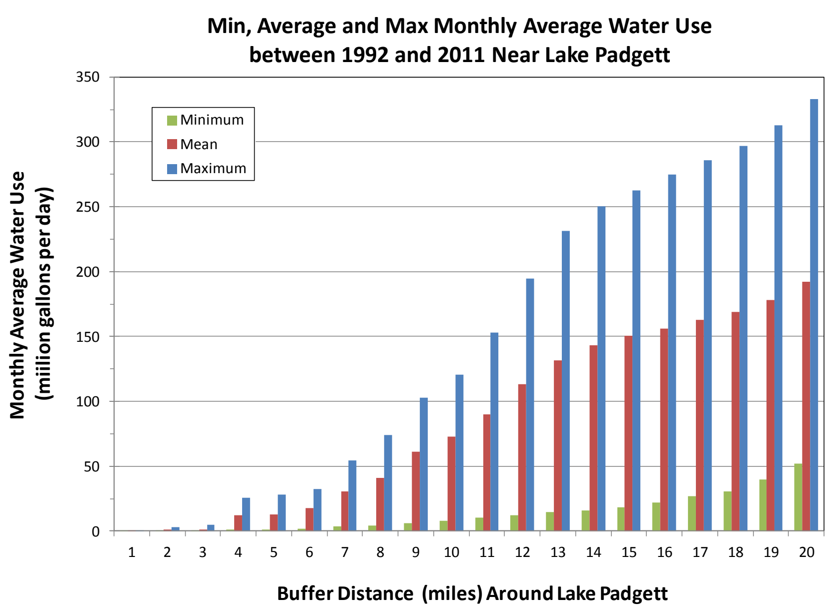



**Figure 20. Minimum, mean and maximum monthly average water use, i.e., groundwater withdrawals, for the period from 1992 through 2011 within one to 20 miles of Lake Padgett.**

## Historical Management Levels and Previously 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 establishing management levels based on hydrologic, biological, physical and cultural aspects of lake ecosystems. By 1996, management levels for nearly 400 lakes had been adopted into District rules.

Based on work conducted in the 1980s (see SWFWMD 1996a), the District adopted management levels, including minimum and flood levels, for Lake Padgett in April 1985 (Table 2) and incorporated the levels into its Water Levels and Rates of Flow Rules (Chapter 40D-8, F.A.C.). As part of the work leading to the adoption of management levels, a Maximum Desirable Level of 70.75 feet above mean sea level was also developed for the lake, but was not adopted by rule.

Based on changes to sections of the Florida Statutes that address minimum flows and levels in 1996 and 1997, and the development of new approaches for establishing MFLs, District Water Levels and Rates of Flow rules were modified in 2000. The modifications included incorporation of rule language addressing MFLs development and the renaming of established levels as Guidance Levels, as indicated for Lake Padgett in Table 2. Subsequent revisions to District rules incorporated additional rule language associated with developing minimum lake levels.

Based on the approaches for establishing MFLs developed in the late 1990s and early 2000s, the District adopted recommended Guidance and Minimum Levels for Lake Padgett (Leeper 2003) into its Water Levels and Rates of Flow rules in December 2004 (Table 3), and removed the previously adopted management levels for the lake from District rules. A Ten Year Flood Guidance Level of 71.5 feet above NGVD that was adopted for the lake along with the other levels in December 2004 was subsequently removed from Chapter 40D-8, F.A.C., in 2007, when the Governing Board determined that flood-stage elevations should not be included in the District's Water Levels and Rates of Flow rules. In April 2010, The Governing Board approved preliminary Flood Insurance Rate Maps (FIRMs) for the Cypress Creek watershed in Pasco County and authorized staff to submit the FIRMs to the Federal Emergency Management Agency (FEMA). The FIRMS were based on work reported in part within Parsons (2006, 2007, 2010 and 2011) and include a 100-year, three-day storm event flood elevation of 71.52 feet above NAVD88 (or ~72.34 feet above NGVD29) for Lake Padgett. Modeling for a 100-year, 24-hour storm event has yielded peak stage values of 71.36 ft above NAVD88 (Parsons 2010) and 71.33 feet above NAVD88 (Interflow Engineering, LLC 2011) for the lake.

Ongoing development of methods for establishing MFLs has led the District to develop and adopt the revised Minimum and Guidance Levels for Lake Padgett identified in this report. These revised levels have been incorporated into rule and replaced those listed in Table 3.

**Table 2. Management levels adopted for Lake Padgett in 1985 and renamed as Guidance Levels in 2000.**

| Management Levels (as originally adopted) | Guidance Levels (as renamed in 2000) | Elevation (feet above Mean Sea Level) |
|---|---|---|
| Ten (10) Year Flood Warning Level | Ten Year Flood Guidance Level | 71.34 |
| Minimum Flood Level | High Level | 71.25 |
| Minimum Low Management Level | Low Level | 69.00 |
| Minimum Extreme Low Management Level | Extreme Low Level | 67.50 |

**Table 3. Previously adopted Minimum and Guidance Levels for Lake Padgett that were adopted in 2004 and replaced in 2015 with the revised levels identified in this report.**

| Minimum and Guidance Levels | Elevation (feet above NGVD29) |
|---|---|
| High Guidance Level | 70.5 |
| High Minimum Lake Level | 70.5 |
| Minimum Lake Level | 69.5 |
| Low Guidance Level | 68.4 |

# Methods, Results and Discussion

## Summary Data Used for Minimum and Guidance Levels Development

Revised Minimum and Guidance Levels were developed for Lake Padgett using the methodology for Category 1 lakes described in Chapter 40D-8, F.A.C.  The levels along with lake surface area for each level are listed in Table 4 along with other information used for development of the revised levels. Detailed descriptions of the development and use of these data are provided in subsequent sections of this report.

**Table 4. Revised Minimum and Guidance Levels, lake stage exceedance percentiles, Normal Pool, Control Point elevation, significant change standards and associated surface areas for Lake Padgett.**

| | Elevation (feet above NGVD29) | Lake Area (acres) |
|---|---|---|
| **Lake Stage Exceedance Percentiles** | | |
| Historic P10[a] | 71.0 | 231 |
| Historic P50[a] | 69.6 | 194 |
| Historic P90[a] | 68.3 | 175 |
| Period of Record P10 | 70.5 | 218 |
| Period of Record P50 | 69.6 | 194 |
| Period of Record P90 | 68.5 | 177 |
| **Normal Pool and Control Point** | | |
| Normal Pool | 70.4 | 216 |
| Control Point | 68.7 - 69.0[b] | 178 |
| **Significant Change Standards** | | |
| Cypress Standard | 68.6 | 177 |
| Dock-Use Standard[c] | 70.0 | 206 |
| Wetland Offset[c] | 68.8 | 179 |
| Aesthetic Standard[c] | 68.3 | 175 |
| Basin Connectivity Standard[c] | 67.8 | 171 |
| Species Richness Standard[c] | 67.1 | 165 |
| Recreation/Ski Standard[c] | 62.2 | 96 |
| Lake Mixing Standard[c] | NA | NA |
| **Revised Guidance and Minimum Levels** | | |
| High Guidance Level | 71.0 | 231 |
| High Minimum Lake Level | 70.0 | 206 |
| Minimum Lake Level | 68.6 | 177 |
| Low Guidance Level | 68.3 | 175 |

[a] Based on a composite Historic water level that includes measured and modeled values.
[b] Approximated control point elevation range based on survey data and filed observations.
[c] Developed for comparative purposes only; not used to establish revised Minimum Levels for Lake Padgett.

## Bathymetry

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

Stage-area-volume relationships were determined for Lake Padgett by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. The DEM, represented as a triangulated irregular network (TIN) (refer to Figure 3), was created with ESRI® ArcMap™ version 10.1 software based on spot elevation data collected from inundated lake areas with an LEI HS-WSPK transducer (operating frequency = 192kHz, cone angle = 20°) mounted to a boat hull, a Lowrance LMS-350A sonar-based depth finder and the Trimble GPS Pathfinder Pro XR/Mapping System (Pro XR GPS Receiver, Integrated GPS/MSK Beacon Antenna, TDC1 Asset Surveyor™ and Pathfinder Office™ software). One-foot contour lines of the immediate area surrounding the lake developed by 3DI, Holy Hill, FL for the Cypress Lakes Aerial Mapping Project were also used for TIN development.

Lake stage-area-volume estimates were derived from the TIN using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments (selected stage-area-volume results are presented in Figure 21).

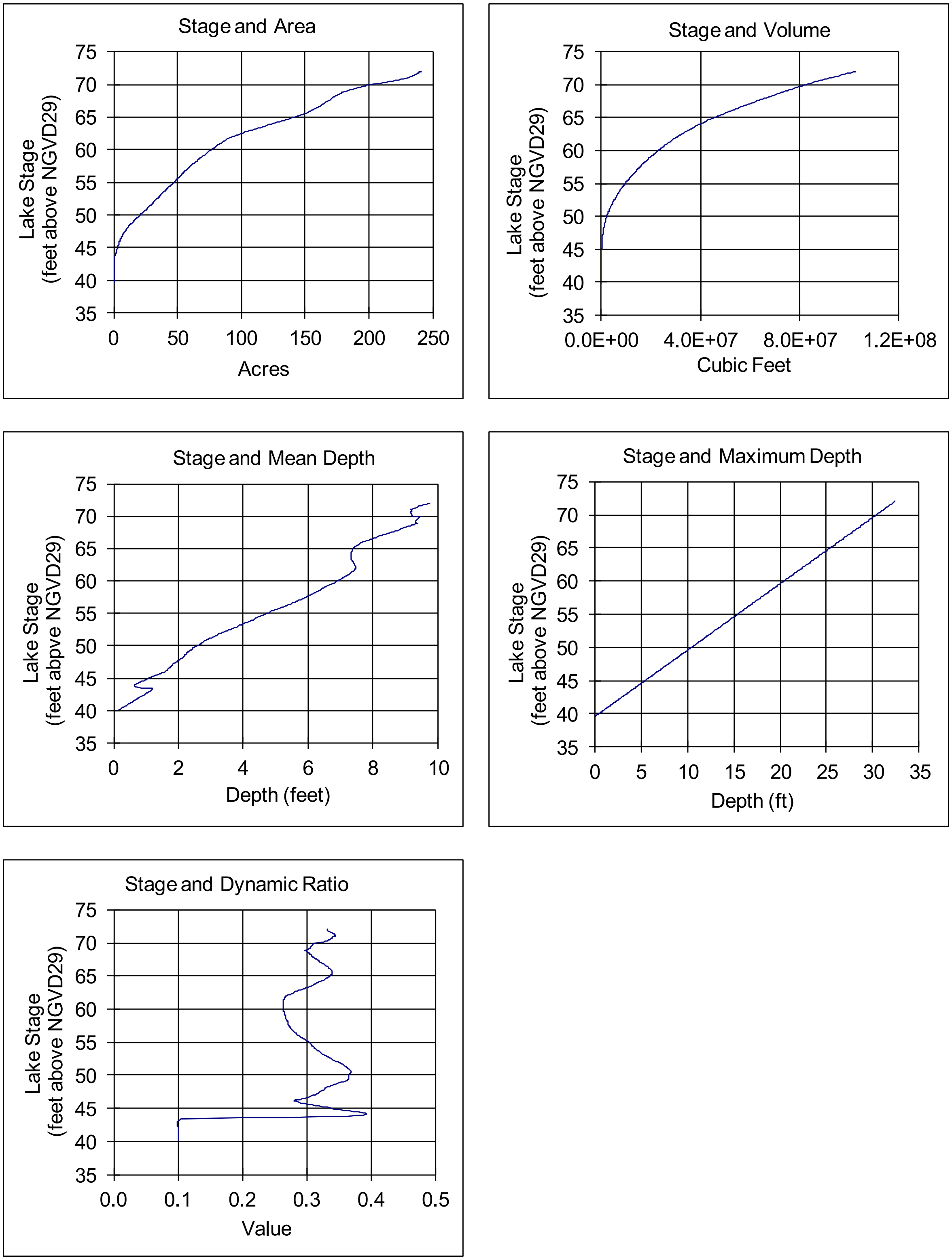



**Figure 21. Lake Padgett surface area, volume, mean depth, maximum depth and dynamic ratio (basin slope) as a function of lake stage.**

## Classification of Lake Stage Data and Development of Exceedance Percentiles

For the purpose of minimum levels determination, lake stage data are categorized as "Historic" for periods when there were no measurable impacts due to water withdrawals, and impacts due to structural alterations were similar to existing conditions. In the context of minimum levels development, "structural alterations" means man's physical alteration of the control point, or highest stable point along the outlet conveyance system of a lake, to the degree that water level fluctuations are affected. 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 water levels and regional ground water fluctuations, all available lake-stage data for Lake Padgett were originally classified as Historic data (SWFWMD 1999a) for development of the previously adopted minimum and guidance levels (SWFWMD 2003). However, given that recent simulations with the INTB model suggested that regional groundwater withdrawals have contributed to drawdown in the surficial and Upper Floridan aquifers in the vicinity of Lake Padgett, a regression modeling approach (Ellison 2010) was used for estimation of lake water levels that would be expected in the absence of potential withdrawal-related effects (see Appendix C). This approach was also considered appropriate for extending the period of record for lake stage values for developing Historic lake stage exceedance percentiles that could be used for development of revised minimum and guidance levels. Development of an extended long-term stage record was considered necessary for characterization of the range of lake-stage fluctuations that could be expected based on long-term climatic cycles that have been shown to be associated with changes in regional hydrology (Enfield et al. 2001, Basso and Schultz 2003, Kelly 2004).

The regression modeling for lake stage predictions was conducted using a linear fitting procedure known as the line of organic correlation (LOC) (see Helsel and Hirsch 1992). The procedure was used to describe the relationship between daily water surface elevations for Lake Padgett derived from measured Historic data and various regional rainfall estimates determined from long-term rainfall stations in the lake vicinity.

Lake stage data used for development of LOC models for Lake Padgett consisted of daily lake surface elevations recorded from January 6, 1965, when data collection was initiated for the lake, through December 28, 1970 at District Site Identification Number 19127 (refer to Figure 17 for a plot that includes these data and subsequently collected records). Data collected after this period were conservatively excluded from model development to preclude inclusion of records that could reflect potential effects from groundwater withdrawals at the Central System Facilities. Rainfall values evaluated for model development included cumulative totals, in inches, for various periods of record preceding the dates associated with the lake stage data. Cumulative rainfall totals were derived using a linear-decay series to weight monthly rainfall values for six-month and one through ten year periods. Rainfall values from two sites were used for model development. The sites included the Myrtle Lake site (District Universal Site Identification

Number 19057), which is located 1.5 miles from Lake Padgett, and, the Lutz site (Number 19629), which is located 3.2 miles from the lake. Daily records from the closer site were used when available and supplemented with records available from the second site when necessary. Final model selection was based on evaluation of the coefficient of determination ($r^2$) associated with models developed using each of the cumulative rainfall data sets.

The best-fit LOC model and rainfall records from the Myrtle Lake, Lutz and other nearby rain gage sites were used to estimate daily water surface elevations for Lake Padgett for the period from January 1, 1946 through January 30, 2013 as described in Appendix C. A Historic, composite data set of daily water surface elevations was then developed using the modeled water surface elevations and available measured lake stage records from District Site Identification Number 19127 that were substituted for modeled daily values for the model development period (Figure 22).

Based on the 61 year and one month Historic, composite data set, the Historic P10 elevation, i.e., the elevation the lake water surface equaled or exceeded ten percent of the time, was 71.0 feet above NGVD29. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 69.6 feet above NGVD. The Historic P90, the lake water surface elevation equaled or exceeded ninety percent of the time during the historic period, was 68.3 feet above NGVD29.

The Historic lake stage exceedance percentile elevations are similar to percentiles derived from measured water levels for the lake. The Historic P50 and Historic P90 are, respectively, 0.1 and 0.3 feet lower than the P50 and P90 value for the measured records observed through January 30, 2013. The Historic P10 is 0.4 feet higher than the P10 of the measured records.

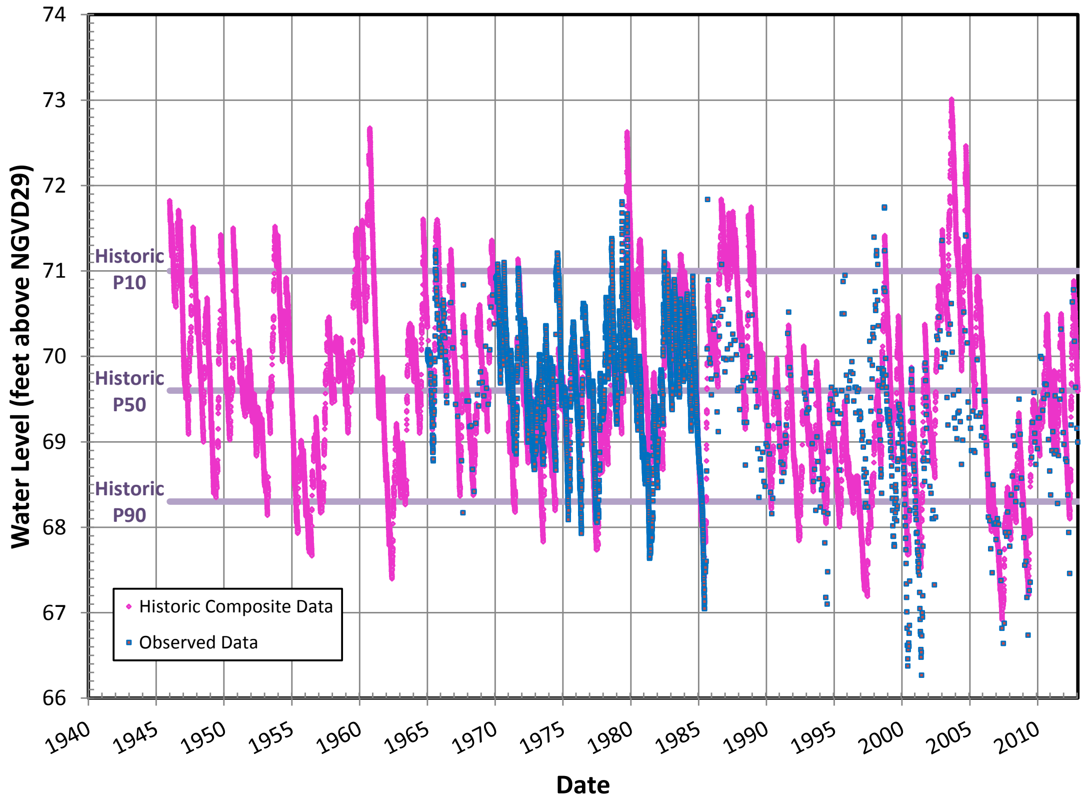



**Figure 22. Observed water surface elevations and composite, Historic stage records and Historic percentiles for Lake Padgett for the period from January 1, 1946 through January 30, 2013. Historic percentiles include water levels equaled or exceeded ten (Historic P10), fifty (Historic P50) and ninety (Historic P90) percent of the time**.

## 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.

Elevations of *Taxodium* sp. buttress inflection points and the elevation of a moss collar on a *Taxodium* trunk that measured in December 2013 and January 2014 at various points along the Lake Padgett shoreline and in wetlands adjacent to the lake were indicative of a Normal Pool elevation of 70.4 feet above NGVD29 (Table 7; Figure 23).

A Normal Pool elevation of 71.3 feet above NGVD29 was previously identified for the lake based on the elevations of cypress buttress inflection points measured in February 2003 (Leeper 2003). Because no inconsistencies in the relative datum used for the elevation determinations (*e.g.*, the lake water level as recorded at the gage site) that could account for the difference between the previously reported and more recently measured Normal Pool elevation were identified, the recently collected and verified measurements were used to establish the Normal Pool elevation.

**Table 7. Summary statistics for hydrologic indicator measurements (elevations of the buttress inflection points of *Taxodium* sp. and a moss collar elevation on a *Taxodium* trunk) that were used to identify a Normal Pool Elevation for Lake Padgett. Elevations were measured by District staff in December 2013 and January 2014.**

| Summary Statistic | Number (N) or Elevation (feet above NGVD29) |
|---|---|
| N | 18 |
| Median | 70.4 |
| Mean [Standard Deviation] | 70.4 [0.23] |
| Minimum | 70.1 |
| Maximum | 71.2 |

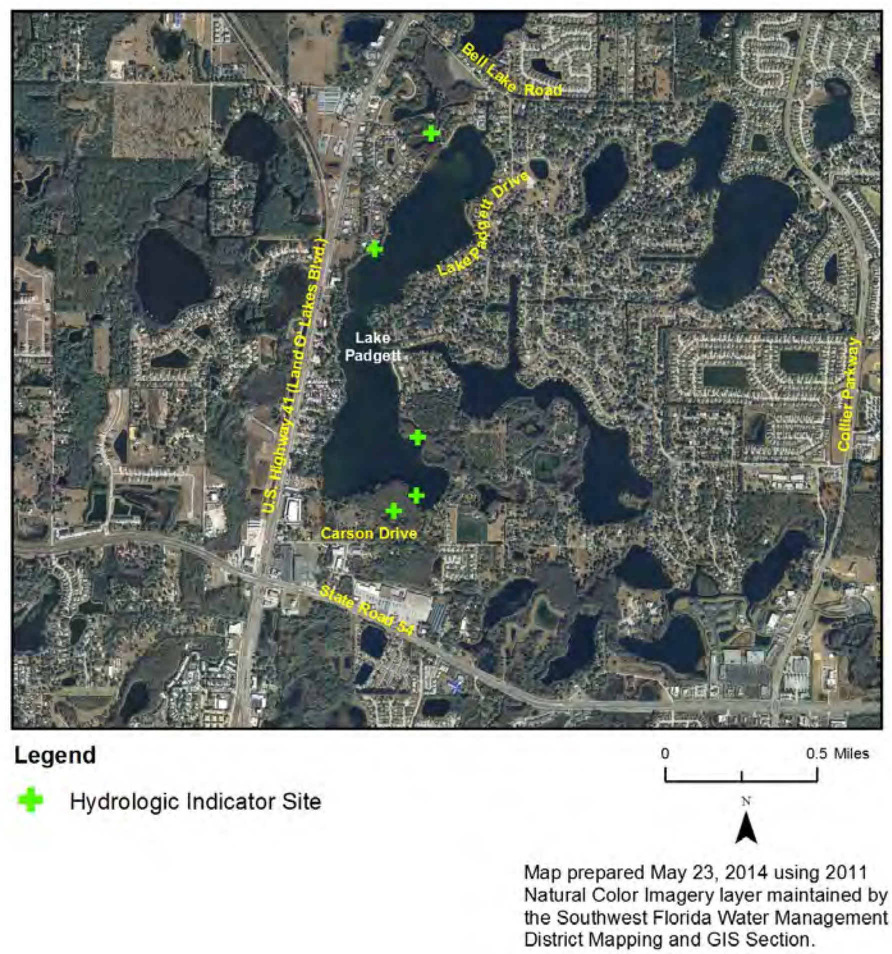



**Figure 23. Locations where hydrologic indicators of Normal Pool were measured at Lake Padgett in 2013 and 2014.**

The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system that principally controls lake water level fluctuations. 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 elevations are the lowest point on the portion of a water-control structure that provides for conveyance of water across or through the structure. For non-operable structures, the crest elevation corresponds to the invert elevation. For operable structures, the invert elevation represents the lowest elevation at which flow may occur past the structure, and the crest elevation corresponds to the highest elevation that must be exceeded for flow to occur. The Control Point associated with an operable structure may, therefore, range from the invert elevation to the crest elevation.

A Control Point elevation of 68.7 feet above NGVD29 has previously been identified for Lake Padgett (Leeper 2003). Evaluations of the outlet conveyance system by District staff in 2009 and 2014 (refer to pages 19-20 and Figures 12 and 13) indicate that the previously identified Control Point elevation may be considered conservative, i.e., low, and that an appropriate Control Point for Lake Padgett lies between 68.7 and 69.0 feet above NGVD29.

In addition to identification of current and historic outlet conveyance system modifications, comparison of the Control point elevation with the Normal Pool elevation can be used to evaluate the structural alteration status of a lake. If the Control Point elevation is below the Normal Pool, the lake is usually considered to be a structurally altered system. If the Control Point elevation is above the Normal Pool or the lake has no outlet, then the lake may not be considered to be structurally altered. Based on the existence of an outlet conveyance system and given that the Normal Pool elevation (70.4 feet above NGVD29) is higher than the Control point elevation (68.7 to 69.0 feet above NGVD29), Lake Padgett was classified as a structurally altered lake. This characterization was used to support development of Guidance Levels, Minimum Levels and the modeling of Historic lake stage records.

## Revised Guidance Levels

The High Guidance Level is provided as an advisory guideline for construction of lakeshore development, water dependent structures, and operation of water management structures. The High Guidance Level is the expected Historic P10 of the lake, and is established using historic data if it is available, or is estimated using the Current P10, the Control Point elevation and the Normal Pool elevation. Based on the availability of Historic data for Lake Padgett, a revised High Guidance Level was established at the Historic P10 elevation, 71.0 feet above NGVD29.

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis. The level is established using Historic or Current lake stage data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate historic or current data are not available. These statistics represent differences between P10, P50 and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals, i.e., reference lakes. Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of Historic data for Lake Padgett, a revised Low Guidance Level was established at the Historic P90 elevation, 68.3 feet above NGVD29.

## 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 occurrence of lake-fringing cypress wetlands of 0.5 acre or more in size within the lake basin, and because the Historic P50 is less than 1.8 feet below the Normal Pool elevation, Lake Padgett was classified as a Category 1 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 environmental values associated with lake ecosystems (see Table 1), in accordance with guidance provided in the Florida Water Resource Implementation Rule (Rule 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 1.8 feet below the Normal Pool elevation. This standard identifies a desired median lake stage that if achieved, may be expected to preserve the ecological integrity of lake-fringing wetlands. Although not identified by name in the District's Minimum Flows and Levels rule, the elevation 1.8 feet below normal pool is typically referred to as the Cypress Standard in District documents pertaining to minimum levels development. For Lake Padgett, the Cypress Standard was established at 68.6 feet above NGVD29. Based on the Historic, composite water level record, the standard was equaled or exceeded eighty-three percent of the time, i.e., the standard elevation corresponds to the Historic P83.

For Category 3 lakes, six significant change standards, including a Basin Connectivity Standard, a Recreation/Ski Standard, an Aesthetics Standard, a Species Richness Standard, a Lake Mixing Standard and a Dock-Use Standard are typically developed. These standards identify desired median lake stages that if achieved, are intended to preserve various natural system and human-use environmental values. Although Lake Padgett is a Category 1 Lake, Category 3 Lake standards were developed for comparative purposes. These standards were not, however, used to establish the revised Minimum Levels.

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. A Basin Connectivity Standard was established for Lake Padgett at 67.8 feet above NGVD29, based on the elevation that ensures connectivity between the main lake sub-basins (64.5 feet above NGVD29), a two-foot water depth in the areas of connectivity to allow for movement of watercraft and biota between the sub-basins, and the 1.3-foot difference between the Historic P50 and Historic P90 elevations. Based on the Historic, composite water level record the standard was equaled or exceeded ninety-seven percent of the time, i.e., the standard elevation corresponds to the Historic P97.

The Recreation/Ski Standard is developed to identify the lowest elevation within the lake basin that will contain an area suitable for safe water skiing. The standard is based on the lowest elevation (the Ski Elevation) within the basin that can contain a 5-foot deep ski corridor delineated as a circular area with a radius of 418 feet, or a rectangular ski corridor 200 feet in width and 2,000 feet in length, and use of Historic lake stage data or region-specific reference lake water regime statistics. For Lake Padgett, a Recreation-Ski Standard was established at 62.2 feet above NGVD9, based on the sum of the 60.9 feet above NGVD29 Ski Elevation and the 1.3-foot difference between the Historic P50 and Historic P90. Based on the Historic, composite water level record, the standard was equaled or exceeded one hundred percent of the time.

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to protect aesthetic values associated with the median lake stage from diminishing beyond the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetic Standard is established at the Low Guidance Level, which for Lake Padgett occurs at an elevation of 68.3 feet above NGVD29. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the standard ninety percent of the time during the Historic period, based on the Historic, composite water level record.

The Species Richness Standard is developed to prevent a decline in the number of bird species that may be expected to occur at or utilize a lake. Based on an empirical relationship between lake surface area and the number of birds expected to occur at a lake, the standard is established at the lowest elevation associated with less than a fifteen percent reduction in lake surface area relative to the lake area at the Historic P50 elevation. For Lake Padgett, a Species Richness Standard was established at 67.1 feet above NGVD29. The standard was equaled or exceeded one hundred percent of the time based on the Historic, composite water level record.

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. Development of a Lake Mixing Standard was not appropriate for Lake Padgett based on consideration of dynamic range values for all water surface elevations that may be expected within the basin (refer to Figure 21).

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. For Lake Padgett, a Dock-Use Standard was established at 70.0 feet above NGVD, based on the elevation of sediments at the end of 90% of the 105 docks at the lake (66.7 ft above NGVD29), a clearance value of 2 feet based on use of powerboats in the lake, and the difference between the Historic P50 and Historic P90 (1.3 feet). Based on the Historic, composite water level record, the standard was equaled or exceeded thirty-five percent of the time, i.e., the standard elevation corresponds to the Historic P35.

Herbaceous Wetland Information is taken into consideration to determine the elevation at which changes in lake stage would result in substantial changes in potential wetland area within the lake basin (i.e., basin area with a water depth of four or less feet). Similarly, changes in lake stage associated with changes in lake area available for colonization by rooted submersed or floating-leaved macrophytes are also evaluated, based on water transparency values. Review of changes in potential herbaceous wetland area or area available for aquatic plant colonization in relation to change in lake stage did not indicate that of use of the Cypress Standard would be inappropriate for establishment of the Minimum Lake Level (Figure 24).

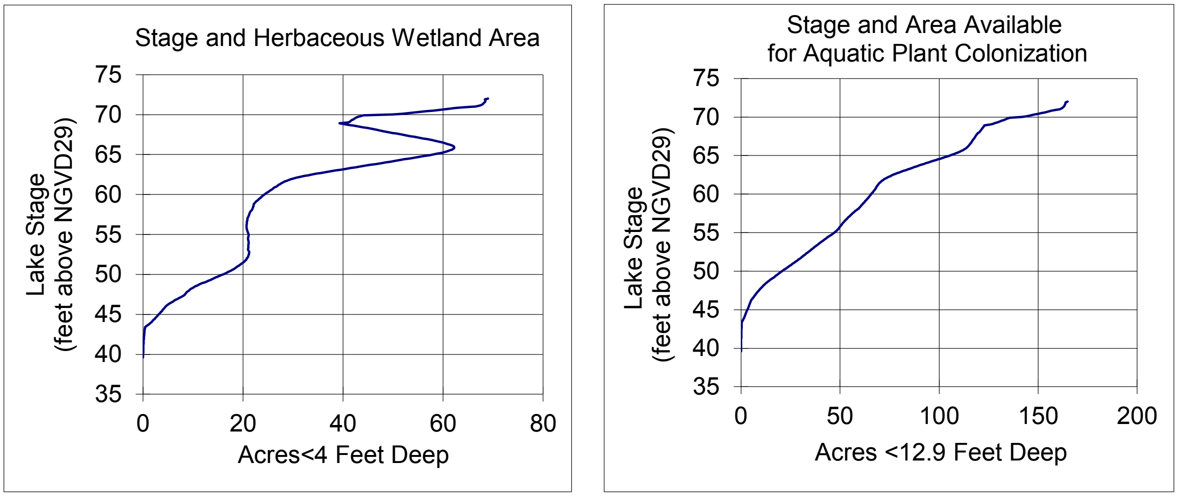



**Figure 24. Potential herbaceous wetland area and area available for macrophyte colonization in Lake Padgett as a function of lake stage*.***

Because herbaceous wetlands are common within the Lake Padgett basin, it was determined that an additional measure of wetland change should be considered for minimum levels development. Based on a review of the development of minimum level methods for cypress-dominated wetlands (Hancock 2006), 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 west-central Florida lake basins. A Wetland Offset elevation of 68.8 feet above NGVD29 was therefore established for Lake Padgett by subtracting 0.8 feet from the Historic P50 elevation. The standard elevation was equaled or exceeded seventy-eight percent of the time, based on the Historic, composite water level record. The Wetland Offset Elevation therefore corresponds to the Historic P78.

# Revised Minimum Levels

Minimum Lake Levels 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 1 lakes, the Minimum Lake Level is established 1.8 feet below the Normal Pool elevation. A revised

Minimum Lake Level for Lake Padgett was therefore established at 68.6 feet above NGVD29.

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 1 lakes, the High Minimum Lake Level is established 0.4 feet below the Normal Pool elevation. A revised High Minimum Lake Level for Lake Padgett was therefore established at 70.0 feet above NGVD29.

Revised Minimum and Guidance levels for Lake Padgett are plotted in Figure 25 along with observed period of record daily water surface elevations. The approximate locations of the lake margin when water levels equal the revised minimum levels are shown in Figure 26.

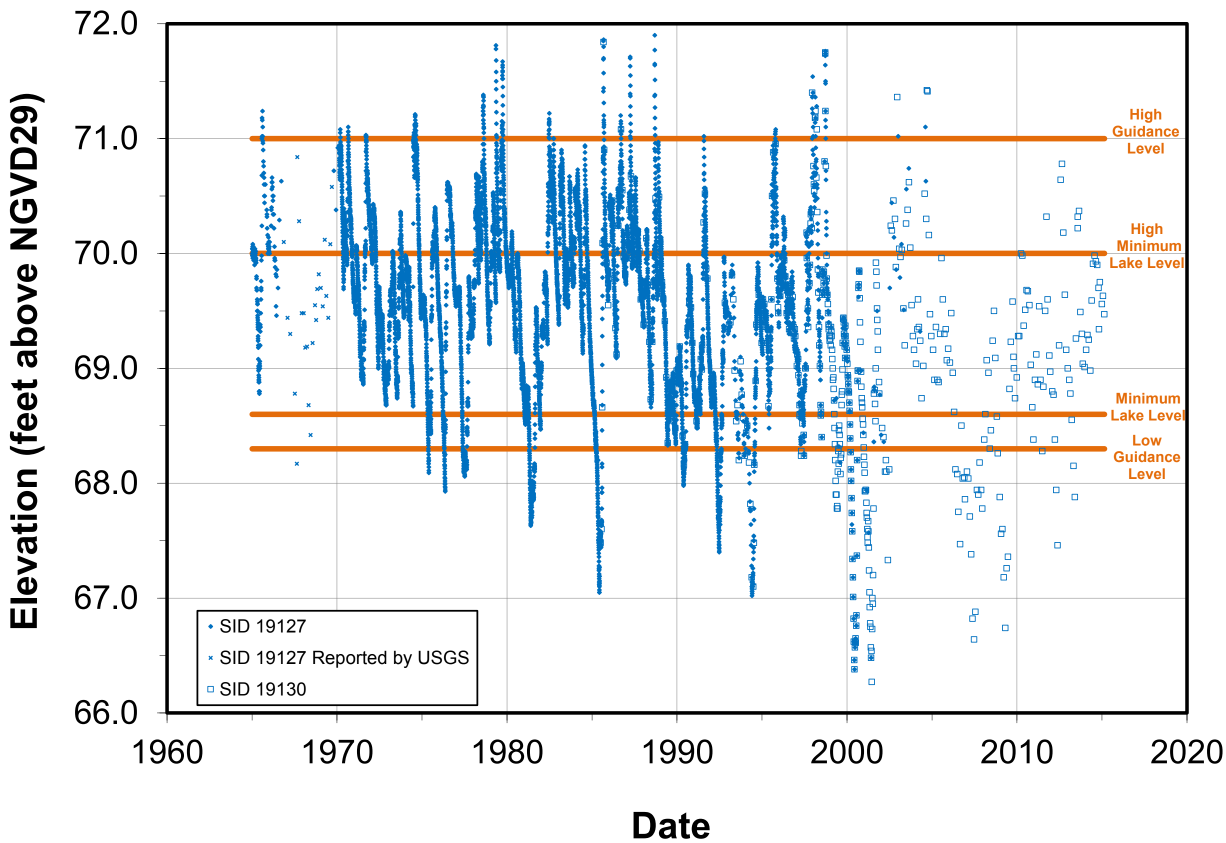



**Figure 25. Revised minimum and guidance levels (horizontal lines) and observed water surface elevations (points) at two gage sites (SID 19127 and 19130) in Lake Padgett from January 6, 1965 through March 30, 2015.**


**Figure 26. Approximate location of elevation contours associated with revised minimum levels for Lake Padgett.**

Because many federal, state, and local agencies, such as the U.S. Army Corps of Engineers, the Federal Emergency Management Agency, U.S. Geological Survey, and the District are in the process of migrating from NGVD29 to the NAVD88 vertical control standard, revised Minimum and Guidance Levels for Lake Padgett relative to NAVD88 are provided in Table 8.

**Table 8. Revised Minimum and Guidance Levels for Lake Padgett relative to the National Geodetic Vertical Datum of 1929 (NGVD29) and the North American Vertical Datum of 1988 (NAVD88).**

| Minimum and Guidance Levels | Elevation (feet above NGVD29) | Elevation (feet above NAVD88) |
|---|---|---|
| High Guidance Level | 71.0 | 70.2 |
| High Minimum Lake Level | 70.0 | 69.2 |
| Minimum Lake Level | 68.6 | 67.8 |
| Low Guidance Level | 68.3 | 67.5 |

# Consideration of Environmental Values

The revised minimum levels for Lake Padgett are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing minimum flows and levels (see Rule 62-40.473, F.A.C.). When developing minimum lake levels, the District evaluates categorical significant change standards and other available information to identify criteria that are sensitive to long-term changes in hydrology and represent significant harm thresholds. A Cypress Standard was used for developing revised Minimum Levels for Lake Padgett based on its classification as a Category 1 Lake. This standard is associated with protection of several environmental values identified in Rule 62-40.473, F.A.C., including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, sediment loads and water quality (refer to Table 1).

Three additional environmental values identified in Rule 62-40.473, F.A.C., are also protected by the revised minimum levels for Lake Padgett. The environmental value, recreation in and on the water is associated with the Basin Connectivity, Recreation/Ski and Species Richness standards develop for the lake, and each of these standards are associated with elevations lower than the Cypress Standard elevation. Similarly, the environmental value, navigation, may be associated with Basin Connectivity Standard, which is also lower than the Cypress Standard. The environmental value, maintenance of freshwater storage and supply is protected by the revised minimum levels based on the relatively modest potential changes in storage associated with the MFLs hydrologic regime as compared to the non-withdrawal impacted historic condition. Maintenance of freshwater supply is also expected to be protected by the revised minimum levels based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted MFLs.

One environmental values identified in Rule 62-40.473, F.A.C., was not considered relevant to development of revised minimum levels for Lake Padgett. Estuarine resources were not considered relevant because the lake is only remotely connected to the estuarine resources associated with the downstream receiving waters of Tampa Bay, and water level fluctuations in the lake are expected to exert little effect on the ecological structure and functions of the bay.

## Comparison of Revised and Previously Adopted Levels

The revised High Guidance Level and Low Guidance Level for Lake Padgett are respectively, 0.5 feet higher and 0.1 feet lower than the previously adopted guidance levels. These differences are associated with application of a new modeling approach for characterization of historic water level fluctuations within the lake, i.e., water level fluctuations that would be expected in the absence of water withdrawal impacts given existing structural conditions.

The revised High Minimum Lake Level for Lake Padgett is 0.5 feet lower than the previously adopted High Minimum Lake Level. The revised Minimum Lake Level is 0.9 feet lower than the previously adopted Minimum Lake Level. These differences are primarily due to differences in Normal Pool elevations that were previously and recently determined for the lake.

## Minimum Levels Status Assessment

To assess whether the revised Minimum Lake Level is being met, observed water levels in Lake Padgett were compared to the revised level using a modified version of the LOC model developed for predicting long-term lake levels. For the status assessment, the intercept of the LOC model and associated 95% prediction intervals were lowered 1.0 foot, a difference in elevation corresponding to the difference between the Historic P50 and the revised Minimum Lake Level. When plotted along with the modified LOC model and prediction intervals, water levels for Lake Padgett observed since January 2007 lie near the top of or above the upper prediction interval, indicating the revised Minimum Lake Level is being met (see Appendix C).

Observed lake data were also used for an empirical-based assessment of the revised Minimum Lake Level and High Minimum Lake Level for the lake. For the status assessment, cumulative median (P50) and cumulative (P10) water surface elevations for time periods starting in 1973, 1983, 1993, 2000, 2004 and 2010 (periods of wellfield pumpage changes) were respectively compared to the revised Minimum Lake Level and High Minimum Lake Level to determine whether long-term water levels for these periods were above the revised levels. Results from these assessments indicate the revised High Minimum Lake Level and Minimum Lake Level for Lake Padgett are being met (see Appendix C).

Because the period of observed water levels since 1973 includes periods of wellfield withdrawals much greater than those proposed for future operation of the Central System Facilities, the revised High Minimum Lake Level and Minimum Lake Level are also expected to be met for the next 20-year planning period.

The District plans to continue regular monitoring of water levels in Lake Padgett and will also routinely evaluate the status of the lake's water levels with respect to adopted minimum levels for the lake included in Chapter 40D-8, F.A.C. In the event that the need for recovery of minimum levels in the lake is identified, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area and the Hillsborough River Strategy (Rule 40D80-073, F.A.C.) would be applicable.

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# Appendix A:

Leeper. D. 2003. Memorandum to file dated December 11, 2003. Subject: proposed minimum and guidance levels for Lake Padgett in Pasco County, Florida. Southwest Florida Water Management District. Brooksville, Florida.

December 11, 2003

**MEMORANDUM**

**TO:** File

**FROM:** Doug Leeper, Senior Environmental Scientist
Resource Conservation and Development Department
Southwest Florida Water Management District

**SUBJECT:** Proposed minimum and guidance levels for Lake Padgett in Pasco County, Florida

# Lake Padgett

### *General Description*

Lake Padgett (Figure 1) is located in the Hillsborough River Basin of the Southwest Florida Water Management District (SWFWMD or District) in Pasco County, Florida (Sections 24 and 25, Township 26S, Range 18E). The region surrounding the lake is categorized as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks 1981). The area is characterized as a plain with many small lakes overlying moderately thick limestone with karst features. As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as the Land-O-Lakes lake region, and described as an area of neutral to slightly alkaline, low to moderate nutrient, clear-water lakes interspersed in sandy uplands (Griffith *et al.* 1997).

Drainage areas for Lake Padgett are listed at 6.6 square miles (Florida Board of Conservation 1969) and ~5.4 square miles (Henderson 1983). The lake receives inflow from Lake Bell to the north and Lake Saxon to the east (Figure 2). A series of culverts drain the lake to the south under Carson Drive, and ultimately, through numerous wetlands and lakes, to Cypress Creek. Residential and commercial development encircles most of the lake. Significant wetlands areas remain intact, however, particularly along the south and northwest shores. Pasco County government maintains a boat ramp in a private park located along the lake's eastern shore. There are no surface water withdrawals from the lake currently permitted by the District. There are, however, numerous permitted groundwater withdrawals in the area.

The 1974 (photorevised 1987) United States Geological Survey 1:24,000 Lutz, Fla. quadrangle map shows a surface water elevation of 69 ft above the National Geodetic Vertical Datum of 1929 (NGVD) for Lake Padgett. The "Gazetteer of Florida Lakes"

(Florida Board of Conservation 1969, Shafer *et al.* 1986) lists the lake area as 200 acres and the surface elevation at 70 ft above NGVD. Based on a topographic map of the basin generated in support of minimum levels development (Figure 3), the lake covers an area of 206 and 184 acres, respectively, when the surface level is at 70 and 69 ft above NGVD. Data used for production of the topographic map were obtained from field surveys conducted in February 2003 and one-foot contours developed from contour data prepared using photogrammetric methods.

**Figure 1. Location of Lake Padgett in Pasco County, Florida.**

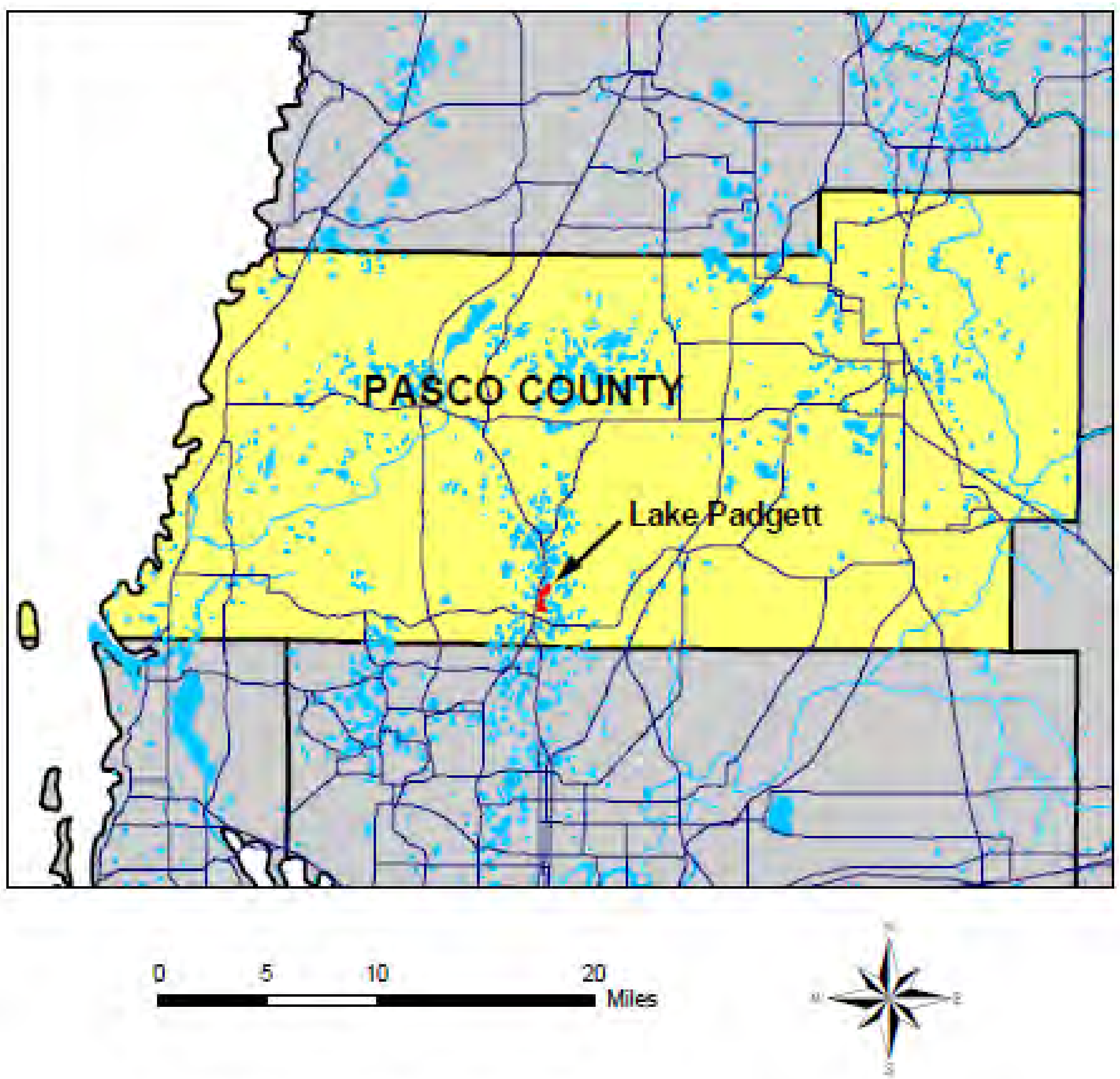


**Figure 2. Location of District lake-level gauge, inlets/outlets, and sites where hydrologic indicators were measured at Lake Padgett in Pasco County, Florida.**

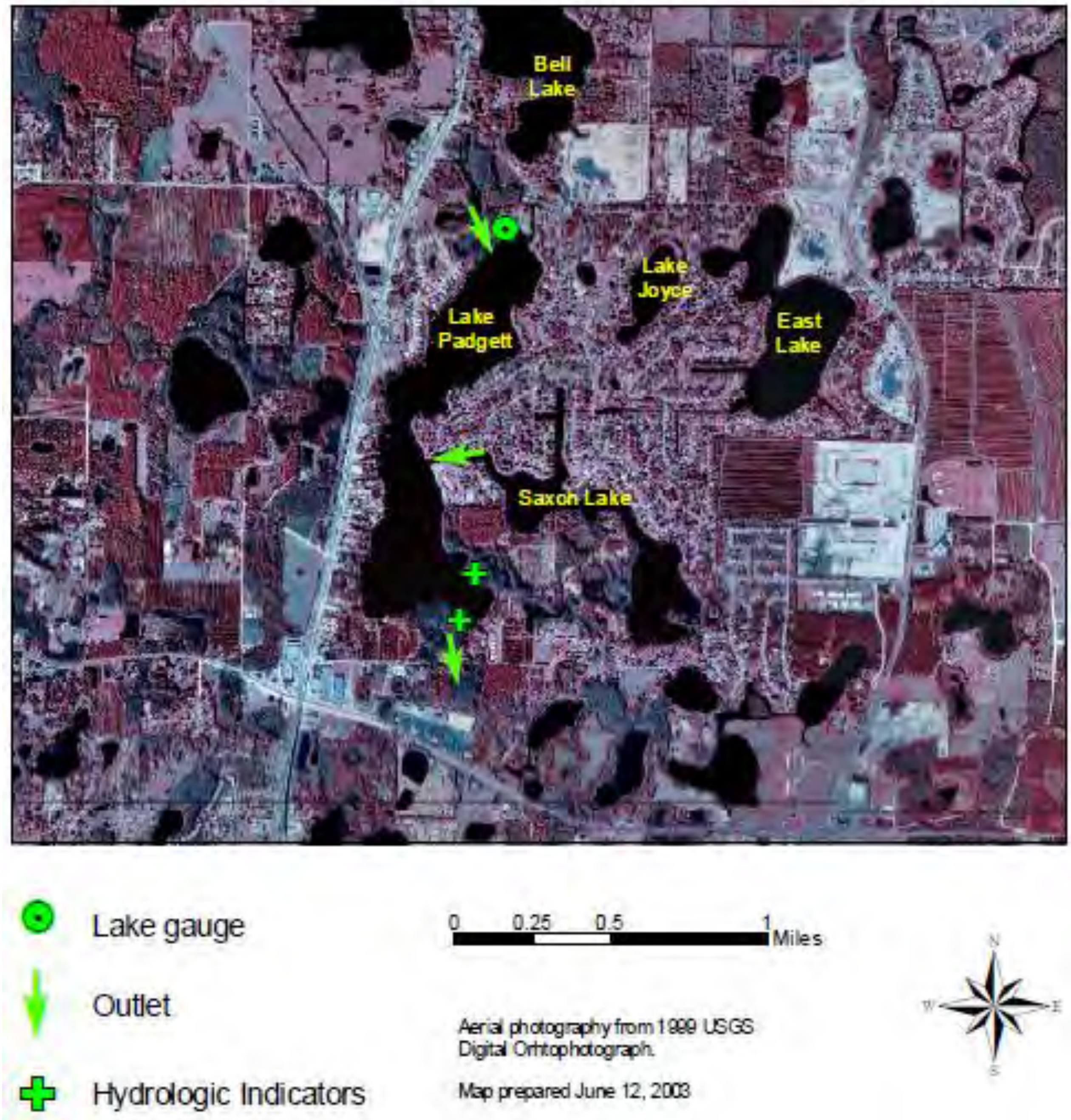
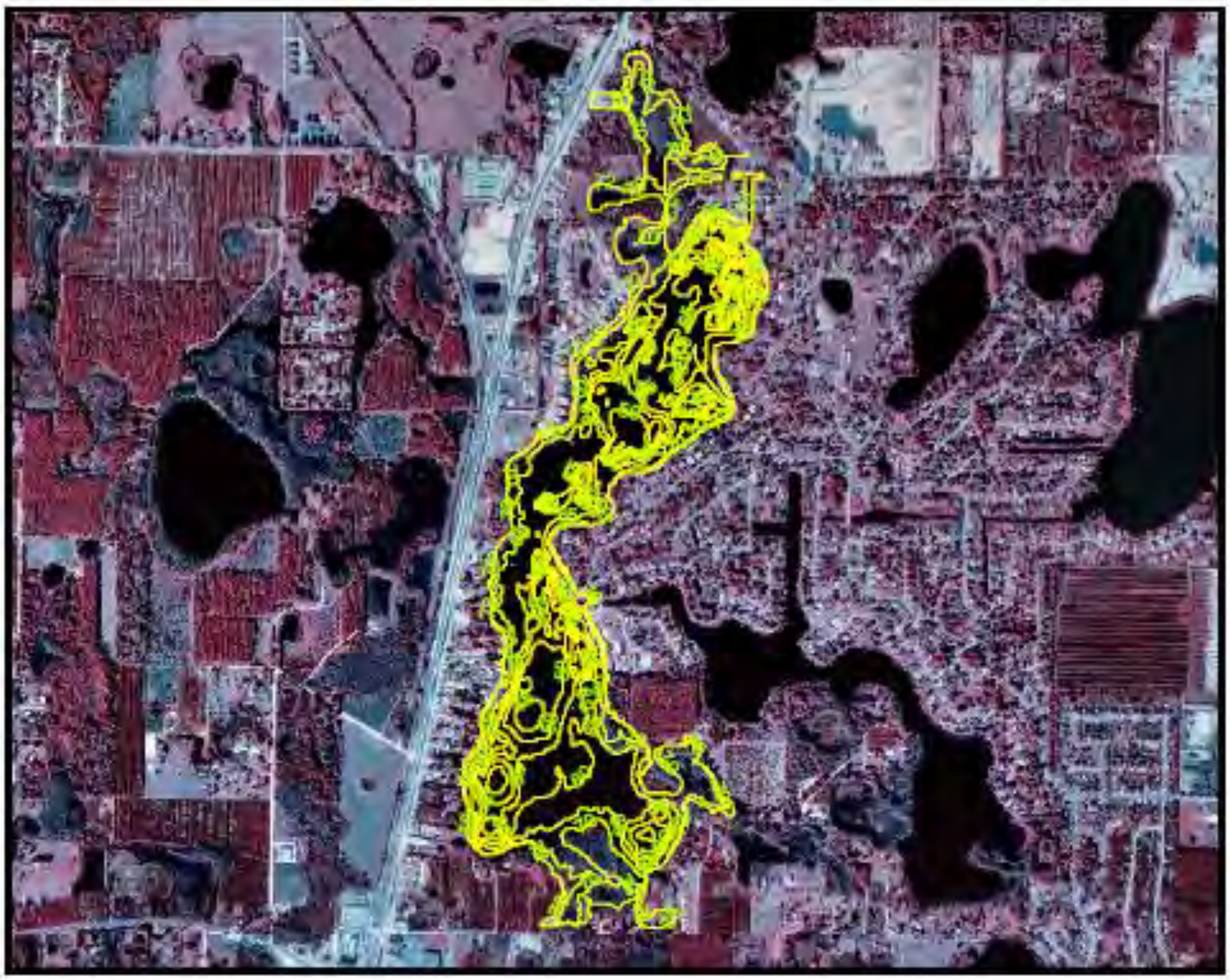


**Figure 3. Five-foot contours (and the 172-ft contour) within the Lake Padgett basin in Pasco County, Florida. Values shown are elevations, in feet above the National Geodetic Vertical Datum of 1929.**



Map prepared June 12, 2003 using 1999 USGS digital orthophotography, one-foot contours based on photogrammetric mapping of Cypress Creek conducted in January 2001 by 3Di, Florida, LLC, and elevation data collected by SWFWMD Staff on February 13, 2003.

0 1,000 2,000 4,000 Feet

### *Previously Adopted Lake Management Levels*

Based on work conducted in the 1980s (see SWFWMD 1996), the District Governing Board adopted management levels (currently referred to as Guidance Levels) for Lake Padgett in April 1985 (Table 1). A Maximum Desirable Level of 70.75 ft above NGVD was also developed, but was not adopted by the Governing Board.

**Table 1. Adopted guidance levels and associated surface areas for Lake Padgett in Pasco County, Florida.**

| Level | Elevation (feet above NGVD) | Total Lake Area (acres) |
|---|---|---|
| Ten Year Flood Guidance Level | 71.34 | 236 |
| High Level | 71.25 | 235 |
| Low Level | 69.00 | 184 |
| Extreme Low Level | 67.50 | 169 |

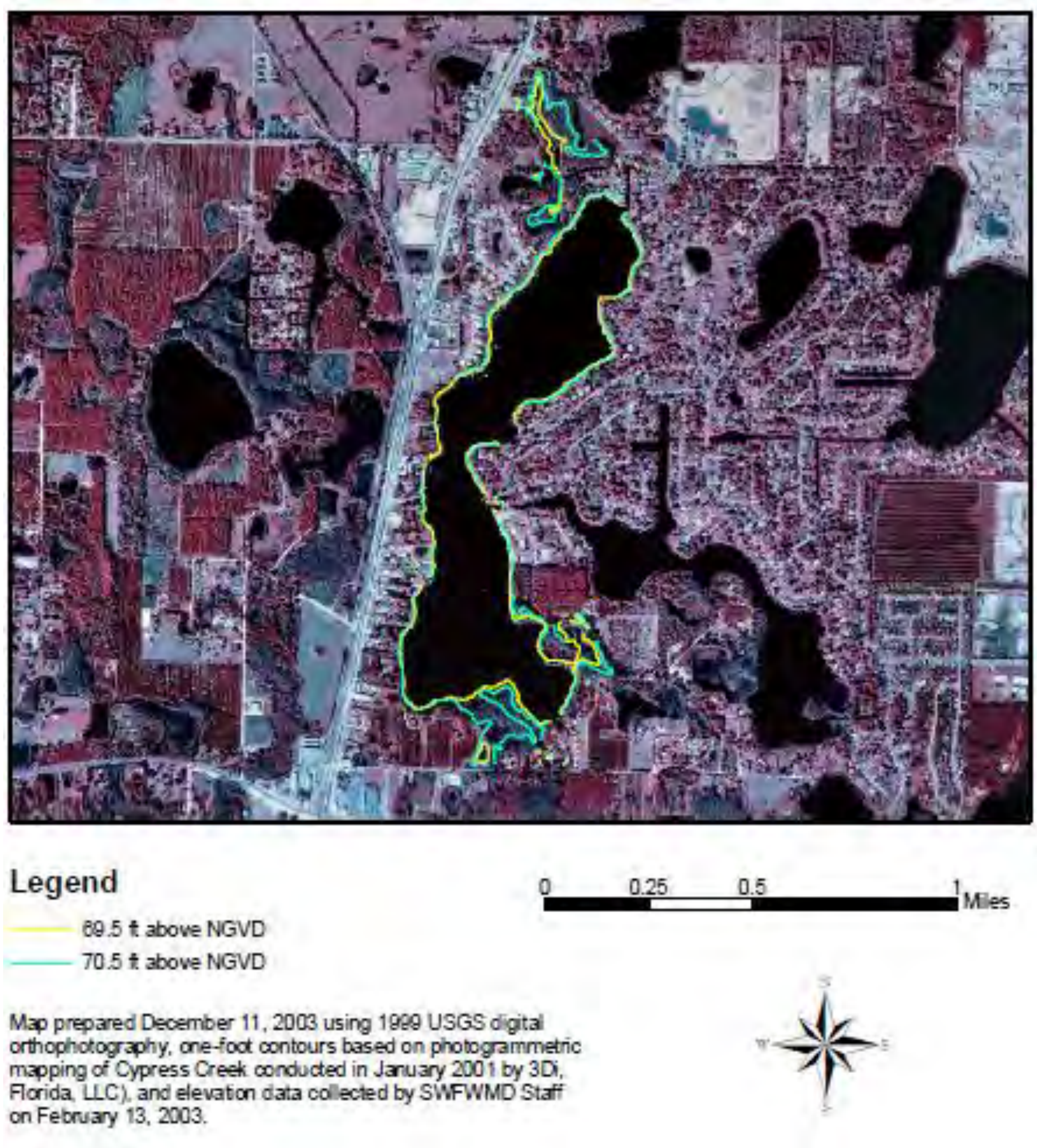
### *Proposed Minimum and Guidance Levels*

Proposed Minimum and Guidance Levels were developed for Lake Padgett using the methodology for Category 1 and 2 Lakes described in SWFWMD (1999) and current District Rules (Chapter 40-D8, Florida Administrative Code). Additional lake-level information was developed using methods outlined in Leeper *et al.* (2001), in accordance with modifications outlined by Dierberg and Wagner (2001). Proposed levels, along with lake surface area values for each level are listed in Table 2. Locations of the proposed minimum levels within the lake basin are shown in Figure 4.

**Table 2. Proposed minimum levels, guidance levels and associated surface areas for Lake Padgett in Pasco County, Florida.**

| Level | Elevation (feet above NGVD) | Lake Area (acres) |
|---|---|---|
| Ten Year Flood Guidance Level | 71.5 | 237 |
| High Guidance Level | 70.5 | 219 |
| High Minimum Lake Level | 70.5 | 219 |
| Minimum Lake Level | 69.5 | 192 |
| Low Guidance Level | 68.4 | 176 |

**Figure 4. Approximate location of the proposed Minimum Lake Level (yellow) and proposed High Minimum Lake Level (blue) for Lake Padgett in Pasco County, Florida.**



### *Summary of Data and Analyses Supporting Recommended Minimum and Guidance Levels*

Hydrologic data are available for Lake Padgett (District Universal ID Numbers STA 325 326 and STA 325 624) from January 1965 to the present date (Figure 5, see Figure 2 for current location of the SWFWMD lake-level gauge). Monthly mean water surface elevations, along with proposed guidance and minimum levels are shown in Figure 6. For the entire period of record, the hydrologic data are classified as Historic data. Historic data collected through January 2003 were used to calculate the Historic P10, P50, and P90 (Table 3).

The Normal Pool elevation was established at 71.3 ft above NGVD based on the elevation of cypress buttresses in two wetlands in the southern portion of the basin (Table 4, Figure 2). The low floor slab elevation, extent of structural alteration and control point elevation were determined using available one-foot contour interval aerial maps and field survey data (Tables 3 and 5, Figure 7). The Normal Pool elevation is above the control point elevation (68.7 ft above NGVD), so the lake is considered to be Structurally Altered.

Based on the availability of Historic hydrologic data for the lake basin, the High Guidance Level was established at the Historic P10 elevation of 70.5 ft above NGVD (Table 3). The Historic P50 and Low Guidance Levels (69. 6 and 68.4 ft above NGVD, respectively) were determined using the Historic P50 and Historic P90 elevations.

The Ten Year Flood Guidance Level for Lake Padgett was established at 71.5 ft above NGVD using the methodology for open basin lakes described in current District Rules (Chapter 40D-8, Florida Administrative Code). For the analysis, the NETWORK flood routing model was used. Model input was based on a ten-year storm event with a 120-hour duration and an 11.3-inch rainfall depth. Based on available lake stage data, the Ten Year Flood Guidance Level has been exceeded numerous times during the past 38 years (Figures 5 and 6). The highest elevation for Lake Padgett recorded in the District Water Management Data Base, 71.90 ft above NGVD, occurred on September 9, 1988. The low of record, 66.27 ft above NGVD, occurred on June 18, 2001.

Lake Padgett contains diverse stands of aquatic macrophytes and other hydrophytes, including hydrilla (*Hydrilla verticillata*), cattail (*Typha* sp.), pickerelweed (*Pontederia cordata*), spatterdock (*Nuphar luteum*), maidencaine (*Panicum hemitomon*), pennywort (*Hydrocotyle umbellata*), eelgrass (*Vallisneria* sp.), red maple (*Acer rubrum*), and wax myrtle (*Myrica cerifera*). The northwest and southern portion of the lake are contiguous with cypress-dominated wetlands of 0.5 or more acres in size, so the lake is classified as a Category 1 or 2 Lake for the purpose of minimum levels development. Because the Historic P50 elevation is less than 1.8 feet below the Normal Pool elevation, the lake is classified as a Category 1 Lake. Note that herein, for discussion purposes, the elevation 1.8 ft below the Normal Pool elevation is identified as the Cypress Standard. For Lake Padgett, this standard is established at 69.5 ft above NGVD. Based on the relationship between the Cypress Standard and the Historic P50 elevation, the proposed Minimum Lake Level was established at the Cypress Standard elevation (69.5 ft above NGVD),

A provisional High Minimum Lake Level was established at 70.9 ft above NGVD, an elevation 0.4 ft below the Normal Pool. This level was considered inappropriate, however, since it is higher than the Historic P10 elevation. The proposed High Minimum Lake Level was, therefore, established at the High Guidance Level elevation (70.5 ft above NGVD). The proposed High Minimum Lake Level is 3.5 ft below the Low Floor Slab elevation, 1.6 ft below the concrete slab of the lowest carport in the immediate lake basin, and 1.2 ft below the low spot on the roads that encircle the lake.

For comparative purposes, minimum level standards used for establishing Minimum Lake Level for lakes without fringing cypress wetlands (see Leeper *et al.* 2001) were developed for Lake Padgett (Table 3). The Dock-Use Standard was established at 69.9 ft above NGVD, based on the elevation of sediments at the end of 90% of the 105 docks at the lake, a clearance value of 2 ft based on use of powerboats in the lake, and the difference between the Historic P50 and Historic P90 (1.2 ft). The Aesthetic-Standard for Lake Padgett was established at the Low Guidance Level elevation of 68.4 ft above NGVD. The Basin Connectivity Standard was established at 67.7 ft above NGVD, based on a critical high-spot elevation of 64.5 ft above NGVD, which insures connectivity among the lake sub-basins, a 2 ft clearance for use of powerboats in the lake, and the difference between the Historic P50 and Historic P90. The Species Richness Standard was established at 67.1 ft above NGVD, based on a limiting reduction in lake surface area to a 15% decrease from the area at the Historic P50 elevation. The Recreation/Ski Standard was established at 62.2 ft above NGVD, based on a critical ski elevation of 61 f above NGVD and the difference between the Historic P50 and Historic P90. Based on basin morphology, a Mixing Standard for preventing change in the sediment re-suspension pattern was not established. Review of changes in potential herbaceous wetland area associated with change in lake stage, and potential change in area available for aquatic macrophyte colonization did not indicate that use of any of the identified standards would be inappropriate for minimum levels development (Figure 7).

**Figure 5. Surface water elevation at Lake Padgett in Pasco County, Florida. Data through January 2003 are shown.**

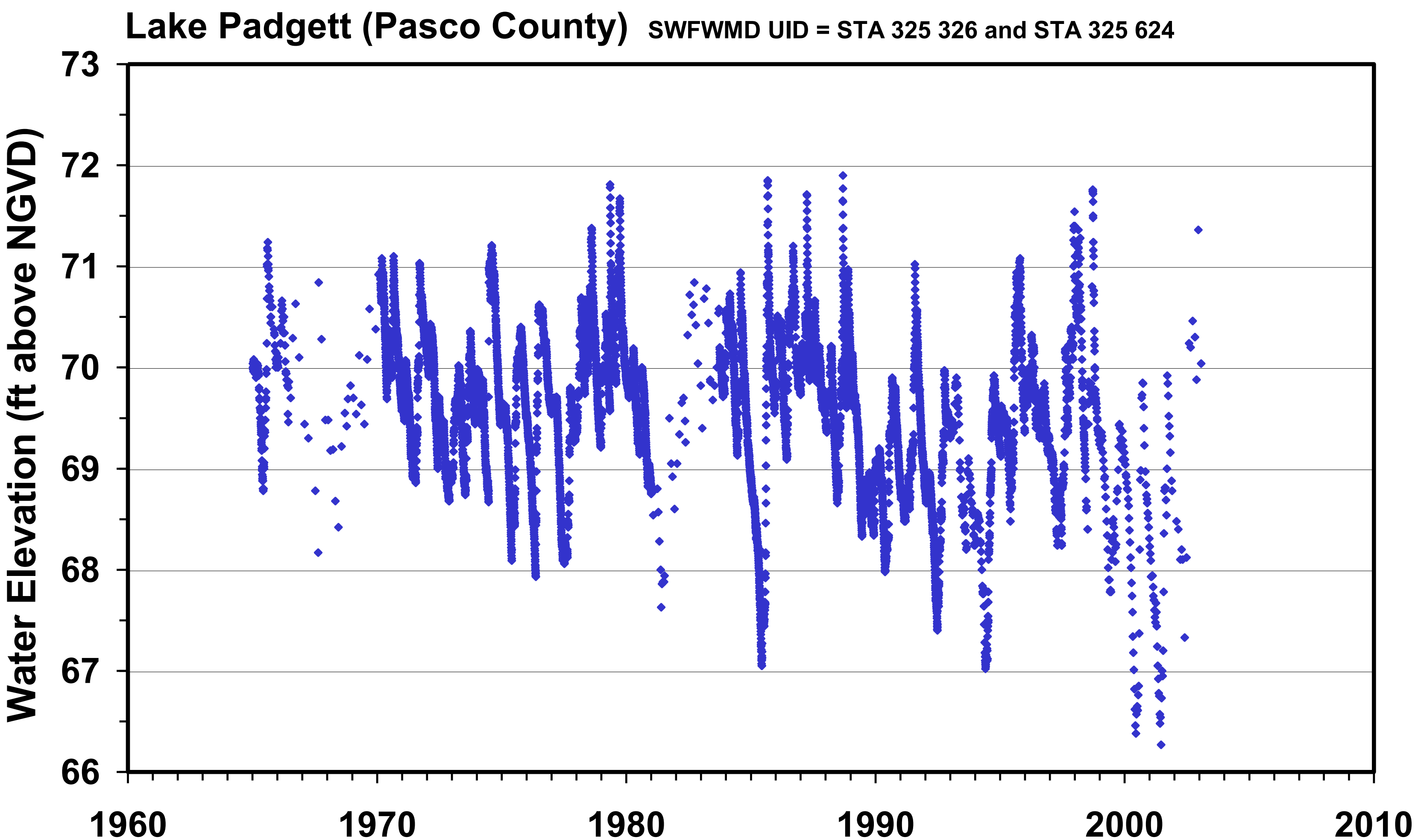


Figure 6. Mean monthly surface water elevation through January 2003, and proposed guidance and minimum levels for Lake Padgett in Pasco County, Florida. Proposed levels include the Ten Year Flood Guidance Level (10-YR), High Guidance Level (HGL), Low Guidance Level (LGL), High Minimum Lake Level (HMLL), and Minimum Lake Level (MLL).

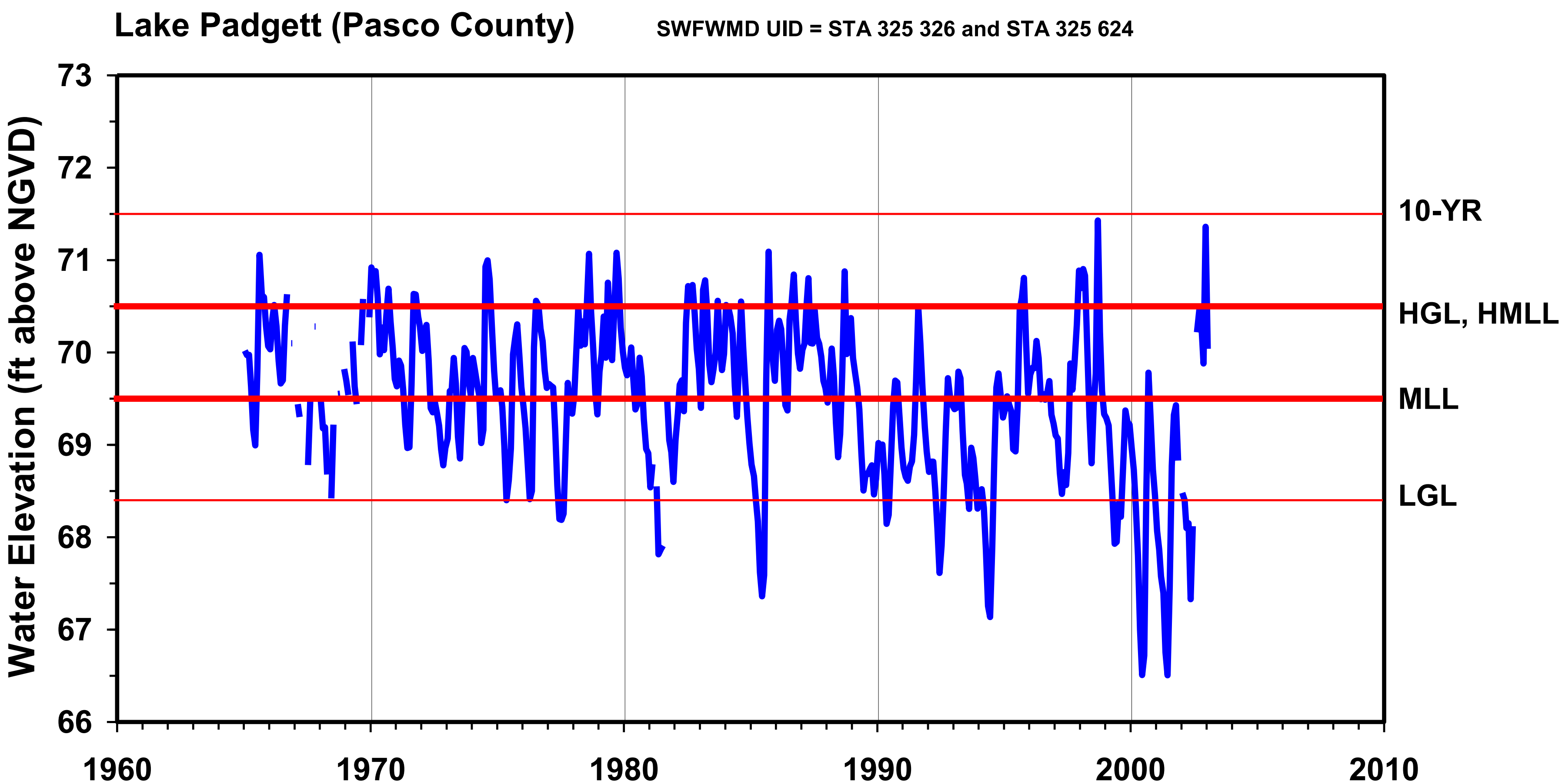


**Table 3. Elevation data and associated area values used for establishing minimum levels for Lake Padgett in Pasco County, Florida.**

| Level or Feature | Elevation (feet above NGVD) | Lake Area (acres) |
|---|---|---|
| Historic P10 | 70.49 | 219 |
| Historic P50 | 69.59 | 194 |
| Historic P90 | 68.40 | 176 |
| | | |
| Normal Pool | 71.3 | 235 |
| Low Floor Slab | 74.0 | NA |
| Low Other (concrete slab of covered picnic shelter) | 73.0 | NA |
| Low Other (floor elevation of second floor of boathouse/cabana) | 72.4 | NA |
| Low Other (concrete slab of covered carport) | 72.1 | NA |
| Low Other (ground shot at well) | 71.9 | 240 |
| Low Road | 71.7 | 239 |
| Control Point | 68.7 | 179 |
| | | |
| High Guidance Level | 70.5 | 219 |
| Historic P50 | 69.6 | 194 |
| Low Guidance Level | 68.4 | 176 |
| | | |
| Cypress Standard | 69.5 | 192 |
| *Dock-Use Standard | 69.9 | 199 |
| *Aesthetic Standard | 68.4 | 176 |
| *Connectivity Standard | 67.7 | 170 |
| *Species Richness Standard | 67.1 | 166 |
| *Recreation/Ski Standard | 62.1 | 97 |

NA = not applicable/not available
*Category 3 Lake Standards developed for comparative purposes only.

**Table 4. Elevation data used for establishing the Normal Pool Elevation for Lake Padgett in Pasco County, Florida. Data were collected by SWFWMD staff in February 2003.**

| Hydrologic Indicator | Elevation (feet above NGVD) |
|---|---|
| Cypress buttress inflection point | 71.09 |
| Cypress buttress inflection point | 71.09 |
| Cypress buttress inflection point | 71.19 |
| Cypress buttress inflection point | 71.19 |
| Cypress buttress inflection point | 71.19 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.29 |
| Cypress buttress inflection point | 71.39 |
| Cypress buttress inflection point | 71.39 |
| Cypress buttress inflection point | 71.39 |
| Cypress buttress inflection point | 71.49 |
| Cypress buttress inflection point | 71.59 |
| Cypress buttress inflection point | 71.59 |
| Cypress buttress inflection point | 71.69 |
| Cypress buttress inflection point | 71.69 |
| Cypress buttress inflection point | 71.79 |
| **N** | **20** |
| **Median** | **71.3** |
| **Mean** | **71.4** |
| **Standard Deviation** | **0.2** |

**Table 5. Outlet conveyance system and control point summary information for Lake Padgett in Pasco County, Florida. Numbered sites correspond to those shown in Figure 7.**

| Site | Description | Elevation (feet above NGVD) |
|---|---|---|
| 1 | Invert at north end of 1.7 ft x 2.5 ft, 32-ft long oval concrete culvert | 69.06 |
| 2 | Invert at north end of 1.7 ft x 2.5 ft, 32-ft long oval concrete culvert | 69.26 |
| 3 | Invert at north end of 1.7 ft x 2.5 ft, 32-ft long oval concrete culvert | 69.23 |
| 4 | Invert at north end of 1.7 ft x 2.5 ft, 32-ft long oval concrete culvert | 68.58 |
| 5 | Invert at north end of 1.7 ft x 2.5 ft, 33-ft long oval concrete culvert | 68.09 |
| 6 | Invert at south end of 1.7 ft x 2.5 ft, 33-ft long oval concrete culvert | 68.63 |
| 7 | Invert at north end of 1.7 ft x 2.5 ft, 33-ft long oval concrete culvert | 68.72 |
| 8 | Control point; high spot in ditch through swamp | 68.7 |

**Figure 7. Outlet conveyance system for Lake Padgett in Pasco County, Florida. Numbered sites are described in Table 5.**

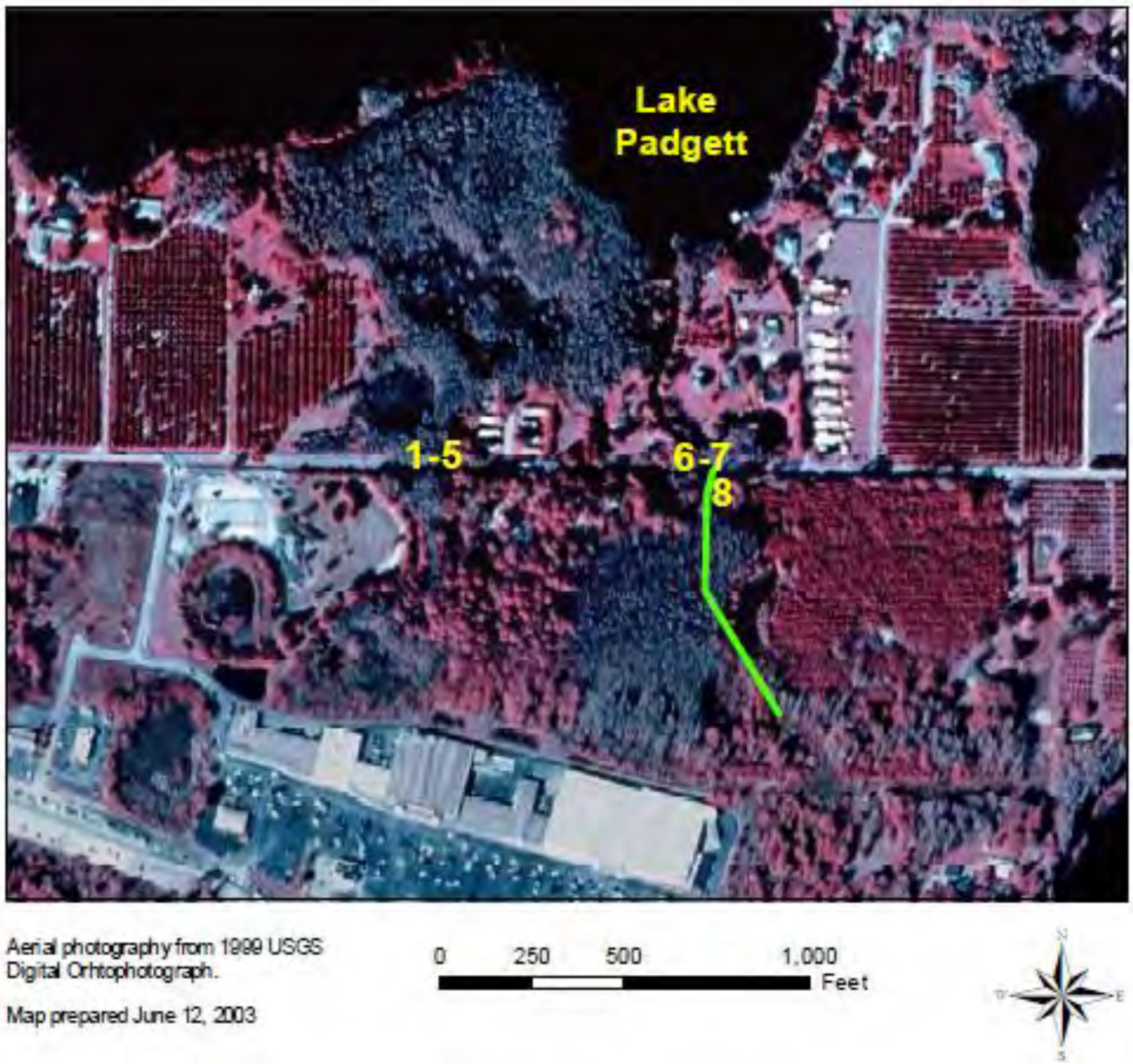
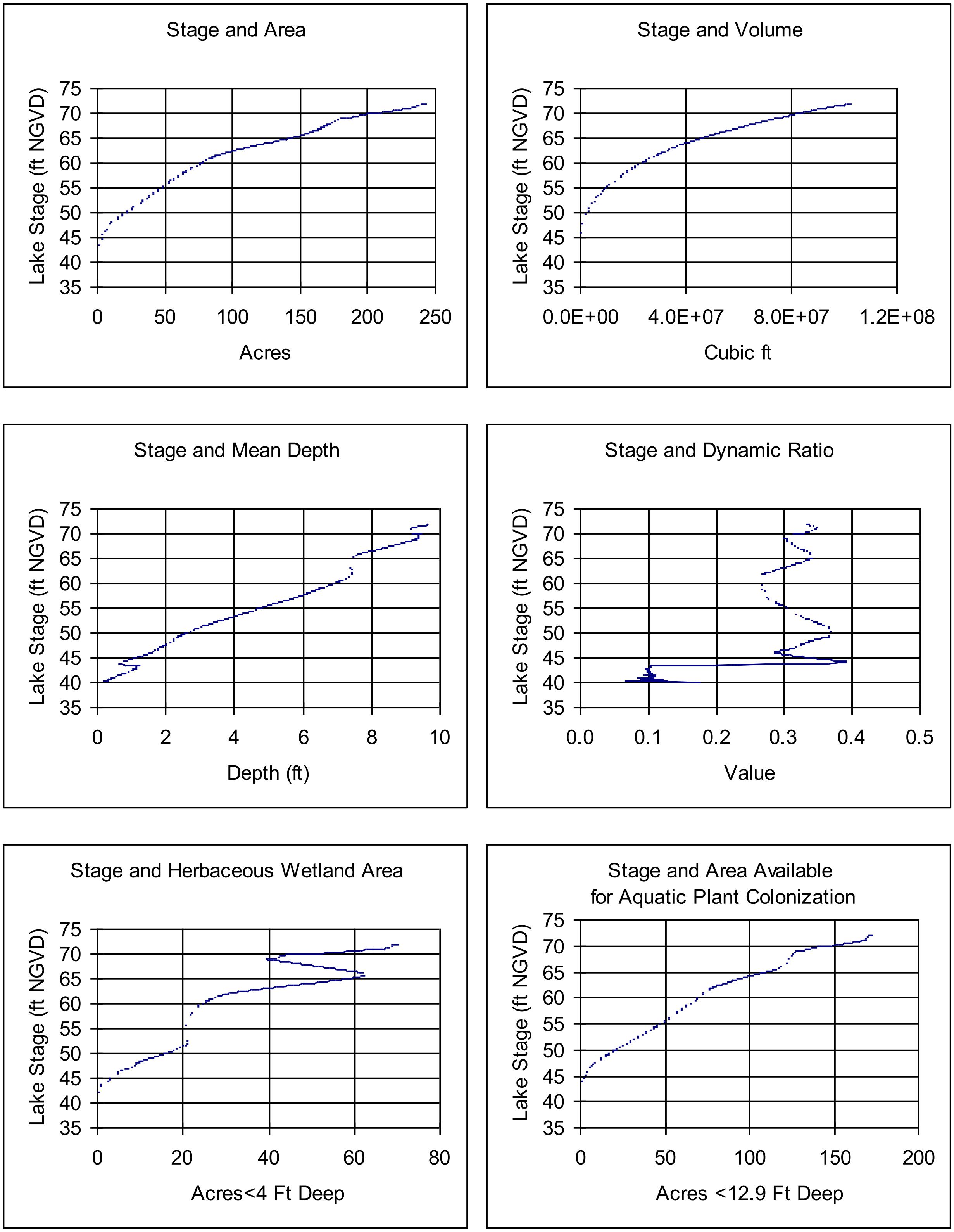


**Table 6. Summary statistics for elevations associated with docks (n = 105) at Lake Padgett in Pasco County, Florida, based on data collected by SWFWMD staff on April 9, 2002. Percentiles (P10, P50, P90) represent elevations exceeded by 10, 50 and 90 percent of the docks.**

| Statistic | Elevation of Sediments at Waterward Ends of Docks (feet above NGVD) | Elevation of Dock Platforms (feet above NGVD) |
|---|---|---|
| **Mean (SD)** | 64.9 (1.7) | 71.7 (0.7) |
| **P10** | 66.7 | 72.5 |
| **P50** | 65.0 | 71.9 |
| **P90** | 63.2 | 70.7 |
| **Maximum** | 68.5 | 73.1 |
| **Minimum** | 55.7 | 70.0 |

**Figure 8. Surface area, volume, mean depth, dynamic ratio (basin slope), potential herbaceous wetland area, and area available for macrophyte colonization versus lake stage for Lake Padgett in Pasco County, Florida.**



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# Appendix B:

Patterson, J. 2014. Draft Memorandum to Keith Kolasa dated July 9, 2014. Subject: Evaluation of groundwater withdrawal impacts to Padgett Lake. Southwest Florida Water Management District. Brooksville, Florida.

**Draft Technical Memorandum**

June 17, 2014

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

FROM: Jason Patterson, Hydrogeologist, Resource Evaluation Section

**Subject: Evaluation of Groundwater Withdrawal Impacts to Padgett Lake**

## 1.0 Introduction

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

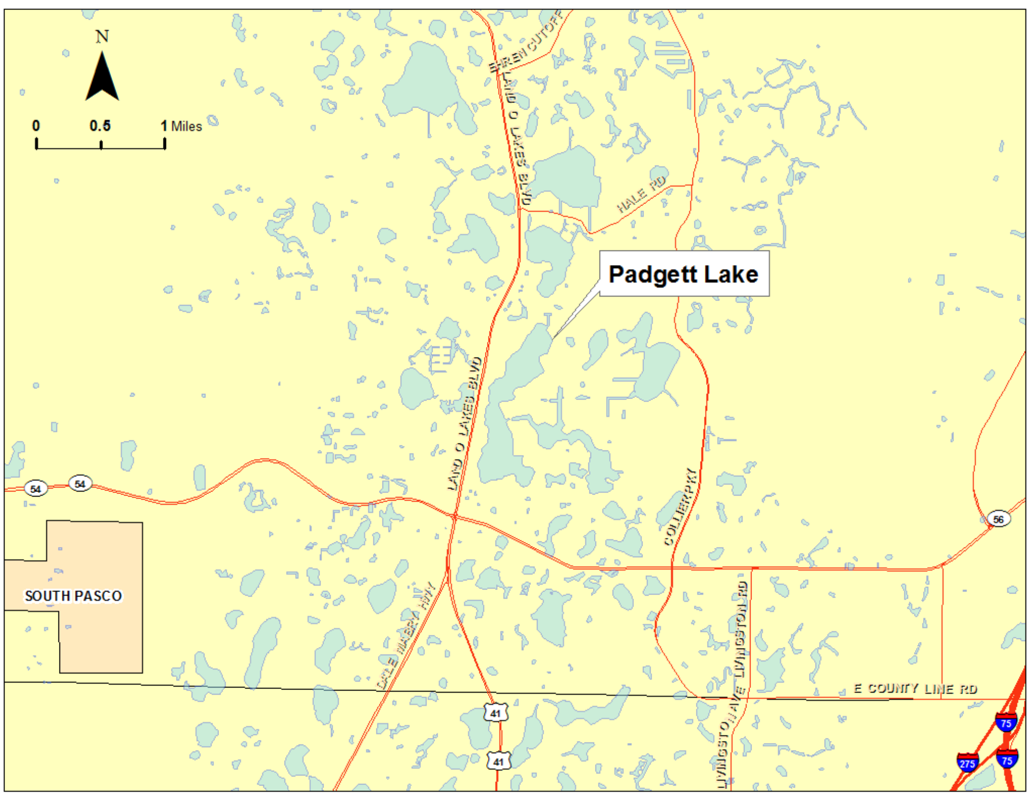


**Figure 1. Location of Padgett Lake.**

## 2.0 Hydrogeologic Setting

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

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

## 3.0 Evaluation of Groundwater Withdrawal Impacts to Padgett Lake

A number of regional groundwater flow models have included the area around Padgett Lake in south-central Pasco County. Ryder (1982) simulated the entire extent of the Southwest Florida Water Management District. In 1993, the District completed the Northern Tampa Bay groundwater flow model that covered a 2,000 square mile area of Hillsborough, Pinellas, Pasco, and Hernando Counties (SWFWMD, 1993). In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002). The most recent and advanced simulation of southern Pasco County and the surrounding area is the Integrated Northern Tampa Bay (INTB) model (Geurink and Basso, 2012). The construction and calibration of this model was part of a cooperative effort between the SWFWMD and Tampa Bay Water (TBW), a regional water utility that operates 11 major wellfields. The Integrated Northern Tampa Bay Model covers a 4,000 square-mile area of the Northern Tampa Bay region (Figure 2).

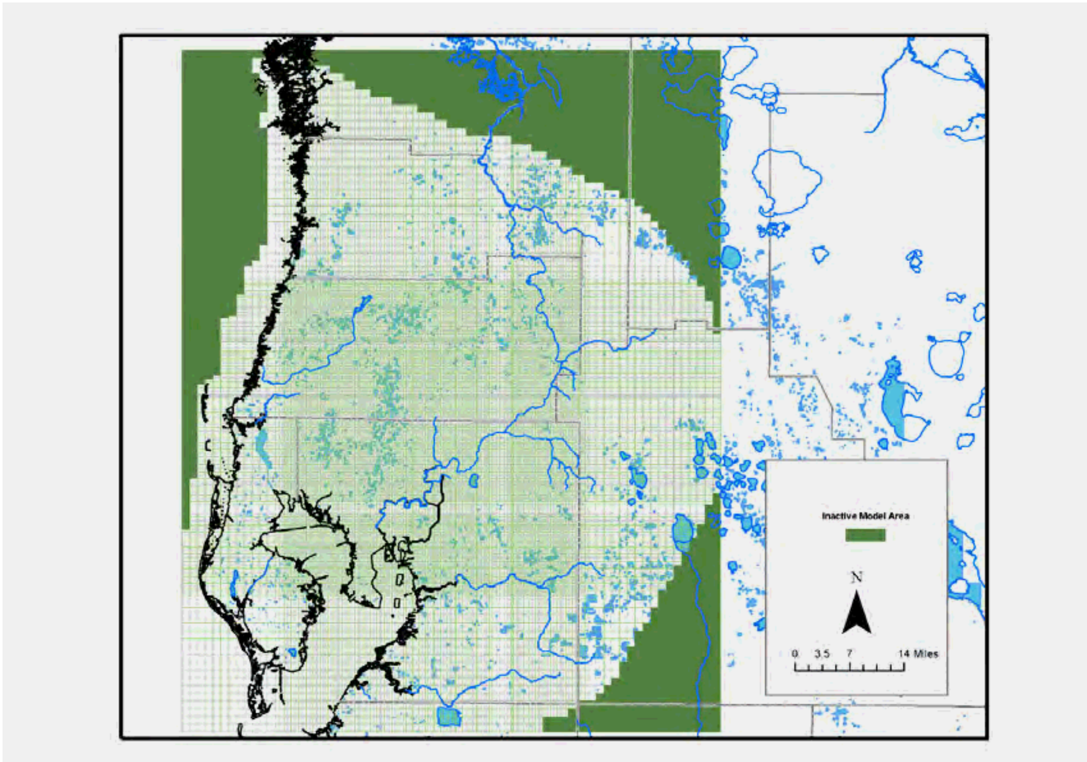


**Figure 2. Groundwater grid used in the INTB model**

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

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

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

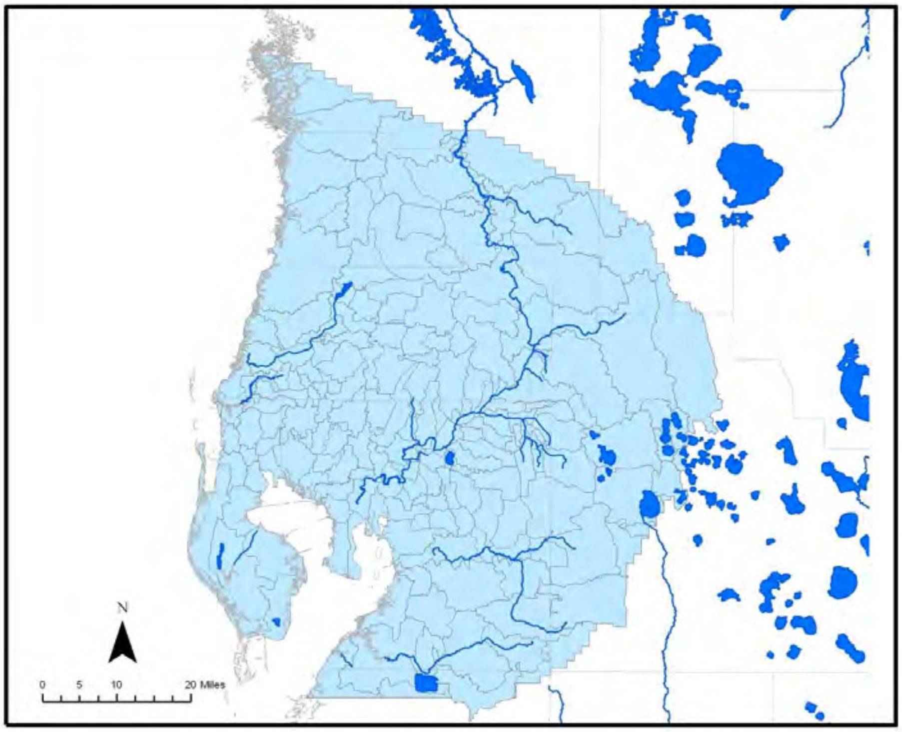


**Figure 3. HSPF subbasins in the INTB model.**

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

The INTB model is a regional simulation and has been calibrated to meet global metrics. The model is calibrated using a daily integration step for a transient 10-year period from 1989-1998. A model Verification period from 1999 through 2006 has recently been added. Model-wide mean error for all wells in both the surficial aquifer and Upper Floridan aquifers is less than 0.2 feet during both the calibration and verification periods. Mean absolute error was less than two feet for both the surficial and Upper Floridan aquifer. Total stream flow and spring flow mean error averaged for the model domain is each less than 10 percent. More information summarizing the INTB model calibration can be found in Geurink and Basso (2012).

3.1 INTB Model Scenarios

Three different groundwater withdrawal scenarios were run with the INTB model. The first scenario consisted of simulating all groundwater withdrawn within the model domain from 1989 through 2000. The second scenario consisted of eliminating all pumping in the Central West-

Central Florida Groundwater Basin (Figure 4). Total withdrawals within the Central West-Central Florida Groundwater Basin averaged 239.4 mgd during the 1989-2000 period. TBW central wellfield system withdrawals were simulated at their actual withdrawal rates during this period. The third scenario consisted of reducing TBW central wellfield system withdrawals to their mandated recovery quantity of 90 mgd from the 11 central system wellfields. For TBW only, the 2008 pumping distribution was adjusted slightly upward from 86.9 mgd to 90 mgd to match recovery quantities.

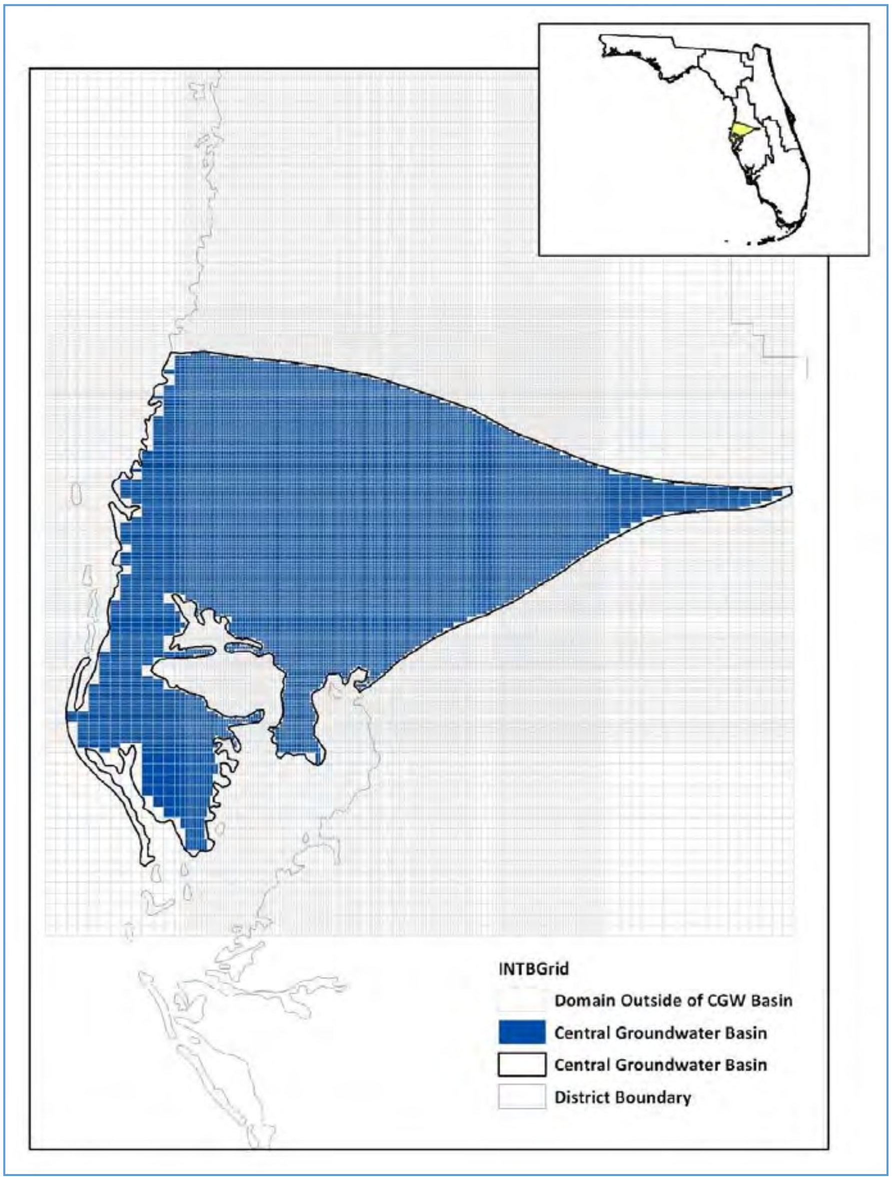


**Figure 4. INTB scenarios where impacts to the hydrologic system were simulated due to groundwater withdrawals in the Central West-Central Florida Groundwater Basin.**

Taking the difference in simulated heads from the 1989-2000 pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Padgett Lake was 1.2 ft and 2.2 ft in the Upper Floridan aquifer (Figure 5 and 6). Taking the difference in modeled heads from the TBW recovery pumping to non-pumping runs, the average predicted drawdown in the surficial aquifer near Padgett Lake was 0.4 ft and 0.6 ft in the Upper Floridan aquifer (Figure 7 and 8). Table 1 presents the predicted drawdown in the surficial aquifer based on the INTB model results.

**Table 1.** INTB model results for Padgett Lake.

| Lake Name | Predicted Drawdown (ft) in the Surficial Aquifer due to 1989-2000 Withdrawals* | Predicted Drawdown (ft) in the Surficial Aquifer with TBW Withdrawals reduced to 90 mgd* |
|---|---|---|
| Padgett | 1.2 | 0.4 |
| Lake Name | Predicted Drawdown (ft) in the Upper Floridan Aquifer due to 1989-2000 Withdrawals* | Predicted Drawdown (ft) in the Upper Floridan Aquifer with TBW Withdrawals reduced to 90 mgd* |
| Padgett | 2.2 | 0.6 |

* Average drawdown from model cells intersecting lake

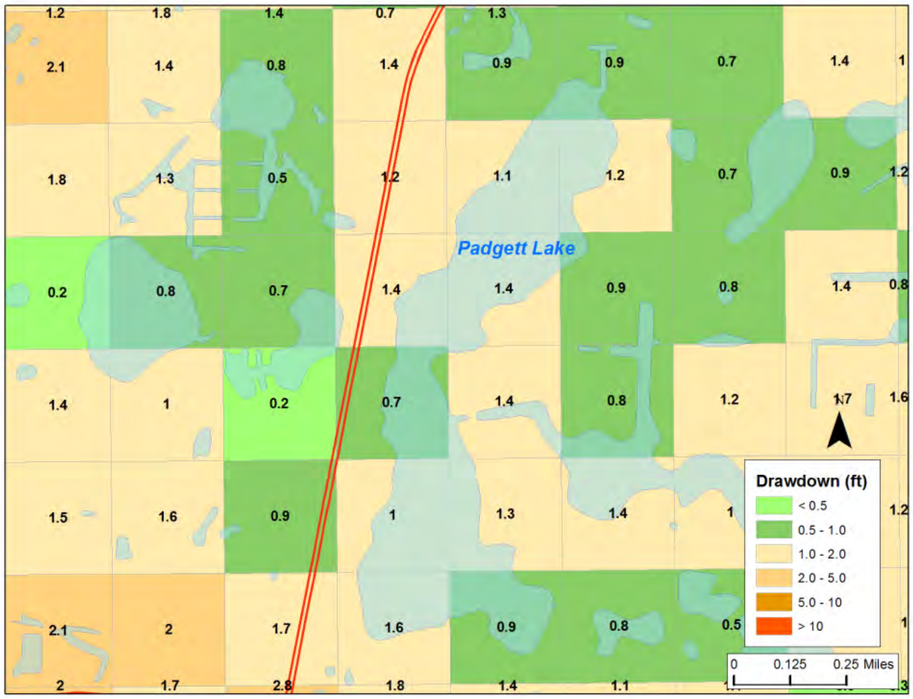


**Figure 5. Predicted mean drawdown in the surficial aquifer due to 1989-2000 groundwater withdrawals.**

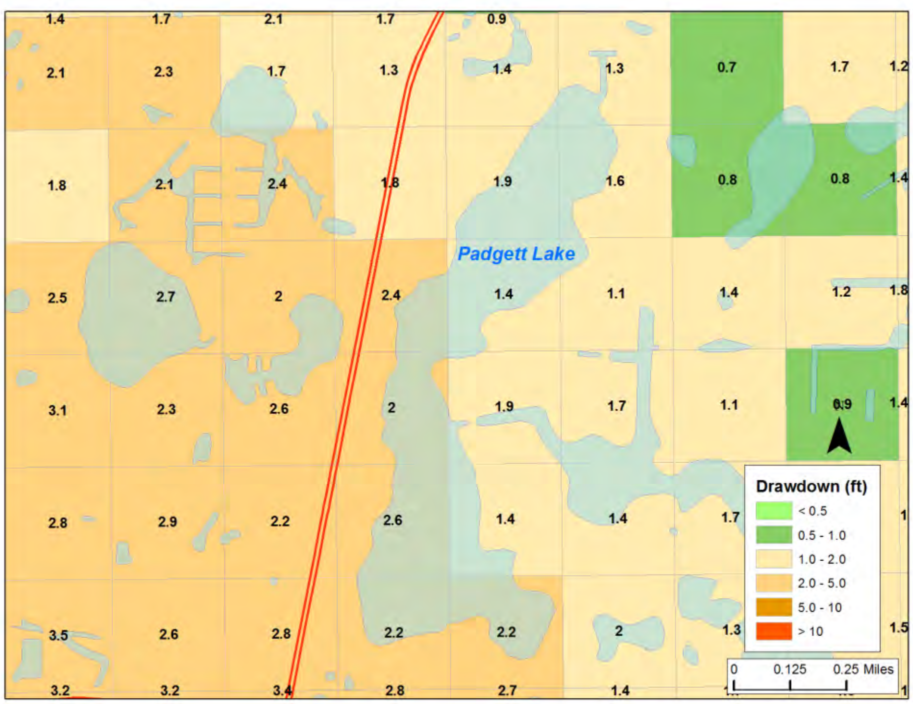


**Figure 6. Predicted mean drawdown in the Upper Floridan aquifer due to 1989-2000 groundwater withdrawals.**

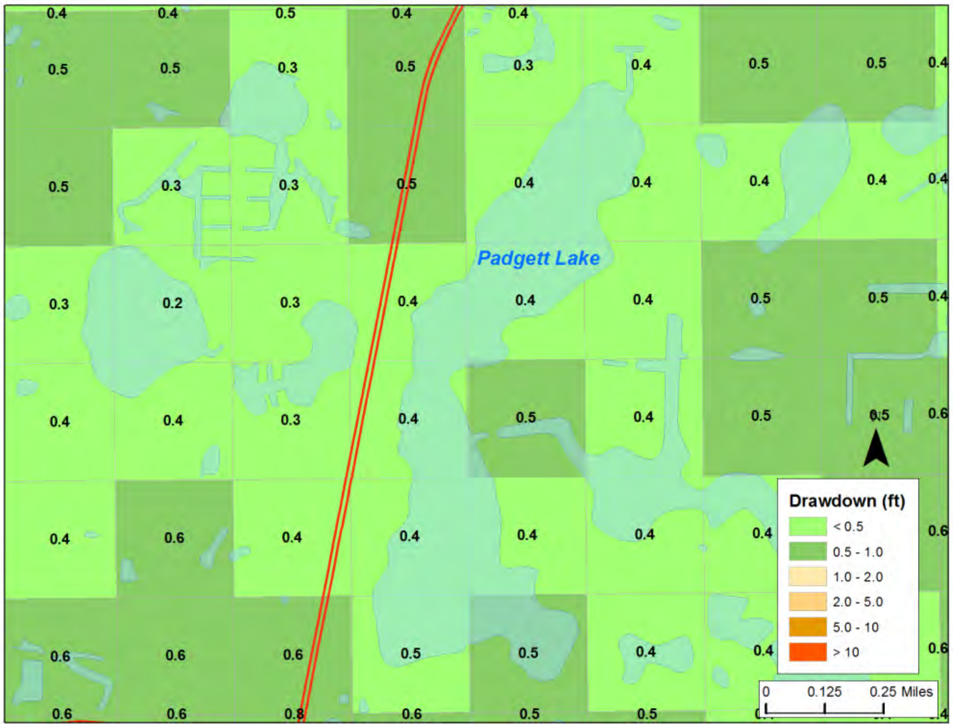


**Figure 7. Predicted mean drawdown in the surficial aquifer due to TBW 90 mgd groundwater withdrawals.**

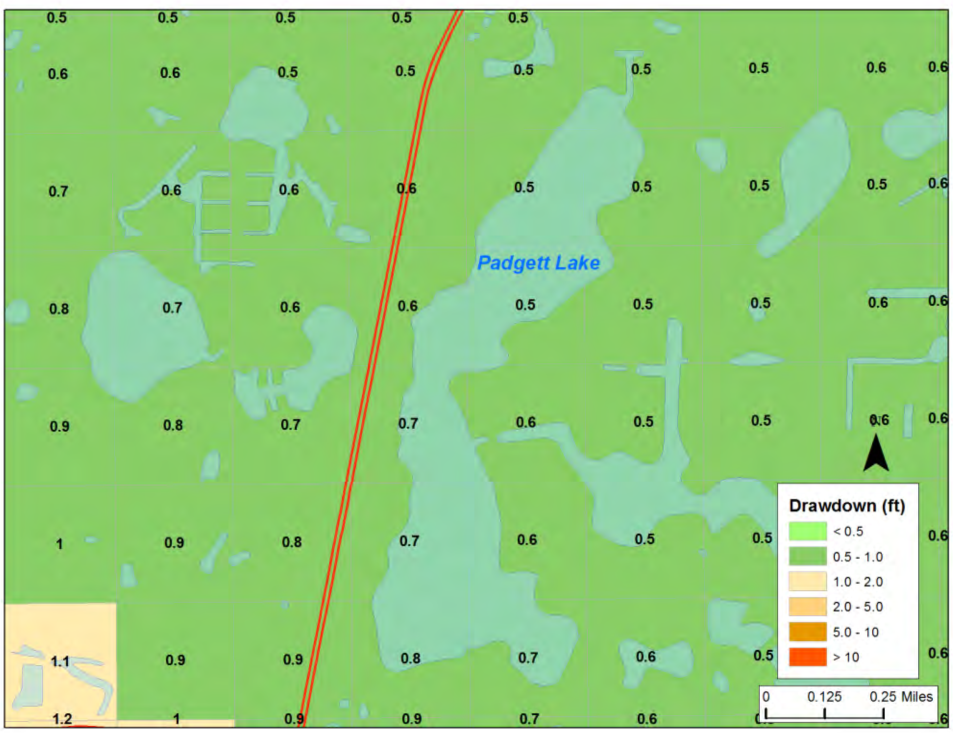


**Figure 8**. Predicted mean drawdown in the Upper Floridan aquifer due to TBW 90 mgd groundwater withdrawals.

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Sepulveda, N. 2002. Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida, U.S. Geological Survey WRI Report 02-4009, 130 p.

Southwest Florida Water Management District, 1993, Computer Model of Ground-water Flow in the Northern Tampa Bay Area, 119 p.

# Appendix C:

Ellison, D.L. 2016. Memorandum to Douglas A. Leeper dated December 5, 2016. Subject: Lake Padgett Hydrogeology, Rainfall Regression Models, Historic Percentile Estimations and Assessment of Minimum Levels Status. Southwest Florida Water Management District. Brooksville, Florida.

**Technical Memorandum**

December 5, 2016

TO: Douglas A. Leeper, Chief Advisory Environmental Scientist, Water Resources Bureau

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

FROM: Donald L. Ellison, P.G., Senior Hydrogeologist, Water Resources Bureau

**Subject: Lake Padgett Hydrogeology, Rainfall Regression Models, Historic Percentile Estimations and Assessment of Minimum Levels Status**

## A. Introduction

A rainfall regression model was developed to assist the Southwest Florida Water Management District (District or SWFWMD) in the establishment of revised minimum and guidance levels for Lake Padgett, located in southeast Pasco County (Figure 1). This document discusses development of the model, hydrogeologic evaluations used to support model development, derivation of lake stage percentiles used to develop revised levels for the lake, and minimum level status assessments (i.e., whether long-term water levels in the lake are above currently and projected to stay above the proposed minimum levels, i.e., whether the levels are being met and may be expected to be met for the next twenty years.

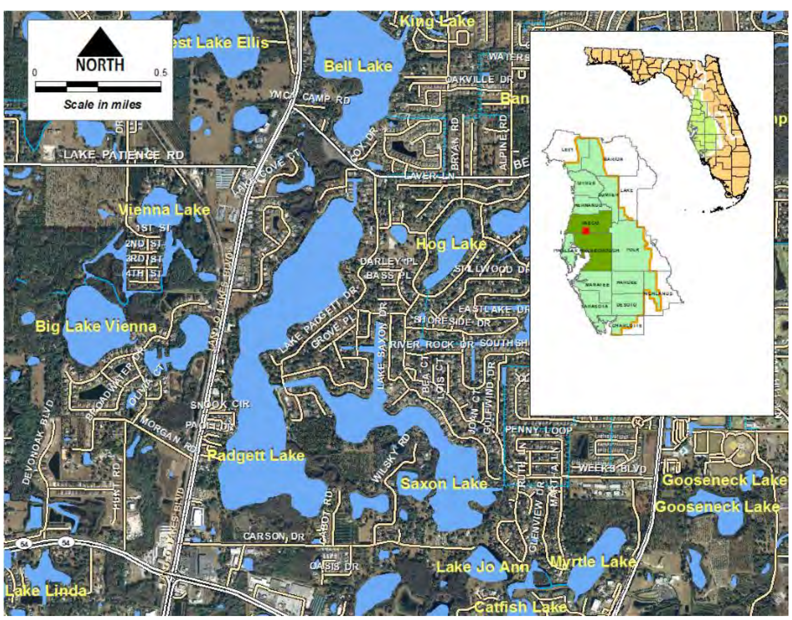



**Figure 1. Location of Lake Padgett in Pasco County, Florida.**

## B. Background and Setting

Lake Padgett is located in south-central Pasco County, approximately 2 miles north of the southern Pasco County line (Figure 1). The lake is located in the Lake Hanna Outlet basin which is also known as Thirteen-Mile Run and lies within the larger Hillsborough River watershed (Figures 2 and 3). White (1970) classified the physiographic area as the Northern Gulf Coastal Lowlands bordered to the east by the Western Valley. The area surrounding the lake is categorized as the Land-O-Lakes subdivision of the Tampa Plain in the Ocala Uplift Physiographic District (Brooks, 1981), a region of many lakes on a moderately thick plain of silty sand overlying limestone (Figure 4). The topography is relatively flat, and drainage into the lake is a combination of overland flow and flow through drainage swales and minor flow systems.

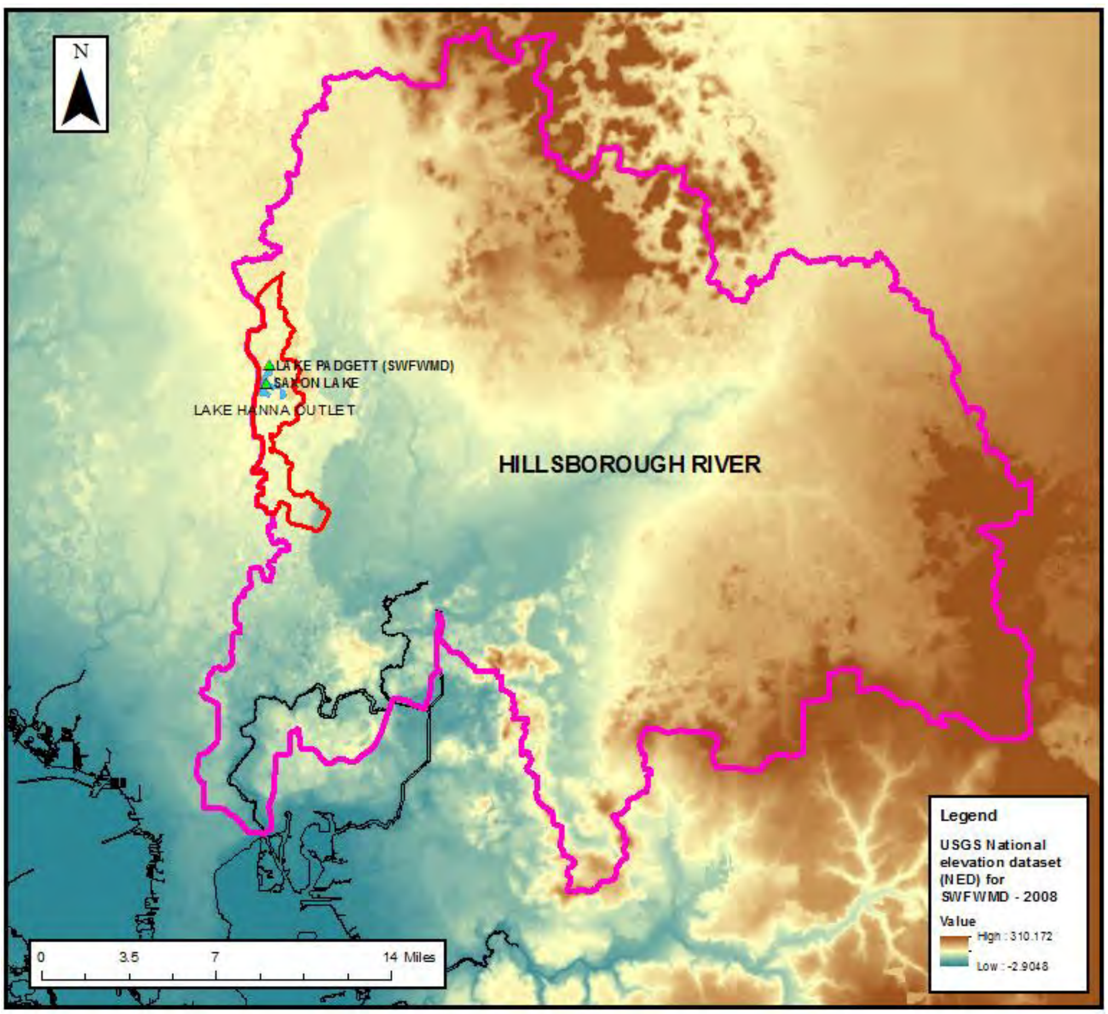



**Figure 2. Watershed delineation and topography.**

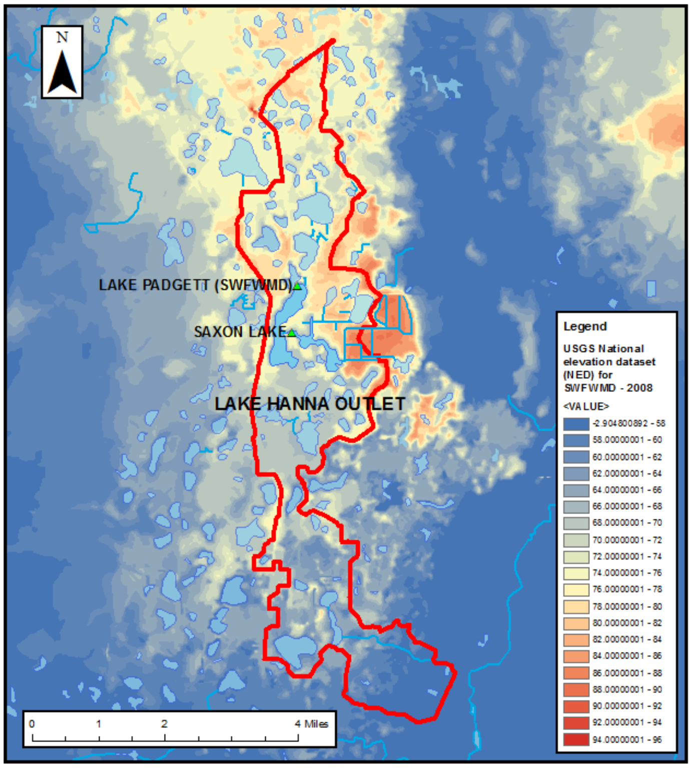



**Figure 3. Drainage Basin delineation and topography.**

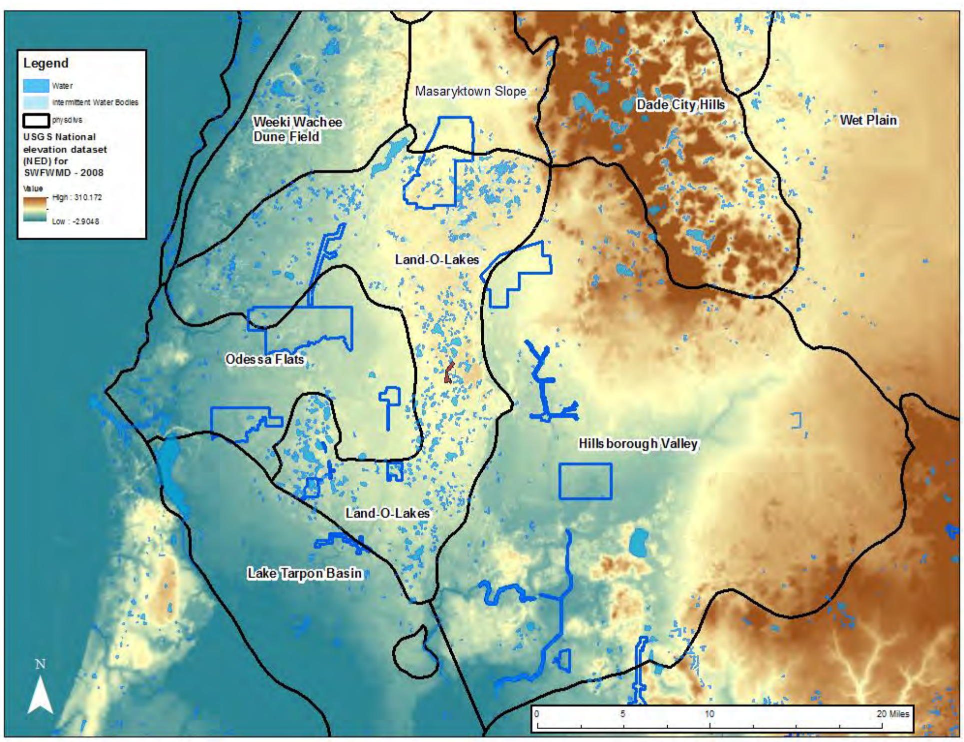



**Figure 4. Physiographic Provinces (Brooks, 1981) and topography.**

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

Lake Padgett is approximately 3 miles northeast of the South Pasco Wellfield, 6 miles southeast of the Starkey Wellfield, 5 miles southwest of the Cypress Creek Wellfield and 5 miles east of Cypress Bridge dispersed wellfields. These wellfields are part of the eleven regional water supply wellfields collectively referred to as the Central System Facilities that are operated by Tampa Bay Water (TBW) (Figure 5). Groundwater withdrawals began at the Section 21 Wellfield in 1963 and incrementally increased to approximately 20 mgd in 1967 (Figure 6). With the development of the South Pasco Wellfield in 1973, withdrawal rates at the Section 21 Wellfield were reduced to approximately 10 mgd, while withdrawal rates at the South Pasco Wellfield rose to 16 to 20 mgd, for a combined withdrawal rate ranging from 20 to 30 mgd in the mid to late 1970s (Figure 6). Cypress Creek Wellfield withdrawals began in 1976 and operated at approximately 30 mgd prior to cutbacks. Cypress Bridge Wellfield withdrawals were initiated in 1982 at a less than 1 mgd and increased to approximately 10 mgd. Combined withdrawal rates since 2005 have ranged from zero to nearly 90 mgd, with several extended periods when individual wellfields were shut down.

Total estimated water use in the area inclusive of other uses such as agriculture and domestic supply wells is presented as sums for radial distances from the approximate center of the lake in Figures 7 through 9. Estimated and metered water use are available from 1994 through 2012.

Changes to surficial and Upper Floridan aquifer levels in the vicinity of Lake Padgett were evaluated (Patterson, 2015) using the Integrated Northern Tampa Bay Model developed by Geurink and Basso (2013). Pumping and non-pumping model scenarios were performed for the period starting in 1989 and ending in 2000. Total withdrawals within the Central West-Central Florida Groundwater Basin, within which Lake Padgett lies, averaged 239.4 mgd during the 1989-2000 period. A third scenario, consisting of reducing TBW central wellfield system withdrawals to their mandated recover quantity of 90 mgd from the 11 central wellfields was also evaluated. Based on the difference in simulated heads from the 1989-2000 pumping and non-pumping model runs, the average predicted drawdown in the surficial and Upper Florida aquifers near Lake Padgett were 1.2 ft. and 2.2 ft., respectively. Based on the difference in modeled heads from the TBW recovery pumping and the non-pumping scenarios, the average predicted drawdown near the lake was 0.4 ft. in the surficial aquifer and 0.6 ft. in the Upper Floridan aquifer.

However, statistical modeling of Lake Padgett water levels and area rainfall as described in the following section of this memorandum indicates that water level fluctuations in the lake are closely associated with rainfall variation, confirming an earlier District (SWFWMD, 1999a) finding that impacts from groundwater withdrawals are minimal for most of the period of record at Lake Padgett.

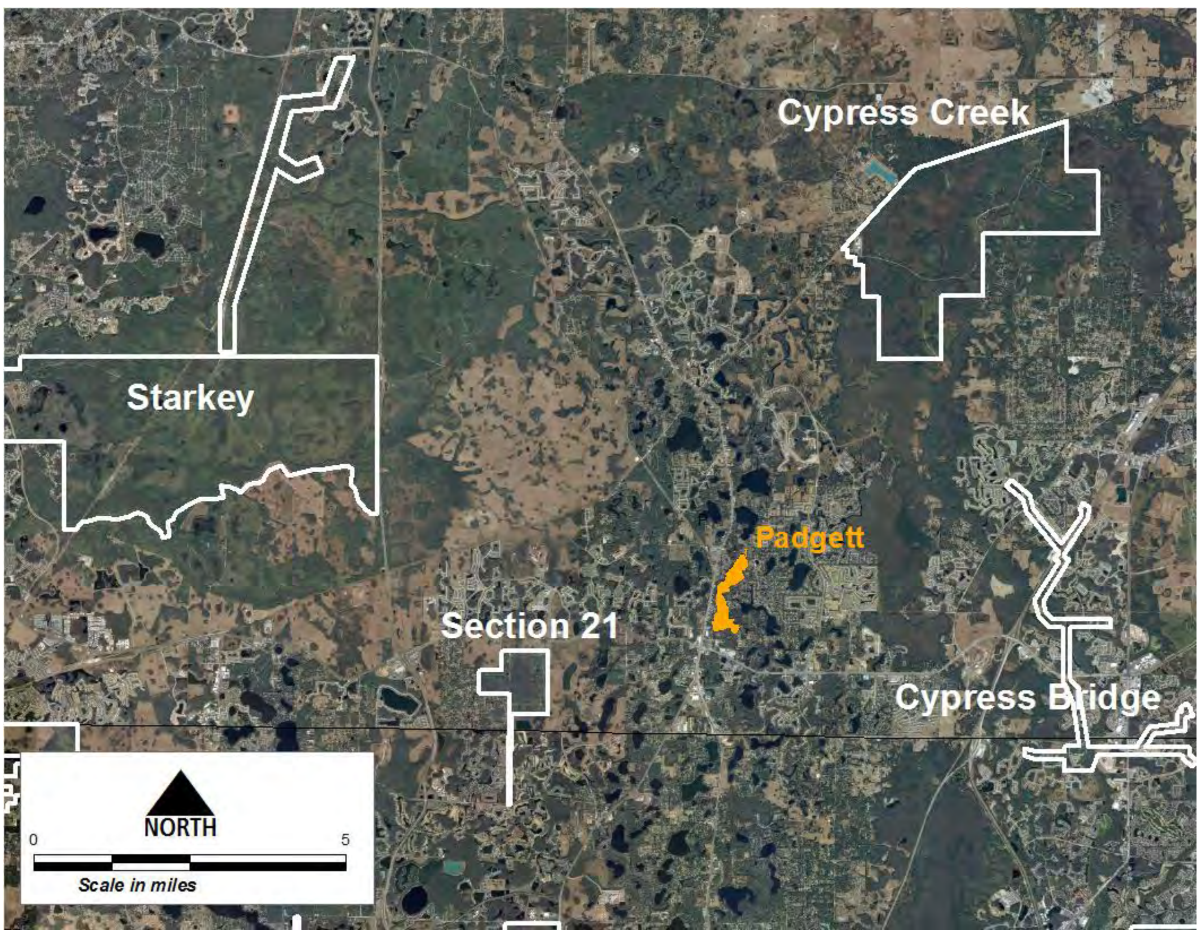



**Figure 5. Lakes Padgett and neighboring wellfields.**

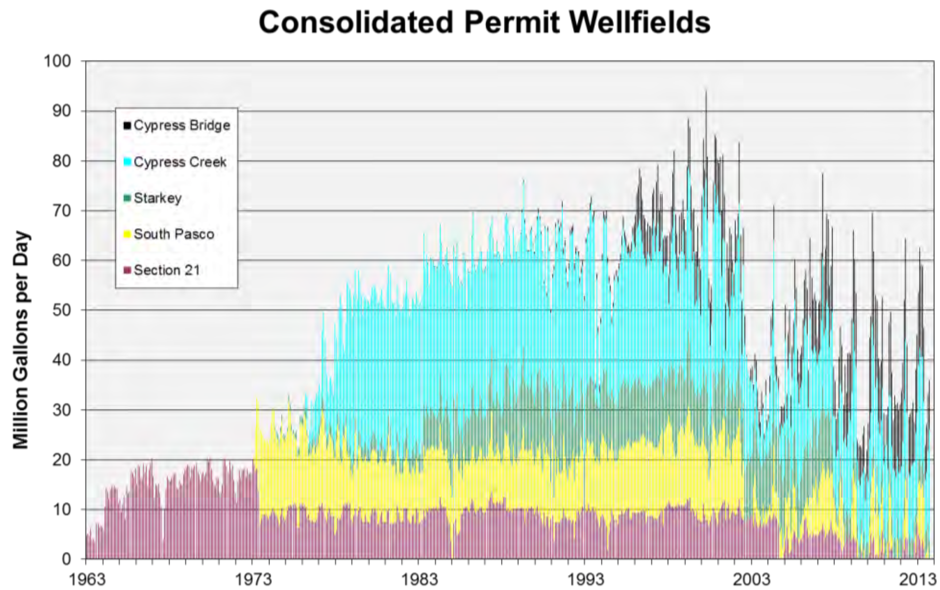



**Figure 6. Section 21, South Pasco, Cypress Creek, Starkey and Cypress Bridge wellfield withdrawals.**

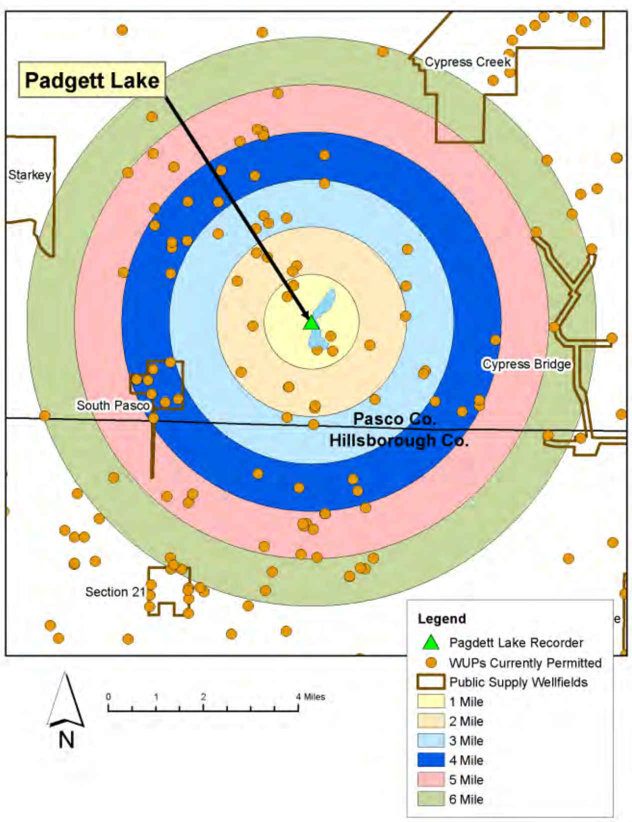



**Figure 7. Location of withdrawals near Lake Padgett.**

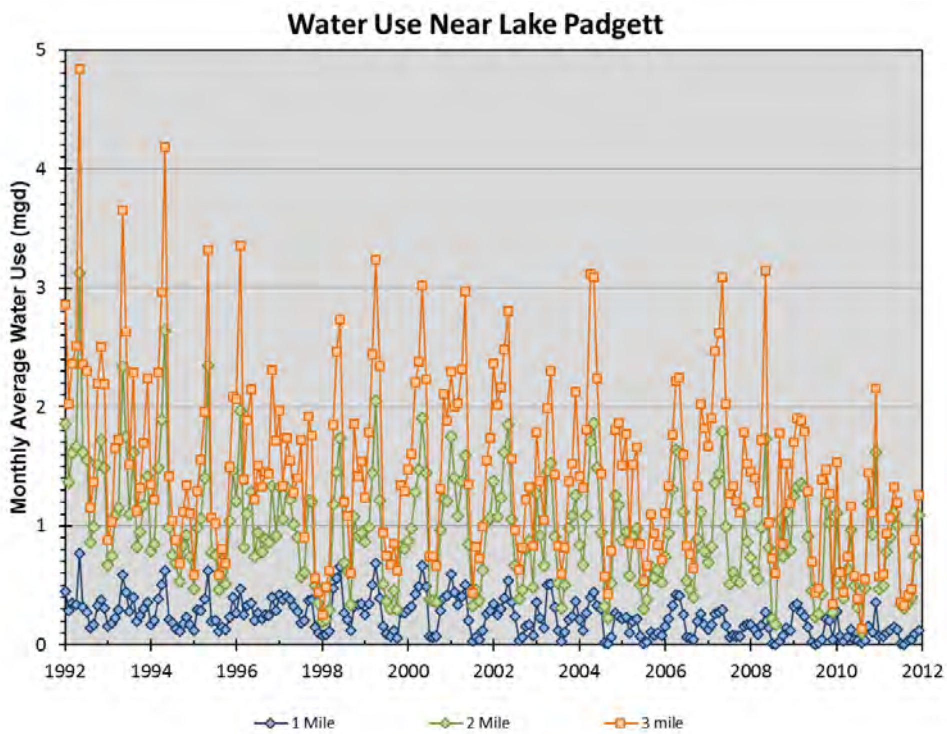



**Figure 8. Metered and estimated water use within 1, 2 and 3 miles of Lake Padgett.**

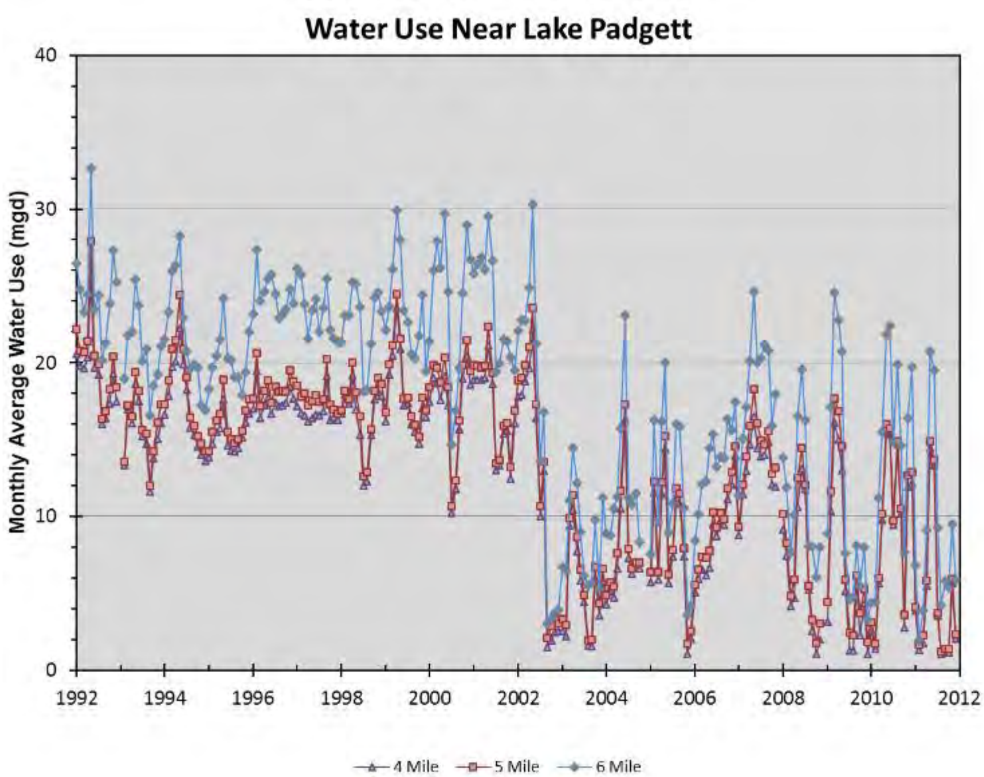



**Figure 9. Metered and estimated water use within 4, 5 and 6 miles of Lake Padgett. Note that y-axis scale differs from that shown in Figure 8.**

**Rainfall Regression Long-Term Historic Lake Percentile Estimation**

The procedure to establish minimum and guidance levels for lakes is based on long-term lake stage percentiles. In the absence of a long-term water level data, a rainfall based regression model may be constructed and used to model lake stage fluctuations and create a long-term water level record. A first step in developing a rainfall regression model is the delineation of “Historic” and “Current” time periods. A Historic time period is a period when there are little to no groundwater withdrawal impacts on the lake, and the lake’s structural condition is similar or the same as the present day. In contrast, a Current time period is a recent long-term period during which withdrawals and structural alterations are stable. To identify Historic and Current time periods, an evaluation of hydrologic changes in the vicinity of the lake is completed to determine if the water body has been significantly impacted by groundwater withdrawals. Examples of hydrological changes that are reviewed include drainage modifications, dredging, filling and modifications to the lake outlets.

Data from the Historic period are typically used to establish a statistical relationship (regression) with rainfall. This rainfall regression is then used to extend the available stage record (i.e., develop a 60 year or longer record) for calculation of long-term P10, P50 (median), and P90 lake stage percentiles. The P10, P50 and P90 are, respectively, the water level elevations equaled or exceeded ten, fifty and ninety percent of the time on a long-term basis. The rainfall regression model can then be used to evaluate whether the lake is fluctuating consistently with climate (primarily rainfall) and can also be used for assessing whether minimum levels are being met.

This memorandum describes the hydrogeologic setting near Lake Padgett, delineation of a Historic period, development of rainfall regression models and selection of a best-fit model for the lake, and assessment of the current and future lake levels with respect to revised minimum levels for the lake.

The rainfall regression method (Ellison 2010) involves development of a Line of Organic Correlation (LOC) between lake stage and rainfall. The LOC is a linear fitting procedure that minimizes errors in both the x and y directions and defines the best-fit straight line as the line that minimizes the sum of the areas of right triangles formed by horizontal and vertical lines extending from observations to the fitted line (Helsel and Hirsch, 1992. The magnitude of the slope of the LOC line is calculated as the ratio of the standard deviations of the x and y variables and its sign, i.e., whether it is positive or negative, determined by the sign (+ or -) of the correlation coefficient (r). The LOC approach, rather than a simple linear regression approach is preferable for the rainfall-regression method since it produces a result that better retains the variance (and therefore retains the "character") of the original data.

Rainfall for the LOC model is correlated to lake water level data using inverse linearly-weighted rainfall sums. The weighted-sums ascribe higher weight to more recent rainfall and progressively less weight to rainfall in the past. For the rainfall regression method, weighted sums varying from 6 months to 10 years are used to develop separate models, and the model with the highest coefficient of determination ($r^2$) is chosen as the best-fit model.

**Lake Padgett Water Level Data and Identification of Historic Data**

Stage data has been measured at two gage sites within Lake Padgett. The first site, District site identification (SID) number 19127, was operated by the U.S. Geological Survey (USGS) from January 1965 through August 2004. The second, SID 192230, was installed in July 1985 and continues to be operated by the District. There is a period of overlap in stage records for the two gages, and comparison of these records show good agreement (Figure 10).

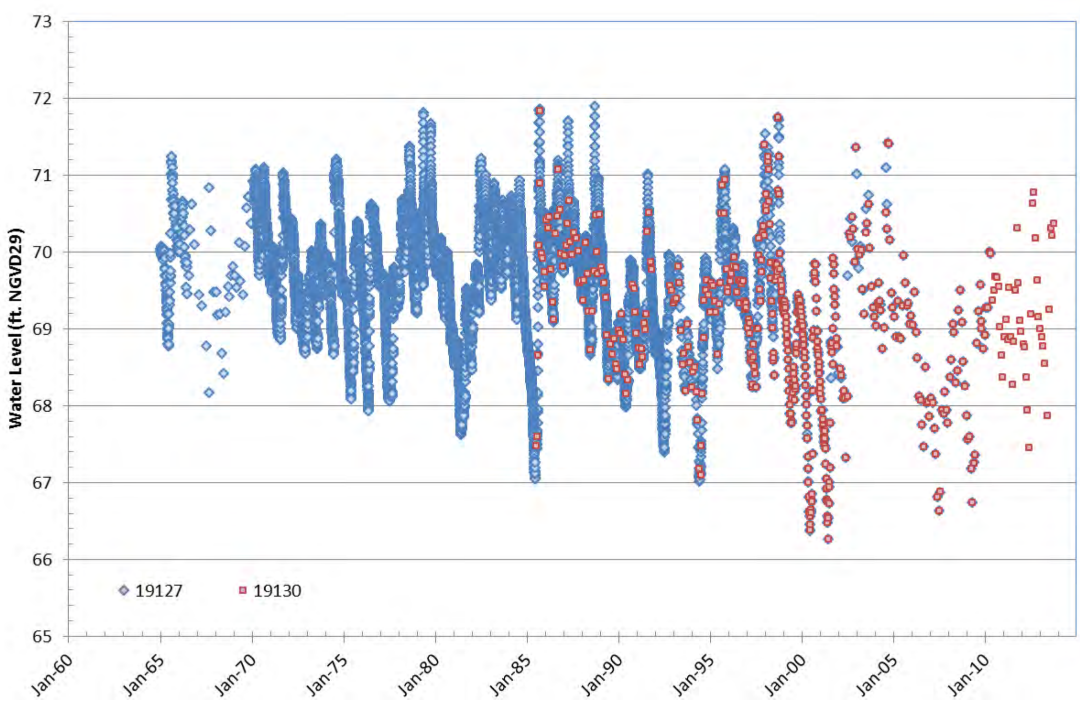



**Figure 10. Lake Padgett water level data for two gage sites (SID 19127 and SID 19130).**

The early water level data for Lake Padgett pre-dates initiation of withdrawals at the nearby South Pasco (started in 1973), Cypress Creek (started in 1976) and Cypress

Bridge (started 1982) wellfields. Section 21 Wellfield, where withdrawals began 1963, is located 5 miles to the south and has little influence on water levels in the area of Lake Padgett (Henderson 1983; SWFWMD 1995). Based on this information, stage data collected for Lake Padgett prior to 1973 is considered to be Historic data.

Lake Padgett is part of the Thirteen-Mile Drainage Run and is considered a structurally altered lake. In 1967, as part of a residential development, a canal was dredged that connected Lake Padgett to Lake Saxon located immediately to the east (Henderson 1983). Both lakes have been dredged and the material was used to enhance lake front property for development. Lake Saxon has been altered more extensively than Lake Padgett (Henderson 1983). Below an elevation of approximately 68.5 ft. NGVD29 the two lakes would be hydraulically separated. Above this elevation water levels in the lakes are equivalent or similar.

### Rain Gauge Data

Available rain gage data were inventoried and sorted by distance from Lake Padgett and their period of record (POR) to locate the closest rain data to the lake for compilation of a long-term rainfall record that could be used to develop rainfall regression LOC models to predict long-term lake levels. Daily records from a rainfall station 1.5 miles from Lake Padgett (Site 19057, Myrtle Lake) were used when available and supplemented with records available from the next closest station (SID 19629, Lutz) when necessary. Table 1 presents the progression of gauges used for model development and model predictions and Figure 11 shows the location of the gages. For days when multiple gages were missing data at the same time an average of several gages was used to infill the missing data.

**Table 1: Rain gauges used in the rainfall-regression model.**

| Site ID | Site Name | Period of Record Begin | Period of Record End | Distance from Lake Padgett (mi.) |
|---|---|---|---|---|
| 19431 | LAKE PADGETT | 12/31/84 | 9/30/94 | 0.0 |
| 19057 | MYRTLE LAKE | 11/30/67 | 5/31/79 | 1.5 |
| 19493 | LAKE COMO | 1/5/95 | 9/17/09 | 1.6 |
| 22870 | SOUTH PASCO (ST PETE 42) | 12/31/75 | 1/9/02 | 3.1 |
| 18301 | LAKE HOBBS | 12/31/85 | 12/31/95 | 3.1 |
| 19629 | LUTZ | 12/31/62 | 8/31/97 | 3.2 |
| 19495 | ST PETE 42 | 2/27/99 | 10/28/13 | 3.8 |
| 18593 | LAKE HANNA | 8/5/99 | 10/28/13 | 4.4 |
| 19829 | CRYSTAL LAKE | 5/31/86 | 4/30/05 | 4.8 |
| 18909 | CYPRESS CREEK TMR-5 | 12/31/95 | 10/28/13 | 5.2 |
| 18901 | SAINT LEO NWS | 12/31/1900 | 12/31/2011 | 15.3 |

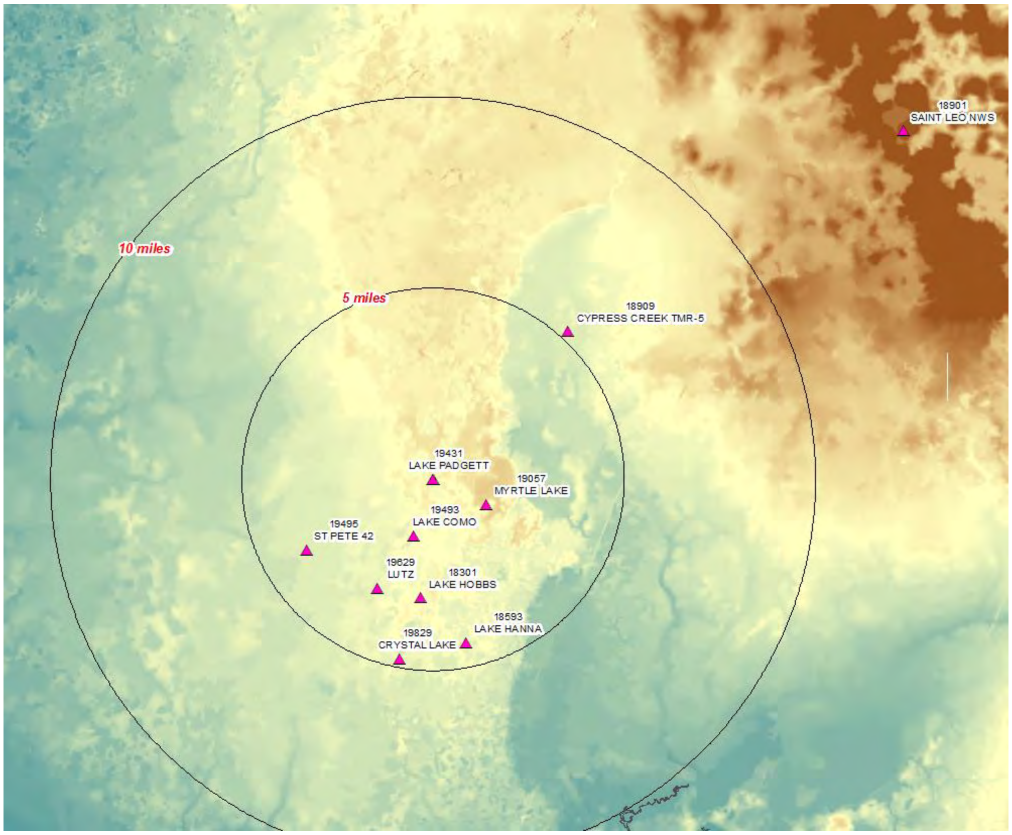



**Figure 11. Rain gauge locations used in the rainfall regression models for Lake Padgett.**

## Lake Padgett Rainfall Regression Model and Historic Percentiles

Rainfall regression LOC models were developed using lake stage data and rainfall data from January 1965 through December 1970. Data collected after this period were conservatively excluded from model development to preclude inclusion of records that could reflect potential effects from groundwater withdrawals at the Central System Facilities. The best-fit LOC model for predicting water levels in Lake Padgett (Figure 12) exhibited a coefficient of determination ($r^2$) of 0.72 and may be simplified as:

$$\hat{y}_i = b_0 + sign[r] * b_i * x_i \qquad \text{(Equation 1)}$$

Where

$\hat{y}_i =$ *the estimate of lake stage expressed as an elevation in feet above NGVD29*

$b_0 =$ *the y intercept, in this case 64.05 feet above NGVD29*

$b_i =$ *the regression slope; in this case 0.100*

$sign[r]$ = *the algebraic sign (+ or -) of the correlation coefficient; in this case "+"*

$x_i$ = the *inversely, linearly-weighted two-year cumulative rainfall sum in inches*

The residuals and a time series plot of actual (i.e., observed) and modeled water levels for the 1965-1970 calibration period are shown in Figures 12 and 13, respectively. A comparison of measured and modeled percentiles for the calibration period is presented in Table 2. The model-derived P10, P50 and P90 percentiles for the calibration period were respectively, 0.1 ft. lower, 0.1 ft. higher and 0.1 ft. lower than the corresponding percentiles for the observed data.

The best-fit LOC model and rainfall records from the rain gages listed in Table 1 were used to estimate water levels for Lake Padgett for the period from January 1, 1946 through January 30, 2013. Model-predicted water levels match actual, i.e., observed period of record data reasonably well, indicating that the lake water levels fluctuate mostly in response to rainfall and impacts from groundwater withdrawals are minimal for most of the record.

Because the model produced a close match with the observed data throughout the period of record, Long-term percentiles were developed as a composite of observed data and modeled data that was used to infill data gaps. Historic long-term percentiles for Lake Padgett based on the hybrid set of modeled and observed records are presented in Table 3.

**Lake Padgett Normal Pool Elevation and Historic Percentiles**

A Normal Pool elevation is a datum established to standardize measured water levels, facilitate comparisons among wetlands and lakes, aid in the design of wetland storm water treatment systems (SWFWMD, 1988) and the development of minimum lake and wetland levels (Southwest Florida Water Management District 1999a, 1999b). The Normal Pool can be consistently identified in cypress swamps or cypress-ringed lakes based on similar vertical locations of several indicators of inundation (Hull, et al., 1989; Biological Research Associates, 1996).

A Normal Pool of 70.4 feet NGVD was determined for Lake Padgett based on buttress inflection points of cypress trees along the lake shore and within wetlands contiguous with the lake. A comparison of the long-term, historic P10 of 71.0 feet for the lake with the Normal Pool elevation indicates that Lake Padgett can exceed long-term lake levels associated with establishment of the remaining fringing wetlands. The long-term P10 is 0.6 feet higher than Normal Pool, which is a relatively large difference. There are two possible factors that may account for the difference. The first may be related to the outlet control structures at the south end of Lake Padgett. It is possible the structures are holding the lake up slightly. A second factor is that the connection to Lake Saxon may have resulted in the equalization of water levels in the two lakes that has slightly raised Lake Padgett and lowered Lake Saxon. Water level data predating the canal dredging that connected the two lakes are not available for Lake Saxon, but Lake Saxon is located upstream from Lake Padgett and water levels in Lake Saxon may have been naturally higher than in Lake Padgett. In addition, extensive modification of drainage features contributing flow to Lake Saxon have occurred, and this may have contributed to higher water levels in both Lake Saxon and Lake Padgett.

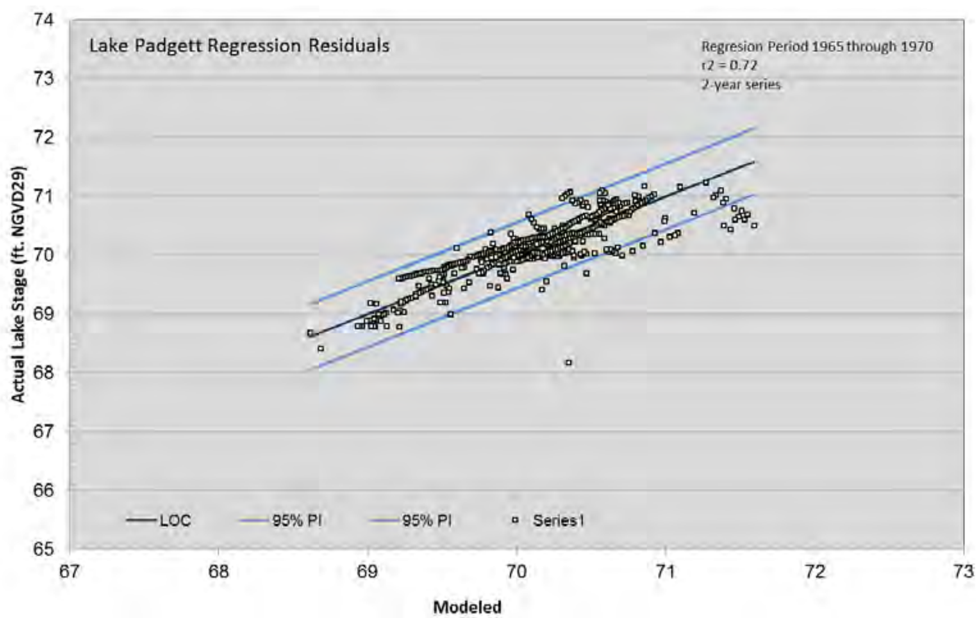
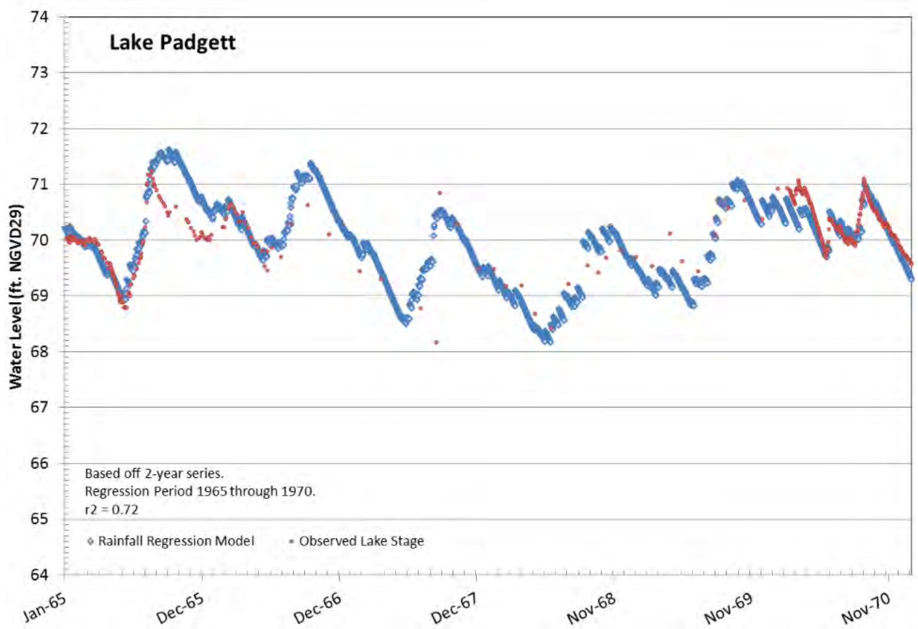



**Figure 12. Lake Padgett Line of Organic Correlation (LOC) model results and 95% prediction intervals.**



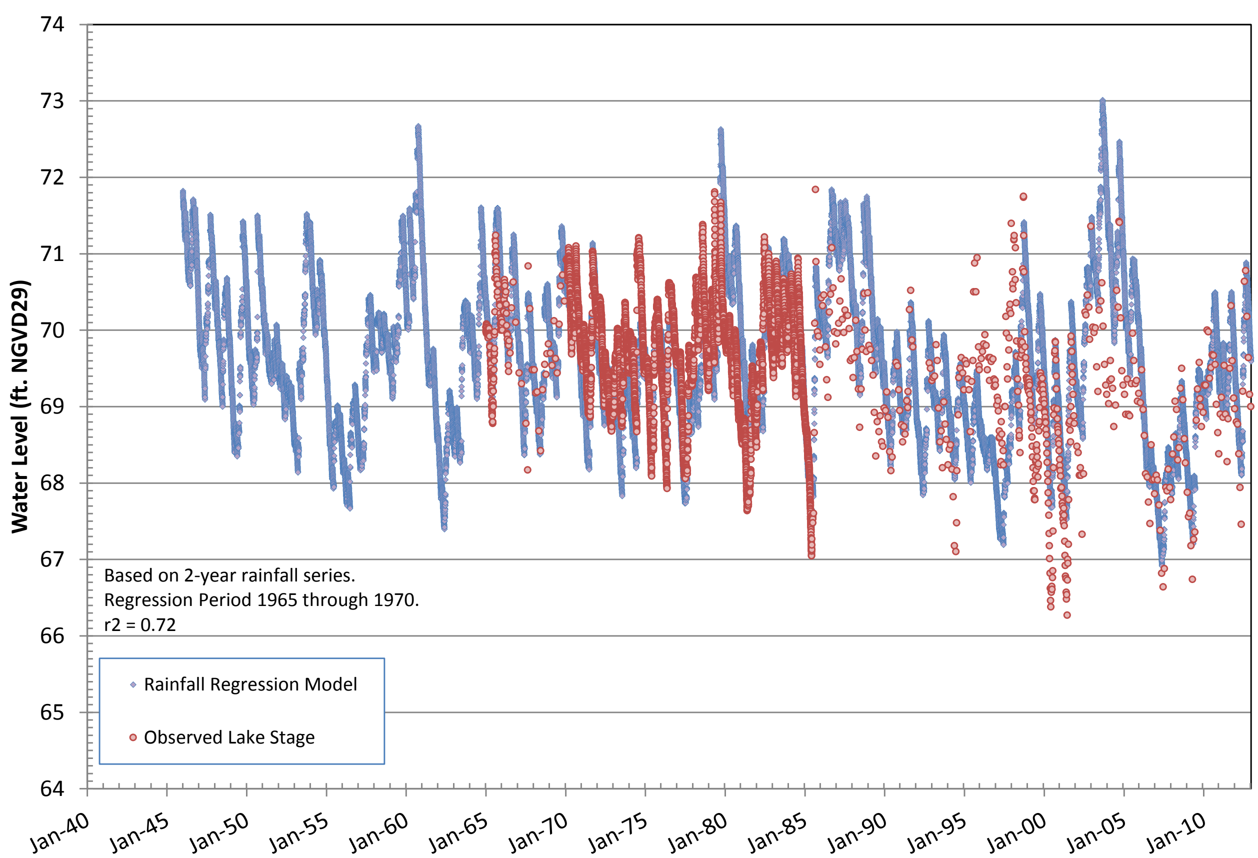




**Figure 14. Lake Padgett LOC-model predicted and actual (i.e., observed) water levels for an 805 month period from January 1, 1946 through January 30, 2013.**

**Table 2. Comparison of Lake Padgett calibration period percentiles.**

| **Calibration 1965 through 1970** | | |
|---|---|---|
| **Percentiles*** | **Observed** | **Model** |
| **P10** | 70.8 | 70.7 |
| **P50** | 70.1 | 70.2 |
| **P90** | 69.5 | 69.4 |

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time

**Table 3. Lake Padgett Long-term Historic percentiles.**

| **Lake Padgett Long-term Historic Percentiles*** **(1/1/1946 through 1/30/2013)** | |
|---|---|
| **Percentiles** | |
| **P10** | 71.0 |
| **P50** | 69.6 |
| **P90** | 68.3 |

* Percentiles listed include the water surface elevation equaled or exceeded ten (P10), fifty (P50) and ninety (P90) percent of the time

## Assessment of Minimum Level Status

The goal of a minimum levels status assessment is to determine if lake levels are fluctuating in accordance with criteria associated with adopted or proposed levels, i.e., to determine whether or not the minimum levels are being met. In addition to use of a rainfall regression model and/or other types of models, the process includes comparison of long-term water levels with adopted or proposed levels, review of periodic groundwater modeling updates, and, if necessary, investigation of other factors that could help explain lake level fluctuations.

An assessment method used for evaluating the Minimum Lake Level (MLL) involves modification of an LOC model and associated prediction intervals based on elevations associated with the Historic P50 and the MLL. For this process, the intercept for the LOC model and prediction intervals are decreased in elevation based on the difference between the Historic P50 and the MLL (Figure 15). These modified, shifted lines represent a defined range of lake levels that would be expected to meet the MLL while exhibiting variation expected due to changes in rainfall.

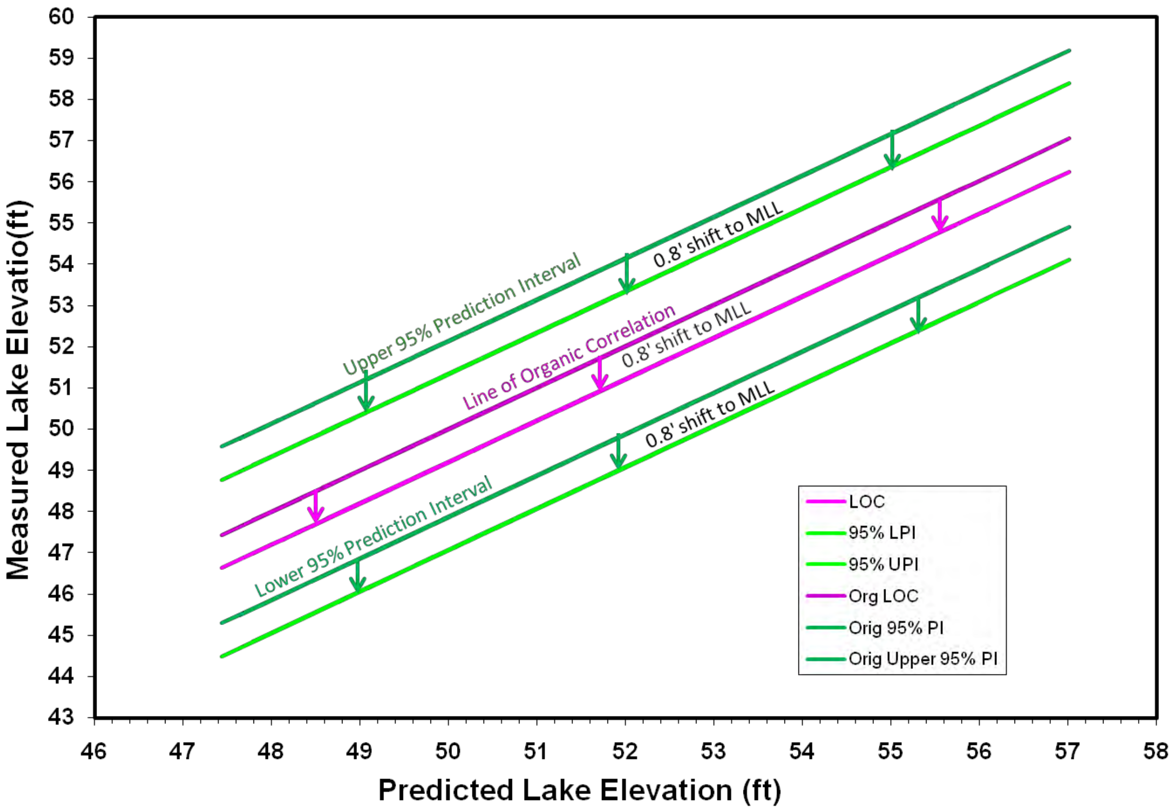



**Figure 15. Example of the shifts to the prediction interval and LOC lines to reflect the MLL.**

Prediction intervals for an LOC model are calculated for alpha equal to 0.025 (single tail) using the following equation (Helsel and Hirsch, 1992):

$$\left(\hat{y} - ts\sqrt{1 - \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{SS_x}}\ ,\ \hat{y} + ts\sqrt{1 - \frac{1}{n} + \frac{(x_0 - \bar{x})^2}{SS_x}}\right); \qquad \text{(Equation 2)}$$

Where

$\hat{y}_i = b_0 + sign[r] * b_i * x_i$ (*the estimate of y given* $x_i$) (refer to Equation 1)

$t = \frac{\bar{y} - \mu_0}{s/\sqrt{n}}$ *Student's t distribution*

$s = \sqrt{s^2}$ *standard error of the regression*

$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n}$ *mean x*

$SS_x = \sum_{i=1}^{n} (x_i - \bar{x}_i) = \sum_{i=1}^{n} x_i^2 - n(\bar{x})^2$ *sums of squares*

The LOC model can also be used to update predicted daily or monthly lake levels which are then combined in an assessment plot along with a shifted LOC and prediction intervals to identify the number of predicted daily or monthly points that plot below the lower 95% prediction interval. For a 95% prediction interval it is expected that 2.5% of the points will plot below the lower prediction interval. However, such a strict interpretation may not be appropriate for MLL status assessments due to the variability in rainfall and the complexities in representing areal rainfall totals with point measurement taken at a gage site. Because of these and other factors such as limitations imposed on calibration to short time periods that may not include the entire range of water levels (extreme highs and record lows), the expected number of predicted water level values that may plot below the 95% prediction interval is doubled, to 5%. The occurrence of more than 5% of the predicted water level values below the lower prediction interval would suggest the lake is lower than can be accounted for based solely on rainfall, and may be affected by changes resulting from groundwater withdrawals or other factor(s).

The revised MLL for Lake Padgett's (68.6 feet above NGVD29) is one foot lower than the modeled Historic P50. For assessment of the MLL status, the intercept of the LOC and prediction intervals were therefore shifted down 1.0 foot. Plotted regression model results versus observed levels for Lake Padgett since January 2007 lie near the top of or above the shifted upper prediction interval (Figure 16), indicating the revised MLL is being met.

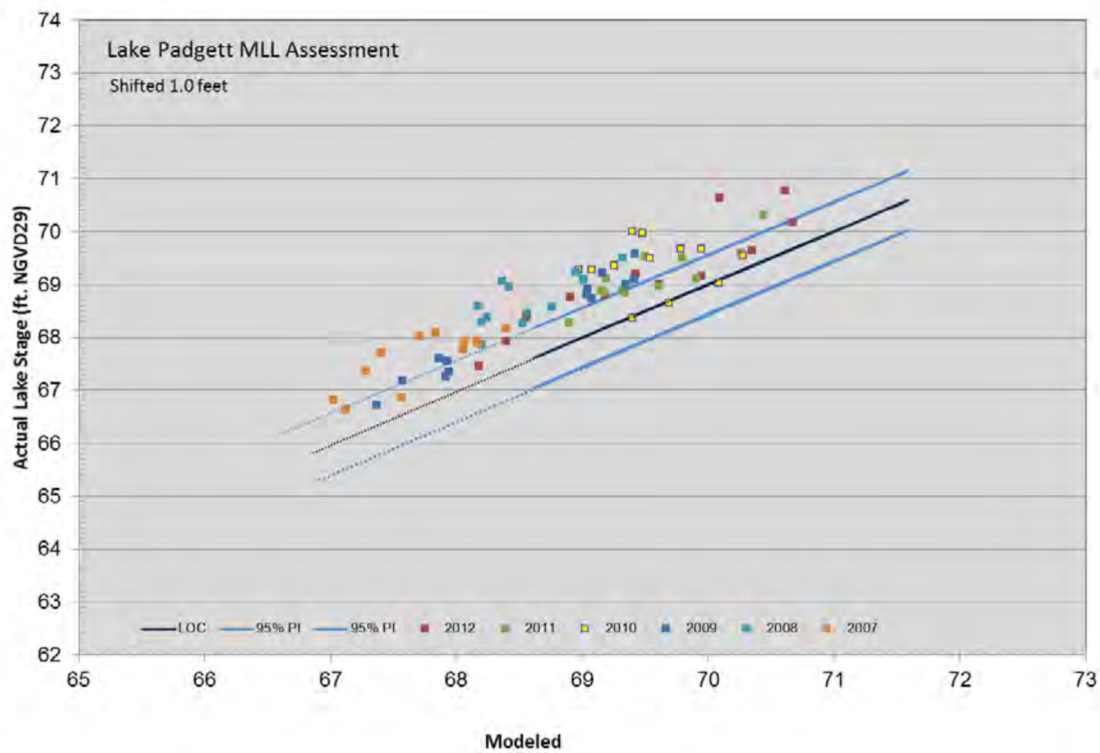



**Figure 16. Lake Padgett MLL assessment prediction intervals and model versus observed data since 2007.**

Use of observed lake data provides an empirical method for assessing whether the MLL and High Minimum Lake Level (HMLL) are being met. The MLL and HMLL represent long-term exceedance percentiles for the P50 and P10, respectively; so full assessment of the MLL and HMLL with actual percentiles requires data from a long period of record.

Assessment of the revised MLL and HMLL for Lake Padgett using the record starting in 1973 allows for evaluation of the lake relative to the history of withdrawals in the area which have been variable through time and include periods of withdrawals that are greater than the proposed withdrawal rates identified for the Northern Tampa Bay recovery effort. Cumulative median (P50) and cumulative P10 water surface elevations were calculated for time periods starting in 1973, 1983, 1993, 2000, 2004 and 2010, and compared with the revised MLL and HMLL. Cumulative medians for all of the evaluated start dates ended with values above the revised MLL (Figure 17). Similarly, cumulative P10s for all of the evaluated periods ended at or above the revised HMLL (Figure 18). These empirical results indicate the proposed MLL and HMLL for Lake Padgett are being met.

Because the period of observed water levels since 1973 includes periods of wellfield withdrawals much greater than those proposed for future operation of the Central

System Facilities, the revised High Minimum Lake Level and Minimum Lake Level are also expected to be met for the next 20-year planning period.


**Figure 17. Lake Padgett observed data cumulative median (P50) water levels starting in 1965, 1973, 1983, 1993, 2000, 2004 and 2010 compared to the revised MLL of 68.6 feet, NGVD29 (horizontal red line).**

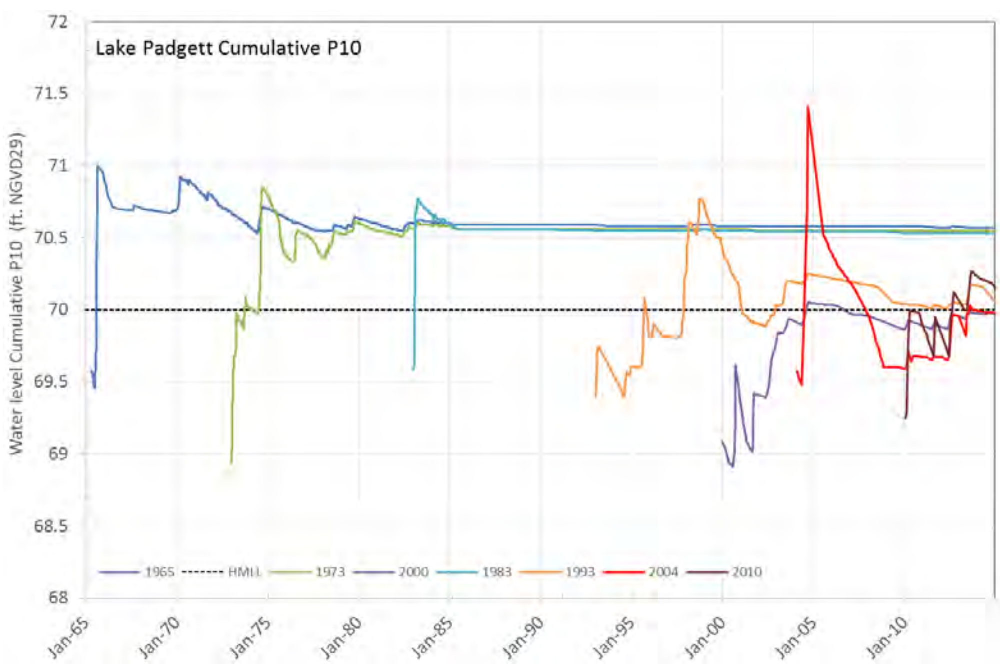



**Figure 18. Lake Padgett observed data cumulative P10 water levels starting in 1965, 1973, 1983, 1993, 2000, 2004 and 2010 compared to the revised HMLL of 70.0 feet, NGVD29 (dashed black line).**

## Conclusions

Lake Padgett has been modified over the years by dredging, filling and modifications to lake's outlet and connection to Lake Saxon. Historic lake stage data pre-dating withdrawals at nearby wellfields such as the South Pasco Wellfield are available for development of a rainfall regression model. Drainage and structural alterations such as the connection to Lake Saxon were made early in this period capturing similar structural conditions as currently in place.

Long-term water levels for Lake Padgett were simulated using a rainfall regression technique. A best-fit LOC rainfall regression model was calibrated to water level data from 1965 through 1970 using weighted two-year cumulative rainfall sums in inches. Model-predicted water levels closely matched observed water levels, indicating that Lake Padgett water level fluctuations are consistent with expectations based on variation in rainfall.

The long-term Historic P50 of 69.6 feet NGVD developed using model-predicted and observed water levels was used in conjunction with a Normal Pool elevation to develop of a revised MLL at 68.6 feet NGVD and a revised HMLL at 70.0 feet NGVD.

Assessment of observed Lake Padgett water levels relative to the revised minimum levels indicates the lake is at or above the two levels. Because the observed water level record includes periods of wellfield withdrawals much greater than those identified for future operation of area wellfields, the revised MLL and HMLL are also expected to be met for the next 20-year planning period.

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