Minimum and Guidance Levels for Crews Lake in Pasco County, Florida

January 20, 2017

Southwest Florida
Water Management District

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Cover: Aerial photograph (looking south) of Crews Lake in 2004 showing the fishing pier along the western lakeshore in Crews Lake Wilderness Park (Southwest Florida Water Management District files).

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Executive Summary

This report describes the development of Minimum and Guidance Levels by the Southwest Florida Water Management District for Crews Lake in Pasco County, Florida. 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.

The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (and corresponding 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 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 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 Minimum Levels will be used 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. These levels were adopted by the District Governing Board and replace currently adopted levels for Crews Lake.

Based on available water level records, the minimum levels for Crews Lake were being met at the time of this assessment, so development of a recovery strategy was not required. In the event that adopted levels for the lake are not met, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area and the Hillsborough River Recover Strategy (Rule 40D-80.073, F.A.C.) will apply for recovery of minimum levels for the lake. The District plans to continue regular monitoring of water levels in Crews Lake and will also routinely evaluate the status of the lake’s water levels with respect to adopted minimum levels for the lake that are included in Chapter 40D-8, F.A.C.

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

Minimum and Guidance Levels	Elevation (feet above NGVD29[a])	Elevation (feet above NAVD88[b])	Level Descriptions
High Guidance Level	55.3	54.4	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	52.4	51.5	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	51.0	50.1	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	48.9	48.0	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** National American Vertical Datum of 1988

Acknowledgements

The authors would like to thank several of our Southwest Florida Water Management District colleagues for their contributions to the work summarized in this report. We thank Richard Gant for his assistance with field-data collection and review of previous draft project reports, Mark Fulkerson for providing information on high water levels at the lake, and Don Ellison, Jason Patterson and Dave Arnold for hydrologic modeling support. We also thank our former District colleague, Lisa Henningsen for review of previous draft reports for the project and hydrologic modeling support.

Introduction

Establishment of Minimum and Guidance Levels for Crews Lake

This report describes the development of minimum and guidance levels by the Southwest Florida Water Management District (District or SWFWMD) for Crews Lake in Pasco County, Florida. The levels were developed using peer-reviewed District methods for establishing minimum and guidance levels for lakes. The 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, Florida Administrative Code, hereafter F.A.C.). These levels were adopted by the District Governing Board and replace currently adopted levels for Crews Lake.

Minimum Flows and Levels Program Overview

Legal Directives

State law (Section 373.042, Florida Statutes; hereafter F.S.) directs the Department of Environmental Protection or the water management districts to establish minimum flows and levels for lakes, wetlands, rivers and aquifers. As currently defined by statute, the minimum flow for a given watercourse "shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area", and the minimum level of an aquifer or surface water body is "the level of groundwater in the aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." Minimum flows and levels (MFLs) are established and used by the Southwest Florida Water Management District for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and use of surface water management systems.

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 MFLs 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 MFLs, 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, F.A.C., provides additional guidance for MFLs establishment, requiring that "…consideration shall be given to natural seasonal fluctuations in water flows or levels, non-consumptive 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

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; 4) development and implementation of recovery strategies; 5) MFLs status assessment 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 Crews Lake; additional information on all tasks associated with the District's MFLs Program is summarized by Hancock *et al.* (2010).

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

Support for these assumptions is provided by a large body of published scientific work addressing relationships between hydrology, ecology and human-use values associated with water resources (e.g., see reviews and syntheses by Postel and Richer 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 an affected watershed, surface water, or aquifer…" in accordance with Section 373.0421(1)(a), F.S. Also, as required by statute, when considering the changes, alterations and their associated effects and constraints, the District does not establish MFLs that would allow significant harm caused by withdrawals. 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;
- support status assessments for 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 MFLs 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.). This 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 SWFWMD (1999a, b) and Leeper *et al.* (2001). Additional information relevant to developing lake levels is presented by Schultz *et al.* (2005), Carr and Rochow (2004), Caffrey *et al.* (2006, 2007), Carr *et al.* (2006), Hoyer *et al*. (2006), Leeper (2006), Hancock (2006, 2007) and Emery *et al.* (2009). Independent scientific peer-review findings regarding 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 is/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 minimum flows or levels. Descriptions of the specific standards and other information are provided in subsequent sections of this report.

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

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

NA[1] = Not applicable for consideration for most priority lakes
NA[2] = Environmental value is addressed generally by development of minimum levels base on appropriate significant change standards and other information and use of minimum levels in District permitting programs

Established Levels

Two Minimum Levels and two Guidance Levels are typically established for lakes. The levels, which are expressed as elevations in feet above the National Geodetic Vertical Datum of 1929 (NGVD 29), 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 NGVD 29 datum to use of the North American Vertical Datum of 1988 (NAVD88). While the NGVD 29 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 NGVD 29. 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

Crews Lake is located in north-central Pasco County, Florida within the Tampa Bay Planning Region of the Southwest Florida Water Management District (Figure 1). The lake extends into portions of Sections 10, 15, 16, 20, 21 and 29, Township 24 South, Range 18 East, and is approximately centered around 28°22’59’’ latitude and -82°30’58” longitude (Figure 2).

Public access to Crews Lake is available through the Crews Lake Wilderness Park, located along the western lakeshore. A public boat ramp, fishing pier and observation tower are available for use in this 113-acre Pasco County park. Pasco County also owns and maintains the Jumping Gully Preserve, a 598 acre Conservation Area adjacent to the central-eastern portion of the lake, although established public uses are currently not supported at the preserve.

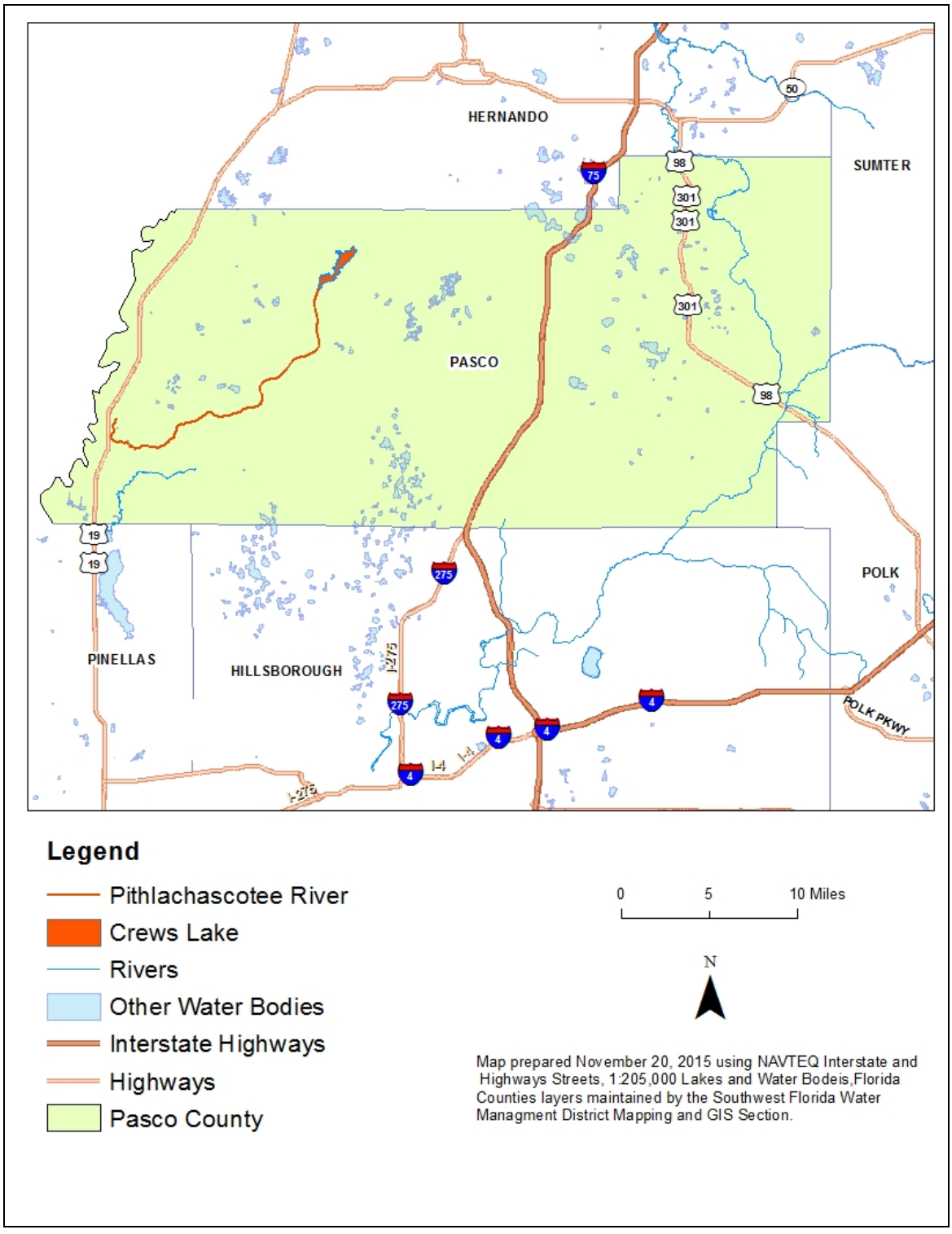

Figure 1. Location of Crews Lake, the Pithlachascotee River and other regional water bodies, highways and major roads within and near Pasco County, Florida

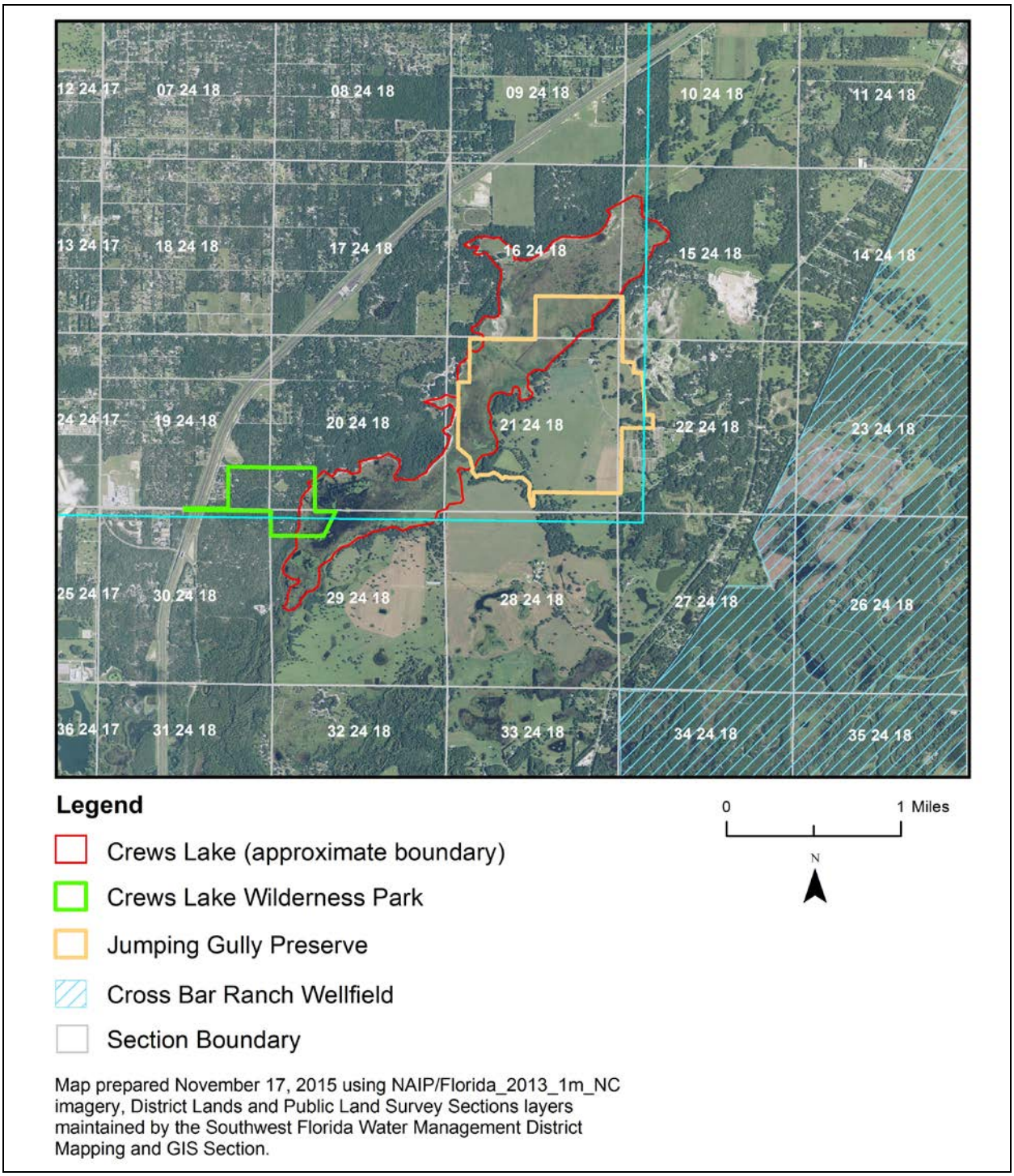

Figure 2. Location of Crews Lake Wilderness Park and Jumping Gully Preserve adjacent to Crews Lake, with numeric section, township (south) and range (east) information labeled. A portion of the Cross Bar Ranch Wellfield is also shown.

Physiography and Hydrogeology

White (1970) classified the region of central or mid-peninsular Florida containing Crews Lake as the Northern Gulf Coastal Lowlands (see Figure 4 in McBride 2016, included as Appendix A to this report). Brooks (1981) categorized the area surrounding the lake as the Land-O-Lakes subdivision (see Figure 5 in Appendix A) of the Tampa Plain division of the Ocala Uplift District, and described the region as a plain with numerous small lakes imbedded in moderately thick silty sand deposits lying above the Tampa Limestone formation. As part of the Florida Department of Environmental Protection's Lake Bioassessment/Regionalization Initiative, the area has been identified as Weeki Wachee Hills (Griffith *et al.* 1997). Lakes in the region are mostly clear-water systems, with circumneutral pH, and moderately low alkalinity, nutrients and chlorophyll *a* levels.

A thin, but mostly continuous clay layer underlies areas adjacent to Crews Lake and the southwestern part of the drainage basin (Trommer 1987). The clay layer thickens toward the east near the Brooksville Ridge. Trommer reports that driller's logs indicate the clay layer is breached by relict sinks in many places. More breaches appear in the northern and eastern areas of the basin than other areas. Consequently, in some areas, the surficial deposits may contain water only during wet periods, or may be locally perched where confining layers retard recharge (Trommer 1987). McBride (2016) notes that there are several sinkholes and a history of sinkhole and subsidence occurrence in and around Crews Lake.

Bathymetry and Basin/Watershed Description and History

Crews Lake is listed as a 693-acre lake in "Gazetteer of Florida Lakes" (Florida Board of Conservation 1969, Shafer *et al.* 1986). A topographic map of the lake basin generated in support of minimum levels development (Figure 3) indicates that the lake would extend over 1,188 acres when the water level is at the elevation of 56 feet above NGVD 29 included on the 1954 U.S. Geological Survey 1:24,000 Port Richey NE, Fla. and Fivay, Fla. quadrangle 7.5 minute topographic maps and the 1988 photorevised versions of the Port Richey NE and Fivay (Fivay Junction), Fla. maps.

Based on review the 2011 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 Crews Lake is classified as upland forests, agriculture, urban and built up, and wetlands (data not shown). The upland areas in the immediate lake basin include extensive areas of native vegetation, including the Crews Lake Wilderness Park, and altered areas that are used for livestock grazing, production of feed-grasses, and low-density residential development. The immediate lake basin includes extensive, forested and non-forested lacustrine and palustrine wetland areas (Figure 4). These areas are populated by wetland and aquatic plant species, including spatterdock (*Nuphar luteum*), fragrant water lily (*Nymphaea odorata*), arrowhead (*Sagittaria* sp.), pickerelweed (*Pontederia cordata*), cypress (*Taxodium* sp.) and a number of grasses and sedges.

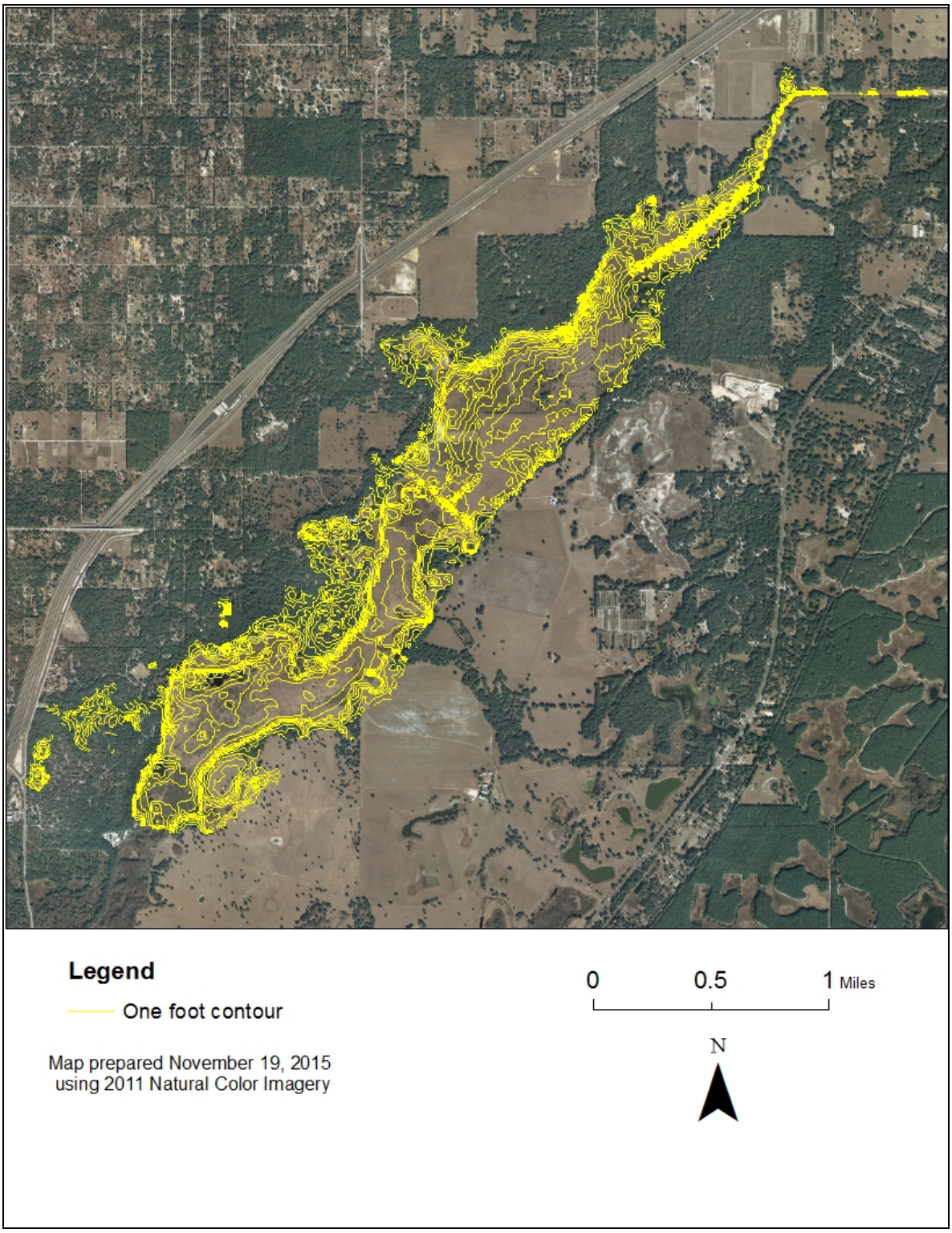

Figure 3. One-foot ground elevation contours (feet above NGVD 29) bounded by the 57-foot contour within the Crews Lake basin

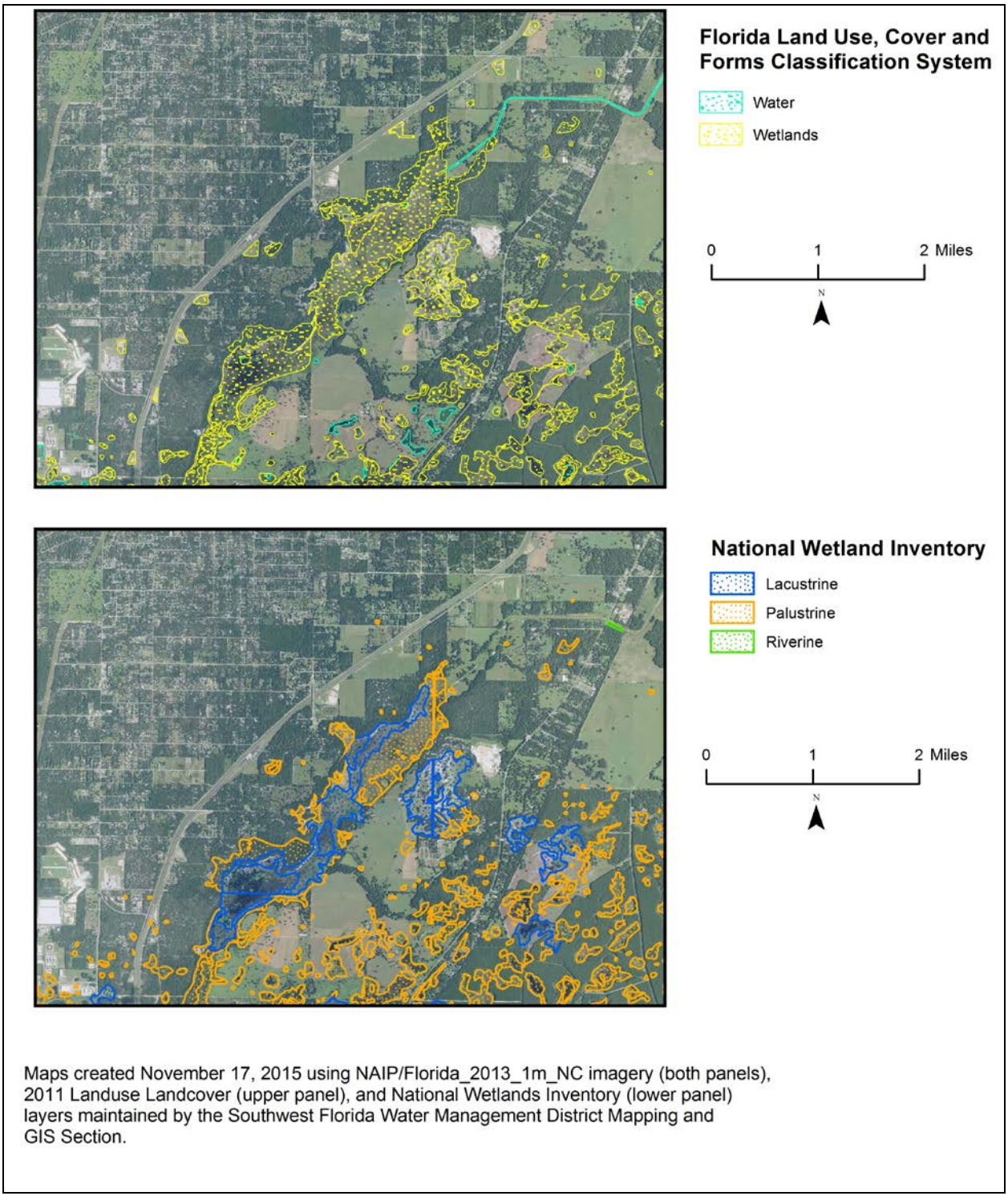

Figure 4. Lake and wetland areas in the Crews Lake vicinity based on 2011 Florida Land Use, Cover and Forms Classification System Classification data (upper panel) and National Wetland Inventory information (lower panel)

The lake lies within the Crews Lake Outlet drainage basin in the Upper Coastal Areas watershed (United States Geological Survey Hydrologic Unit Classification System), and drains an area of 138 square miles (Florida Board of Conservation 1969, Foose 1981). A recent, alternative basin delineation by Ardaman and Associates, Inc. (2015) includes the lake in the Pithlachascotee River/Bear Creek Watershed (see Figure 2 in Appendix A). Surface water inputs to the lake include precipitation on the lake surface or immediate basin area, runoff from adjacent upland areas, and inflows from the Masaryktown Canal and Jumping Gully (Figure 5). The Masaryktown Canal, a District-owned flood management system, was constructed in the mid-1960s to drain areas south and east of Masaryktown into the north end of Crews Lake. Hutchinson (1985) reports that flow in the canal is "known to be zero during most of the year." Jumping Gully conveys water into the lake from Unnamed Lake Number 22 (aka Loyce Lake) and other upstream water bodies, including Unnamed Lake Number 10, Pasco Lake, and various wetlands and ponds on the Cross Bar Ranch Wellfield. Jumping Gully discharge has been measured by the United States Geological Survey at a site named Jumping Gully at Loyce, FL (USGS Number 02310240, aka District Site Identification or SID number 20524) near U.S. Highway 41, from the mid-1960s through January 1988, and since January 1998 to September 2010. Prior to 1984, flows were typically less than 100 cubic feet per second, but reached as high as 890 cubic feet per second on September 19, 1964.

An earthen berm located about three quarters of a mile north of the point where Jumping Gully enters the lake bisects the Crews Lake basin into roughly equal-sized northern and southern sub-basins (Figures 5 and 6). A secondary berm partitions the most southeastern portion of the northern sub-basin from the rest of the sub-basin. Conveyance across the berm that separates the northern and southern sub-basins is provided by a 60-inch diameter corrugated metal pipe when water levels on either side of the pipe exceed 51.8 feet above NGVD 29 (Figure 6). Dry-season drainage into a sinkhole (Figure 7) located north of the berm may reduce the inundated area of the northern sub-basin and may induce northward flow through the berm-culvert from the southern basin (Hutchinson 1985). As summarized in Appendix A, Trommer (1987) provides information on additional sinkholes in the lake vicinity that may affect lake levels. Historical photographs indicate that the berm has been in place since the 1940s, and also show that much of the northern sub-basin has frequently been dry (see Figures 8 through 22). Crews Lake is the headwaters of the Pithlachascotee River, which extends about twenty-five miles from the southern sub-basin of the lake to the Gulf of Mexico (Figure 5, see also Figure 1). Discharge from the lake to the river may occur when the lake surface exceeds 54.1 feet above NGVD 29, the elevation at a high spot in the riverine wetlands south of the lake (Ardaman & Associates, Inc. 2007).

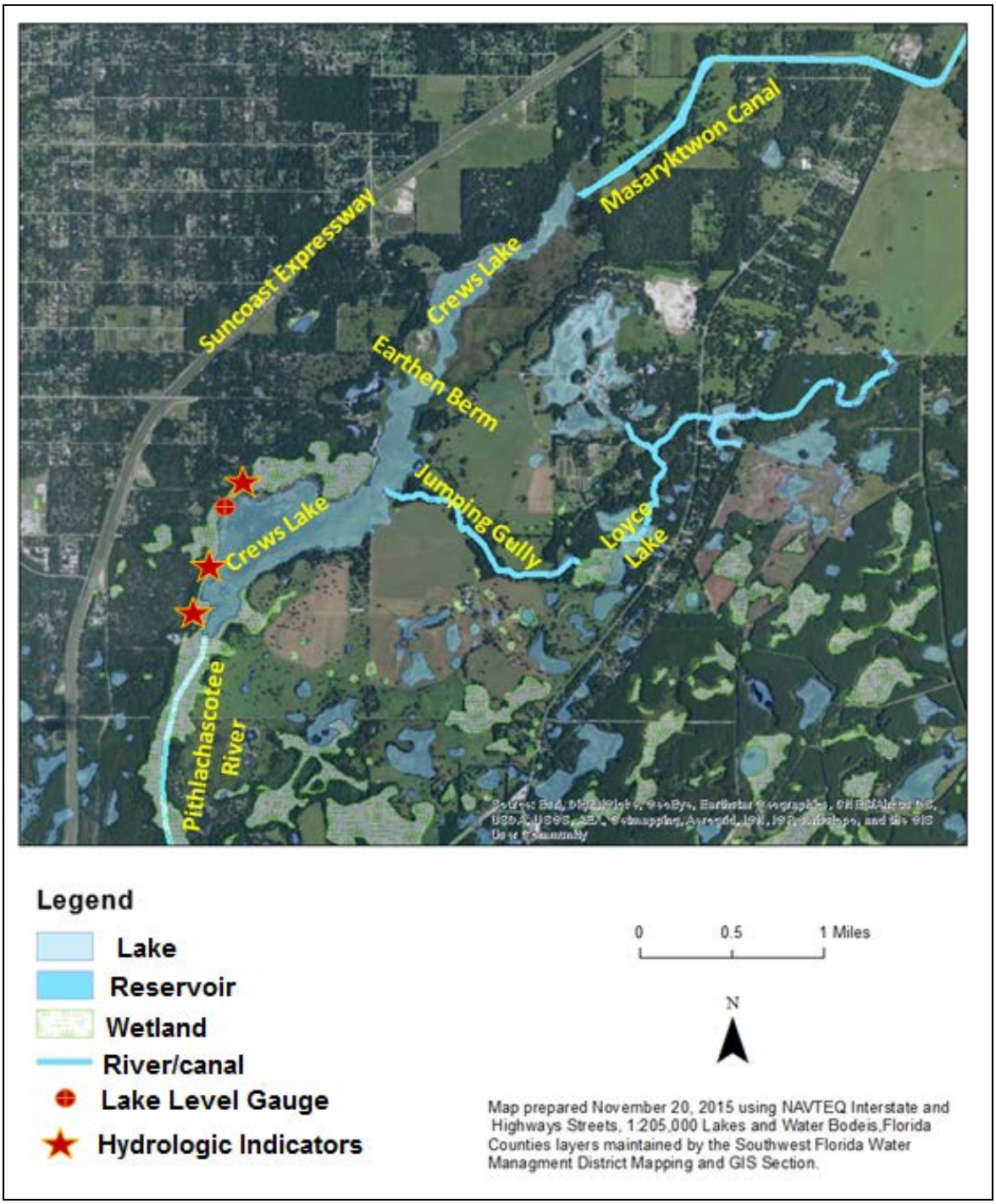

Figure 5. Aerial photograph of the Crews Lake area in 2006, showing major surface water bodies and other features in the lake vicinity, the current District water-level gage site, lake inlets and the lake outlet, sinkhole and sites where hydrologic indicators were measured (photographic image source: Woolpert, Inc. 2006)

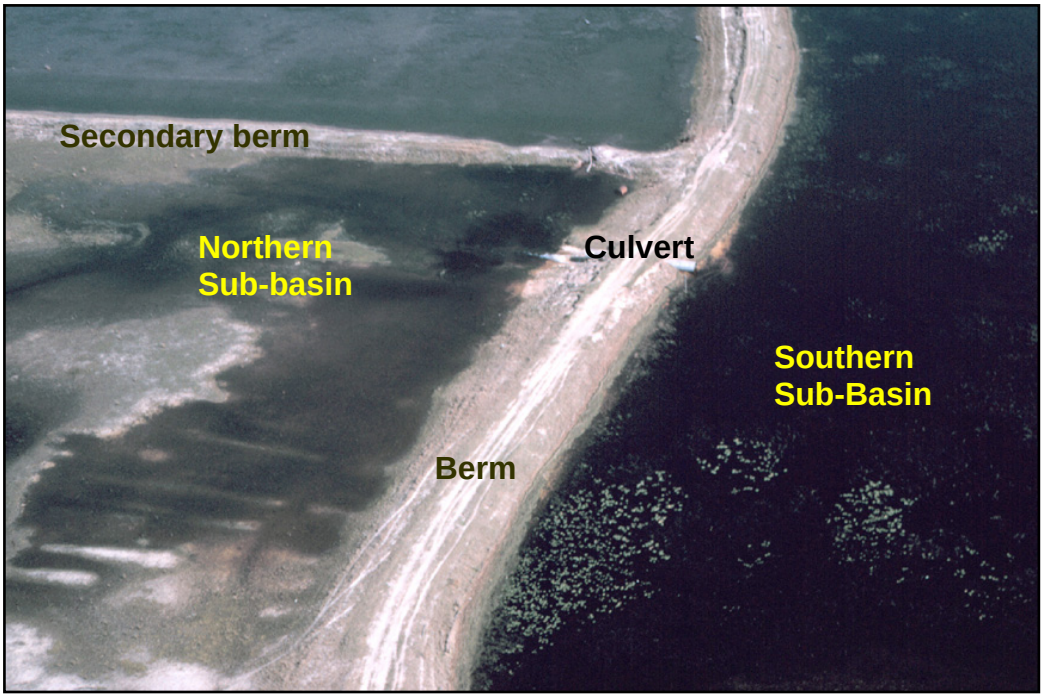

Figure 6. Photographs of the earthen berm that separates the northern and southern sub-basins of Crews Lake and the culvert that provides for surface water conveyance past the berm. The upper photograph, from 1971 (District files), also shows a portion of a secondary berm in the northern sub-basin that partitions a portion of the sub-basin from the rest of the sub-basin. The lower photograph shows flow between the northern and southern sub-basins in 1982 (District files).

Figure 7. Sinkhole in the northern sub-basin of Crews Lake in 1985 (District files)

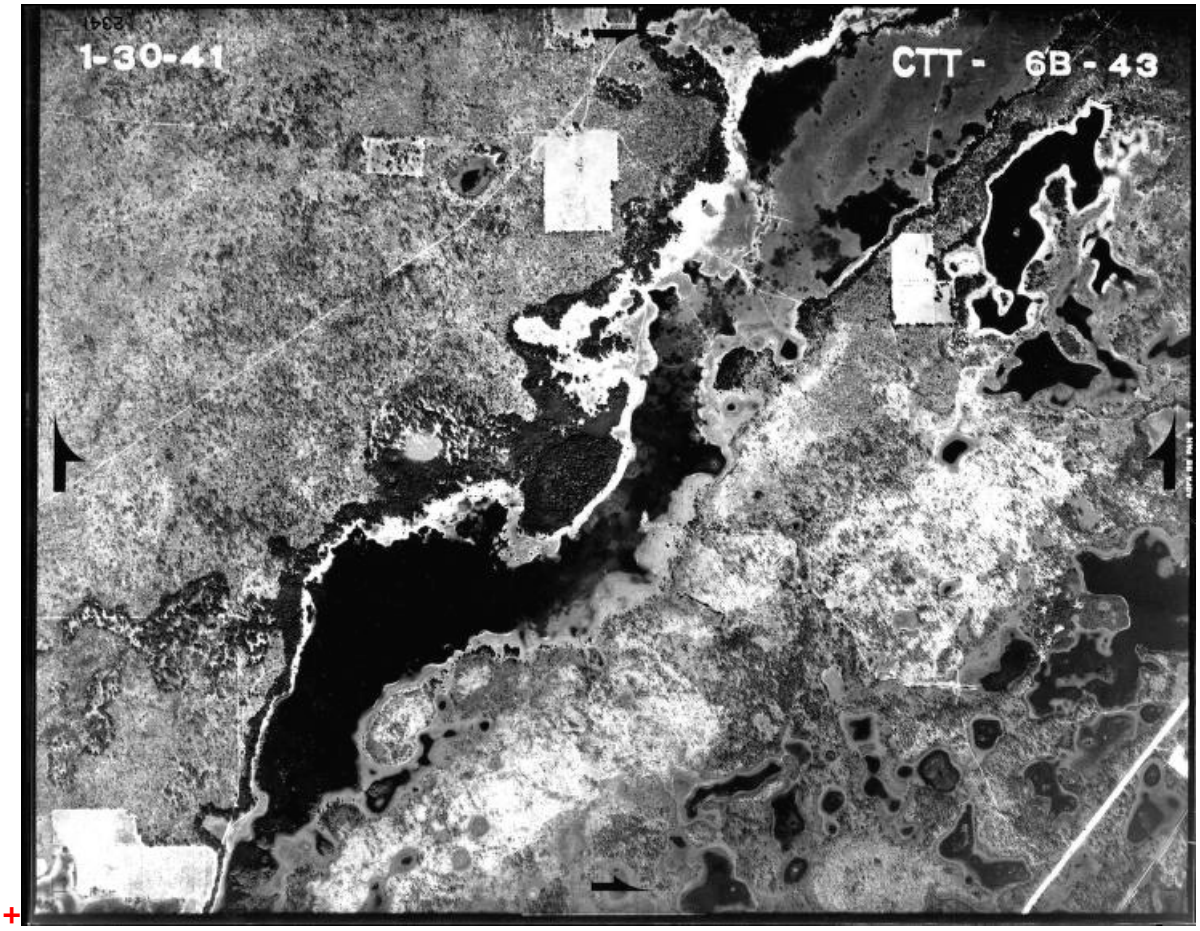

Figure 8. Aerial photograph of Crews Lake in January 1941 (United States Department of Agriculture 1941b)

Figure 9. Aerial photograph of the northern portion of Crews Lake in March 1952 (United States Department of Agriculture 1952b)

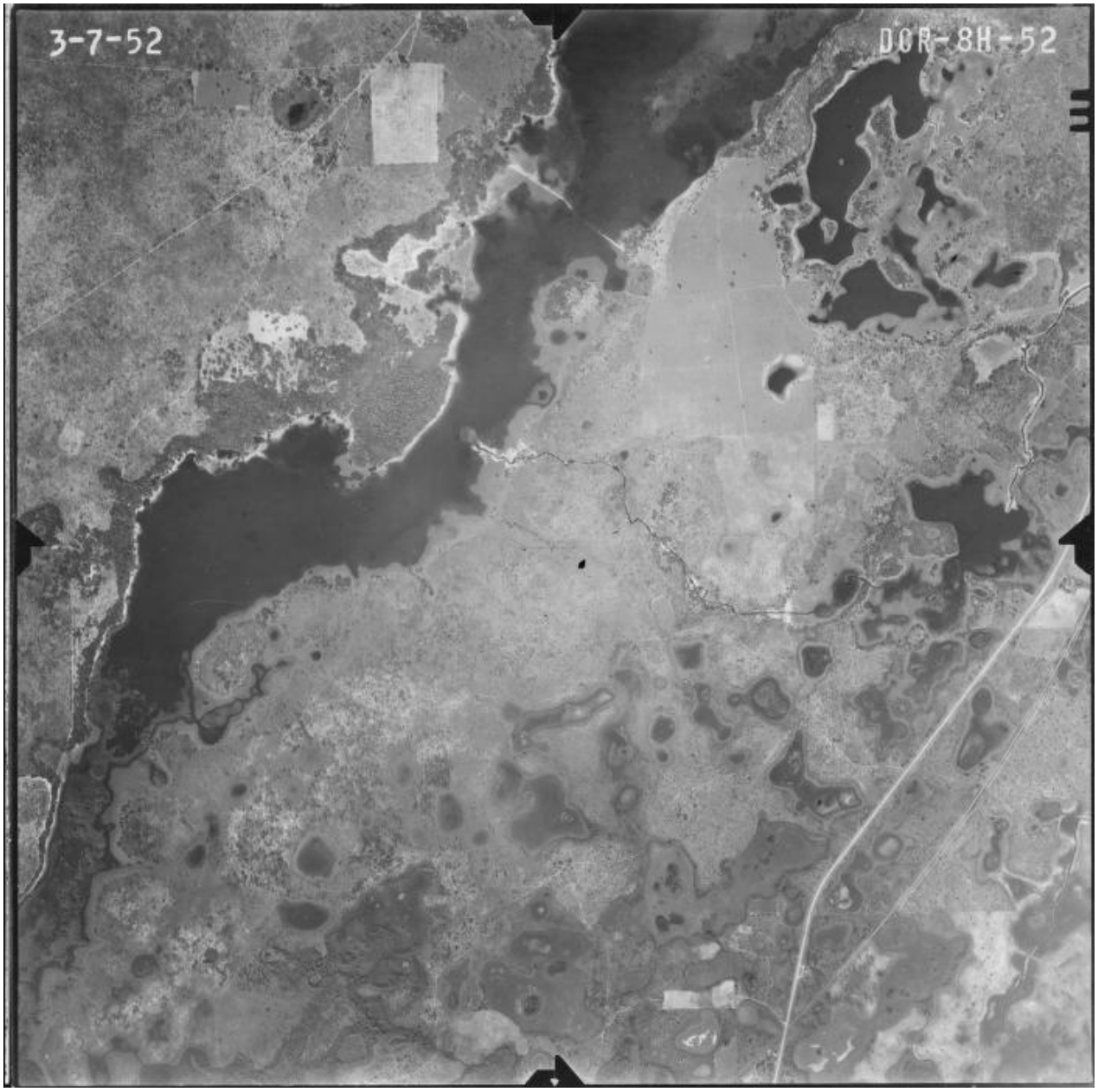

Figure 10. Aerial photograph of the southern portion of Crews Lake in March 1952 (United States Department of Agriculture 1952c)

Figure 11. Aerial photograph of northern portion of Crews Lake in March 1957 (United States Department of Agriculture 1957c)

Figure 12. Aerial photograph of the southern portion of Crews Lake in March 1957 (United States Department of Agriculture 1957b)

Figure 13. Aerial photograph (looking northeast) of Crews Lake in 1967 (District files)

Figure 14. Aerial photograph (looking east) of the northern portion of Crews Lake in 1969 (District files)

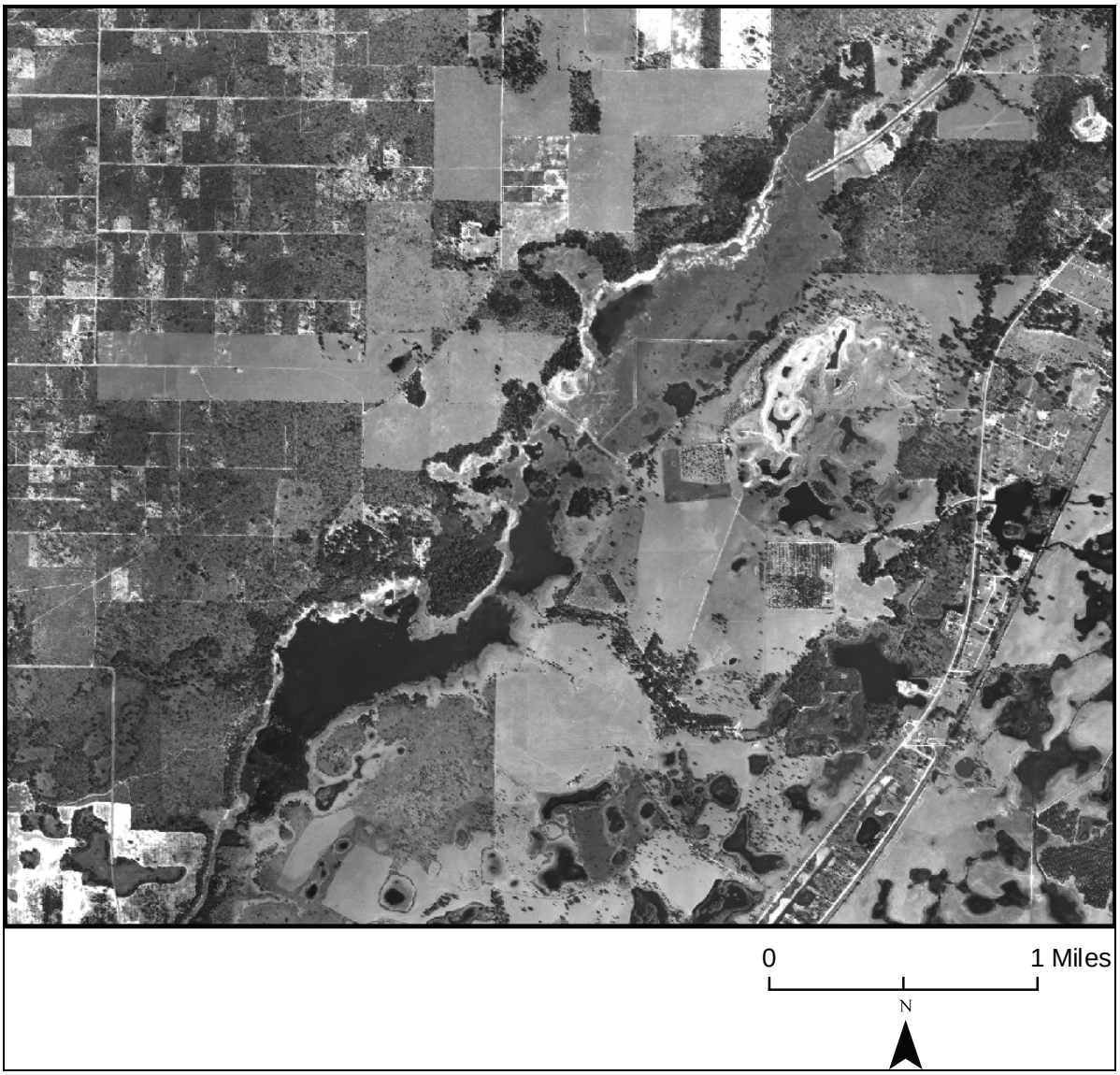

Figure 15. Aerial photograph of Crews Lake in the 1973 (image source: Woolpert 2005a)

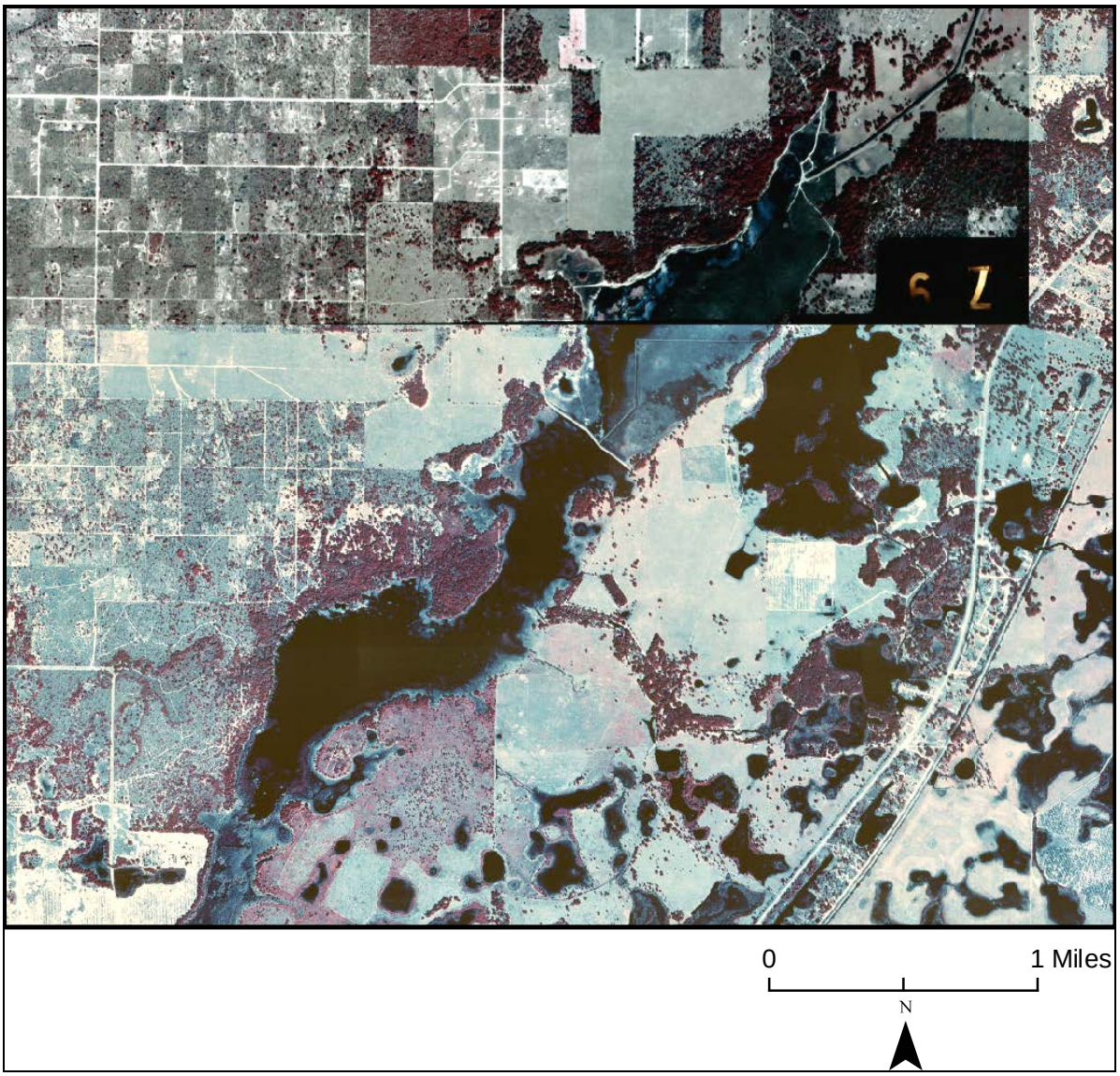

Figure 16. Aerial infrared photograph of Crews Lake in 1984 (image source: United States Geological Survey 2004a)

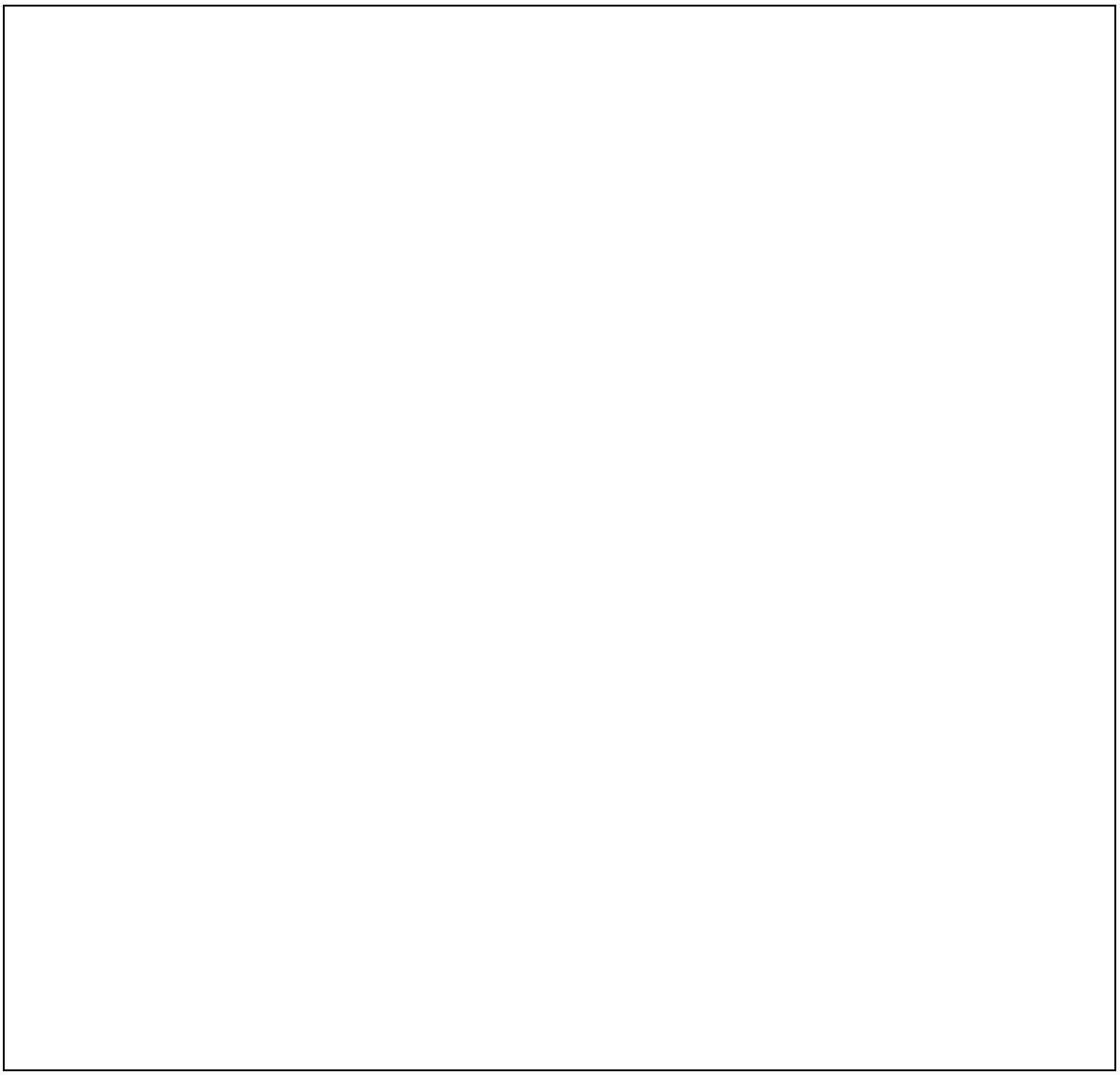

Figure 17. Aerial infrared photograph of Crews Lake in 1994 (image source: Southwest Florida Water Management District, date unknown)

Figure 18. Aerial photograph (looking northwest) of the Crews Lake outlet in 1996 (District files). This region marks the headwaters of the Pithlachascotee River.

Figure 19. Aerial photograph (looking southwest) of Crews Lake and the southern terminus of the Masaryktown Canal in 1998 (District files)

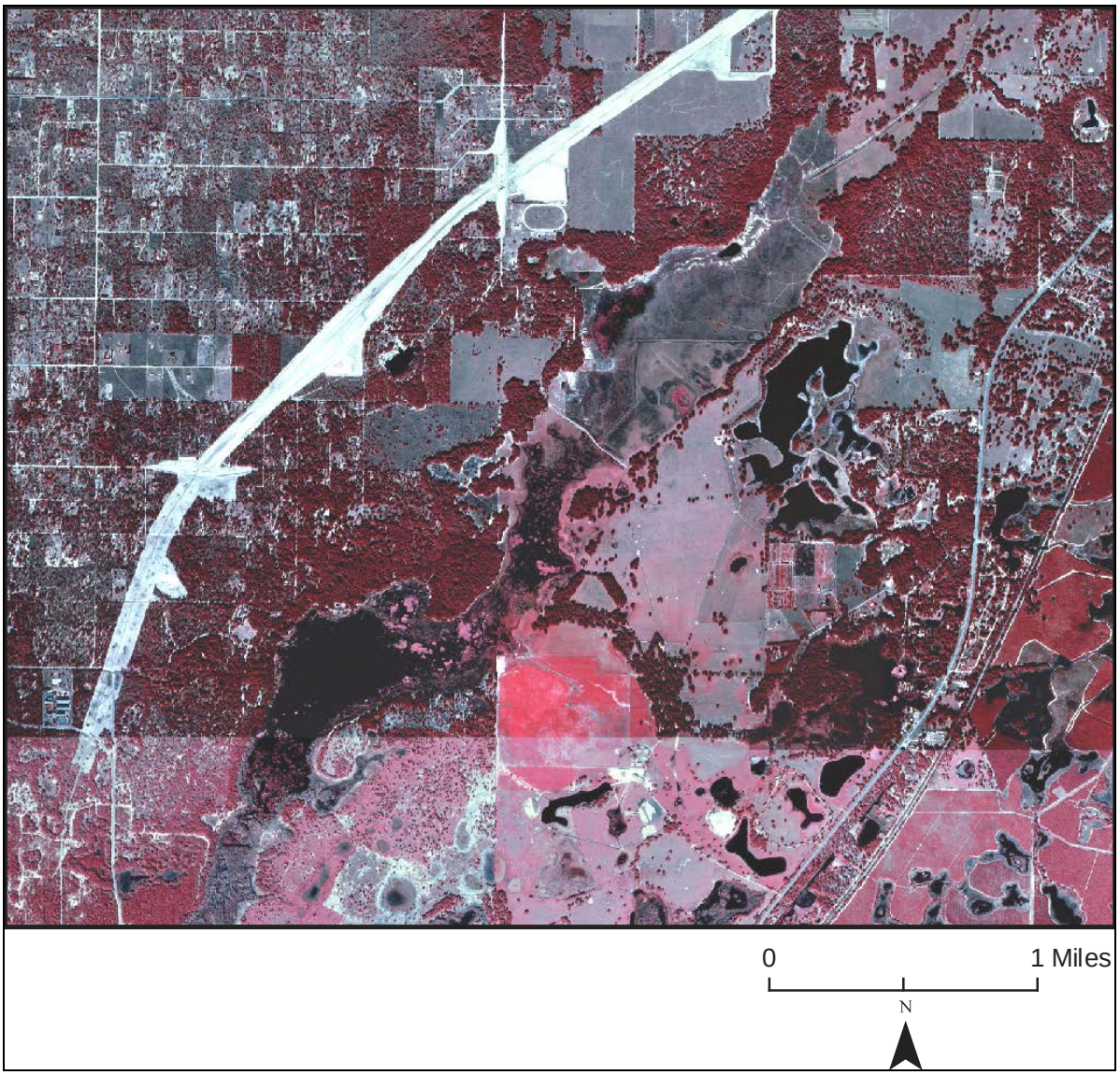

Figure 20. Aerial infrared photograph of Crews Lake in 1999 (image source: Southwest Florida Water Management District 2002a)

Figure 21. Aerial photograph (looking south) of Crews Lake in 2000 (District files). The fishing pier and observation tower in Crews Lake Wilderness Park are shown along the west shore of the lake basin in the right portion of the photograph

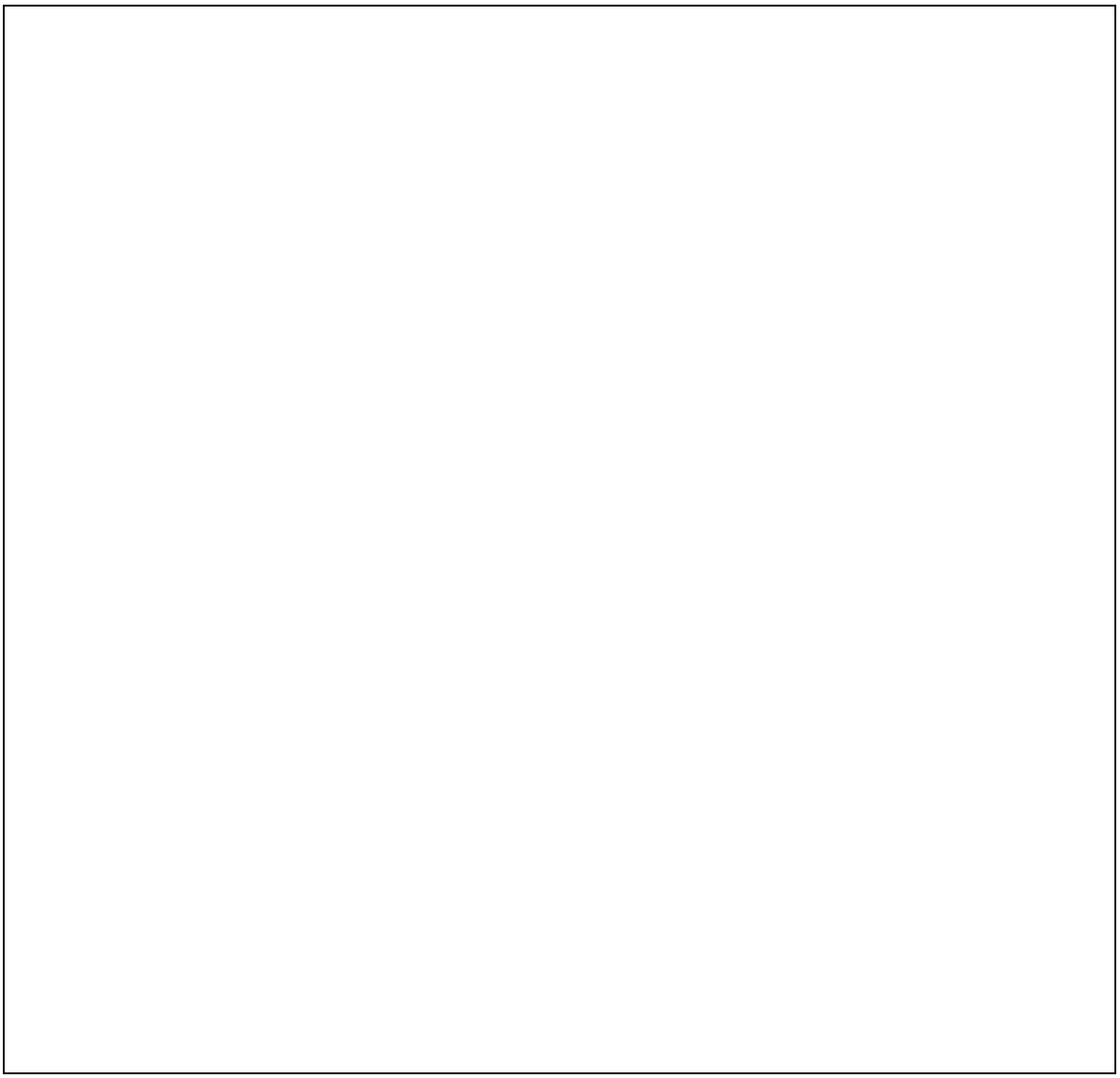

Figure 22. Aerial photograph of Crews Lake in 2005 (image source: Woolpert, inc. 2005b)

Hydrology

Climate and Rainfall

The climate of west-central Florida, where Crews Lake occurs, may be characterized as humid southern temperate to subtropical, with frost and freezing temperatures occurring at least once a year. Local weather patterns are strongly influenced by the Gulf of Mexico, which moderates winter and summer temperatures. Daily temperatures in the Tampa Bay watershed, just to the south of Crews Lake average about 70° Fahrenheit on an annual basis, with mean summer temperatures in the low 80s and mean winter temperatures are in the upper 50s (Wolfe *et al.*1990, as cited in SWFWMD 2002b).

Based on data available from long-term rainfall gaging stations in Pasco and Hernando counties (see Appendix A), annual rainfall in the vicinity of Crews Lake ranged from 32.4 to 81.0 inches and averaged 55.5 inches for the 85-year period from 1930 through 2014 (Figure 23). On an annual basis, rainfall for this period was typically highest during the months of June through September, 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 85-year 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 (e.g., see Figure 23). A plot of annual departure from the long-term average annual rainfall in the Crews Lake area provides another means for identifying periods of above or below average area rainfall.

Since 1930, the three years with the highest departure above the mean occurred in the earlier part of the record, in 1945, 1953, and 1975. The three years with the lowest departure below the mean occurred in the recent record, in 1999, 2000, and 2006. The longest sustained period of rainfall departure below the long-term mean lasted 9 years, from 2005 to 2013. Prior to that period, there were three years above the annual mean (2002-2004) and three years below the annual mean (1999-2001), two of which were the first and second largest departure below the mean for the period of record. Annual rainfall was below the annual mean for 21 of the 35 years since the wellfield began operation in 1980.

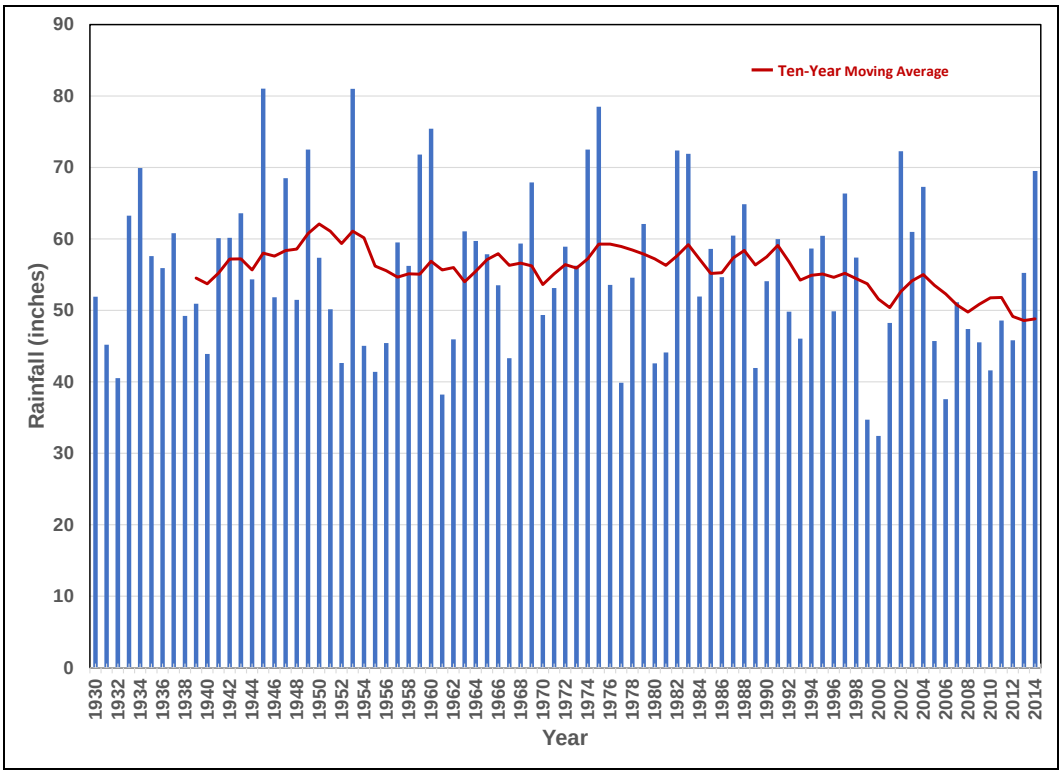

Figure 23. Annual rainfall in the Crews Lake area from 1930 through 2014 (see Appendix A for description of the rainfall data)

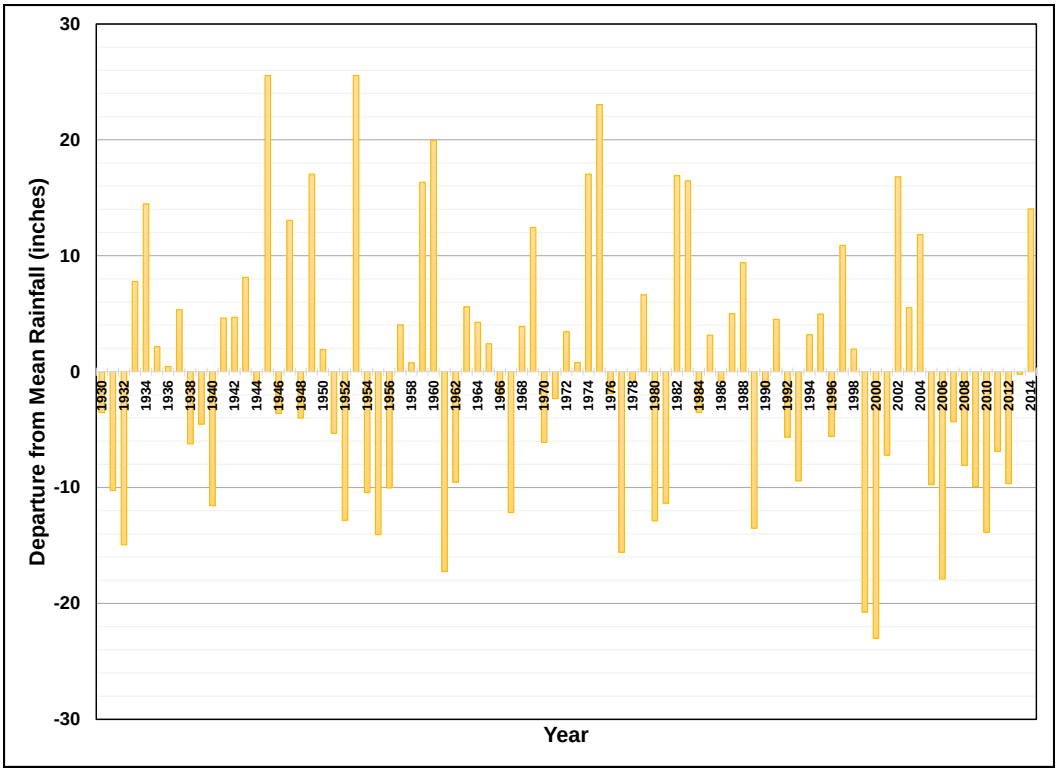

Figure 24. Annual departure from the mean annual rainfall of 55.4 inches in the vicinity of Crews Lake from 1930 through 2014 (data source: same as for Figure 23)

Water Level (Lake Stage) Record

Water levels in Crews Lake are currently monitored at a District-maintained site named Crews Lake (SID number 20506) located adjacent to the fishing pier in Crews Lake Wilderness Park (see Figures 5). Period of record (POR) lake stage data, i.e., surface-water elevations relative to NGVD 29 for this and other monitoring sites within Crews Lake were obtained from the District's Water Management Information System (WMIS). Records available for SID numbers 734367, 782429, 20506, and 777811 (see Figure 20 in Appendix A) were used to develop a long-term lake stage record for the period from March 20, 1964 through August 31, 2015 (Figure 25) for characterizing water level fluctuations in the basin and for hydrologic modeling purposes. As described in Appendix A, records for another monitoring site within the lake basin, SID 734366, were not used for the long-term stage record because the site was located in a sinkhole at the northern end of the lake.

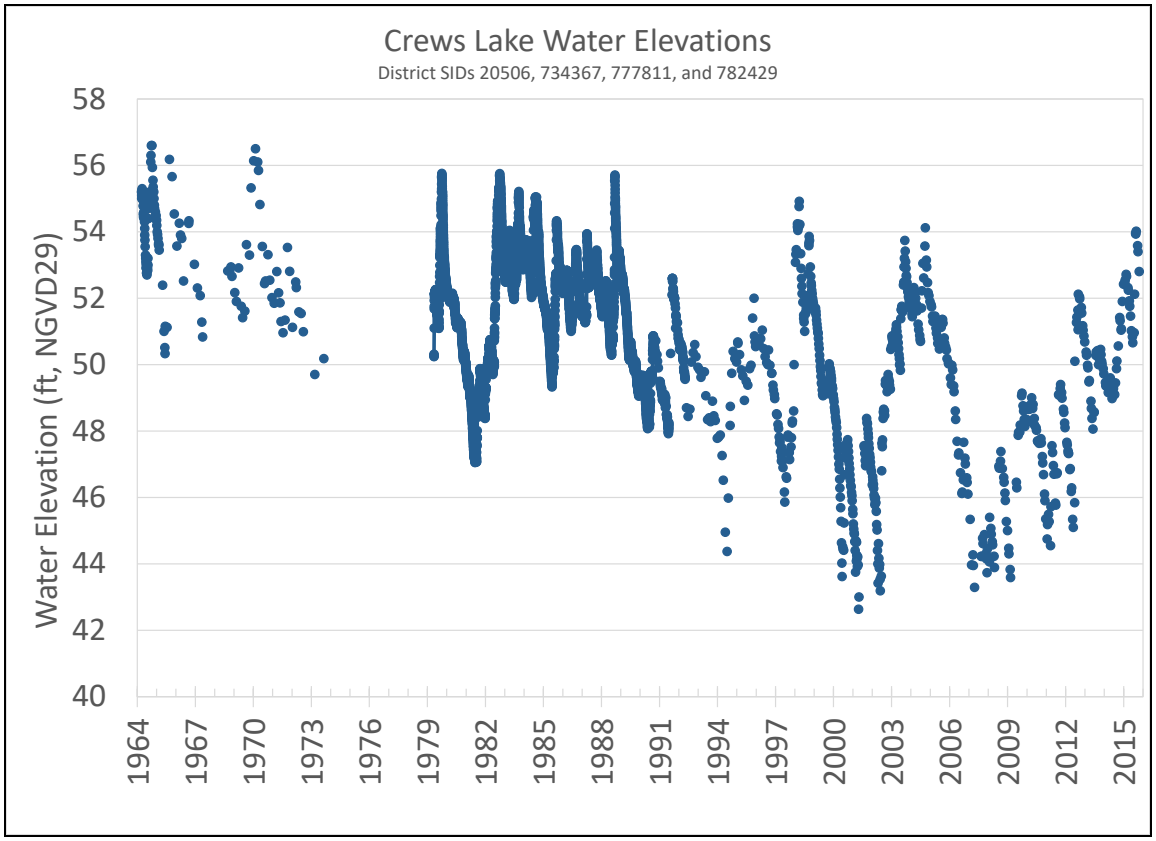

Figure 25. Measured water surface elevations for Crews Lake from March 20, 1964 through August 31, 2015 based on records from four sites (SIDs = Site identification numbers)

Period of record P10, P50 and P90 elevations, i.e., water levels equaled or exceeded ten, fifty and ninety percent of the time, respectively, for the long-term lake stage record are 53.7, 51.7 and 48.6 feet above NGVD 29. The highest surface water elevation for the lake included in the long-term record, 56.60 feet above NGVD 29, occurred on September 24 and October 3, 1964. Based on review of federal survey notes of the

General Land Office, Wharton (1984b) estimates that Crews Lake was staged at approximately 55 feet above mean sea level in April 1847. Notes from this nineteenth century survey indicate that the lake level was "very high" at the time of the survey (Wharton 1984a). The low of record, 42.63 feet above NGVD 29, was recorded on April 16, 2001.

Water Use in the Lake Area and Evaluation of Withdrawal Impacts

Surface water withdrawals from Crews Lake 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 lake vicinity (Figure 26).

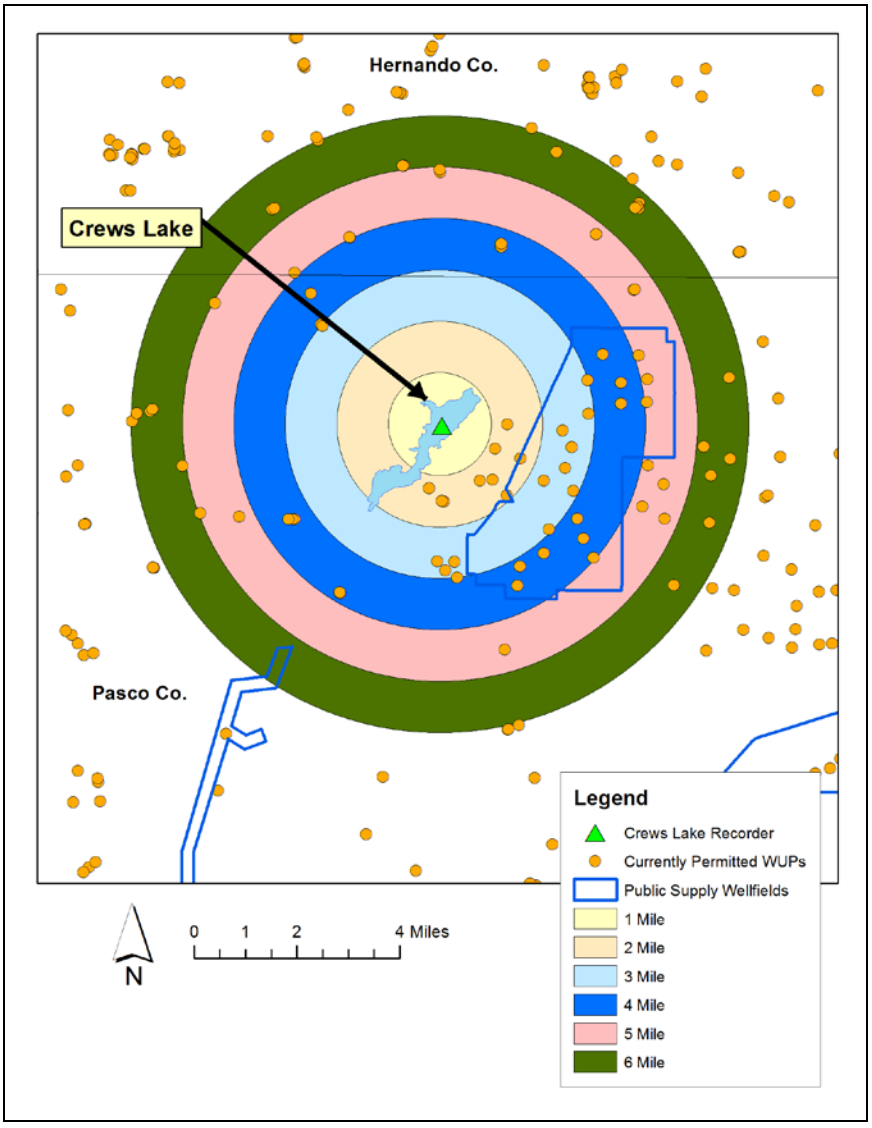

Figure 26. Permitted water use permit (WUP) withdrawal sites within one to six miles of Crews Lake. Central System Facility wellfields (Public Supply Wellfields) near the lake are also shown.

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 (Figure 27). In the early 1930's the first facility wellfield, the Cosme-Odessa Wellfield, which is located southwest of Crews Lake in Hillsborough County, began operation. In the late 1950s and during subsequent decades, additional wellfields that comprise the current Central System Facilities became operational. The Cross Bar Ranch Wellfield, which is located 1.5 miles east of Crews Lake and is the closest Central System Facility to the lake (see Figures 2, 26 and 27), began in 1980. The peak monthly withdrawal quantity from the wellfield was approximately 41 mgd in 1993 (see Figure 16 in Appendix A). Groundwater withdrawals at Cross Bar Ranch Wellfield have declined significantly since they peaked in the early 1990s and have recently been at a 12-month moving average quantity of 12 to 15 mgd. These recent withdrawal quantities are similar to the quantities withdrawn when the wellfield began operation in 1980.

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 Crews Lake is located (see Figure 27). 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.

Withdrawal-related changes to Upper Floridan aquifer levels in the vicinity of Crews Lake were evaluated (Patterson, personal communication, 2015) using the Integrated Northern Tampa Bay Model developed by Geurink and Basso (2013). A scenario where Central System Facility withdrawals were maintained at the mandated average annual rate of 90 mgd was evaluated. Simulation results indicated average predicted drawdown in the Upper Floridan aquifer near Crews Lake ranged from 0.5 feet at the southern end of the lake to 1.3 feet near the center of the lake and to 1.8 feet at the northern end of the lake. Drawdown in the surficial aquifer at Crews Lake was not simulated, because the northern edge of the surficial aquifer in the model domain lies south of Crews Lake.

However, statistical modeling of Crews Lake 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 Appendix A 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 Crews Lake.

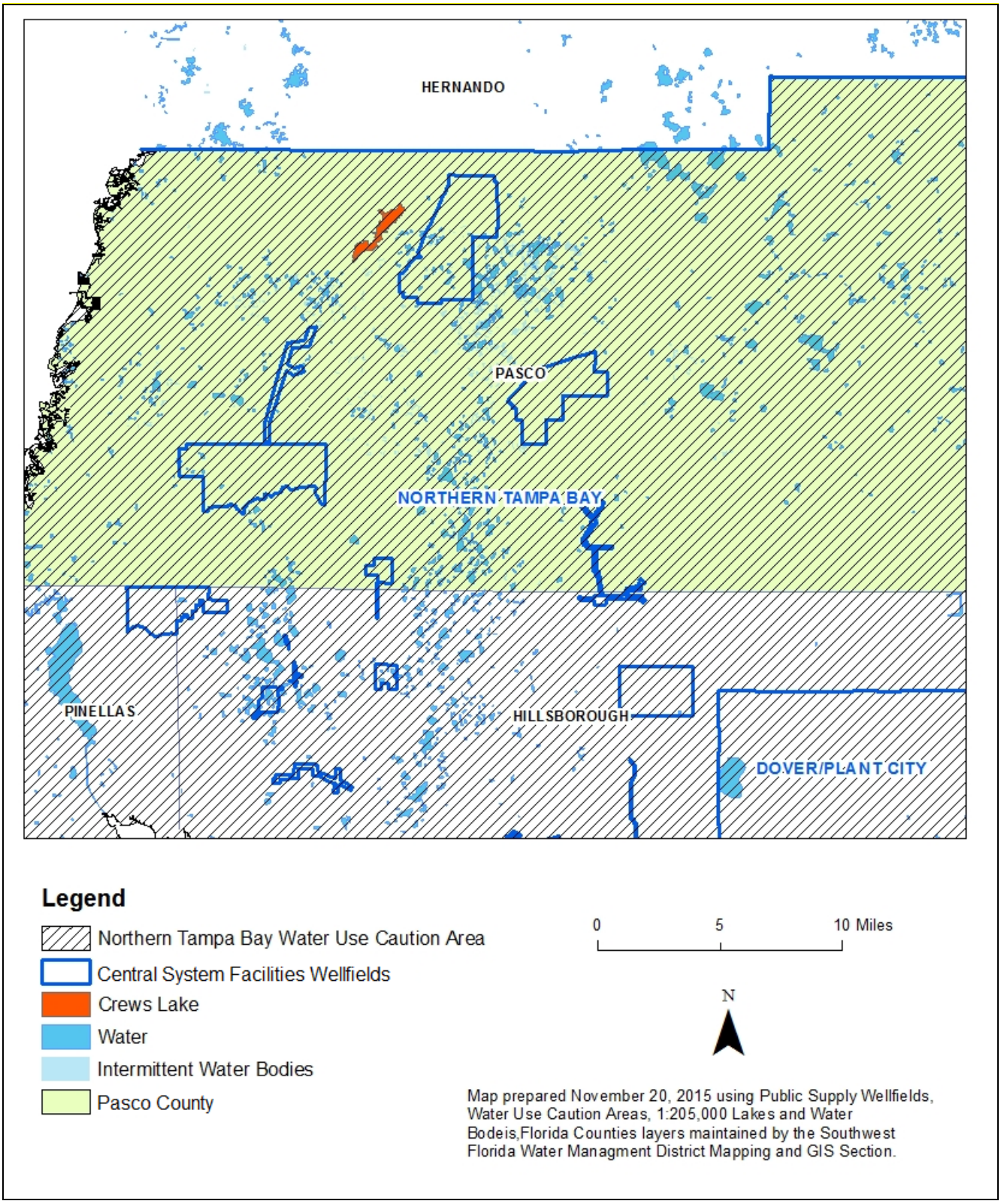

Figure 27. Location of Tampa Bay Water's Central System Facilities wellfields, Northern Tampa Bay Water Use Caution Area, Crews Lake and other area water bodies

Historical Management Levels and Currently Adopted Guidance Levels

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

In November 1984, the District adopted management levels, including minimum and flood levels that are currently referred to as Guidance Levels, for Crews Lake and incorporated (i.e., adopted) the levels into Chapter 40D-8, F.A.C. (Table 2). As part of the work leading to the adoption of the management levels, a Maximum Desirable Level of 54.50 feet above NGVD 29 was also developed 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 previously established levels as Guidance Levels. Subsequent revisions to District rules incorporated additional rule language associated with developing minimum lake levels, and the Ten Year Flood Guidance Level for Crews Lake and other lakes were 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. The intent of this latter action was not to discontinue development of regional and site-specific flood stage information, but rather to promote organizational efficiency by eliminating unnecessary rules. Flood stage levels for lakes will continue to be developed under the District's Watershed Management Program, but ten-year flood recurrence levels will not be incorporated into Chapter 40D-8, F.A.C. Historical and more recent flood-stage information for Crews Lake is available in numerous published reports (e.g., SWFWMD 1978, 1997, Turner *et al.* 1979, Ghioto & Asociates 1997, Ardaman and Associates, Inc. 2007, 2015).

The currently adopted Guidance Levels and the Maximum Desirable Level for Crews lake were developed using methods that differ from the current District approach for establishing Minimum and Guidance Levels. The adopted levels do not, therefore, necessarily correspond with levels developed using current methods. Upon adoption by the District Governing Board, Minimum and Guidance Levels established using current methodologies will replace the existing Guidance Levels.

Annually since 1989, a list of stressed lakes has been developed to support the District's water-use permitting program. As described in the District's Consumptive Use of Water Rule (Chapter 40D-2, F.A.C.), "a stressed condition for a lake is defined to be chronic fluctuation below the normal range of lake level fluctuations." For lakes with

adopted Guidance Levels, chronic fluctuation below the Low Level is considered a stressed condition. For lakes without adopted levels, the evaluation of stressed condition is conducted on a case-by-case basis. Crews Lake is classified as a stressed lake since 1992.

Table 2. Currently and previously adopted management/guidance levels for Crews Lake

Management Levels (as originally adopted)	Guidance Levels[a]	Elevation (feet above NGVD 29)
Ten (10) Year Flood Warning Level	Ten Year Flood Guidance Level	57.00[b]
Minimum Flood Level	High Level	55.00
Minimum Low Management Level	Low Level	52.00
Minimum Extreme Low Management Level	Extreme Low Level	50.00

[a] Adopted management levels were renamed as Guidance Levels in District rules in 2000.

[b] Removed from District rules in 2007.

Methods, Results and Discussion

Summary Data Used for Minimum and Guidance Level Development

Minimum and Guidance Levels were developed for Crews Lake using the methodology for Category 1 lakes described in Chapter 40D-8, F.A.C. The levels and additional information are listed in Table 3, along with lake surface areas for each elevation. Detailed descriptions of the development and use of these data are summarized in subsequent sections of this report.

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

	Elevation In feet NGVD 29	Lake Area (acres)
Lake Stage Exceedance Percentiles		
Historic P10	55.3	1102.2
Historic P50	52.0	579.3
Historic P90	48.9	239.5
Period of Record P10	53.7	855.9
Period of Record P50	51.7	540.9
Period of Record P90	48.6	211.4
Normal Pool and Control Point		
Normal Pool	52.8	710.5
Control Point	54.1	916.6
Significant Change Standards		
Cypress Standard	51.0	465.3
Basin Connectivity Standard*	NA	NA
Recreation/Ski Standard*	NA	NA
Species Richness Standard*	51.3	494.2
Wetland Offset*	51.2	483.8
Aesthetic Standard*	48.9	239.5
Dock-Use Standard*	NA	NA
Lake Mixing Standard*	45.7	62.8
Minimum and Guidance Levels		
High Guidance Level	55.3	1102.2
High Minimum Lake Level	52.4	638.4
Minimum Lake Level	51.0	465.3
Low Guidance Level	48.9	239.5

NA = not available or not applicable

* = developed or evaluated for comparative purposes only

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 Crews Lake by building and processing a digital elevation model (DEM) of the lake basin and surrounding watershed. To develop the DEM, Light Detection and Ranging Data (LiDAR) obtained from the SWFWMD Mapping and GIS Section was processed with QCoherent LP360 for ArcGIS and merged with bathymetric data collected using a combination of GPS and a sonar-based depth finder system by DC Johnson Associates Surveying and Mapping (2006) and Southeastern Surveying (2015).

The overall process involves merging the terrain morphology of the lake drainage basin with the lake basin morphology to develop topographic contours of the lake basin (refer to Figure 3) and to create a triangulated irregular network (TIN). The TIN was used to calculate the stage areas and volumes using a Python script file to iteratively run the Surface Volume tool in the Functional Surface toolset of the ESRI® 3D Analyst toolbox at one-tenth of a foot elevation change increments, starting at the largest size of the lake at its peak or flood stage, and working downward to a base elevation associated with the deepest pools in the lake basin. Selected stage-area-volume results are presented in Figure 28).

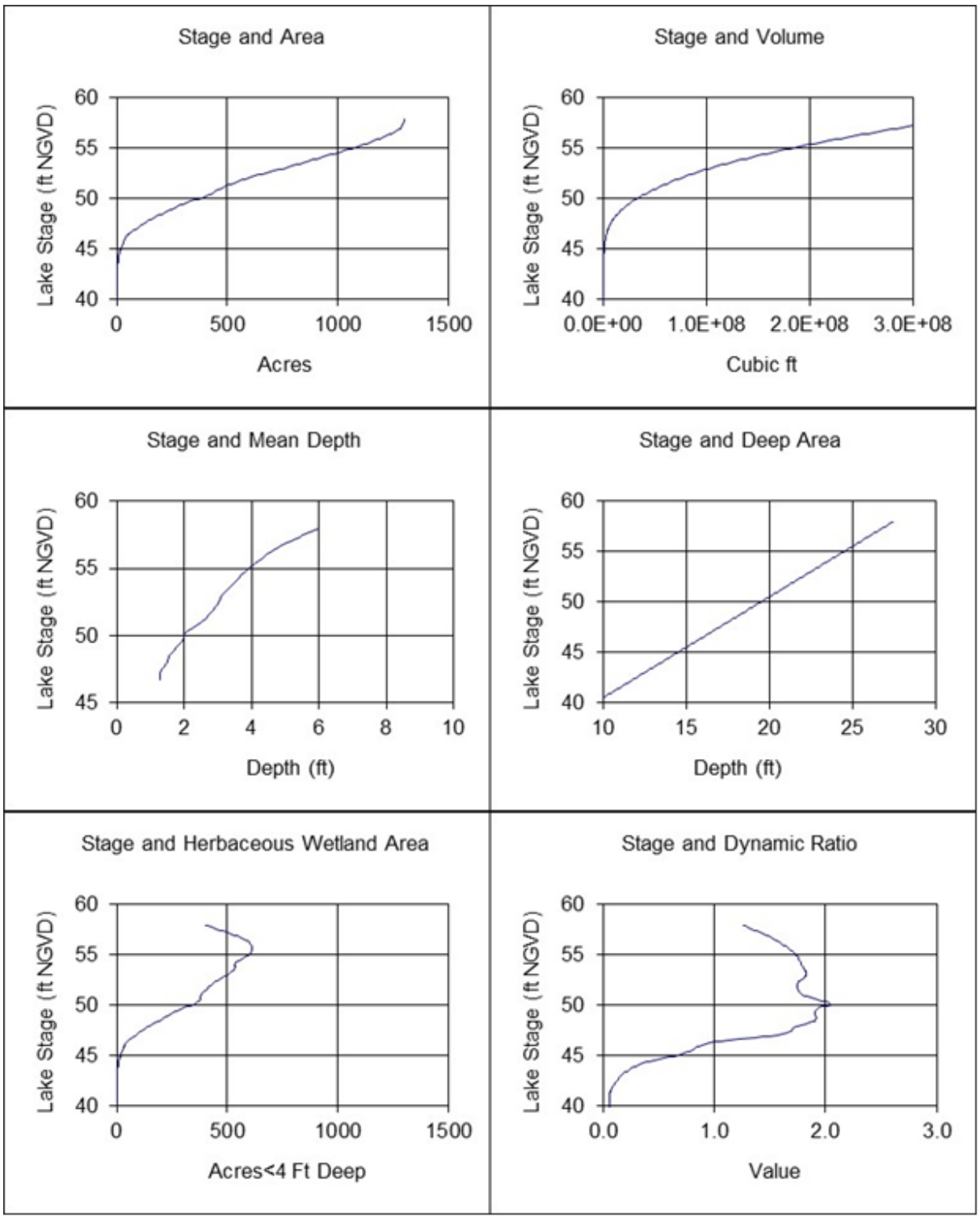

Figure 28. Crews Lake surface area, volume, mean depth, maximum depth, herbaceous wetland area and dynamic ratio (basin slope) as a function of lake stage.

Classification of Lake Stage Data and 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 stage and regional ground water fluctuations, hydrologic data for Crews Lake collected through and after December 1980 were considered to be Historic and Current data, respectively. Based on the relatively short "historic" period of record, measured Historic data were considered insufficient for calculating Historic lake-stage exceedance percentiles *(i.e.*, the Historic P10, P50 and P90 elevations) for the lake. Historic lake-stage exceedance percentiles were, instead, developed using a modeled 68.7-year Historic record of daily lake surface elevations. The 68.7-year period was considered sufficient for incorporating the range of lake-stage fluctuations that would be expected based on long-term climatic cycles that have been shown to be associated with regional hydrologic variability (Enfield *et al.* 2001, Basso and Schultz 2003, Kelly 2004).

Modeled daily lake stage values for the Historic data set were estimated using a linear fitting procedure known as the line of organic correlation (LOC). 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 (see Helsel and Hirsch 1992). The procedure was used to describe the relationship between available lake stage data for Crews Lake from the period that predated withdrawal impacts (*i.e.*, from March 20, 1964 through December 31,1980) and regional rainfall, as measured at nearby long-term rainfall gaging stations in Pasco and Hernando counties (see Appendix A). Rainfall values used for the analysis consisted of weighted twenty-four month cumulative totals that were derived using a linear-decay series to weight monthly rainfall values for the 24-month periods.

The LOC equation developed using lake and rainfall data from March 1964 through December 1980 was used to estimate water surface elevations for Crews Lake for the 68.7-year period from January 1, 1946 through August 31, 2015 (Figure 29). The modeled record included periods when estimated water surface elevations were higher than the highest value of 56.6 feet above NGVD 29 that has been measured at the lake gaging stations. Model predicted values higher than that elevation were assigned a value of 56.6 feet above NGVD 29 for further analyses, including development of lake stage exceedance percentiles, because physical limitations that constrain model peaks were not parameterized in the model. This data truncation did not affect estimated long-

term lake stage exceedance percentiles used to develop minimum and guidance levels because the truncation elevation exceeded the estimated percentile elevations. For instances where modeled water levels were truncated, elevations are expected to have been at or above the highest observed stage of 56.6 feet above NGVD 29.

The Historic P10 elevation, the elevation the lake water surface equaled or exceeded ten percent of the time during the 69.7-year historic period, was 55.3 feet above NGVD 29. The Historic P50, the elevation the lake water surface equaled or exceeded fifty percent of the time during the historic period, was 52.0 feet above NGVD 29. The Historic P90, the elevation the lake water surface equaled or exceeded ninety percent of the time during the historic period, was 48.9 feet above NGVD 29. It should be noted that these percentiles and the modeled record from which they were derived are not recommended for other water management analyses such as floodplain mapping.

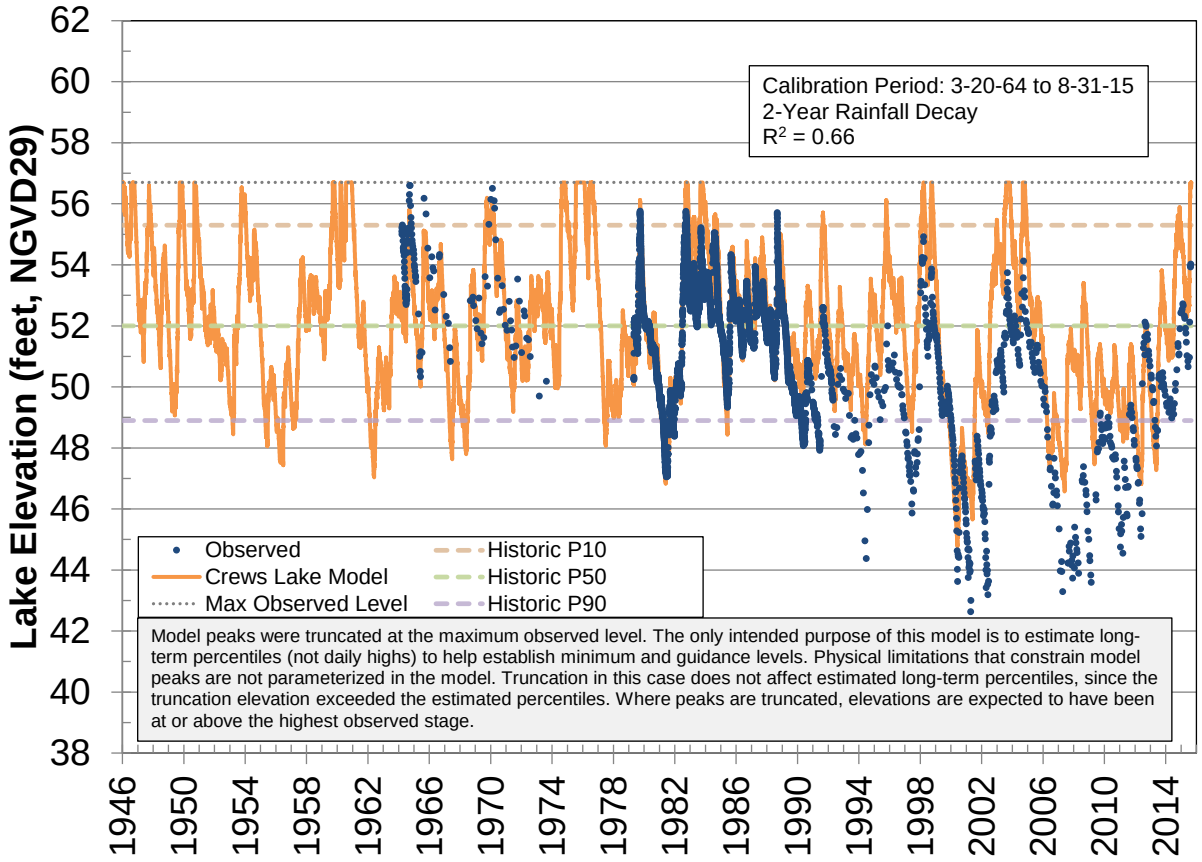

Figure 29. Measured (blue) and modeled (orange) Historic water surface elevations and Historic lake-stage exceedance percentiles for Crews Lake, for the period from January 1946 through August 2015. Modeled water levels higher than the highest observed water level of 56.6 feet above NGVD 29 were assigned an elevation of 56.6 feet above NGVD 29. Historic exceedance percentiles include the Historic P10, Historic P50 and Historic P90, which are water surface elevations equaled or exceed ten, fifty and ninety percent of the time, respectively.

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 based on the distribution of Hydrologic Indicators of sustained inundation. Hydrologic indicators of Normal Pool include biological and physical features that become established as a result of recent or long-term water levels. For development of Minimum Lake Levels, the Normal Pool elevation is considered an approximation of the Historic P10.

Based on elevation of buttress inflection points measured on 31 cypress (*Taxodium* sp.) trees along the southwestern lakeshore, the Normal Pool elevation was established at 52.8 feet above NGVD 29 (Table 4, see Figure 5). The Normal Pool elevation is similar to the safe upland line of 52.0 feet above NGVD 29 identified for the lake by the Florida Department of Environmental Protection, but is 2.7 feet lower than median ground elevations measured at the base of saw palmetto (*Serenoa repens*) shrubs and live oak (*Quercus virginian*a) trees (Table 5), two common indicators of the upland-wetland transition zone that were observed along the lake shoreline.

For development of Minimum and Guidance levels, lakes are classified as open or closed basin lakes. Open basin lakes are systems that are connected to, or are part of an ordered surface water conveyance system, *i.e.*, they have outlets or inlets for conveyance of surface water. Closed basin lakes are those that are not part of an ordered conveyance system. Crews Lake was classified as an open basin lake because it receives inflow from the Masaryktown Canal and Jumping Gully, and is considered the headwaters of the Pithlachascotee River.

The Control Point elevation is the elevation of the highest stable point along the outlet profile of a surface water conveyance system (*e.g.,* a weir, canal or culvert) that is the principal control of water level fluctuations in the lake. A Control Point may be established at the invert or crest elevation associated with a water control structure at a lake outlet, or at a high, stable point in a lake-outlet canal, ditch or wetland area. The invert or crest elevation is the lowest point on the portion of a water control structure that provides for conveyance of water across or through the structure. Based on review of available aerial photography with contours maps of the region (SWFWMD 1974 a-f, 1978, 1982 a,b), LiDAR data (EarthData International, Inc. 2004a) and survey work completed for development of floodplain analyses for the Pithlachascotee River watershed (Ghiotto & Associates 1997), the control point elevation for Crews Lake was established at 54.1 feet above NGVD 29, at a high spot south of the lake in the wetlands associated with the Pithlachascotee River (Ardaman & Associates, Inc. 2007).

Structural alteration status is determined to support development of the High Guidance Level. In addition to identification of outlet conveyance system modifications, comparison of the Control Point elevation with the Normal Pool is typically used to determine if a lake has been structurally altered. If the Control Point elevation is below the Normal Pool, the lake is classified as a structurally altered system. If the Control

Point elevation is above the Normal Pool or the lake has no outlet, then the lake is not considered to be structurally altered. Although the Crews Lake basin has been modified from it's presumed natural state (see Figures 5 through 19), based on the relative elevations of the Normal Pool and Control Point elevations, the lake was determined not to be Structurally Altered.

Table 4. Summary statistics for hydrologic indicator measurements (buttress inflection points of Taxodium sp. trees) used for establishing the Normal Pool Elevation for Crews Lake. Elevations were measured by District staff in February 2004 and July 2006.

Statistic	Statistic Value (N) or Elevation (feet above NGVD 29)
N	31
Median	52.8
Mean (SD)	53.0 (0.7)
Minimum	51.7
Maximum	55.1

Table 5. Summary statistics for additional hydrologic indicator measurements (elevation at the base of Serenoa repens shrubs or Quercus virginiana trees) for Crews Lake. Elevations were measured by District staff in February 2004 and July 2006.

Indicator	Statistic	Statistic Value (N) or Elevation (feet above NGVD 29)
Serenoa repens	N	52
	Median	55.5
	Mean (SD)	55.4 (0.6)
	Minimum	53.0
	Maximum	56.2
Quercus virginiana	N	19
	Median	55.4
	Mean (SD)	55.1 (0.8)
	Minimum	53.4
	Maximum	56.3

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 and the Normal Pool elevation. Based on the availability of the composite Historic data set developed for Crews Lake, the High Guidance Level was established at the Historic P10 elevation, 55.3 feet above NGVD 29.

The Low Guidance Level is provided as an advisory guideline for water dependent structures, and as information for lakeshore residents and operation of water management structures. The Low Guidance Level is the elevation that a lake's water levels are expected to equal or exceed ninety percent of the time on a long-term basis, and is established using Historic or Current data and, in some cases, reference lake water regime statistics. Reference lake water regime statistics are used when adequate historic or current data are not available. These statistics represent differences between P10, P50 and P90 lake stage elevations for typical, regional lakes that exhibit little or no impacts associated with water withdrawals. Reference lake water regime statistics include the RLWR50, RLWR90 and RLWR5090, which are, respectively, median differences between P10 and P50, P50 and P90, and P10 and P90 lake stage percentiles for a set of reference lakes. Based on the availability of the composite Historic water level record for Crews Lake, the Low Guidance Level was established at the Historic P90 elevation, 48.9 feet above NGVD 29.

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 (see Figures 4 and 18), and because the Historic P50 (52.0 feet above NGVD 29) is less than 1.8 feet below the Normal Pool elevation of 52.8 feet above NGVD 29), Crews Lake 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 Resources 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 Crews Lake, the Cypress Standard was established at 51.0 feet above NGVD 29. The standard elevation was equaled or exceeded sixty-seven percent of the time during the Historic period; *i.e.*, the standard elevation corresponds to the Historic P67 based on the composite Historic water level record.

For Category 3 lakes, six significant change standards, including a Basin Connectivity Standard, a Recreation/Ski Standard, a Species Richness Standard, an Aesthetics Standard, a Dock-Use Standard, and a Lake Mixing Standard are developed. These standards identify desired median lake stages that if achieved, are intended to preserve various natural system and human-use environmental values. Although Crews Lake is a Category 1 Lake, Category 3 Lake standards were developed for comparative purposes, but were not used to establish 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. Based on the elevation that ensures connectivity between the northern and southern sub-basins of the lake (51.8 feet above NGVD 29 (the invert elevation of the culvert in the earthen berm that bisects the lake basin), the Basin Connectivity Standard could be established at 55.9 feet above NGVD 29, by adding a one-foot water depth in the area of connectivity to allow for movement of biota between the sub-basins, and the difference between the Historic P50 and Historic P90 elevations (3.1 feet). However, because the standard elevation was equaled or exceeded only seven percent of the time during the Historic period and was not considered appropriate for development of Minimum Levels for Crews Lake.

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 area 200 feet in width and 2,000 feet in length, and use of Historic lake stage data or region-specific reference lake water regime statistics. For Crews Lake, the Recreation-Ski Standard was established at 55.2 feet above NGVD 29, based on the sum of the Ski Elevation (52.1 ft above NGVD 29) and the 3.1-foot difference between the Historic P50 and Historic P90. Based on the Historic, composite water level record, the standard elevation was equaled or exceeded eleven percent of the time during the Historic period; *i.e*., the standard elevation corresponds to the Historic P11. Because the standard exceeds the Historic P50, it was not, however, considered appropriate for Minimum Levels development. Also, based on the distribution of aquatic and wetland plants throughout most of the lake basin, it seems unlikely that Crews Lake is utilized for recreational skiing.

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 (Hoyer *et al.* 2066, Emery *et al.* 2009), 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 Crews Lake, the Species Richness Standard was established at 51.3 feet above NGVD 29. The Species Richness Standard was equaled or exceeded sixty percent of the time during the Historic period; *i.e*., the standard elevation corresponds to the Historic P60.

The Aesthetics Standard is developed to protect aesthetic values associated with the inundation of lake basins. The standard is intended to limit potential change in aesthetic values associated with the median lake stage from diminishing beyond the values associated with the lake when it is staged at the Low Guidance Level. The Aesthetic Standard is established at the Low Guidance Level, which for Crews Lake occurs at an elevation of 48.9 feet above NGVD 29. Because the Low Guidance Level was established at the Historic P90 elevation, water levels equaled or exceeded the Aesthetics Standard ninety percent of the time during the Historic period.

The Dock-Use Standard is developed to provide for sufficient water depth at the end of existing docks to permit mooring of boats and prevent adverse impacts to bottom-dwelling plants and animals caused by boat operation. The standard is based on the elevation of lake sediments at the end of existing docks, a two-foot water depth for boat mooring, and use of Historic lake stage data or region-specific reference lake water regime statistics. Because there are no docks currently located within the basin, a Dock-Use Standard was not developed for Crews Lake.

The Lake Mixing Standard is developed to prevent significant changes in patterns of wind-driven mixing of the lake water column and sediment resuspension. The standard is established at the highest elevation at or below the Historic P50 elevation where the

dynamic ratio (see Bachmann *et al.* 2000) shifts from a value of <0.8 to a value >0.8, or from a value >0.8 to a value of <0.8. The Lake Mixing Standard for Crews lake was established at 45.7 feet above NGVD 29. Review of the stage-area information indicates that the lake size would be 31 acres at the elevation corresponding to the Lake Mixing Standard. The Lake Mixing Standard was equaled or exceeded 100 percent of the time during the Historic period defined by the Historic composite data record, *i.e*., the standard elevation corresponds to the Historic P100.

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 typically evaluated, based on water transparency values. Review of herbaceous wetland area in relation to change in lake stage did not indicate that use of any of the identified Category 3 Lake significant change standards would be inappropriate (Figure 28). Changes in the area available for aquatic plant colonization associated with changes in lake stage could not be evaluated for Crews Lake due to the lack of sufficient water transparency measurements.

Because herbaceous wetlands are common within the Crews Lake basin (e.g., see Figure 4), 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, it was determined that up to an 0.8 foot decrease in the Historic P50 elevation would not likely be associated with significant changes in the herbaceous wetlands occurring within lake basins (Hancock 2006). A Wetland Offset elevation of 51.2 feet above NGVD 29 was therefore established for Crews Lake by subtracting 0.8 feet from the Historic P50 elevation. The standard elevation was equaled or exceeded sixty-two percent of the time during the Historic period defined by the Historic composite data record, *i.e*., the standard elevation corresponds to the Historic P62.

Minimum Levels

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

The Minimum Lake Level is the elevation that a lake's water levels are required to equal or exceed fifty percent of the time on a long-term basis. For Category 1 lakes, the

Minimum Level is established 1.8 feet below the Normal Pool elevation, i.e., at the Cypress Standard elevation. The Minimum Lake Level for Crews Lake was therefore established at 51.0 feet above NGVD 29.

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. The High Minimum Lake Level for Crews Lake was therefore established at 52.4 feet above NGVD 29.

The Minimum and Guidance levels for Crews Lake relative to NGVD 29 are listed in Table 6 and plotted in Figure 30 along with measured water surface elevations through October 2015. 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 the NGVD29 to the NAVD88 vertical control standard, Minimum and Guidance Levels for Crews Lake relative to NAVD88 are also included in Table 6. The NAVD88 elevations were estimated using a datum conversion of 0.86 feet derived with Corpscon 6.0 software distributed by the United States Army Corps of Engineers.

Table 6. Minimum and Guidance Levels for Crews Lake 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	55.3	54.4
High Minimum Lake Level	52.4	51.5
Minimum Lake Level	51.0	50.1
Low Guidance Level	48.9	48.0

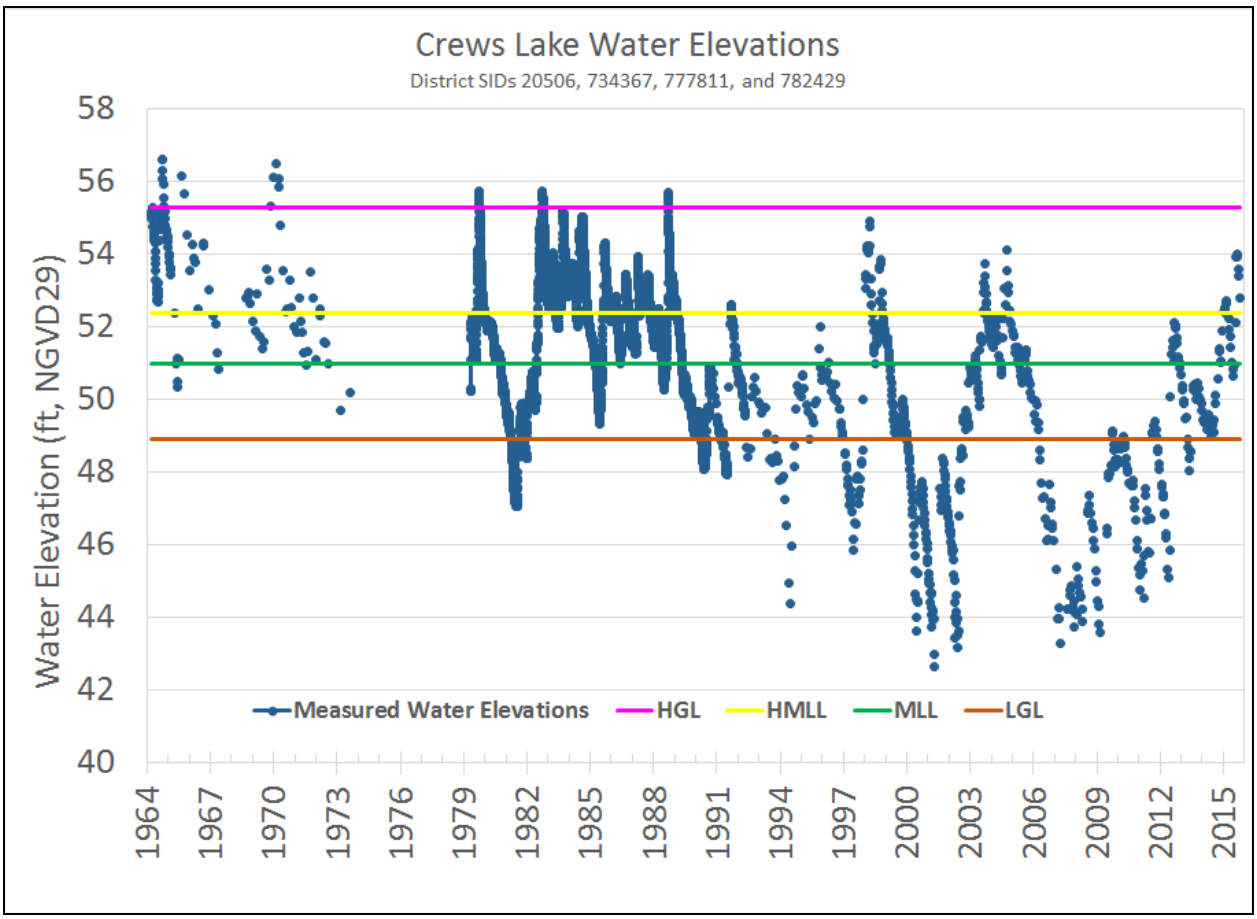

Figure 30. Measured water surface elevations for Crews Lake through October 2015 based on records from four sites (SIDs – Site Identificatin numbers) and established levels including the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL) and Low Guidance Level (LGL).

The approximate locations of the lake margin when water levels equal the minimum levels are shown in Figure 31. Staging of the lake at Minimum Levels is not expected to flood any man-made features within the immediate lake basin. Based on field survey data (Southwest Florida Water Management District 2006 a, unpublished District data), the High Minimum Lake Level is approximately 7.1 feet below the lowest residential home floor slab within the immediate lake basin, and about 5.1 feet below the floor slab of the public restroom located adjacent to the lakeshore in Crews Lake Wilderness Park (Table 7). Water depth at the bottom of the public boat ramp in the park would be approximately 3.3 and 1.9 feet, respectively, when the lake is staged at the High Minimum Lake Level and Minimum Lake Level (Table 7).

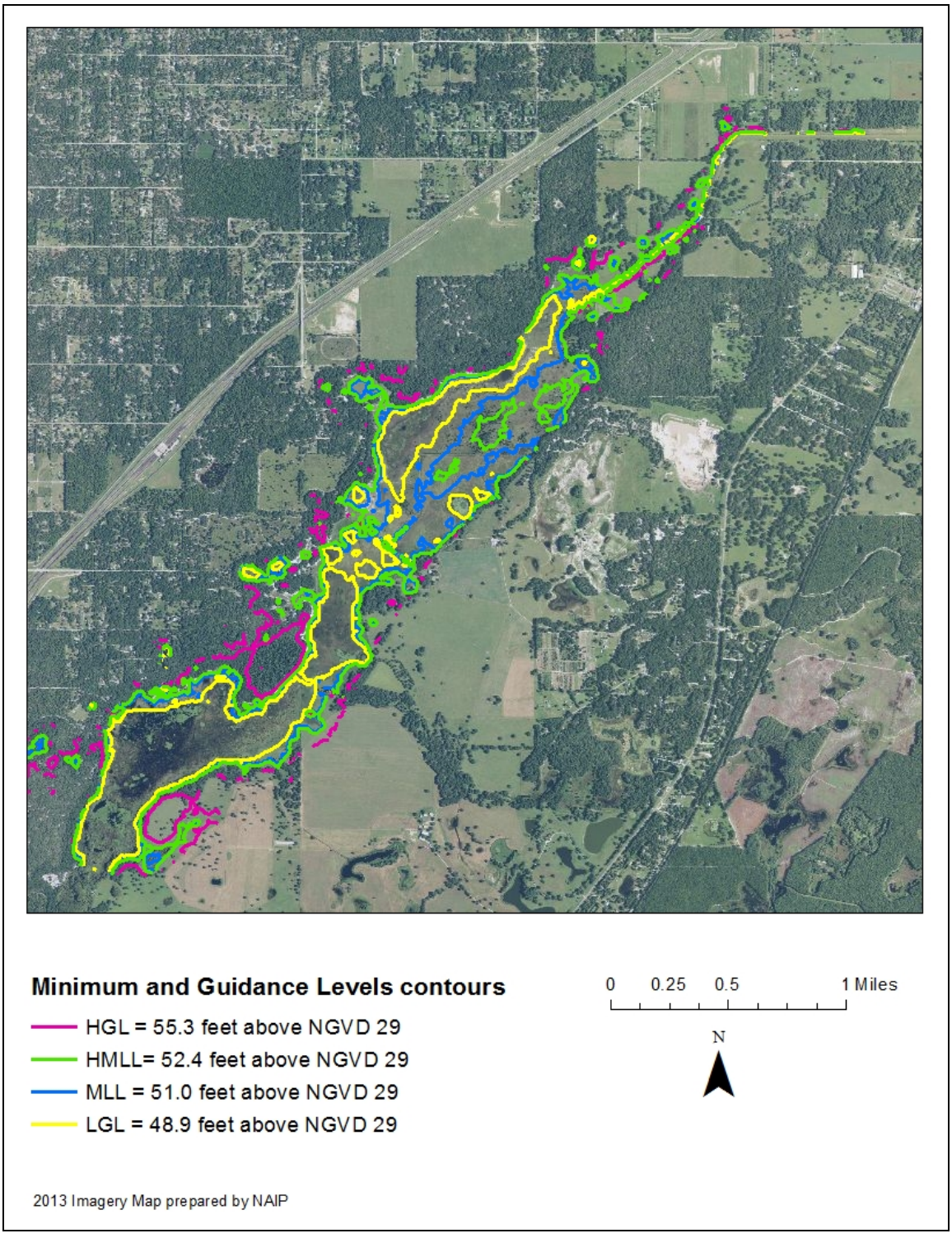

Figure 31. Approximate location of the High Guidance Level (HGL), High Minimum Lake Level (HMLL), Minimum Lake Level (MLL) and Low Guidance Level (LGL) for Crews Lake

Table 7. Elevations of selected man-made features occurring at relatively low elevations within the immediate Crews Lake basin.

Lake Basin Features	Elevation (feet above NGVD 29)
Lowest floor slab – residential dwelling	59.50
Second lowest floor flab – residential dwelling	62.20
Concrete slab for picnic pavilions in Crews Lake Wilderness Park	57.62 & 58.45
Concrete slab for public restrooms in Crews Lake Wilderness Park	57.45
First floor of wooden observation tower in Crews Lake Wilderness Park	56.9
Platform of wooden boardwalk/fishing pier in Crews Lake Wilderness Park	54.9 – 55.4
Top/bottom of concrete boat ramp in Crews Lake Wilderness Park	54.2 / 49.1

Consideration of Environmental Values

The Minimum Levels for Crews Lake are protective of all relevant environmental values identified for consideration in the Water Resource Implementation Rule when establishing MFLs (see Rule 62-40.473, F.A.C.). When developing minimum 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.

An elevation 1.8 feet below Normal Pool, i.e., the Cypress Standard was identified to support development of Minimum Levels for Crews Lake based on the occurrence of lake-fringing cypress wetlands of one-half an acre or greater in size and classification of the lake as a Category 1 Lake. The Cypress Standard and the comparable elevation 0.4 feet below Normal Pool used to develop Minimum Levels for Crews Lake are associated with protection of several environmental values identified in the Water Resource Implementation Rule, including: fish and wildlife habitats and the passage of fish, transfer of detrital material, aesthetic and scenic attributes, filtration and absorption of nutrients and other pollutants, and water quality (refer to Table 1). Because the Cypress Standard is associated with an elevation that is higher than that associated with an Aesthetics Standard developed for the lake, the Minimum Levels are also considered protective of the environmental value recreation in and on the water (refer to Tables 1 and 3). The Minimum Levels are also considered protective of the environmental value, navigation, based on the assessment of water depths that would be expected at the public boat ramp at the lake when the lake surface is at the elevations associated with the established levels. In addition, the environmental value, maintenance of freshwater storage and supply is also expected to be protected by the established Minimum Levels based on inclusion of conditions in water use permits that stipulate that permitted withdrawals will not lead to violation of adopted minimum flows and levels.

Two environmental values identified in the Water Resource Implementation Rule, were not considered relevant to development of Minimum Levels for Crews Lake. Estuarine resources were not considered relevant because the lake is not directly connected to estuarine resources and water level fluctuations in the lake are not expected to affect the ecological structure and functions of any estuaries. Sediment loads were similarly not considered relevant for Minimum Levels development for the lake, because the transport of sediments as bedload or suspended load is a phenomenon typically associated with flowing water systems.

Minimum Levels Status Assessment

The goal of a Minimum Levels status assessment is to determine if lake levels are fluctuating in accordance with criteria associated with Minimum 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 typically includes comparison of long-term water levels with Minimum Levels, review of periodic groundwater modeling updates, and, if necessary, investigation of other factors that could help explain lake level fluctuations.

Lake status was assessed (McBride 2016, included as Appendix B to this report) by comparing the P50 and P10 of measured lake stage data for Crews Lake to the Minimum Lake Level and the High Minimum Lake Level. The P50 and P10 statistics were calculated using data from March 1964 through October 2015 and from May 1979 (when pumping began at Cross Bar Ranch Wellfield) through October 2015. The Minimum Levels for Crews Lake are considered to currently be met, because the P50 and P10 for both periods exceeded Minimum Levels. In addition, because the assessment included a period of groundwater withdrawals at the Cross Bar Ranch Wellfield that are greater than those anticipated for the twenty-year planning period that must be evaluated for minimum flows and levels per Section 373.0421, F.S., the minimum levels are also expected to be achieved for the planning period.

An alternate method for evaluating lake status that involved data aggregation was aslo investigated due to the variability in the frequency of observed data (Appendix B). Results from this evalution indicated that the P10 and P50 for the aggregated measured lake stage data from March 1964 through October 2015, repectively exceeded the High Minimum Lake Level and Minimum Lake Level. The P10 for the aggregated data for May 1979 through October 2015 coincident with withdrawals at the Cross Bar Ranch Wellfield was also higher than the High Minimum Lake Level. The P50 for May 1979 through October 2015 was, however, 0.3 feet lower than the Minimum Lake Level. Based on expectations for P50 values derived for assessment periods shorter than 60 or more years, consideration of rainfall and wellfield withdrawal trends and other factors, the P50 value calculated for the aggregated data from the period of wellfield withrawals was not contraindicative of the status assessment findings based on use of the non-aggregated measured lake stage data.

Crews Lake is currently in an area with a recovery and prevention strategy for minimum flows and levels. While recovery is not anticipated to be needed at this time, the Comprehensive Environmental Resources Recovery Plan for the Northern Tampa Bay Water Use Caution Area and the Hillsborough River Recovery Strategy (Rule 40D-80.073, F.A.C.) applies to the area. The District plans to continue regular monitoring of water levels in Crews Lake and will also routinely evaluate the status of the lake's water levels with respect to adopted Minimum Levels for the lake that are included in Chapter 40D-8, F.A.C.

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