Lake Clinch Water Quality Management Plan

Kissimmee River Basin

Lake Istokpoga Planning Unit

WBID 1706

Prepared for:

Polk County

Parks and Natural Resources Division

POLK COUNTY

September 2015

Executive Summary

Lake Clinch is a 1,260 acre Lake located within Polk County. The quality of water within the lake has been extensively measured and monitored during the past twenty years. In 2012 the State of Florida replaced the Trophic State Index (TSI) as a measurement of impairment for freshwater lakes with a new set of criteria. This new criteria identified Chlorophyll-a, nitrogen, and Phosphorous as key water quality parameters that, absent the establishment of Total Maximum Daily Loads (TMDLs), are to be utilized in the management of all freshwater inland lakes in Florida. These water quality parameters are collectively known as 'Numeric Nutrient Criteria' (NNC)

This report serves as a Water Quality Master Plan for Lake Clinch. The report identifies water quality trends apparent based on available lake water quality data as they relate to NNC criteria. The report identifies opportunities for lake and watershed management that will help to abate future nutrient loading to the lake from the watershed based on the information that is available. Additional data that, if it were collected, would be useful in establishing a nutrient budget for the lake is also identified in the report. Lake Clinch is categorized as impaired based on the draft IWR49 water quality dataset that has been released. The lake is subject to elevated levels of Chl-a which is an indicator of unsustainably high nitrogen (N) levels within the lake water.

Key Findings:

- Chl-a and N levels are directly correlated (Reducing N will likely lower Chl-a levels)
- Nutrient loadings from the watershed do not statistically correlate with Chl-a levels
- Target N levels should be set lower than NNC criteria to achieve and maintain an unimpaired status
- Nutrient balance is not fully understood due to lack of groundwater and sediment data

Key Recommendations:

- Encourage reduction of nitrogen use within the watershed through public education
- Encourage proper disposal of grass clippings
- Evaluate effects of reducing inflows from Crooked Lake
- Evaluate N contributions present in groundwater
- Obtain samples of lake sediment and evaluate for nitrogen flux
- Consider establishing native emergent plant species within the littoral lake edge (about 15 acres).
- Consider establishing SAV in the 0 to 10 foot range range (about 177 acres).

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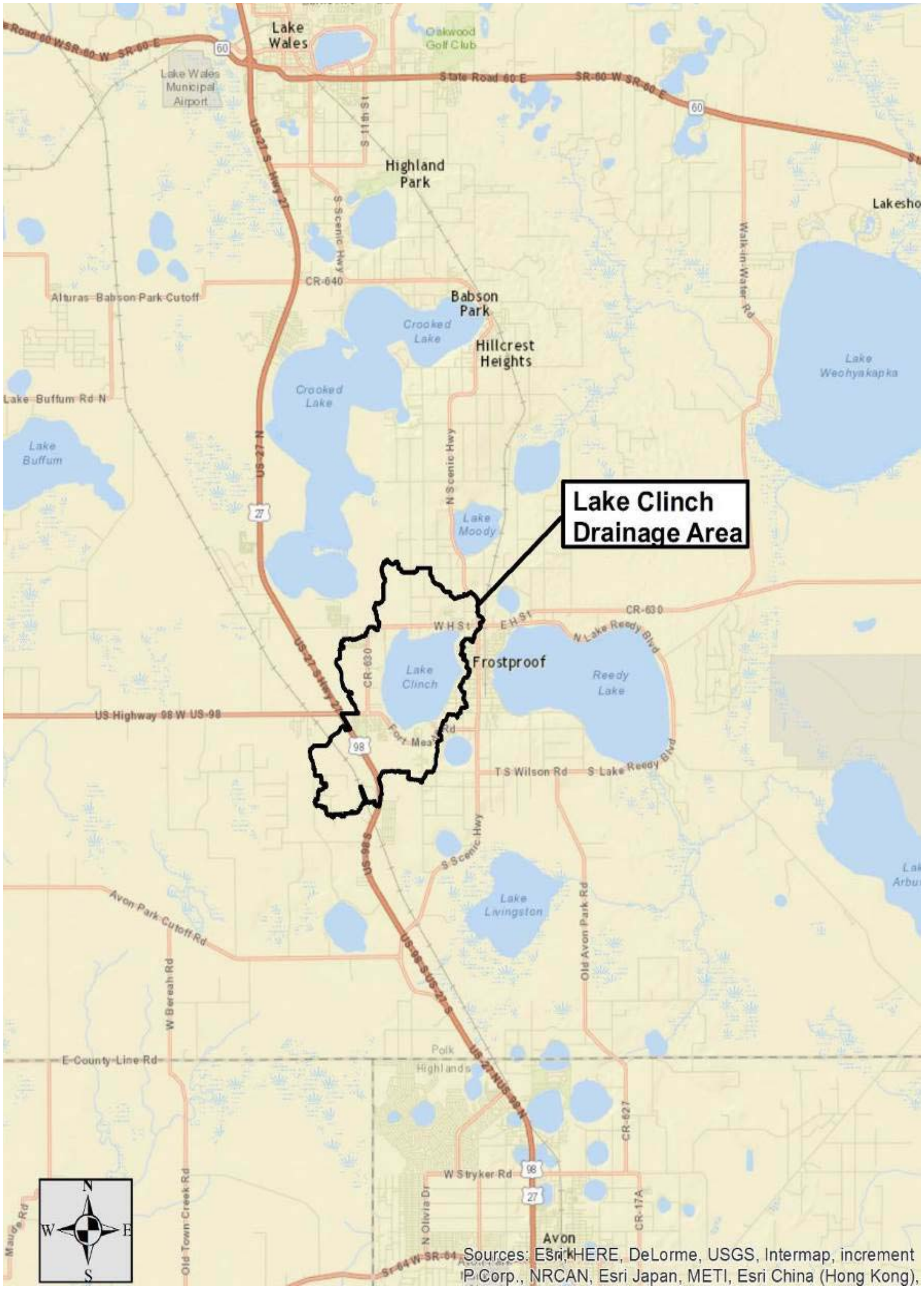
1. INTRODUCTION

1.1. Purpose

The purpose of this Water Quality Management Plan (WQMP) is to provide a scientific analysis of Lake Clinch that provides a context for understanding the relationship between its water quality and contributing watershed inputs and in-lake processes. Lake Clinch is located in Polk County, Florida (Figure 1) and receives runoff from an approximately 6 square mile watershed. The lake has been identified as being within the Northern Lake Wales Ridge region which is described as an area of slightly alkaline, low to moderate nutrient laden clear-water lakes with high nitrogen concentration (Griffith et al. 1997). Watershed inputs to the lake include pollutant loadings derived from runoff from the watershed area, atmospheric deposition, ambient groundwater conditions, and point source loadings resulting from culverts or ditches discharging into the lake.

This analysis begins with a compilation of available data that deals with existing and historical lake and watershed conditions and inputs, and observed and measured lake attributes such as water quality and lake stage over time. Previous technical analyses concerning the lake are also taken into consideration, reviewed, and in some cases utilized for the baseline data that they are able to provide regarding the lake. This information, after being compiled is then assimilated to determine the meaning of both short-term and long-term water quality trends within the lake, and to identify how any undesirable trends may be mitigated. Mitigation options for these trends include the implementation of both non-structural and structural watershed management practices and improvements and in-lake treatments, some or all of which may utilize local, state, and federal agency partnering.

Figure 1 - Location Map



1.2. Current Management Activities, Regulatory Issues, and Impairment Status

Current regulatory agencies involved with the lake and watershed affecting the lake include the Polk County Parks and Natural Resources Division (PCP&NR), the Florida Department of Environmental Protection (FDEP), the Polk County Health Department, the Southwest Florida Water Management District (SWFWMD), and the Florida Department of Agriculture and Consumer Services (FDACS). These agencies are involved with the lake and its associated watershed in a variety of ways. Activities that stakeholder agencies routinely engage in that have a long-term impact on the lake include the promulgation of rules, the approval of changes to the watershed (i.e. development), the funding of special projects or continuing management efforts, and lake monitoring and public education.

The deleterious effects of urbanization within the watershed as it relates to the water quality of the lake are mitigated almost solely through the implementation of Best Management Practices (BMPs) within the watershed. These BMPs are those appropriate for agricultural entities voluntarily enrolling in the FDACS BMP program as well as those required for construction sites and new development through the FDEP, the SWFWMD, and the County. Additional mitigation of watershed impacts on the lake can be achieved through the construction of permanent water quality treatment projects implemented by the County and funded by the County and partnering agencies. The lake is currently designated as impaired based on the Tropic State Index (TSI). Based on data contained within IWR 49, the lake is expected to also be determined to be impaired for Chlorophyl-a and nitrogen.

2. SUMMARY OF EXISTING INFORMATION

2.1. Available Data Sets

A variety of data sets have been provided by Polk County, and additional data has been collected as part of this effort. The data collection effort focused on identifying, collecting and cataloging spatial and temporal data sets which can be used to characterize existing and historical lake conditions and evaluate potential water quality improvement alternatives. The spatial data sets include topography, bathymetry, aerial imagery, land use coverages, soil coverages, and regulatory coverages. The temporal data sets include rainfall, lake levels, and water quality measurements. The data was collected from various government agencies and much of the data is available without charge. The primary objective of the data collection effort was to establish baseline data that would allow for a more in-depth review of lake and watershed parameters than had previously been conducted by the County or outside agencies. Existing literature and reports were also reviewed as part of the data collection and identification of existing conditions effort of this report, and they are listed as references.

Table 1 provides a summary of the data sets collected for these analyses.

Table 1 - Data Collection Summary

Dataset Title	Author/Sponsor	Date	Dataset Description	Format	Use
IWR Stations Run49	FDEP	2014	To identify the locations of the stations whose data was used in the IWR Run	Shapefile	Mapping
IWR Stations Run49	FDEP (STORET)	2014	Water quality data used for state assessment	Access Database	Analysis
1952 Aerial Imagery	FDOT	1952	Aerial Image	SID Raster	Develop a Timeline of Changes in the Watershed
1995 Aerial Imagery	FDOT	1995	Aerial Image	SID Raster	Provide a Timeline of Changes in the Watershed
2014 Aerial Imagery	FDOT	2014	Aerial Image	SID Raster	Provide a Timeline of Changes in the Watershed
On-Site (OSTDS) Septic	Florida Department of Health	2013	Location of Known Septic Systems	GIS Point Shapefile	Pollutant Loading Calculations
Rainfall Data NOAA	NOAA	1945 – 1991	Daily Rainfall Data	Excel Spreadsheet	Rainfall Analysis and Pollutant Loading Calculations
Lake Water Quality Data	Polk County	2012	Water Quality Data from 1991 to 2012, with WQI and TSI Calculation	Shapefile	Water Quality Analysis
PC TMDL Lakes Drainage Areas	Polk County	2014	Polk County Impaired Lakes Drainage Area	GIS Polygon Shapefile	Define Lake's Drainage Area and Pollutant Loading Calculations
Flood Zone 2012	Polk County	2012	FEMA Flood Hazard Area	GIS Polygon Shapefile	Mapping

Dataset Title	Author/Spouse	Date	Dataset Description	Format	Use
Lake Bathymetry	Polk County	2001	Bathymetric Contours	GIS Polygon Shapefile	Represent Lake Bottom
Land Use 2011	Polk County	2011	Land Cover as of 2011. Review Shows Coverage is Representative of Current Conditions	GIS Polygon Shapefile	Quantify Current Development and Pollutant Load Calculation
Roadways	Polk County	2014	Centerline of Roadways within Polk County	GIS Polyline Shapefile	Infrastructure Mapping
MS4 Outfalls	Polk County	2014	County's MS4 Outfalls	GIS Point Shapefile	Infrastructure Mapping
MS4 Drainage Areas	Polk County	2014	Drainage Area for each of the County's MS4 Outfalls	GIS Polygon Shapefile	Watershed Mapping
AMEC PL Tool	Polk County	2012	Pollutant Loading Estimation Spreadsheet	Excel Spreadsheet	Used as Reference EMCs, and Runoff Coefficients for Pollutant Loading Calculations
Trans Pipes	Polk County	2012	County Storm Pipes	GIS Polyline Shapefile	Infrastructure Mapping
Lake Vegetation Summary	Polk County Parks and Natural Resources		Summary of Vegetation Observations on Polk County lakes	Word Document	Background Information, Analysis
Treatment Report	Polk County Parks and Natural Resources	2014	Log of Herbicide Applications for Invasive Plant Species	PDF	Background Information, Analysis
Digital Elevation Model	SFWMD	2008	LiDAR Based Topography	Raster	Represents Watershed Topography

Dataset Title	Author/Spouse	Date	Dataset Description	Format	Use
Water Level Monitor	SWFWMD	1983 - 2014	Station 23863	Excel Spreadsheet	Evaluate Historical Lake Hydrology
ERP	SWFWMD	2014	Environmental Resource Permit Boundaries	GIS Polygon Shapefile	Identify Extent of Environmental Regulatory Coverage and Pollutant Loading Calculations
Rainfall Data NEXRAD	SWFWMD	1995 – 2014	15 min Rainfall Data	Excel Spreadsheet	Rainfall Analysis and Pollutant Loading Calculations
Hydro100 Features	SWFWMD	2011	Streams and Shoreline	GIS Polyline Shapefile	Mapping
Land Use 1995	SWFWMD	1995	Land Cover as of 1995	GIS Polygon Shapefile	Provide a Timeline of Development in the Watershed and Pollutant Load Calculations
Wetlands	U.S. Fish and Wildlife Service	1984	Online National Wetlands Inventory Map Showing Approximate Wetland Boundaries	Shapefile	Mapping and Analysis
Soils	United States Department of Agriculture	2014	Soil Survey Geographic Database (SSUGO) Soil Survey of Polk County	GIS Polygon Shapefile	Represent Soil Coverage and Pollutant Loading Calculations

2.2. Existing Research Literature and Studies

Summary of "Prioritizing Future Actions Related to Impaired Lakes and the FDEP TMDL Program", Atkins and ESA, September 2014.

Polk County is presently a participant in the National Pollution Discharge Elimination System (NPDES) by virtue of their permit to operate a Municipal Separate Storm Sewer System (MS4). A resulting requirement of the County NPDES MS4 permit is that the County was required to develop a plan to address water bodies for which Total Maximum Daily Loads (TMDLs) had been defined by either the Florida Department of Environmental Protection (FDEP) or Environmental Protection Agency (EPA).

A total of twenty-one (21) lakes within the County were identified as having FDEP or EPA approved nutrient related TMDLs. The County subsequently engaged a consultant to prepare a summary report to prioritize future actions related to these 21 water bodies and the TMDL program. The prioritization list was completed in September of 2014. The initial analysis of the 21 water bodies was expanded to an additional 97 water bodies that did not have specific TMDLs assigned to them but were impaired and had the potential to be assigned TMDLs in the future. This proactive approach to lake management required analysis of water quality data for these water bodies.

To accomplish this, lake-specific empirical water quality targets were derived for each of the lakes without TMDLs from correlations between nutrients and chlorophyll-a concentrations which were compared to the recently approved FDEP nutrient criteria. The annual percent reduction required to meet calculated lake-specific nutrient and chlorophyll-a targets was calculated. Lake-specific targets were often found to be more stringent than the FDEP nutrient criteria. This was generally the case but for Lake Clinch, no correlation between nutrients and chlorophyll-a was found. The probable impairment status was also determined using the FDEP nutrient criteria which were adopted in November of 2012 but became effective in October of 2014. The water quality data used were limited to a period from 1983 – 2013. The methods for comparison were consistent with those employed by FDEP to determine impairment. Results indicate Lake Clinch would be impaired for total nitrogen, total phosphorus and chlorophyll-a.

Each lake was assigned to a tier based on the magnitude of the percent reduction required for each parameter concentration to meet FDEP lake (NNC) for total nitrogen, total phosphorus and chlorophyll-a (corrected). Five tiers were created ranging from 0 (no reduction) –to 4 (>60% reduction). Each lake was assigned the largest tier score from each of the three parameters. Within each tier, a context score was determined using the following parameters: regulatory, potential cooperative partners, lake size, potential socio-economic use, number of MS4 outfall to the lake and the proportion of the basin draining to the lake via County MS4 outfalls. Each of these scores was weighted based on their relative importance.

Two intensity factors were developed to quantify the changes in water quality status for the waterbody: frequency of exceedance and water quality trend. The percent frequency of exceedance represents the percentage of time a waterbody exceeded the annual criteria for TN, TP or chlorophyll-a-a (corrected). The water quality trend score was determined using a seasonal Kendall-Tau test to determine the presence and direction of a trend. A lake's final score is the sum of the context and intensity scores. The context score was calculated as the average weighted score of all factors while the intensity score was computed as the average of the two intensity factors. Table 2 shows the results of the scoring analysis for Lake Clinch. Lake Clinch was ranked number 9 in Tier 3.

Table 2 - Lake Clinch Scoring Analysis

WBID	Name	Regulatory	Lake Size	# of Partners	Socio-Economic	# of MS4 Outfalls	% Basin Draining from MS4	Frequency of Exceedance	Water Quality Trend	Average Context	Average Intensity	Final
1706	Clinch	4	2	4	2	6	6	6	8	4	7	11

Note: This table represents scores only which were used to compute a final ranking.

The specific recommendations as they relate to Lake Clinch were that internal and external nutrient loads for the lake should be evaluated and that a Water Quality Management Plan (WQMP) be developed and implemented.

3. EXISTING AND HISTORICAL CONDITIONS ASSESSMENT

3.1. GENERAL LAKE INFORMATION

3.1.1. Lake Location

Lake Clinch (the lake) is generally located in southern Polk County, about 1 mile east of US-27, just north of US-98, within the corporate limits of the City of Frostproof, as shown on Figure 1 .**Error! No bookmark name given.**

3.1.2. Lake Description

Lake Clinch is an approximately 1,240 acre lake, identified by the FDEP as Water Body Identification Number (WBID) 1706. The WBID is an approximate map shape that roughly delineates the lake. The WBID enables areas to be grouped into planning units which then become part of the basin rotation for the Total Maximum Daily Load Program (TMDL) which is administered by the FDEP as delegated by use PA.

Figure 2 shows the lake's 3,745 acre drainage area delineation provided by Polk County and revised to eliminate land draining to Silver Lake to this on 2014 aerial imagery obtained from the Florida Department of Transportation (FDOT). A significant hydraulic connection from Crooked Lake discharges into Lake Clinch along the northwestern shoreline. The connection between Lake Clinch and Crooked Lake (the Crooked Clinch Canal) was observed flowing as recently as January of 2015. Discharge from Lake Clinch occurs along the eastern lakeshore, through a control structure and a 72" concrete pipe, to Reedy Lake. Figure 3 shows the major hydraulic connections into and from Lake Clinch based on the Hydro Feature GIS coverage, provided by Polk County. Section 3.2.3 describes the culvert connecting Lake Clinch to Lake Reedy. The watershed to lake area ratio is 3.0, which means that there is 3 times more land area than open waters. This has an effect of a likelihood of watershed based impacts occurring in the lake.

Figure 2 - Drainage Area (2014 Aerials)

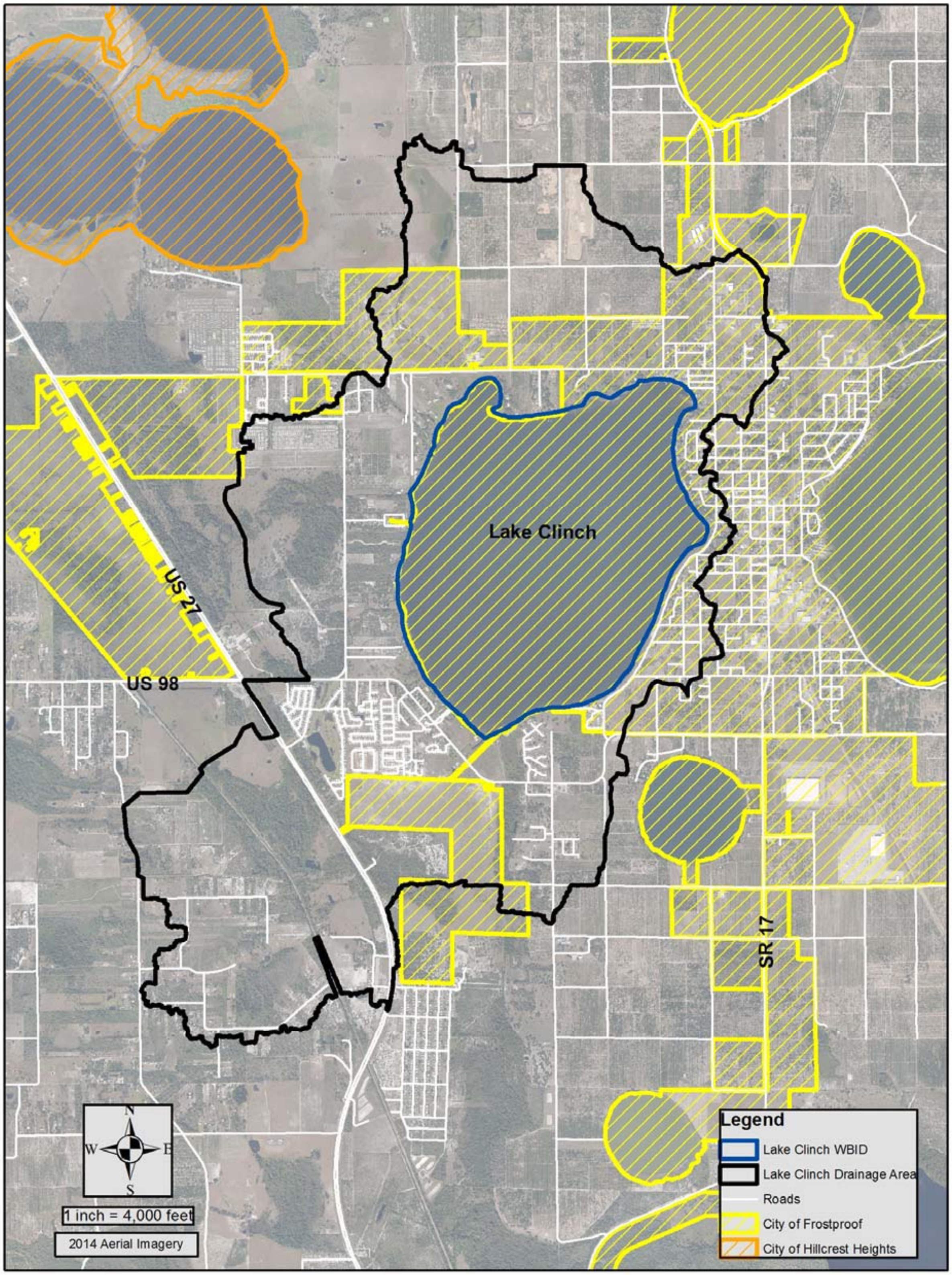
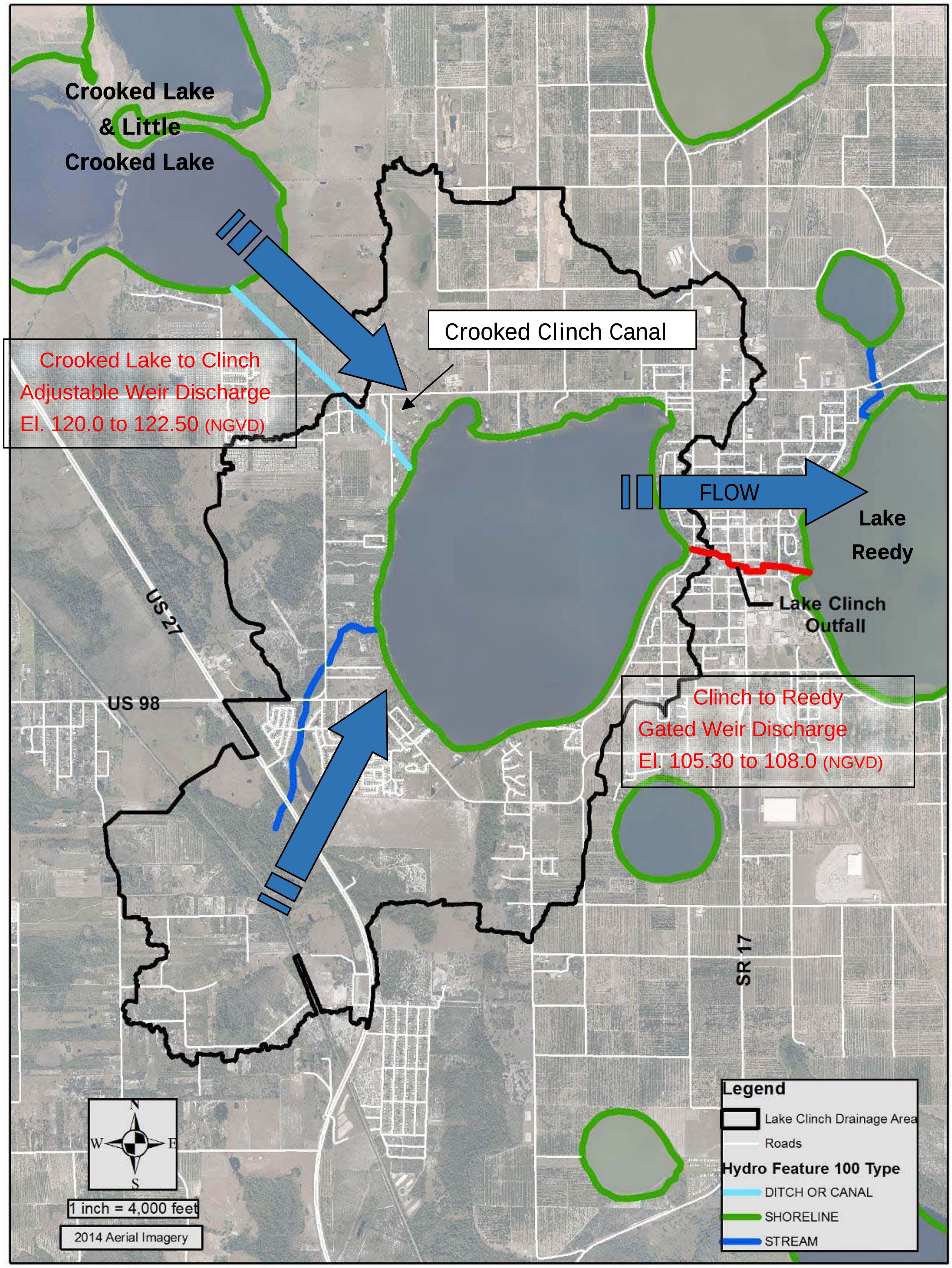


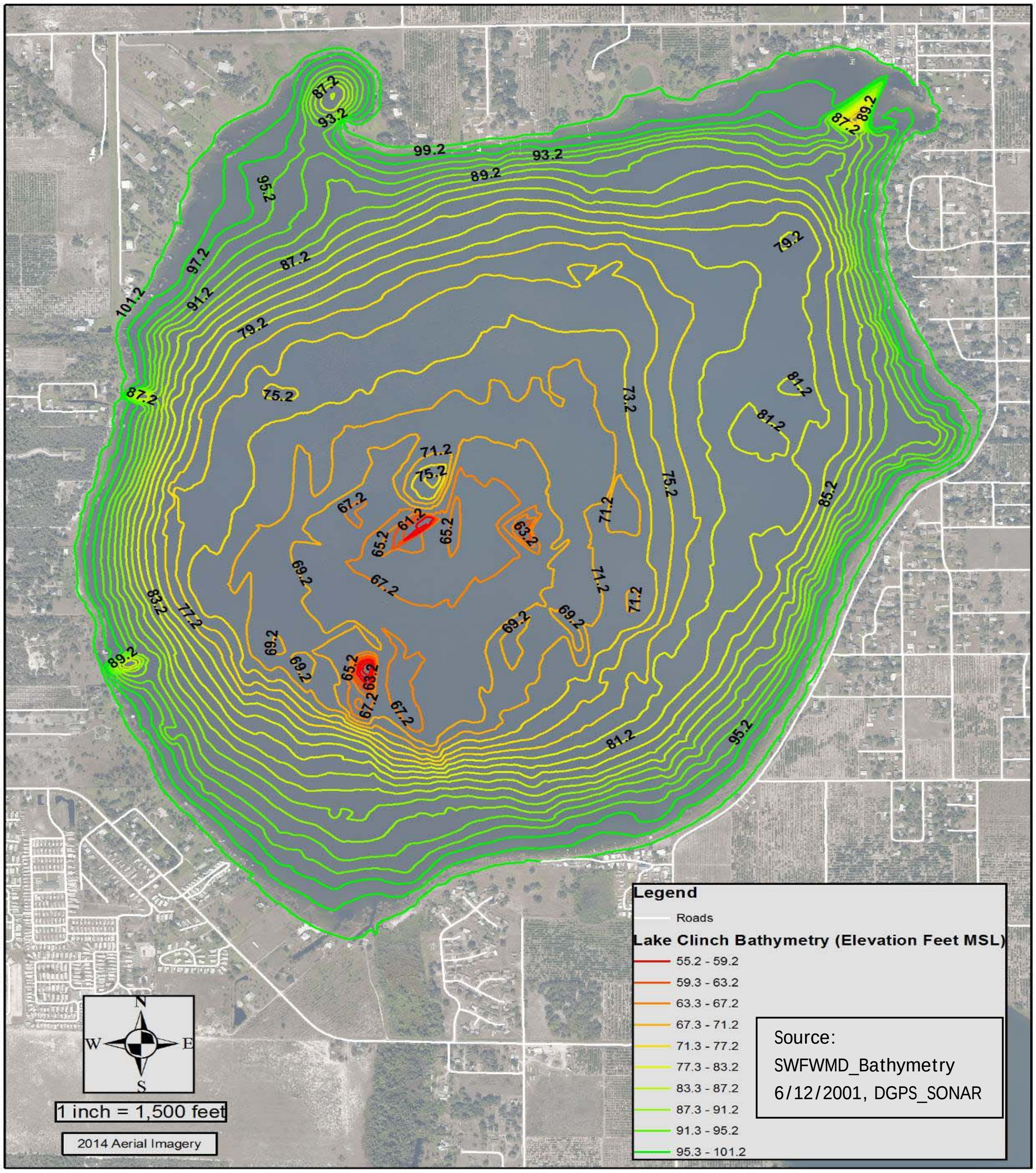
Figure 3 - Lake Surface Hydrology Features



3.1.3. Lake Bathymetry

Bathymetric data was provided by Polk County and represents the lake bottom elevation as of June 2001. The lake bottom ranges from elevation 55 to 101 feet Mean Sea Level (MSL). The maximum depth of the lake was approximately 46 feet below the water surface on 6/12/2001. Figure 4 shows the 2001 bathymetric contours for Lake Clinch.

Figure 4 - Lake Bathymetry

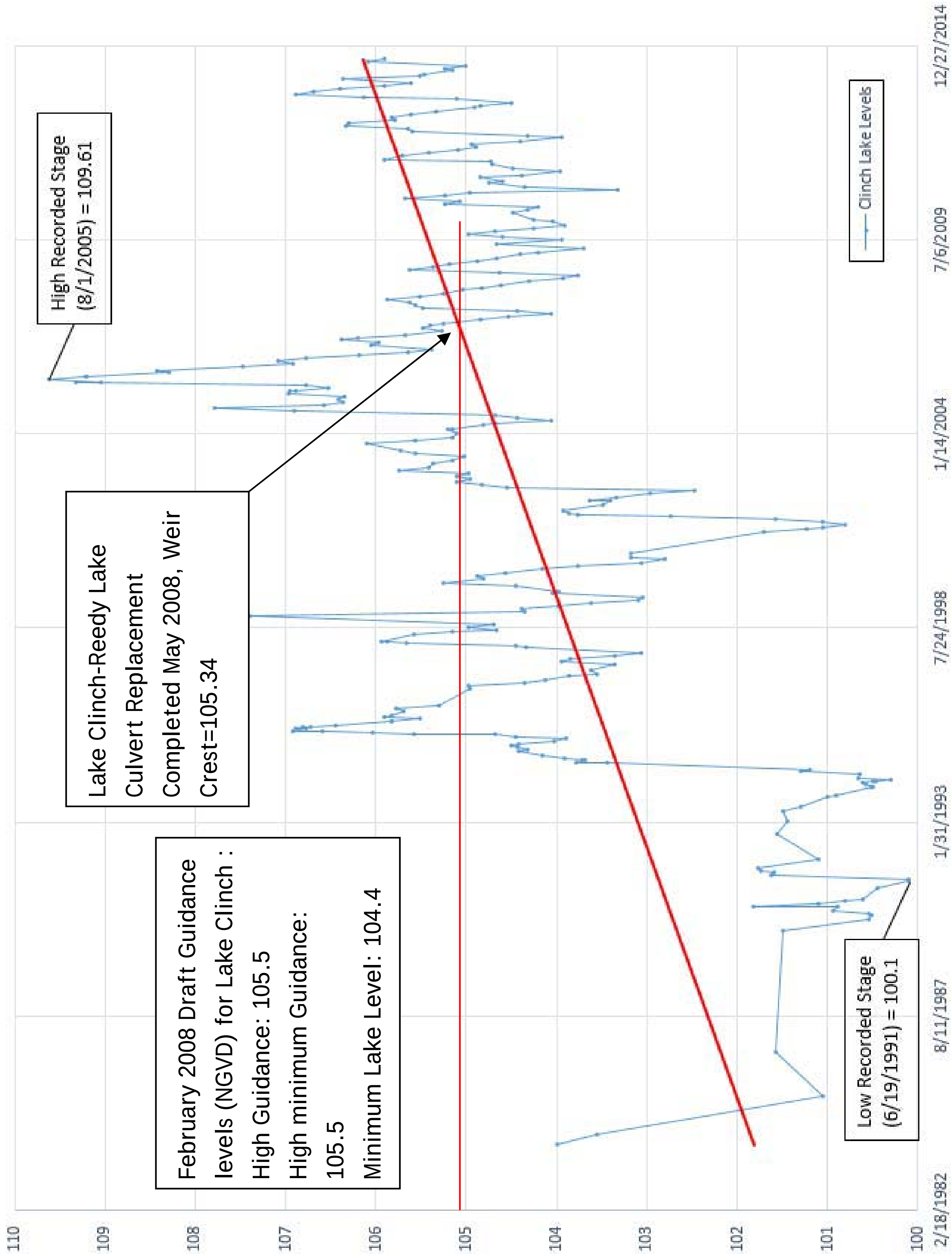


3.1.4. Lake Levels

Historical lake stages for Lake Clinch were obtained from the Polk County Water Atlas which provided data collected by SWFWMD for station 23863 (Lake Clinch). Lake level data is available from 12/20/1983 to 8/11/2014. The lake levels have ranged from a high of 109.61 (8/1/2005) to a low of 100.1 (6/19/1991). The lake stage trend is clearly increasing and is highly variable over the period of record. In 2008, an existing drainage connection between Lake Clinch and Reedy Lake was replaced with new piping. This new drainage connection includes a weir with a slide gate. The weir crest is set at elevation 105.34 NGVD. A review of lake stages following completion of the new drainage structure and culvert indicates that the lake has generally been maintained above the minimum control elevation of 105.34. However, since 2006, the variability in lake stages has decreased and generally maintained a two foot range between wet and dry seasons. Figure 5 provides the detailed stage history for Lake Clinch.

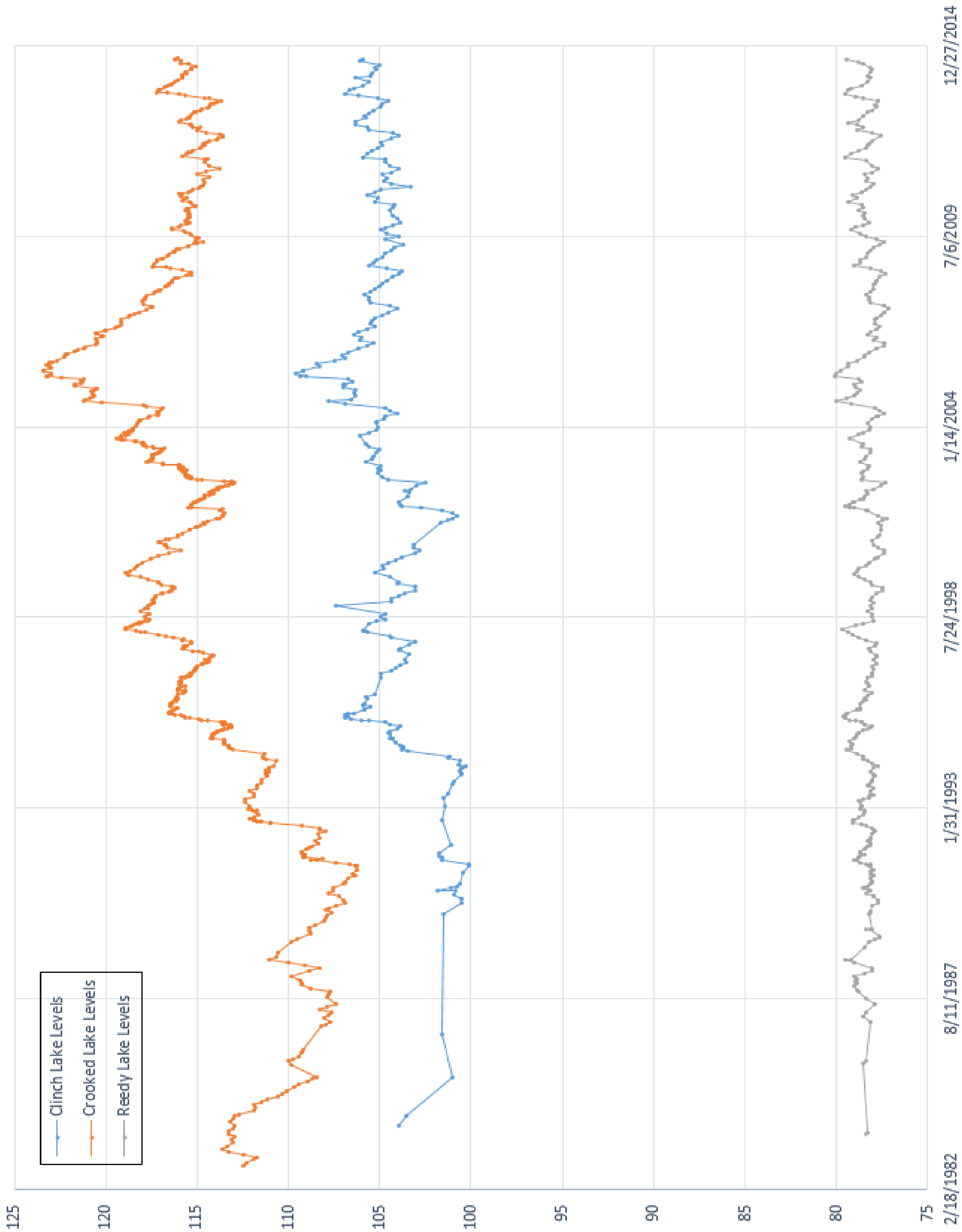
The overall change in lake stage ranges is likely due to construction of the Lake Clinch Outfall Structure in late 2006. The outfall structure has a top elevation of 111.09ft NGVD with the bottom cord of the top slab estimated to be at elevation 101.09ft and the structure consists of two (2) 5' wide by 5' tall overflow weirs which both crest at elevation 105.30ft into a 72" concrete pipe. The 72" concrete pipe has an upstream invert elevation of 100.67ft and a downstream invert of 82.39ft and flows through a series of intermediate stormwater junction boxes along the route. The total length of 72" pipe is approximately 2,300ft and terminates at a junction box which then discharges into Lake Reedy through approximately 80ft of double 48" concrete culverts. Control of flows to Lake Reedy is accomplished at the Lake Clinch outfall structure by one 5ft wide slide gate which is affixed to the south weir only. Since construction of the outfall structure the lake stage has not exceeded 107.0 feet (NGVD). Figure 6 shows historical lake levels for Lake Clinch and the adjacent Crooked Lake and Lake Reedy. The water level record suggests that Lakes Crooked and Clinch are more hydraulically connected than Clinch and Reedy.

Figure 5 - Historical Lake Clinch Water Levels National Geodetic Vertical Datum (NGVD)



Source:
SWFWMD_Bathymetry
6/12/2001, DGPS_SONAR

Figure 6 - Historical Lake Levels for Reedy Clinch and Crooked National Geodetic Vertical Datum (NGVD)



The recommended lake level management criteria for Lake Clinch SWFWMD, 2008 has changed little in the past twenty years as shown in Table 3. The most significant change is that the recommended high stage and low stage operation range for Lake Clinch has been reduced by approximately 1.8' with the total recommended lake stage operating range now being 4.32' compared to 5.5' in 1984. The 2008 recommended change in the lake stage management results in a 22% decrease in total water volume available within the lake. Since construction of the outfall control structure the lake has operated between the high and low guidance levels, generally averaging just above 105 (NGVD).

Table 3 - Minimum and Guidance Elevations (Feet NGVD) for Lake Clinch (SWFWMD, 2008)

Level Description	1984	2008	Difference	2008 Lake Area (Acres)
Ten Year Flood Guidance Level	108.00	107.40	-0.60	1,258
High Guidance Level	106.75	105.53	-1.22	1,229
High Minimum Lake Level	105.53	NA	NA	1,229
Minimum Lake Level	104.00	104.43	+0.43	1,207
Low Guidance Level	102.50	103.08	+0.58	1,181

3.2. GENERAL WATERSHED INFORMATION

3.2.1. Historical Aerials

Historical aerial imagery has been collected from the FDOT for 1995 shown as Figure 7 and 1952 shown as Figure 8. These historical aerials provide a visual comparison of changes in land cover within the lake's drainage area over time and show little change since 1995.

Figure 7 - Drainage Area (1995 Aerials)

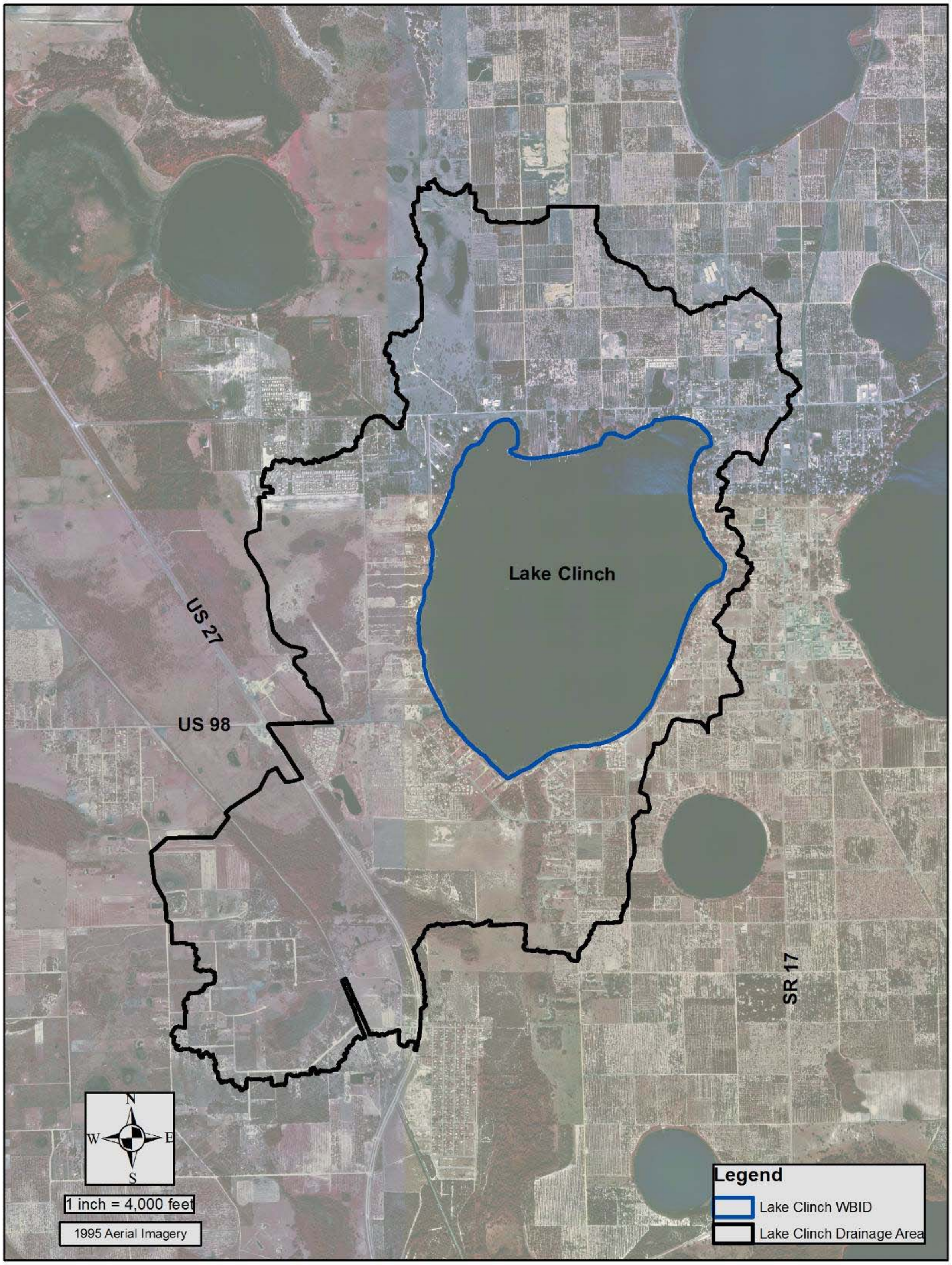
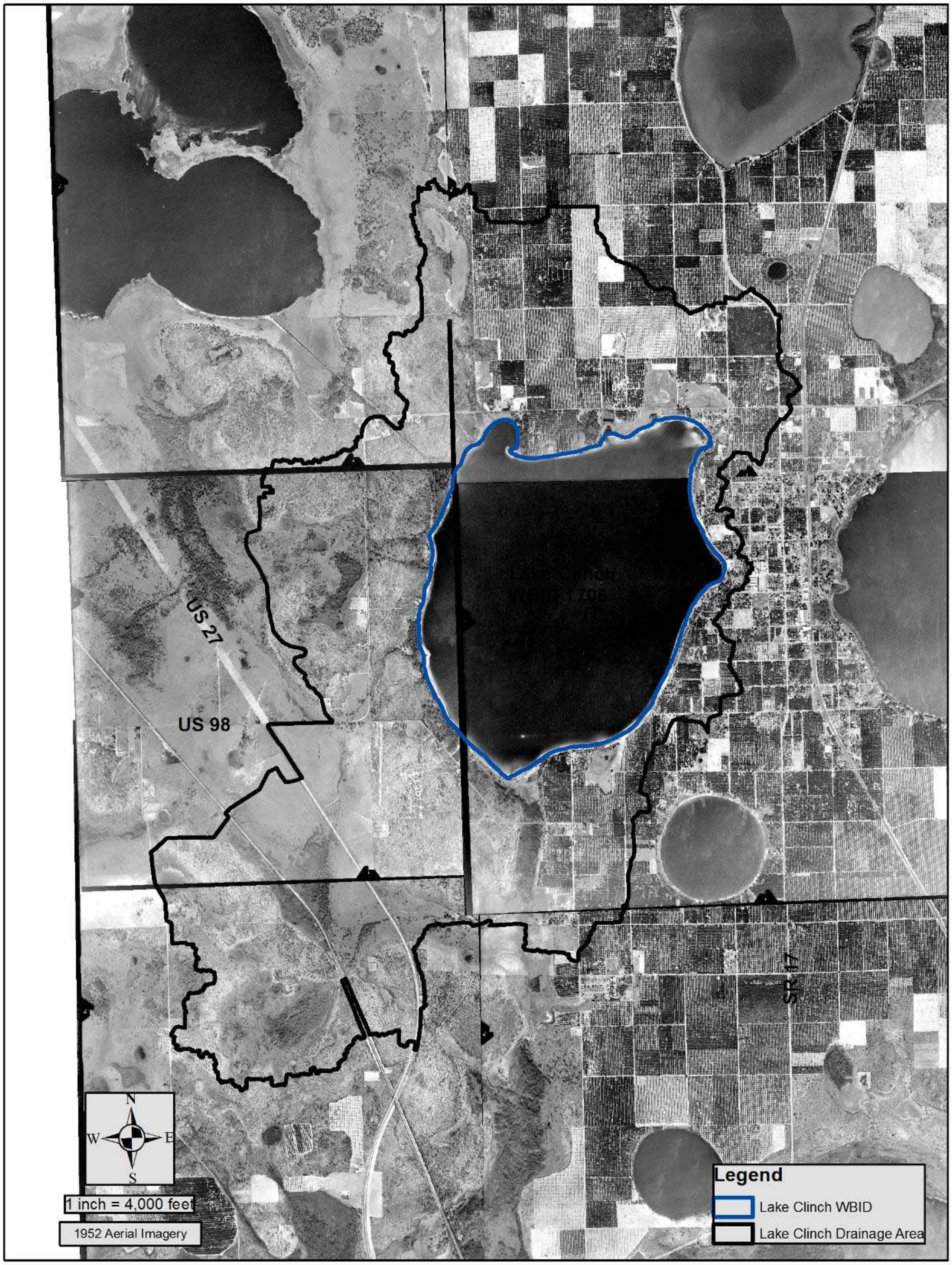


Figure 8 – Drainage Area (1952 Aerials)



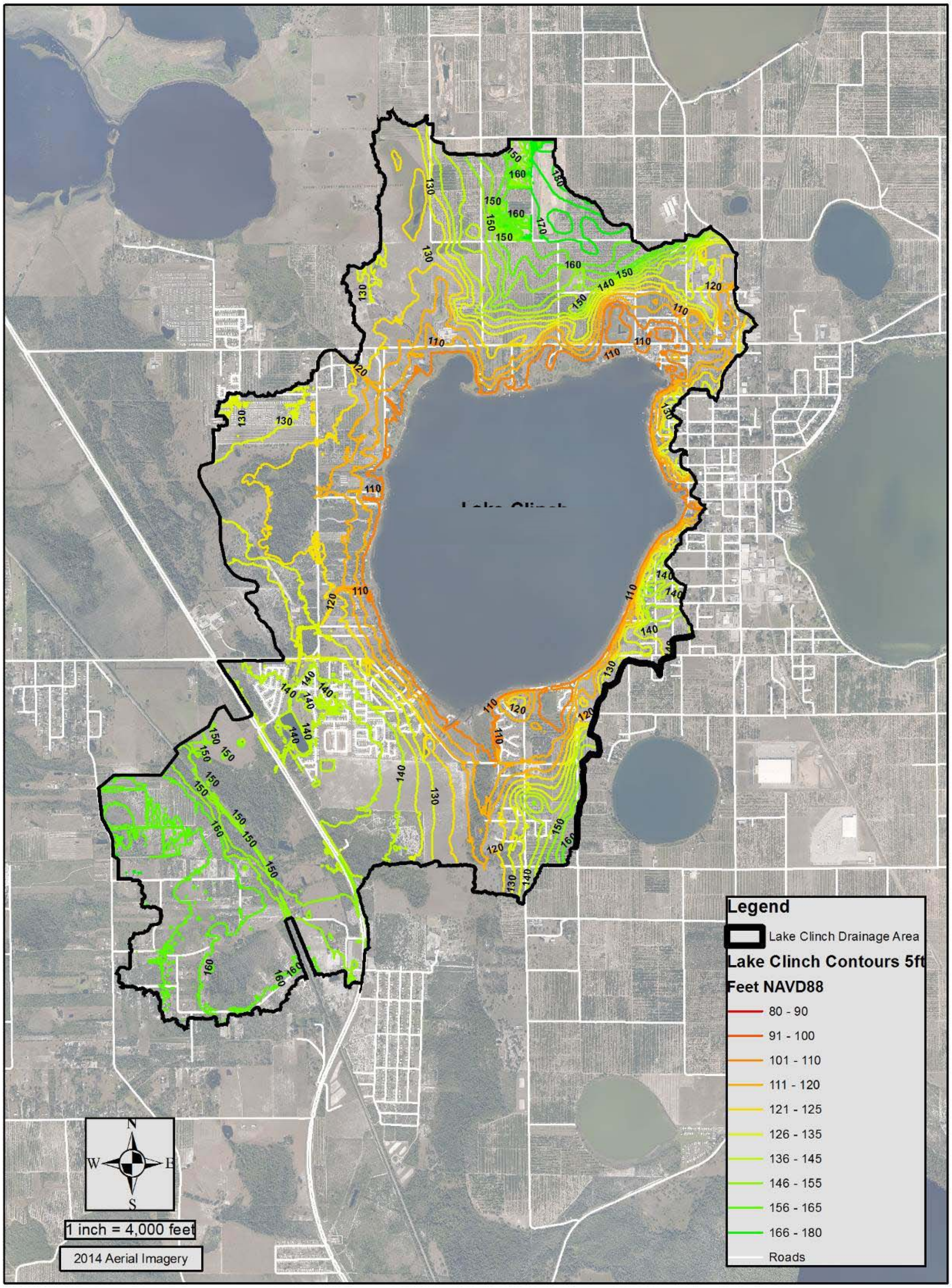
3.2.2. Topography

Topographic data was obtained from the South Florida Water Management District (SFWMD), in the form of a Digital Elevation Model (DEM), produced using LiDAR data, dated 2007-2008. The DEM was produced jointly by the SFWMD and the South West Florida Water Management District (SWFWMD). The topography within the lake watershed generally slopes from the west to the east. Elevations range from 180.0 feet to 105.0 feet and are based on the North American Vertical Datum of 1988 (NAVD). Figure 9 shows the topography of the lake's drainage area in the form of contour lines produced from the DEM. Much of the elevation data used for these analysis is referenced to NGVD. To convert between NAVD and NGVD the following equation, based on the United States Army Corps of Engineers' (ACOE) CORPSCON software, can be applied at this location:

NAVD88 Elevation (Feet) = NGVD29 Elevation (Feet) – 0.994

The CORPSCON adjustment factor is important as it provides the ability to relate vertical elevations that were collected using two different datum. It is worth noting that the NGVD datum now rarely used for most contemporary data collection and monitoring efforts. Data sets that seek to represent long-term trends in existing conditions need to be carefully reviewed in order to provide appropriate adjustments.

Figure 9 – Topography



3.2.1. MS4 Outfalls (Polk County)

Based on the current MS4 permit, Polk County maintains six (6) stormwater outfalls to Lake Clinch (Table 4). The MS4 outfalls have been classified as major (1), minor (4), and undetermined (1) and their combined drainage basins cover 447 acres (8.2%) of the lake's 4,985 acre drainage area.

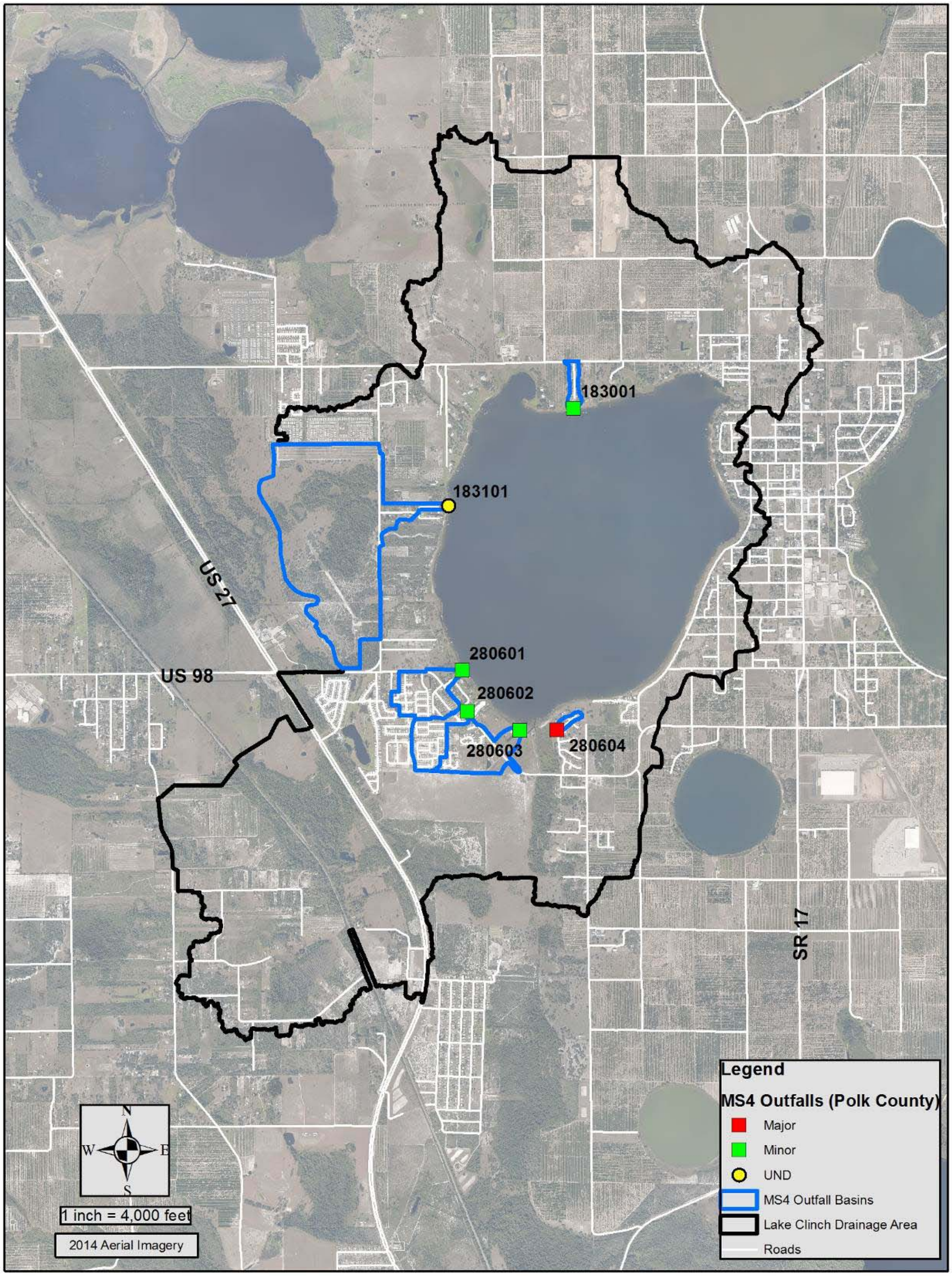
A major outfall is defined as a single pipe with an inner diameter of 36" (12" or more receiving runoff from an area zoned for industrial activity) or a single conveyance other than a circular pipe associated with a drainage area of more than 50 acres. Figure 10 shows the location and drainage area for each Polk County NPDES outfall and Table 4 provides a summary of each.

The Crooked-Clinch Canal connection between Lake Crooked and Clinch is not considered an NPDES outfall for programmatic purposes because the County does not maintain the canal (not part of the public portion of the MS4) but it does represent a loading to Lake Clinch when the connection is flowing.

Table 4 - Polk County MS4 Outfalls

Outfall ID	Outfall Type	Outfall Description	Drainage Area (ac)	Outfall Location
183001	Minor	18" CMP	7.44	End of Ft. Clinch Heights Rd
183101	Und	Not Available	316.30	Silver Sands Dr
280601	Minor	3-28" RCP	41.88	Barney Bass N 250 Yards W of Barney Bass on CR 630A Cross-Drains
280602	Minor	18" PP to 5' swale	29.64	Brewton Rd 100 Yards E of Brewton Rd next to MHP on CR 630A
280603	Minor	2-3' swales to lake	48.87	End of Barney Bass Rd off of CR 630A
280604	Major	10' ditch	3.28	Corner of Kennedy Ct and King St

Figure 10 - MS4 Outfalls (Polk County)



3.2.2. Rainfall

Rainfall data was obtained from both the National Oceanographic and Atmospheric Agency, (NOAA) and the SWFWMD's NEXRAD radar interpolated rainfall dataset. The NEXRAD dataset is available in 15 minute increments, from June 1995 through December 2014.

Figure 11 shows the NEXRAD cells used for this analyses. The NEXRAD grid was intersected with the lake's drainage area to develop a weighted average monthly rainfall depth and has been provided as Figure 12. Yearly rainfall depths based on the NEXRAD dataset are shown as Figure 5.

Table 5 - NEXRAD Yearly Rainfall Summary

Year	Rainfall (Inch)	Year	Rainfall (Inch)
1996	39.2	2006	42.6
1997	47.4	2007	43.3
1998	48.7	2008	47.5
1999	51.4	2009	46.0
2000	28.0	2010	47.9
2001	48.4	2011	51.4
2002	57.9	2012	51.7
2003	48.1	2013	48.3
2004	62.9	2014	59.1
2005	76.0	**Average**	**49.8**

Figure 11 - NEXRAD Radar Rainfall Grid

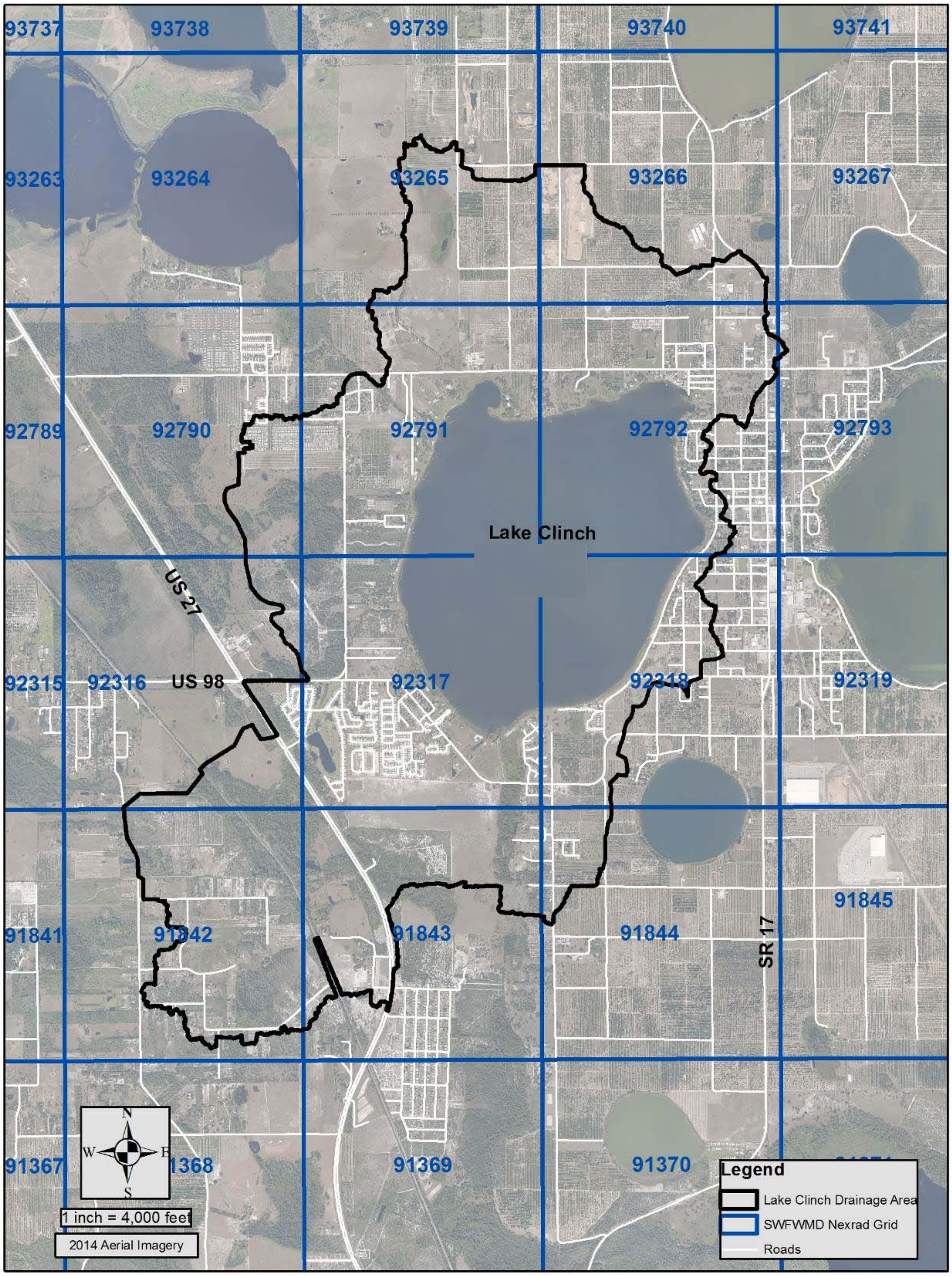
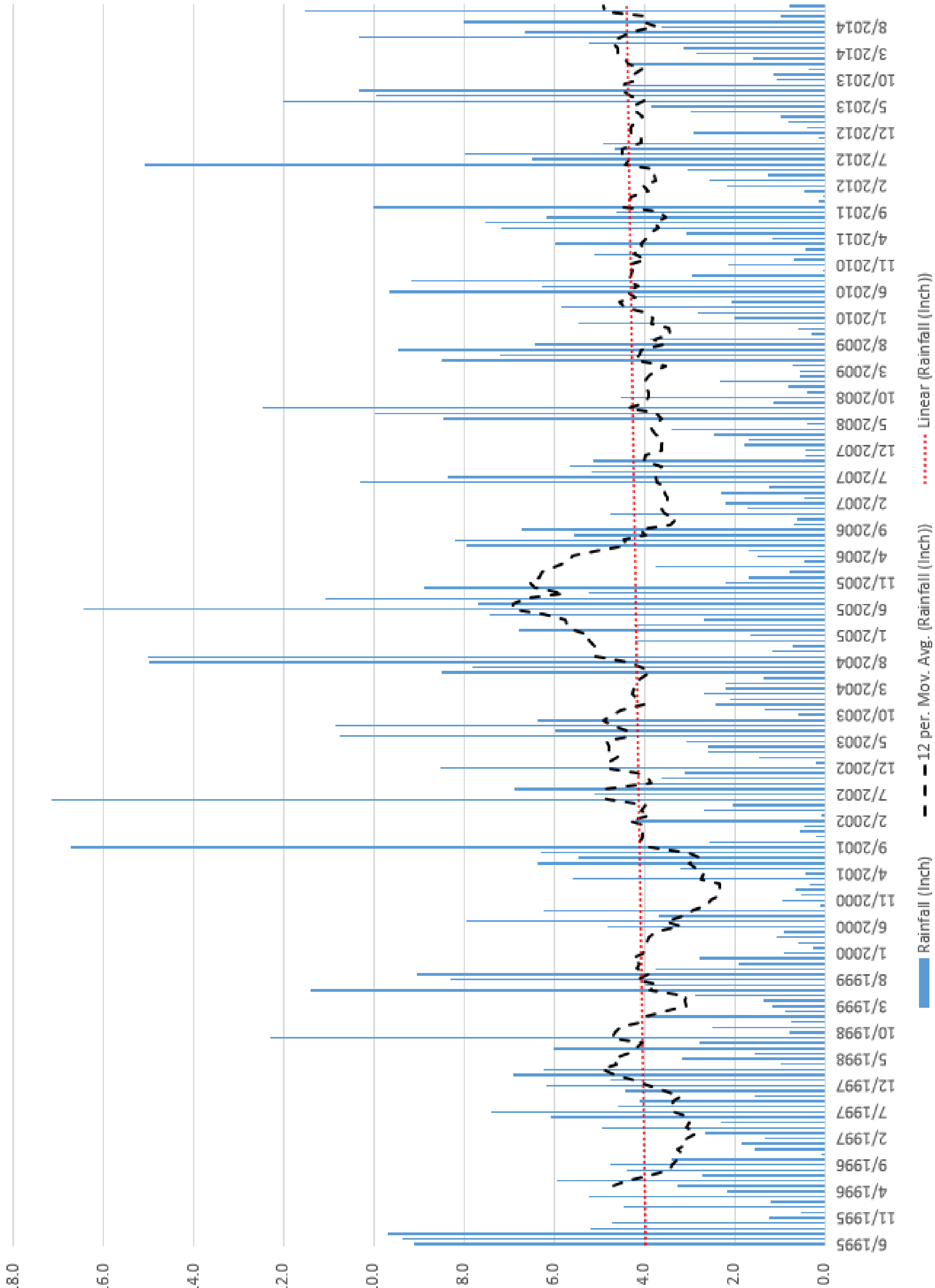


Figure 12 - NEXRAD Radar Monthly Rainfall (1995-2014)



A significant increase in rainfall during 2004 and 2005 is seen in both the 6-month and 12-month moving averages as well as the yearly totals. The yearly average rainfall for 1995-2014 based on the available NEXRAD data is 49.8”.

Rainfall data from 1947-1991 was obtained from NOAA for the USC00080390- BABSON PARK rainfall monitoring site which is located about 8 miles north east of Lake Clinch. A chart of monthly rainfall totals has been provided as Figure 13. Yearly rainfall depths based on the NOAA dataset are shown as Table 6. The NOAA rainfall data, excluding 1955 which appears to be incomplete (only 8.7”), shows an average annual rainfall amount for 1947-1991 of 50.1”. A slight decrease in the linear average during the NOAA period of record is noted, however the decrease is seen to recover during the NEXRAD period of record. Figure 14 shows yearly rainfall totals using both NEXRAD and NOAA rainfall datasets.

Table 6 - NOAA Yearly Rainfall Summary (Babson Park Station)

Year	Rainfall (in)	Year	Rainfall (in)	Year	Rainfall (in)	Year	Rainfall (in)
1948	38.3	1959	67.0	1970	43.7	1981	31.2
1949	50.8	1960	53.1	1971	42.4	1982	63.8
1950	48.2	1961	34.7	1972	45.7	1983	67.6
1951	55.2	1962	47.0	1973	59.4	1984	33.8
1952	53.8	1963	62.5	1974	56.6	1985	47.5
1953	77.0	1964	39.4	1975	50.4	1986	51.1
1954	48.2	1965	53.4	1976	50.0	1987	54.9
1955	*8.7	1966	49.3	1977	46.2	1988	50.7
1956	36.5	1967	39.2	1978	58.3	1989	43.9
1957	50.5	1968	50.5	1979	48.1	1990	47.1
1958	57.5	1969	61.3	1980	36.8	1991	53.0
						Average	50.1

Figure 13 - NOAA (USC00080390 - Babson Park) Monthly Rainfall (1947 - 1991)

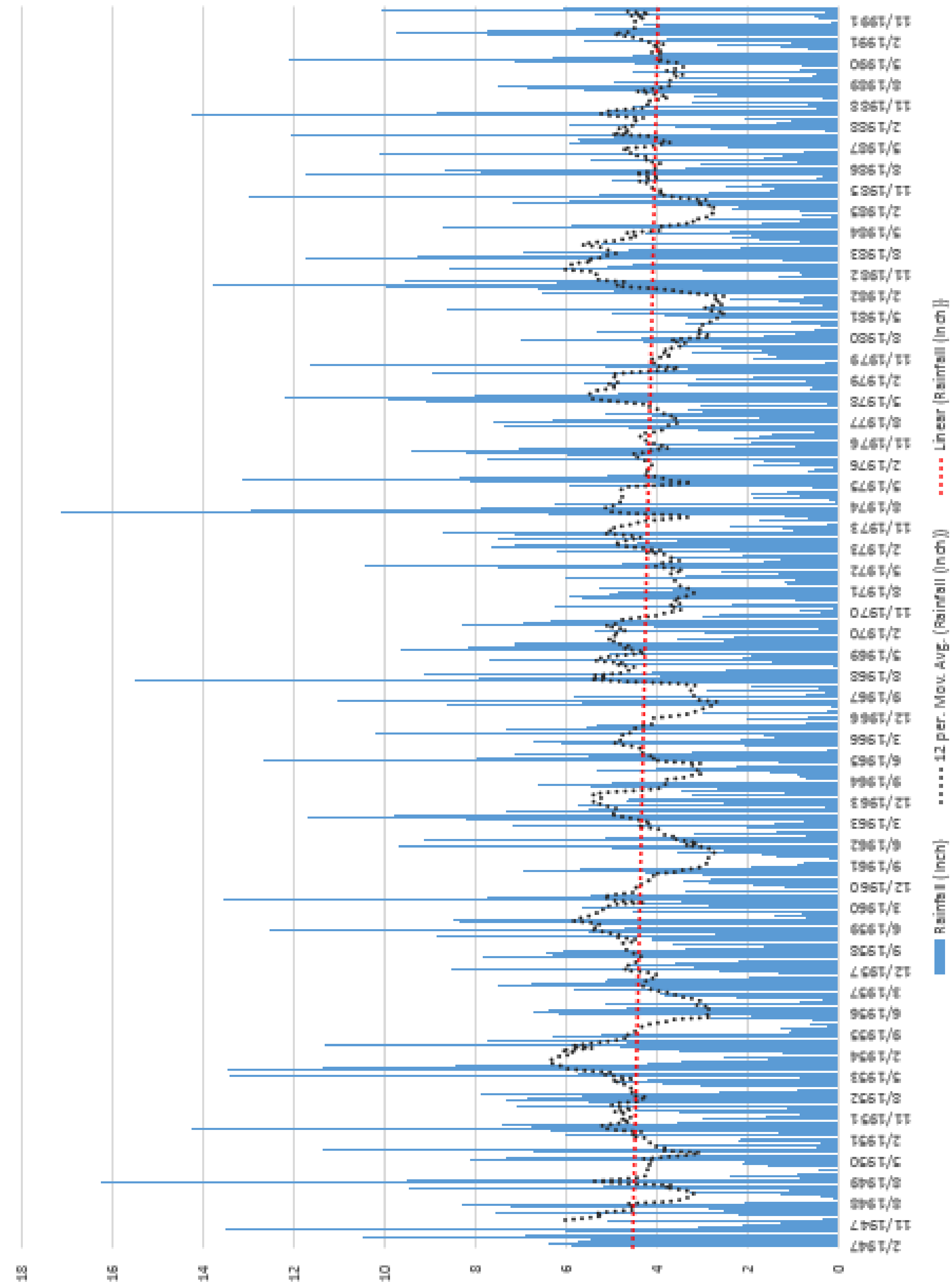
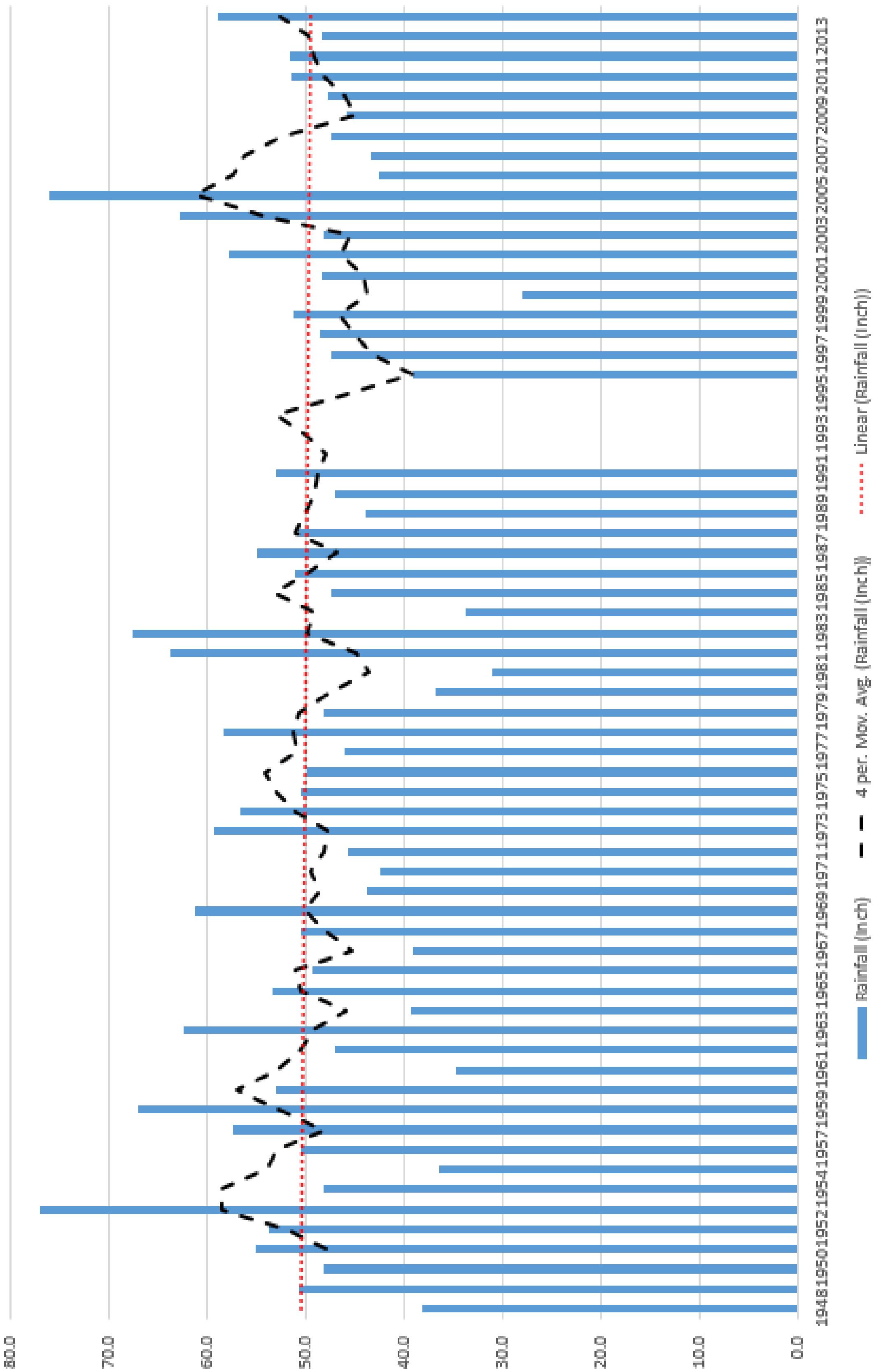


Figure 14 - Yearly Rainfall for Period of Record (NOAA 1948-1991, NEXRAD 1996-2014)



3.2.3. Land Use Classification

The land use GIS coverage was last updated in 2012 but can be considered to represent current conditions due to little development within the lake's drainage area since 2012. The GIS coverage is based on the Florida Land Use and Cover Classification System (FLUCCS, Florida Fish & Wildlife Commission, 2011) and is shown as Figure 15. A GIS land use coverage representing 1995 was also provided by the SWFMWD and is shown as Figure 16. Currently, the Lake's drainage area consists primarily of agricultural (30.7%) land use with a significant amount of urbanization (28.1%). Table 7 is a generalized land use comparison from 1995 to present and shows a significant reduction (453.4 acres) in natural undeveloped lands and an almost equal increase in urban lands. Table 8 shows a more detailed land use comparison.

Figure 15 - 2012 Land Use Coverage

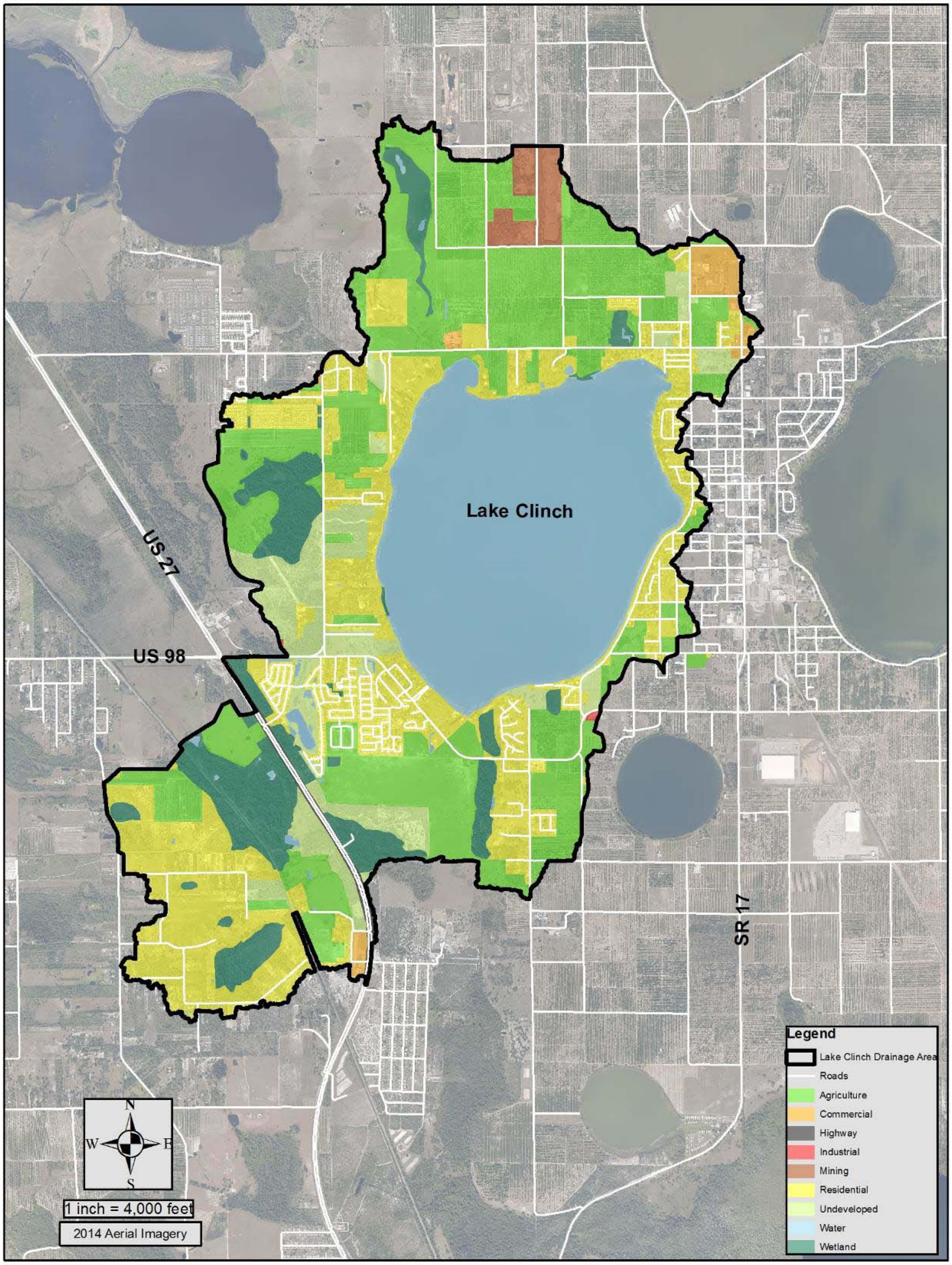


Figure 16 - 1995 Land Use Coverage

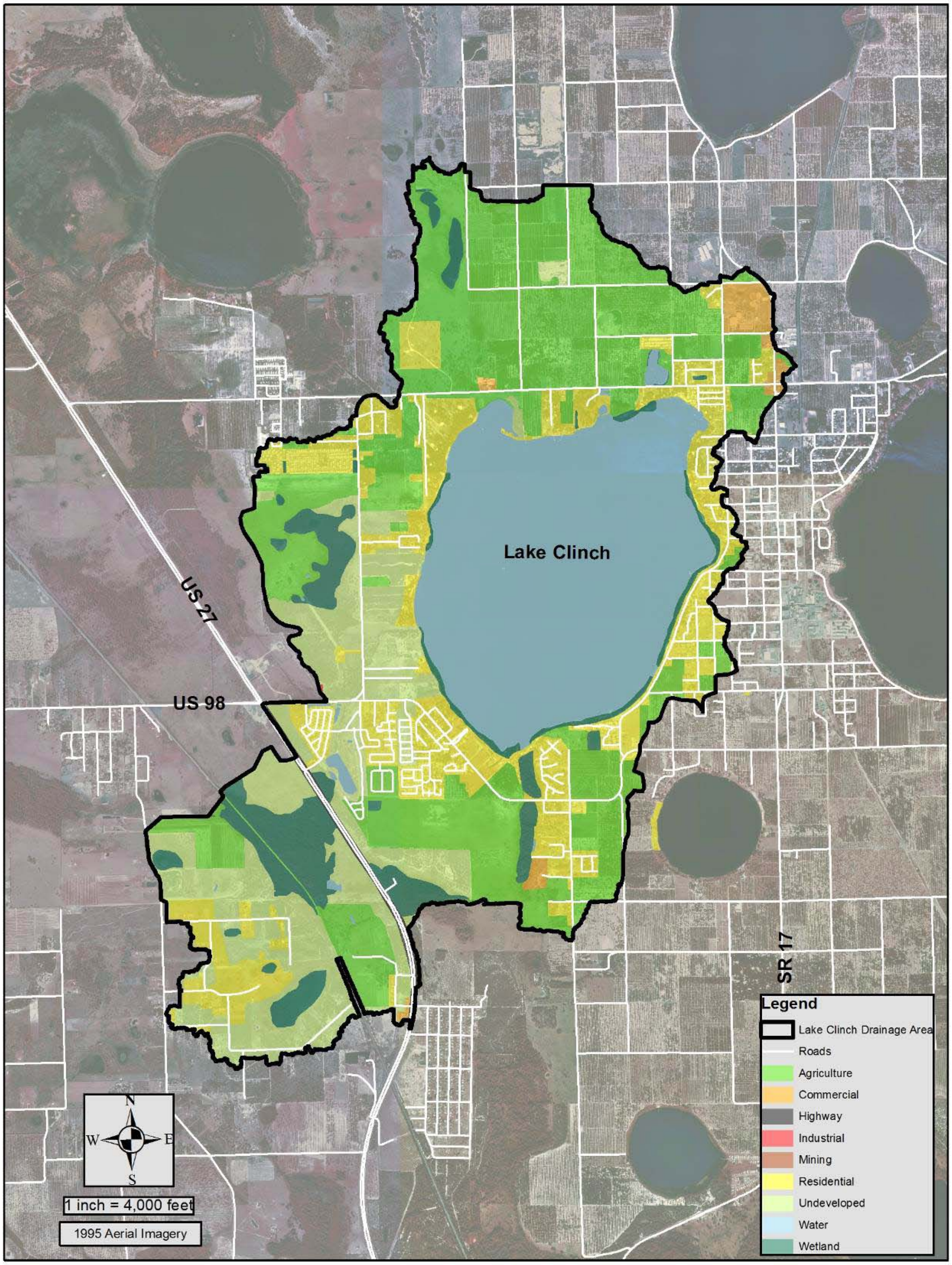


Table 7 - Generalized Land Use Distribution Summary (1995 through 2012)

General Description	1995 Area (Acres)	1995 % of Total	Present Area (Acres)	Present % of Total	Change Area (Acres)	Change % Change
Agriculture	1,606.0	32.2%	1,531.1	30.7%	-74.8	-4.7%
Natural/Undeveloped	832.6	16.7%	379.2	7.6%	-453.4	-54.5%
Urban	996.8	20.0%	1,401.3	28.1%	404.5	40.6%
Water	1,192.7	23.9%	1,239.8	24.8%	47.1	3.9%
Wetland	358.6	7.2%	438.6	8.8%	80.0	22.3%
Total	4,985	100%	4,985	100%		

Table 8 - Detailed Land Use Distribution Summary (1995 and Present 2012)

FLUCSDESC	1995 Area (Acres)	1995 % of Total	Present Area (Acres)	Present % of Total	Change Area (Acres)	Change % Change
Citrus	989.4	19.8%	792.9	15.9%	-196.5	-19.9%
General Agriculture	53.3	1.1%	133.4	2.7%	80.1	150.3%
High-Intensity Commercial	40.7	0.8%	41.9	0.8%	1.2	2.9%
Highway	35.8	0.7%	35.8	0.7%	0.0	0.1%
Light Industrial	1.1	0.0%	2.7	0.1%	1.6	138.5%
Low-Density Residential	394.0	7.9%	773.8	15.5%	379.7	96.4%
Low-Intensity Commercial	29.8	0.6%	29.6	0.6%	-0.2	-0.8%
Mining / Extractive	0.0	0.0%	83.0	1.7%	83.0	
Multi-Family	35.0	0.7%	202.9	4.1%	168.0	480.5%
Open Water / Lake	1,192.7	23.9%	1,239.8	24.9%	47.1	3.9%
Pasture	560.7	11.2%	521.8	10.5%	-38.9	-6.9%
Row Crops	2.5	0.1%	0.0	0.0%	-2.5	-100.0%
Single-Family	460.4	9.2%	314.6	6.3%	-145.8	-31.7%
Undeveloped / Rangeland / Forest	832.6	16.7%	379.2	7.6%	-453.4	-54.5%
Wetland	358.6	7.2%	438.6	8.8%	80.0	22.3%
Total	4,985.0	100%	4,985.0	100%		

3.2.4. Soils Classification

The soils coverage was obtained from Polk County's GIS data library and is based on the United States Department of Agriculture – Natural Resource Conservation Service (formerly USDA/SCS) soil maps. Soils are classified by their hydrologic characteristics. The hydrologic soil groups (HSG) designation for soils is used to estimate runoff from precipitation. There are four major HSG groups in addition to "water", which is classified independently. Their characteristics are described below:

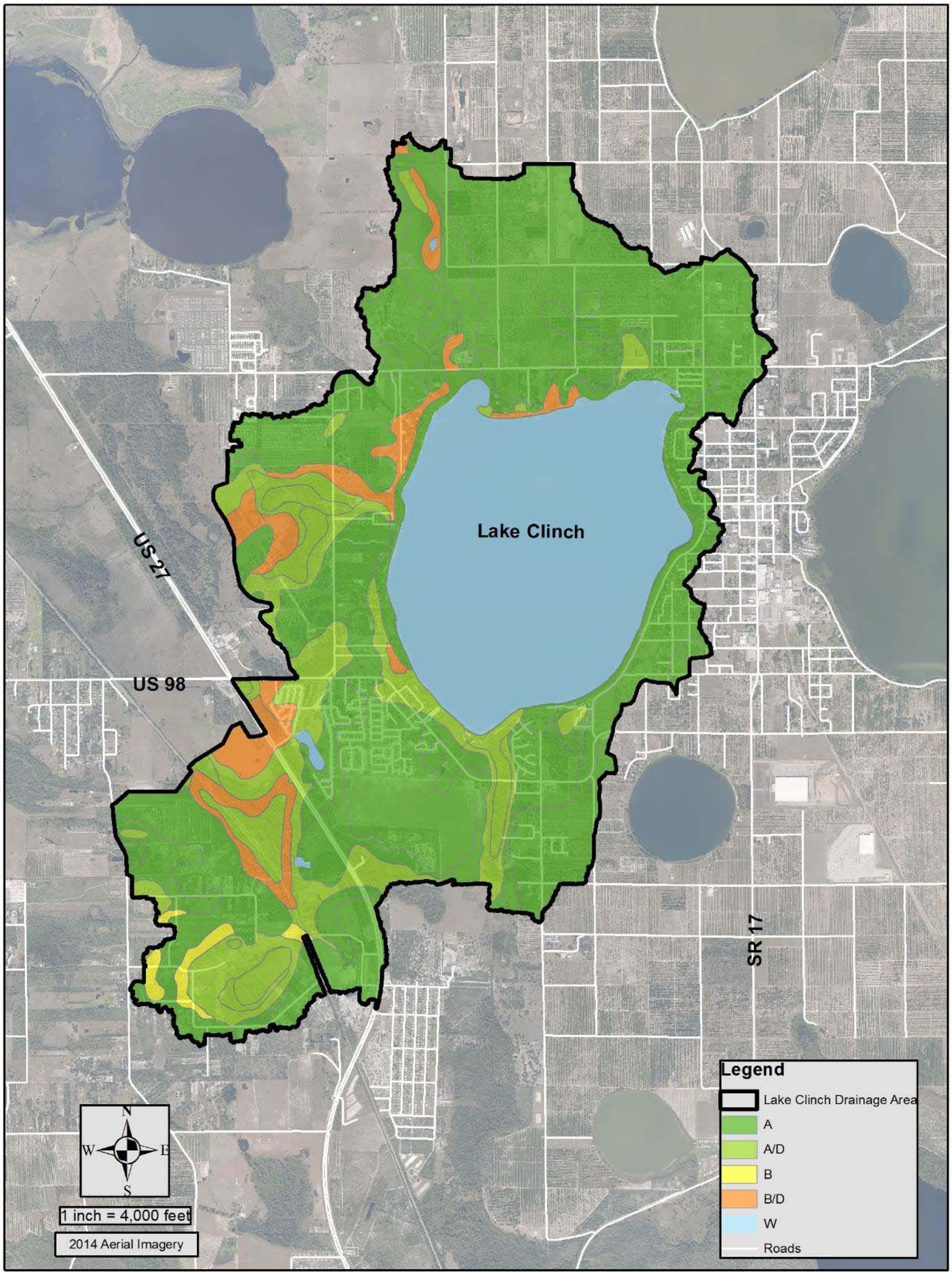
- HSG A: Soils having high infiltration rates. Soil types comprising this group generally include deep well drained to excessively drained sands that produce significant rainfall losses as infiltration.
- HSG B: Soils having a moderate infiltration rate when saturated. This group is chiefly comprised of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture.
- HSG C: Soils having a slow infiltration rate when saturated. This group consists chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture.
- HSG D: Soils having a very slow infiltration rate and high runoff potential. These consist primarily of soils that have a permanent high water table; soils that have a claypan, clay layer, or other relatively impermeable material at or near the surface; or mucky wetland soils.

The soil coverage is shown in Figure 17 Table 9 shows the soil distribution within the lake's drainage area are highly permeable and consist primarily of hydrologic soil groups (HSG) A (56.3%) and A/D (13.6%). HSG A is considered well-drained and so relatively less surface runoff occurs in soils of HSG A so these soils are also ideal for groundwater recharge.

Table 9 - Soil Distribution Summary

Hydrologic Soil Group (HSG)	Area (Acres)	Percent Total (%)
A	2,808.4	74%
A/D	679.9	18%
B	41.5	1%
B/D	260.5	7%
Total	**3,786**	**100.0%**

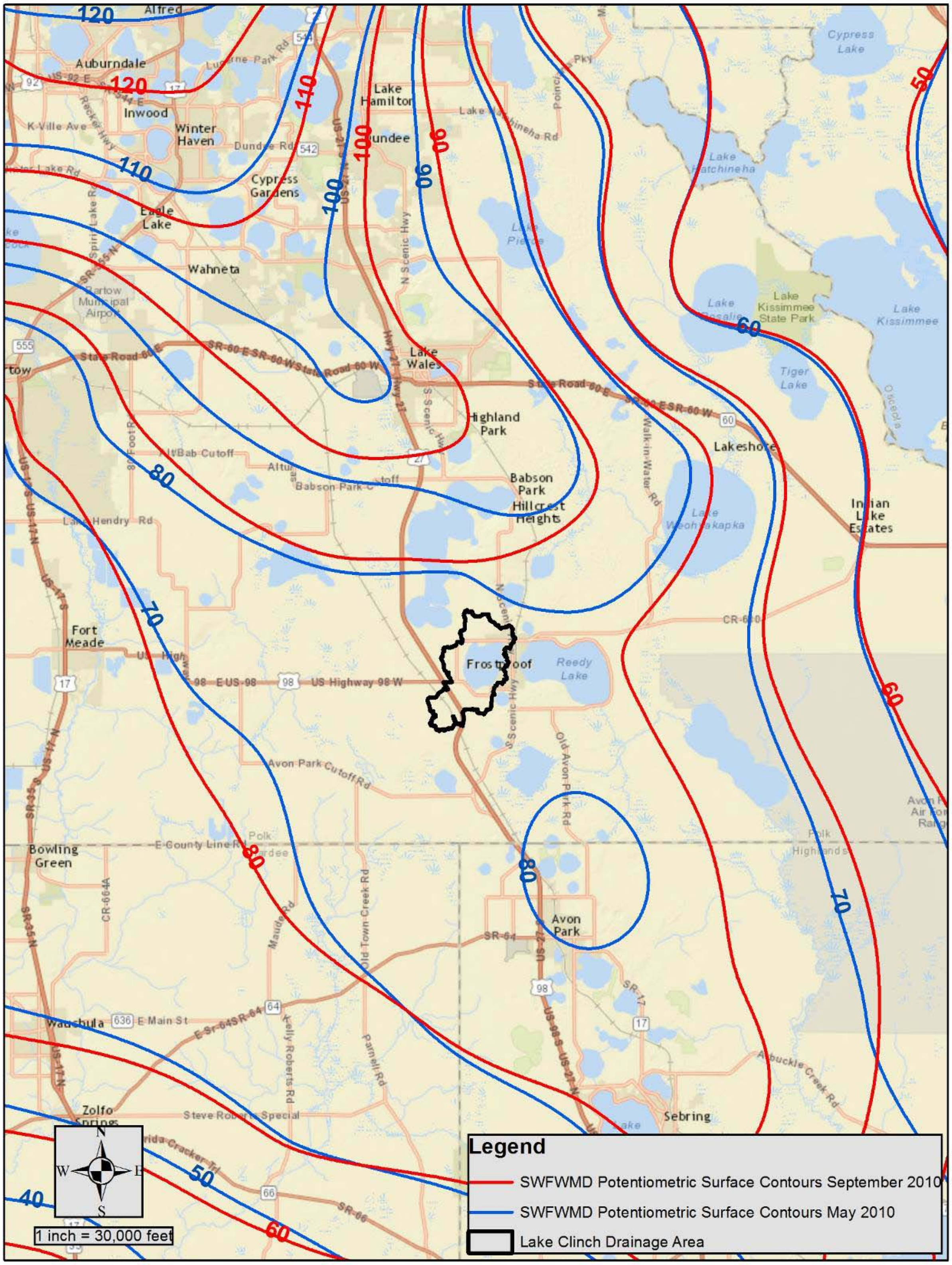
Figure 17 – Soil Hydrologic Groups



3.2.5. Potentiometric Surface

The potentiometric surface of ground water is useful in understanding the recharge characteristics in lakes. The potentiometric surface represents that elevation at which groundwater would be expected to flow into an open pit or hole from the confined Floridian aquifer. Due to the fact that Florida geology includes stratification, a given region in Florida could have more than one potentiometric surface. In the study of inland freshwater lakes, the potentiometric surface that intersects the lake bottom is important as variations of the potentiometric surface can result in flows into the lake through the lake bottom. The potentiometric surface elevation of the Floridan Aquifer below Lake Clinch has been interpolated using the GIS coverage provided by the SWFWMD and generally ranges between elevation 78 feet (NGVD) in May 2010 (dry season) to 88 feet (NGVD) in September 2010 (wet season). Figure 18 shows the potentiometric contours in the vicinity of Lake Clinch for May and September of 2010. The lowest bathymetric elevation for Lake Clinch is at approximately elevation 61.2 with the next highest occurring contour at approximately elevation 65. This means that the potentiometric surface of the Floridan aquifer intersects the lake. This potentiometric surface represents the surface elevation that groundwater would be expected to rise when exposed to atmospheric conditions within a well. In the case of the lake bottom, the hydrostatic pressures at the lake bottom is higher than atmosphere. This higher pressure would be expected to inhibit inflows into the lake from the Floridan Aquifer. Other groundwater flows into the lake could however occur from surficial aquifers that are located along the lake perimeter. These surficial groundwater flows carry with them leachate from septic tanks as well as leachate from groundwater associated with agricultural operations.

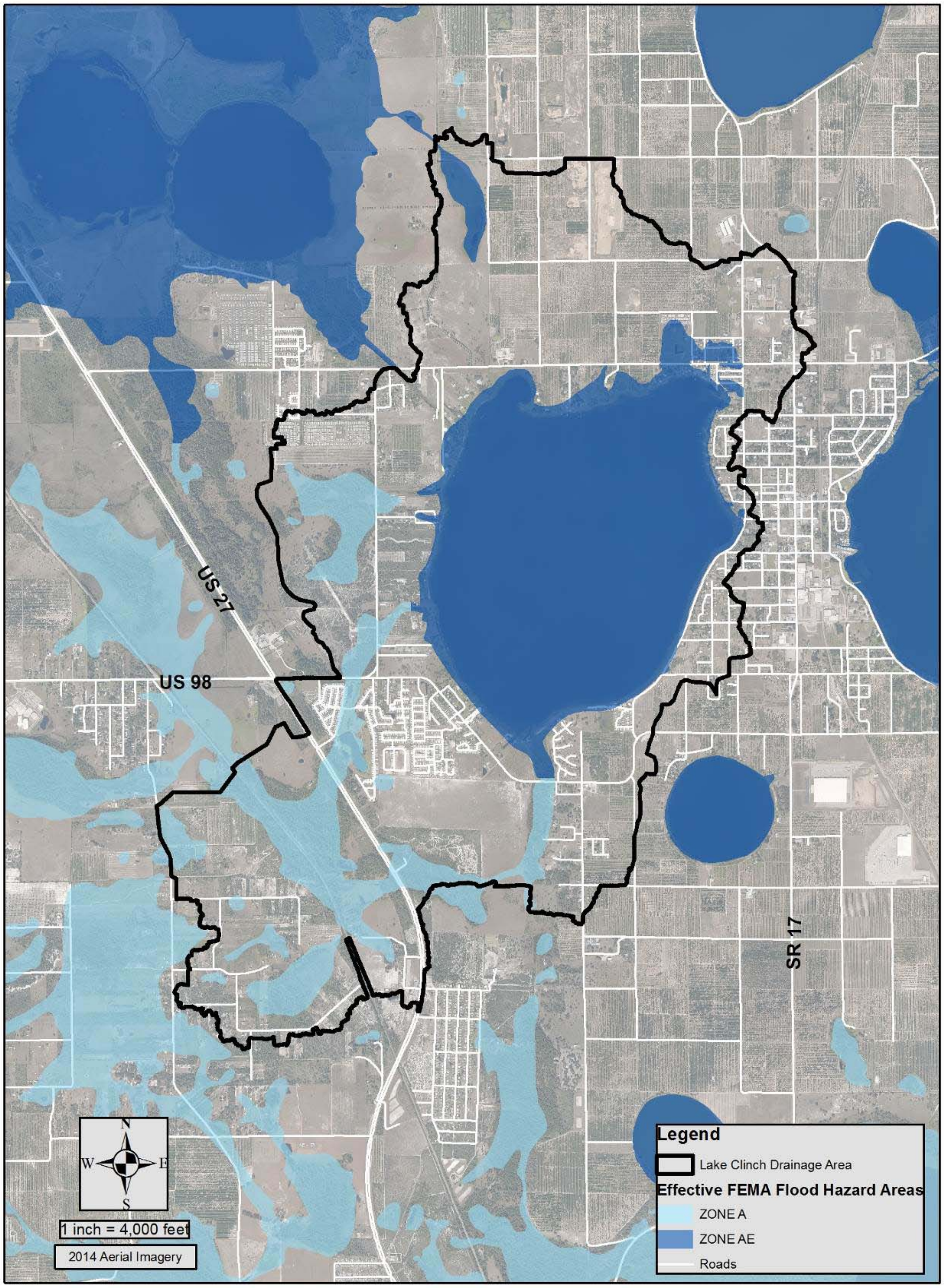
Figure 18 - Potentiometric Surface - Feet National Geodetic Vertical Datum(May & September 2010)



3.2.6. FEMA Flood Hazard Areas

The published Federal Emergency Management Agency (FEMA) 100-year flood stage for Lake Clinch is elevation 110.0 feet NGVD and is published within FEMA Firm Map #12105C0935 dated December 20, 2000 which is shown in Figure 19 Based on a review of these flood insurance rate maps, approximately 64 structures along the perimeter of Lake Clinch are located within the floodplain that is adjacent to the lake perimeter. The finished floor elevations of these structures in relation to published lake stages is tracked by FEMA but generally not widely published and was unavailable at the time of this study. Revised flood maps are being prepared by FEMA at this time and have been published in a draft version for public review.

Figure 19 - FEMA Flood Zones



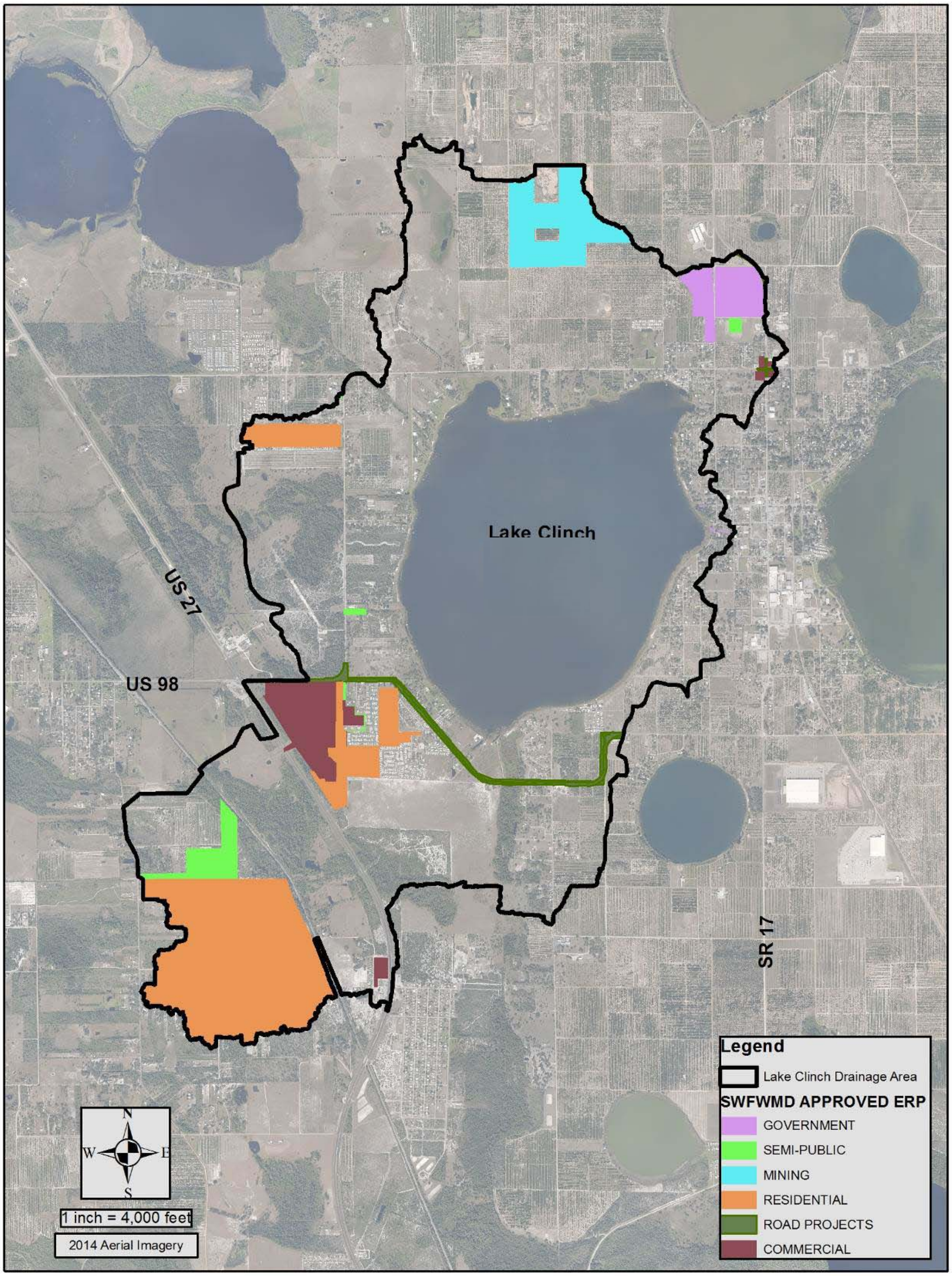
3.2.7. Environmental Resource Permits

Though a significant portion of Lake Clinch drainage area is developed, much of the development occurred prior to environmental resource permitting. Figure 20 shows a GIS coverage of approved Environmental Resource Permits (ERPs) provided by SWFWMD and Table 10 summarizes the ERPs by type, quantity, and date range. ERPs are significant as they provide insight into which portions of the watershed can be expected to have intermediate detention of runoff as opposed to direct runoff. In general, SWFWMD required ERP's result in the construction of either wet or dry detention facilities to provide treatment for runoff. ERPs provide treatment for 29% of the 3,745 Acre watershed area. For example, an urbanized drainage sub-basin with no ERPs would be expected to have higher pollutant load production than a basin that was developed within the past 20 years and was 100% regulated by ERPs.

Table 10 - ERP Summary

ERP Type	Number of Permit Issues	Gross Area Covered (Acres)	First Permit Issue Date	Last Permit Issue Data
Commercial	6	139	12/17/1987	11/1/2013
Government	6	64	6/22/1992	8/30/2012
Mining	2	247	3/22/2007	2/17/2014
Residential	7	515	1/26/1988	10/8/2010
Road Projects	3	60	6/27/1988	2/15/2006
Semi-Public	5	58	6/4/1993	4/3/2012
Total		1083		

Figure 20 - SWFWMD ERP Coverage



3.2.8. Stormwater Best Management Practices Treatment Areas

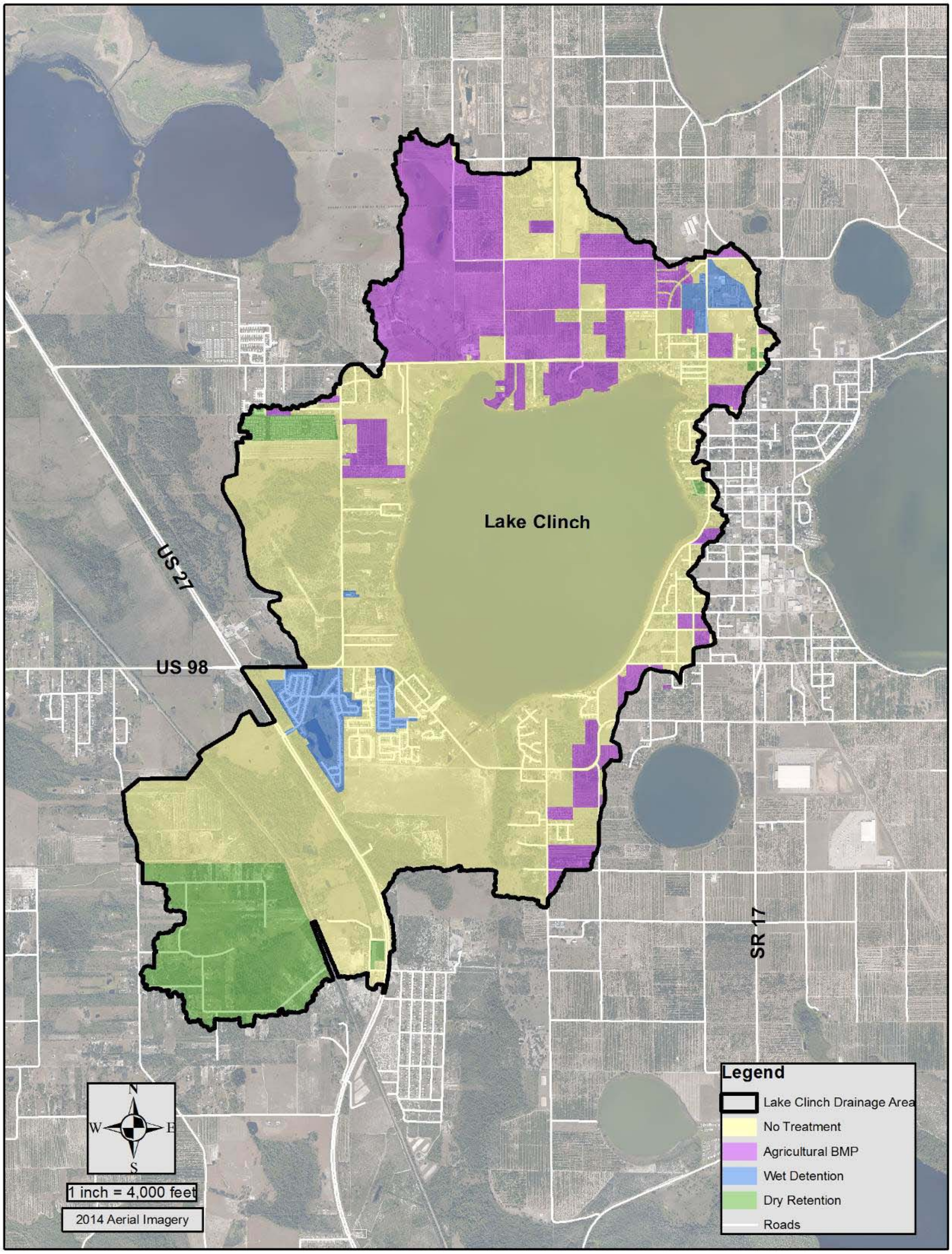
A GIS coverage was developed to identify portions of the drainage area which are treated by a stormwater management system using Florida Department of Agriculture and Consumer Services (FDACS) best management practices (BMP). The FDACS BMP program is a voluntary program. Typical program BMPs include non-structural BMPs such as nutrient management, sediment and erosion control, and integrated pest management to protect water resources. Figure 21 shows the identified FDACS BMP treatment areas.

The lack of stormwater treatment over the majority of the drainage area is primarily due to much of the basin being undeveloped or agricultural land use. Approximately 569 acres of the Lake's drainage area is estimated to be treated by an ERP (414 Acres dry detention, 154 Acres wet detention) regulated stormwater management system, prior to discharge to Lake Clinch. Implementation of BMPs for agricultural areas have resulted in the implementation of Agricultural BMPs on approximately 805 acres.

Table 11 - BMP Treatment Summary

Treatment	Area (Acres)	Percent Total (%)
Dry Detention	414.4	8.3%
Agricultural BMP	805.8	16.2%
No Treatment	3610.8	72.4%
Wet Detention	154.7	3.1%
Total	4985.0	100.0%

Figure 21 - BMP Treatment Areas Coverage



3.2.9. Septic Systems

The septic system GIS coverage was developed by the Florida Department of Health (DOH) and was provided by Polk County and identified 139 septic sites. The DOH coverage only included septic tanks for which permits had been pulled. A review of listed septic tanks compared to known areas of sanitary sewer service within the watershed was performed. Based on this review, it became apparent that the septic tank coverage contained within the GIS coverage for Lake Clinch included significant data gaps. An analysis was performed to identify which improved properties were not served by public or private sanitary sewer system. Based on this analysis, 479 structures were identified as containing septic tanks and this number will be used for pollutant loading analysis in lieu of the Department of Health GIS coverage. Figure 22 shows the location of septic systems estimated as part of these analysis.

Figure 22 - Septic System Coverage

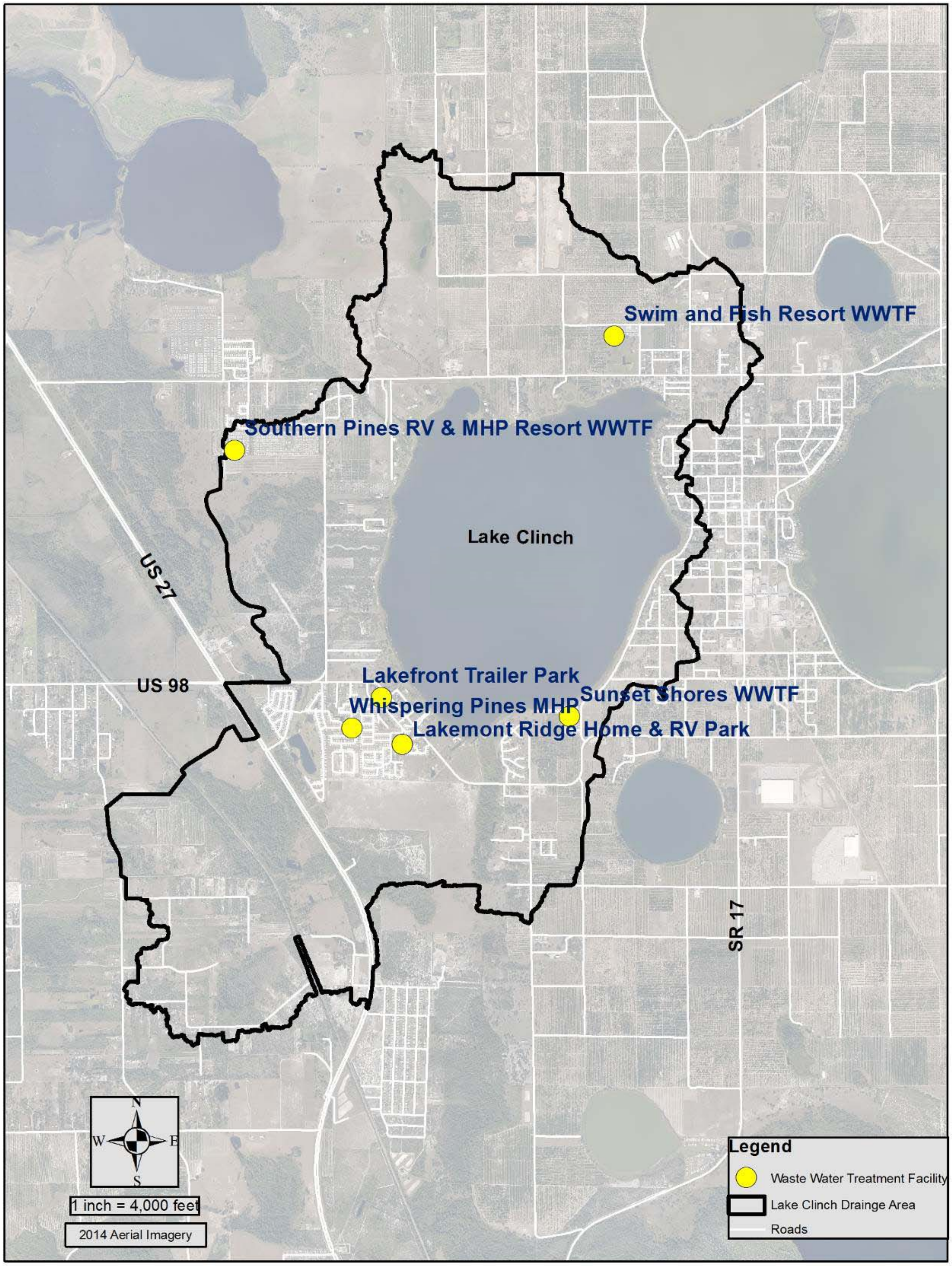
3.2.10. Wastewater Treatment Facilities

A total of six (6) active Wastewater Treatment Facilities were identified as being within the Lake Clinch watershed boundaries based on a review of the October 2014 Polk County Domestic Wastewater Facilities map which was prepared by FDEP. The total permitted treatment capacity of these facilities in aggregate is 0.1267 MGD. These facilities are considered as part of the loading analysis of the water quality management plan. Figure 23 shows the location and Table 12 provides a summary of these facilities.

Table 12 - WWTF Summary

Facility ID	Facility Name	Design MGD	Effluent Disposal Method
FLA012995	Lakefront Trailer Park	0.0057	Reuse/Land Application/RIBS
FLA012998	Lakemont Ridge Home	0.03	Reuse/Land Application/RIBS
FLA013128	Southern Pines	0.045	Reuse/Land Application/RIBS
FLA013089	Sunset Shores	0.015	Reuse/Land Application/RIBS
FLA012996	Frostproof Mobile Village	0.012	Reuse/Land Application/RIBS
FLA013005	Whispering Pines	0.019	Reuse/Land Application/RIBS
	Total:	0.1267	

Figure 23 - Surrounding Domestic Waste Water Treatment Facilities



3.2.11. Lakeshore Ecology

Aquatic and wetland plants play an important role in the ecology of Florida lakes. These plants provide food and shelter for fish and other wildlife, help stabilize shorelines and bottom sediments, dampen wave action, and help improve water clarity. Historically, much of the upland buffer areas surrounding Lake Clinch has been cleared of natural vegetation to be used first for citrus production and pasture, and later for residential development and citrus production. The earliest available aerial photography (1941) shows that only about 30 percent of the property adjacent to the lake was in a semi-natural land use condition at that time. Presently, almost the entire perimeter is comprised of low-density residential parcels. These agricultural and residential land use activities increase the potential for nutrient loading to Lake Clinch as well as reduce the ability of these historical Natural areas to filter nutrients and suspend solids associated with stormwater runoff inputs in the watershed. The lakeshore perimeter is approximately 29,000 ft. in length with the majority of the shoreline existing in an altered state, 2,000 ft. +/- hardened, 17,000 ft. +/- as yard area, and the remainder, 10,000 ft. +/- in a natural state within 30 ft. of the normal water line. There are also approximately 50 boat docks extending into the lake which are dispersed along the shoreline in addition to, numerous scattered man-made beach heads.

The U.S. Fish and Wildlife Service National Wetland Inventory (NWI) classified Lake Clinch as approximately 98% lacustrine (habitat of and dependent on the lake) with the majority (95%) identified as an open deep water habitat (limnetic-of or inhabiting the open water of a lake) with unconsolidated bottom. Unconsolidated bottom is defined as habitats with at least 25% cover of particles smaller than stones (less than 6-7 cm), and a vegetative cover less than 30%. The remainder of the lacustrine system (3%) was identified as a littoral wetland community, found primarily in the shallower areas in the north region of the lake. The NWI classified approximately 2% of Lake Clinch shoreline as palustrine (wetland habitat adjacent to, but not part of the shoreline) emergent (open water and fringing marsh wetlands waterward of the shoreline), with a dominance of rooted herbaceous (non-woody) wetland plants present in the northeastern and southern shoreline of the lake.

The Aquatic Invasive Plant Management program in the PCP&NR Division manages exotic aquatic plants including water hyacinth and water lettuce, and surveys periodically for hydrilla within Lake Clinch. Between 1995 and 2014, about 16.5 acres in Lake Clinch were chemically treated for water hyacinth and water lettuce and approximately 1.6 acres for cattail. In a recent survey (September 2014) by the Invasive Plant Management Program the following observations were made.

- Fairly clear water observed with a vertical secchi disk reading of 3.2 meters
- No submerged aquatic vegetation (SAV) observed

- Emergent species included:
    - American lotus (Nelumbo lutea),
    - primrose willow (Ludwigia octavalvis/ peruviana),
    - pickerel weed (Pontederia cordata),
    - Cuban bulrush (Oxycaryum cubense),
    - Cattail (Typha spp.),
    - water hyacinth (Eichhornia crassipes),
    - spadderdock lily (Nuphar advena),
    - duck potato (Sagittaria lancifolia),
    - sprouting spikerush (Eleocharis vivipora),
    - and various grass species.

Additional aquatic macrophytes reported within Lake Clinch, not observed above, include torpedo grass (Panicum repens), water pennywort (Hydrocotyle umbelatta), and primrose willow (Ludwigia sp.).

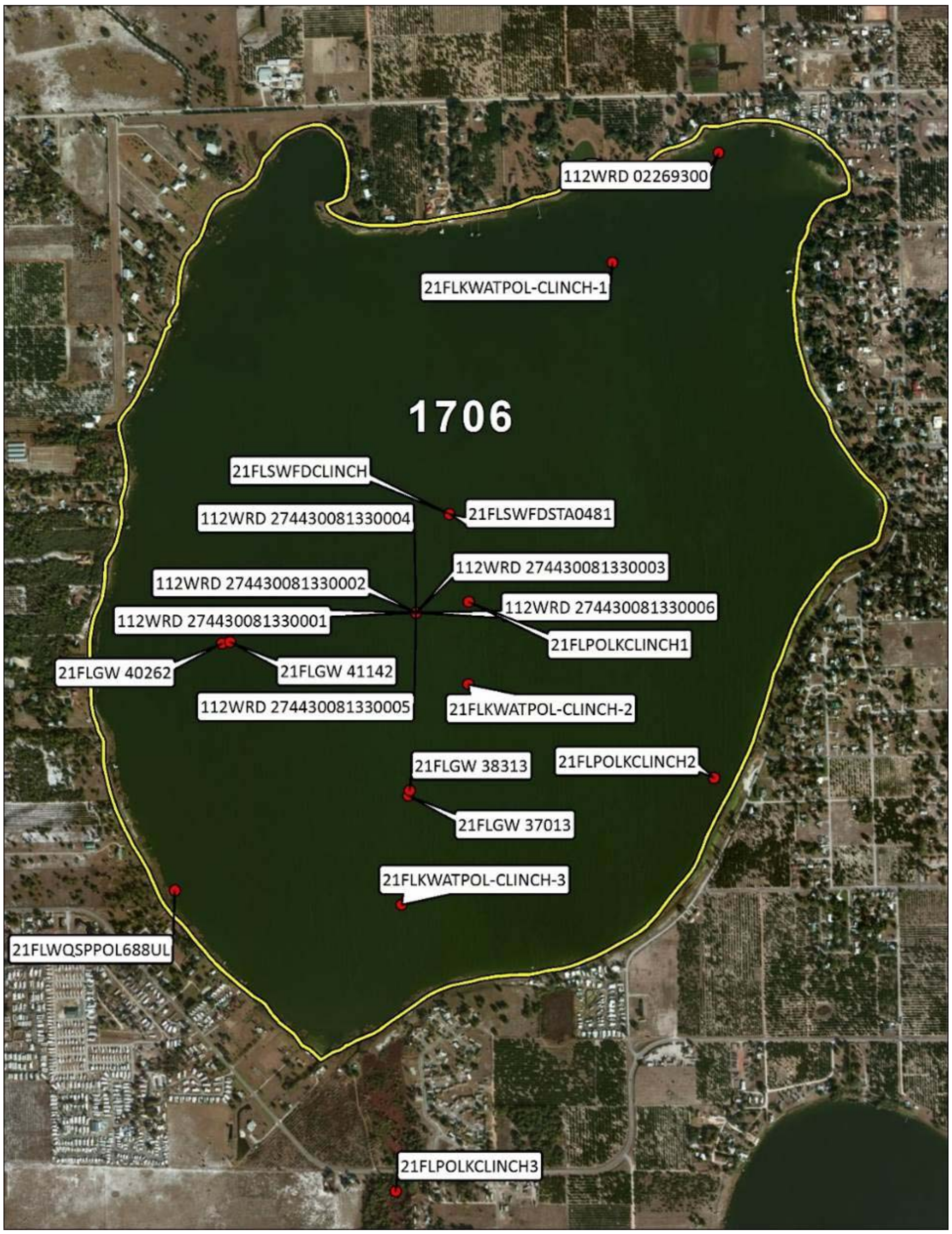
The lack of significant shallow shoreline surrounding Lake Clinch due to steep lake bottom slopes and bathymetry limits the potential area for in-lake shoreline restoration as a viable alternative to improve water quality. Based on the bathymetric data, there is are approximately 15 acres (about 1% of the lake surface area) of littoral lake edge between the shoreline and the 2 foot depth contour where emergent wetland plants could be established. This limited available area for marsh restoration would not be expected to contribute to a measurable change in lake water quality. Appropriate depths for submerged aquatic vegetation (SAV) typically range from about 0 to 10 feet, but can approach as much as 30 feet with exceptional water clarity conditions and strong buffering capacity (Caffrey, 2007) (Gu, 2005). The 0 to 10 foot range in Lake Clinch, which constitutes an area of about 177 acres (about 15% of the lake surface area) and volume of 180 acre-feet (about 15% of the lake volume). Relationships between lake water quality and vegetative cover suggest a positive correlation between SAV abundance and chlorophyll-a concentration for lakes with volumetric SAV cover exceeding 20 percent (Moreno 2010). Based on the morphometric characteristics of Lake Clinch, it would require the establishment of dense SAV cover throughout the 0 to 10 feet zone in order to possibly affect in-lake chlorophyll-a concentrations. Given the challenges often associated with SAV establishment and the apparent absence of SAV reported by the County, attempts to establish SAV in Lake Clinch for purposes of water quality improvement are likely to be challenging and costly.

Lake Clinch is part of an active aquatic vegetation chemical treatment program that is operated by the County. The effects of aquatic vegetation treatment as it relates to loading and decomposing biomass are discussed in the loading section of this plan.

3.2.12. Lake Ambient Water Quality Monitoring Program

Water quality sampling of the lake was initiated by the County in 1968. A total of twenty (20) identified locations (Figure 24) mostly located in the central portion of the lake, have been sampled on a highly variable schedule. Several locations have only been visited once during the 45-year program. The frequency of samples collected annually on a parameter basis has varied substantially during the program, ranging from 20 or fewer samples for most years, except for a period of more frequent measurements during 1996 through 1999. Both the County and the FDEP continue to collect water quality samples in this lake.

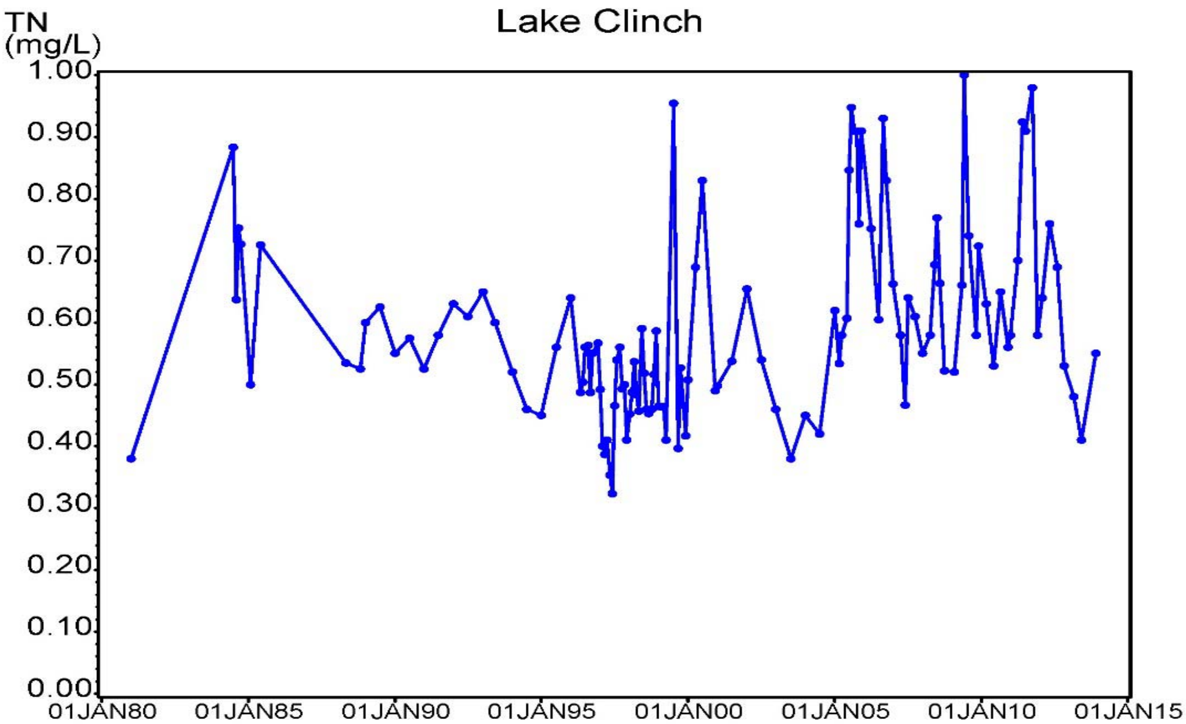
Figure 24 –Water Quality Monitoring Sites



3.2.13. Total Nitrogen

Mean total nitrogen (TN) concentration for the period January 1981 to December 2013 (a total of 293 observations) is 0.575 mg/L (Figure 25). The overall long-term record of TN appears quite consistent, however, there is substantial variation between measurements, with concentrations generally ranging from near 0.3 mg/L to 1 mg/L. Statistical trend analyses of the period of record confirm the lack of long-term change (p=0.328) but suggest a small magnitude increase in concentrations.

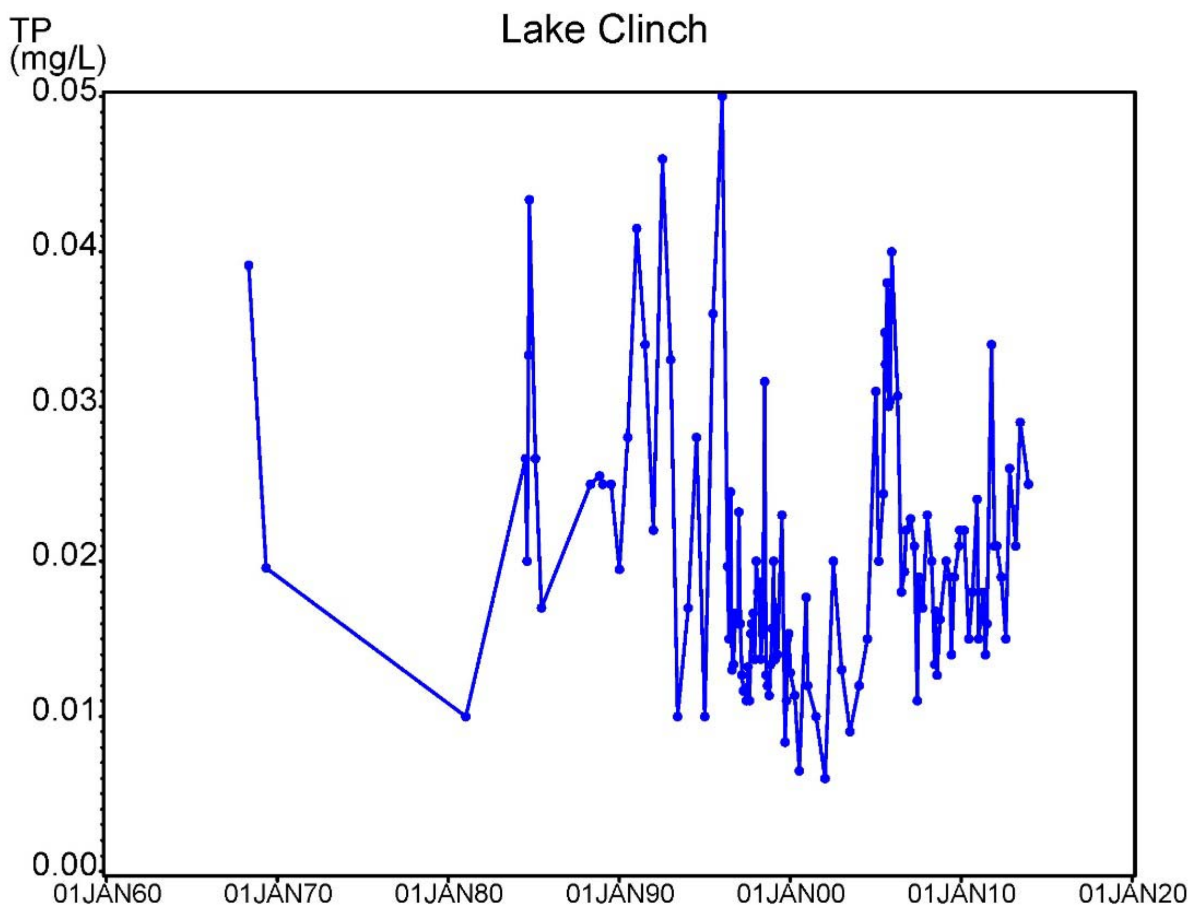
Figure 25 - Mean Monthly TN Concentrations



3.2.14. Total Phosphorus

Mean Total Phosphorus (TP) concentration for the period May 1968 to December 2013 (a total of 292 observations) is 0.019 mg/L (Figure 26). Substantial variation between measurements is evident, specifically during the periods of infrequent collections. However, a decreasing trend is suggested during the 1990s, and a generally increasing trend is indicated for the most recent period starting near year 2000. Statistical trend analyses of the period of record indicate a lack of significant long-term change (p=0.590) but suggest a small magnitude decrease in concentrations.

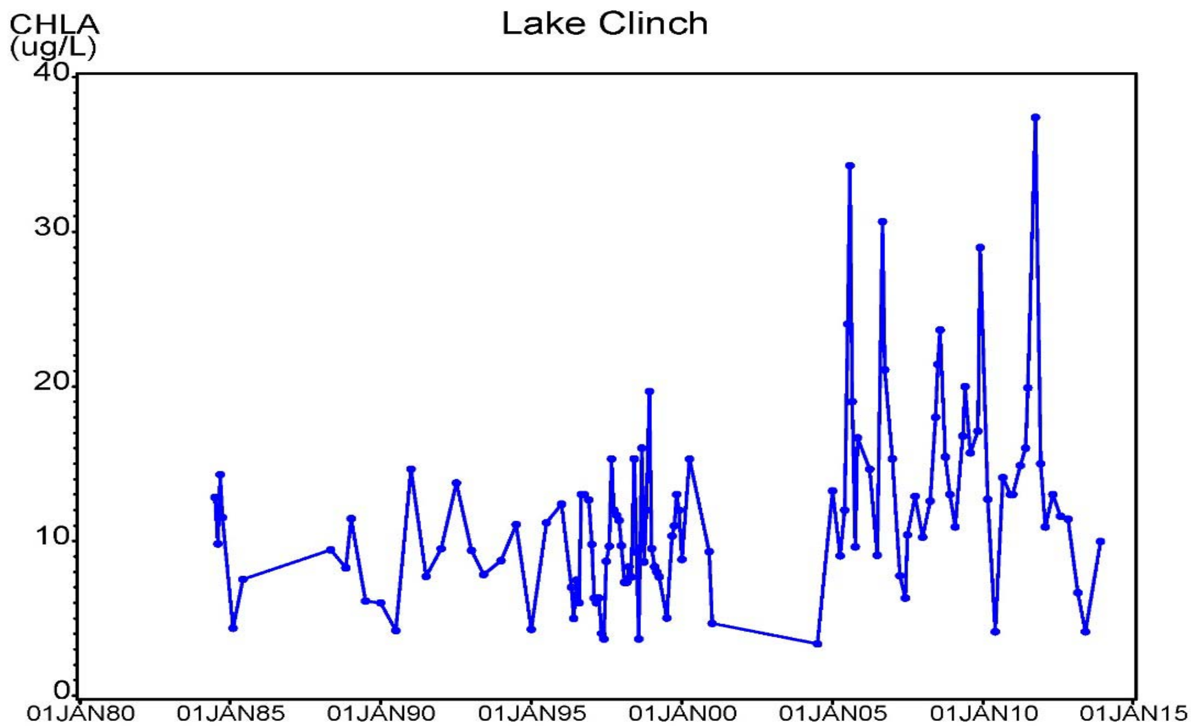
Figure 26 - Mean Monthly TP Concentrations



3.2.15. Chlorophyll-a

Mean chlorophyll-a concentration for the period July 1984 to December 2013 (a total of 268 observations) is 11.68 ug/L (Figure 27). An overall increasing trend is evident during the period of record, with the possible exception of a most recent period of decreasing concentrations. Large variation between measurements likely reflects seasonal variation in phytoplankton biomass. Chlorophyll-a has ranged from low concentrations near 5 ug/L to high levels near 30 ug/L during the latter period of the record. Statistical trend analyses of the period of record information indicate a statistically significant (p=0.040) increasing trend with a small magnitude increase in concentrations.

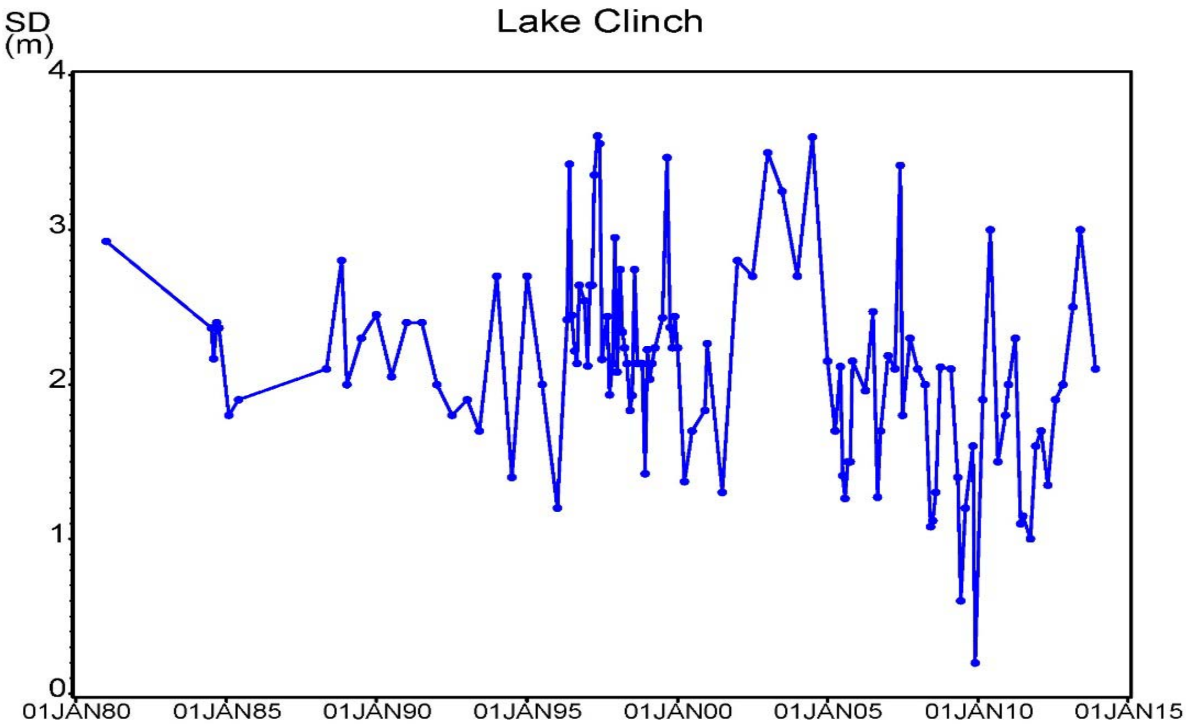
Figure 27 - Mean Monthly Chlorophyll-a Concentrations



3.2.16. Secchi Disk Depth

Mean secchi disk depth for the period January 1981 to December 2013 (a total of 294 observations) is 2.19 m (Figure 28). Large variations between measurements occur throughout most of the record, which likely are associated with the noted seasonal variation in chlorophyll-a. Measured Secchi Disk depths generally range from less than 1 m to greater than 3.5 m. Statistical trend analyses of the period of record indicate a lack of significant long-term change (p=0.119) but suggest a small magnitude decrease in Secchi Disk depth.

Figure 28 - Mean Monthly Secchi Disc Depth



4. SUMMARY OF HISTORICAL AND CURRENT CONDITIONS

4.1. Pollutant Load Calculation Method

An Event Mean Concentration (EMC) based method for estimating the quantity of pollutants carried downstream by stormwater runoff was utilized for these analyses. The method was used to identify where pollutant loads are being produced. The loading estimate were calculated on a monthly interval to attempt to correlate surface loadings to in-lake sampling results. Monthly loads have been estimated for total nitrogen (TN) and total phosphorous (TP) from 1996 to 2014. The methods used to estimate surface runoff and the associated nutrient loads for this project is the same method used by the County Pollutant Loading spreadsheet (AMEC_PLATool 2014). For this study, the pollutant loading estimate data development, parameterization and calculations were conducted using GIS and MS Access to facilitate reporting and reproducibility of calculations. Additionally, loads from septic systems and WWTPs have been estimated on monthly intervals. Additional potential loading sources that could not be quantified as part of this study include loading sources from unusual groundwater conditions and internal lake sources, such as in-lake sediment, as an ambient source of loading. Past practices in how fertilizer was land applied within the watershed, as well as how sewage from wastewater treatment plants was disposed of, prior to the implementation of contemporary standards, could serve as pollutant loading sources today even though these practices may have ceased to exist decades ago. The following sections describe the input parameters and equations utilized to calculate the average yearly gross and net pollutant loads for the Lake Clinch WBID area. These load calculations may be updated if and when data on groundwater or in lake sediment as potential loading sources becomes available.

4.1.1. Rainfall/Runoff

EMC-based pollutant loading estimates are highly dependent on the amount of runoff produced over the drainage area. The NEXRAD 15-minute radar rainfall data, provided by the SWFWMD, was summarized on monthly intervals and is provided as Table 13 Each monthly rainfall depth is then converted to a runoff depth. Based on the land use/soil combination, a non-Directly Connected Impervious Area (NDCIA) Curve Number (CN) and DCIA percentage is selected using Table 14. The CN/DCIA combination is converted to a runoff coefficient (C) using Table 15 Zone 2 runoff coefficients were selected based on data provided by Polk County. A 10% initial abstraction value was used based on standard literature.

The following formula was applied to calculate the annual runoff depth:

*Annual Runoff (in) = 0.9 * Runoff Coefficient (C) * Annual Rainfall (in)*

Table 13 - NEXRAD Rainfall Monthly Summary

Year	Month	Rainfall (Inch)	Year	Month	Rainfall (Inch)	Year	Month	Rainfall (Inch)	Year	Month	Rainfall (Inch)
1995	6	9.1	**2000**	5	0.9	**2005**	4	2.7	**2010**	3	5.9
1995	7	9.4	**2000**	6	4.8	**2005**	5	7.4	**2010**	4	2.1
1995	8	9.7	**2000**	7	8.0	**2005**	6	16.4	**2010**	5	4.3
1995	9	5.2	**2000**	8	3.7	**2005**	7	7.7	**2010**	6	9.7
1995	10	4.7	**2000**	9	6.2	**2005**	8	11.1	**2010**	7	6.3
1995	11	1.2	**2000**	10	0.1	**2005**	9	5.2	**2010**	8	9.2
1995	12	0.5	**2000**	11	0.9	**2005**	10	8.9	**2010**	9	2.9
1996	1	4.5	**2000**	12	0.5	**2005**	11	2.2	**2010**	10	0.0
1996	2	1.2	**2001**	1	0.7	**2005**	12	1.7	**2010**	11	2.1
Year	**Month**	**Rainfall (Inch)**	**Year**	**Month**	**Rainfall (Inch)**	**Year**	**Month**	**Rainfall (Inch)**	**Year**	**Month**	**Rainfall (Inch)**
1996	3	5.2	**2001**	2	0.3	**2006**	1	0.8	**2010**	12	0.7
1996	4	2.2	**2001**	3	5.6	**2006**	2	3.7	**2011**	1	5.1
1996	5	3.3	**2001**	4	0.4	**2006**	3	0.5	**2011**	2	0.4
1996	6	5.9	**2001**	5	3.2	**2006**	4	1.5	**2011**	3	6.0
1996	7	2.7	**2001**	6	6.4	**2006**	5	1.7	**2011**	4	1.2
1996	8	4.4	**2001**	7	5.4	**2006**	6	8.0	**2011**	5	3.1
1996	9	4.8	**2001**	8	6.3	**2006**	7	8.2	**2011**	6	7.2
1996	10	3.4	**2001**	9	16.7	**2006**	8	5.6	**2011**	7	7.5
1996	11	0.1	**2001**	10	2.6	**2006**	9	6.7	**2011**	8	6.2
1996	12	1.5	**2001**	11	0.2	**2006**	10	0.7	**2011**	9	4.6
1997	1	1.8	**2001**	12	0.6	**2006**	11	0.6	**2011**	10	10.0
1997	2	1.3	**2002**	1	0.5	**2006**	12	4.8	**2011**	11	0.1
1997	3	2.6	**2002**	2	4.2	**2007**	1	1.7	**2011**	12	0.1
1997	4	4.9	**2002**	3	0.1	**2007**	2	2.2	**2012**	1	0.5
1997	5	2.3	**2002**	4	2.7	**2007**	3	0.4	**2012**	2	2.2
1997	6	6.1	**2002**	5	2.0	**2007**	4	2.3	**2012**	3	2.6
1997	7	7.4	**2002**	6	17.1	**2007**	5	1.2	**2012**	4	1.3
1997	8	4.6	**2002**	7	5.1	**2007**	6	10.3	**2012**	5	3.0
1997	9	4.1	**2002**	8	6.9	**2007**	7	8.4	**2012**	6	15.1
1997	10	1.5	**2002**	9	4.1	**2007**	8	5.2	**2012**	7	6.5
1997	11	4.4	**2002**	10	3.6	**2007**	9	5.7	**2012**	8	8.0
1997	12	6.2	**2002**	11	3.1	**2007**	10	5.1	**2012**	9	4.7
1998	1	4.7	**2002**	12	8.5	**2007**	11	0.4	**2012**	10	4.9
1998	2	6.9	**2003**	1	0.2	**2007**	12	0.4	**2012**	11	0.1
1998	3	6.2	**2003**	2	1.4	**2008**	1	1.8	**2012**	12	2.9
1998	4	1.0	**2003**	3	2.6	**2008**	2	1.7	**2013**	1	0.4
1998	5	3.2	**2003**	4	2.6	**2008**	3	2.5	**2013**	2	0.8
1998	6	1.5	**2003**	5	3.1	**2008**	4	3.4	**2013**	3	1.0
1998	7	6.0	**2003**	6	10.8	**2008**	5	0.4	**2013**	4	3.0
1998	8	2.8	**2003**	7	6.0	**2008**	6	8.5	**2013**	5	3.8
1998	9	12.3	**2003**	8	10.8	**2008**	7	10.0	**2013**	6	12.0
1998	10	0.8	**2003**	9	6.4	**2008**	8	12.5	**2013**	7	9.9
1998	11	2.5	**2003**	10	0.6	**2008**	9	1.1	**2013**	8	10.3
1998	12	0.8	**2003**	11	1.3	**2008**	10	4.5	**2013**	9	4.5
1999	1	3.9	**2003**	12	2.4	**2008**	11	0.4	**2013**	10	1.1
1999	2	0.9	**2004**	1	2.1	**2008**	12	0.8	**2013**	11	1.1
1999	3	1.2	**2004**	2	2.7	**2009**	1	2.3	**2013**	12	0.4
1999	4	1.3	**2004**	3	2.2	**2009**	2	0.6	**2014**	1	4.4
1999	5	2.9	**2004**	4	2.2	**2009**	3	0.5	**2014**	2	1.6
1999	6	11.4	**2004**	5	1.4	**2009**	4	0.7	**2014**	3	2.8

1999	7	4.0	**2004**	6	8.5	**2009**	5	8.5	**2014**	4	3.1
1999	8	8.3	**2004**	7	7.8	**2009**	6	7.2	**2014**	5	5.2
1999	9	9.0	**2004**	8	15.0	**2009**	7	9.5	**2014**	6	10.3
1999	10	3.8	**2004**	9	15.0	**2009**	8	6.4	**2014**	7	6.6
1999	11	1.9	**2004**	10	1.2	**2009**	9	3.9	**2014**	8	3.6
1999	12	2.8	**2004**	11	0.7	**2009**	10	0.3	**2014**	9	8.0
2000	1	0.9	**2004**	12	4.2	**2009**	11	0.6	**2014**	10	1.0
2000	2	0.3	**2005**	1	1.7	**2009**	12	5.5	**2014**	11	11.5
2000	3	0.6	**2005**	2	6.8	**2010**	1	2.0	**2014**	12	0.8
2000	4	1.1	**2005**	3	4.2	**2010**	2	2.8			

Table 14 - CN and DCIA Lookup Table (FLUCC Based)

FLUC Code	Land Use Description	A	A/D	B	B/D	C	C/D	D	W	DCIA
1400	COMMERCIAL AND SERVICES	39	39	61	61	74	74	80	98	85
2100	CROPLAND AND PASTURELAND	39	80	61	80	74	80	80	98	0
6210	CYPRESS	98	98	98	98	98	98	98	98	100
6440	EMERGENT AQUATIC VEGETATION	98	98	98	98	98	98	98	98	100
1600	EXTRACTIVE	39	39	61	61	74	74	80	98	0
6410	FRESHWATER MARSHES	98	98	98	98	98	98	98	98	100
1820	GOLF COURSES	39	80	61	80	74	80	80	98	10
4340	HARDWOOD CONIFER MIXED	39	79	58	79	72	79	79	98	0
1500	INDUSTRIAL	39	39	61	61	74	74	80	98	72
1700	INSTITUTIONAL	39	39	61	61	74	74	80	98	65
6530	INTERMITTENT PONDS	98	98	98	98	98	98	98	98	100
5200	LAKES	98	98	98	98	98	98	98	98	100
3300	MIXED RANGELAND	39	73	48	73	65	73	73	98	0
2400	NURSERIES AND VINEYARDS	67	89	78	89	85	89	89	98	5
1900	OPEN LAND	39	80	61	80	74	80	80	98	0
2600	OTHER OPEN LANDS <RURAL>	39	80	61	80	74	80	80	98	0
4110	PINE FLATWOODS	39	79	58	79	72	79	79	98	0
1800	RECREATIONAL	39	80	61	80	74	80	80	98	10
5300	RESERVOIRS	98	98	98	98	98	98	98	98	100
1300	RESIDENTIAL HIGH DENSITY	39	39	61	61	74	74	80	98	50
1100	RESIDENTIAL LOW DENSITY	39	39	61	61	74	74	80	98	20
1200	RESIDENTIAL MED DENSITY	39	39	61	61	74	74	80	98	25
3200	SHRUB AND BRUSHLAND	39	73	48	73	65	73	73	98	0
6150	STREAM AND LAKE SWAMPS	98	98	98	98	98	98	98	98	100
8100	TRANSPORTATION	83	83	89	89	92	92	93	98	25
2200	TREE CROPS	39	79	58	79	72	79	79	98	10
8300	UTILITIES	83	83	89	89	92	92	93	98	25
6430	WET PRAIRIES	98	98	98	98	98	98	98	98	100
6300	WETLAND FORESTED MIXED	98	98	98	98	98	98	98	98	100

Table 15 - Mean Annual Runoff Coefficients as a Function of CN and DCIA

Zone 2 Mean Annual Runoff Coefficients (C Values) as a Function of DCIA Percentage and Non-DCIA Curve Number (CN)																					
NDCIA	Percent DCIA																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
30	0.002	0.043	0.083	0.123	0.164	0.204	0.244	0.285	0.325	0.366	0.406	0.446	0.487	0.527	0.567	0.608	0.648	0.688	0.729	0.769	0.809
35	0.004	0.044	0.085	0.125	0.165	0.205	0.246	0.286	0.326	0.366	0.407	0.447	0.487	0.528	0.568	0.608	0.648	0.689	0.729	0.769	0.809
40	0.007	0.047	0.087	0.127	0.167	0.207	0.248	0.288	0.328	0.368	0.408	0.448	0.488	0.528	0.569	0.609	0.649	0.689	0.729	0.769	0.809
45	0.010	0.050	0.090	0.130	0.170	0.210	0.250	0.290	0.330	0.370	0.410	0.450	0.490	0.530	0.570	0.610	0.650	0.690	0.729	0.769	0.809
50	0.015	0.055	0.095	0.134	0.174	0.214	0.254	0.293	0.333	0.373	0.412	0.452	0.492	0.531	0.571	0.611	0.651	0.690	0.730	0.770	0.809
55	0.022	0.061	0.101	0.140	0.179	0.219	0.258	0.298	0.337	0.376	0.416	0.455	0.494	0.534	0.573	0.613	0.652	0.691	0.731	0.770	0.809
60	0.030	0.069	0.108	0.147	0.186	0.225	0.264	0.303	0.342	0.381	0.420	0.459	0.498	0.537	0.576	0.615	0.654	0.693	0.731	0.770	0.809
65	0.042	0.080	0.119	0.157	0.195	0.234	0.272	0.311	0.349	0.387	0.426	0.464	0.502	0.541	0.579	0.618	0.656	0.694	0.733	0.771	0.809
70	0.057	0.095	0.133	0.170	0.208	0.245	0.283	0.321	0.358	0.396	0.433	0.471	0.509	0.546	0.584	0.621	0.659	0.697	0.734	0.772	0.809
75	0.079	0.116	0.152	0.189	0.225	0.262	0.298	0.335	0.371	0.408	0.444	0.481	0.517	0.554	0.590	0.627	0.663	0.700	0.736	0.773	0.809
80	0.111	0.146	0.181	0.216	0.251	0.285	0.320	0.355	0.390	0.425	0.460	0.495	0.530	0.565	0.600	0.635	0.670	0.705	0.740	0.774	0.809
85	0.160	0.192	0.225	0.257	0.290	0.322	0.355	0.387	0.420	0.452	0.485	0.517	0.550	0.582	0.614	0.647	0.679	0.712	0.744	0.777	0.809
90	0.242	0.270	0.299	0.327	0.355	0.384	0.412	0.440	0.469	0.497	0.526	0.554	0.582	0.611	0.639	0.667	0.696	0.724	0.753	0.781	0.809
95	0.404	0.424	0.444	0.464	0.485	0.505	0.525	0.546	0.566	0.586	0.606	0.627	0.647	0.667	0.688	0.708	0.728	0.749	0.769	0.789	0.809
98	0.595	0.605	0.616	0.627	0.638	0.648	0.659	0.670	0.680	0.691	0.702	0.713	0.723	0.734	0.745	0.756	0.766	0.777	0.788	0.799	0.809

4.1.2. Event Mean Concentrations

The concentration of pollutant loads is specific to the type of land use, where the runoff is being produced. Monitoring and field measurements of the pollutant concentrations from runoff produced by various Florida land use types have been compiled and converted to standardized EMC values, expressed in milligrams/liter (mg/L). The EMC values are multiplied by the monthly runoff volume to calculate a mass of pollutants, expressed as pounds/month (lb/month). The land use specific EMC values utilized for this project are based on those provided by Polk County and included as Table 16 (AMEC_PLATool 2014).

Table 16 - Event Mean Concentration Input Values

	Event Mean Concentration (mg/L)						
Land Use Description	TN	TP	BOD	TSS	Copper	Lead	Zinc
Low-Density Residential	1.5	0.18	4.7	23	0.008	0.002	0.031
Single-Family	1.85	0.31	7.9	37.5	0.016	0.004	0.062
Multi-Family	1.91	0.48	11.3	77.8	0.009	0.006	0.086
Low-Intensity Commercial	0.93	0.16	7.7	57.5	0.018	0.005	0.094
High-Intensity Commercial	2.48	0.23	11.3	69.7	0.015	0	0.16
Light Industrial	1.14	0.23	7.6	60	0.003	0.002	0.057
Highway	1.37	0.17	5.2	37.3	0.032	0.011	0.126
Pasture	2.48	0.7	5.1	94.3	0	0	0
Citrus	2.31	0.16	2.55	15.5	0.003	0.001	0.012
Row Crops	2.47	0.51	0	19.8	0.022	0.004	0.03
General Agriculture	2.42	0.46	3.8	43.2	0.013	0.003	0.021
Undeveloped / Rangeland / Forest	1.15	0.055	1.4	8.4	0	0	0

Mining / Extractive	1.18	0.15	7.6	60	0.003	0.002	0.057
Wetland	1.01	0.09	2.63	11.2	0.001	0.001	0.006
Open Water / Lake	0	0	0	0	0	0	0

4.1.3. Pollutant Loading Calculations

The annual pollutant load was calculated for each unique land use/soil area, using the above referenced monthly rainfall, monthly runoff, and EMC values by spatially intersecting the land use and soil coverage. The monthly pollutant load produced by each unique area was accumulated, to express the gross average monthly pollutant load, for the watershed areas.

The following formula was applied to estimate the gross average monthly pollutant load:

*Gross Average Monthly Load (lbs) = 0.226 * Monthly Runoff (in) * EMC (mg/L) * Area (Ac)*

4.1.4. Septic Loading Calculations

Based on septic coverage referenced in Section 0, a total of 479 septic systems have been identified. Septic loads were estimated using a method recently used by the Charlotte Harbor Estuary program to estimate the loadings of nitrogen and phosphorus to the lakes (Janicki Environmental, 2010). The loading estimate assumes a per capita water use of 60 gallons per day with 2.7 persons per household and a 5% septic tank failure rate.

4.1.5. Waste Water Treatment Plant (WWTP) Loading Calculations

Pollutant loading from WWTP has been estimated using a TN concentration of 1.2 mg/l and TP concentration of 0.05 mg/L. Six (6) WWTPs (Table 12) have been identified, based on the permitted average annual discharge rates, TN loading rates have been estimated at 1.26 lb/day and TP loading rates have been estimated at 0.05 lb/day.

4.1.6. Best Management Practices (BMP) Treatment Reductions

To calculate pollutant load reductions associated with currently implemented stormwater Best Management Practices (BMP), the SWFWMD ERP coverage was used to identify permitted stormwater projects which provide a reduction of pollutant loads. Each project pollutant load reduction percentage was obtained from Polk County and assigned the project BMP coverage.

The following formula was applied to estimate pollutant load reductions associated with the identified BMPs:

*Net Average Monthly Load = Gross Average Monthly Load * (1 – BMP Removal)*

4.2. Review of Historical and Current Pollutant Loadings

Based on the methodologies described above, monthly estimates of TN and TP loadings were calculated for the period 1996 – 2013. Four sources were reported: direct runoff, atmospheric deposition, point sources and septic tanks. Two additional sources were identified but could not be quantified within this analysis due to lack of data. These included groundwater sources and loading sources internal to the lake.

The total monthly TN and TP loadings, the sum of the loads from direct runoff, atmospheric deposition, point sources and septic tanks are presented in, Figure 29 and Figure 30 respectively. Monthly TN loads generally range from 100 to 5000 lbs/ month with two points exceeding 6000 lbs/month in June 2002 and June 2010. The majority of the TP loadings were less than 200 lbs/month but values up to and exceeding 300 lbs/month frequently occurred. The temporal trends in the total monthly TP loads were similar to those observed in the TN loads.

Figure 29 - Total Monthly TN Loadings (lbs/month)

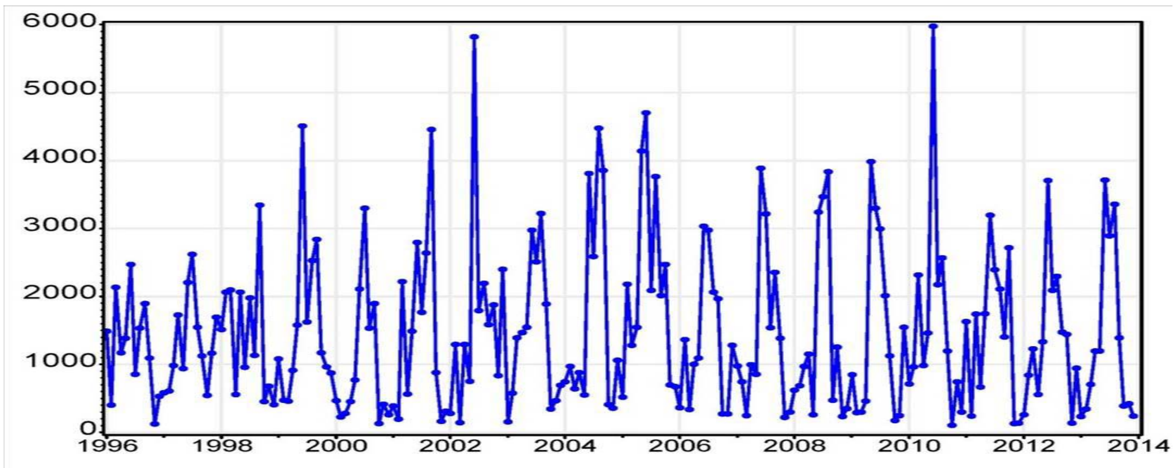
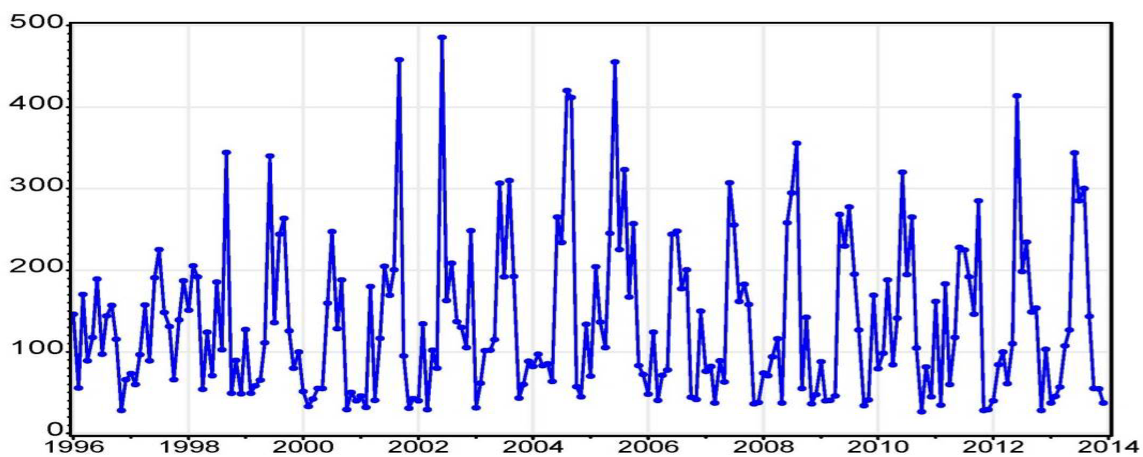


Figure 30 - Total Monthly TP Loadings (lbs/month)



An effective lake management plan will not depend solely on knowledge of the total nutrient loading but also the relative importance of the sources of nutrient loads. The monthly TN and TP loadings from direct runoff, atmospheric deposition, point sources and septic tanks are presented in Figure 31 through Figure 38 Typical monthly TN loads from direct runoff were less than 2000 lbs/month, atmospheric deposition ranged from 0 lbs/month (no rain) to greater than 2000 lbs/month, while loadings from septic tanks and point sources contributed less than 65 lbs/month and 40 lbs/month, respectively. The constant loading estimates provided for both point sources and septic tanks reflect the assumptions used rather than the true likely seasonal variation over time.

Figure 31 - Monthly TN Loadings Direct Runoff (lbs/month)

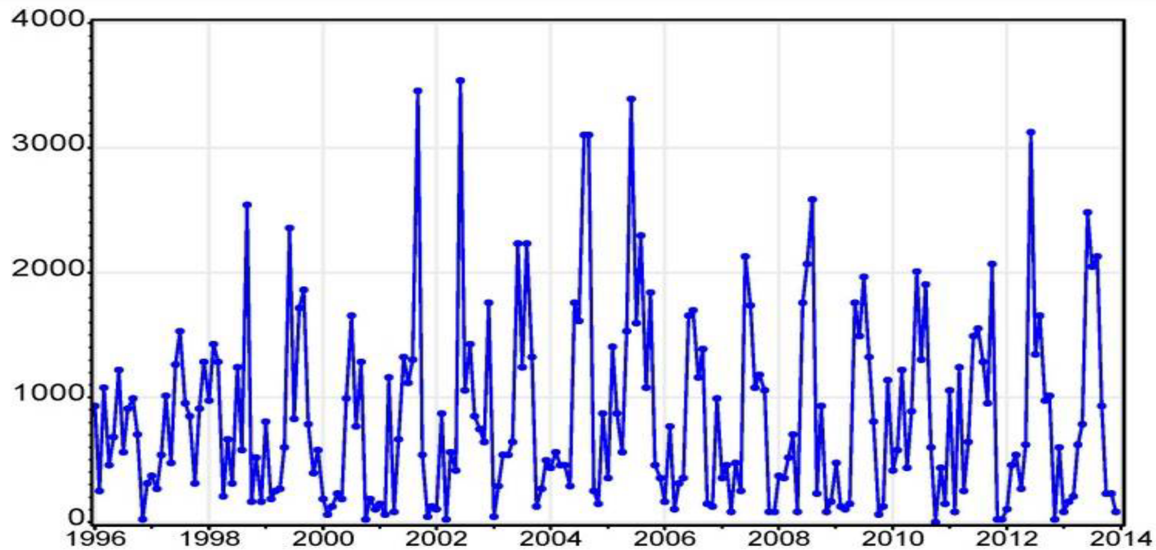


Figure 32 - Monthly TN Loadings Atmospheric Deposition (lbs/month)

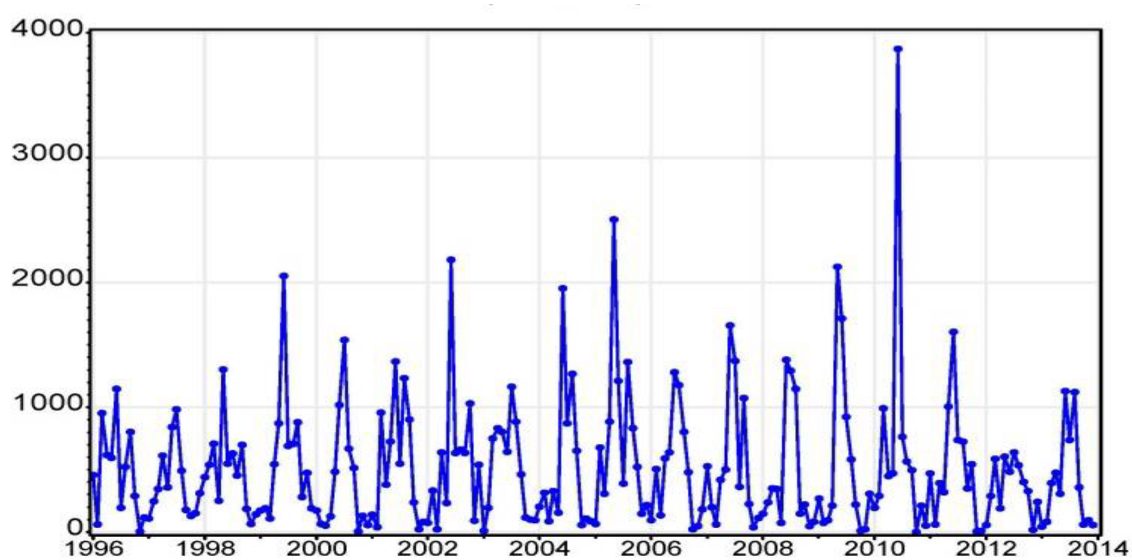


Figure 33 - Monthly TN Loadings Point Sources (lbs/month)

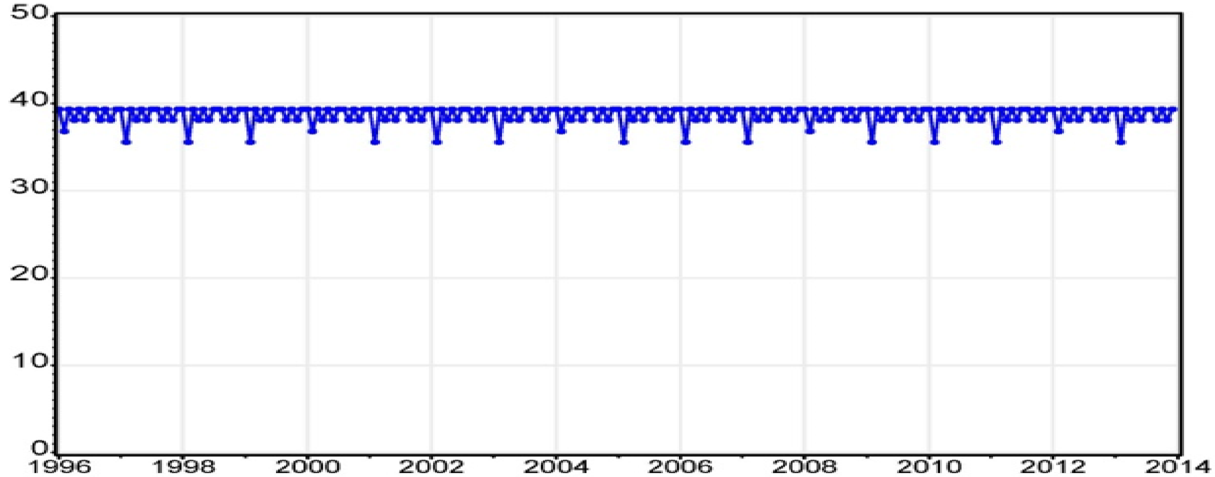


Figure 34 - Monthly TN Loadings Septic Tanks (lbs/month)

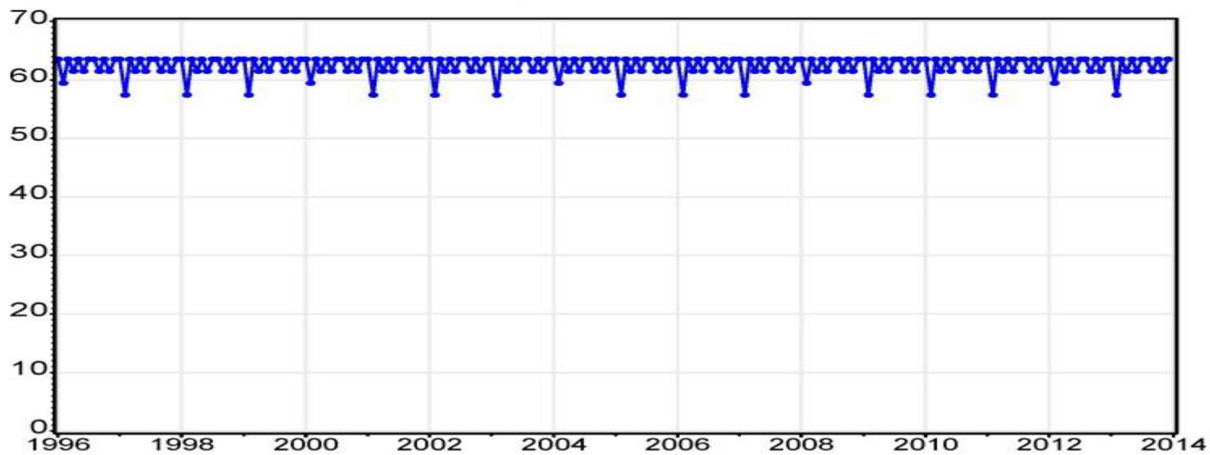


Figure 35 - Monthly TP Loadings Direct Runoff (lbs/month)

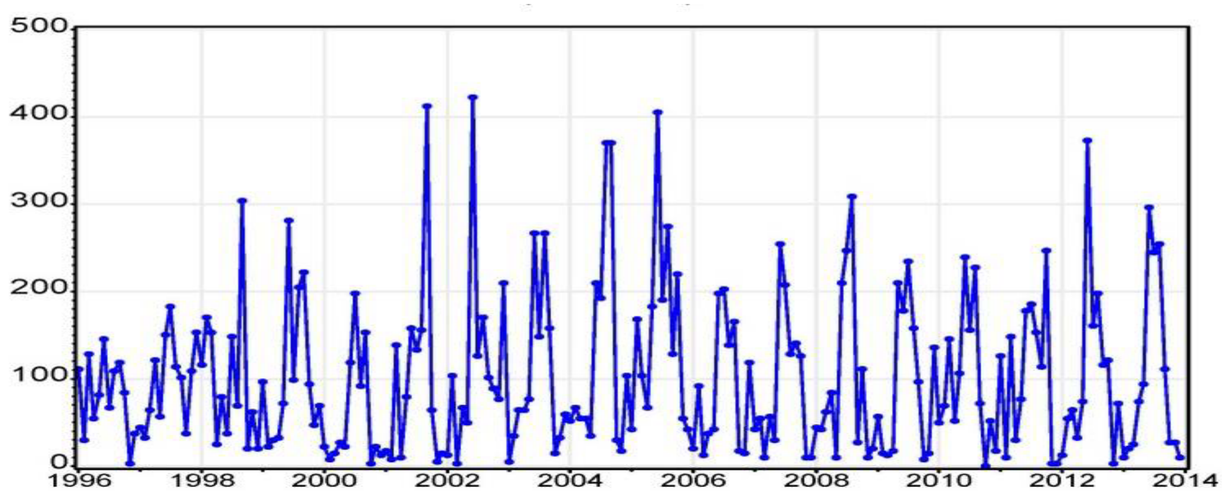


Figure 36 - Monthly TP Loadings Atmospheric Deposition (lbs/month)

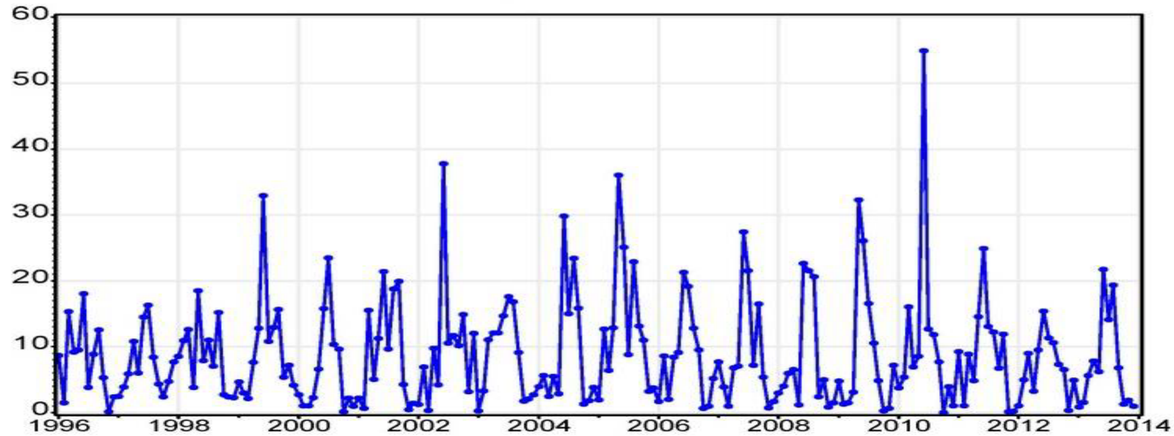


Figure 37 - Monthly TP Loadings Point Sources (lbs/month)

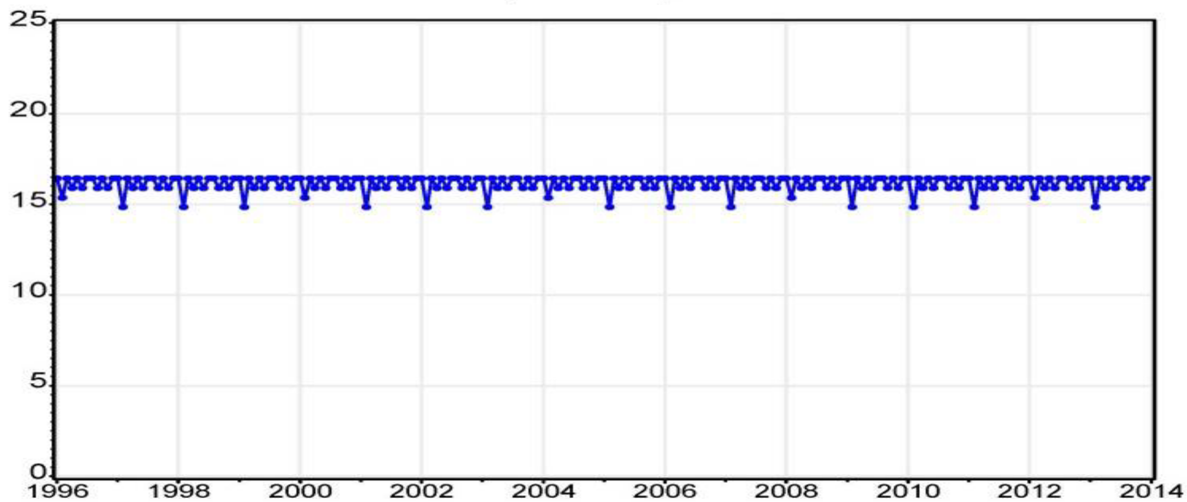
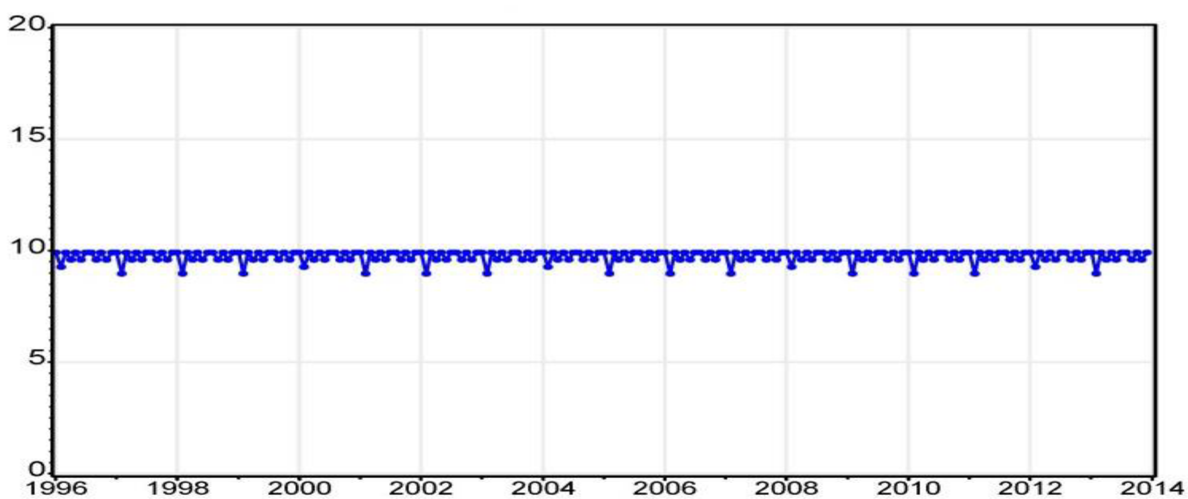


Figure 38 - Monthly TP Loadings Septic Tanks (lbs/month)



Typical monthly TP loads from direct runoff, by far the largest contributor, ranged from < 5 lbs/month to greater than 500 lbs/month, with typical values less than 200 lbs/month. Typically less than 15 lbs/month were from atmospheric deposition. Point sources and septic tanks accounted for about 16 lbs/month and <9 lbs/month, respectively. The TP loadings closely followed the temporal trends in rainfall especially during periods of elevated rainfall. As for the TN loads, the constant loading estimates provided for both point sources and septic tanks reflect the assumptions used rather than the true likely seasonal variation over time.

Figure 39 and Figure 40 present the contribution of the four nutrient sources to the total annual TN and TP loads, respectively. Over the 1996 to 2013 period, the TN loads due to direct runoff were contributing 60% of the TN loadings. The relative contribution from atmospheric deposition typically provided another one-third of the load while septic tanks and points sources provided less than 5%.

Figure 39 - Total Annual TN Loadings by Source

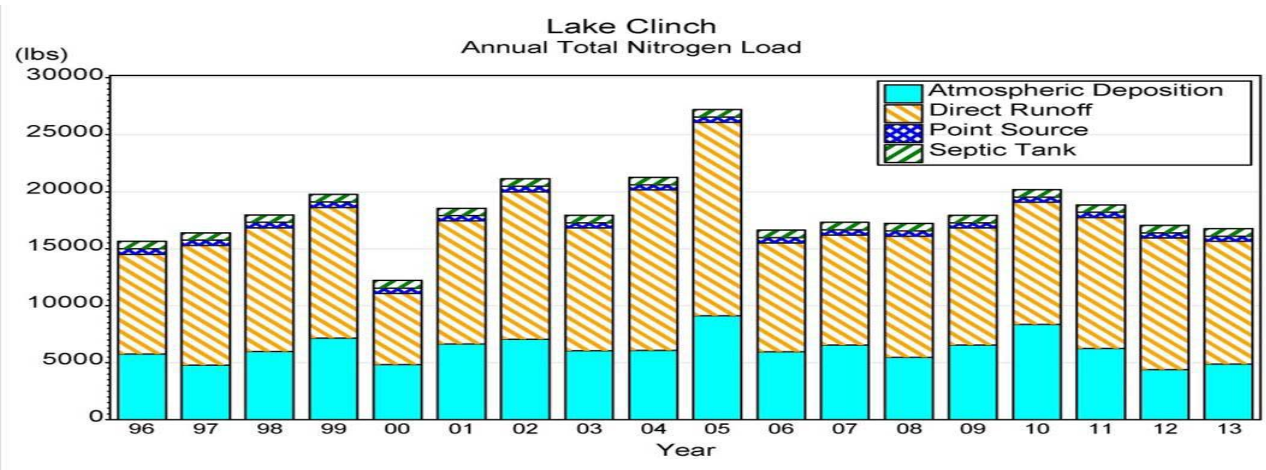
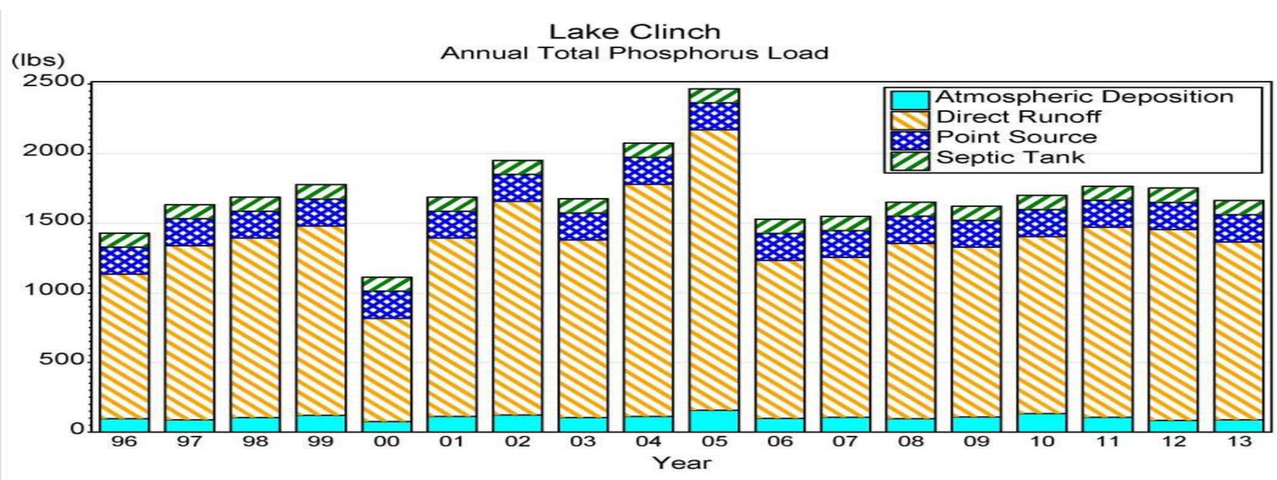


Figure 40 - Total Annual TP Loadings by Source



Direct runoff loads were the predominant source of TP loads over the 1996 to 2013 period, typically accounting for 70-80% of the load. The relative contribution of point source loads ranked second or near 10%. TP loads due to atmospheric deposition and septic tanks were both smaller, approximately 5% or less throughout the study period.

Figure 41 and Figure 42 present the intra-annual variation in the relative contributions of the four nutrient sources to total TN and TP loads, respectively. The TN and TP loads from both atmospheric deposition and direct runoff, as expected, were greater from June through September both in terms of absolute and relative contributions to the total nutrient loads. The proportion from point sources and septic tank TN and TP loads were similar throughout the 12 calendar months.

Figure 41 - Calendar Monthly TN Loadings by Source

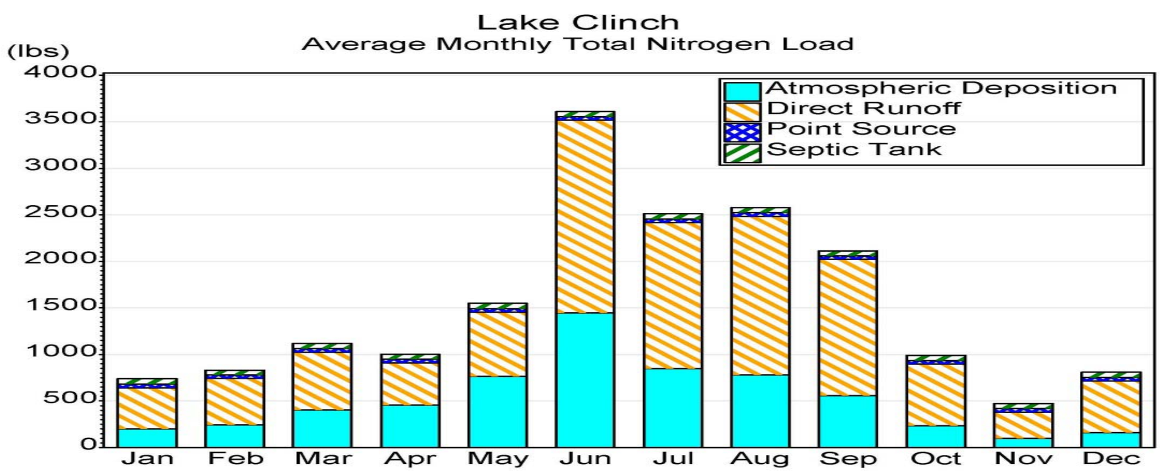
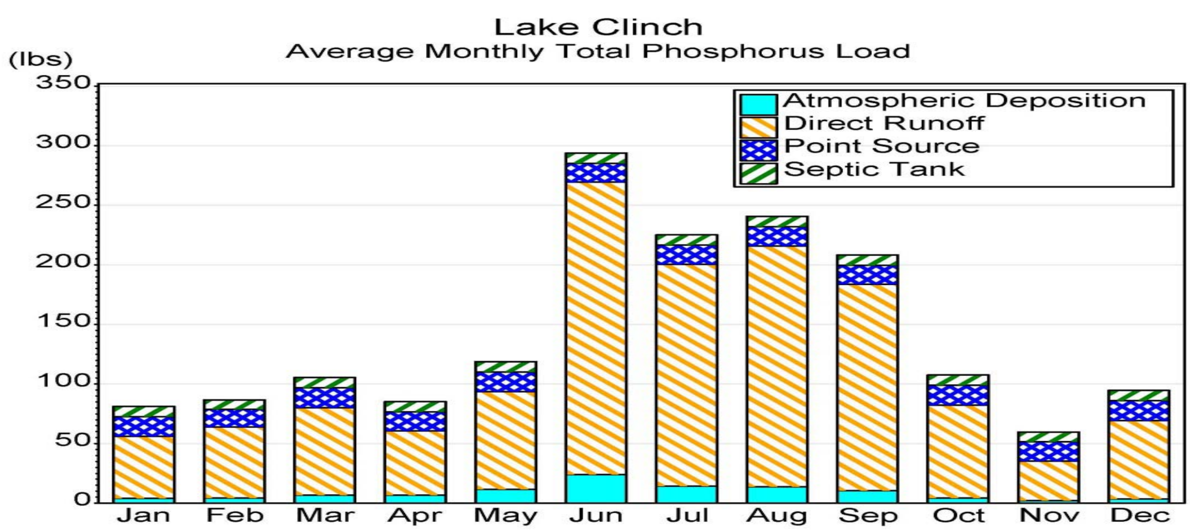


Figure 42 - Calendar Monthly TP Loadings by Source



4.3. Identification and Assessment of Factors That Could Affect Water Quality

4.3.1. Introduction

Assessment factors that could affect water quality are not limited to only analysis of pollutant loading sources. There is a long history of research that examined the relationships between algal biomass or productivity and nutrient conditions in a water body. Two of the most notable, Vollenweider (1968) in lakes and Boynton et al. (1982) in estuaries, examined the relationships between nutrient loading and chlorophyll-a concentrations. In the simplest of terms, this research found that the organic carbon production is driven by the rate of supply of the limiting nutrient. Dillon and Rigler (1974) and Kerekes (1982) identified the importance of lake residence time on the phosphorus – chlorophyll-a relationships in lakes. Previously, Atkins and ESA (Atkins and ESA 2014) reported correlations between chlorophyll-a concentrations and TN and TP concentrations in Lake Clinch.

The biological community in a lake cannot only be an indicator of excessive nutrient loading to a lake, but can actually become a source of toxic pollution in certain cases where nutrient loading becomes too high. An example of this is blue-green algae (Phylum Cyanophyta) which is a common algae found everywhere. Persistent Cyanobacteria blooms, which is a form of blue-green algae, have been associated with lakes with high nitrogen levels. An index has not yet been developed that can use Cyanobacteria populations as an indicator of elevated nutrient concentrations. However, research has indicated that high ratios of total nitrogen to total phosphorous are related to lower levels of blue-green algae and that lower ratios (Redfield ratio 16:1) enable blue-green algae to grow. No significant blue-green algae blooms are known to have occurred on Lake Clinch during the study period and this seems to be corroborated by the fact that TP is a limiting nutrient for Lake Clinch.

For this task, we have examined the relationship between chlorophyll-a and nutrient conditions (loads and ambient concentrations). Given the potential importance of lake residence time, the relationship between chlorophyll-a and hydrologic loadings were also examined. The SAS statistical software code PROC REG (Regression) was used for these analyses. Residuals from the statistically significant regressions were computed to allow examination of the potential relationships with other factors not specifically included in the model.

4.3.2. Previous Studies

As pointed out above, Atkins and ESA (Atkins and ESA, 2014) reported the results of the analysis of empirically-derived nutrient targets for water quality. The correlations included both ambient TN and TP concentrations and were based on IWR run 47. Also, simple plots of the variables examined would point to the specific nature of the relationship examined (i.e., negative or positive). Their analyses were reported as correlations and included coefficients of determination (R2). For Lake Clinch, neither TN nor TP displayed a significant relationship with chlorophyll-a.

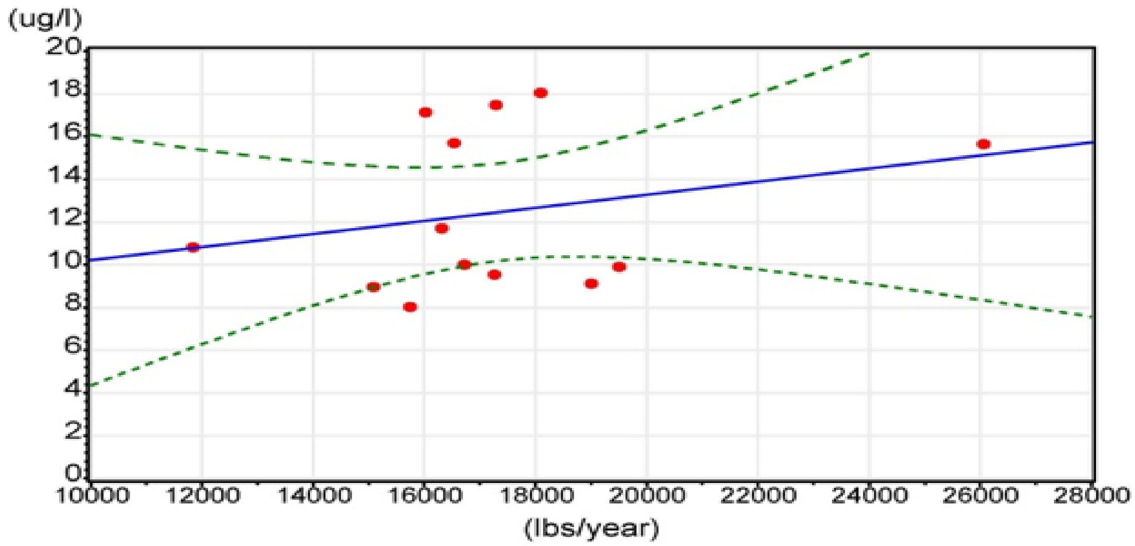
4.3.3. Results

The regressions analyses conducted in this task included two time scales: monthly and annual. The monthly scale analyses also included a series of lag effects that examined whether the responses in chlorophyll-a were related to the cumulative loads over 1 to 6 month time period. None of the monthly scale analyses identified any significant relationships. For the annual scale analyses, the annual geometric mean chlorophyll-a concentrations were regressed on:

- Annual geometric mean TN concentrations,
- Total annual TN loadings,
- Annual geometric mean TP concentrations,
- Total annual TP loadings, and
- Total annual hydrologic loads.

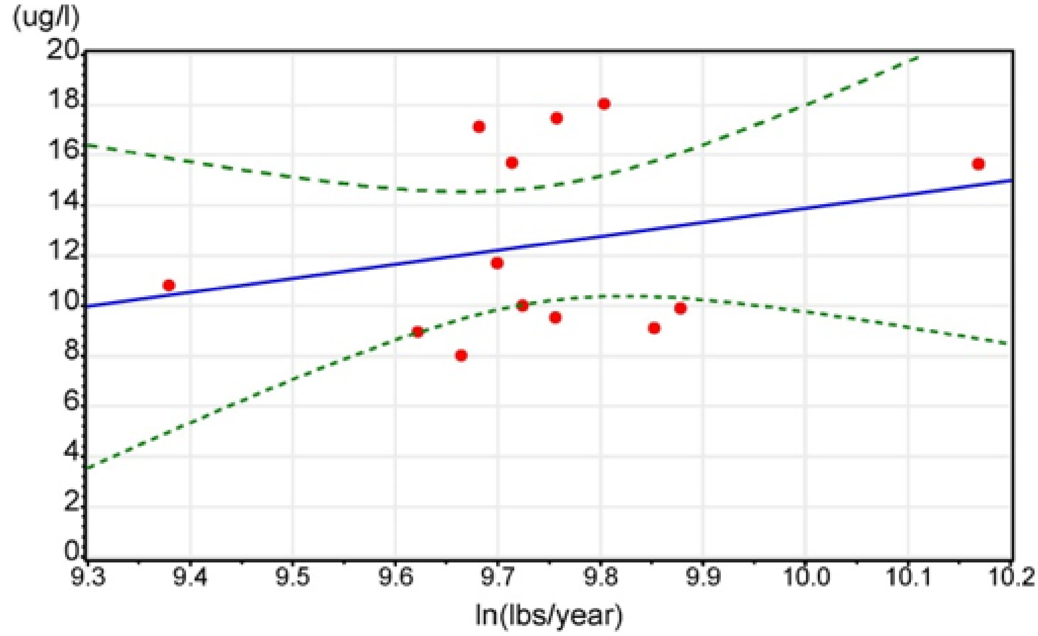
Figure 43, Figure 44 , and Figure 45 present the relationships between the annual geometric mean chlorophyll-a concentrations and the total annual TN, TP and hydrologic loadings. There are no significant relationship between the annual geometric mean chlorophyll-a and any of the three loadings, rather it points to the likely importance of in-lake processes in determining the response to external loadings.

Figure 43 – Relationship between Annual Geometric Mean Chlorophyll a Concentrations and Total Annual TN Loadings



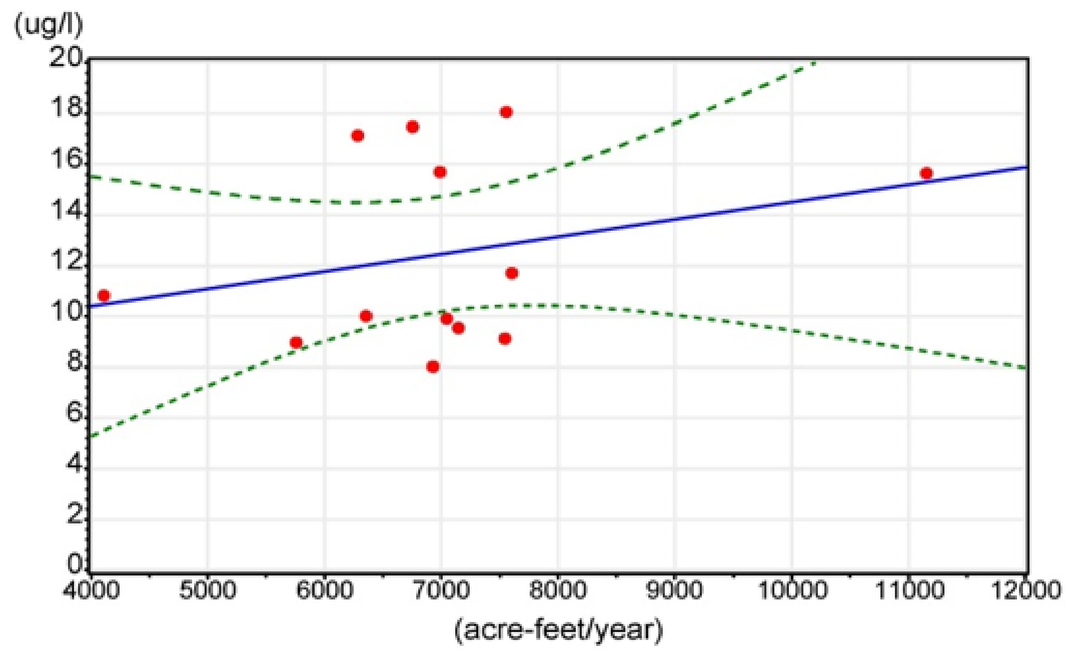
Regression Equation:
geochla = 7.149436 + 0.000307*ann_tnload

Figure 44 - Relationship between Annual Geometric Mean Chlorophyll a Concentrations and Total Annual TP Loadings



Regression Equation:
geochla = -41.90529 + 5.578914*logtnld

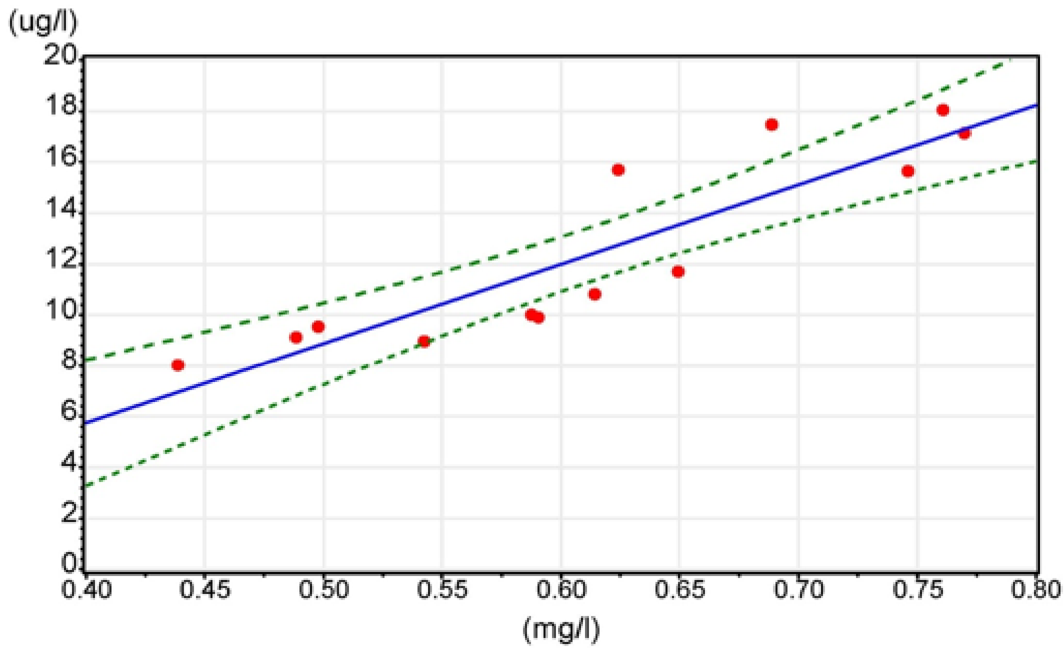
Figure 45 - Relationship between Annual Geometric Mean Chlorophyll a Concentrations and Total Annual Hydrologic Loadings



Regression Equation:
geochla = 7.66335 + 0.000685*total_hydro

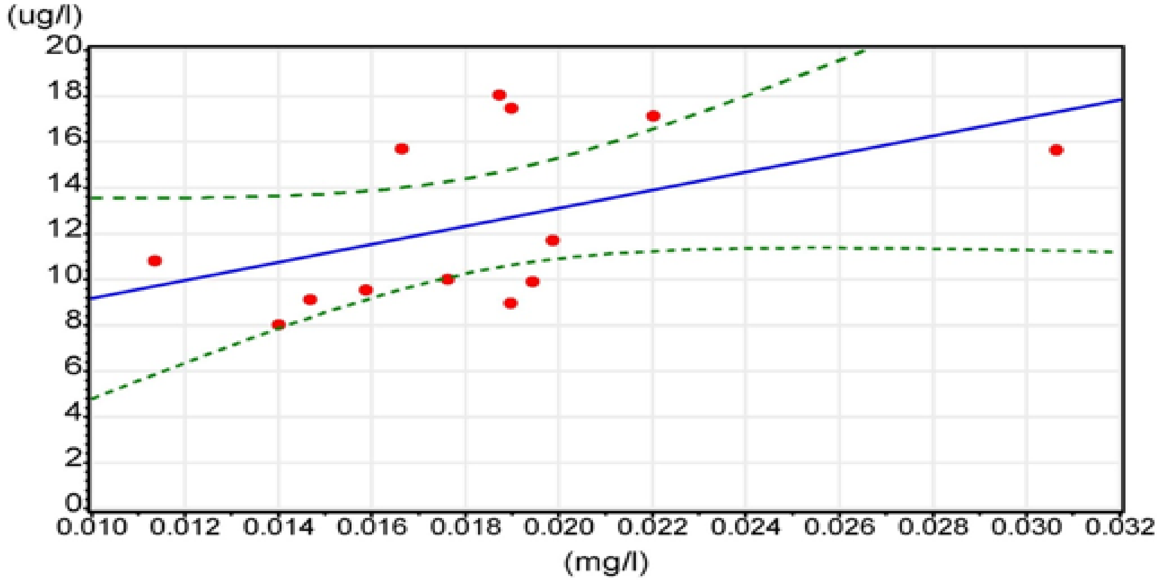
Next, comparisons are shown between the annual geometric mean chlorophyll-a and the annual geometric mean TN and TP concentrations within the lake. These relationships can be seen in Figure 46 and Figure 47 respectively. The annual geometric mean for total nitrogen was highly significant (P=<0.0001) and with an r2 = 0.80. The relationship with TP was not significant. A final analysis, shown in Figure 48 and Figure 49 was made between annual geometric mean nutrient concentrations and annual nutrient load. There was a low significant relationship for TP but there was no significant relationship between TP and chlorophyll-a. The ambient concentrations in a lake are influenced by many factors other the loadings, such as internal cycling of nutrients in the sediments or ground-water seepage. Given the physical nature of the lake, this inference is highly probable. This, however, does not negate the need for managing nutrient loading.

Figure 46 - Relationship between Annual Geometric Mean Chlorophyll a Concentrations and Annual Geometric Mean TN Concentrations



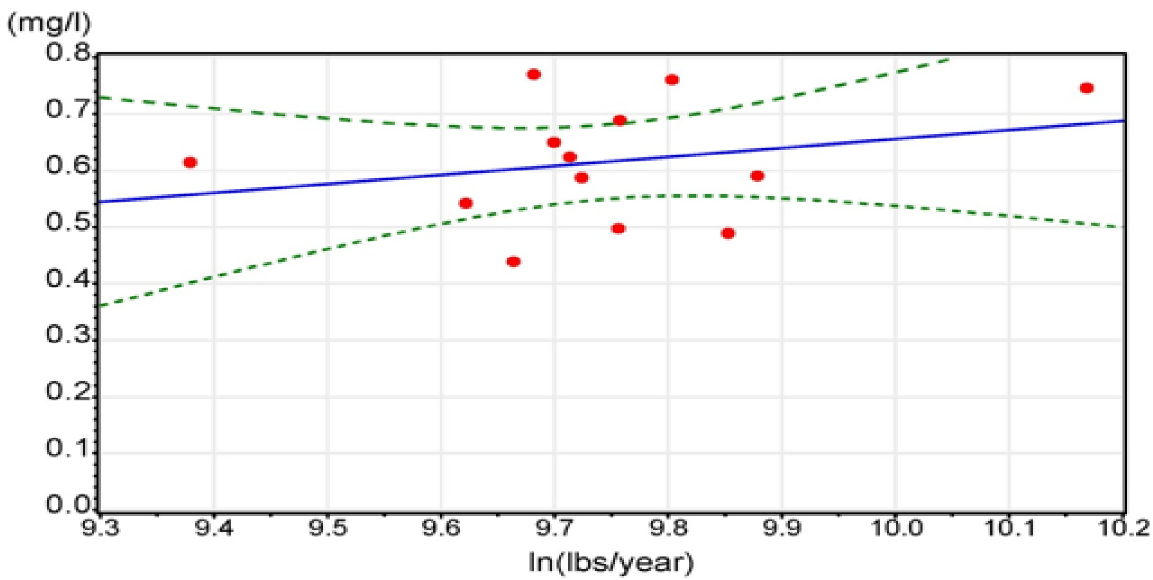
Regression Equation:
geochla = -6.74469 + 31.22306*geotn

Figure 47 - Relationship between Annual Geometric Mean Chlorophyll a Concentrations and Annual Geometric Mean TP Concentrations



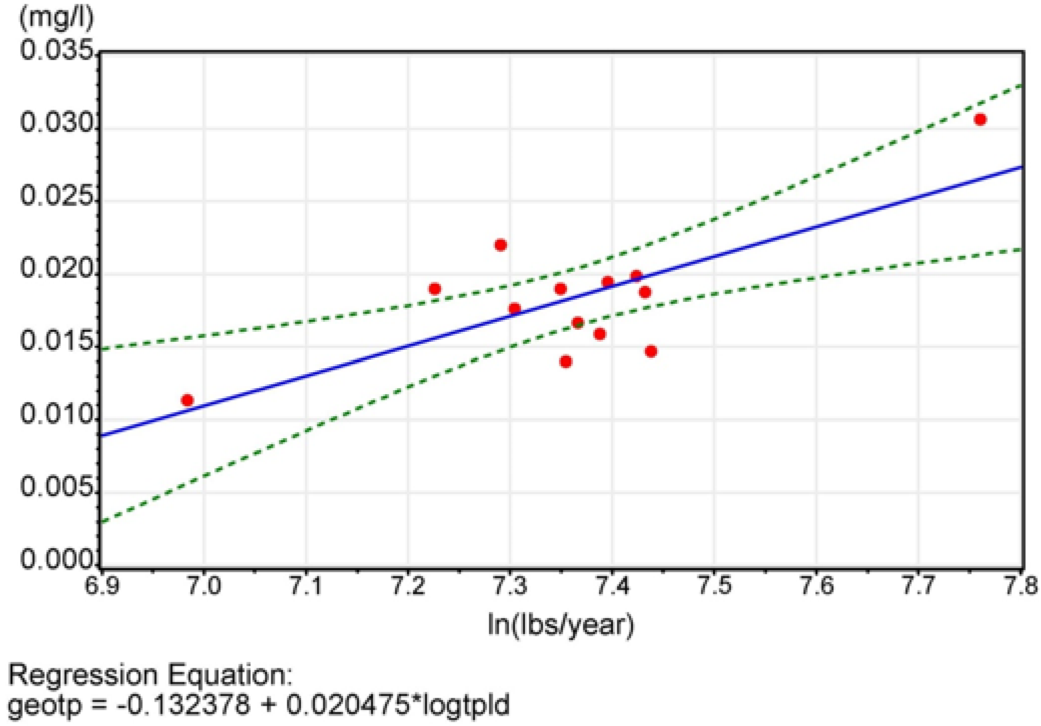
Regression Equation:
geochla = 5.233315 + 393.8276*geotp

Figure 48 - Relationship between Annual Geometric Mean TN concentrations and Total Annual TN Loadings



Regression Equation:
geotn = -0.924349 + 0.157977*logtnld

Figure 49 - Relationship between Annual Geometric Mean TP Concentrations and Total Annual TP Loadings



4.3.4. Conclusions

Atkins and ESA (Atkins and ESA 2014) defined the target chlorophyll-a concentration for Lake Clinch (which is classified as clear and alkaline by FDEP) as 6 mg/L based on the NNC. Utilizing the significant relationship between chlorophyll-a concentration and the annual geometric mean TN, solving for the target chlorophyll-a of 6 mg/L gives the follow result:

- annual geometric mean TN concentration = 0.41 mg/L

This value is 0.1 mg/l less than the lower limit of the FDEP 0.51 mg/l annual geometric mean criteria for nitrogen Numeric Nutrient Criteria (NNC) for lakes of this type. A review of the draft FDEP IWR run 49 which has been updated to include the new NNC indicates that Lake Clinch would be listed as impaired for nitrogen, as well as chlorophyll-a and phosphorus, indicating a lower concentration of nitrogen is necessary to meet both the nitrogen and chlorophyll-a criteria.

The FDEP set NNC criteria for corrected chlorophyll-a. The above analyses utilized the data available in the IWR Run 49 (draft), the vast majority of which was uncorrected chlorophyll-a, 268 samples versus 65. As such, the relationships built for this analysis were based on uncorrected rather than corrected chlorophyll-a.

5. POTENTIAL REMEDIAL ACTION TO PROTECT OR IMPROVE LAKE CONDITIONS

5.1. Discussion

Lake Clinch is currently on the impaired list for the previously utilized impairment criteria of TSI. This impairment is compounded by the fact that the lake is also impaired for NNC criteria, as shown in the table below with nitrogen levels that are 30% higher than they should be for a lake of this type. Total phosphorous from 1968 to 2013 was found to be 0.019mg/l, which is below the NNC maximum allowable limits of 0.03 mg/l.

The watershed for Lake Clinch leaves little opportunity for large scale interception and treatment of runoff. This is compounded by the fact that all known conventional water quality treatment technologies would not be capable of reducing in-water nitrogen levels to levels below the current lake ambient level.

This leaves only a handful of approaches to use when attempting to reduce lake nitrogen to desired levels. These are:

1. Reduce or eliminate nitrogen import into the watershed (i.e. fertilizer operations)
2. Reduce or eliminate groundwater sources of nitrogen into the lake
3. Eliminate sediment flux as a significant load source for nitrogen
4. Encourage in-lake biological processes for nitrogen removal
5. Dilute nitrogen levels by artificial means

The lake N level that should be targeted for Lake Clinch is at a minimum the level set by the FDEP NNC criteria which is 0.51 mg/l for nitrogen and 6 ug/l for Chl-a. Based on a statistical analysis of historical data for the Lake, Chl-a concentrations of 6 ug/l would only be expected to be achieved if nitrogen levels were reduced to 0.41 mg/l. The 0.41 mg/l target represents approximately a 40% reduction in nitrogen levels within the lake.

5.2. Challenges Associated with Remediation

A core challenge with protecting and improving water quality within the lake is that the NNC criteria applicable to this Lake in respect to N require nutrient levels that are below even the most conservative estimate of N loading from any land use that discharges stormwater runoff. The nutrient criteria are also below the minimum nutrient levels identified in any FDEP established design standard for water of any type including potable water, wastewater, and stormwater. In short, no non-biological technologies have been adopted or identified by FDEP that have been demonstrated to be capable of lowering TN concentrations in treated water to levels below the targeted TN for the Lake. Electrolysis of the water, which reduces water into its elemental compounds (H and O) is the only technological approach capable of eliminating N concentrations altogether, but this technology is highly energy intensive and currently would be considered impractical.

The implication of this is that treatment of watershed runoff alone will not be sufficient to reduce Lake TN concentrations. Reduction of lake water nitrogen levels will require a better understanding of the nutrient budget for the lake. This will require identification of problematic groundwater inflows into the lake as well as an understanding of nitrogen flux associated with lake sediment.

Although actual remediation of in-lake nitrogen will be difficult to achieve in the short term, this is not to say that the County should not consider implementing BMPs within the watershed. These BMPs could focus on mitigating the highest sources of N and would be targeted at both surface water sources and groundwater sources. A full suite of in-lake and watershed based BMPs and approaches has been considered and is outlined below.

5.3. Summary of BMP Options Considered:

The targeted Lake N levels are very low when compared to the known capabilities of widely accepted BMP approaches and water treatment strategies. In fact, the target nitrogen levels are below N reduction achievable for wastewater plants using conventionally accepted treatment approaches. Three basic BMP approaches are contemplated in Table 17. These are 1.) In-lake Nutrient reduction approaches, 2.) Watershed based Nutrient reduction approaches, and 3.) Regulation based approaches. A general description of each of these approaches is included in the Appendix. The In-Lake and Watershed approaches involve both commonly used BMPs as well as other approaches that are relatively new to implementation in Florida. Both of these types of improvements require Capital expenditures to construct and then operate. The third approach, which is regulation-based, is a watershed approach that would provide specific regulation regarding the land application of nitrogen within the watershed the lake serves. These regulatory approaches include enhanced development standards as well as possible restrictions on land use. In some cases the State has already adopted similar regulations and one option in terms of increased regulatory discharges of N would be to engage the State in implementing watershed based standards that exceed the standards already in place for OFW watersheds and may perhaps be tailored to the specific needs of Lake Clinch.
Table 17 summarizes BMP options considered for the Lake. The options include the following generalized approaches listed below:

In-Water or Near Shore: Treatment approaches that involve either the water column or the near shore littoral zone. These include plantings as well constructed mitigation areas and floating or anchored structures such as aerators.

Upstream Interception: This approach involves interception of runoff before it enters the lake and requires the construction or installation of improvements that may be adjacent to the littoral zone of the lake or may be located further up into the watershed depending on topography and hydraulic characteristics of the channel to be treated. Pollutant reductions are achieved by either retaining or detaining the runoff. These facilities can be on-line or off-line. An on-line facility is one where the improvement retains runoff until a pre-determined stage at which point runoff continues to flow through the impoundment. An off-line improvement is where runoff is intercepted for base flow conditions and treated. An off-line system can be convenient for removing sediment and debris flowing from upstream sources.

Land Use Regulation: This approach entails using land use regulations that would seek to ensure that best management practices are incorporated into future changes in the land use of sites. This approach would suggest the implementation of performance based land use regulations that provide further load reductions to the lake. These additional load reductions could be achieved a number of ways the most restrictive of which would involve the retention of increased volumes of runoff between post development and pre-development conditions.

Nitrogen and Phosphorous Use restrictions: This approach suggests localized regulation that is implemented independent of land use regulations involving development. This approach is generally more complex since the use of fertilizers is regulated by the State of Florida and it could be difficult to promulgate local regulations of products which are regulated by the State.

Current state of the art BMP were evaluated for their compatibility with each generalized approach. If a BMP was deemed compatible with a generalized approach it is noted with a 'Y' (Yes) in the corresponding column. In the cases where a given BMP was determined to be incompatible with a generalized approach, an 'N' (No) is entered in the corresponding column.

Table 17 – BMP Options Considered

Description	In-Water or Near Shore	Upstream Interception	Land Use Regulation	Nitrogen use restrictions
Floating Wetlands	Y	N	N	N
Alum Injection	Y	N	N	N
Reverse Osmosis Purification	Y	N	N	N
Filtration	Y	N	N	N
Wetland system-near shore	Y	N	N	N
Wetland system-upstream	N	Y	N	N
Stormwater Treatment Pond	Y	Y	N	N
Diversion	Y	Y	N	N
Bio-reactor	Y	N	N	N
Reduction of targeted land uses	N	N	Y	N
Reduction of targeted N Use	N	N	N	Y
Sediment Removal	Y	N	N	N
Deep Well Injection	Y	Y	N	N
Lake Hydrologic Optimization	Y	Y	N	N
Vegetative Harvesting	Y	N	N	N
Groundwater Remediation	N	Y	Y	N
NPDES BMPs Street sweeping	Y	Y	Y	NA
NPDES BMPs Public Education	Y	Y	Y	NA

In establishing these approaches, the project team consulted internally as well as externally to identify BMPs implemented within Florida and to identify technologies that are on the cutting edge and fore front in dealing with the issue of de-nitrification of water. These BMPs were then evaluated and assigned a ranking in the categories of 1.) Land Intensive, 2.) Regulatory Hurdles, 3.) Time to Implement, 4.) Length of time to operate, and 5.) N removal/effectiveness. These categories are defined below:

Land Intensive: A ranking of 3 denotes treatment approaches that are the most land intensive and would therefore be expected to require the purchase or lease of land. A ranking of 1 denotes a relatively less land intensive approach.

Regulatory Hurdles: A ranking of 3 denotes an approach with high regulatory hurdles. This includes approaches where significant additional scientific study or engineering would be required in order to demonstrate project compliance with Federal or State regulations. A ranking of 1 denotes projects where relatively few regulatory hurdles exist.

Time to Implement: A ranking of 3 denotes projects where the time to implement is significant (on the order of 7 years or more). A ranking of 1 denotes projects where time to implement is relatively short and expected to be less than 2 years. Projects which can be implemented sooner would be expected to have a more immediate impact on lake water quality.

Length of time to operate: A ranking of 3 denotes projects where the operating time is the longest. Long operating times entailed recurrent maintenance costs and so when a present value analysis is used, projects which may have a seemingly lower cost in terms of capital expenditures can actually be more expensive over the long term.

Design target nitrogen levels: This column represents the design target levels for each type of BMP. The design target nitrogen level is effectively the lowest concentration of nitrogen attainable from the respective BMP at the BMP point of discharge. This column is provided in an effort to identify those technologies today that are capable of reducing pollutant loads from inflow sources to levels that are below the targeted level for the lake. BMP that are unable to discharge water with nitrogen concentrations that are lower than the targeted nitrogen concentrations for the lake will not be able to remediate the lake water quality in and of themselves. To the extent, these technologies may provide an overall reduction in pollutant loading to the lake and therefore have the potential to become part of an overall long term NNC compliance program.

Table 18 provides a summary of each BMP as it relates to operational, regulatory, or capital hurdles unique to a given BMP. A description of each concept is included in the appendix to this report.

Table 18 - BMP relative implementation costs

Technology	Land Intensive	Regulatory Hurdles	Time to Implement	Length of time to operate	Typical resultant N (mg/l)
Floating Wetlands	1	1	2	3	1.0
Alum Injection	2	2	3	3	10.0
Reverse Osmosis	3	3	3	3	5.0
Filtration	3	3	3	3	10.0
Wetland system-near shore	3	3	3	3	1.0
Wetland system-upstream	3	3	3	3	1.0
Stormwater Treatment	3	3	3	3	2.5
Diversion	3	3	3	3	0.0
Bio-reactor	2	2	3	3	0.0
Regulation of land use	NA	3	3	1	1.0 to 3.0
Reduction of N use	NA	3	3	3	0.0
Sediment Removal	3	3	3	1	0.0
Deep Well injection	3	3	3	3	0.0
Lake Hydrologic Optimization	3	3	3	3	Requires study
Vegetative Harvesting	1	2	2	2	0.0
Groundwater Remediation	3	3	3	3	TBD
NPDES BMP-street sweeping	1	1	1	1	varies
NPDES BMP-public education	1	1	1	1	varies

As can be seen from Table 18, only a handful of BMP approaches result in N levels for the particular BMP that are below the Lake target N levels. The other BMP approaches provide an incremental improvement to N levels only in those cases where the inflow N concentration exceed the output concentration of the BMP. BMPs where this is the case would need to be located within areas where watershed flows contain high N levels and the watershed flows could be diverted into the BMP. The varying terrain around the lake limits the areas where these BMPs could be located geographically unless a significant pumping or pipeline configuration were to be considered. An exhibit depicting a potential large scale (>50 Acres) BMP candidate site locations is included in the Appendix. Each of these BMPs was discussed with County staff in terms of past County experience with a given BMP to confirm that the BMP would be considered by the County if deemed cost effective.

5.4. Conclusion

The statistical analysis of collected nutrient data, when evaluated against the rigorous requirements of the FDEP NNC criteria, point to an ideal planning target for Lake N levels that is on the order of 0.41 mg/l. This target nitrogen level is below the natural historic nitrogen level of the Lake and is below the minimum NNC N concentration established for a lake of this type. The reasons for this are several. First, the NNC criteria established by the State are independent of a lake's historic nutrient levels. Impairment classification is assigned independent of the actual natural condition of the specific lake in question. This means that even a slight exceedance of an established criteria within an otherwise pristine lake within a responsibly managed watershed may be classified as impaired. Second, the State criteria does not provide consideration for nutrient variations that result from exceptionally wet or dry periods or extreme loading conditions. The criteria of exceedance does not require that the criteria be exceeded within the same year and technically, a lake that demonstrated an exceedance for a criteria at the beginning and end of a 3 year period could be classified as impaired.

A prudent course of action for the County to undertake would therefore be to develop a phased implementation plan over a 15 year horizon. The implementation plan should provide for 3 years of additional data collection regarding loadings from within the watershed, outfalls into the lake, lake discharges, and sediment sampling and laboratory analysis. Incremental BMPs could be programmed for the remaining 12 years of the program and data collected during the first 3 years could be used to calibrate more precise models for the lake. N levels should be measured through the water column to arrive at an accurate level of total N contained within the Lake. This approach to water quality management would provide a total approach that would employ all reasonable means of lake protection.

6. RECOMMENDATIONS

6.1. Discussion

The goal of water quality management for Lake Clinch as it relates to NNC criteria is to establish NNC levels within the lake that both conform to published FDEP criteria and that represent a healthy, balanced lake. The key component of water quality that is identified for reduction is nitrogen. There is a full range of approaches available to the County to institute best management practices within the lake and the watershed. These approaches will not singularly stop nor reverse the moderate trending in increased nitrogen levels that are associated with the lake, but will over a period of twenty years or more help to re-mitigate forty years of lake impact, resulting from land uses with the watershed.

The key recommendations are:

1. Engage in greater public education of the watershed and its issues and encourage property owners large and small to manage property with the goal of reducing nitrogen introduced into the watershed system either through fertilization practices or the management of yard waste.
2. Collect additional data necessary to better understand the nutrient balance in the lake and the watershed. Watershed mass loadings of nitrogen are passed through the lake on an annual basis but some nitrogen is retained within the lake and results in the moderate upward trend in lake nitrogen levels that were observed in the data.
3. Review historical agricultural uses and practices and identify those sites where groundwater concentrations of nitrogen have been increased due to land application of fertilizer. Identify loadings to the lake from these areas and determine if reduction or elimination of the loading source(s) will result in less nitrogen loading to the lake.
4. Evaluate in-lake sediment flux and determine if this is a meaningful feed source of nitrogen.
5. Evaluate submerged aquatic vegetation present in the lake and consider efficiencies that consider establishing native emergent plant species within the littoral lake edge (about 15 acres). Consider establishing SAV in the 0 to 10 foot range (about 177 acres).

6.2. Additional Monitoring

The nutrient loading model utilized readily available data regarding runoff estimates, atmospheric deposition and septic/point source loads though internal nutrient loading and groundwater may play an equally important role in the lake nutrient cycle. Unfortunately, there wasn’t data available at this time to incorporate into the analysis thus far. Additional data sources that would help to refine recommendations for the lake as well as to provide a better overall understanding are listed below. These additional monitoring activities include a lake vegetation survey, groundwater monitoring and a sediment flux analysis. Descriptions for each of these activities is provided below.

Lake Vegetation Survey:
In a recent survey (September 2014) by the Invasive Plant Management Program the following observations were made.

- Fairly clear water observed with a vertical secchi disk reading of 3.2 meters
- No submerged aquatic vegetation (SAV) observed

A recent SAV survey performed in 2014 by the County's Invasive Plant Management Program observed no submerged aquatic vegetation. The limits of the survey performed by the County should be reviewed and a more comprehensive SAV survey planned to confirm the absence of SAV in the lake. This updated SAV information would be helpful in planning for and encouraging the growth of future SAV within the Lake and would provide a baseline for comparison in the future.

Groundwater Monitoring:
Information regarding groundwater loading is not available for this lake. The pollutant loading model attempts to characterize the septic/point source loads but is not specifically tied to this location. The model doesn't estimate groundwater loadings from other source, i.e. agriculture. It is recommended that a groundwater monitoring survey be conducted to estimate the potential effect of groundwater loadings to the lake. If wells are not readily available, shallow well points could be set down gradient of likely sources. The results could identify the need for additional management actions within the vicinity.

Sediment Monitoring:
An additional source of nutrients could be the lake's sediments. A sediment monitoring effort would characterize the nature of the lake sediments and obtain estimates of nutrient fluxes across the sediment/water interface. Sampling sites would be based primarily on bathymetry, with consideration of any additional information available concerning external sources and/or nature of the sediments. Both the laboratory and *in situ* measurements provide nutrient flux and sediment oxygen demand estimates which will aid in estimation of the internal loadings to the lake.

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8. Appendix A

BMP Terms

Alum Injection- A process whereby pollutants contained within an inflow to a lake are removed by removal of Total Suspended Solids (TSS). The TSS are removed from the inflow via a coagulant (Alum) applied to the stream flow. The resulting sediment is then captured, retained, and later removed from the sediment basis via mechanical means.

Bio-Dredging- An example of this is the BioDi aerobic digester which biologically dredges the accumulated organic matter from sediments. This process can reduce nutrient loadings resulting from sediment and also may serve to consolidate the muck layer.

Bio-Reactor- A system whereby N contained within a stream flow or water body is removed by changing the form of N from a dissolved form into a gaseous form. Other forms of pollution may also be removed as a function of the active biological process and whether it is an aerobic or anaerobic process.

Conversion of Agricultural Lands - Convert existing agricultural and/or public lands to wetlands.

Denitrification- A process whereby Nitrogen concentrations present in water or soil are reduced by some mechanical or biological process.

Detailed upland floodplain mapping - Preserves upland floodplain area which are not currently mapped from future development.

Filtration- A process whereby nutrients are removed using granular or other media.

Floating Wetland- A technology whereby a floating mat is placed in the water. Claimed benefits include reduction of N, P, TSS, Pathogens, and Heavy metals from a water body. Additional benefits may include improvements in dissolved oxygen by reducing BOD demand from suspended organics in the water.

Flowway Improvements - Improve flow way between Crooked and Clinch to expand wetland and surface water storage areas. Develop second wetland/sheet flowway to the west of existing canal to add storage, extend travel time and wetland interactions prior to discharge into Clinch.

Lake Bottom Dredging- A process whereby lake bottom sediment is removed by mechanical means.

Lake Hydrologic Optimization – Add storage areas adjacent or downstream of the lake. Additional storage allows the lake stage to be held higher allowing more interaction with greater areas of shoreline vegetation.

Off-line System- A stormwater runoff treatment and flow attenuation system whereby the base flows and stormwater flows from a watershed are intercepted but may bypass the treatment system for peak flow conditions in those cases where the off-line system itself would not be able to withstand the hydraulic loads from a given storm event or there is a need to maintain some baseflow downstream of the system.

On-line System- A stormwater runoff treatment and flow attenuation system whereby the base flows and stormwater flows from a watershed are intercepted and must pass through the system prior to discharging downstream.

Pilot Project- A project designed and constructed to field test the effectiveness of an existing technology or new technology to achieve targeted reductions in water. These projects may be cooperatively funded and/or sponsored by the provider of the equipment.

Reverse Osmosis System- A water purification process that uses a semipermeable membrane to strip water of various molecules and ions. RO is commonly used in the production of potable water for consumption.

Stormwater Facility- A constructed facility that may be on-line or off-line and that functions to attenuate and treat stormwater runoff flows via either detention or retention of the runoff. The facility may be a wet or dry facility. Pollutant remove efficiencies are typically a function of the facility design and whether or not it is accompanied with plants or other WQ enhancement approaches.

Vegetative Harvesting- A process whereby plants which uptake or fix a desired pollutant in a water body are harvested out of the water body in order to remove the pollutant which was extracted by the plant.