Final

Nutrient Total Maximum Daily Load

For Trout Lake,

Lake County, Florida

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January 4, 2006

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Acknowledgments

This study could not have been accomplished without the significant contributions from staff within the Watershed Assessment Section. Particular appreciation goes to Barbara Donner for her contribution, as all of the basin delineation's, landuse aggregations, and much of the data gathering are a result of her efforts. Additional appreciation is extended to Dr. TS Wu for his assistance and insights on modeling and to Dr. Paul Lee for his assistance in understanding the ground water system. The Department also recognizes the substantial support and assistance provided by the St. Johns River Water Management District staff, particularly their contributions towards understanding the issues, history, and processes at work in the Trout Lake watershed.

1. INTRODUCTION

1.1 Purpose of Report

This report represents the efforts to develop a nutrient TMDL for Trout Lake (Lake). The Lake, located in central Lake County near Eustis (Figure 1), was verified as impaired by nutrients based on elevated levels of the Trophic State Index for lakes, and was included on the verified list of impaired waters for the Ocklawaha Basin that was adopted by Secretarial Order on August 28, 2002.

According to Section 303(d) of the federal Clean Water Act (CWA) and the Florida Watershed Restoration Act, Chapter 403, Florida Statutes, the Florida Department of Environmental Protection (DEP) is required to submit on a recurring basis lists of surface waters that do not meet applicable water quality standards (impaired waters). The methodologies used by the state for the determination of impairment are established in Chapter 62-303, Identification of Impaired waters (IWR), Florida Administrative Code (FAC). Once a waterbody or waterbody segment has been verified as impaired and referenced in the Secretarial Order Adopting the Verified List of Impaired Waters, work on establishment of the Total Maximum Daily Load (TMDL) begins. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water quality based controls to reduce pollution from both point and nonpoint sources and restore and maintain the quality of their water resources (USEPA, 1991)

1.2 Identification of Water Body

Trout Lake is located in the Hicks Ditch watershed (central Lake County, Florida; Latitude $28^0$52’0”, Longitude $81^0$40’56”, Figures 1-A and 1-B). The original 2003 TMDL study by the Department utilized the entire Hicks Ditch Watershed. Subsequent to the adoption of the nutrient TMDL for Trout Lake, the SJRWMD provided significant comments regarding the area of the Hicks Ditch watershed that contributed runoff to Trout Lake. The Department, incorporating the comments of the SJRWMD, revised the Trout Lake watershed to reflect the changes recommended by the WMD. Figure 1-A shows the original watershed (Hicks Ditch) and the current revised watershed (Trout Lake) side by side. The Lake has a surface area of about 102 acres (Florida Lake Watch) and a mean depth of about 9 feet (SJRWMD, 1996). A stream (Hicks Ditch) northeast of the lake collects surface runoff from the majority of the Hicks Ditch watershed and discharges into the lake. Trout Lake has a single major surface-water outlet, which discharges into Lake Eustis.

For assessment purposes, the State of Florida has been divided into water body assessment polygons that are identified using Waterbody Ids and are referred to as WBIDs. Trout Lake is part of WBID 2819A. Additional information about derivation and use of these WBIDs is provided in the “Documentation For The 2002 Update To The State Of Florida’s 303(d) List” dated October 1, 2002, and GIS shapefiles of the WBIDs can be obtained from the following website:
http://www.floridadep.org/water/watersheds/basin411/downloads.htm

The climate of the watershed is generally humid and subtropical. Average annual rainfall is about 51 inches, based on records from 1969 to 1999. The rainfall may enter aquifers through infiltration, fall onto the surface of lakes and streams, enter surface waterbodies as runoff from adjacent land, or return to the atmosphere through evaporation and transpiration. The potential annual evapotranspiration of the area ranges from 41 to 45 inches, with the remaining 6 to 10 inches of rainfall either recharging ground water or entering surface waters through runoff.

Based on the information from Florida's ground water quality monitoring program, the Hicks Ditch watershed is isolated from the Floridan Aquifer by the Hawthorn formation. Therefore, influence from Floridan Aquifer was not considered in this study. The soil of the Hicks Ditch watershed is dominated primarily by seven soil series including Astatula sands, Eureka sands, Wauchula sands, Brighton soils, Fellowship soils, Myakka sands, and Albany sands. All these soil series, except for Astatula sands, are poorly drained. The majority of the watershed area is drained relatively poorly; therefore it is reasonable to consider the surface runoff as the major source of water for Trout Lake.

The watershed contains several land use types, with the predominate land uses consisting of agriculture, wetlands, pine flatwoods, lakes, and residential/urban development (SJRWMD, 1996). Agricultural land use consists of pasture, citrus, a small muck farm, and a few ferneries. The predominate wetland types are marshes, cypress, bayheads, forested depressions, and shrub swamps. There are two types of lakes in the watershed: those that are part of the primary drainage systems and those that are internally drained (landlocked) and only discharge during major storm events. The communities of Eustis and Umatilla are the two significant urban areas in the study area. Residential development is located in the vicinity of these two cities and around several of the lakes in the study area.

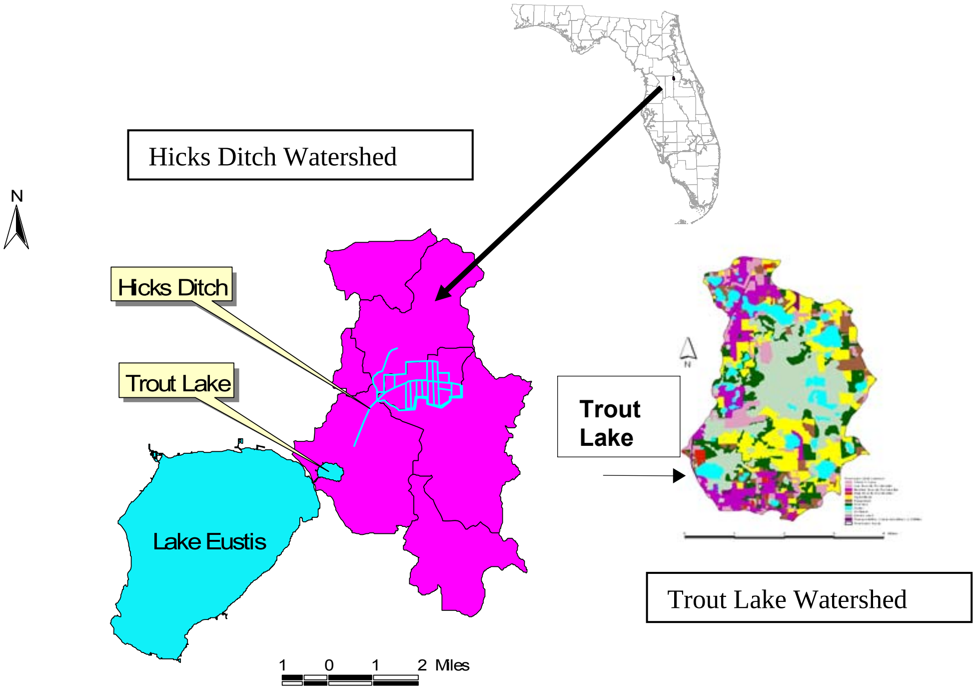


Figure 1-A
Original Hicks Ditch Watershed and
Revised Trout Lake Watershed
(Notice location of Trout Lake in each watershed)

2. STATEMENT OF PROBLEM

Prior to regulatory surface water controls, development in the Trout Lake watershed created flooding and water quality problems. These changes in land use increased the amount of runoff and lowered water quality. The increase of nutrient loading into Trout Lake was one of the consequences of these changes in landuse. In fact, Hicks Ditch is part of the upper Ocklawaha River basin (UORB), which has been identified by the St. Johns River Water Management District (SJRWMD) as a high priority basin for restoration. As an initial effort to reduce nutrient runoff into the Lake, a 670-acre muck farm in the watershed was purchased by the SJRWMD in 1992 through an active muck farm acquisition program (Environmental Science & Engineering, Inc. 1996). At this point in time, data indicate that further reduction of nutrient loading from the watershed into the lake is necessary because the lake is still impaired by the nutrients.

Based on data contained in the DEP database (data), the long-term (1993 – 2000) average concentrations of total phosphorus (TP), total nitrogen (TN), and chlorophyll a (Chl a) were 0.187 mg/L, 1.67 mg/L, and 68.5 µg/L, respectively. The long term TSI calculated from these data according to the procedures adopted in the IWR is 74 (Table 2). For the verified period (June, 1995 – December, 2000), the TP, TN, and Chl a concentrations averaged 0.192 mg/L, 1.62 mg/L, and 59.4 ug/L, respectively, with an average TSI of 73 for the verified period. The mean color of the lake was calculated as 252 platinum-cobalt units. Exceeding the threshold TSI of 60 in any year of the verified period would be sufficient to verify the lake as impaired. Not only is the average TSI of the verified period (73) greater than 60, but each annual mean TSI from the verified period is greater than 60 (Table 2). Based on this information, Trout Lake was verified as impaired by nutrients.

3. Description of Applicable Water Quality Standards and Criteria

Trout Lake is classified as a Class III freshwater body, with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. The Class III water quality criteria applicable to the observed impairment is the narrative nutrient criterion (nutrient concentrations of a body of water shall not be altered so as to cause an imbalance in natural populations of aquatic flora or fauna). Because the nutrient criterion is narrative only, a nutrient related target was needed to represent levels at which imbalance in flora or fauna are expected to occur. For lakes, the IWR threshold for impairment is based on a trophic state index (TSI) and the average color (platinum cobalt units) of the lake water. Since the Lake has a mean color greater than 40 platinum cobalt units, the IWR threshold for impairment is an annual mean TSI of 60, unless paleolimnological or other information such as modeling indicates the natural TSI of the lake was different than 60.

The TSI originally developed by R. E. Carlson (1977) was calculated based on Secchi depth, chlorophyll a concentration, and total phosphorus concentration and was used to describe a lake's trophic state. Carlson's TSI was developed based on the assumption that the lakes were all phosphorus limited. In much of Florida, because the local geology produced a phosphorus rich soil, nitrogen can be the sole or co-limiting factor for phytoplankton population in some lakes. In addition, because of the existence of dark-water lakes in the state, using Secchi depth as an index to represent lake trophic state can produce misleading results. Therefore, the TSI was revised to be based on chlorophyll a, total nitrogen, and total phosphorus concentrations.

The Florida-specific TSI was determined based on the analysis of data from 313 Florida lakes. The index was adjusted so that a chlorophyll a concentration of 20 ug/L was equal to a TSI value of 60. A TSI of 60 was then set as the threshold for nutrient impairment for most lakes (for those with a color higher than 40 platinum cobalt units) because, generally, the phytoplankton may switch to communities dominated by blue-green algae at chlorophyll a levels above 20 ug/L. These blue-green algae are often an unfavorable food source to zooplankton and many other aquatic animals. Some blue-green algae may even produce toxins, which could be harmful to fish and other animals. In addition, excessive growth of phytoplankton and the subsequent death of these algae may consume large quantity of dissolved oxygen and result in anaerobic condition in lakes, which makes conditions in the impacted lake unfavorable for fish and other wildlife. All of these processes may negatively impact the health and balance of native faunal and floral communities.

Because of the amazing diversity and productivity of Florida lakes, some lakes have a natural background TSI that is different from 60. In recognition of this natural variation, the IWR allows for the use of a lower TSI (40) in very clear lakes, a higher TSI if paleolimnological data indicate the lake was naturally above 60, and the development of site-specific thresholds that better represent the levels at which nutrient impairment occurs. As Trout Lake has a mean color greater than 40 platinum cobalt units, the default IWR threshold for impairment is 60. For this study, the Florida Department of Environmental Protection (DEP) used modeling to estimate the natural background TSI by setting land uses to represent natural conditions, and then compared the resulting natural background TSI to the IWR thresholds. The IWR uses as one measure of impairment in lakes, a 10 unit change in TSI from “historical” levels. This 10 unit increase is assumed to represent the transition of a lake from one trophic state (say mesotrophic) to another nutrient enriched condition (eutrophic). The Department has assumed that allowing a 5 unit increase in TSI over the natural background condition would prevent a lake from becoming impaired (changing trophic states) and reserve 5 TSI units to allow for future changes in the basin and as part of the implicit margin of safety in establishing the assimilative capacity.

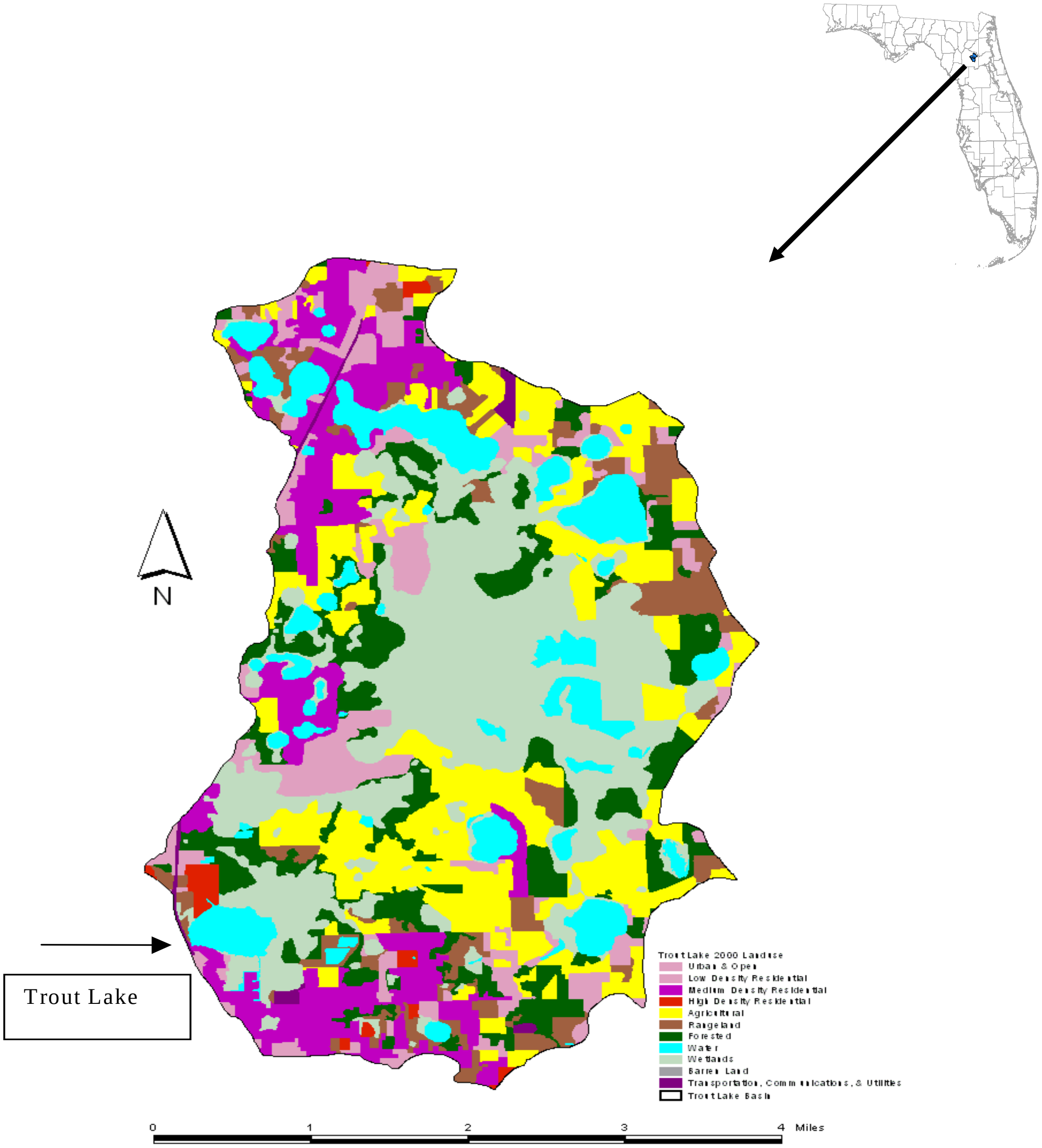


Figure 1-B. The general location and landuse types of Trout Lake watershed.

4. ASSESSMENT OF SOURCES

4.1 Types of Sources

An important part of the TMDL analysis is the identification of pollutant source categories, source subcategories, or individual sources of nutrients in the Trout Lake watershed and the amount of pollutant loading contributed by each of these sources. Sources are broadly classified as either “point sources” or “nonpoint sources.” Historically, the term point sources has meant discharges to surface waters that typically have a continuous flow via a discernable, confined, and discrete conveyance, such as a pipe. Domestic and industrial wastewater treatment facilities (WWTFs) are examples of traditional point sources. In contrast, the term “nonpoint sources” was used to describe intermittent, rainfall driven, diffuse sources of pollution associated with everyday human activities, including runoff from urban land uses, runoff from agriculture, runoff from silviculture, runoff from mining, discharges from failing septic systems, and atmospheric deposition.

However, the 1987 amendments to the Clean Water Act redefined certain nonpoint sources of pollution as point sources subject to regulation under EPA’s National Pollutant Discharge Elimination Program (NPDES). These nonpoint sources included certain urban stormwater discharges, including those from local government master drainage systems, construction sites over five acres, and from a wide variety of industries (see Appendix A for background information about the State and Federal Stormwater Programs).

To be consistent with Clean Water Act definitions, the term “point source” will be used to describe traditional point sources (such as domestic and industrial wastewater discharges) AND stormwater systems requiring an NPDES stormwater permit when allocating pollutant load reductions required by a TMDL (see Section 6). However, the methodologies used to estimate nonpoint source loads do not distinguish between NPDES stormwater discharges and non-NPDES stormwater discharges, and as such, this source assessment section does not make any distinction between the two types of stormwater.

4.2 Potential Sources of TN and TP in Trout Lake Watershed

Point Sources

There are no wastewater facilities authorized to discharge to the lake. Based on the information provided by Department NPDES Stormwater Program staff, the City of Eustis is on the Phase II MS4 list. However, none of the watershed currently lies in an area covered under an MS4 area. As such, there are currently no point sources authorized to discharge to the lake under the NPDES Program.

Nonpoint Sources

The TN and TP loadings to Trout Lake are generated from nonpoint sources. Nonpoint sources addressed in this study primarily include TN and TP loadings from surface runoff, precipitation directly on the surface of the lake, and the contribution from leaking septic tanks. TN and TP loadings through surface runoff were estimated using the Watershed Management Model (WMM) based on the imperviousness and event mean concentration (EMC) of TN and TP from different landuse types of the watershed. The spatial distribution and acreage of different landuse categories were identified using the St. Johns River Water Management District (SJRWMD) 1995 landuse coverage (scale 1:40,000) contained in the DEP GIS library. Methods used to estimate the TN and TP loadings precipitation directly on the surface of the lake, and the contribution from leaking septic tanks are described in detail in Section 5.2.

Landuse of Trout Lake Watershed

Based on information provided by the SJRWMD, the area of Hicks Ditch watershed that drains directly to Trout Lake was subdivided into a Trout Lake watershed. The Trout Lake watershed drains an area of about 9,686 acres into Trout Lake. Landuse categories of the watershed were aggregated using the simplified level 1 codes tabulated in Table 1. The spatial distribution of different landuse types of Trout Lake watershed is given in Figure 1-B.

Table 1. Classification of landuse categories of Trout Lake watershed

Code	Landuse	Acreage
1000	Urban Open	460
	Low density residential	458
	Medium density residential	1137
	High density residential	81
2000	Agriculture	1846
3000	Rangeland	704
8000	Transportation, communication, and utilities	66
4000	Forest/rural open	1267
5000/6000	Water/Wetland	3667

Estimating Nonpoint TN and TP loadings using WMM

WMM development was originally funded by DEP under contract to Camp Dresser and McKee (CDM). Subsequently, CDM has refined the model. WMM is a watershed model designed to estimate annual or seasonal pollutant loadings from a given watershed and evaluate the effect of watershed management strategies on water quality (WMM User's Manual: 1998). While the strength of the model is its capability to characterize pollutant loadings from nonpoint sources, such as those through stormwater runoff, stream baseflow, and leakage of septic tanks, the model handles point sources such as discharge from wastewater treatment facilities. Estimation of pollution load reduction due to partial or full-scale implementation of onsite or regional best management practices (BMP) is also part of this model. The fundamental assumption of the model is that the amount of stormwater runoff from any given landuse is in direct proportion to annual rainfall. The quantity of runoff is controlled by that fraction of the landuse category that is characterized as impervious and the runoff coefficients of both pervious and impervious area.

The governing equation is:

(1) $R_L = [C_p + (C_I - C_p)\ IMP_L] * I$

Where:

R_L = total average annual surface runoff from land use L (in/yr);
IMP_L = fractional imperviousness of land use L;
I = long-term average annual precipitation (in/yr);
C_P = pervious area runoff coefficient; and
C_I = impervious area runoff coefficient.

The model estimate of pollutant loadings is based on nonpoint pollution loading factors (expressed as lbs/ac/yr) that vary by land use and the percent imperviousness associated with each land use. The pollution loading factor M_L is computed for each land use L by the following equation:

(2) $M_L = EMC_L * R_L * K$

Where:

M_L = loading factor for land use L (lbs/ac/yr);
EMC_L = event mean concentration of runoff from land use L (mg/L); EMC varies by land use and pollutant;
R_L = total average annual surface runoff from land use L computed from Equation (1) (in/yr); and
K = 0.2266, a unit conversion constant.

Data required for WMM application include:

- Area of all the landuse categories and the area served by septic tanks
- Percent impervious area of each landuse category
- EMC for each pollutant type and landuse category
- Percent EMC of each pollutant type that is in suspended form
- Annual precipitation
- Annual baseflow and baseflow concentrations of pollutants
- Point source flows and pollutant concentrations.

Because no flow data were available for Hicks Ditch or the outlet from the Lake for the verified period, WMM model calibration was not conducted in this study. Additionally, due to the lack of data, TN and TP contribution from ground water was not considered.

5.0 Loading Estimates

Overall Approach

The goal of the TMDL development for Trout Lake is to identify the maximum allowable TP and TN loadings to the lake so that the lake will meet the water quality standard and maintain its function and designated use as a Class III water. It was initially anticipated that the following three steps would be taken to achieve this goal. The target in the third step was modified, as described in Section 6.

1. TN and TP loadings from various sources in the Trout Lake watershed were estimated using the Watershed Management Model (WMM).
2. Loading estimates from the WMM were entered into the Bathtub eutrophication model to establish the relationship between TN and TP loadings and in-lake TN, TP, and Chl a concentrations. The model results for in-lake TN, TP, and Chl a were used to calculate TSI-predicted (TSI-P) for several different loading scenarios discussed later.
3. The loadings to the lake were adjusted until the TSI-P calculated from the model results was less or equal to the target TSI for the Lake, and the TN and TP loadings that resulted in the target TSI become the nutrient TMDL for Trout Lake.

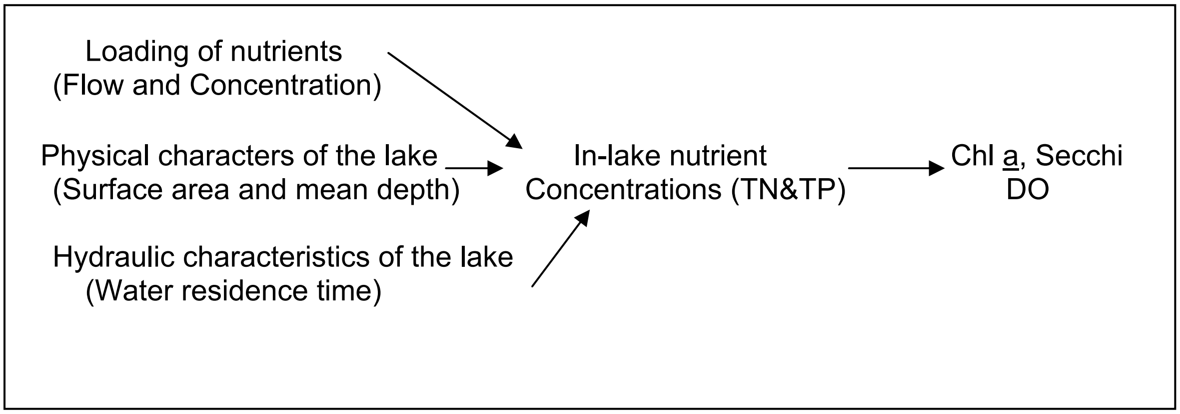
Lake Modeling Using the Bathtub Model

The Bathtub eutrophication model is a suite of empirically derived steady state models developed by the U. S. Army Corps of Engineering (ACOE) Waterways Experimental Station. The primary function of these models is to estimate nutrient concentrations and algal biomass resulting from different patterns of nutrient loadings. The procedures for selection of the appropriate model for a particular lake are described in the Users Manual. The empirical prediction of lake eutrophication using this approach typically can be described as a two stage procedure using the following two categories of models (Walker 1999):

- *Nutrient balance model.* This type of model relates in-lake nutrient concentration to external nutrient loadings, morphometry, and hydrology.
- *Eutrophication response model.* This type of model describes relationships among eutrophication indicators within the lake, including nutrient levels, Chl a, transparency, and hypolimnetic oxygen depletion.

Figure 2 describes the concept scheme used by Bathtub to relate external loading of nutrients to the in-lake nutrient concentrations and the physical, chemical, and biological response of the lake to the level of nutrients.

Figure 2. Bathtub concept scheme



The *nutrient balance model* adopted by Bathtub assumes that the net accumulation of nutrients in a lake is the difference between nutrient loadings into the lake from various sources and the nutrients carried out through outflow and losses of nutrient through whatever decay process occur inside lake:

(3) Net accumulation = Inflow – Outflow – decay

Equation (3) is solved by assuming that the pollutant dynamics in the lake are at a steady state, i.e., the net accumulation of the pollutant in the lake equals zero.

In this study, “inflow” included TN and TP loadings though stormwater surface runoff from various landuse categories, leakage of septic tanks, and atmospheric precipitation. Nutrient outflow was considered primarily through the outflow to Lake Eustis. However, because there was no flow gauging station located in the outflow stream of Trout Lake, the outflow was not specifically defined in the Bathtub modeling process. In this case, the outflow was automatically calculated by Bathtub assuming the inflow and outflow were at a steady state.

To address nutrient decay within the lake, Bathtub provided several alternatives depending on the inorganic/organic nutrient partitioning coefficient and reaction kinetics. The major pathway of decay for TN and TP in the model is through sedimentation to the bottom of the lake.

Prediction of the *eutrophication response* by Bathtub involves choosing one of several alternative models, depending on whether the algal communities are limited by phosphorus or nitrogen, or co-limited by both nutrients. Scenarios that include algal communities limited by light intensity or controlled by the lake flushing rate are also included in the suite of models. In addition, the response of chlorophyll a concentration to the in-lake nutrient level is characterized by two different kinetic processes: linear or exponential. The variety of models available in Bathtub allows the user to choose specific models based on the particular condition of the project lake.

One feature offered by Bathtub is the “calibration factor.” The empirical models implemented in Bathtub are mathematical generalizations about lake behavior. When applied to data from a particular reservoir, measured data may differ from predictions by a factor of two or more. Such differences reflect data limitations (measurement or estimation errors in the average inflow and outflow concentrations), unique features of the particular lake (Walker 1999), and unexpected processes inherent to the lake. The calibration factor offered by Bathtub provides model users with an ability to calibrate the magnitude of lake response predicted by the empirical models. The model calibrated to current conditions against measured data from the lake can then be applied to predict changes in lake conditions likely to result from specific management scenarios under the condition that the calibration factor remains constant for all prediction scenarios.

Data Requirements for Running Bathtub

Data requirements for the Bathtub model include:

- Physical characteristics of the lake (surface area, mean depth, length, and mixed layer depth)
- Meteorological data (precipitation and evaporation retrieved from Climate Interactive Rapid Retrieval Users System of National Climate Data Center)
- Measured water quality data (TN, TP, and Chl a concentrations of the lake water, TN and TP concentrations in precipitation, etc.)
- Loading data (flow and TN and TP concentrations of the flow from various sources)
- Coefficient of variance (CV) of all the measured data

Calculation of Trophic State Index (TSI)

TSI values were calculated using the procedures outlined in Florida’s 1996 305(b) report:

$$TSI = (CHLA_{TSI} + NUTR_{TSI})/2$$

Where:

$CHLA_{TSI} = 16.8 + 14.4 \times LN(CHLA)]$
$TN_{TSI} = 56 + [19.8 \times LN(TN)]$
$TN2_{TSI} = 10 \times [5.96 + 2.15 \times LN(TN + 0.0001)]$
$TP_{TSI} = [18.6 \times LN(TP \times 1000)] - 18.4$
$TP2_{TS} = 10 \times [2.36 \times LN(TP \times 1000) - 2.38]$

The procedure addresses limiting nutrient considerations by calculating $NUTR_{TSI}$:

If $TN/TP > 30$ then $NUTR_{TSI} = TP2_{TSI}$
If $TN/TP < 10$ then $NUTR_{TSI} = TN2_{TSI}$
If $10 < TN/TP < 30$ then $NUTR_{TSI} = (TP_{TSI} + TN_{TSI})/2$

TMDL Scenario Development for Trout Lake

The TMDL of the lake was developed through evaluating TSIs for the following scenarios:

A. The TSI for current conditions.
B. Natural background. TSI after the loadings from all human activities (urban open, low, medium, and high density residential, agriculture and rangeland, and transportation, communication, utilities, and septic tanks) were removed.

Scenario B was considered the natural background condition of the lake. If the TSI of Scenario B is greater than 60, then natural background will become the new target TSI threshold for the lake.

6. Results

6.1 Historical trend of trophic status of Trout Lake

Monthly TN, TP, and Chl a concentrations for Trout Lake from 1993 through 2000 were retrieved from the DEP database. The general locations of the individual stations from which water quality data were collected are shown in Figure 3. Analysis of the data indicated that the spatial variation between stations across Trout Lake is not significant. Therefore, data from all the stations within Trout Lake were pooled together and treated as data collected from one station. Quarterly mean values for TN, TP, and Chl a concentrations were calculated based on the monthly data, and quarterly TSIs were calculated based on the quarterly mean values of TN, TP, and Chl a concentrations. Quarterly TN, TP, Chl a, and TSI values were then used to calculate annual mean values. The long term annual average values of these data were calculated based on annual mean values of each year from 1993 through 2000. The long-term annual average values for the entire verified period were calculated based on the individual mean values of each year from 1995 through 2000. The seasonal trend of TN, TP, Chl a, and TSI were examined by calculating the long-term quarterly mean values based on the quarterly mean values of each year (1993 – 2000). The quarterly means for the verified period were calculated using the data from 1995 through 2000. The individual annual mean TN, TP, Chl a, and TSI values are listed in Table 2, and the long-term quarterly TN, TP, Chl a, and TSI results are listed in Table 3.

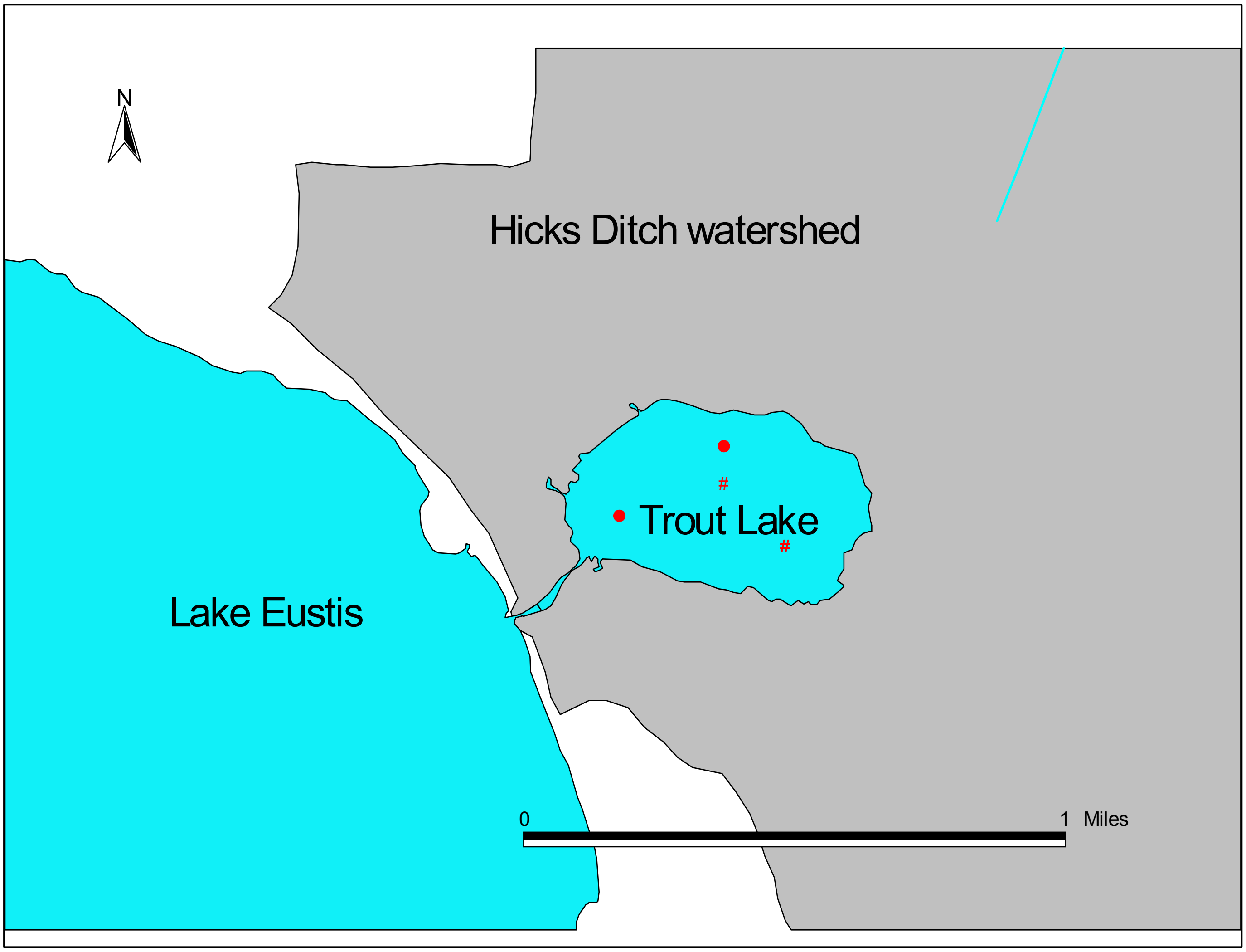


Figure 3. General locations of water quality stations in Trout Lake

As shown in Table 2, the long-term annual average of TN, TP, and Chl a concentrations are 1.67 mg/L, 0.187 mg/L, and 68.5 µg/L, respectively. The long-term TSI is 72. Long-term average TN/TP ratio is about 9.4, which is not significantly different from 10, indicating that the algal communities in this lake may be either borderline co-limited by both nitrogen and phosphorus, or nitrogen limited. For the verified period, the TN, TP, and Chl a concentrations are 1.62 mg/L, 0.192 mg/L, and 59.4 µg/L, respectively. The TSI of the verified period is 71. Based on these data, the lake is eutrophic and exceeded the IWR TSI threshold of 60 for lakes in each year of the verified period.

Table 2. Annual averages of TN, TP, Chl a, and TSI values of Trout Lake from 1993 through 2000. Data represent mean ± 1SE (n=4)

	TN (mg/L)	TP (mg/L)	Chl a (µg/L)	TSI
1993	1.87 ± 0.19	0.205 ± 0.044	110.4 ± 19.3	78 ± 2
1994	1.73 ± 0.14	0.137 ± 0.016	81.5 ± 27.7	71 ± 6
1995	**1.41 ± 0.07**	**0.138 ± 0.014**	**50.8 ± 10.8**	**70 ± 2**
1996	**1.31 ± 0.04**	**0.153 ± 0.026**	**45.6 ± 6.5**	**68 ± 1**
1997	**1.54 ± 0.12**	**0.128 ± 0.024**	**76.0 ± 16.1**	**73 ± 2**
1998	**1.62 ± 0.04**	**0.231 ± 0.024**	**23.5 ± 4.3**	**66 ± 1**
1999	**1.61 ± 0.04**	**0.242 ± 0.030**	**48.6 ± 12.1**	**70 ± 2**
2000	**2.25 ± 0.26**	**0.261 ± 0.052**	**111.9 ± 35.5**	**79 ± 4**
Mean-L	1.67 ± 0.10	0.187 ± 0.019	68.5 ± 11.3	72 ± 2
Mean-V	1.62 ± 0.12	0.192 ± 0.021	59.4 ± 10.8	71 ± 2
Mean-P	1.80 ± 0.07	0.171 ± 0.034	95.9 ± 14.4	74 ± 3

Note:

- Mean-L represents results of record mean (1993 through 2000)
- Bolded data were annual means for the verified period.
- Mean-V: mean values for the modified verified period (January of 1995 through December of 2000)
- Mean-P: mean values for the pre-verified period (1993 through 1994)

Table 3. Seasonal variation of TN, TP, Chl a, and TSI in Trout Lake

	TN (mg/L)	TP (mg/L)	Chl a (µg/L)	TSI
General long-term quarterly mean				
1st quarter	1.78 ± 0.13	0.244 ± 0.026	81.1 ± 16.2	74 ± 2
2nd quarter	1.80 ± 0.15	0.211 ± 0.031	89.9 ± 15.3	75 ± 2
3rd quarter	1.63 ± 0.15	0.140 ± 0.016	54.5 ± 20.3	68 ± 3
4th quarter	1.46 ± 0.06	0.153 ± 0.015	48.6 ± 8.0	70 ± 1
Quarterly mean for the verified period				
1st quarter	1.63 ± 0.10	0.256 ± 0.030	61.7 ± 11.5	72 ± 2
2nd quarter	1.78 ± 0.20	0.215 ± 0.035	83.3 ± 19.3	75 ± 3
3rd quarter	1.66 ± 0.20	0.140 ± 0.019	55.8 ± 25.1	69 ± 3
4th quarter	1.42 ± 0.08	0.158 ± 0.020	36.8 ± 2.9	68 ± 1

Data represent mean ±1SE and sample size (n) equals 8 years for the general long-term quarterly mean values and 6 for quarterly mean values for the verified period.

Examination of the values for TN, TP, Chl a, and TSI in Trout Lake from 1993 through 2000 indicates that all of these water quality indices are relatively higher in 1993 and 2000, and relatively lower in the period from 1994 through 1999. The amount of rainfall appears to explain at least some portion of the variance (Figures 4-A, B, C, and D). Lower rainfall was observed in 1993 and 2000 than the rest of the years during the study period. This is consistent with the trend of the water quality indices.

Except for the TN concentration, the general trend for the seasonal variation is that TP and Chl a concentrations and TSI tend to be at the lowest level in the third and fourth quarter of the year (Table 3). The lowest TN concentration appears in the fourth quarter of the year. While low temperature might contribute to the low Chl a in the fourth quarter of the year, and high rainfall during the third quarter might dilute out the TP concentration in lake, the precipitation alone can not account for the observed seasonal pattern of TN, TP, and Chl a concentrations (Figures 5-A, B, C, and D).

Critical Conditions

Nutrient reductions in the UORB lakes proposed by the SJRWMD were based upon a 10-year average loads. Fulton et al. (2003) note that load reduction goals should be treated as long-term average annual loads and that there is substantial year to year variation in the loadings to the UORB lakes.

Based on Department regulations for nutrient impairment of lakes (62-303, FAC), the overall critical condition (worst case) is based on the annual mean TSI unless other conditions such as unusual relationships between season and TSI or the presence of NPDES point source facilities indicate a different critical condition would be required to ensure that water quality standards will be attained in the water body. As there are no point sources discharging into the Lake, and no unusual seasonal differences in TSI, the critical condition (worst case) for this TMDL is annual mean TSI.

6.2 Estimating TN and TP Sub-basin loadings using WMM

Data required for estimating TN and TP loadings Trout Lake watershed using WMM

To estimate TN and TP loadings from the Trout Lake watershed using WMM, the following data were collected:

A. *Precipitation data* from the weather station located in Lisbon [Lake County (UCAN: 4025,COOP: 085076)]. These data were retrieved from the Climate Interactive Rapid Retrieval User System (CIRRUS) hosted by the Southeast Regional Climate Center. Annual average precipitation and seasonal variation are depicted in Table 4 and Table 5, respectively.

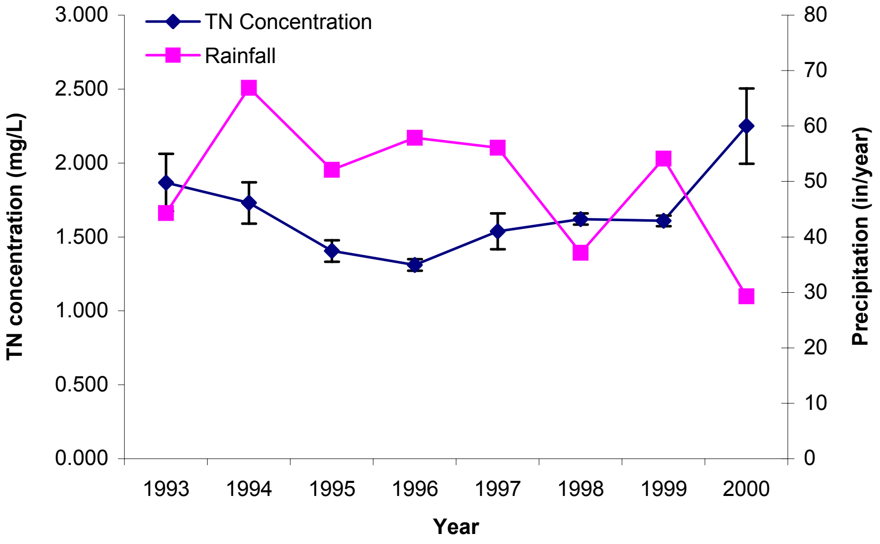


Figure 4-A TN concentration of Trout Lake vs. precipitation

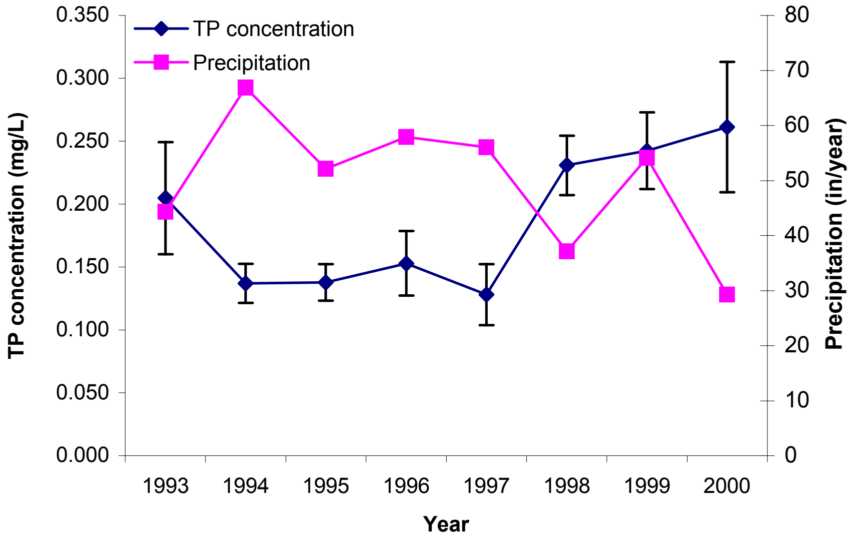


Figure 4-B TP concentration of Trout Lake vs. precipitation

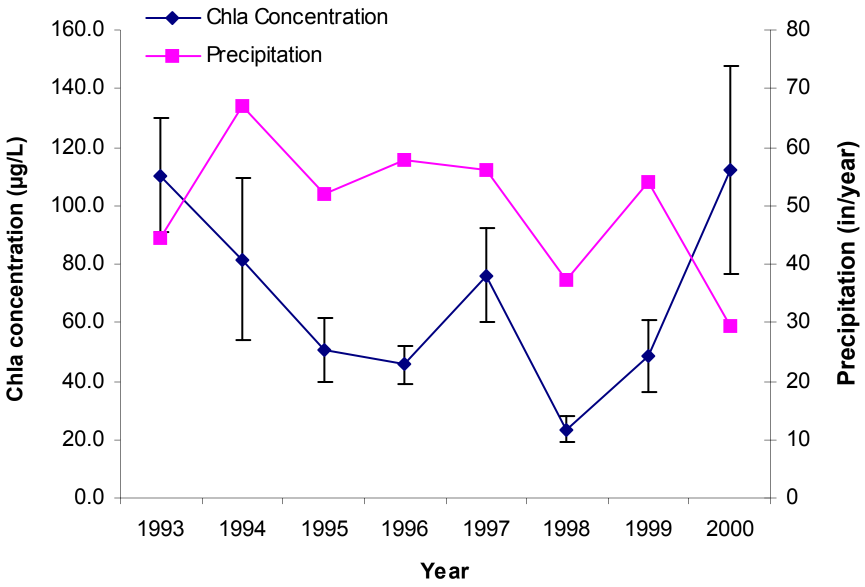


Figure 4-C. Chl a concentration of Trout Lake vs. precipitation

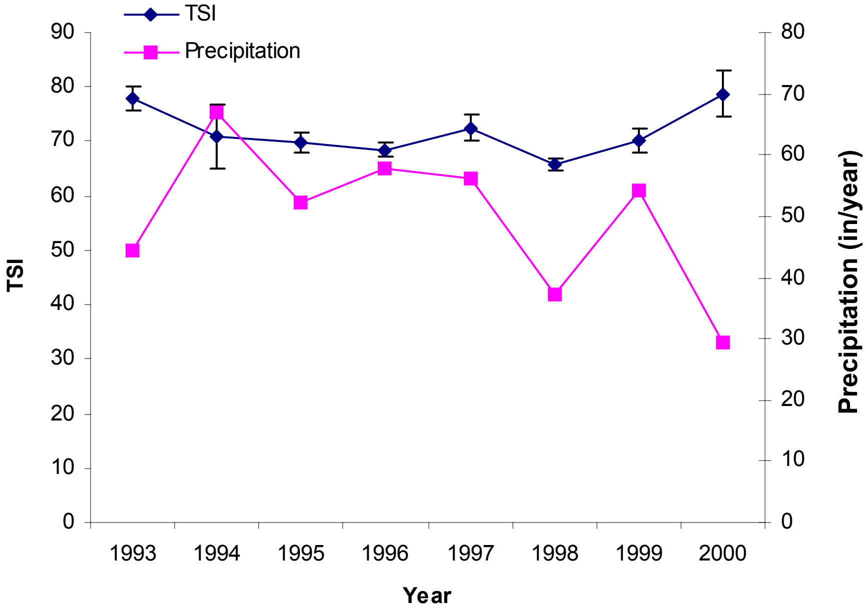


Figure 4-D. TSI of Trout Lake vs. precipitation

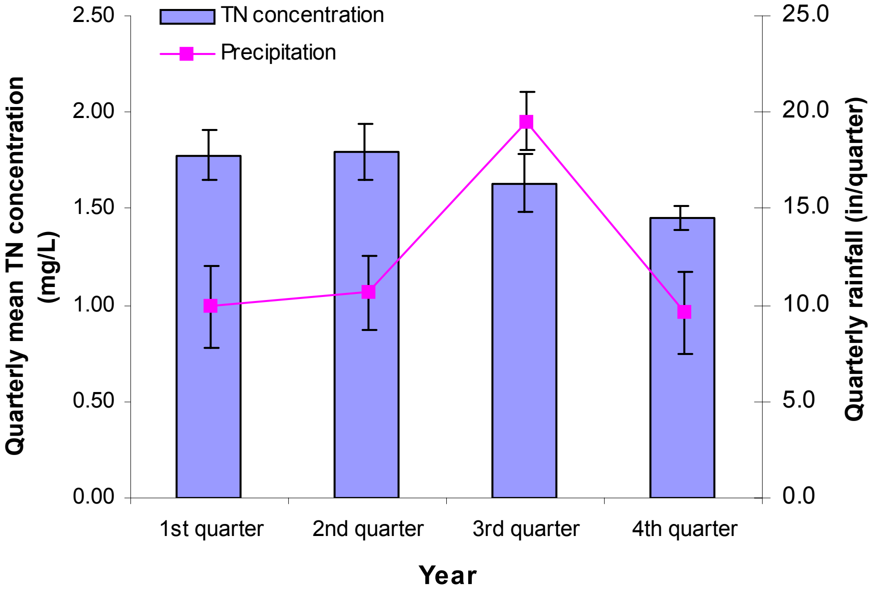


Figure 5-A. Quarterly mean TN concentration of Trout Lake vs. quarterly mean rainfall

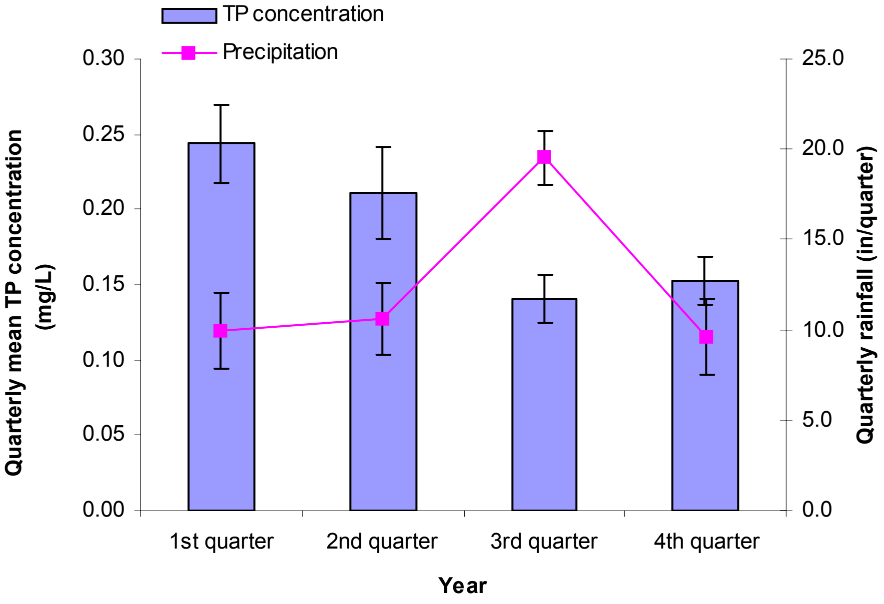


Figure 5-B. Quarterly mean TP concentration of Trout Lake vs. quarterly mean rainfall

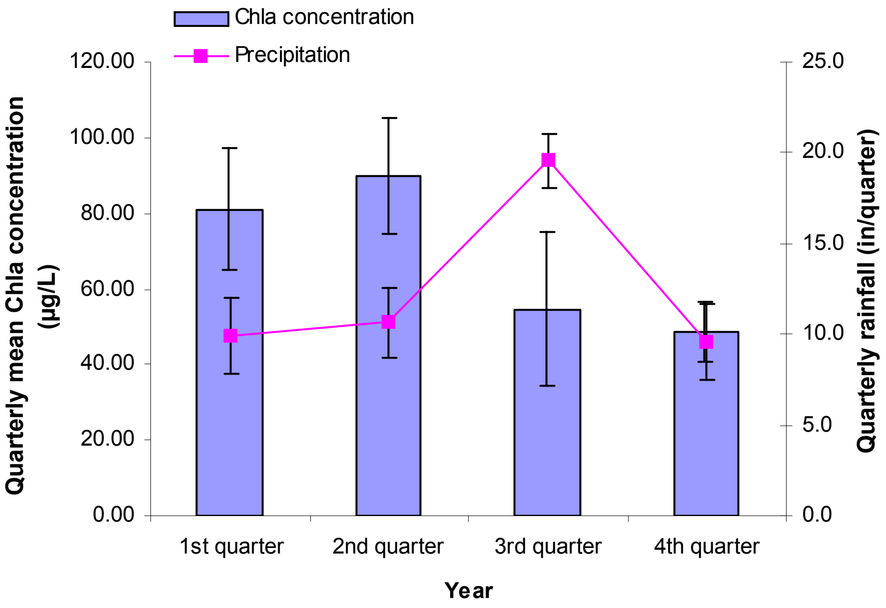


Figure 5-C. Quarterly mean Chl a concentration of Trout Lake vs. quarterly mean rainfall

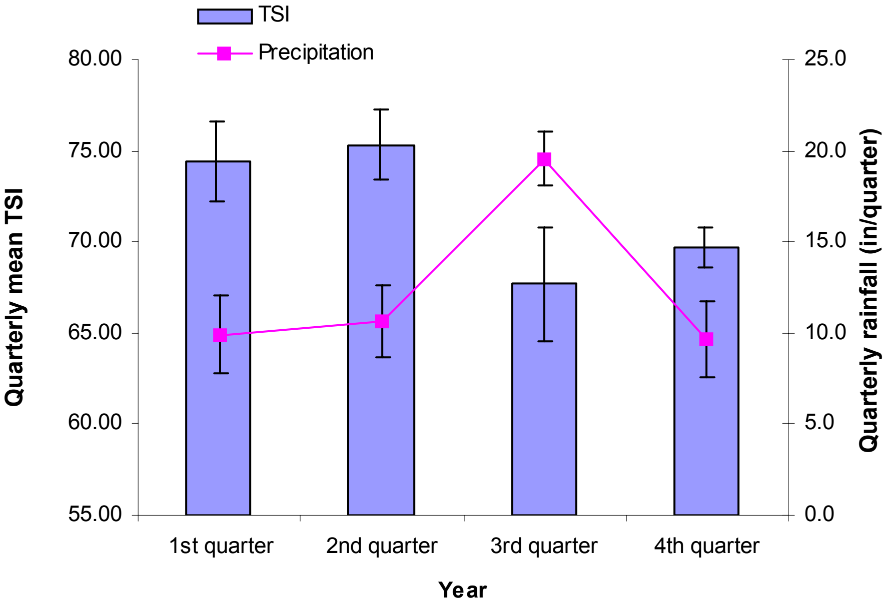


Figure 5-D. Quarterly mean TSI of Trout Lake vs. quarterly mean rainfall

Table 4. Annual precipitation

Year	Annual Precipitation (in/year)
1995	52.12
1996	57.90
1997	56.06
1998	37.18
1999	54.13
2000	29.26

Table 5. Long-term average quarterly precipitation. Data represent mean ±SE (n=6)

Quarter	Quarterly Precipitation (in/quarter)
1st quarter	9.92 ± 2.11
2nd quarter	10.64 ± 1.96
3rd quarter	19.55 ± 1.48
4th quarter	9.62 ± 2.11

For modeling purposes, the Trout Lake watershed was further divided into three sub-basins including the Trout Lake sub-basin (TL) with 8,834 acres, the Pine Meadow sub-basin (PM) with 623 acres, and the Springhill sub-basin (SH) with 229 acres (Figure 6). The subdivision of the watershed into three subbasins was required as the SJRWMD had site-specific EMC's for landuses within PM and SH that were different from those generally used. Pine Meadow was a muck farm purchased by SJRWMD and converted to wetlands. Areas of different landuse categories in the three sub-basins were obtained by aggregating GIS landuse coverage based on the simplified level 1 code and are listed in Table 6. In all three sub-basins, Water/Wetland occupies the highest percentage acreage (32% in TL, 100% in PM, and 78% in SH). The second largest landuse category in TL is claimed by agriculture, which accounts for about 20% of the TL sub-basin. Forest coverage in TL is about 14%, and the rest of the TL sub-basin was occupied by urban, residential area, and transportation facilities. In SH, Water/Wetland occupies the majority of the landuse and about 18% of the land is occupied by agriculture. Forest coverage of the sub-basin is only about 2%.

Based on a study conducted by SJRWMD (Fulton et. al., 2003) the TN and TP concentrations of the discharge from the Water/Wetland areas of the Pine Meadow restoration area and Springhill muck farm were substantially higher than the event mean concentrations (EMC) of the corresponding landuse category in other parts of the Trout Lake watershed (Table 8).

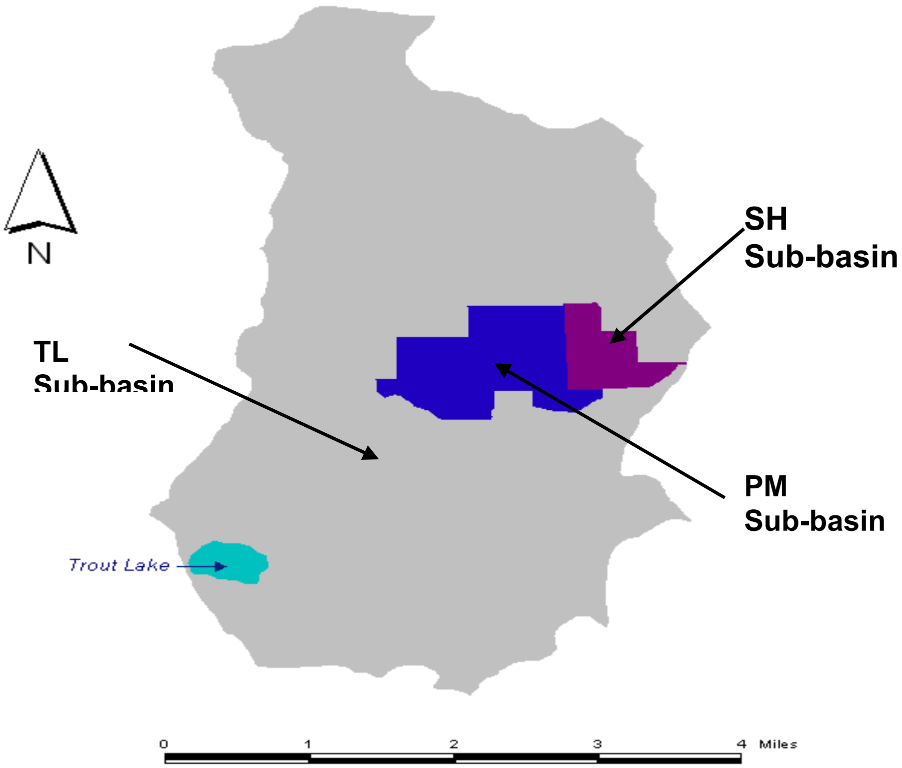


Figure 6. Three sub-basins of the Trout Lake watershed.

Table 6. Distribution of landuse categories of three Trout Lake sub-watersheds

Code	Landuse	Area (acre)		
		TL	PM	SH
1000	Urban Open	460	0	0
	Low density residential	457	0	1
	Medium density residential	1137	0	0
	High density residential	81	0	0
2000	Agriculture	1804	0	42
3000	Rangeland	702	0	2
8000	Transportation, communication, and utilities	66	0	0
4000	Forest/Rural open	1261	0	6
5000/6000	Water/Wetland	2866	623	178

B. *Percent impervious area* of each landuse category is a very important parameter in estimating surface runoff using WMM. Nonpoint pollution monitoring studies throughout the U.S. over the past 15 years have shown that annual “per acre” discharges of urban stormwater pollution are positively related to the amount of imperviousness in the landuse (WMM User’s Manual 1998). Ideally, *impervious area* is considered as the area that does not retain water and therefore, 100% of the precipitation falling on the impervious area should become surface runoff. In practice, the runoff coefficient for impervious area typically ranges from 95 to 100%. Impervious runoff coefficients lower than this range were observed in the literature, but usually this number should not be lower than 80%. For pervious area, the runoff coefficient usually ranges between 10 to 20%. However, values lower than this range were also observed (WMM User’s Manual: 1998). In this study, runoff coefficients of 90% and 1.24% were used for impervious and pervious area, respectively, according to a study conducted previously by SJRWMD (Fulton, et al. 2003).

It should be noted that the impervious area percentages do not necessarily represent directly connected impervious area (DCIA). Using a single-family residence as an example, rain falls on rooftops, sidewalks, and driveways. The sum of these areas may represent 30% of the total lot. However, much of the rain that falls on the roof drains to the grass and infiltrates to the ground or runs off the property and thus does not run directly to the street. For WMM modeling purpose, whenever the area of the watershed that contributes to the surface runoff was considered, DCIA was used in place of impervious area. Because local values were not available, DCIAs used in this study were from literature published values or results from other studies (Table 7).

Table 7 Percent direct connected impervious area for different landuse categories

Landuse Categories	DCIA	Reference
Forest/Rural Open	0.5%	WMM User's Manual: 1998
Urban Open	0.5%	WMM User's Manual: 1998
Agriculture	3.7%	Brown 1995
Low Density Residential	12.40%	Brown 1995
Medium Density Residential	18.70%	Brown 1995
High Density Residential	29.60%	Brown 1995
Communication and Transportation	36.20%	Brown 1995
Rangeland	3.7%	CDM
Water/Wetlands	30%	Harper and Livingston 1999

C. Event mean concentrations (EMC*)* of TN and TP for different landuse categories were provided by SJRWMD (Fulton, personal communication) and are listed in Table 8.

Table 8. Event mean concentration of TN and TP for different landuse categories

Unit: mg/L

Landuse Categories	**TN**	**TP**
Forest/Rural Open	1.25	0.057
Urban Open	2.03	0.313
Agriculture	2.98	0.421
Low Density Residential	1.77	0.177
Medium Density Residential	2.29	0.300
High Density Residential	2.42	0.490
Communication and Transportation	2.83	0.430
Rangeland	1.25	0.057
Water/Wetlands in TL sub-basin	0.82	0.03
Water/Wetlands PM and SH sub-basins	2.54	0.47

EMCs of TN and TP for Urban Open, Agriculture, and Communication and Transportation landuse categories were not specified in the data provided by the SJRWMD. The EMCs for Urban Open used in this study were calculated as the average between the Low Density Commercial area and the High Density Commercial area characterized by SJRWMD. The EMCs for Agriculture landuse were the mean values for Pasture, Tree Crops, Cropland, and

Other Agriculture provided by SJRWMD. The EMCs for Communication and Transportation took the value for the High Density Commercial area provided by SJRWMD.

Based on a study conducted by SJRWMD, TN and TP concentrations of the Water/Wetland area in the Pine Meadow Restoration area and Springhill muck farm were significantly higher than the EMCs of the corresponding landuse category in the TL sub-basin. Based on their suggestion, the TN and TP EMCs for the Water/Wetland area in PM and SH were set at 2.54 mg/L and 0.47 mg/L, respectively (Table 8).

D. Not all of the TN and TP are transported by the stormwater in the dissolved form. The *percentage of the total EMC represented by TN and TP attached to suspended particles* can be defined in WMM. The percent suspended TN and TP values used in this study were provided by SJRWMD and assigned to land uses following the same procedures as used for determining EMCs (Table 9).

Table 9. Percent TP and TN in suspended form for different landuse categories.

Landuse Categories	TP	TN
Forest/Rural Open	50%	25%
Urban Open	41%	29%
Agriculture	34%	9%
Low Density Residential	50%	25%
Medium Density Residential	50%	25%
High Density Residential	50%	25%
Communication and Transportation	41%	29%
Rangeland	50%	25%
Water/Wetlands	69%	41%

E. The *Sediment delivery ratio* determines how much TN and TP attaching to suspended particles will be delivered to the destination waterbody. In this study, the sediment delivery ratio was estimated using the correlation between delivery ratio and watershed area developed by Roehl (1962), which in this case is 0.18.

F. To estimate the TN and TP loadings from leakage of septic tanks, WMM incorporates the concept of “septic tank failure loading rate.” The annual failure rate reported for the country is 3 – 5 percent. Pollutant loading rates reported in the WMM Users Manual assume 50 gallons per capita per day usage. The mid-range of loading rates for failing septic tanks is 2.0 mg/L for TP (about a 160% to 250% increase) and for TN is 15.0 mg/L (about a 140% to 200% increase). To provide a Margin of Safety, this study adopted the high end of the range in the User Manual, which were 30.0 mg/L for TN and 4.0 mg/L for TP (WMM User Manual: 1998).

Another value required by WMM to estimate the influence from leaking septic tanks on TN and TP loading is the “septic tank failure rate,” which defines the frequency at which septic tanks may fail. Studies conducted on the water quality of the Ocklawaha River Basin found that annual frequency of septic tank repairs was about 0.97% (Ocklawaha Basin Status Report 2001). For average annual conditions, it is conservative to assume that septic tank systems failures would be unnoticed or ignored for five years before repair or replacement occurred (WMM User Manual: 1998). Therefore, the septic tank failure rate used in this study was calculated by multiplying repairing frequency (0.97%) by 5 (years) and was about 5%.

The quantity of surface runoff into Trout Lake estimated using WMM

The year by year surface runoff into Trout Lake from TL, PM, and SH predicted using WMM is listed in Tables 10-1, 10-2, and 10-3, respectively.

Table 10-1. Annual surface runoff from TL.

Unit: acre-feet/year

Landuse Categories	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Forest/Rural Open	92	103	99	66	96	52
Urban Open	34	37	36	24	35	19
Agriculture	354	394	381	253	368	199
Low Density Residential	243	270	262	173	253	137
Medium Density Residential	881	978	947	628	915	494
High Density Residential	97	108	104	69	101	54
Communication and Transportation	96	106	103	68	100	54
Rangeland	138	153	148	98	143	77
Water/Wetlands	3469	3854	3731	2473	3603	1947
Total	5404	6003	5812	3852	5612	3034

Table 10-2. Annual surface runoff from PM.

Unit: acre-feet/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	0	0	0	0	0	0
Urban Open	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Low Density Residential	0	0	0	0	0	0
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	0	0	0	0	0	0
Water/Wetlands	1474	1638	1586	1051	1531	828
Total	1474	1638	1586	1051	1531	828

Table 10-3. Annual surface runoff from SH.

Unit: acre-feet/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	0	1	0	0	0	0
Urban Open	0	0	0	0	0	0
Agriculture	8	9	9	6	9	5
Low Density Residential	1	1	1	1	1	0
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	0	0	0	0	0	0
Water/Wetlands	422	469	454	301	438	237
Total	431	480	464	308	448	242

According to Table 10, among the three sub-basins, the largest surface runoff was from TL, which ranged from 3,034 to 6,003 acre-foot/year from 1995 through 2000. The surface runoff produced in PM and SH in the same period was 828 to 1,638 acre-foot/year and 242 to 480 acre-foot/year, respectively. In all the three sub-basins, surface runoff from the Water/Wetland dominated, and accounted for about 64%, 100%, and 98% of the total stormwater produced in TL, PM, and SH, respectively. The Medium Density Residential area in TL contributed about 16% of the flow. The individual flow contributions from all the other landuse categories of all the three sub-basins were less than 10%.

Considering that 1996 has the highest annual rainfall and 2000 has the lowest annual rainfall, and that no difference was found between the percent surface runoff between these two years, it appears that the percent distribution of surface runoff from different landuse categories is not significantly influenced by the annual rainfall.

TN and TP loadings from Trout Lake watershed

The annual TN and TP loadings from the three sub-basins are listed in Table 11-1, 11-2, and 11-3 and 12-1, 12-2, and 12-3.

According to Table 11, TL at 8,834 acres contributed the largest total amount of TN among the three sub-basins, with loads ranging from 8,634 to 17,086 lbs/year (0.977 to 1.934 lbs/acre TN) from 1995 through 2000. In comparison, PM at 623 acres contributed between 4,971 to 9,837 lbs of TN/year (7.979 to 15.790 lbs/acre TN), and SH at 229 acres contributed 1,130 to 2,233 lbs TN/year (4.934 to 9.751 lbs/acre TN), in the same time period. For all the three sub-basins, Water/Wetland area was the largest contributor of TN among all the landuse categories, contributing about 34%, 100% and 97% of the TN load in TL, PM, and SH, respectively. In TL, the Medium Density Residential area was the second largest TN contributor. The TN contribution from this landuse area was about 28%. Agriculture contributed about 17% of the TN in TL sub-basin, and the individual contributions from all the other landuse categories in all three sub-basins were less than 10%.

Table 11-1. Annual TN loadings from TL.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	250	278	269	178	260	140
Urban Open	142	157	152	101	147	80
Agriculture	2656	2950	2856	1893	2758	1491
Low Density Residential	933	1037	1004	665	969	524
Medium Density Residential	4374	4859	4704	3117	4542	2455
High Density Residential	508	565	547	362	528	285
Communication and Transportation	563	626	606	401	585	316
Rangeland	374	415	402	266	388	210
Water/Wetlands	5158	5730	5548	3676	5357	2896
Septic tanks	422	469	454	301	439	237
Total	15380	17086	16542	10960	15973	8634

Table 11-2. Annual TN loadings from PM.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	0	0	0	0	0	0
Urban Open	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Low Density Residential	0	0	0	0	0	0
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	0	0	0	0	0	0
Water/Wetlands	8855	9837	9524	6312	9197	4971
Septic tanks	0	0	0	0	0	0
Total	8855	9837	9524	6312	9197	4971

Table 11-3. Annual TN loadings from SH.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	1	1	1	1	1	1
Urban Open	0	0	0	0	0	0
Agriculture	62	69	67	44	64	35
Low Density Residential	3	3	3	2	3	2
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	1	1	1	1	1	1
Water/Wetlands	1944	2159	2091	1385	2019	1091
Septic tanks	0	0	0	0	0	0
Total	2011	2233	2163	1433	2088	1130

From 1995 through 2000 the TL sub-basin was the largest source of TN, with loads ranging from 8,634 to 17,086 lbs TN/year. During the same period, the largest TP contribution was from the PM sub-basin with loads ranging from 793 to 1,550 lbs TP/year. TL contributed from 641 to 1,270 lbs TP/year, and SH contributed, 136 to 269 lbs TP/year, in the same time period (Figure 12). For both PM and SH, the largest TP contributor was the Water/Wetland area. In TL, however, the Medium Density Residential area was the largest TP source, accounting for about 37% of the total TP created in the TL sub-basin. The second largest TP contributor was agriculture, contributing 26%. The TP contribution from the Water/Wetland area only accounted for about 11% of the total TP loading in TL, and individual contributions from all the other landuses categories were less than 10%.

Table 12-1. Annual TP loadings from TL.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	8	9	9	6	9	5
Urban Open	19	21	20	14	20	11
Agriculture	293	325	315	209	304	164
Low Density Residential	69	77	74	49	72	39
Medium Density Residential	425	472	457	303	441	238
High Density Residential	76	85	82	54	79	43
Communication and Transportation	74	83	80	53	77	42
Rangeland	13	14	14	9	13	7
Water/Wetlands	130	145	140	93	135	73
Septic tanks	35	39	37	25	36	19
Total	1142	1270	1228	815	1186	641

Table 12-2. Annual TP loadings from PM.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	0	0	0	0	0	0
Urban Open	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0
Low Density Residential	0	0	0	0	0	0
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	0	0	0	0	0	0
Water/Wetlands	1395	1550	1500	994	1449	783
Septic tanks	0	0	0	0	0	0
Total	1395	1550	1500	994	1449	793

Table 12-3. Annual TP loadings from SH.

Unit: lbs/year

Landuse Categories	1995	1996	1997	1998	1999	2000
Forest/Rural Open	0	0	0	0	0	0
Urban Open	0	0	0	0	0	0
Agriculture	7	8	7	5	7	4
Low Density Residential	0	0	0	0	0	0
Medium Density Residential	0	0	0	0	0	0
High Density Residential	0	0	0	0	0	0
Communication and Transportation	0	0	0	0	0	0
Rangeland	0	0	0	0	0	0
Water/Wetlands	235	261	253	168	244	132
Septic tanks	0	0	0	0	0	0
Total	242	269	260	173	251	136

Like the percent distribution of TN loading, the distribution of TP loadings from different landuse categories is not significantly influenced by annual precipitation.

Atmospheric loading of TN and TP into Trout Lake

One source of TN and TP loading to Trout Lake that is not considered by WMM is the TN and TP falling directly into the lake through precipitation. In this study, atmospheric loading of TN and TP was calculated by multiplying the amount of precipitation directly falling on to the lake surface (calculated by multiplying annual precipitation by surface area of the lake) by the TN and TP concentration of the rainfall. Because no TN and TP concentrations of the rainfall were found for the project area, published values were adopted in this study, which were 0.1 mg/L and 0.05 mg/L for TN and TP, respectively (Stites, et al 2001). Calculated annual TN and TP loadings are tabulated in Table 13.

Table 13. Atmospheric Loading of TN and TP into Trout Lake

Unit: lbs/year

Year	TN	TP
1995	121	60
1996	134	67
1997	130	65
1998	86	43
1999	125	63
2000	68	34
Mean	**110**	**55**
SE	**11**	**6**
CV	**10%**	**10%**

Summary of the TN and TP loadings into Trout Lake from the various sources

The annual average TN and TP loadings (over the period from 1995 through 2000) from runoff in the Trout Lake watershed, septic tank leakage, and atmospheric deposition is summarized in Table 14.

Table 14. Average annual quantity of surface runoff and TN and TP loadings into Trout Lake. Data represent mean ± 1 SE (n=6)

Item	Quantity
Surface runoff from Trout Lake watershed (acre-foot/year)	6700 ± 671
Precipitation (acre-foot/year)	406 ± 41
TN loading from Trout Lake watershed (lbs/year)	23668 ± 2369
TN loading from atmospheric precipitation (lbs/year)	110 ± 11
TN loading from septic tank (lbs/year)	387 ± 39
TP loading from Trout Lake watershed (lbs/year)	2516 ± 252
TP loading from atmospheric precipitation (lbs/year)	55 ± 6
TP loading from septic tank (lbs/year)	32 ± 3
Total amount of water into Trout Lake (acre-foot/year)	7106 ± 711
Total TN loading into Trout Lake (lbs/year)	24165 ± 2419
Total TP loading into Trout Lake (lbs/year)	2603 ± 261

6.3 Establishing the relationship between TN and TP loading and in-lake TN, TP, and Chl a concentrations using the Bathtub model

Data required for calibrating Bathtub eutrophication model

The relationship between TN and TP loading and the in-lake TN and TP concentrations was established through fitting the Bathtub predictions with the measured TN and TP concentrations of the lake. To calibrate the model, the following data were required:

1. Physical characteristics of the lake (surface area, mean depth, and mixed layer depth)
2. Meteorological data (precipitation and evaporation)
3. Measured water quality data (TN, TP, and Chl a concentrations of the lake water)
4. Loading data (flow and TN and TP concentrations of the flow from various sources).

Because Bathtub allows both error and variability analysis, whenever there were historical data, long-term average values and the corresponding coefficient of variance (CV) of the average values were calculated and entered into the model as inputs. All the data that were required for model calibration are shown in Tables 15 through 17.

Because no lake stage data were available at the time this study was conducted, a fixed lake volume was adopted for the Bathtub modeling. The long-term average surface area was obtained from Florida LAKEWATCH (http://lakewatch.ifas.ufl.edu/), as 102 acres (about 0.413 km^2). The mean depth is about 9 feet (about 2.74 m, SJRWMD 1996). Because the lake is relatively shallow, the mixed layer depth is assumed equal to the mean depth of the lake.

Table 15. Precipitation and evaporation

Unit: ft/year

Year	Precipitation	Evaporation
1995	4.33	4.07
1996	4.82	4.49
1997	4.66	4.23
1998	3.08	3.51
1999	4.49	3.81
2000	2.43	4.46
Mean	3.97	4.10
SE	**0.12**	**0.05**
CV	**10.0%**	**3.8%**

Table 16. Measured TN, TP, and Chl a concentrations of Trout Lake

Year	TN (mg/L)	TP (mg/L)	Chl a (ug/L)
1995	1.40	0.138	50.8
1996	1.31	0.153	45.6
1997	1.54	0.128	76.0
1998	1.62	0.231	23.5
1999	1.62	0.242	48.6
2000	2.25	0.261	111.9
Mean	1.62	0.192	59.4
SE	117	21	10.8
CV	7%	11%	18%

Table 17. Predicted Flow and TN and TP concentrations of different sources

(hm^3/year = cubic hectometers/year)

Land Use	Flow (hm^3/year)	TN (mg/L)	TP (mg/L)
Forest/Rural Open	0.10	0.997	0.034
Urban Open	0.04	1.547	0.208
Agricultural	0.41	2.755	0.304
Low density residential	0.28	1.412	0.105
Medium density residential	1.00	1.826	0.177
High density residential	0.11	1.930	0.290
Transportation, Communications, and Utilities	0.11	2.162	0.286
Rangeland	0.16	0.997	0.034
Water/Wetlands	6.07	1.094	0.121

Note:

a) Bathtub does not allow direct input of loading, therefore the data presented in Table 17 are the simulated flow and TN and TP concentrations.

b) The flow and TN and TP concentrations presented here are the mean values simulated for the verified period (1995 through 2000).

c) The TN and TP concentrations are different from the EMC's listed in Table 8. The EMC concentrations in Table 8 represent the concentrations at the beginning of the overland transport to the Lake. Because some fraction of the TN and TP from each landuse category is in the particulate form and thus subject to attenuation during transport to the water body, the final concentrations entering the Lake (Table 17) will be different from the starting concentration (EMC).

Calibrating Bathtub eutrophication model

To calibrate the model, each source of TN and TP previously identified (except septic tanks) was input to the model as an independent tributary (Table 17). The TN and TP contributions from septic tanks are characterized with areal flux rates, which are 1.17 mg/m^2-day for TN and 0.1 mg/m^2-day for TP.

Bathtub provides alternative models for estimating the influence of sedimentation on the in-lake TN and TP concentrations. In this study, the settling velocity model was chosen for both TN and TP. This model assumes that the sedimentation of TN and TP is in first-order kinetics and should linearly correlate with the in-lake TN and TP concentration. The model also assumes that the sedimentation is influenced by the depth of the lake, i.e., the deeper the lake, the slower the sedimentation. This model fit the condition of Trout Lake because the lake is relatively shallow. Continued wind mixing prevents the lake from forming thermal stratification, a process that prevents the particles from being re-suspended once settled down to the bottom. Continued wind mixing through the entire water column also reduces the particle settling rate by continuously bringing the settled particle back in to water column. These processes could produce a relatively low settling rate in the lake. Other sedimentation models provided by Bathtub assume second-order kinetics, which fit reasonably well with lakes that thermally stratify during the summer, but could overestimate the sedimentation of Trout Lake, and in turn cause underestimation of the in-lake TN and TP concentration.

Bathtub provides two chlorophyll a models based on the assumption of nitrogen and phosphorus co-limitation: Model 1 and 3. Model 1 assumes that algal communities are co-limited, not only by nitrogen and phosphorus, but also by light intensity. This model seemed to fit Trout Lake because the lake has a high chlorophyll concentration and the self-shading effect was possible. However, application of this model yielded a Chl a concentration much lower than the measured data. Therefore, in simulating Chl a response, Model 3 was adopted. This model assumes that the primary production of the lake was co-limited by nitrogen and phosphorus, but not by light intensity (Walker 1999). This could be the case in Trout Lake because the lake was large and shallow. Wind mixing could constantly stir the entire water column and bring the algal cells in the deep water up to the surface so that no cells would be permanently shaded. Using this model, a reasonable fit between predicted and measured Chl a was achieved.

Calibration factors were applied to fit TN and TP predictions to the measured data. Two calibration methods are provided by Bathtub for phosphorus and nitrogen: Method 0 calibrates decay rates and Method 1 calibrates concentration. In the first case, the calibration factors are applied to estimated sedimentation rates in computing nutrient balances. In the second case, the factors are applied to estimated concentrations. In Method 0, it is assumed that the error is attributed primarily to the sedimentation model. In Method 1, the error source is unspecified (some combination of input error and sedimentation model error). The latter may be used when predicted nutrient profiles are insensitive to errors in predicted sedimentation rate because the mass balance is dominated by inflow and outflow terms (low hydraulic residence times) (Walker 1999). In this study, Method 1 was adopted to calibrate the concentration. Typical calibration factors for TN and TP recommended by the Bathtub user’s manual are 0.5 – 2.0 for TP and 0.33 – 3 for TN. In this study, 1.4 and 1.3 were adopted for calibrating TP and TN, respectively. Results of model calibration are listed in Table 18.

Table 18. Bathtub calibration results

Parameter	Measured	Estimated	Error
TP (mg/l)	0.192	0.191	1%
TN (mg/l)	1.622	1.649	2%
Chl a (µg/l)	59.4	60.2	1%
TSI	73	74	1%

TSI was calculated using the procedures outlined in Florida's 1996 305(b) report for both measured and Bathtub predicted data. Using the measured TN, TP, and Chl a concentration, the calculated TSI is 73. When Bathtub predicted TN, TP, and Chl a concentrations were used, the resulted TSI is 74. The error between these two TSIs is only 1%, indicating the TSI calculated based on Bathtub predicted TN, TP, and Chl a concentrations properly predicted the TSI resulting from the measured data.

Evaluating Natural Background TSI of Trout Lake

Once the model was calibrated, the background TN and TP loading without the loadings generated from the existing level of human activities were estimated using the following procedures:

1. All the man-made landuse categories (Urban open, Agricultural, Low-Density Residential, Medium Density Residential, High Density Residential, Transportation and Communication, and Rangeland) were evaluated as Forest/Rural open. The loading from septic tanks was also removed.
2. The TN and TP concentrations of the Water/Wetland area in PM and SH were reduced to the level of the natural Water/Wetland.
3. TN and TP loadings through surface runoff were then estimated using the calibrated WMM, and a long-term average precipitation of 47.77 inches/year (over the period from 1995 through 2000).
4. TN and TP concentrations from Forest/Rural Open and Water/Wetland were calculated by dividing the total loadings from the Trout Lake watershed by the total flow (Table 19).

Table 19. Flow and TN and TP concentrations of surface runoff from Forest/rural open and Water/Wetland area

Land Use	Flow (Hm^3/year)	TN concentration (mg/L)	TP concentration (mg/L)
Forest/Rural Open	0.5	0.997	0.034
Water/Wetland	6.07	0.592	0.016

5. The flow and TN and TP concentrations of surface runoff from Forest/rural open and Water/wetland area were then entered into Bathtub to estimate the in-lake TN, TP, and Chl a concentrations.

6. The TSI was calculated based on the predicted TN, TP, and Chl a concentrations. The resulting TSI of 49 was considered the natural background TSI of Trout Lake and any further reduction of the TSI of the lake by additional reductions in the loadings was not considered. The resulting TN, TP, and Chl a concentration and TSI are listed in Table 20.

Table 20. TN, TP, and Chl a concentrations and TSI after all the human landuse categories were treated as Forest/Rural Open and Water/Wetland

TP (mg/l)	0.028
TN (mg/l)	0.78
Chl a (µg/l)	9.9
TSI	49

According to Table 20, after all the human landuse categories were treated as Forest/Rural Open area, TN, TP, and Chl a concentrations decreased about 53%, 85%, and 84%, respectively, over the existing condition (Table 18). The TSI value decreased from 74 to 49.

The results in Table 20 compare favorably to those obtained by the SJRWMD for the Upper Oklawaha River Basin Pollutant Load Reduction Goal. The SJRWMD used the ecoregional approach and found a TP range of 0.021 – 0.025 mg/L (Table 20 value of 0.028 mg/L) and a TN range of 0.72 – 0.82 mg/L (Table 20 value of 0.78 mg/L).

According to the IWR, a lake is only considered impaired by nutrients when (1) The TSI of the lake is higher than 60 (if the water color of the lake is higher than 40 pcu.); (2) The current TSI is 10 units higher than the background TSI; (3) There is a positive increase in TSI over the study period. As previously stated, when natural background can be established, the TMDL target will be the natural background TSI of 49 plus 5 TSI units, which in this case is a TSI of 54.

TSI-nutrient loading curves were developed for both TN and TP in this study (Figure 7 and Figure 8). According to these curves, the TN and TP loadings that result in a TSI of 54 are 9,733 and 521 lbs/year respectively. These loadings represent a 60% and 80% loading reduction from the current loadings of 24,165 lbs/year TN and 2,603 lbs/year TP.

7. Determination of TMDL

The objective of a TMDL is to provide a basis for allocating acceptable loads among all of the known pollutant sources in a watershed so that appropriate control measures can be implemented and water quality standards achieved. A TMDL is expressed as the sum of all point source loads (Waste Load Allocations), nonpoint source loads (Load Allocations), and an appropriate margin of safety (MOS), which takes into account any uncertainty concerning the relationship between effluent limitations and water quality:

$$\mathbf{TMDL = \sum WLAs + \sum LAs + MOS}$$

As mentioned in Section 4.1, the WLA is broken out into separate subcategories for wastewater discharges and stormwater discharges regulated under the NPDES Program:

$$\mathbf{TMDL \cong \sum WLAs_{wastewater} + \sum WLAs_{NPDES\ Stormwater} + \sum LAs + MOS}$$

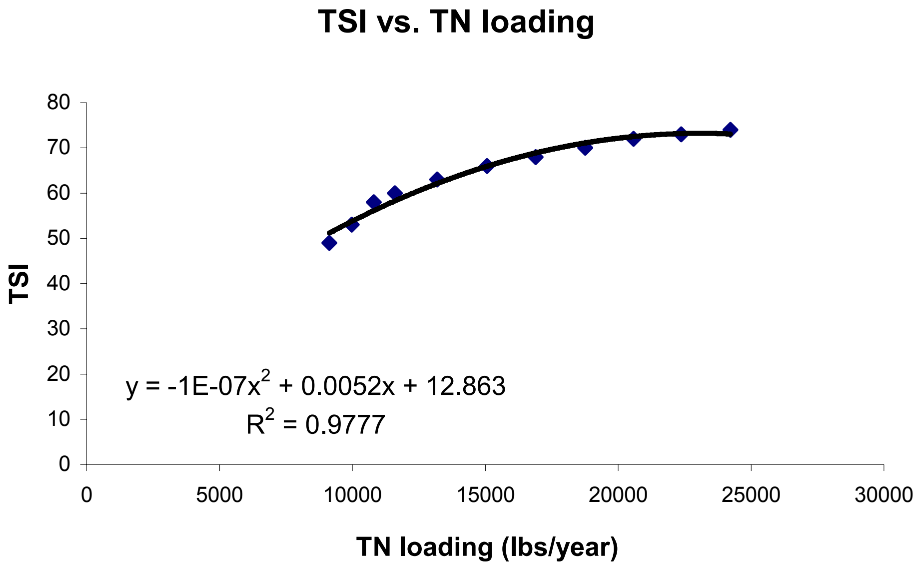


Figure 7. TSI-TN loading curve

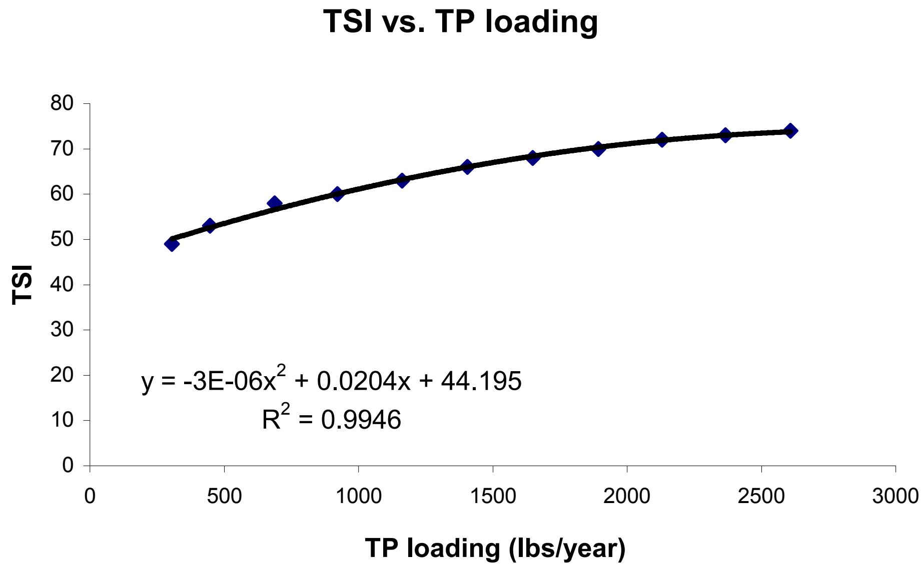


Figure 8. TSI-TP loading curve

It should be noted that the various components of the TMDL equation may not sum up to the value of the TMDL because a) the WLA for NPDES stormwater is typically based on the percent reduction needed for nonpoint sources and is accounted for within the LA, and b) TMDL components can be expressed in different terms [for example, the WLA for stormwater is typically expressed as a percent reduction and the WLA for wastewater is typically expressed as a mass per day].

WLAs for stormwater discharges are typically expressed as “percent reduction” because it is very difficult to quantify the loads from MS4s (given the numerous discharge points) and to distinguish loads from MS4s from other nonpoint sources (given the nature of stormwater transport). The permitting of stormwater discharges is also different than the permitting of most wastewater point sources. Because stormwater discharges cannot be centrally collected, monitored and treated, they are not subject to the same types of effluent limitations as wastewater facilities, and instead are required to meet a performance standard of providing treatment to the “maximum extent practical” through the implementation of Best Management Practices.

This approach is consistent with federal regulations [40 CFR § 130.2(I)], which state that TMDLs can be expressed in terms of mass per time (e.g. pounds per day), toxicity, or **other appropriate measure**. The nutrient TMDL for Trout Lake (Table 21) is expressed in terms of pounds per year and percent reduction.

The total annual average loadings to Trout Lake for the current condition are 24,165 lbs/year for TN and 2,603 lbs/year for TP. These loadings result in a current annual average TSI of 74. The target TSI for this study is 54, which is 5 units above the background TSI of 49. The annual TN and TP loadings that result in the target TSI are 9,733 lbs/year for TN and 521 lbs/year for TP, respectively, which represent a 60% reduction of TN and a 80% reduction of TP loadings from the current condition. The TN and TP loadings that result in the TSI of 54 are considered as the TMDL for Trout Lake.

Table 21 TMDL Components

WBID	Parameter	WLA		LA (lbs/year)	MOS	TMDL (lbs/year)	Percent Reduction
		Wastewater (lbs/year)	NPDES Stormwater (1)				
2819A	TN	None	60% reduction	9,733	Implicit	9,733	60
2819A	TP	None	80% reduction	521	Implicit	521	80

(1) Required if during development of the City of Eustis MS4 permit it is determined that the Eustis MS4 contributes TN or TP to Trout Lake.

7.1 Load Allocation

The allowable LA is 521 lbs/year for TP and 9,733 lbs/year for TN. This corresponds to reductions from the existing loadings of 60 percent for TN and 80 percent for TP. It should be noted that the LA includes loading from stormwater discharges regulated by the Department and the Water Management Districts that are not part of the NPDES Stormwater Program (see Appendix A).

7.2 WasteLoad Allocation

NPDES Stormwater Discharges

As noted in Sections 4 and 7.1, loadings from stormwater discharges permitted under the NPDES Stormwater Program are placed in the WLA, rather than the LA. This includes loads from municipal separate storm sewer systems (MS4). Based on comments from the US Environmental Protection Agency (EPA), Trout Lake is within the city limits of Eustis, which is scheduled to receive a Phase II permit under EPA's NPDES stormwater permitting program in 2004. EPA has stated that if the City of Eustis MS4 area contributes any TN or TP to Trout Lake the TMDL must include a $\text{WLA}_{\text{NPDES Stormwater.}}$ Therefore, if during preparation of the MS4 permit it is determined that Eustis contributes TN or TP to Trout Lake, the WLA for stormwater discharges will be a 60 percent reduction in TN and a 80 percent reduction in TP in the current loading from the MS4. It should be noted that any MS4 permittees will only be responsible for reducing the loads associated with stormwater outfalls for which it owns or otherwise has responsible control, and is not responsible for reducing other nonpoint source loads within its jurisdiction.

NPDES Wastewater Discharges

There are no known NPDES point source discharges within the watershed.

7.3 Margin of Safety

The implicit margin of safety exists due to conservative assumptions used in the modeling process. For example, the estimates of septic tank failures were set to the maximum values instead of the mean values.

8. NEXT STEPS: IMPLEMENTATION PLAN DEVELOPMENT AND BEYOND

Following adoption of this TMDL by rule, the next step in the TMDL process is to develop an implementation plan for the TMDL, which will be a component of the Basin Management Action Plan for the Trout Lake Basin. This document will be developed in cooperation with local stakeholders and will attempt to reach consensus on more detailed allocations and on how load reductions will be accomplished.

The Basin Management Action Plan (B-MAP) will include:

- Appropriate allocations among the affected parties.
- A description of the load reduction activities to be undertaken.
- Timetables for project implementation and completion.
- Funding mechanisms that may be utilized.
- Any applicable signed agreements.
- Local ordinances defining actions to be taken or prohibited.
- Local water quality standards, permits, or load limitation agreements.
- Monitoring and follow-up measures.

It should be noted that TMDL development and implementation is an iterative process, and this TMDL will be re-evaluated during the BMAP development process and subsequent Watershed Management cycles. The Department acknowledges the uncertainty associated with TMDL development and allocation, particularly in estimates of nonpoint source loads and allocations for NPDES stormwater discharges, and fully expects that it may be further refined or revised over time. If any changes in the estimate of the assimilative capacity AND/OR allocation between point and nonpoint sources are required, the rule adopting this TMDL will be revised, thereby providing a point of entry for interested parties.

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Appendix A

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of nonpoint source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as authorized in Chapter 403, Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, Florida Administrative Code (F.A.C.).

The rule requires Water Management Districts (WMDs) to establish stormwater pollutant load reduction goals (PLRGs) and adopt them as part of a SWIM plan, other watershed plan, or rule. Stormwater PLRGs are a major component of the load allocation part of a TMDL. To date, stormwater PLRGs have been established for Tampa Bay, Lake Thonotosassa, Winter Haven Chain of Lakes, the Everglades, Lake Okeechobee, and Lake Apopka. No PLRG has been developed for Trout Lake at the time this study was conducted.

In 1987, the U.S. Congress established section 402(p) as part of the Federal Clean Water Act Reauthorization. This section of the law amended the scope of the federal NPDES to designate certain stormwater discharges as “point sources” of pollution. These stormwater discharges include certain discharges that are associated with industrial activities designated by specific Standard Industrial Classification (SIC) codes, construction sites disturbing five or more acres of land, and master drainage systems of local governments with a population above 100,000 [which are better known as “municipal separate storm sewer systems” (MS4s)]. However, because the master drainage systems of most local governments in Florida are interconnected, EPA has implemented Phase 1 of the MS4 permitting program on a county-wide basis, which brings in all cities (incorporated areas), Chapter 298 urban water control districts, and the DOT (Department of Transportation) throughout the 15 counties meeting the population criteria.

An important difference between the federal and the state stormwater permitting programs is that the federal program covers both new and existing discharges while the state program focuses on new discharges. Additionally, Phase 2 of the NPDES stormwater permitting program will expand the need for these permits to construction sites between one and five acres, and to local governments with as few as 10,000 people. These revised rules require that these additional activities obtain permits by 2003. While these urban stormwater discharges are now technically referred to as “point sources” for the purpose of regulation, they are still diffuse sources of pollution that can not be easily collected and treated by a central treatment facility similar to other point sources of pollution, such as domestic and industrial wastewater discharges. The DEP recently accepted delegation from EPA for the stormwater part of the NPDES program. It should be noted that most MS4 permits issued in Florida include a re-opener clause that allows permit revisions to implement TMDLs once they are formally adopted by rule.