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Pilot Study Of Nutrient Loading In A Wet Detention Lake

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PILOT STUDY OF NUTRIENT LOADING IN A WET DETENTION LAKE

by

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ABSTRACT

Florida is surrounded by water, and its many internal lakes and rivers have long been recognized for their excellent fishing and boating. This notoriety draws land developers to the lake shores to establish residential and commercial infrastructure. This land development brings with it flood plain alteration, water level stabilization, and increased nutrients which cause adverse impacts to our lakes. In response, the United States Environmental Protection Agency (EPA) passed the Federal Clean Water Act (CWA) in 1972 which set the framework for the water quality standards for the entire United States. As a result of the CWA many point sources were eliminated, but in the process it became apparent that nonpoint source loads represented even more of a threat. To further study the physical and chemical characteristics of urban runoff the Nationwide Urban Runoff Program (NURP) was established in 1978. This research lead to a series of management options, named Best Management Practices (BMPs) which proposed various structural and non-structural methods to reduce nutrient loads. But the research and data collection on the effectiveness of these systems to remove nutrients is in its infancy.

The main objective of this study was to generate accurate and effective water quality and water quantity data that future stormwater management decisions can be based upon. More specific, this study established automatic monitoring sites throughout the City of Kissimmee, Florida to determine the pollutant loadings into the tributaries of Lake Tohopekaliga. These monitoring sites are located such that inflows from outside the city limits can be isolated and external pollutant loads quantified. Also, additional internal monitoring sites were established to determine the pollutant loads of internal sections of the city. Data from these internal monitoring sites will also be used to determine the variable pollutant removal efficiencies and hydraulic fluctuations of natural, irregular riverine systems.

The secondary objective of this study was to perform a pilot study using the discrete grab samples in tandem with the continuous hydraulic and hydrologic data from the monitoring stations. An existing lake within the project limits was chosen for the pilot study area. Monitoring stations are located at the influent and effluent sections of the lake which provided data on the hydraulic and hydrologic parameters. The pilot study determined the nutrient loads to and from the lake and checked for any seasonal variations in pollutant loading or removal efficiencies. For the purpose of this pilot study, only total nitrogen and total phosphorous were examined for two monitoring sites.

The nutrient removal efficiency was performed using both the event mean concentration method and the summation of loads method to check for seasonal variation. There were no storm event concentrations available for used in this analysis, however, there were 25 discrete grab samples collected on a bi-monthly basis over a twelve month period. This data was used with corresponding five-minute rainfall and flow data from both the inflow and outflow points.

The results of this study did not reveal any seasonal variation in the nutrient concentrations either flowing into or out from the lake. Although there were some relatively lower values in late spring, the concentration levels of total nitrogen did not seem to vary significantly from its mean value of 0.90 mg/l throughout the year. The concentration levels of total phosphorus did range from 0.02 mg/l to 0.48 mg/l, but not in relation to either season or flow volume fluctuations. The lake showed no net removals of total nitrogen and was actually found to be releasing total phosphorus to the downstream receiving waters.

The findings of this study are limited due to the fact that the period of pilot study was only for twelve months and there were no rainfall events used in the analysis. Rainfall events are typically high sources of nutrient loads to a lake. The lower efficiencies were probably due to missing the actual higher nutrient load concentrations during the rainfall event. However, even considering the lack of event data, the nutrient removal efficiency for the pond was still low. This analysis did serve well as a basis for performing future analysis once additional data, including rainfall events, has been collected.

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CHAPTER 1: INTRODUCTION

Background

Lake Apopka is Florida's fourth largest lake. Until recently, following decades of fish, bird and alligator deaths, Lake Apopka was also known by many as Florida's most polluted lake (Riley, 1999). Lake Apopka was not always like this. The lake used to be clear, densely vegetated and nationally known for its sports fishery. In fact, fishermen were once quoted as saying, "The fishing is so good, and the water so clear you can pick the particular bass you want to catch. It's the best fresh water fishing in the United States" (Franz, 2006).

Like many lakes in Florida, Lake Apopka was changed in the early twentieth century by flood plain alteration, water level stabilization, and increased land development (Huffstutler, 1965). The nutrients carried by the runoff from these developments caused large blooms of microscopic algae (phytoplankton) in the lake. As these algae died, they depleted the lake's oxygen as the decomposed plankton settled to the bottom of the lake. At one time, more than 90 percent of the lake was filled with a layer of dead algae, which often floated suspended in the water, blocking much needed sunlight (Riley, 1999). With limited sunlight and depleted oxygen, the aquatic vegetation that feeds game fish and other water creatures could not survive.

What took place in Lake Apopka is not an isolated incident. Florida is surrounded by water, and its many internal lakes and rivers have long been recognized for their excellent fishing and boating. This notoriety draws land developers to the lake shores to establish residential and commercial infrastructure. The altering of the natural environment during the urbanization of watersheds can cause harmful side effects such as decreased infiltration of rainfall, increased runoff volumes, and increased occurrences of flooding. These hydrologic factors lead to streambank erosion which is the main transport mechanism for pollutant export to receiving waterbodies (Schueler, 1987). The influx of these nutrients carried by the runoff from developed watersheds can lead to the similar type of algae blooms experienced in Lake Apopka.

In an attempt to keep a fate similar to Lake Apopka from occurring to the rest of the lakes in country, the United States Environmental Protection Agency (EPA) passed the Federal Clean Water Act (CWA) in 1972 which set the framework for the water quality standards for the entire United States. As a result of the CWA many point sources were eliminated, but in the process it became apparent that nonpoint source loads represented more than 65 percent of pollutants entering our nation's waterbodies (Rushton and Dye, 1993, Livingston, 1985). Research that began prior to the adoption of the CWA documented that a large source of nonpoint pollution is the runoff from urban and industrial areas (Whipple and Hunter, 1977). The Nationwide Urban Runoff Program (NURP) was established in 1978 to collect basic data on the physical and chemical characteristics of urban runoff across the country (EPA, 1983).

A series of management options, named Best Management Practices (BMPs) were developed to control the pollutants transported in urban runoff (Schueler, 1987). These BMPs can be either maintenance or development practices that do not include the construction of a permanent stormwater management structure like street sweeping or Low Impact Development (LID) which are referred to as "non-structural" or they can be actual ponds, swales, or physical processes which are referred to as "structural." The effectiveness of each of these BMPs varies according to the targeted pollutant, pollutant concentration, and site conditions. An overview of the removal efficiencies of total nitrogen and total phosphorus for different types of BMPs is provided in Table 1.

Table 1: Overview of BMP Efficiencies

BMP	TP	TN	References
Structural BMPs			
Infiltration Trench	50-75	45-70	Young et al. (1996)
Infiltration Basin	50-70	45-70	Young et al. (1996)
Bioretention	50	50	Prince George's County (1993)
Detention Ponds	20-94	28-50	City of Austin (1990); City of Austin (1995); Harper & Herr (1993); Gain (1996); Martin & Smoot (1986);Young et al. (1996); Yu & Benelmouffok (1988); Yu et al. (1993 & 1994)
Wetlands	25	20	USEPA (1993)
Detention Tanks	NA	NA	NA
Underground Sand Filters	43-70	30-50	Bell et al. (1995); Horner & Horner (1995); Young et al. (1996)
Surface Sand Filters	27-80	27-71	City of Austin (1990); Welborn & Veenhuis (1987)
Organic Media Filters	49	55	Claytor and Schueler (1996); Stewart (1992); Stormwater Management (1994)
Vegetated Swales	20-85	0-50	City of Austin (1995); Claytor and Schueler (1996); Kahn et al. (1992); Yousef et al. (1985); Yu & Kaighn (1995); Yu et al. (1993 & 1994)
Vegetated Filter Strips	20-40	20-40	Yu and Kaighn (199 Young et al. (1996)
Oil-Grit Separators	10	10	Young et al. (1996)
Catch Basin Inserts	NA	NA	King County (1995)
Manufactured Systems	NA	NA	Bryant et al. (1995)
Porous Pavements	60-71	80-85	
Nonstructural BMPs			
Streetsweeping	40-74	42-77	
New and Innovative Practices			
Alum Injection	89	78	Harper (1990)3
MCTT	NA	NA	Pitt (1996)
Biofilters (e.g., StormTreat System)	89	NA	Allard et al. (1996)
Vegetated Rock Filters	82	75	DRMP (1995)

NA = Not Applicable or Not Available. Removal efficiencies may be based on either mass balance or average concentration calculations. The values may originate from evaluation of multiple events or from long-term monitoring. Ranges are provided wherever possible. 1. Based on capture of 12.7 mm (0.5 in) of runoff volume. Effectiveness directly related to volume of captured runoff. 2. Typical values; actual performance strongly related to the type of equipment, cleaning frequency, and number of passes. 3. Study examined improvement in water quality within the lake receiving alum-treated stormwater runoff. 4. Included are results for three different types of ponds: extended detention wet pond, wet pond, and extended detention dry pond.

Scope and Objectives

The main objective of this study is to generate accurate and effective water quality and water quantity data that future stormwater management decisions can be based upon. More specific, this study aims to establish automatic monitoring sites throughout the City of Kissimmee, Florida to determine the pollutant loadings into the tributaries of Lake Tohopekaliga. These monitoring sites are to be located such that inflows from outside the city limits can be isolated and external pollutant loads quantified. Also, additional internal monitoring sites are to be established to determine the pollutant loads of internal sections of the city. These internal monitoring sites will also be used to determine the variable pollutant removal efficiencies and hydraulic fluctuations of natural, irregular riverine systems.

The monitoring and sampling methodology includes criteria for collecting, and analyzing data from the study area (e.g., discharge monitoring data, sample analysis reports). Under 40 CFR 130.4(b), the monitoring program should include collection and analysis of physical, chemical, and biological data. This monitoring program should include quality assurance and control programs to ensure the data are scientifically valid.

The methodology of this study defines a set of core indicators (e.g., water quality parameters) for the study area, which includes physical, chemical, and biological attributes of the tributaries. The core indicators were selected to reflect general parameters of the water resources field so they can be used to assess attainment of applicable water quality standards throughout the basin. These indicators are monitored to assure that the fundamental parameters that affect the impairment of water quality in an aquatic environment are accurately assessed.

The secondary objective of this study is to use the discrete grab samples in tandem with the continuous hydraulic and hydrologic data from the monitoring stations upstream and downstream of a 15 acre, man-made lake to determine if there are any seasonal variations in pollutant loading or removal efficiencies. For the purpose of this study, only total nitrogen and total phosphorous will be examined for monitoring sites number 8 and 9. The pilot study area is depicted in Figure 1.

This essential nutrient removal pilot study was chosen to verify the results of a nationwide urban runoff program in which the Environmental Protection Agency rated detention basins with a permanent wet pool very effective at reducing nutrients from urban runoff (EPA 1983). In addition, researcher in Florida report that detention ponds designed as sedimentation basins can be used as a stormwater management BMP to improve water quality (Rushton and Dye, 1993, Baker and Yousef, 1995). In contrast, studies have shown that regardless of deliberate planting, wet ponds frequently become dominated by aggressive plants such as cattails which decrease the pollutant removal efficiencies (Athanas and Stevenson, 1991; Shenot, 1993). Wind driven wave action can resuspend organic matter from the lake bottom or mix stratified water which will lower the dissolved oxygen levels. This pilot study intends to obtain nutrient data at the inflow and outflow points of this lake to provide more information on effectiveness of essential nutrient removal in an in-line, wet detention system.

Figure 1: Pilot Study Area

Limitations

The limitations of this study include the lack of rainfall event samples. The automatic samplers were not in place in time to provide flow-weighted concentrations resulting from rainfall runoff. This will prevent the inclusion of first flush flow and storm recession concentrations from the study. The study does not include any sediment data from the lake floor. This will prevent the inclusion of resuspended pollutants from being accounted for in the analysis. Although the grab samples were obtained over a 26 month period, the corresponding continuous measuring equipment was only in operation for 12 months. During this operation period there were times when the equipment was covered in debris or silt which rendered blanks in the flow data. This could lead to interpolation errors in flow data where these gaps are filled. There were no measurements taken on the atmospheric contribution of pollutants to the lake. This is anticipated to only result in minor underestimates of lake performance, but the data is not available to verify this assumption. The initial and final pollutant loads within the lake were not measured, so an assumption was made that it remained unchanged from year to year. Also, any contribution from waterfowl was not accounted for even though there is a rather large roust of birds along the maintenance berm of the lake.

CHAPTER 2:
LITERATURE REVIEW

Introduction

The fish kills in Lake Apopka were attributed to nutrients carried by the runoff from increased land development (Huffstutler, 1965). These nutrients caused large blooms of microscopic algae (phytoplankton) in the lake. This plankton depleted the dissolved oxygen levels in Lake Apopka when they decomposed at the end of their life cycle. The dissolved oxygen levels were further impacted when floating layers of dead algae significantly reduced the production of oxygen through photosynthesis by blocking the sunlight. The game fish, aquatic vegetation, and other water creatures could not survive with the critically low oxygen in the lake.

As a result of situations like Lake Apopka, the United States Environmental Protection Agency (EPA) passed the Federal Clean Water Act (CWA) in 1972 which set the framework for national water quality standards. Over the years it became apparent that runoff from urban and industrial areas represented more than 65 percent of nonpoint source loads entering our nation's waterbodies (Rushton and Dye, 1993, Livingston, 1985, Whipple and Hunter, 1977). The Nationwide Urban Runoff Program (NURP) was established in 1978 to collect basic data on the physical and chemical characteristics of urban runoff across the country (EPA, 1983). This research lead to the creation of a series of management options, named Best Management Practices (BMPs) to control the pollutants from urban runoff (Schueler, 1987)

Nutrient Sources

The process of nutrient enrichment to our lakes is the most widespread water quality problem in the US and many other nations. There are two main types of these nutrient sources.

The first is the point source such as a wastewater treatment plant. These point sources are easy to identify and their pollutant loads are relatively easy to quantify. The second type, referred to as non-point sources are more difficult to identify and quantify. These non-point sources come from multiple sources including sanitary sewer leaks, septic system leachate, lawn fertilizers, agricultural wastes, highway runoff, urban development, and wildlife.

The leachate from septic tank systems, runoff from highways, and agricultural land wastes provide excess nutrients such as nitrogen and phosphorus. Residential areas also contribute nitrogen and phosphorus from lawn fertilizers, grass clippings, leaves, and animal wastes. Industrial areas contain nitrogen and phosphorous in cleaning chemicals or degreasers. The quantity of these nutrient contributions is dependent upon local human population densities and the type of land use (Klein, 1975). In terms of water quality, nutrients are considered pollutants when their concentrations are sufficient enough to allow excessive growth of aquatic plants, particularly algae.

Essential Nutrients

The essential chemical compounds that all plants and animals require to grow and flourish are called nutrients. The two elements in these essential compounds that are required in the greatest proportions and frequently limit growth of plants and animals are nitrogen and phosphorus.

Nitrogen compounds are primary constituents of concern in surface waters due to their limiting role for plant growth. The most important forms of inorganic nitrogen in surface waters are ammonia, nitrite, and nitrate. Organic nitrogen is also an important constituent of surface waters and occurs in both dissolved forms and in particulate organic matter. Nitrogen concentrations in surface water are generally reported as the mass of nitrogen in the compound. Nitrogen is the critical element required for protein synthesis and, hence, is critical to life of all plants and animals.

Phosphorus occurs as soluble and insoluble complexes in both organic and inorganic forms in aquatic systems. The principal inorganic form is ortho-phosphate and is the preferred form for plant (macrophyte) growth. Dissolved phosphorus includes both phosphate and dissolved organic phosphorus. Particulate phosphorus includes biological matter such as plankton (microbiota) and phosphorus sorbed on biotic and abiotic suspended particles. Dissolve organic phosphorus and insoluble forms of organic and inorganic phosphorus are generally not biologically available until they are transformed into soluble inorganic forms. Phosphorus may be permanently or semi-permanently lost from aquatic ecosystems to the sediments and to a lesser extent as phosphine gas to the atmosphere. Because organic phosphorus can be transformed and used by plants, it is generally sufficient to consider the ambient concentrations of total phosphorus in natural water bodies to anticipate ecological effects. Naturally occurring inputs of phosphorus originate from surface inflows, groundwater inflows, leaching from soils, and atmospheric deposition. Anthropogenic inputs are typically from the use of inorganic phosphorus fertilizers for agriculture and landscaping, the use of animal feeds rich in phosphorus, and from discharges of phosphorus in wastewaters and stormwaters.

Nutrient Transport

On earth, water exists in a liquid, solid or vapor form. In the liquid form it creates the oceans, seas, lakes, rivers and groundwater. In the solid state it exists as ice and snow cover. The atmosphere contains water in its vapor form. The energy from the sun puts all of this water into motion. The sun heats the earth's surface (oceans, lakes, etc.) and evaporates the water which transforms from a liquid to a vapor. Water is also transformed into vapor directly from plants which lose water to the air in a process called “transpiration.” This water vapor eventually condenses and forms tiny droplets in the clouds. Winds transport clouds containing warm water vapor over land masses to cooler air which triggers precipitation. Water returns as precipitation to either a liquid state as rain, or if cold enough, a solid state as snow. Some of this precipitation soaks into the ground to form groundwater, but most of the water flows downhill as runoff (over ground or underground), eventually returning to the seas.

This circulation of the earth’s water from the land to the sky and back again is called the “hydrological cycle.” Figure 2 shows a depiction of the various stages in the hydrologic cycle. This process places the oceans, rivers, clouds, and rain in a never-ending state of change. The total amount of water on the earth and in its atmosphere does not change but the form of water is in a continuous motion.

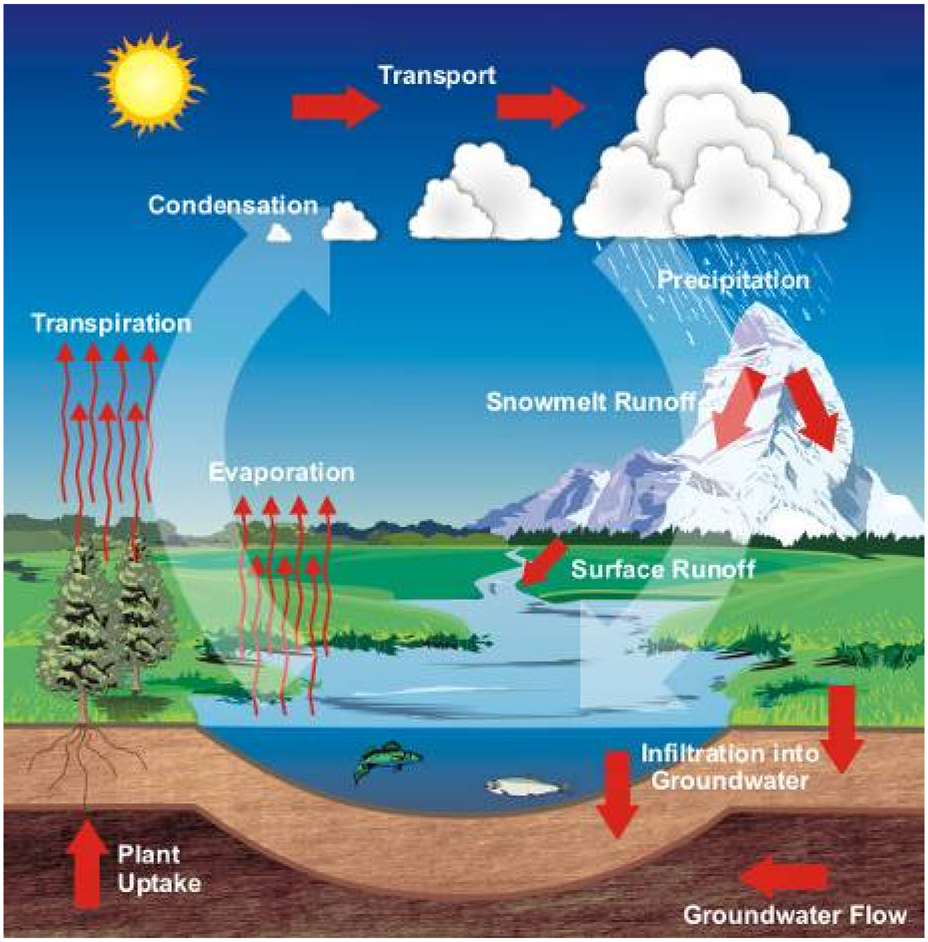


Figure 2: Hydrologic Cycle

Although other processes aid in nutrient transport, the surface runoff process depicted in the hydrologic cycle in Figure 2 is the primary nutrient transport mechanism. The importance placed on the surface runoff process is due to particles of sediment being dislodged from the earth (erosion) and carried with the water until it is deposited into the receiving waterbody (sedimentation). Therefore the rate of weathering and erosion from the soils in the contributing watershed directly affects the nutrient concentrations in receiving waterbody. In fact, land use alterations in the watershed can actually serve as early warning indicators for environmental impacts to a lake (EPA 1996).

Of course the degree and size of the land use disturbance relative to the size of the receiving waterbody will ultimately determine the magnitude of the impact. In addition to the type and size of land use, the geology of the watershed also has a determination on the amount of nutrients that are transported to the lake.

Eutrophication and Trophic State Index (TSI)

Large quantities of nitrogen and phosphorus transported by surface runoff can enrich the nutrient levels of a receiving lake. The classification of this degree of nutrient enrichment is called ‘Eutrophication’ and can also be used as a measure of lake health. Eutrophication is broken down into three classifications, or levels based on nutrient concentrations. The first classification is called “Oligotrophic” and has very low levels of nutrients, very little organic material along the lake bottom, and high levels of dissolved oxygen near the lake floor. “Mesotrophic” lakes are the second classification with moderately enriched nutrient levels and have a natural accumulation of sediments and a normal growth of aquatic vegetation is occurring. The final classification is called “Eutrophic” which are highly nutrient enriched, have an accumulation of organic sediments, and low levels of dissolved oxygen in water near the lake bottom. Eutrophic lakes typically have high concentrations of algae or aquatic vegetation and also differ from oligotrophic and mesotrophic lakes in the type of vegetation and animal life that can exist in the lake.

There are also different schemes to classify the quality of lakes relative to one another. Recently, the most common method of classifying lakes is by the Trophic State Index (TSI) created by Einar Naumann. The trophic state refers to the degree or amount of enrichment, or eutrophication, the lake has with the nutrients in the water. The trophic state number is a measure of the productivity of a lake with regards to biomass which is directly related to nitrogen and phosphorous levels. Higher nutrient levels lead to higher productivity of biomass, which in turn means a higher trophic state. Although the trophic state focuses on nutrient levels to measure plant growth, other components of the lake ecosystem, such as zooplankton concentrations are affected as well by plant growth thereby making this a good indicator of lake health.

Eutrophication Process

Fish need dissolved oxygen in the water to survive. Lakes obtain their dissolved oxygen from either the atmosphere or the photosynthesis by aquatic plants. When excessive nutrients are introduced into the lake the production, death and decay of phytoplankton is increased to a level to produce the algae mats. Not only does the decay of plankton decrease the dissolved oxygen levels but the algae mats that are typically produced in the process allow very little sunlight to reach the plants. This reduced sunlight reduces or in severe cases even stops the photosynthesis process and thereby prevents the production of dissolved oxygen. When this occurs there is not enough dissolved oxygen produced during the day to compensate for normal daily uses by fish, plants, and bacteria. If this condition continues until the dissolved oxygen is depleted then the fish will suffocate. In shallow ponds that are heavily vegetated and have high levels of decomposing organic matter this can occur in only a few days.

Other conditions reduce the oxygen in the water which accelerates the effects of nutrient loading to a lake. Dissolved oxygen levels are at their highest on sunny days late in the afternoon after a long period of photosynthesis. When the sun sets the production of oxygen ends, but the oxygen consumption still continues. Therefore the photosynthesis during the day must be great enough to supply the demand during the night. Cloudy weather during the day will reduce the amount of dissolved oxygen generated by photosynthesis.

Although the light from the sun is beneficial to dissolved oxygen production, the heat from the sun can create a temperature difference in the water. This temperature difference causes a stratification of the lake water with the less dense warmer water remaining at the surface and the cooler, denser water forced to the bottom. These temperature differences between surface and bottom layers may be up to 10 to 15°F. The surface water layer typically has enough dissolved oxygen, however the bottom layer will often have little or none due to the consumption of dissolved oxygen by bacteria breaking down organic matter. If any significant, sudden mixing of these two layers occurs by wind or wave action, then the oxygen deficient bottom water can cause the ponds overall dissolved oxygen to drop drastically. This condition is called ‘inversion’ and is a common reason for fish kills in small ponds with heavy sudden inflows.

The effects of this eutrophication process are more pronounced in watersheds with nutrient rich, heavily urbanized surface runoff. However, some studies have shown significant impacts to aquatic life in ponds with less than 10 percent urbanization. In Maryland a study was conducted on 27 small watersheds having similar physical characteristics, but varying land uses. The findings indicated aquatic life problems when at least 12 percent of the watershed was impervious and severe aquatic life problems were noted after the imperviousness reached 30 percent (Klein, 1975). Also, nineteen wetlands impacted by varying levels of urbanization were studied in New Jersey by Ehrenfeld and Schneider. The findings showed a significant increase in nutrient impacts to the wetlands from all of the urban runoff. Finally, a study conducted by the Northeastern Illinois Planning Commission found that a majority of streams with watersheds having population densities greater than three hundred people per square mile showed signs of significant impairment.

The primary nutrient criteria variables of concern in over enrichment are nitrogen and phosphorus (EPA, 1999). Vollenweider's (1968) advances in limnology and lake management following many years of experience dealing with temperate climes and freshwater lakes has developed a general rule-of-thumb about eutrophication with regards to nutrients. Ambient total phosphorus (TP) concentration of greater than about 0.15mg/L and or total nitrogen (TN) of about 1.5 mg/L is likely to cause blue-green algal bloom problems during the growing season. This over enrichment leads to lake quality degradation in the form of low dissolved oxygen, fish kills, algal blooms, expanded macrophytes, increased sedimentation, and shifts in both flora and fauna.

Governing Regulations

The United States Environmental Protection Agency (EPA) passed the Federal Clean Water Act in 1972 which set the framework for the water quality standards in the United States. Although this framework has existed for over thirty years, it has only been through the recent creation of the Florida Watershed Restoration Act in 1999 that a quantifiable stormwater quality criterion was established. This criterion is defined by the Total Maximum Daily Load (TMDL) levels which will be set for each impaired waterbody in the State of Florida. These TMDLs have been incorporated into the Environmental Protection Agency's (EPA's) National Pollutant Discharge Elimination System (NPDES) permitting requirements and are managed by the Florida Department of Environmental Protection (FDEP).

These requirements all fall within the framework of the original Clean Water Act [40 CFR Part 130] established back in 1972 which in its current form requires each State to identify waters within its boundaries not meeting water quality standards applicable to the water's designated uses. This list of identified waters (referred to as the 303[d] list) must be submitted to the U.S. Environmental Protection Agency (EPA) for review and approval. The "listed" waters identified by the State are prioritized for Total Maximum Daily Loads (TMDL) development based on factors described in CWA regulations, such as the use of the water and the severity of pollution. A separate TMDL is established for each pollutant at a level necessary to attain the applicable water quality standards taking into account seasonal variations and a margin of safety. The TMDL establishes allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. With this information, States can establish water-quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA, 1991).

Delisting of waterbodies from the previous 303(d) list requires States or territories to demonstrate to the EPA its rationale for the delistings. According to the regulations at 40 CFR 130.7(b), a waterbody may be delisted for the following reasons:

- More recent or accurate data demonstrate compliance with water quality standards;
- More sophisticated water quality modeling;
- Flaws in the original analysis that led to the water being listed in the categories in section 130.7(b)(5);
- Changes in conditions (e.g., new control equipment, elimination of discharges).

For each segment proposed for removal from the most recent 303(d) list, states, or territories needs to provide EPA with sufficient documentation as justification. They must provide a description of the assessment and listing methodology used to develop their Section 303(d) lists and Section 305(b) reports. This methodology should include a description of the processes and procedures used to assess the quality of the waters and explain how all existing and readily available data (chemical, physical, biological, land use) and information was assembled and used to determine the attainment status in each Assessment Unit (AU), consistent with the applicable water quality standards. EPA will review this data and approve or disapprove the delisting determinations listed. EPA's review and approval of the 303(d) list will be based on a determination that:

- State's or territory's assessment and listing methodology was used to prepare the list, that the assessment and listing methodology is scientifically sound;
- It is consistent with the State's or territory's water quality standards;
- State or territory reasonably considered all existing and readily available data and information and listed all waters not attaining water quality standards.

Upon completing its review of the 303(d) list, EPA will send a letter to the State or territory notifying it of full approval, partial approval/disapproval, or disapproval. If the list is partially approved/disapproved, or disapproved, EPA will develop a list for the State or territory. EPA will also provide 30 days for public comment on the EPA developed list.

These regulations and procedures are useful in identifying whether a tributary or its receiving waterbody is impaired, and if not, how to have it delisted. But what if the tributary is found to contribute pollutants to its receiving waterbody and is actually impairing the health of the lake? A means of preventing these harmful nutrients from entering the waterbody must be identified so that the lake can be restored back to a more natural state.

The key in preventing harmful nutrients from entering the waterbody is to remove them from the tributaries before they can reach the lakes. The Water Management Districts (WMD) are responsible for reviewing the stormwater management systems of urban development projects. Urban development affects the quantity of stormwater runoff by reducing the area available for soil infiltration and it increases the peak runoff rates by shortening the times of concentration. These two factors cause accelerated channel erosion and increases the nutrient loads to the receiving waterbody. Stormwater ponds are typically designed to attenuate the peak runoff rates, but they also aid in decreasing nutrient concentrations.

In addition to water quantity attenuation of the twenty-five year, twenty-four hour duration rainfall event, the WMD rules require that the proposed stormwater treatment systems must store the first one inch of runoff from the entire site or the first two and one-half inches of the runoff from all impervious areas, whichever is greater. This required treatment volume must be filtered by mechanical or biological processes prior to being released from the pond. This outfall of the pond must be designed to discharge the first half of the treatment volume between twenty-four and thirty hours following the rainfall event. A fifty percent reduction of the required treatment volume is given if a dry retention system with infiltration is used.

Nutrient Removal

Data is still being gathered on exactly how effective stormwater ponds are at removing nutrients. Table 2 provides a summary of the general nutrient removal efficiencies for different types of stormwater ponds. From the data collected so far, both researchers and government agencies recognize wet detention ponds, which provide mechanisms for sediment deposition are very effective at reducing nutrients from urban runoff (EPA 1983, Rushton and Dye, 1993, Baker and Yousef, 1995).

Table 2: Pond Nutrient Removal Efficiency Percentages

Study	TP	TKN	NO3	Comments
City of Austin (1990) [1]	37	14	36	In-line wet pond
City of Austin (1995) [1]	81	44	64	Wet retention pond
Yu & Benelmouffok (1988) [2]	70	65	75	Extended detention wet pond
Martin & Smoot (1986) [2]	20	-	-	In-line wet detention pond as pretreatment to wetland system. Efficiencies are for pond only
Gain (1996) [1]	30	16	24	Evaluates modification by flow barrier in wet pond; pond is pretreatment to wetland
Harper & Herr (1993) [1]	54	26	92	Based on water column sampling from various sites in the wet detention pond
Yu et al. (1993) [2]	75 - 94	-	-	Dry detention pond
Yu et al. (1994) [2]	81	44	64	Dry detention pond, study evaluated modifications to outlet
1 Removal efficiencies based on concentrations. 2 Removal efficiencies based on mass loading.				

One example of these wet detention pond effectiveness is the monitoring that was conducted on a system of man-made wetlands in Palm Beach (Blackburn, 1985). The results of grab sampling showed estimated influent nutrient removals of greater than 50% for both total phosphorus and nitrate. Another example is the study conducted on a shallow, 0.2 acre wet detention system built in 1986 (Rushton and Dye, 1993). The pond was able to remove 50 percent of the total phosphorus and 70 percent of the total nitrogen from the stormwater runoff of a 6.3 acre light commercial development. In a follow-up to this 1993 study, the pond was reshaped to increase treatment volume, thereby increasing the retention time from 2 days to 14 days (Rushton, 1997). In the altered pond configuration, nutrient load removals improved by at least 20%.

Some other studies for various wet detention configurations show different results for nutrient removal efficiencies, in particular lower nitrogen compound removals. The first of these studies was conducted near Lake Apopka to examine nitrogen and phosphorus removal from agricultural drainage (Reddy, 1982). The results from a system of three reservoirs in series showed better than 50% removal of phosphorus in most of the lakes, however, the reductions in nitrogen compounds were somewhat diminished. Total nitrogen and total phosphorus removal from agricultural runoff were also studied for a constructed wetland in Florida (Moustafa, 1995). The results of this study showed a similar trend in mass removal efficiencies being higher for total phosphorus (71%) than for total nitrogen (26%). Still another study on a constructed wetland system which included a sediment basin was conducted in Orlando (McCann and Olson, 1994). The wetland was effective at removing estimated total loads of phosphorus (61.5%) but the removal of nitrogen was poor. Finally, two wetlands, one natural and the other constructed, were studied in southern Florida (Goldstein, 1986). Both wetlands received runoff from watersheds involved in cattle production and both showed greater than 50% removal of inorganic nitrogen, and 20 to30% removal of total phosphorus. However, they were both found to be least effective at removing total nitrogen.

From these studies one thing is certain; more research needs to be conducted on the effectiveness of wet detentions systems in removing nutrient loads. The more data that can be gathered on how these ponds respond to a variety of configurations and nutrient loading conditions can only help in the future design of wet detention systems to remove nutrients from tributaries.

Wet Detention Pond Design

Wet detention ponds use a permanent pool of water to achieve nutrient removal. To maintain a permanent pool it is important to have sufficient surface runoff, fairly impermeable soils, and an adequate base flow to the pond. The effectiveness of these permanent pools at removing nutrients depends on the inflow rate and detention time, which are both functions of the storm intensity, runoff volume, and pond size. These parameters determine the fraction of nutrients captured in the pond for treatment, especially during quiescent periods between events (Woodward-Clyde, 1986)

Sizing of this wet pond should also consider the runoff volume in relation to the water depth and pond length so that settlement of suspended solids is achieved. This pond depth should be shallow enough so it does not become anoxic and to encourage mixing, which prevents thermal stratification (Schueler, 1987). However, the pond depth must be deep enough so that wind-generated disturbance of bottom sediments does not cause resuspension of bottom sediments. The recommended permanent pool depths are between three feet and eight feet. A typical design of a wet detention pond is shown in Figure 3.

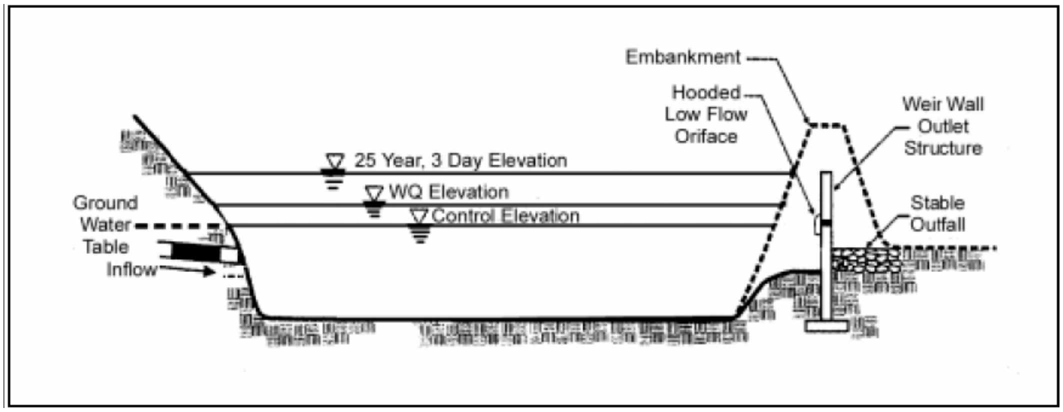


Figure 3: Wet Detention Pond Design

Monitoring and Sampling

The two most common approaches to water quality monitoring in a watershed are the influent-effluent constituent monitoring approach and the watershed monitoring approach. The three commonly used types of watershed approaches are upstream-downstream, before and after, and paired watershed (Coffey, 1993). These watershed monitoring approaches are typically used only when the physical constraints of a site do not permit the adoption of an influent-effluent approach. However, these watershed approaches are useful in wide scale applications to evaluate the effectiveness of nonstructural BMPs such as streetsweeping.

In contrast, the influent-effluent approach is the most effective method for estimating the pollutant removal efficiency of an individual, structural BMP. This is because pollutant removal efficiencies are based on calculating the difference between influent and effluent loads (Urbonas, 1994). Since the locations of the sampling points are immediately upstream and downstream of the BMP, it makes it possible to isolate the pollutant loads for the mass balance calculations. This simplicity in evaluating BMPs is not the only benefit of the influent-effluent approach. The monitoring costs are substantially less since very few additional environmental factors need to be factored into the overall evaluation to determine the BMPs effectiveness. Also, the time needed for monitoring can be substantially less and, since it is an isolated analysis, the evaluation results of a particular BMP can be extrapolated to other local systems. One drawback to the influent-effluent approach is the difficulty of establishing any downstream benefits of the BMP without additional data being collected from the receiving waterbody.

Once the monitoring approach is selected there are numerous ways to actually collect and prepare the samples. These various sample types are shown in Table 3. The two most commonly used samples types are flow-proportional and flow-weighted. The flow-proportional sample is the most common type of composite sample. It consists of constant sample volumes taken at time intervals which are spaced in proportion to the volume of flow passing by the collection point. The flow-weighted sample are a series of samples taken at equal time increments which are composited in proportion to the volume of flow since the last time the sample was collected.

Table 3: Water Quality Sample Types

Sample Type	Principle	Comments	Disadvantages
Discrete (individual)	Sample quantity taken over short period, generally less than 5 minutes.	Most commonly used.	Does not describe time variations or representative average conditions.
Discrete (sequential)	Series of individual discrete samples taken at constant increments of either time or discharge.	Used by some automatic samplers; impracticable to collect manually. Provides a history of variation with time.	Most useful if rapid fluctuations encountered (detailed characterization). Analyses may need attendant.
Composite (constant time-constant volume)	Samples of equal volume are taken at equal increments of time and composited to make an average sample.	This method not normally acceptable for samples taken for compliance with stormwater permit.	Useful only if variations are relatively small, say +/-15%.
Composite (constant time-volume proportional to flow increment)	Samples are taken at equal increments of time and are composited proportional to the volume of flow since the last sample was taken.	Used by few automatic samplers; easily done manually.	Requires a flowmeter; or a flow record if composited manually.
Composite (constant time-volume proportional to instantaneous flow rate)	Samples are taken at equal increments of time and are composited proportional to the flow rate at the time each sample was taken.	Done by some automatic samplers; easily done manually.	Requires a flowmeter; or a flow record if composited manually. Often used for determining event loads for a constituent.
Composite (constant volume-time proportional to flow volume increment)	Samples of equal volume are taken at equal increments of flow volume and composited.	Most common type of flow proportional composite. Usually done using automatic equipment.	Requires a flowmeter; or a flow record if composited manually. Often used for determining event loads for a constituent.
Large-Volume Sampling (sediment or water)	Sample Volumes of between 100 to 1000 L are processed with a centrifuge.	Used to acquire sufficient sample material for trace organic constituent analyses (i.e., PAHs).	Labor-intensive and cannot be done as frequently as sampling for conventional constituents.
Low level trace metals monitoring (water)	Series of individual or sequential discrete samples.	Used when the risk of sample contamination is high such as in waters with very low trace metals concentrations.	Requires specialized sample bottle preparation, sampling equipment and laboratory procedures.
Source: Adapted from Bellinger, 1980; USEPA, 1992.			

Nutrient Removal Efficiencies

The total mass of nutrients being transported during an interval of time is called the nutrient load. An analysis of this nutrient loading to determine the loss or gain of mass between two points is called a mass balance. The United States Environmental Protection Agency proposed two different mass balance methods for computing nutrient removal efficiency in a lake. The first method, called the average event mean concentration efficiency ratio (E_{emc}), uses an average of the event mean concentrations from all of the samples distributed over the sum of the sample volumes. The (E_{emc}) is expressed as percentages and is computed as follows:

$$E_{emc} = (1 - AEMC_{out} / AEMC_{in)} \times 100$$

Where: AEMC is the average event mean concentration and the subscripts "out" and "in" refer to outlet and inlet, respectively.

Loads are computed as the product of event mean concentrations and the associated volume. Since the average event mean concentration efficiency method averages all of the event volumes, it gives equal weight to each storm event.

The second method, called the summation of loads efficiency ratio (Esol), sums the product of each sample volume multiplied by its corresponding event mean concentration. The (Esol) is expressed as percentages and is computed as follows:

$$E_{sol} = (1 – SOL_{out} / SOL_{in)} \times 100$$

Where: SOL is the summation of loads and the subscripts “out” and “in” refer to outlet and inlet, respectively.

Loads are computed as the product of event mean concentrations and the associated volume, but unlike the average event mean concentration method, sample data is required for each events input and output loads.

Although, both of these methods are independent of the number of samples collected and assume their results represent the storms that normally occur in the region, the summation of loads method also assumes the collected samples represent all significant input and output loads (Martin, 1986). A comparison of these two methods found them to yield similar results, with the average event mean concentration method producing slightly lower values (Martin, 1986). Even though the average event mean concentration method is capable providing efficiencies of BMPs, the summation of loads method was found to be a better measure of the overall efficiency of a BMP (Martin, 1986). Additional research on BMPs found that where there is a permanent pool, computing pollutant removal effectiveness for individual storms may not be meaningful since the outflow typically has limited relationship to the inflow. For wet detention ponds, it may be more appropriate to use total loads over the monitored period to compute removal efficiencies (Strecker, 1992). Therefore, it appears that for wet detention ponds, a summation of loads method approach that does not focus on storm events but increases its temporal base to cover the summation of loads over the total monitored period may be worthy of investigation.

CHAPTER 3:
DATA COLLECTION

Introduction

The main objective of this study included the collection of various types of chemical, biological, and physical data from specific locations throughout the City of Kissimmee and in adjacent sections of Osceola and Orange Counties. For the secondary objective of this study, the data analysis was only performed on the Total Nitrogen and Total Phosphorus concentrations at the inflow and outflow points of an in-line, wet detention lake within the study area.

The number and specific locations of the main projects collection sites were based on the topographic, hydrologic and land use characteristics of the study area. Each location for sample collection needed to be evaluated to determine the appropriate water quality sampling method and corresponding collection apparatus. These methods and apparatus reviews included an evaluation of the required measurement accuracy, operational cost, ease of maintenance and operational efficiency for each site. The frequency of sample collection and the level of detail for the water quality analysis had to be within budgetary constraints. Water quality sampling protocols were established to cover field sampling procedures, sample labeling conventions, sample transit and laboratory result verification. All analysis of water quality samples were required to be conducted by laboratories certified in the state of Florida and the continuous field monitoring equipment needed to be maintained on a daily basis by personnel licensed by the equipment manufacturers.

Monitoring Stations

Management decisions require both accurate and effective flow measurement and water quality monitoring data at multiple locations throughout each watershed in the study area. To be accurate the monitoring stations had to be able to collect data over a wide range of stream flow conditions which were encountered through the change in seasons. To be effective the monitoring stations had to depict the internal hydrologic, hydraulic and water quality conditions within the study area as well as the exterior boundary conditions of the study area.

Study Area Description

The area selected for this study encompasses the corporate limits of the City of Kissimmee located in Osceola County, Florida which has a population of approximately fifty-five thousand (55,000) residents. Adjacent portions of Osceola and Orange counties were also included in this study to define the points where stormwater flows in to and out of the City of Kissimmee. This area was chosen because of its significant contribution of water flow into Lake Tohopekaliga. Lake Tohopekaliga is located in the upstream portion of the Upper Kissimmee Watershed. The Upper Kissimmee Watershed is depicted in Figure 4.

The study area encompasses approximately twenty (20) square miles of surface area with a relatively flat topography and poorly drained soils. A mixed land use of residential, commercial, and agricultural can be found throughout the City of Kissimmee. Stormwater runoff in the city is conveyed to Lake Tohopekaliga by six (6) distinct tributaries which receive flow from the runoff of their respective watersheds.

Shingle Creek is the largest of these tributaries which has its headwaters in Orange County and discharges along the western side of the City of Kissimmee into Lake Tohopekaliga. Shingle Creek is mostly rural and the lower portions which flow through the City of Kissimmee are undeveloped wetland floodplains. The second largest tributary flowing through the City into the lake is Mills Slough which is located towards the east side of the city and has its headwaters in southern Orange County. Bass Slough is located at the eastern side of the City of Kissimmee and has its headwaters in northern Osceola County. Both Mills Slough and Bass Slough are mostly residential land uses. East City Ditch, West City Ditch, and Downtown Area are the final three tributaries and have their headwaters completely inside the city limits. East City Ditch is a mixture of residential and light commercial land use. West City Ditch is a mixture of residential and light industrial land use. The Downtown Area has mostly a light commercial land use. The watersheds and Land uses are depicted in Figure 5 and Figure 6, respectively.

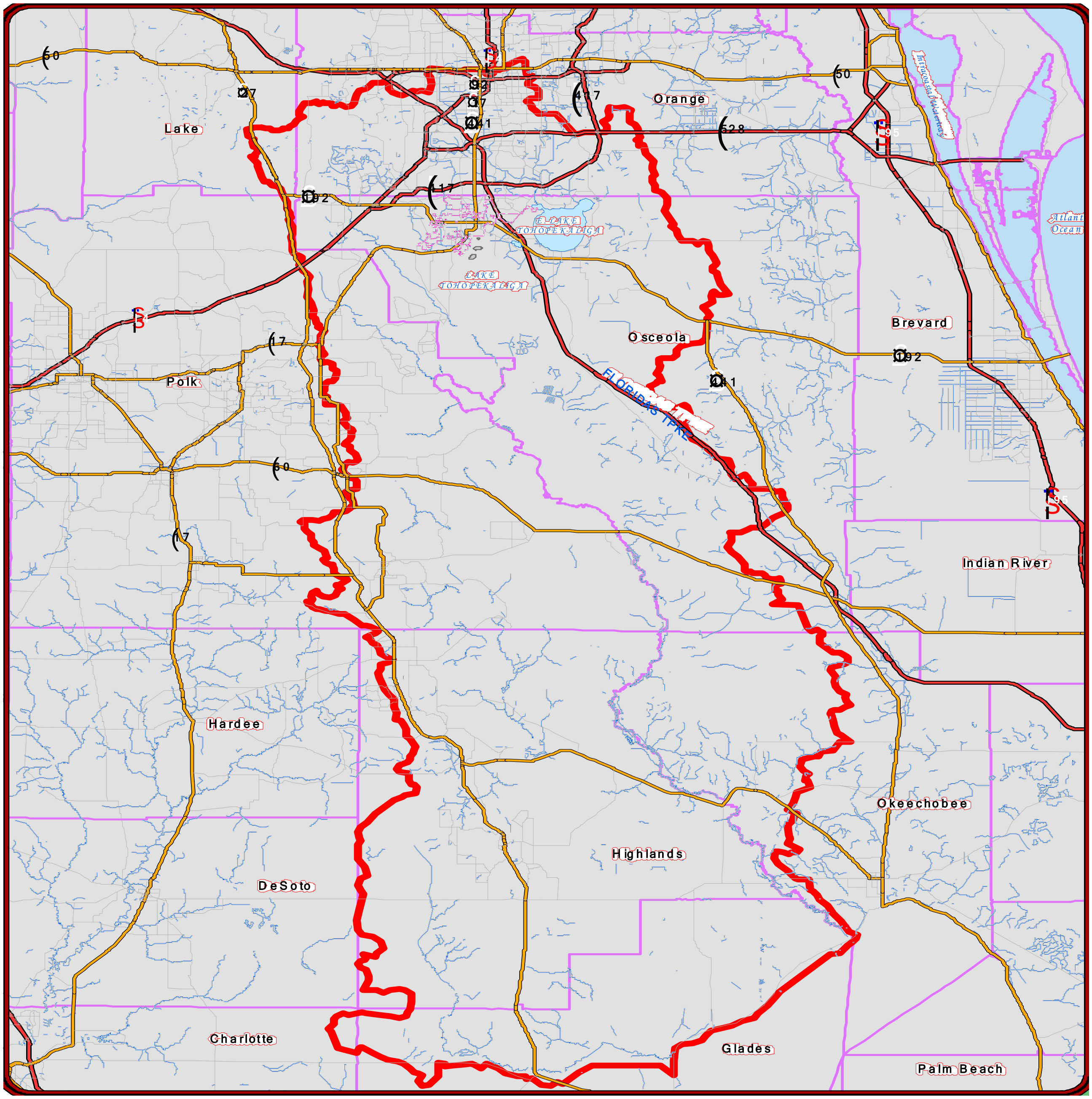


Figure 4: Upper Kissimmee Watershed, Florida

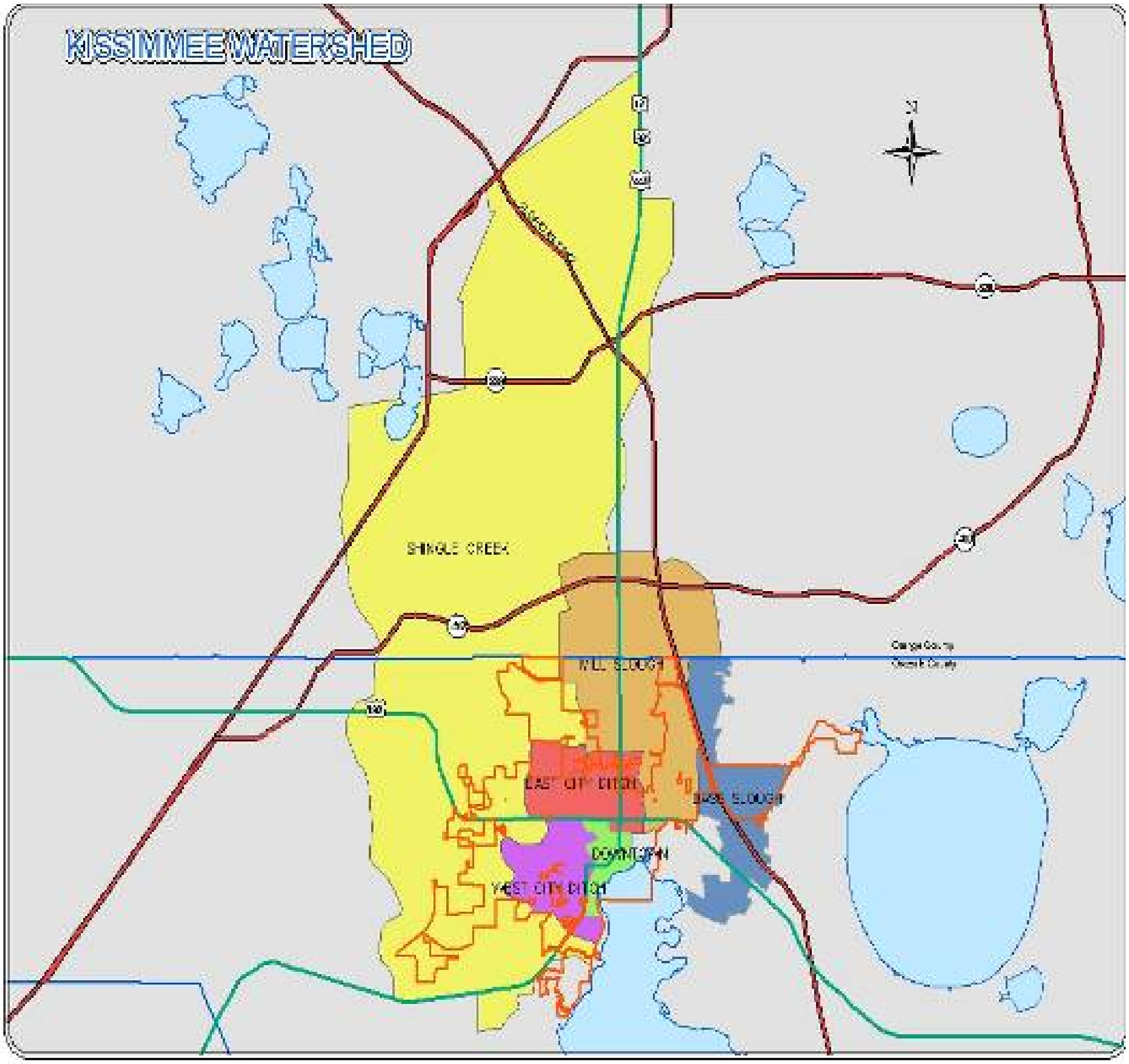


Figure 5: Six Tributaries to Lake Tohopekaliga

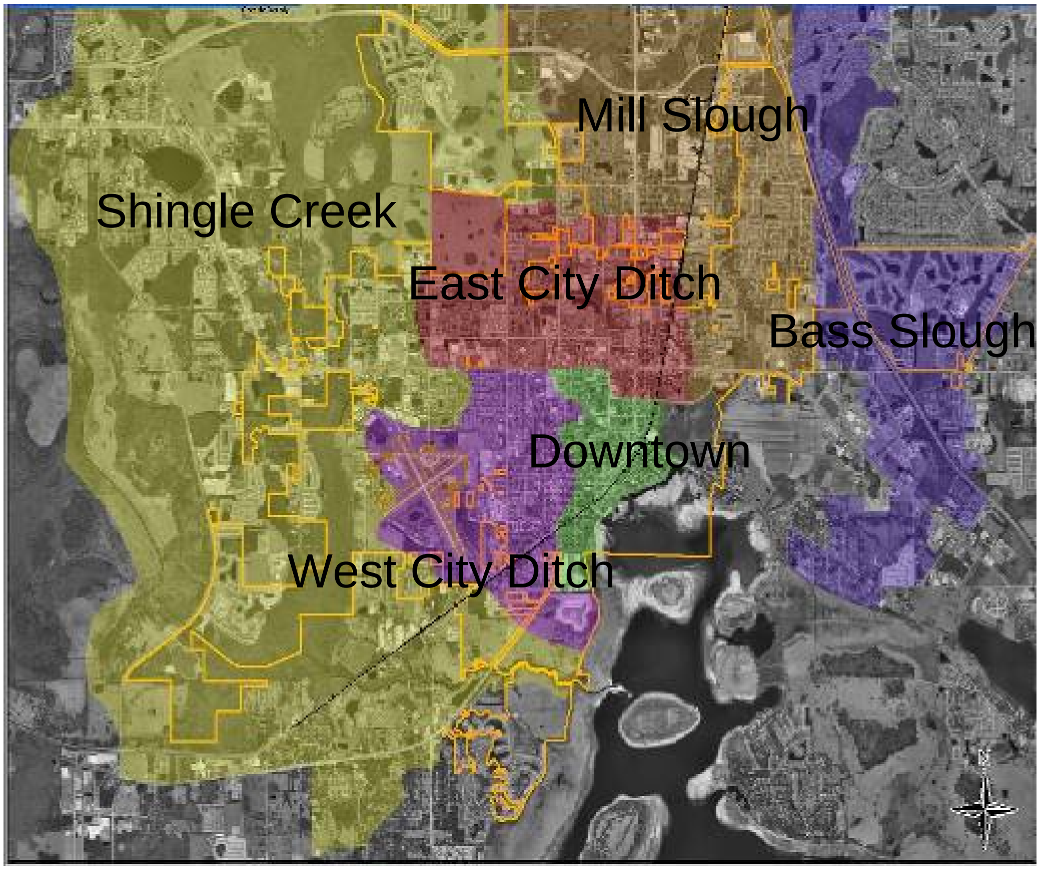


Figure 6: Land Use of Six Tributaries to Lake Tohopekaliga

Monitoring Station Locations

The first priority for location of the monitoring stations was at the outfalls of each tributary to Lake Tohopekaliga. Refer to the Monitoring Site Location Map in Figure 7 to see a view of how these stations are placed within the City of Kissimmee. These outfall locations were chosen because they were along tracks of land owned by the city and were the closest available land to Lake Tohopekaliga that were still accessible for construction and maintenance personnel.

Shingle Creek outfall is Station Number 14 which is located in a relatively straight portion of the creek, just upstream of a bridge at John Young Parkway. Station Number 3 is the outfall of Mills Slough and it was placed south of US 192 on a long, straight canal section, immediately prior to its discharge to Lake Tohopekaliga. The outfall of Bass Slough does not occur within the corporate limits of the City of Kissimmee, so Station Number 4 was located immediately upstream of the bridge a Boggy Creek Road. This location represents the outfall of water from the City of Kissimmee into the waters of Osceola County. Station Number 4 was placed immediately downstream of a discharge structure for a residential retention pond in a rip rap lined channel. The outfall of East City Ditch is Station Number 2 which is located south of Oak Street along a straight canal section just upstream of Lake Tohopekaliga. Station Number 13 is the outfall of West City Ditch which is located east of John Young Parkway on a straight canal section just upstream of Lake Tohopekaliga. The final watershed outfall into Lake Tohopekaliga is for the Downtown area. Station Number 1 is the outfall for the Downtown area and it is located along Lakeshore Drive and Dakin Street at the downstream end of a concrete box culvert which drains into Lake Tohopekaliga.

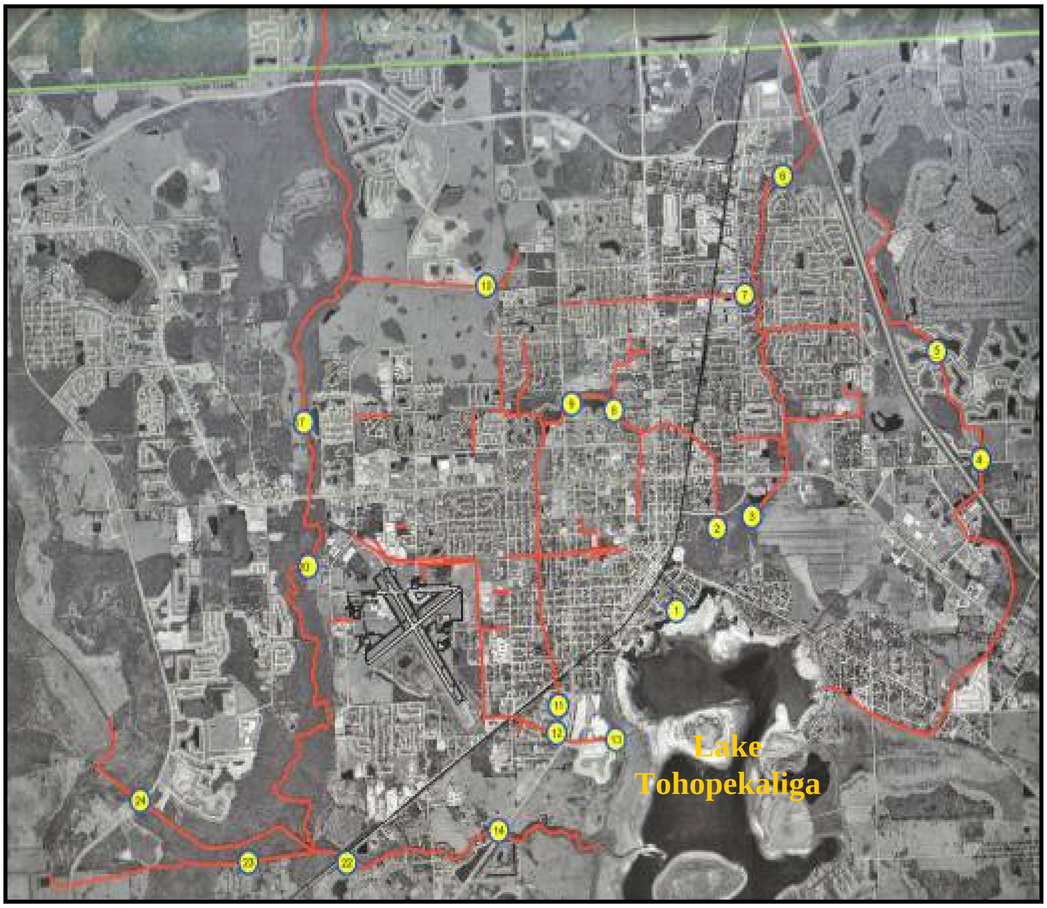


Figure 7: Monitoring Station Locations

The next priority for location of the monitoring stations was to collect data at the inflow points to the study area. Only three of the six watersheds have headwaters located outside of the City of Kissimmee. Shingle Creek, Mills Slough, and Bass Slough will have monitoring stations placed at these inflow points to determine the pollutant contributions from areas outside of the study area. These monitoring station locations were also chosen because they were on public owned tracks of land and were the closest available land to inflow points that were still accessible for construction and maintenance personnel.

Shingle Creek has four points of inflow into the City of Kissimmee limits from Osceola and Orange Counties. Station Number 15 represents the primary channel of Shingle Creek from its headwaters in Orange County. The closest viable location for this monitoring station was in southern Orange County, on the banks of a straight section of Shingle Creek, just upstream of a bridge at Hunters Creek Boulevard. Station Number 10 is located at the intersection of Thacker Road and Carroll Street, just upstream of a concrete box culvert bridge. This location monitors contributions from Osceola County into Shingle Creek flowing from the east into the City of Kissimmee. Station Number 24 is located on the banks of Browns Canal immediately upstream of a bridge at Poinciana Boulevard. This location monitors contributions from Osceola County into Shingle Creek flowing from the west into the City of Kissimmee. Station Number 23 is located in a drainage ditch east of Poinciana Boulevard which is typically dry. This location monitors contributions from Osceola County into Shingle Creek flowing from the west into the City of Kissimmee when heavy upstream flows cross a weak basin divide.

Mills Slough has two points of inflow into the City of Kissimmee limits from Osceola County. Station Number 6 represents the primary channel of Mills Slough from its headwaters in Orange County. The closest viable location for this monitoring station was downstream of a natural wetland and upstream of a bridge at Mill Run. Station Number 7 is located on a straight section of the drainage ditch, just downstream of a cross drain at Michigan Street. This location monitors contributions from Osceola County into Mills Slough flowing from the west into the City of Kissimmee.

Bass Slough has only one point of inflow into the City of Kissimmee limits from Osceola County. Station Number 5 represents the primary channel of Bass Slough from its headwaters in

Osceola County. The closest viable location for this monitoring station was downstream of a natural wetland and adjacent to a cul-de-sac at the northwest side of Lakeshore Subdivision.

The remaining seven monitoring stations are located in the Shingle Creek, East City Ditch, and West City Ditch watersheds. Station Numbers 17, 20 and 22 were located on the main channel of Shingle Creek to provide more information on the distribution of pollutant concentrations and to help identify the flow characteristics of the natural stream. Station Numbers 9 and 8 were placed on the upstream and downstream points, respectively, of a man-made lake which was constructed for water quality treatment and attenuation. Station Numbers 11 and 12 were placed on two separate contributing sections of the West City Ditch to help isolate light industrial and light commercial pollutant generators. The detailed locations of all of the monitoring stations can be found in the appendix.

Monitoring Station Configuration

There are two basic configurations of the monitoring stations with slight modifications to accommodate variations in field conditions at each site. The first of these two configurations is the catwalk monitoring station which is depicted in Figure 8. This system has the automatic sampler, telemetry system, and measuring equipment mounted at the end of a long, narrow wooden structure. The foundation of the catwalk extends out into the flow of the water and is typically used on wide and deep channels.

Figure 8: Catwalk Monitoring Station

There are four catwalk monitoring stations used in this study and all of them are located within the Shingle Creek watershed. These four catwalks are located at station numbers 14, 20, 22, and 24 which are all deep flowing channels with wide cross sections.

The second basic monitoring station configuration is the side mounted monitoring station which is depicted in Figure 9. This system has the automatic sampler, telemetry system, and measuring equipment mounted on the side of the channel. Pipes come out from the structure which is mounted on the side bank and extend into the flow of water. This system is typically used on narrow and shallow channels. The flow measuring instrument is anchored to a three foot square concrete pad to maintain its orientation and integrity.

Figure 9: Side Mounted Station

There are seven standard side mounted monitoring stations used in this study and the remaining nine monitoring stations are modified versions of the side mounted configuration. The seven standard side mounted sites are located at station numbers 2, 3, 11, 12, 13, 15, and 17 which have flows ranging from four to eight feet deep and shallow cross sections.

The side mounted configuration was modified at station number 1 to accommodate a concrete box culvert. Rather than running a pipe from the equipment structure to the measuring instruments, a hole was cut into the top of the concrete box culvert and the equipment structure was installed directly over the culvert. The flow measuring instrument was anchored directly to the base of the concrete culvert instead of to a separate concrete pad.

The remaining eight monitoring stations used in this study were located in areas where the depth of flow reaches very shallow levels. In fact, some of these sites even experience dry conditions. Since the measuring and sampling equipment needed wet conditions to operate effectively, a unique concrete channel was designed to maintain a minimum water depth and to direct lower flows across the instruments. With this design, the equipment structure is still located on the side bank, but the concrete pad is replaced with four interconnected concrete boxes. Figure 10 shows the installation of these concrete boxes.

Figure 10: Concrete Box Installation

The channel is excavated to suppress the concrete boxes two feet lower than the surrounding channel bottom. Figure 11 shows the concrete boxes being installed in the excavated portion of the channel. A hole was cut in the side of one of the concrete boxes to allow for pipes to extend from the equipment structure to the measuring instruments. The installation of the measuring equipment into the concrete channel is shown in Figure 12. Once these concrete channels were installed it was important that the water levels remained at a minimum of twelve inches over the instruments so that the flows could be measured and the water quality samples could be collected through the sampling tubes. Figure 13 shows the concrete channel under normal operation.

Figure 11: Suppressed Concrete Channel

Figure 12: Concrete Channel Equipment Installation

Figure 13: Submerged Concrete Channel

The concrete channels were installed at monitoring station numbers 4, 5, 6, 7, 8, 9, 10, and 23. At station number 7 the side slopes of the channel are extremely steep so sheet piling was driven to provide bank stability. The sheet piling interfered with the hole in the concrete channel so a short wooden structure was constructed to allow for the extension of the pipes to the flow measuring instruments inside the concrete channel.

Monitoring Station Facilities

Additional facilities are required at each site to support the operation of the measuring and sampling equipment. These support facilities include such items as a walk-in enclosure, YSI EcoNet data acquisition system, solar panels, three 300 amp 12VDC batteries, wiring junctions, solar regulator, antenna, dessicant, conduit, mounting pipes and a telemetry system. Figure 14 shows a view of these support facilities from the outside of the walk-in enclosure. All of the monitoring stations have basically these same support facilities regardless of whether they are the catwalk or side mount configuration. The main difference is the addition of a vault in the side mount configuration. In the catwalk configuration the collection pipes extend directly from the enclosure down the wooden structure into the water. To protect the instruments from vandalism and to make them more aesthetically pleasing to the eye, a 2’x4’x3’ vault was installed below grade as a conduit junction for the instrument pipes.

Figure 14: Support Facilities

Continuous Measurements

Continuous monitoring devices have been installed in all of the monitoring stations except for station number 23. The flows at station number 23 only occur in extreme rainfall events when water levels in Osceola County breech the watershed divide. Since these extreme rainfall events happen too infrequently to maintain a wet condition in the channel, the continuous monitoring equipment could not be permanently installed at this location. Future plans are to construct a mobile sampling unit to be used in this and other similar dry channels.

The remaining nineteen (19) monitoring stations have been installed with continuous monitoring equipment which will automatically collect water quality samples and gather continuous measurements of the channel parameters. This data will be compiled in the future to determine the pollutant concentrations and estimate the corresponding pollutant loading to Lake Tohopekaliga.

Measurement Devices

The continuous monitoring equipment includes instruments that gather physical data from the channel. One of these is a long, tubular, multi-parameter water quality instrument called the YSI 6600 EDS Component. It is used to measure temperature, dissolved oxygen, pH, Chlorophyll, conductivity, salinity, turbidity, and total dissolved solids. Another one of the continuous monitoring equipment is the Sontek Argonaut (SL) which has a shorter, stubbier cylindrical shape used to measure water level, velocity, and temperature. Both of these instruments are shown in Figure 15.

Figure 15: Continuous Measurement Devices

The Sontek Argonaut (SL) instrument in which the “SL” stands for “Side Looker” was used on the deeper wider channels in conjunction with the catwalk monitoring station configuration. It is mounted on the side of the channel and measures flow sideways across the channel. For shallow, narrow channel flow conditions a Sontek Argonaut (SW) in which the “SW” stands for “Shallow Water” was used for measuring the same parameters. This unit is mounted at the bottom of the channel and measures in a vertical direction. Figure 16 shows a view of the Sontek Argonaut (SW) unit fastened to a mounting bracket.

Figure 16: Sontek Argonaut (SW) Flowmeter

Although both Sontek Argonaut units will give a water depth measurement, each station was equipped with a specialized water level measuring instrument for a higher accuracy. The catwalk monitoring stations were equipped with Shaft Encoder instruments and the side mount configurations were equipped with Pressure Transducers for determining the water levels. All stations were outfitted with a Sutron Rain Gauge to measure the rainfall depths and intensities.

Two of the stations were equipped with YSI 9600 Nitrate Analyzers. The limited number of nitrate analyzers was due to budget constraints and the relatively high operation costs. The two sites chosen for these units were Monitoring Station Numbers 9 and 8 which are located on the inflow and outflow points of a man-made lake, respectively. These units provide an analysis of nitrate concentrations on a continuous two-hour interval and are shown in Figure 17.

Figure 17: YSI 9600 Nitrate Analyzer

Sampling Devices

The continuous monitoring equipment includes instruments that gather samples of water from the channel. The water quality sampling instrument installed at all sites is called the ISCO Avalanche Refrigerated Autosampler. It is used to drawl specific volumes of water through a tube at selected intervals throughout a duration of time and deposit them into containers. These containers are refrigerated and stored until the samples are ready to be transported to the lab for analysis. The specified volumes and times of sampling are established prior to the time of collection based on the type of pollutants that are expected to be captured for analysis. The ISCO Avalanche Refrigerated Autosampler is shown in Figure 18.

Figure 18: ISCO Avalanche Refrigerated Autosampler

Since this project is focused on collecting the pollutant loading from runoff a twenty-four hour overall sampling duration was selected with four distinct sampling periods. The ISCO automatic sampler was programmed to collect 1200 milliliters of water in the first container four times every ten minutes. This first sampling would last over a 30 minute period and be an indication of the first flush of runoff. Programming was set to continue collecting 200 milliliters of water 20 times every nine minutes in the second container. The third container was then to collect 200 milliliters of water every 18 minutes 20 more times. The ISCO automatic sampler was programmed to fill the final container 20 additional times, every 45 minutes with 200 milliliters of water. This programming would last for just over a 24 hour duration.

Water Quality Sampling

A sampling protocol for the water quality monitoring program of this study has been developed. This protocol includes procedures during the water quality monitoring phase of the project to assure the samples are properly collected, handled, and transported to the environmental lab for analyses. The focus on this study is the grab sampling rather than the automatic sampling of rainfall events.

A training program was held at the City of Kissimmee to demonstrate the sampling protocol to the sampling team. The training included a demonstration of sample collection procedures, sampling equipment, sampler programming, sample container handling, field quality assurance/quality control (QA/QC) procedures, field sampling documentation, equipment decontamination, waste management, sampler maintenance, sample handling, sample documentation, sample labeling, chain-of-custody, and sample shipment.

Sampling Schedule

The sampling schedule refers only to the grab sampling portion of this project which is the focus of this study. The water quality samples of this study were collected on Mondays, Wednesdays, and Thursdays for four weeks per month. This resulted in each site initially being sampled three times per month. After a four month period, the sample results were analyzed and only critical pollutants were tested from that point on. The number a samples collected was reduced to twice per month on Mondays and Thursdays. This rate of two samples per month was maintained throughout the remainder of this study.

The sites were divided into four groups designated by A, B, C, and D. Each site group included four to six sites as shown in Table 4. With samples being collected from each site twice a week in four groups, each site was visited twice a month which also worked well for the equipment maintenance schedule. Duplicate samples were collected at each site during the first, seventh, and fifteenth sampling events of that site.

Table 4: Designated Site Groups

Site Group	Site Number	Basin
A	3, 4, 5, 6, 7	Mill Slough and Bass Slough
B	2, 8, 9, 11, 12, 13	East City Ditch and West City \Ditch
C	1, 10, 15, 17, 20	Downtown and Upper Shingle Creek
D	14, 22, 23, 24	Lower Shingle Creek

These field duplicates were obtained by subsampling the composite samples. Field blank samples were also collected at the same intervals as the duplicate samples for quality control purposes. Filed blanks were used to test the purity of the chemical preservatives, check for contamination of sample containers or equipment that was used in sample collection. These field blanks also helped detect handling, transportation, systemic or random errors.

Labeling Convention

Sample containers were provided by the certified labs without any information on the labels. Prior to collection of the water quality samples the containers needed to be marked with an identification of where the sample was grabbed, what date it was collected and for which pollutants it needed to be tested. This was accomplished by marking the containers a unique series of letters and numbers that provided the necessary information. The first three characters of this alphanumeric series were “COK” to indicate that the sample is for the City of Kissimmee. The next two digits indicate at which monitoring station location the sample was collected (i.e., the site number). The next six digits indicate the date the sample which consist of the year (2 digits), the month (2 digits), and the day of month (2 digits), for example “060429” would indicate a sample collected on April 29th, 2006. On occasion a final character was added to the sample identification to indicate by either a letter “D” or “B” if the sample was a duplicate or a blank, respectively.

Sampling Apparatus

Certain items were required to be able to collect accurate water quality samples. These items included gloves to keep any contaminants on the hands from getting into the sample containers. The sample containers themselves also needed to be contamination free and in some cases, such as with metals, filled with a stabilizing agent. Sample bottles and composite containers needed to be clean and protected. Ice chests and ice were needed to keep the samples cool during transport. Finally, sampling rods and clean glass jars were needed to actually collect the grab samples from the channel.

Sampling Procedures

Procedures were established for the collection of the water quality samples to maintain their validity. The sampling team used a glass bottle attached to a long sampling pole to collected grab samples manually from the channel. For each site, a different glass bottle was used to avoid any cross contamination between sites. Also, the grab sample was taken from the middle of the channel approximately one-foot below the water surface to avoid any surface or side channel contaminants. The first grab sample from the channel was not used to avoid any potential for residual contaminants in the glass from reaching the sample. Finally, the glass bottle was inverted as it entered the water and then righted once it was fully submerged to avoid the suction of surface water into the sample.

The grab samples from the channel were used to fill a five liter composite container. This composite container was gently rotated 180 degrees (upside down) twice prior to gently pouring off the sub-sample into the corresponding laboratory container. The laboratory containers were labeled immediately after the sub-samples were collected to avoid any potential notation errors. As noted in the previous section, a unique alphanumeric identification was used to separate different samples and avoid later confusion between samples. Once the laboratory containers were filled and labeled they were immediately sealed into plastic bags and placed into ice chests.

Ice cubes were then added on top of the sealed laboratory containers as soon as possible to preserve the samples at a temperature near 4 °C. As previously mentioned, powder-free latex gloves were used in handling the samples to avoid any cross contamination between the sites. The Chain-of-Custody was prepared at each site to document the water quality sample collection and field conditions.

Water Quality Sample Analysis

The composite grab samples were placed into containers at each site and transported in ice chests to the state certified laboratories for biological and chemical analysis. The success of the remaining data collection process was based on how well the water quality samples were handled and analyzed. This included the selection of the proper laboratories to analyze the samples, choosing the best means of transporting the containers, maintaining accurate documentation for sample tracking and reviewing the laboratory results to verify any needs for re-testing.

Laboratories

16 different laboratories in the Central Florida area were initially contacted to verify which laboratories could meet the City of Kissimmee project requirements. These 16 laboratories were asked to give their bids for performing the necessary analysis. The final selection of the two laboratories was based on their proximity to the project and the ability to perform the required water quality analysis within the required time frame. The PE LaMoreaux and Associates (PELA) Lab located at 4320 Old Highway 37, Lakeland, Florida was chosen to perform the nutrient and metal laboratory analysis. These nutrient and metal water quality parameters are

listed as items 1 through 26 in Table 5. Test America Lab located at 4310 East Anderson Road, Orlando, Florida performed the analyses for the bacteriological parameters. These bacteriological water quality parameters are listed as items 27 through 29 in Table 5.

Table 5: List of Analytical Parameters for Water Analysis

No.	Parameter
1	Ammonia as N
2	Kjeldahl Nitrogen-total
3	Nitrate-Nitrite as N
4	Organic Nitrogen
5	Orthophosphorous
6	Phosphorous, total
7	Residue-filterable (TDS)
8	Residue-nonfilterable (TSS)
9	Biological Oxygen Demand-BOD5
10	Chemical Oxygen Demand (COD)
11	Turbidity
12	pH
13	Chlorophyll a
14	Mercury, total
15	Lead, total
16	Copper, total
17	Zinc, total
18	Iron, total
19	Cadmium, total
20	Chromium, total
21	Nickel, total
22	Arsenic, total
23	Silver, total
24	Barium, total
25	Selenium, total
26	Total Petroleum Hydrocarbons
27	Total Coliforms
28	Fecal Coliforms
29	E. Coli (if Fecal Coliform is positive)

Chain of Custody

The sample containers were bagged and placed into the ice chest such that space exists above and between the containers for ice and packing material. Sufficient ice was added to each cooler to maintain sample temperature near 4°C. Immediately upon packing the containers into the ice chests a Chain of Custody (COC) form was prepared. This Chain of Custody form included the alphanumeric sample identification and the date and time the sample was collected. This COC form also provided the name of the site where the sample was collected and its location. The type of water quality sample analysis required and the preservative used to maintain the sample is provided on this COC form. The full names of all of the water quality sample collectors and their signatures are required on this COC form, as well as the full names and signatures of who they transferred the water quality samples to for transport to the laboratory. The dates and times of sample transfer from the water quality sample collectors in the field to the transporters and then finally to the laboratory are also included on this COC form. The final step in the process is the signature of the state certified laboratory accepting the successfully transported water quality samples. This process was repeated for every sample collected for this project.

Data Verification

The reported preliminary results of the analyzed samples received from the laboratories were checked for data quality assurance. The laboratories that performed the analyses were asked to verify any doubtful results such as outliers, missing data or syntax issues. In addition, the preliminary results were checked to determine if the laboratory testing methods needed to be revised to better analyze field conditions.

Summary of Data Collection

The objective of this study was to determine the water quality condition of the tributaries to Lake Tohopekaliga. This information is used in conjunction with the water quantity data to estimate the corresponding pollutant loadings. To meet these objectives nineteen water quality monitoring stations were constructed at strategic points of the study area. These stations were equipped with instruments to measure the physical, chemical, and biological characteristics of the six watersheds contributing flow from the City of Kissimmee to Lake Tohopekaliga. Manual grab samples were collected and transported to the state certified laboratories to be analyzed and the results were verified.

CHAPTER 4:
DATA ANALYSIS AND RESULTS

Introduction

The study had two objectives, first to establish a permanent system of monitoring stations to collect valuable water quality and quantity data and second to use some of this data in a pilot study to verify that the system is capable of providing the correct data for future analysis of pollutant loads. A fifteen acre, man-made lake within the project limits was chosen for the pilot study area. This lake ranges from 3 to 8 feet deep and has an average depth of approximately five feet. This lake has an average annual flow rate of 3.5 cubic feet per second which results in a residence time of eleven days. The lake has not been planted with vegetation and little natural growth has occurred. Monitoring stations are located at the influent and effluent sections of the lake which provided data on the hydraulic and hydrologic parameters. The pilot study determined the nutrient loads to and from the lake and checked for any seasonal variations in pollutant loading or removal efficiencies. For the purpose of this pilot study, only total nitrogen and total phosphorous were examined for two monitoring sites.

Monitoring Stations

The process of determining the monitoring site locations, equipping them with the appropriate instrumentation, and integrating these various measurement components so that they could effectively communicate with each other was performed successfully. Of the initial twenty field locations, only nineteen were actually placed online. The only station that was not placed in operation was at site number 23. This site was left off-line since it was found to have only intermittent periods of inundation. Other than this site, all other sites are on-line and functioning properly. The main obstacle encountered in the field was vegetation and sediment interfering with the functioning of the YSI 6600 EDS, YSI Argonaut and the YSI 9600 Nitrate Analyzer units. These are the only three instruments that are submerged during their operation. The malfunctioning of the YSI Argonaut was particularly disruptive to meeting the data requirements of the secondary objective.

The graph of the nutrient results for the initial fifteen grab samples at all 20 sites are provided in Figure 19. These results are also shown with the twenty-five and seventy-five percentile levels plotted to provide a regional view of pollutant concentrations.

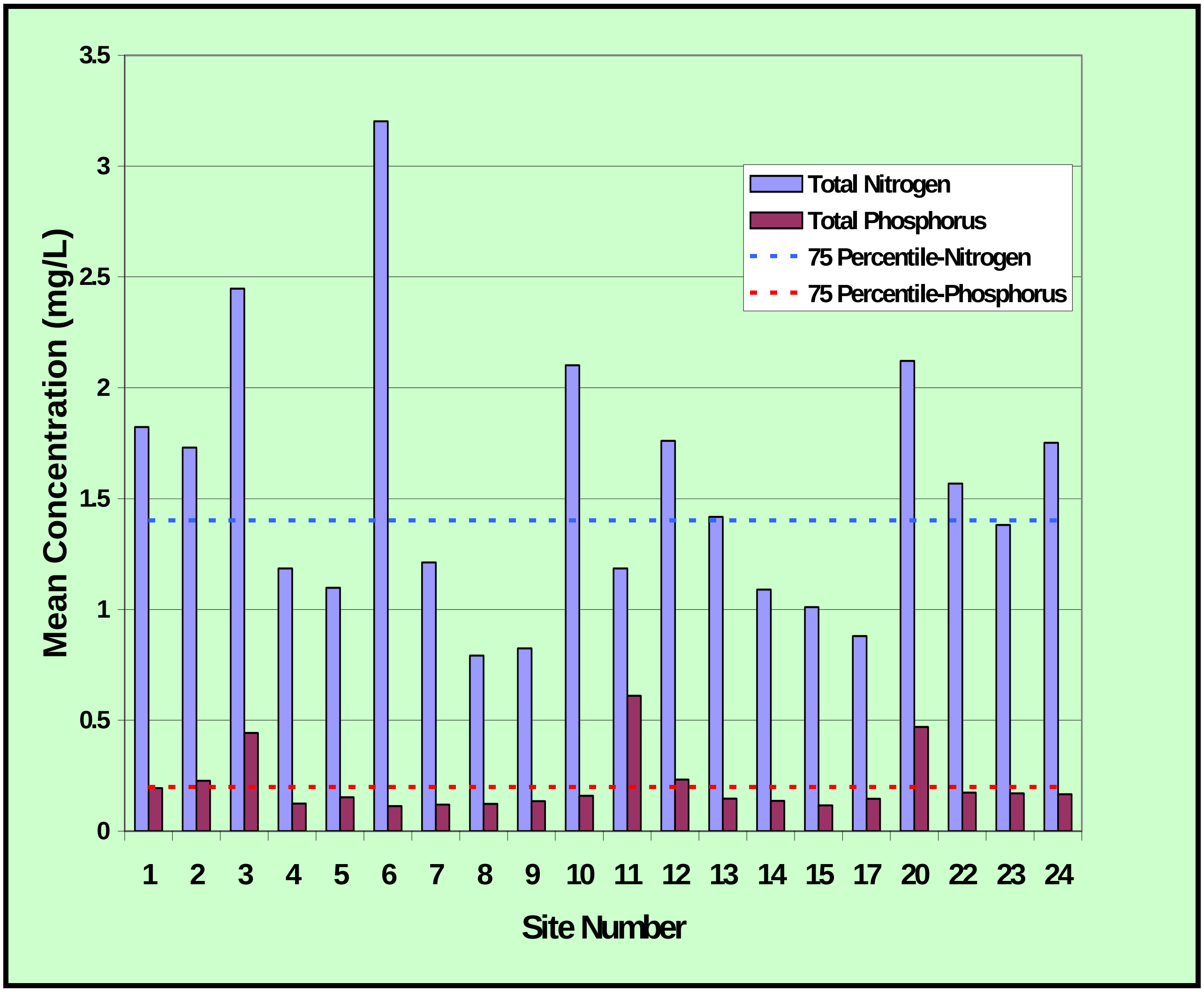


Figure 19: Initial Nutrient Grab Sample Results

Pilot Study Data Collection

The grab sample data was collected and the flow data from the continuous monitoring station sites was downloaded from the web site. Figures 20 and 21 show the nutrient grab sample results for sites 8 and 9, respectively. The flow meter data blanks caused by the measuring equipment being disrupted occurred during the winter months of December 2006 through February 2007 and mainly affected site number 8. Fortunately, the two stations are located in a close enough proximity that there measurements of rainfall and flow approaches redundancy. A comparison of the data from the two sites showed that the instantaneous measurements were different, but over a longer period, such as a few days, the data matched very well.

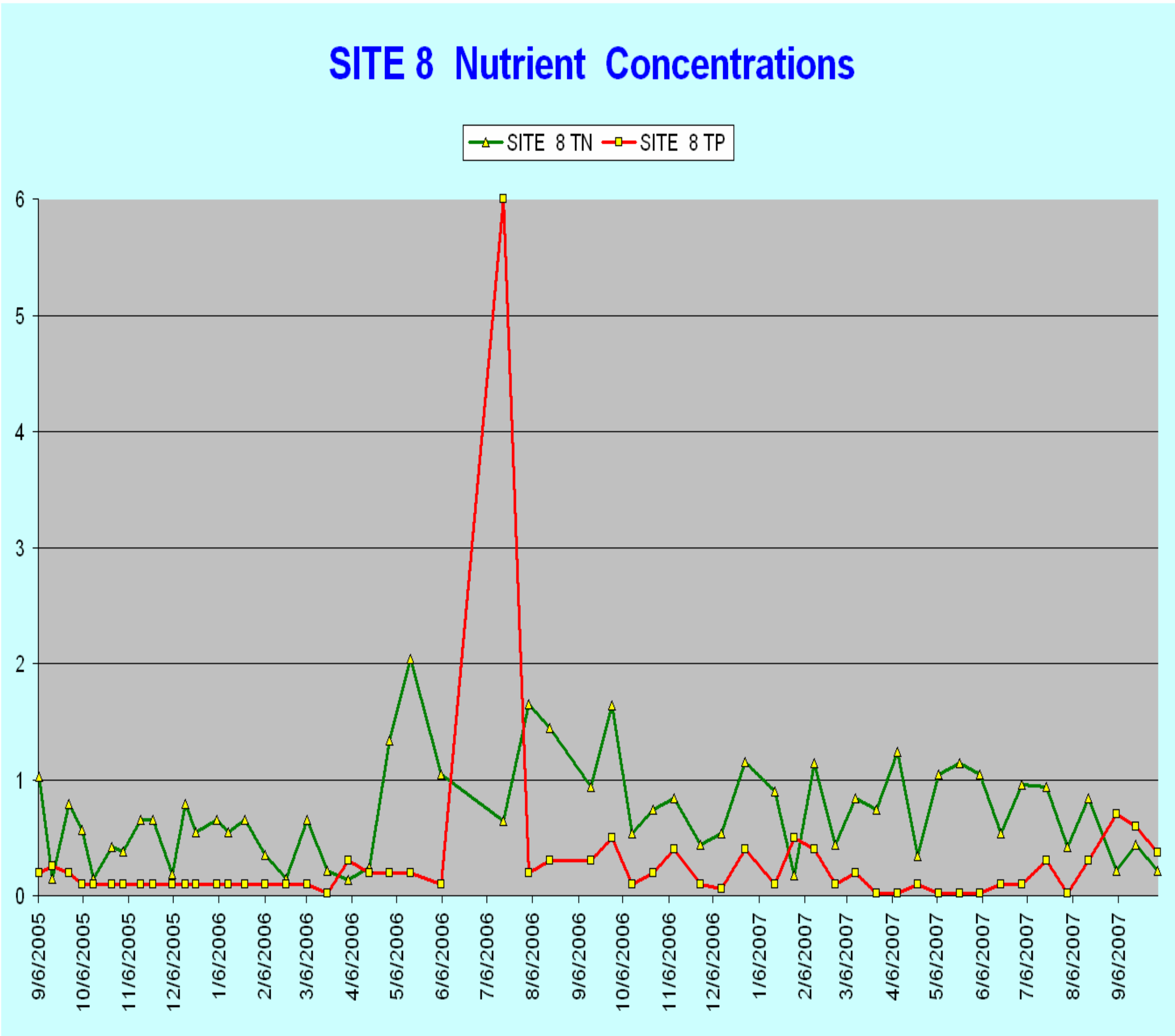


Figure 20: Site 8 Nutrient Grab Sample Results

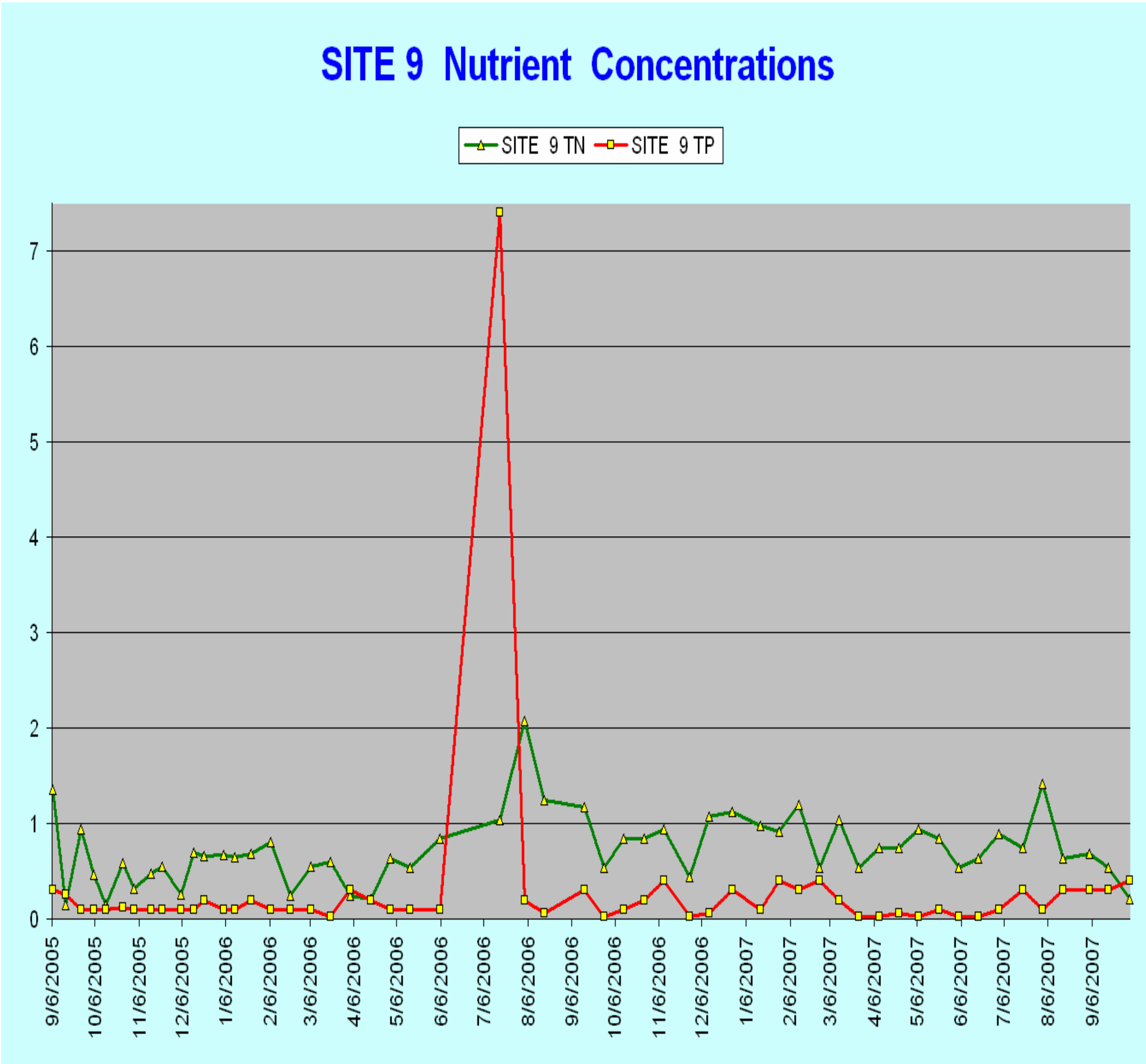


Figure 21: Site 9 Nutrient Grab Sample Results

Pilot Study Data Analysis

The first step in the data analysis was to fill in the flow and rainfall blanks of site 8. Since the analysis of the flow volumes was conducted on a two week interval, which followed the grab sample spacing, the variation in flow values between site 8 and 9 were felt to be negligible. In addition, this period of time was devoid of any significant rainfall events and represented only a minor base flow correction. The combined water quality and water quantity data for total nitrogen and total phosphorus were compiled into the tables that are presented here as Tables 6 and 7, respectively.

The nutrient removal efficiency was performed using both the event mean concentration method and the summation of loads method to check for any seasonal variations. There were no storm event concentrations available for used in this analysis, however, there were 25 discrete grab samples collected on a bi-monthly basis over a twelve month period. This data was used with corresponding five-minute rainfall and flow data from both the inflow and outflow points.

Table 6: Total Nitrogen Results

DATES	FLOW VOLUME		TN CONCENTRATION		TN LOAD		REMOVAL EFF.	RAIN
	IN	OUT	IN	OUT	IN	OUT		
	AC-FT	AC-FT	mg/L	mg/L	LBS.	LBS.	%	in
01 AUG 06 to 16 AUG 06	77	68	1.95	1.53	409	284	30	1.05
16 AUG 06 to 31 AUG 06	255	263	1.27	1.45	881	1034	-17	5.67
AUG-06 TOTALS	332	331	1.61	1.49	1454	1340	8	6.72
01 SEP 06 to 15 SEP 06	142	148	1.20	1.17	464	470	-1	1.68
16 SEP 06 to 30 SEP 06	49	43	1.08	1.04	144	121	16	0.37
SEP-06 TOTALS	191	190	1.14	1.11	592	572	3	2.04
01 OCT 06 to 16 OCT 06	38	35	0.60	1.40	62	134	-116	0.15
16 OCT 06 to 31 OCT 06	43	46	0.84	0.60	98	75	24	0.37
OCT-06 TOTALS	81	81	0.72	1.00	159	221	-39	0.52
01 NOV 06 to 15 NOV 06	47	59	0.88	0.78	112	125	-12	0.56
16 NOV 06 to 30 NOV 06	77	65	0.75	0.68	157	121	23	0.84
NOV-06 TOTALS	124	124	0.81	0.73	275	247	10	1.40
01 DEC 06 to 16 DEC 06	13	71	0.62	0.47	21	90	-328	2.38
16 DEC 06 to 31 DEC 06	156	98	1.09	0.75	462	199	57	2.43
DEC-06 TOTALS	169	169	0.85	0.61	391	279	29	4.81
01 JAN 06 to 16 JAN 06	55	50	1.08	1.09	162	148	9	0.12
16 JAN 06 to 31 JAN 06	66	72	0.97	0.87	175	171	2	1.07
JAN-07 TOTALS	122	122	1.03	0.98	339	325	4	1.19
01 FEB 06 to 14 FEB 06	48	53	0.98	0.39	128	56	57	0.45
15 FEB 06 to 28 FEB 06	37	32	1.06	0.99	106	86	19	0.14
FEB-07 TOTALS	85	85	1.02	0.69	235	159	32	0.58
01 MAR 06 to 16 MAR 06	43	45	0.65	0.53	76	64	16	0.53
16 MAR 06 to 31 MAR 06	49	46	0.88	0.81	116	102	12	0.06
MAR-07 TOTALS	92	91	0.76	0.67	190	165	13	0.59
01 APR 06 to 15 APR 06	98	92	0.63	0.95	167	239	-43	2.13
16 APR 06 to 30 APR 06	51	58	0.74	0.79	103	124	-20	0.07
APR-07 TOTALS	150	150	0.68	0.87	278	355	-28	2.20
01 MAY 06 to 16 MAY 06	45	48	0.85	0.74	105	96	8	0.71
16 MAY 06 to 31 MAY 06	45	42	0.87	1.11	106	126	-19	0.05
MAY-07 TOTALS	90	90	0.86	0.92	211	225	-7	0.76
01 JUN 06 to 15 JUN 06	329	360	0.60	1.06	540	1039	-92	8.62
16 JUN 06 to 30 JUN 06	114	82	0.63	0.61	194	137	29	1.56
JUN-07 TOTALS	442	442	0.62	0.84	740	1006	-36	10.17
01 JUL 06 to 16 JUL 06	225	239	0.87	0.93	533	605	-13	3.54
16 JUL 06 to 31 JUL 06	317	302	0.76	0.94	657	774	-18	5.62
JUL-07 TOTALS	542	541	0.82	0.94	1203	1378	-14	9.16
TOTALS	2,418	2,415	21.85	21.69	6,067	6,273	-3	40.13
AVERAGE EVENT MEAN CONCENTRATION			0.91	0.90	5,987	5,936	1	

Table 7: Total Phosphorus Results

DATES	FLOW VOLUME		TP CONCENTRATION		TP LOAD		REMOVAL EFF.	RAIN
	IN	OUT	IN	OUT	IN	OUT		
	AC-FT	AC-FT	mg/L	mg/L	LBS.	LBS.	%	in
01 AUG 06 to 16 AUG 06	77	68	1.05	0.88	219	164	25	1.05
16 AUG 06 to 31 AUG 06	255	263	0.07	0.30	45	212	-369	5.67
AUG-06 TOTALS	332	331	0.56	0.59	502	530	-6	6.72
01 SEP 06 to 15 SEP 06	142	148	0.19	0.30	73	120	-66	1.68
16 SEP 06 to 30 SEP 06	49	43	0.26	0.33	35	38	-10	0.37
SEP-06 TOTALS	191	190	0.22	0.31	116	163	-40	2.04
01 OCT 06 to 16 OCT 06	38	35	0.04	0.41	4	40	-934	0.15
16 OCT 06 to 31 OCT 06	43	46	0.13	0.13	15	16	-6	0.37
OCT-06 TOTALS	81	81	0.08	0.27	19	60	-223	0.52
01 NOV 06 to 15 NOV 06	47	59	0.29	0.29	36	46	-26	0.56
16 NOV 06 to 30 NOV 06	77	65	0.25	0.28	53	50	5	0.84
NOV-06 TOTALS	124	124	0.27	0.28	91	96	-6	1.40
01 DEC 06 to 16 DEC 06	13	71	0.03	0.09	1	17	-1496	2.38
16 DEC 06 to 31 DEC 06	156	98	0.14	0.18	60	47	22	2.43
DEC-06 TOTALS	169	169	0.09	0.13	40	61	-53	4.81
01 JAN 06 to 16 JAN 06	55	50	0.25	0.33	37	44	-18	0.12
16 JAN 06 to 31 JAN 06	66	72	0.11	0.12	20	23	-12	1.07
JAN-07 TOTALS	122	122	0.18	0.22	60	73	-22	1.19
01 FEB 06 to 14 FEB 06	48	53	0.38	0.48	49	69	-39	0.45
15 FEB 06 to 28 FEB 06	37	32	0.32	0.34	32	29	9	0.14
FEB-07 TOTALS	85	85	0.35	0.41	81	94	-17	0.58
01 MAR 06 to 16 MAR 06	43	45	0.36	0.12	42	15	65	0.53
16 MAR 06 to 31 MAR 06	49	46	0.14	0.14	19	18	5	0.06
MAR-07 TOTALS	92	91	0.25	0.13	62	33	48	0.59
01 APR 06 to 15 APR 06	98	92	0.02	0.02	5	5	6	2.13
16 APR 06 to 30 APR 06	51	58	0.04	0.06	6	9	-69	0.07
APR-07 TOTALS	150	150	0.03	0.04	12	16	-33	2.20
01 MAY 06 to 16 MAY 06	45	48	0.04	0.05	5	7	-55	0.71
16 MAY 06 to 31 MAY 06	45	42	0.07	0.02	9	2	75	0.05
MAY-07 TOTALS	90	90	0.06	0.04	14	9	33	0.76
01 JUN 06 to 15 JUN 06	329	360	0.04	0.02	33	20	41	8.62
16 JUN 06 to 30 JUN 06	114	82	0.02	0.09	6	20	-221	1.56
JUN-07 TOTALS	442	442	0.03	0.05	34	65	-90	10.17
01 JUL 06 to 16 JUL 06	225	239	0.09	0.10	58	65	-13	3.54
16 JUL 06 to 31 JUL 06	317	302	0.27	0.27	233	222	5	5.62
JUL-07 TOTALS	542	541	0.18	0.19	269	273	-1	9.16
TOTALS	2,418	2,415	4.60	5.34	1,300	1,473	-13	40.13
AVERAGE EVENT MEAN CONCENTRATION			0.19	0.22	1,259	1,461	-16	

The concentration levels of total nitrogen did not seem to vary significantly from its mean value of 0.90 mg/l throughout the year. The concentration levels of total phosphorus did range from 0.02 mg/l to 0.48 mg/l, but not in relation to either season or flow volume fluxuations. The lake showed no net removals of total nitrogen and was actually found to be releasing total phosphorus to the downstream receiving waters.

Both of these tables show the levels of total nitrogen and total phosphorus are at the threshold levels for generating algae blooms of 1.5 mg/l and 0.15 mg/l for total nitrogen and total phosphorus, respectively. Only two minor algae blooms were observed at the time of the field measurements and they each only lasted a few days. The tables also show the analysis of the data using both the summation of loads (SOL) approach and the average event mean concentration (AEMC) approach for computing the mass balance for nutrient loads. The SOL approach was preformed on a bi-monthly and monthly basis. The AEMC approach was performed on the entire year of the study.

A review of the data shows that the SOL and AEMC methods yielded approximately the same results. This is mostly because the study period was such a short duration of only one year. It is interesting to note that the magnitude of total nitrogen loads coming into the lake were basically unaltered. In contrast, the total phosphorus levels actually were increased at the outlet of the lake.

Figures 22 and 23 represent the total nitrogen and total phosphorus concentrations with respect to the seasonal flow variations at the inflow and outflow of the lake, respectively. Figures 24 and 25 represent the total nitrogen and total phosphorus loads with respect to the seasonal flow variations at the inflow and outflow of the lake, respectively. Figures 26 and 27 represent the seasonal nutrient loads flowing into and out from the lake for total nitrogen and total phosphorus, respectively. All six charts seem to show the variation of flows during the wet and dry cycles, but there does not appear to be any significant fluxuation of nutrient concentration levels or removal efficiency with respect to season. The only nutrient that showed any seasonal variation was nitrogen and it only showed slightly lower values towards the later part of spring and early summer.

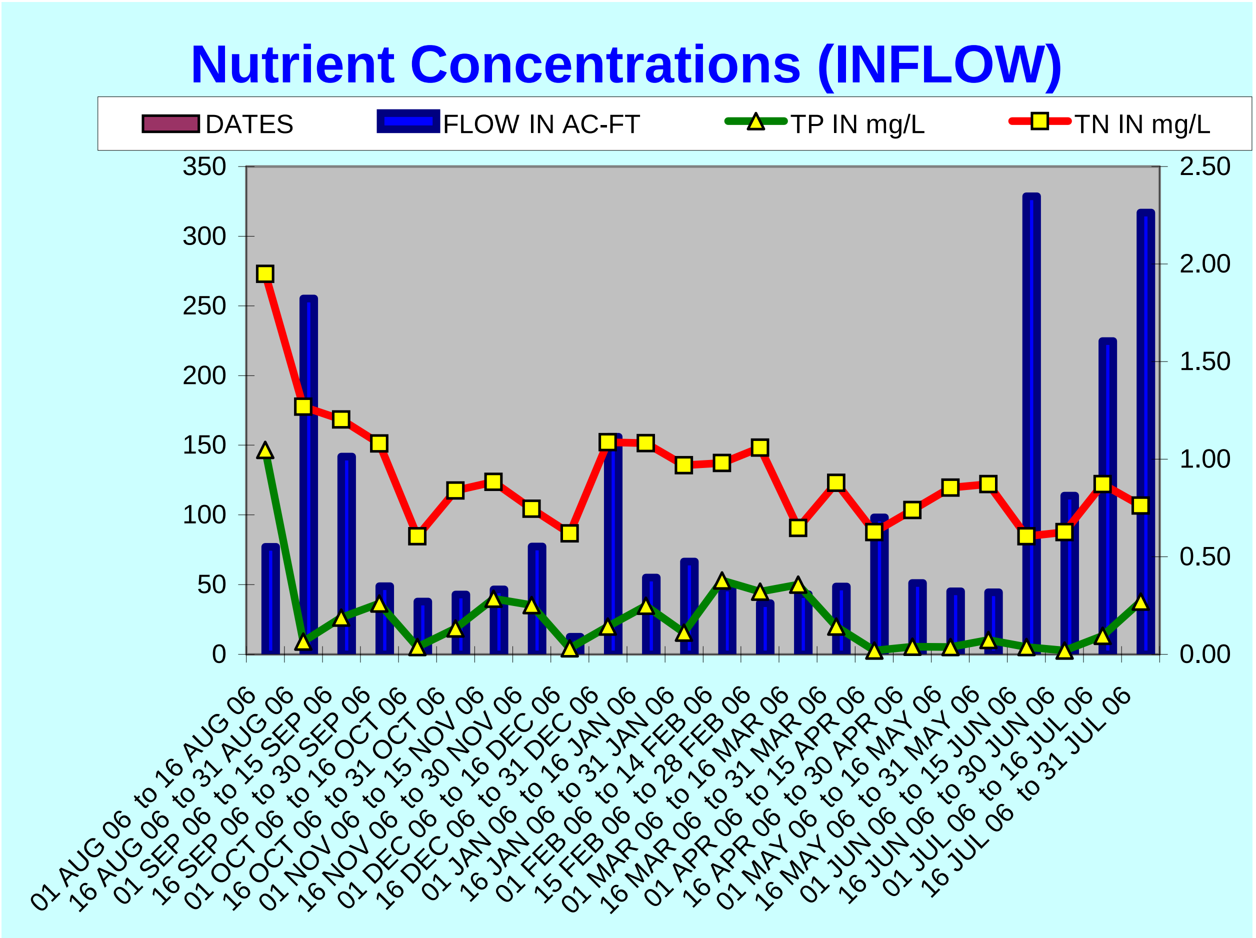


Figure 22: Seasonal Nutrient Inflow Concentrations

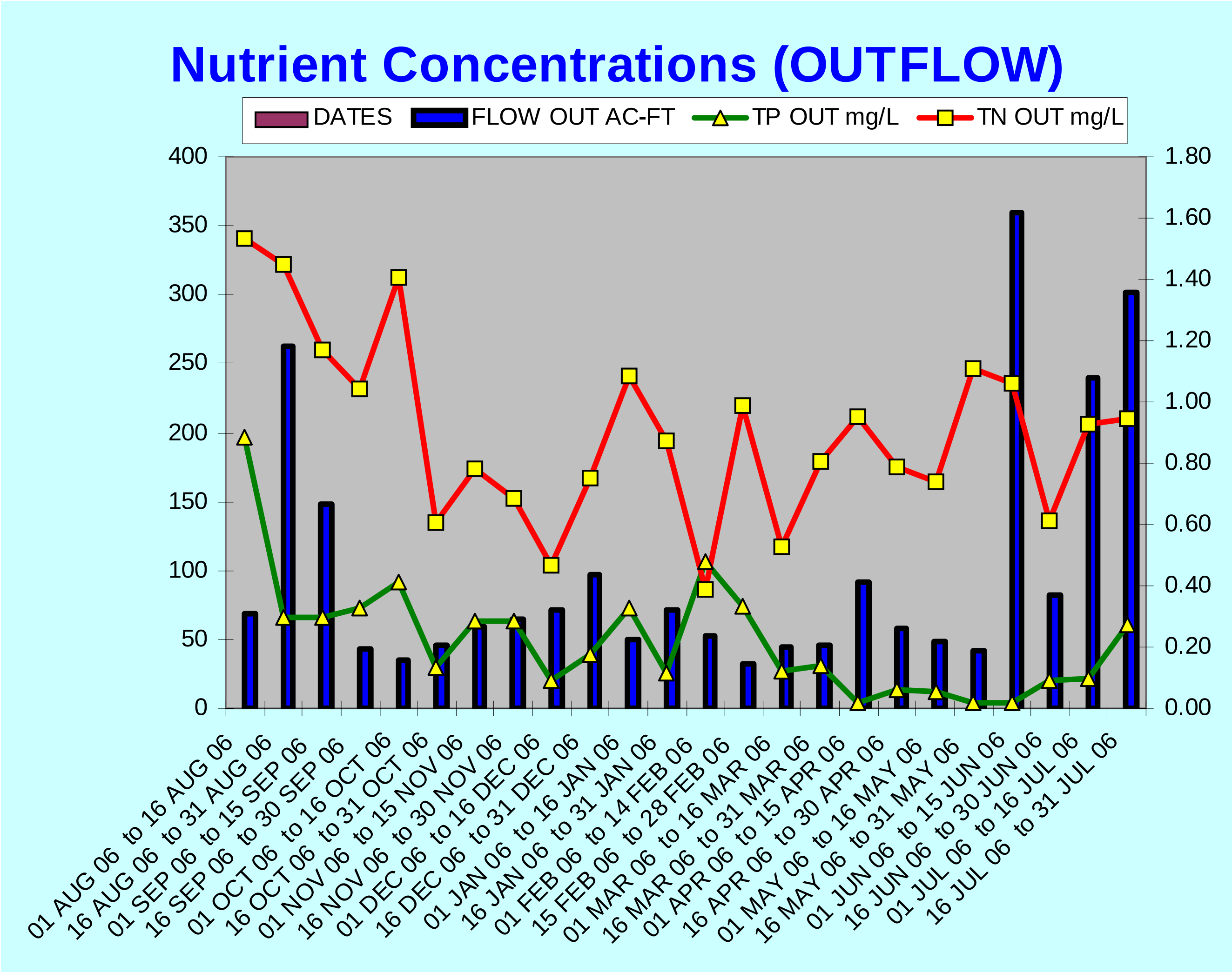


Figure 23: Seasonal Nutrient Outflow Concentrations

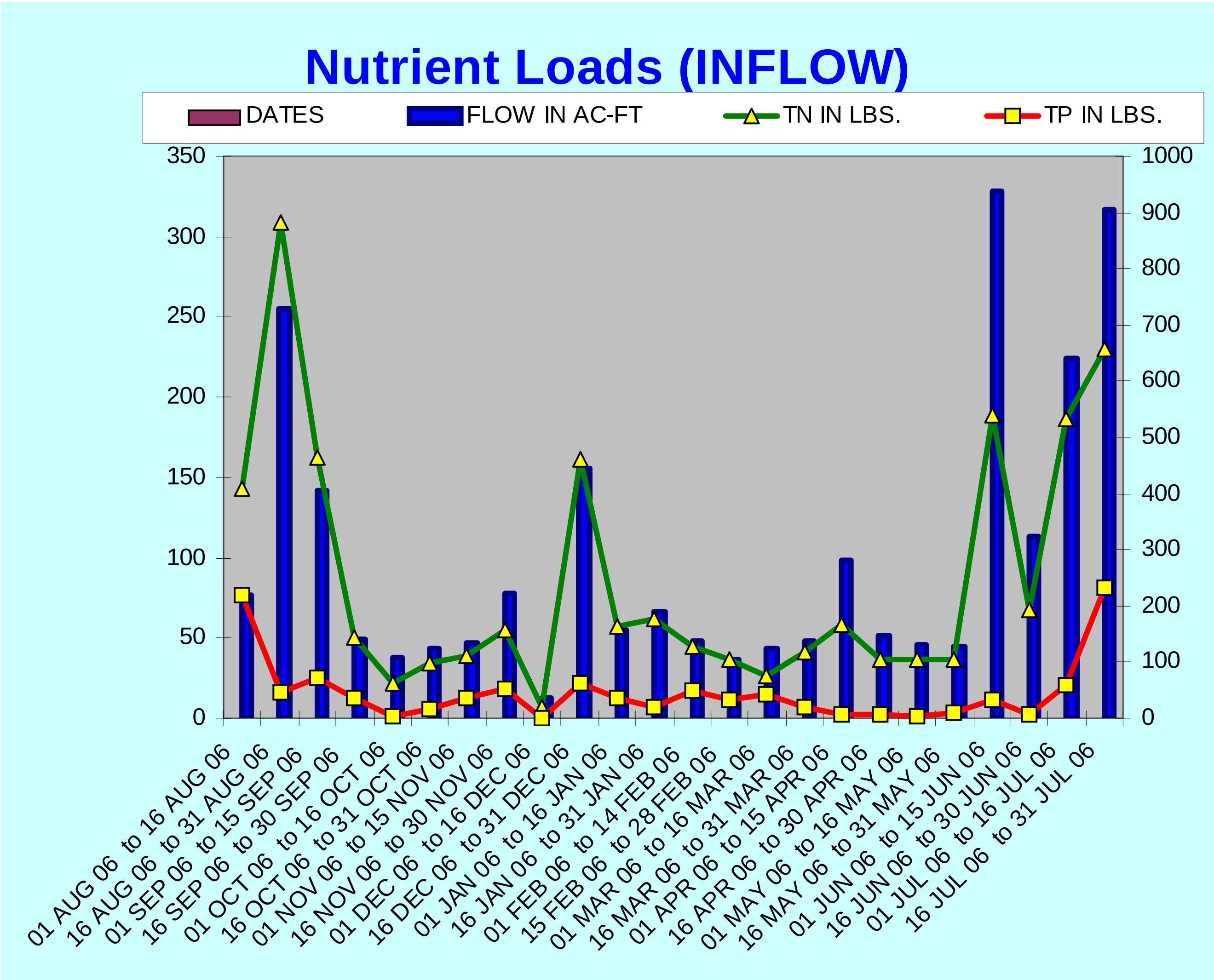


Figure 24: Seasonal Nutrient Inflow Loads

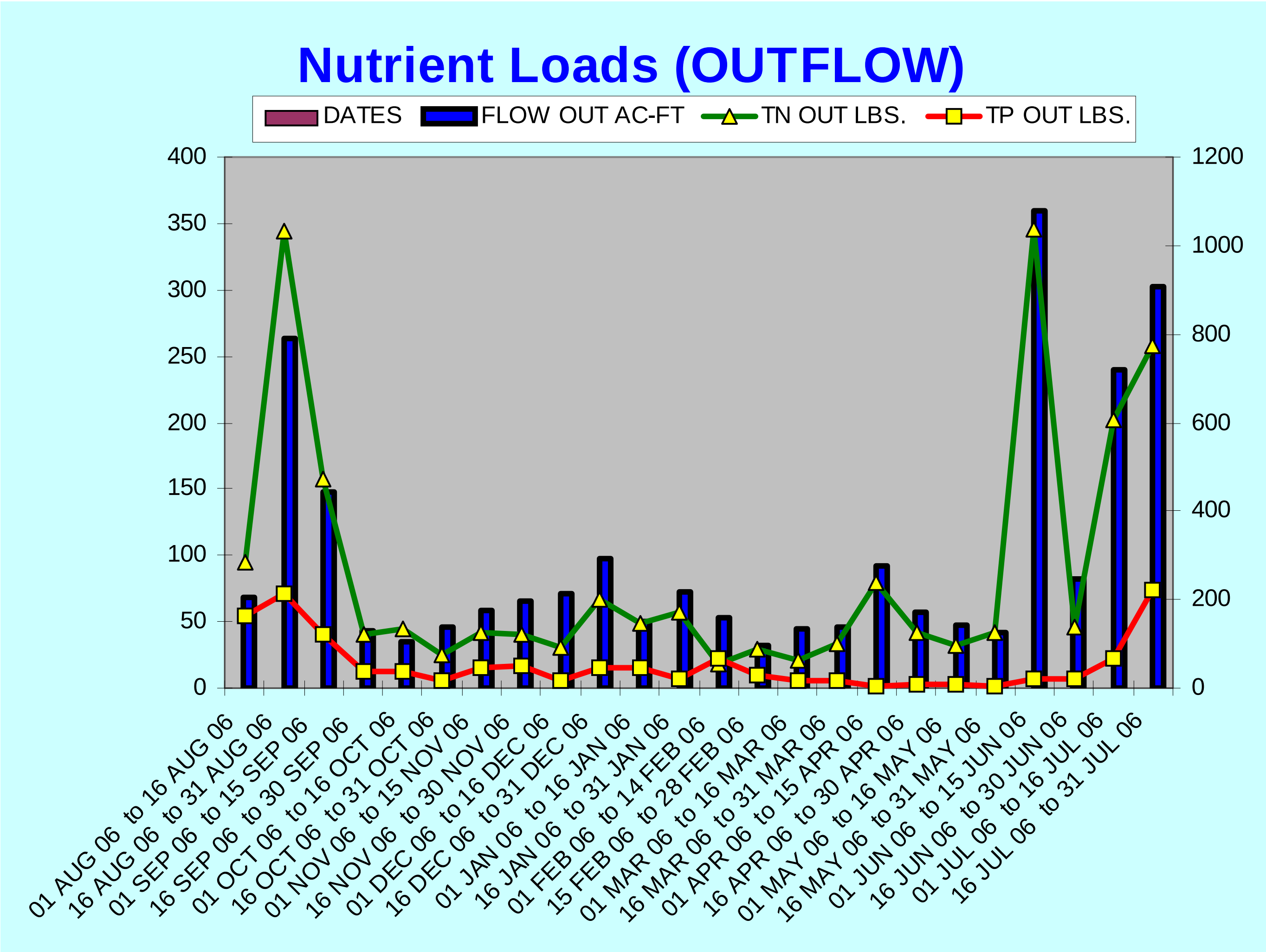


Figure 25: Seasonal Nutrient Outflow Loads

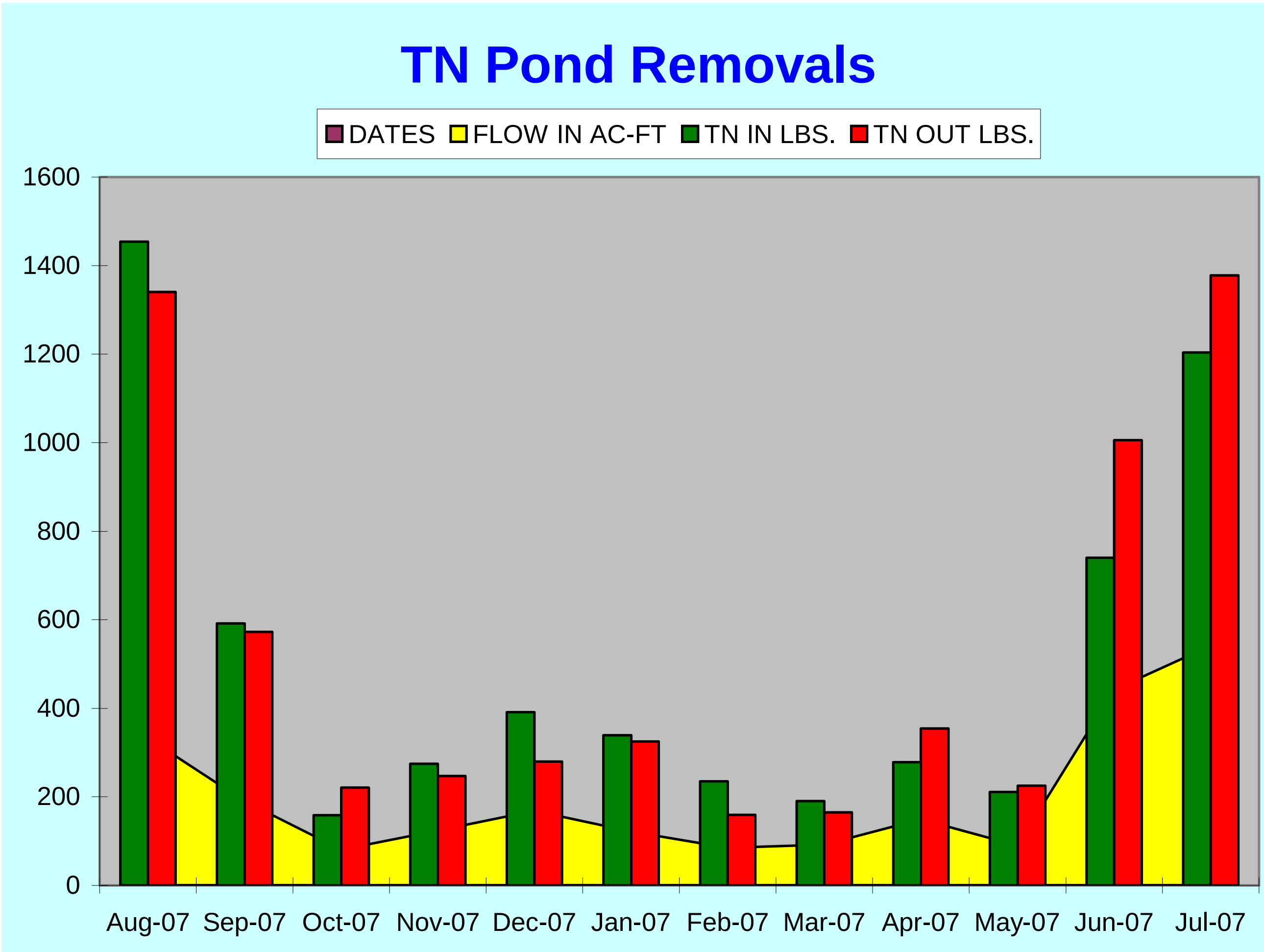


Figure 26: Total Nitrogen Loads

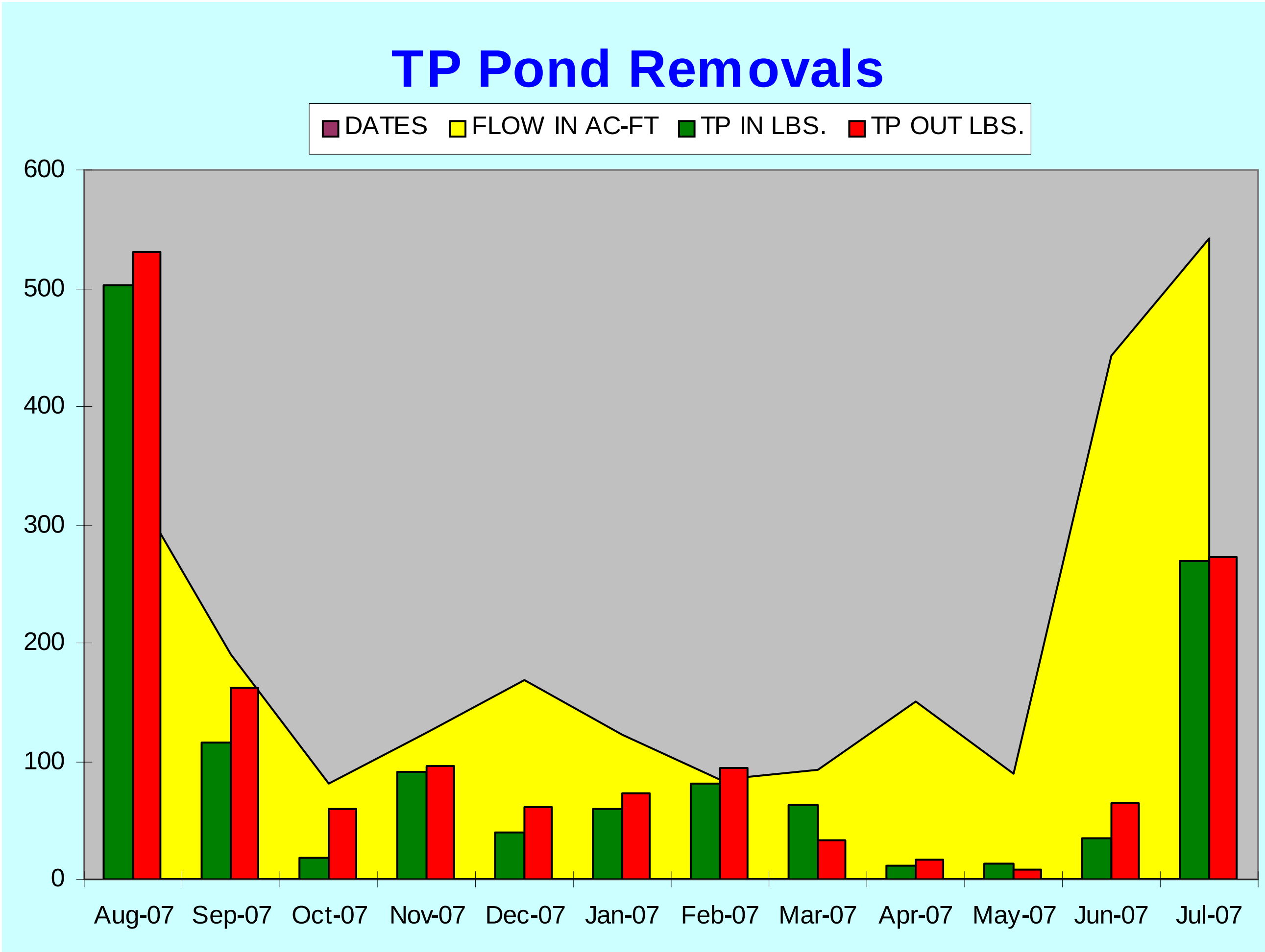


Figure 27: Total Phosphorus Loads

CHAPTER 5:
CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main objective of this study was to generate accurate and effective water quality and water quantity data by establishing automatic monitoring stations at the appropriate sites throughout the City of Kissimmee, Florida. These sites were constructed and are currently producing useful data. In fact, the data from two of these monitoring stations was used in the subsequent phase of this study to perform a preliminary analysis on a pilot study.

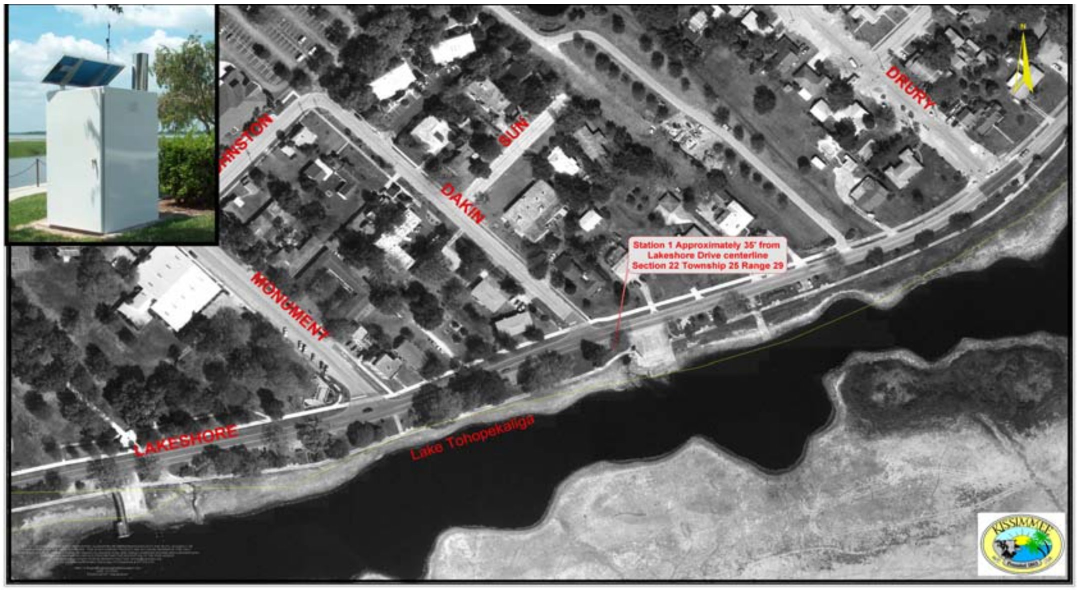
The results of the pilot study did not reveal any seasonal variations in the nutrient concentrations either flowing into or leaving the lake. The concentration levels of total nitrogen did not seem to vary significantly from its mean value of 0.90 mg/l throughout the year. The concentration levels of total phosphorus did range from 0.02 mg/l to 0.48 mg/l, but not in relation to either season or flow volume. The lake showed no net removals of total nitrogen and was actually found to be releasing total phosphorus.

Recommendations

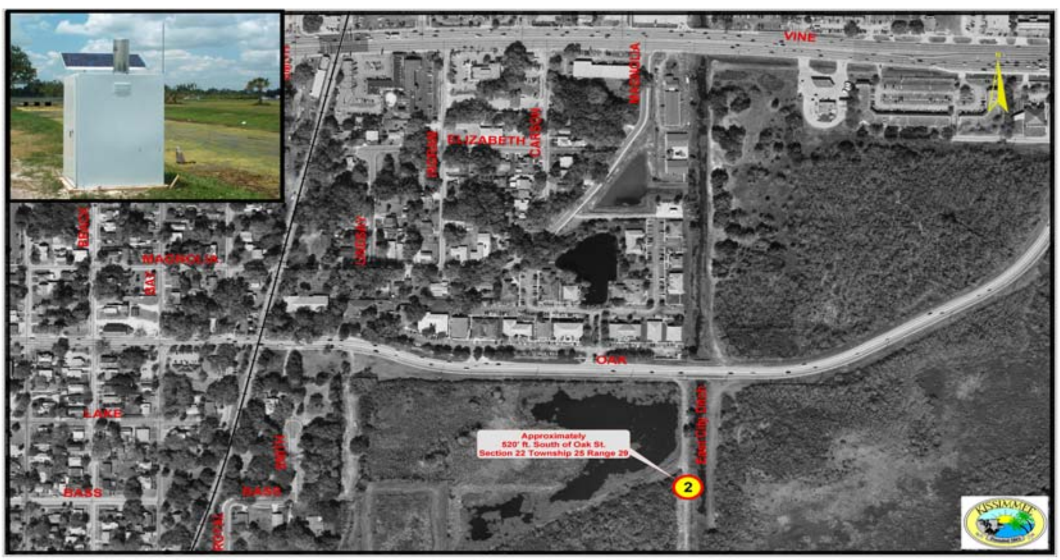
The lake does not appear to be removing any total nitrogen and actually donating total phosphorus. The possibility of reshaping the lake bottom to allow for a vegetative shelf should be investigated to increase the potential for nutrient removal. Also, the middle section of the lake should be taken down to at least eight feet of depth and intermittent rises placed in route to the outfall. These lake bottom inundations should promote the sedimentation of suspended solids. Until more data can be collected. Even with these lake modifications, it is highly recommended to investigate the potential for water reuse. The areas to the north of the lake are undeveloped and to the south there is an existing residential complex. The lake can be a great source of irrigation water for these areas since they already contain many beneficial fertilizing nutrients.

The findings of this study are limited due to the fact that the period of study was only for twelve months and there were no rainfall events used in the analysis. Rainfall events are typically high sources of nutrient loads to a lake. The lower efficiencies could be due to missing the actual higher nutrient load concentrations during rainfall events. This analysis did serve well as a basis for performing future analysis once additional data, including rainfall events, has been collected.

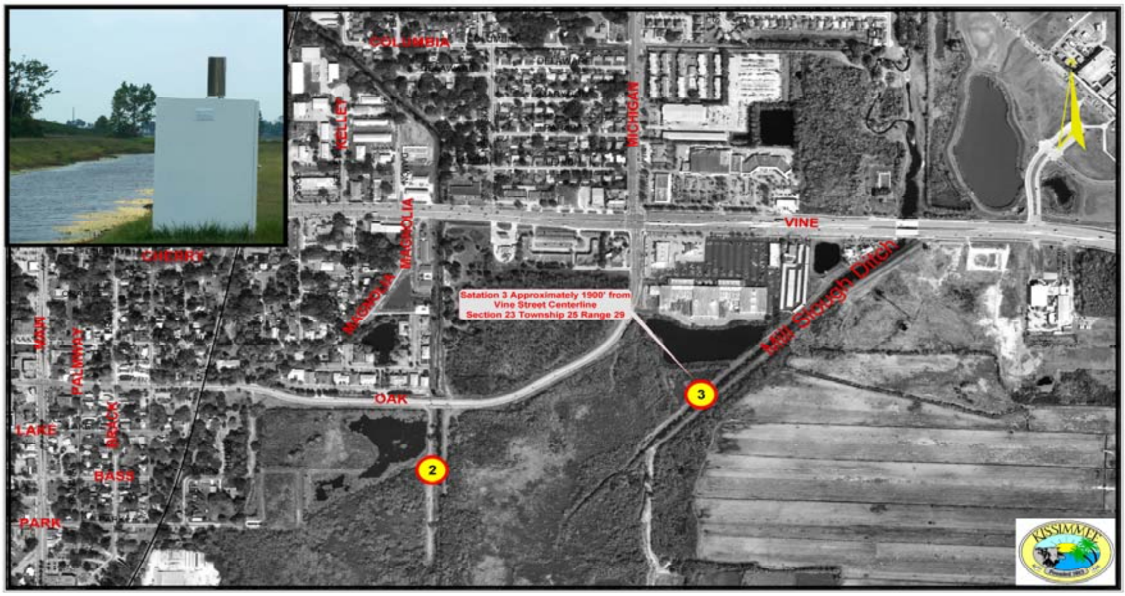
APPENDIX:
MONITORING STATION LOCATION MAPS



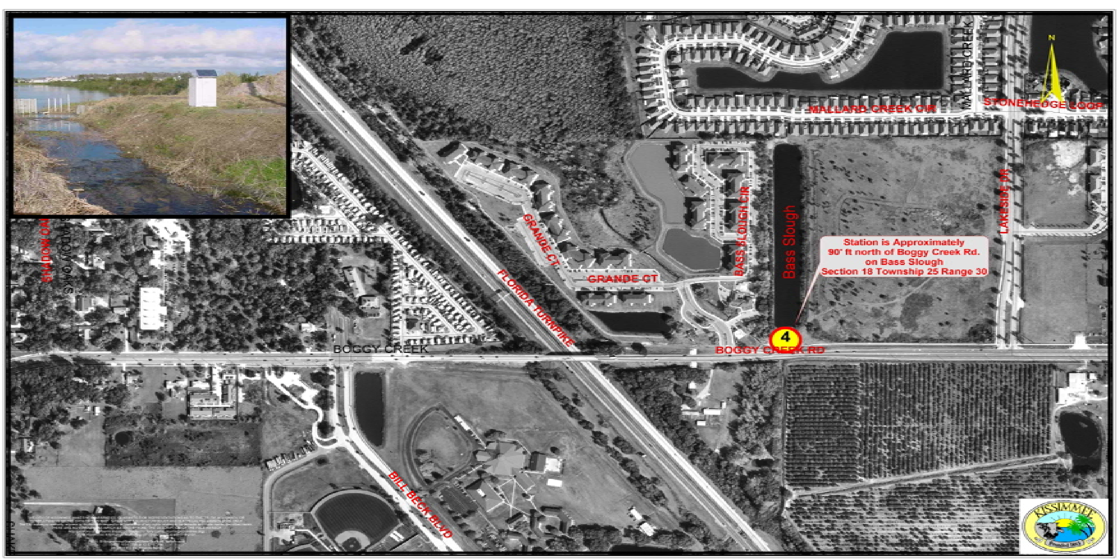
City Of Kissimmee Monitor Station # 1



City Of Kissimmee Monitor Station # 2



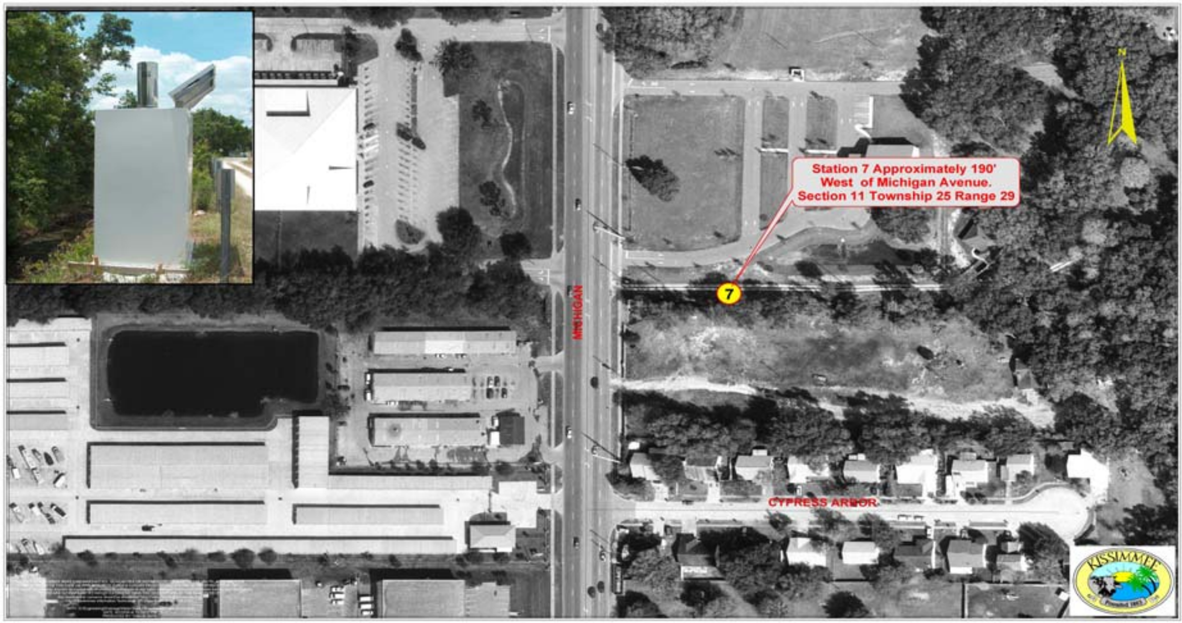
City Of Kissimmee Monitor Station # 3



City Of Kissimmee Monitor Station # 4

City Of Kissimmee Monitor Station # 5

City Of Kissimmee Monitor Station # 6



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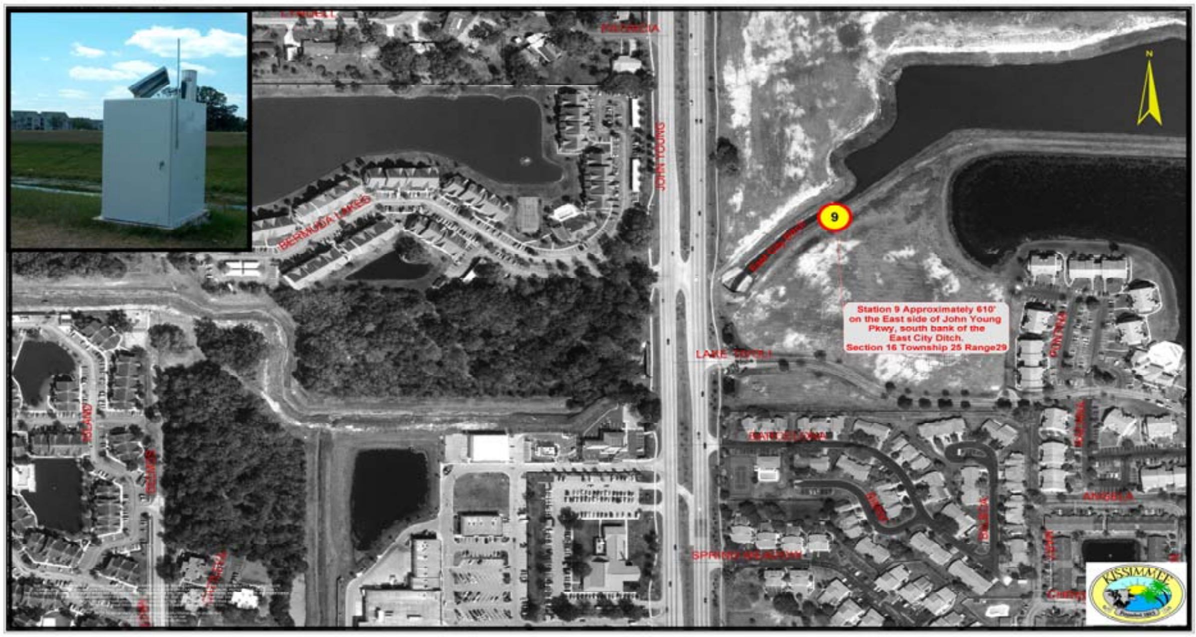

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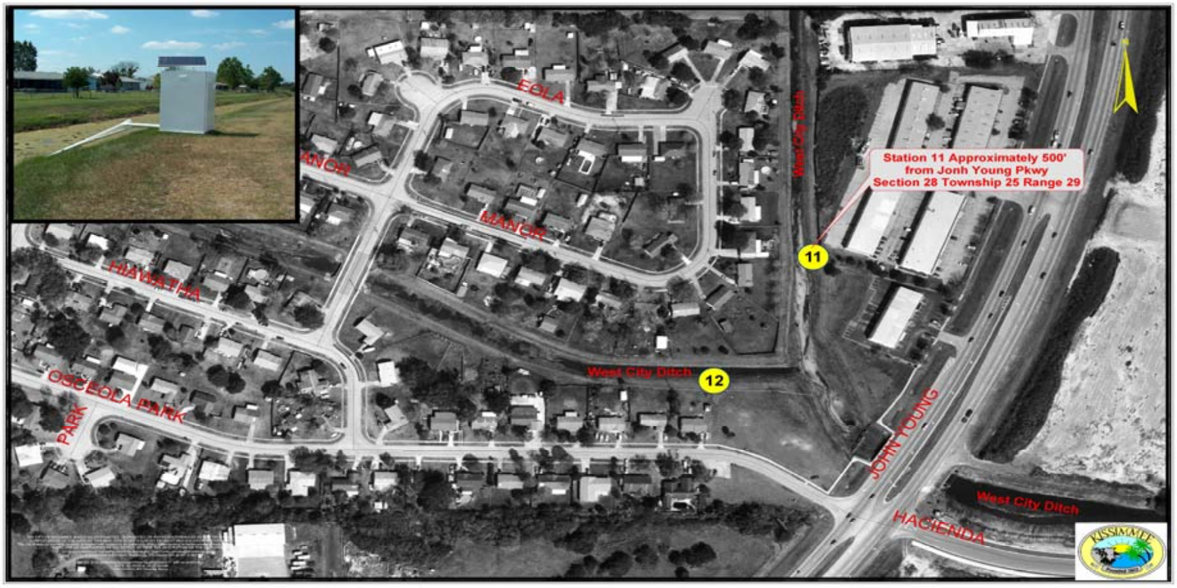

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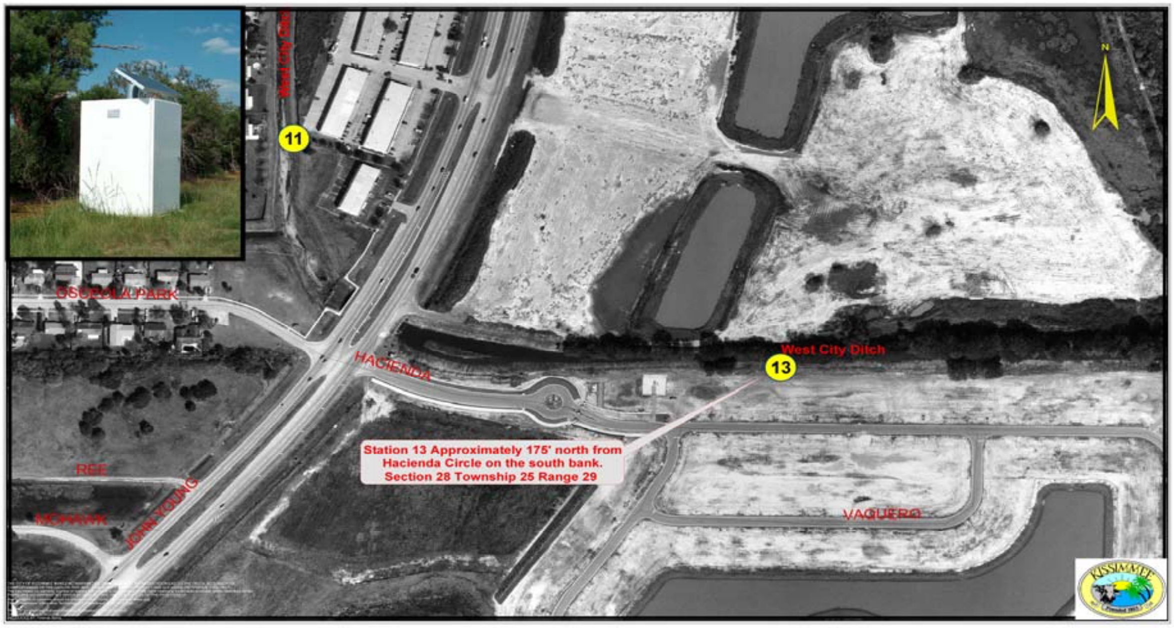

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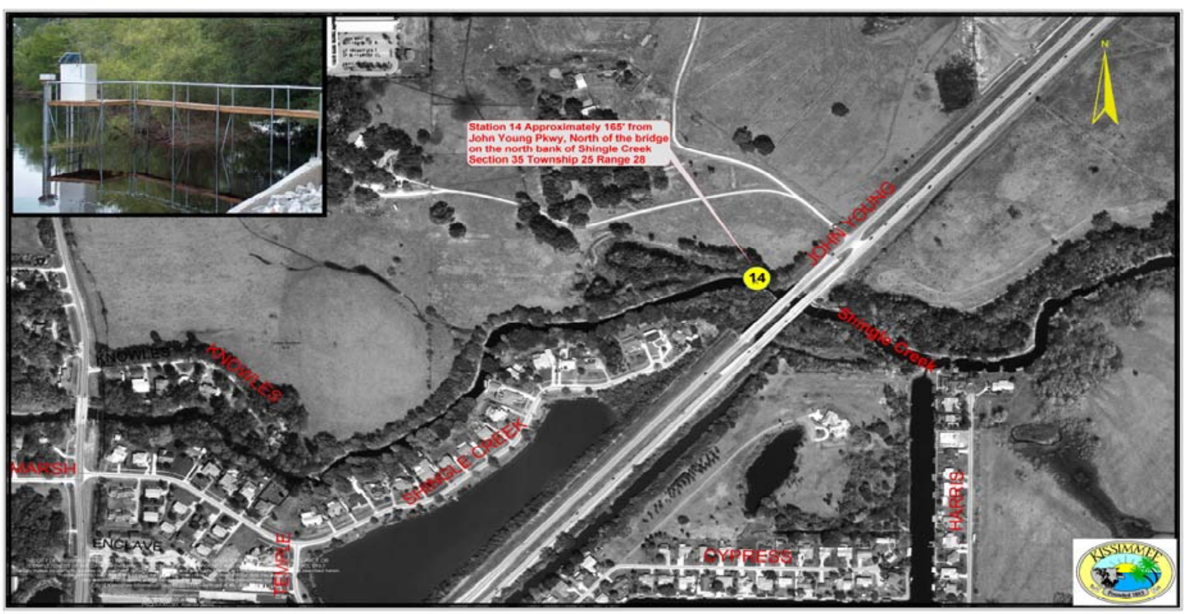
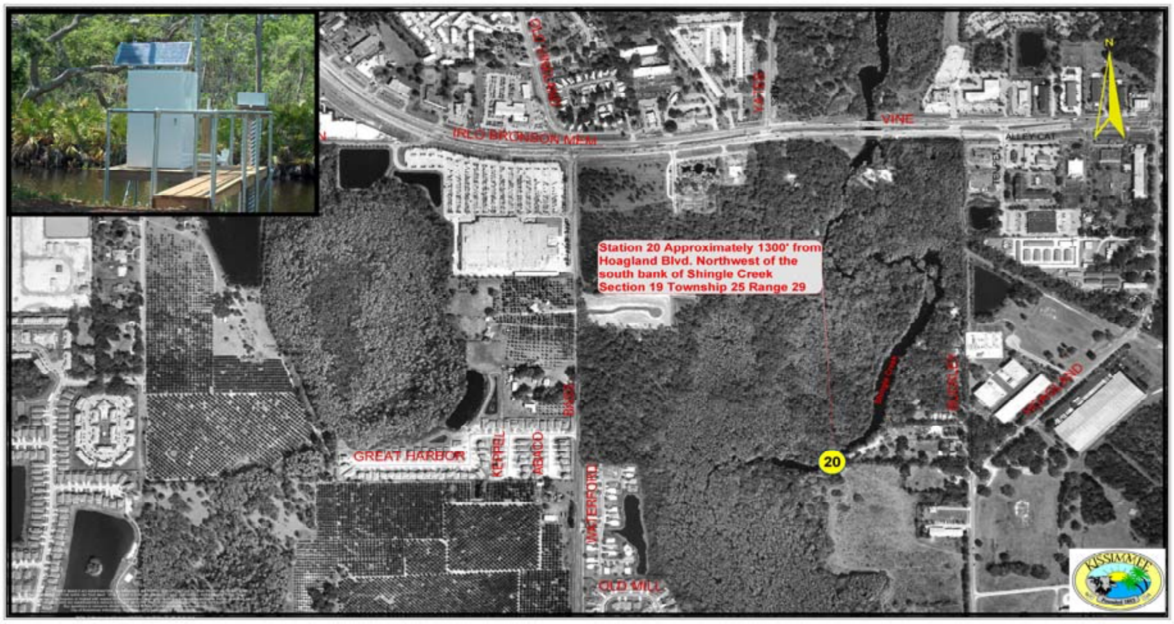


City Of Kissimmee Monitor Station # 14

City Of Kissimmee Monitor Station # 15

City Of Kissimmee Monitor Station # 17



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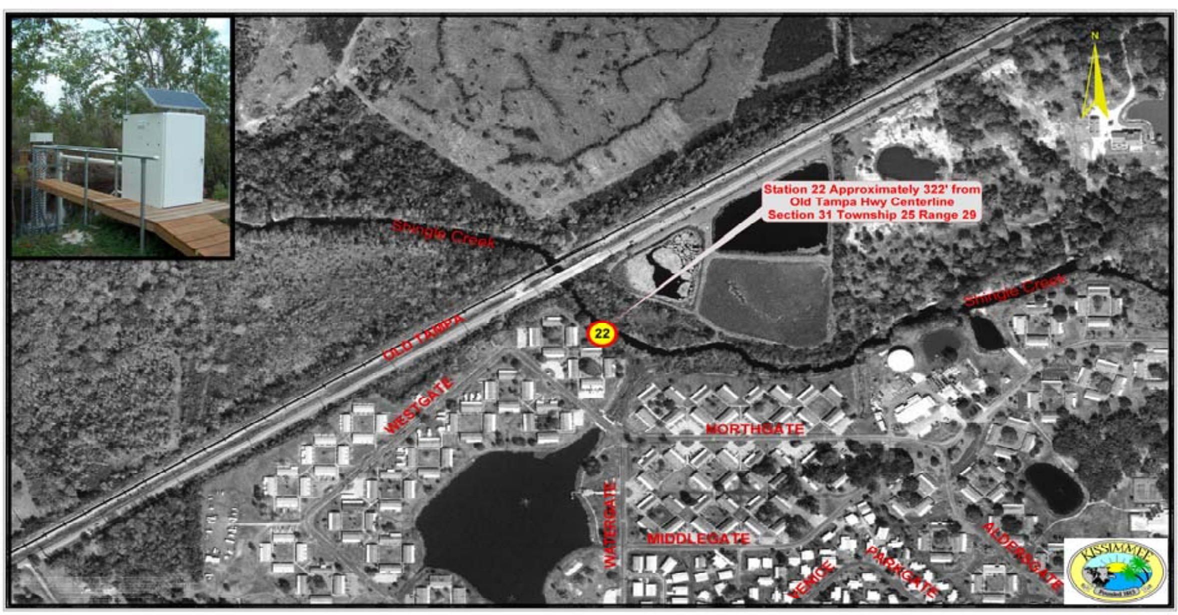

City Of Kissimmee Monitor Station # 22

City Of Kissimmee Monitor Station # 23

City Of Kissimmee Monitor Station # 24

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