Final Report
on the

Water Quality Impacts of Reservoirs

Task 3-Analysis of Data Sets

September 2004

WATER QUALITY IMPACTS OF RESERVOIRS

Task 3 – Analysis of Data Sets

Prepared for

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
WEST PALM BEACH, FLORIDA

September 2004

Burns & McDonnell Project 35106

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September 13, 2004

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South Florida Water Management District
Contract No. C-C20104P-WO02
Water Quality Impacts of Reservoirs
Final Task 3 Report

Dear Ms. Zhao:

Burns & McDonnell is pleased to present this report on the *Water Quality Impacts of Reservoirs, Task 3 – Analysis of Data Sets*. This report is the final deliverable for Task 3 of the Water Quality Impacts of Reservoirs project (Contract No. C-C20104P-WO02).

In Task 3, Burns & McDonnell developed daily water and phosphorus balances for eight water bodies located in Central and South Florida. These eight data sites, which were identified in Task 2 as the best candidates for analysis, were Crescent Lake, Lake George, Lake Harney, Lake Istokpoga, Lake Jessup, Lake Thonotosassa, Rodman Reservoir and the St. Johns Marsh Conservation Area.

We wish to express our thanks to you and the other members of the District staff who participated in this study for your helpful direction, advice and assistance during the preparation of this report. We also acknowledge the contributions of our two subconsultants, Engineering and Applied Science and Wetland Solutions, Inc. We are available at your convenience to discuss the details of this report.

Sincerely,

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Water Quality Impacts of Reservoirs
Task 3 – Analysis of Data Sets
(Contract C-C20104P-WO02)
Project 35106

INDEX AND CERTIFICATION

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Certification

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Galen E. Miller, PE Florida PE # 40624
Date: ____________________________
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1 INTRODUCTION

1 INTRODUCTION

This report section presents a discussion of the background and objectives of the Water Quality Impacts of Reservoirs (WQIR) study, and an overview of the methodology used in this study. This study was completed under Contract C-C20101P-WO02 with the South Florida Water Management District (District) to investigate the potential water quality impacts of the proposed Everglades Agricultural Area (EAA) storage reservoir(s). This report addresses Task 3, the third of four principal tasks in the WQIR study.

1.1 BACKGROUND

The long-term goal of Florida's 1994 Everglades Forever Act (EFA) is to ensure that all waters discharged to the Everglades Protection Area (EPA) meet the applicable water quality standards. The EPA includes Water Conservation Areas 1, 2A, 2B, 3A and 3B; Loxahatchee National Wildlife Refuge; and Everglades National Park. For the Class III waters in the EPA, the Florida Department of Environmental Protection (DEP) has established a numeric criterion for total phosphorus (TP) of 10 parts per billion (ppb), measured as a long-term geometric mean. Compliance will be achieved through a combination of source controls, stormwater treatment areas (STA), advanced treatment technologies (ATT), and regulatory programs. Substantial progress in reducing phosphorus levels discharged to the EPA has already been made through the combined effects of regulatory programs in the EAA and construction of the STAs. Current projections suggest that the long-term flow-weighted average TP concentrations in discharges to the EPA will be approximately 35 ppb after all of the planned STAs are operational. However, additional measures will be necessary to ensure compliance with the applicable water quality standards.

The recommended approach to achieve additional water quality improvements is outlined in the District's Long-Term Plan for Achieving Water Quality Goals (Long-Term Plan) (Burns & McDonnell, 2003). The Long-Term Plan includes three primary components:

- Pre-2006 Projects: The pre-2006 projects include structural and operational modifications that can be supported by the current scientific and engineering knowledge base as well as continued operation, maintenance and monitoring of the STAs. Where feasible, these projects are to be implemented by the end of 2006. By themselves, these projects may or may not be successful in meeting the long-term water quality goals.

- Process Development and Engineering (PDE): The PDE activities are designed to expand the current scientific and engineering knowledge base. These initiatives include the following activities:
  - Further understand and optimize water quality performance in existing and proposed facilities
  - Facilitate integration with the Comprehensive Everglades Restoration Plan
  - Maintain and improve upon the contribution of source controls to overall water quality improvement goals
  - Investigate ways to accelerate the recovery of previously impacted areas in the EPA

- Post-2006 Strategy: Depending on the success of the pre-2006 projects in meeting the target water quality goals and new management strategies identified through the PDE activities, additional water quality improvement measures may be necessary.

In parallel with the District's water quality improvement initiatives that are necessary for compliance with the EFA, the U.S. Army Corps of Engineers (Corps) and District have developed the Comprehensive Everglades Restoration Plan (CERP). The CERP provides a framework and guide to restore, protect, and preserve the water resources of central and southern Florida, including the Everglades. The CERP evolved from a restudy of the Corps' Central & Southern Florida (C&SF) Project, which provides water supply, flood protection, water management and other benefits to south Florida. Although the C&SF Project has performed these functions well, its construction and operation has also resulted in unintended adverse effects on the unique environment of south Florida, including the Everglades. The CERP includes more than 60 elements designed to mitigate for these adverse effects. The major components of the CERP can be segregated into 13 catagories (Corps of Engineers and South Florida Water Management District, no date):

1. Surface water storage reservoirs

2. Water preserve areas
3. Management of Lake Okeechobee as an ecological resource
4. Improved water deliveries to the estuaries
5. Underground water storage
6. Treatment wetlands
7. Improved water deliveries to the Everglades
8. Removal of barriers to sheetflow
9. Storage of water in existing quarries
10. Reuse of wastewater
11. Pilot projects
12. Improved water conservation
13. Additional feasibility studies

Completion of all the CERP projects is anticipated to take more than 30 years and cost an estimated $7.8 billion.

One of the 11 initial CERP projects authorized under the Water Resources Development Act of 2000 is construction of one or more surface water storage reservoirs within the EAA. Phase 1 of the EAA storage reservoirs project is scheduled for completion by 2009. The primary goals of this project are to:

- Reduce Lake Okeechobee regulatory releases to the estuaries and back pumping from the EAA into Lake Okeechobee by providing a temporary storage site for these waters
- Improve environmental releases to the Everglades through the temporary storage of water for release to meet dry season demand
- Provide flow equalization and optimization of treatment performance in the STAs by capturing peak storm runoff in the reservoirs and slowly releasing this stormwater to the STAs
- Improve flood control and regional water supply for agricultural interests within the EAA

1.2 STUDY OBJECTIVE AND SCOPE OF WORK

The project team for the EAA reservoirs project is currently evaluating analytical models for use in projecting the quality of water that is released from the reservoirs. The primary objective of the WQIR study is to acquire and analyze data sets that can be used to help calibrate these analytical models.

The WQIR study is being performed under Contract C-C20104P, Work Order No. 02 (C-C20104P-WO02) between the District and Burns & McDonnell Engineering Company, Inc. Burns & McDonnell has subcontracted portions of the work for this study to two Florida-based subconsultants. These subconsultants are Engineering & Applied Science, Inc. (EAS) of Tampa and Wetland Solutions, Inc. (WSI) of Gainesville.

The work to be completed under the WQIR study has been segregated into four primary tasks. These four tasks are described below.

1.2.1 Project Orientation Meeting

A project orientation meeting (Task 1) was held for the WQIR project on November 10, 2003, in the District's West Palm Beach offices. The purpose of this meeting was to finalize the project's work plan and schedule, and provide the project team with a list of data sources. District staff and the principal members of the Burns & McDonnell project team attended this meeting.

1.2.2 Identification of Data Sites and Data Acquisition

In Task 2 of the WQIR study, the applicable water management districts and other data holders were contacted to identify existing lakes and reservoirs in the project area that may yield favorable data sets for model calibration. Through this research, the project team identified 36 candidate water bodies that appeared to have high potential for use as data sets. The available hydrologic, water quality and other relevant data for these candidate data sites were then collected. These data were imported into a project database for efficient organization and analysis. Through review of the data available for each candidate data site, 8 of the 36 data sites were selected for continued analysis in subsequent study tasks. The locations of these eight data sites are shown on Figure 1-1. Readers are referred to the Task 2 report for additional discussion on the selection process for these eight potential data sites (Burns & McDonnell, 2004).

1.2.3 Analysis of Data Sets

The eight potential data sites were subjected to additional analyses in Task 3. The work completed under Task 3 was further broken down into the following subtasks:

- Subtask 3.1 – Develop Analysis Methodology and QA/QC Plan
- Subtask 3.2 – Data Analysis
- Subtask 3.3 – Prepare and Submit Draft Report
- Subtask 3.4 – Review Meeting
- Subtask 3.5 – Prepare and Submit Final Report

The results of Task 3 are the principal topic of this report.

1.2.4 Data Interface

The primary goal of Task 4 is to deliver all of the data collected for the 36 candidate data sites along with a web-based interface so these data are easily accessible to all interested parties.

1.3 ORGANIZATION OF THE REPORT

This report is organized into the following sections. Each of these sections is listed below along with a brief description of its contents.

- Chapter 1 – Introduction: A description of the study's background, objectives and scope of work.
- Chapter 2 – Data Analysis Methodology: This chapter describes analysis methodology and quality assurance/quality control (QA/QC) procedures used in Task 3.

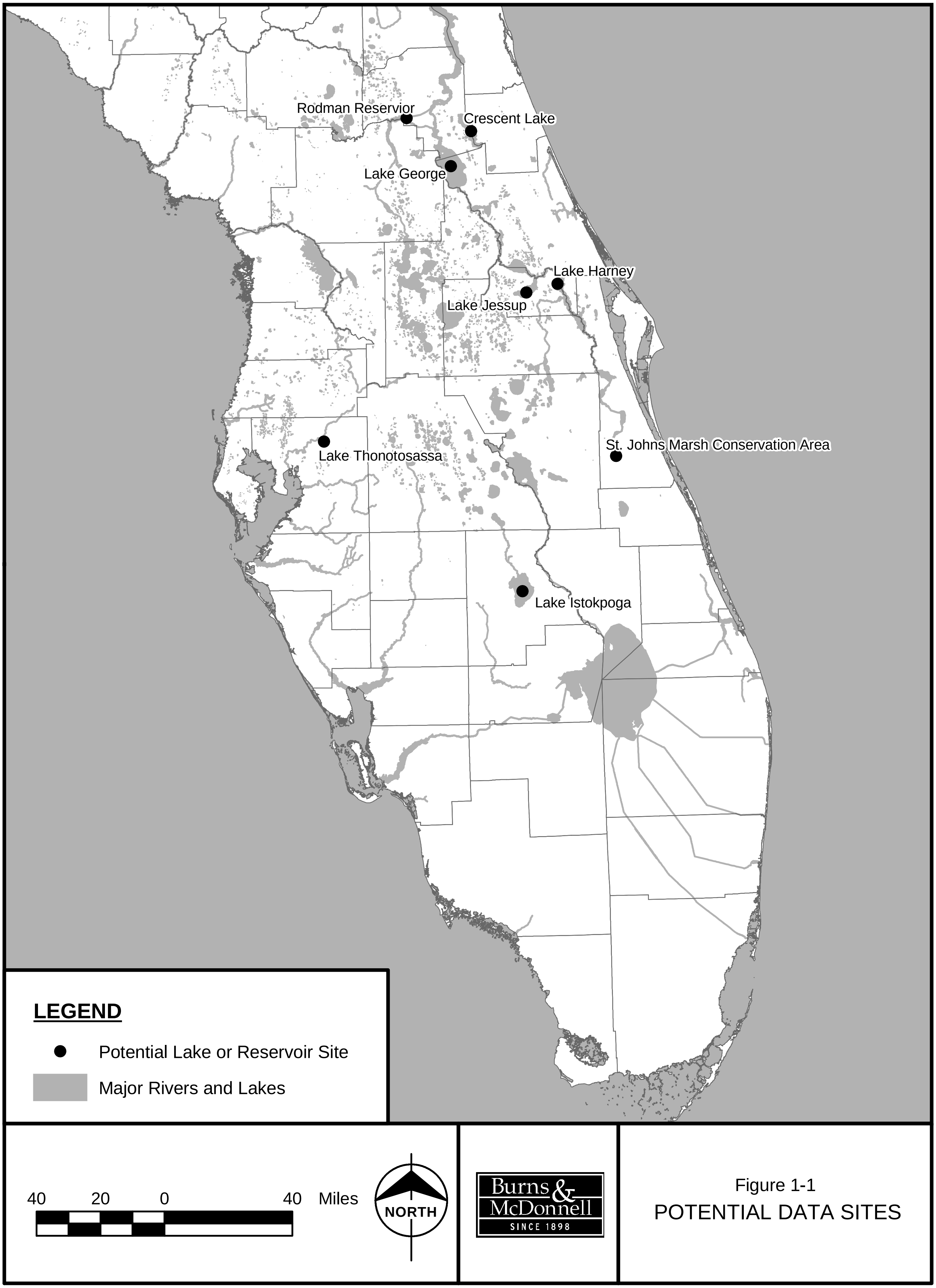


Figure 1-1
POTENTIAL DATA SITES

- Chapters 3 through 10 – One entire chapter is devoted to a discussion of the analyses and results for each of the eight potential data sites.
- Chapter 11 – Summary and Recommendations: An overall summary of the results of Task 3 and recommendations for further study.
- Chapter 12 – References and Bibliography: A list of the references cited in the report and a bibliography of technical reports for each potential data site.

* * * * *

2 DATA ANALYSIS METHODOLOGY

2 DATA ANALYSIS METHODOLOGY

This report section describes the methodology that was used to analyze each of the potential (good-rated) data sites identified in Task 2 of the Water Quality Impacts of Reservoirs (WQIR) study. This methodology discusses both the specific analyses that were completed for each potential data set and the quality assurance/quality control (QA/QC) procedures that were implemented to ensure the accuracy of these analyses and underlying data.

2.1 RAW DATA VALIDATION

In Task 2, the data collection and organization efforts were concentrated on those data available electronically. For the most part, these are time series data that contain the results of hydrologic and climatic monitoring, and water quality sampling at specific locations (stations) collected over time. The first step in the data analysis process was to verify that the electronic data obtained for each potential data site were complete. In conjunction with this raw data validation effort, the specific sources of these data were formally documented to allow easy replication of the collection effort if desired.

The available electronic data for each potential data site were generally obtained in one of two ways:

- Directly from the respective data holder (delivered in person, by postal or express delivery, or by electronic mail)
- Downloaded from a public database over the Internet

Using these raw data — in the format provided by the data holder or as downloaded from a public source — an inventory of the available data was completed. This inventory contains such basic information as the data source, available monitoring stations, types of data provided and overall periods of record for each monitoring station. These data inventories for each potential data site were used as a checklist in subsequent data validation steps.

For electronic data received directly from a data holder, the principal validation effort completed for these raw data was to verify that none had been omitted. For data downloaded from a public source over the Internet, these sources were revisited and scanned for comparison against the developed data inventories to identify obvious missing, but relevant, data. As appropriate, this scanning process was done on-line or the data was downloaded again, and the new and original data files were compared. Although relatively few instances were discovered, if any missing, relevant data were discovered through this process, these data were downloaded and the respective inventories were updated.

The respective data holders were assumed to have implemented any appropriate QA/QC procedures to ensure the validity of the electronic data provided, whether provided directly from a data holder or downloaded from a public database. No further validation of the raw electronic data occurred.

2.2 REVIEW OF NON-ELECTRONIC DATA

In addition to the electronic, time series data discussed above, printed technical reports were also collected for many of the data sites. These reports are available either in an electronic PDF format or as paper copies. These technical reports were reviewed to determine if they contain time series or other relevant data that have not already been obtained in an electronic format. While these reports were found to contain a wealth of useful background and other anecdotal information, they did not contain significant quantities of new time series data.

2.3 VERIFICATION OF DATABASE IMPORTS

A relational database is the only practicable way to efficiently store and manipulate large amounts of time series and other similar data. The electronic data available for the 36 candidate data sites were previously imported into a Microsoft Access database in Task 2. The next QA/QC step was to verify that the data contained in the project database were complete and accurate. Any missing data elements or new data derived from non-electronic sources were imported into the database prior to completing this step.

Database imports were verified by generating a report for each potential data site that lists all monitoring stations, the types of data available at each station and the periods of record for these data. These data were compared to the data inventories developed previously (Section 2.1) to identify any missing data. If any missing data were discovered, these missing data were imported into the project database and the process was repeated to verify completion.

Generally, data were imported into the project database in large batches so an exhaustive comparison between the original data and data in the database was unwarranted. A small subset of the data contained in the database was compared with the same data in the original data files. Approximately one data point per year per data type per monitoring station was selected at random for comparison. If these data matched, then all of the other data imported in the same batch process were assumed to match. If any discrepancies were discovered, the extent of the errors was investigated and the bad data were re-imported and re-verified.

2.4 MONTHLY DATA SUMMARIES

The time series data collected for each data site have various sampling frequencies, ranging from daily data points to single, lone samples. The most frequently sampled or monitored parameters were generally flow rates and stages (water surface elevations, gage heights, or depths). In comparison, most water quality parameters have been sampled less frequently. Although some water quality data have semimonthly or even weekly sampling frequencies, monthly or less frequent sampling was generally the norm.

After the previous data validation and completeness reviews were completed, the first step in the actual data analyses process was to generate monthly data summaries for each potential data site. For monitoring stations with data collected more than once a month, these individual data points were “rolled up” or averaged into a single value representative of each month. For example, for a lake with daily inflow data, these daily values were averaged to generate average monthly inflow rates.

These monthly summary data were calculated by relative location. That is, if a lake or reservoir should have multiple sampling stations that are representative of interior water quality conditions, all of these interior stations were combined to generate a single average data value for each month and sample parameter. When corresponding flow data were available and more than one water quality sample was available in a month, the monthly averages were calculated on a flow weighted basis.

The monthly data summaries were generated in a batch process using simple database queries. After completion of the monthly data summaries, several (5–10) of the monthly summaries were recalculated by hand to verify the accuracy of the database queries. If any errors were found, the cause of these errors was determined and resolved before the monthly summaries were recalculated.

Some of the monitoring stations at the potential data sites have data available for dozens of individual hydrologic or water quality parameters; however, only a select few of these parameters are of primary interest in this study. For this reason, the monthly data summaries and subsequent analyses were completed for only those data parameters listed below. Also listed below in parentheses for each parameter is the default reporting units.

- Flow (cubic feet per second or cfs)
- Total phosphorus concentration [milligrams per liter (mg/L)]
- Total orthophosphorus concentration (mg/L as P)
- Total nitrogen concentration (mg/L)
- pH (standard units)
- Water temperature (degrees C)
- Dissolved calcium concentration (mg/L)

2.5 TIME SERIES PLOTS

Using the monthly time series data generated in the previous step, the data for certain key parameters at each potential data site were plotted on a common time scale. At a minimum, the following parameters were plotted, when available:

- Flow volumes or rates
- Total phosphorous concentrations

- Total orthophosphorus concentrations
- Total nitrogen concentrations
- Total calcium concentrations
- Water levels (elevation, stage, and/or depth)
- Water temperature
- pH

As appropriate, these parameters were plotted for three relative locations: inflow, interior and outflow.

The time series data plots provided a visual display of data richness (periods of record, continuity and completeness) at each data site. From these plots, an appropriate analysis period was selected for each potential data site. Of primary importance in the selection of an analysis period was the presence of sufficient data on inflow and outflow water volumes and phosphorus concentrations needed to generate credible water and phosphorus balances for each data site.

For those cases where data gaps occur, data were statistically generated by interpolation. These data fills were clearly identified in the raw and monthly data sets.

2.6 FLOW AND PHOSPHORUS BALANCES

Daily flow and phosphorous balances were calculated for the selected analysis period at each potential data site. Flow balances included daily estimates of the following components:

- Gaged inflow volume (calculated from recorded stream gaging data when and where available)
- Ungaged inflow volume (estimated from gaged inflow when appropriate)
- Outflow volume (calculated from recorded stream gaging data when and where available)
- Direct precipitation (estimated from available precipitation data for vicinity)
- Gross evapotranspiration (estimated from available pan evaporation data)
- Changes in storage (calculated from available stage data, and applicable stage-volume relationships when available or lake surface area otherwise)

Any imbalance in the water balance each day was attributed to the net of the following miscellaneous flow components: groundwater discharge/infiltration, seepage, and ungaged tributary inflow or direct runoff. Most of the potential data sites were dominated by flow-thorough hydrology so these imbalance terms were typically small on a relative basis. As necessary, the estimates for ungaged inflow and outflow were adjusted to yield close agreement between total inflow and outflow over the selected analysis period for each data site.

Daily mass balances for phosphorus were calculated for each potential data site from the flow balances and available phosphorus concentration data. No daily phosphorus sampling data were available for any of the data sites so inflow and outflow concentrations between sample points were estimated. The procedures used to estimate these intermediate phosphorous concentrations varied and are described later.

Direct dry and wet phosphorus deposition to each lake were estimated separately. Dry deposition was assumed to be a constant 84.88 $\mu g/m^2/d$ and wet deposition was calculated from rainfall amounts using a phosphorus concentration of 9.39 µg/L (Ahn & James, 2001). Any net loading due to other miscellaneous flow components was ignored.

From the inflow and outflow phosphorous mass flux estimates, the net phosphorus removal rates were calculated. These phosphorus removal rates were expressed as mass removals, mass removal efficiencies and as k values (net settling rates). These removal rate summaries were used in subsequent regression analyses.

The flow and phosphorous mass balances were calculated from data already stored in the project database using a batch process involving either simple database queries or custom processing routines. A small subset of the resultant water and phosphorus mass balances was calculated manually to verify the accuracy of these queries or routines. For any discrepancy discovered, the cause was determined and resolved, and the balances were recalculated.

2.7 STATISTICAL ANALYSES

Statistical analyses were performed for each potential data site using the available data. Both descriptive statistics on individual data parameters and regression analyses to discover relationships between variables were completed.

All descriptive statistics were calculated using database queries or a standard statistics package such as SPSS. All correlation/regression analyses were performed using SPSS. As such, the QA/QC procedures for these statistical analyses were limited to verification that the proper input data were selected and any results were properly transcribed.

2.7.1 Descriptive Statistics

For each potential data site, descriptive statistics were calculated for each primary inflow, outflow and interior data parameter. These descriptive statistics include the following values: number of data points, mean, minimum, and maximum.

2.7.2 Regression Analyses

Regression analyses were performed to investigate relationships between raw and calculated parameters at each potential data site. Regression analyses indicate how the changes in one variable (dependent variable) can be explained by changes in one or more other variables (independent variables). The dependent variable was the calculated phosphorus removal rates (mass removal rate, removal efficiency, and k-values) and the anticipated independent variables include hydraulic loading rates, nominal hydraulic retention time, pH, Ca, water temperature, water depth, etc. Regression analyses were repeated for each independent-dependent variable pair and associated scatter plots were developed.

* * * * *

3 CRESCENT LAKE

3 CRESCENT LAKE

Crescent Lake is located approximately 56 miles south of Jacksonville and 58 miles north of Orlando on the border between Flagler and Putnam counties (Figure 1-1). This lake is within the St. Johns River Water Management District (SJRWMD). The data collected for Crescent Lake and the analyses completed with these data are described in the balance of this chapter.

3.1 DATA SOURCES

The data for Crescent Lake were collected from a number of sources. These sources are listed in Table 3-1 along with a listing of the individual sample stations obtained from each source. This table also lists each sample station's absolute location (latitude/longitude coordinates) and location relative to Crescent Lake. Relative locations were assigned to each station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 3-1 shows the locations of these monitoring stations.

3.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 3-1: Crescent Lake Monitoring Stations

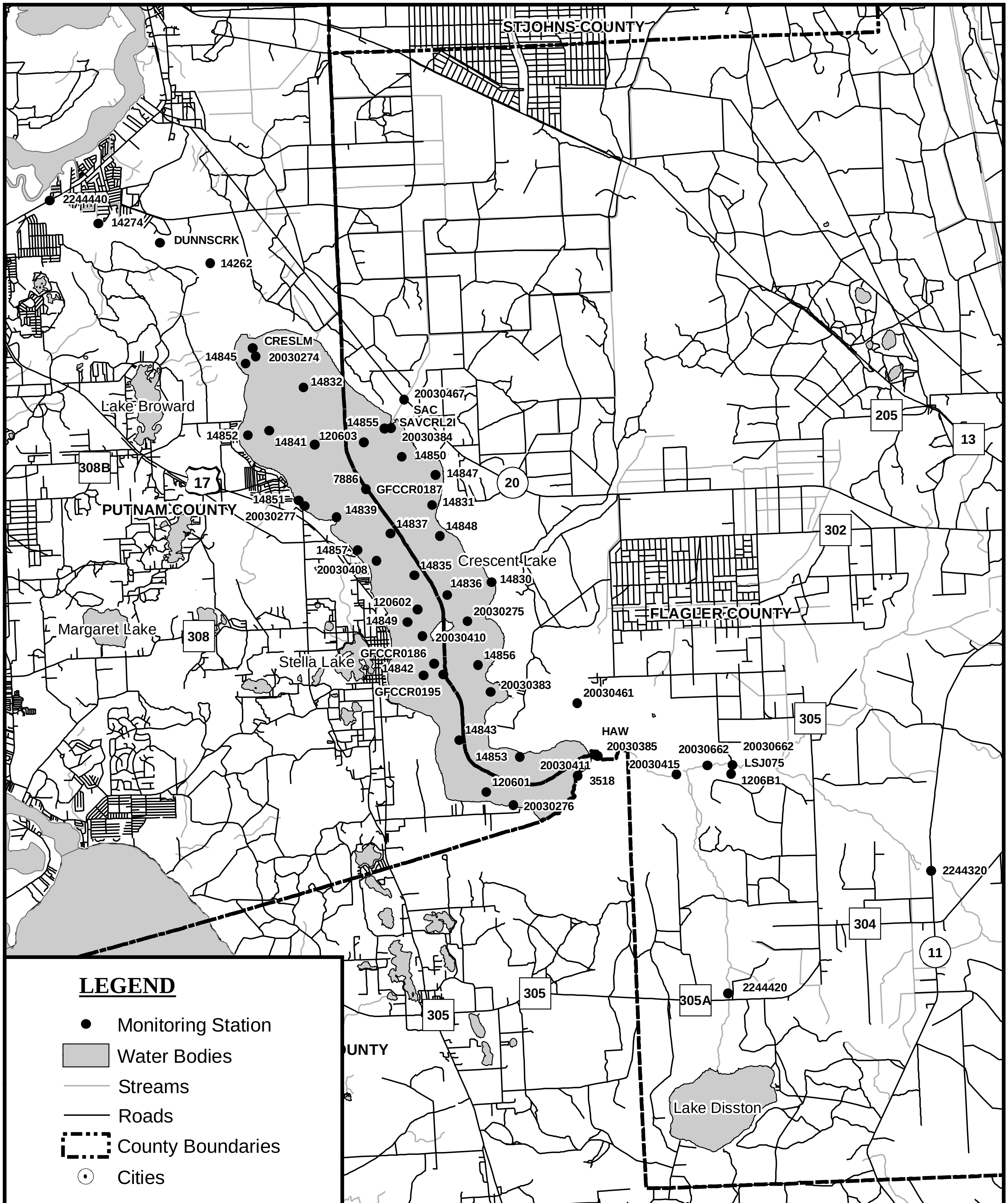
Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	14857	SJB-LL-1037	29.46496	81.51713
	20030384	CRESCENT LAKE SALT BRANCH CANAL	29.50333	81.50653
	20030385	HAW CREEK AT MOUTH	29.39847	81.43200
	20030411	CRESCENT LK BY MARKER NO.9	29.39222	81.43889
	20030415	HAW CREEK AT CONF WITH LITTLE HA	29.39194	81.40305
	20030461	DEAD LAKE CENTER	29.41517	81.43850
	20030467	SALT BRANCH AT SR 100	29.51228	81.49917
	20030662	HAW CREEK OFF CR 2007	29.39453	81.38267
	20030662	HAW CREEK OFF CR 2007	29.39453	81.38267
	3518	CRESCENT LK BY MARKER NO.9	29.39222	81.43889
	HAW010	HAW CREEK	29.39444	81.38333
Outflow	14262	SJB-LR-1004	29.55669	81.56845
	14274	SJB-LR-1025	29.56987	81.60885
	14845	SJB-LL-1020	29.52472	81.55634
	20030274	CRESCENT LK BY MARKER NO.2	29.52686	81.55267
	20030363	DUNNS CR SW PARADISE VILLAGE WWTP	29.56997	81.60653
	20030469	DUNNS CR NE PARADISE VILLAGE WWTP	29.57036	81.60614
Interior	14830	SJB-LL-1002	29.45393	81.46886
	14831	SJB-LL-1003	29.47868	81.48966
	14832	SJB-LL-1004	29.51675	81.53552
	14835	SJB-LL-1008	29.45653	81.49670
	14836	SJB-LL-1010	29.45018	81.48490
	14837	SJB-LL-1011	29.46998	81.50516
	14839	SJB-LL-1013	29.47553	81.52453
	14841	SJB-LL-1016	29.50334	81.54837
	14842	SJB-LL-1017	29.42489	81.49413
	14843	SJB-LL-1018	29.40418	81.48165
	14847	SJB-LL-1024	29.48831	81.48836
	14848	SJB-LL-1026	29.46887	81.48718
	14849	SJB-LL-1027	29.44183	81.49967
	14850	SJB-LL-1028	29.49417	81.50043
	14851	SJB-LL-1029	29.48097	81.53820
	14852	SJB-LL-1030	29.50192	81.55613
	14853	SJB-LL-1031	29.39850	81.45970
	14855	SJB-LL-1035	29.49908	81.51409
	14856	SJB-LL-1036	29.42781	81.47427
	20030275	CRESCENT L 2 E TIP BEAR ISL	29.44167	81.47778

Table 3-1: Crescent Lake Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Interior	20030276	CRESCENT L 3 S END L	29.38333	81.46250
	20030277	CRESCENT L 4 2/3 UP L BOAT RAMP	29.47917	81.53611
	20030383	SEGMENT 20.3JA BODY OF WATE	29.41917	81.47000
	20030408	CRESCENT LK BY RED MARKER NO.4	29.46142	81.51022
	20030409	CRESCEN LK BY MARKER NO. 6	29.46144	81.50628
	20030410	CRESCENT LK BY MARKER NO.7	29.43733	81.49411
	20030459	CRESCENT LK CENTER OF NORTH LOBE	29.50033	81.52883
	20030460	CRESCENT LAKE SOUTH AT EASTERLY BEND	29.39100	81.46900
	22628			
	22628A			
	7886	CRESCENT LAKE MIDDLE	29.48417	81.51361
Florida Game and Fresh Water Fish Commission (FGFWF)				
Interior	GFCCR0186	CRESCENT LAKE 1/2 MILES SOUTH OF BEAR IS	29.42861	81.49028
	GFCCR0187	CRESCENT LAKE MID LAKE BTWN SALT BR. A	29.48417	81.51361
	GFCCR0195	CRESCENT LAKE MID LAKE	29.42500	81.48695
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	81978	Crescent City	29.41667	81.50000
	82915	Federal Point	29.75000	81.53333
	86753	Palatka	29.65000	81.65000
Saint Johns River Water Management District (SJRWMD)				
Inflow	20030411	CRESCENT LAKE AT MARKER 9	29.39222	81.43889
	HAW	HAW CREEK MOUTH AT DEAD LAKE	29.39833	81.43166
	LSJ075	HAW CREEK AT HWY 305	29.39444	81.39194
	SAC	SALT CREEK @ SR 100	29.50333	81.50639
	SAVCRL2I	Crescent Lake site #2 inside grassbed	29.50333	81.50417
Outflow	CRESLM	Crescent Lake at Outlet to Dunns Creek	29.52956	81.55372
	DUNNSCRK	Dunns Cr Midway betw Crescent L & SJR	29.56347	81.58678
Interior	CRESLK	CRESCENT LAKE	29.44750	81.50000
U.S. Geological Survey (USGS)				
Inflow	2244320	MIDDLE HAW CREEK NR KORONA, FLA.	29.35972	81.31167
	2244420	LITTLE HAW CR NR SEVILLE, FLA.	29.32222	81.38611
Outflow	2244440	DUNNS CREEK NEAR SATSUMA, FL	29.57750	81.62639
	2244440A	DUNNS CREEK NEAR SATSUMA, FL	29.57750	81.62639

Table 3-1: Crescent Lake Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
US EPA--Storet (US EPA)				
Inflow	1206B1	HAW CREEK	29.39167	81.38333
Outflow	111280	ST JOHNS R US 17 AT PALATKA	29.56667	81.61667
	111280A	ST JOHNS R US 17 AT PALATKA	29.56667	81.61667
Interior	120601	LAKE CRESCENT	29.38750	81.47222
	120602	LAKE CRESCENT	29.44583	81.49583
	120603	LAKE CRESCENT	29.49861	81.53194



3 1.5 0 3 Miles

1 Inch equals 3 Miles

NORTH

Burns & McDonnell SINCE 1898

Figure 3-1
CRESCENT LAKE
MONITORING STATIONS

- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station was representative of a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 3-2 through 3-9 contain the time series graphs for Crescent Lake for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data, principally flow data, are available back to the early 1950s for Crescent Lake. For the most part, there are relatively few water quality monitoring data available for this lake before 1975. Because of the lag time between when samples are collected and analyzed, and when the resultant data are recorded in a database or other electronic repository, the most recent data available are for late 2003. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are the flow rate and phosphorus concentration data necessary to calculate flow and phosphorus balances at Crescent Lake. The graphs of available flow and phosphorus concentration data are shown in Figures 3-2 and 3-3, respectively. These figures show inflow and outflow data are available continuously since 1978 but the most frequent sampling for phosphorus has occurred only since 1997. For this reason, water years 1997–2003 (10/1/1996–9/30/2003) were selected as the period of record for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are most prevalent during this same period.

Figure 3-2: Long-term Flow at Crescent Lake

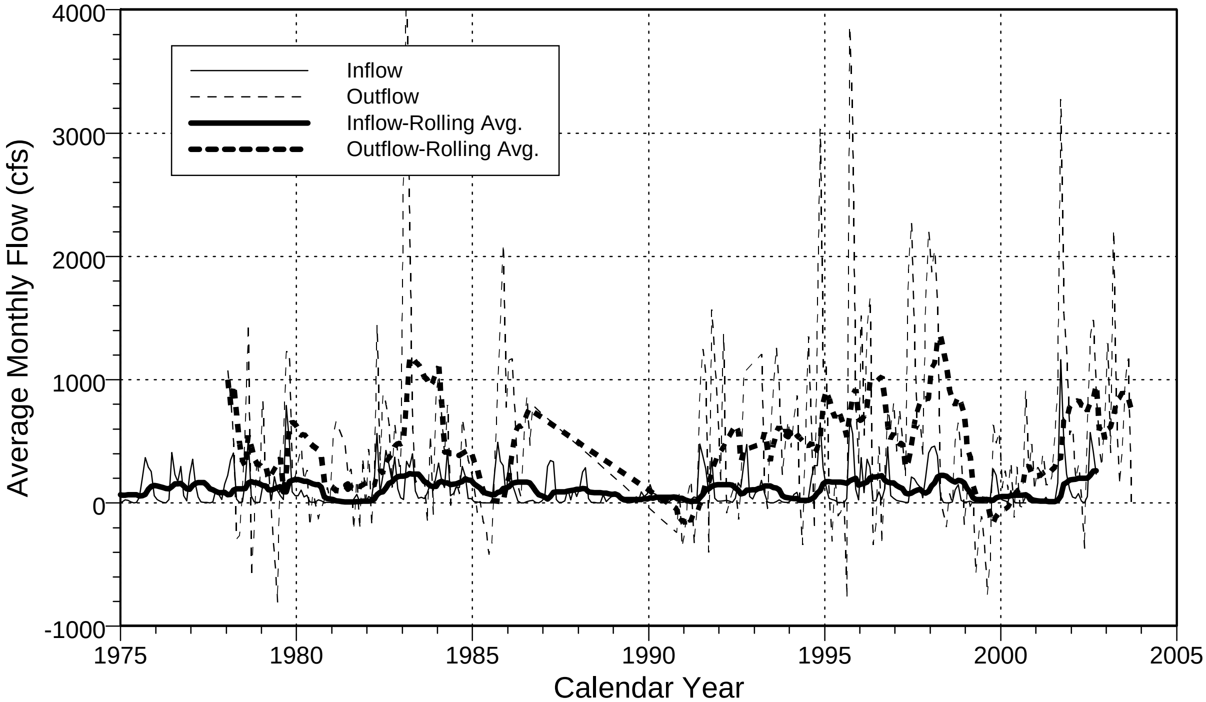


Figure 3-3: Long-term Total Phosphorus at Crescent Lake

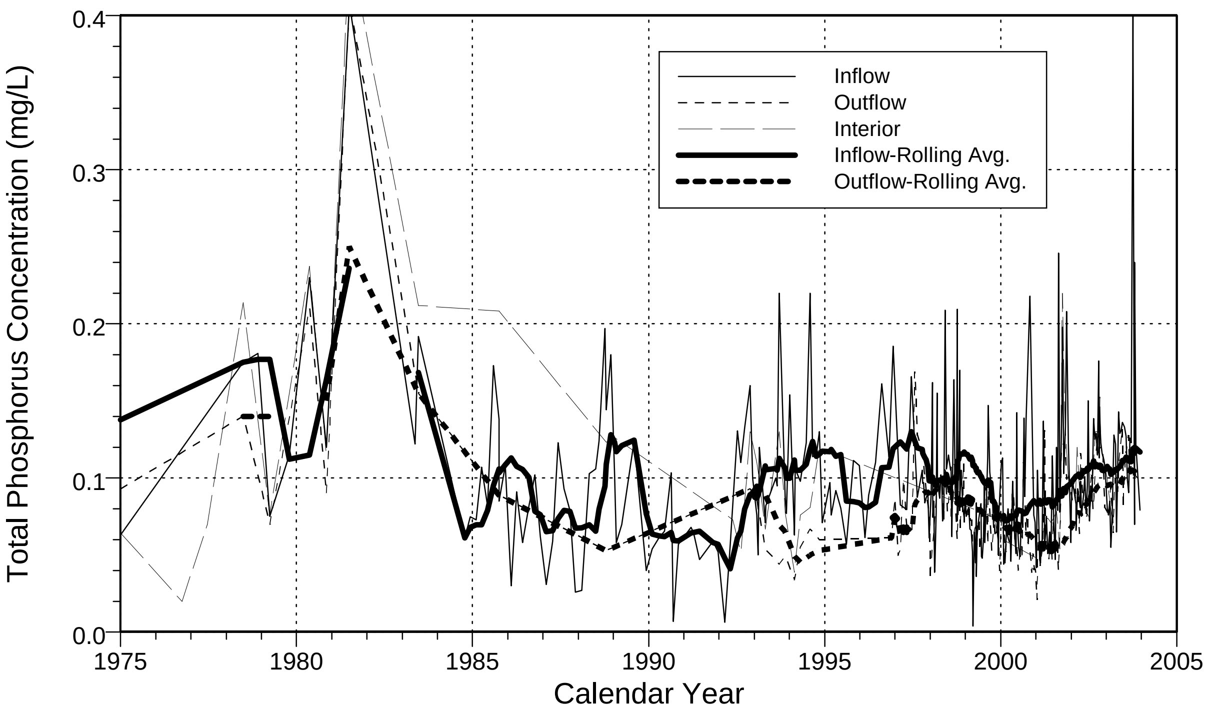


Figure 3-4: Long-term Orthophosphorus at Crescent Lake

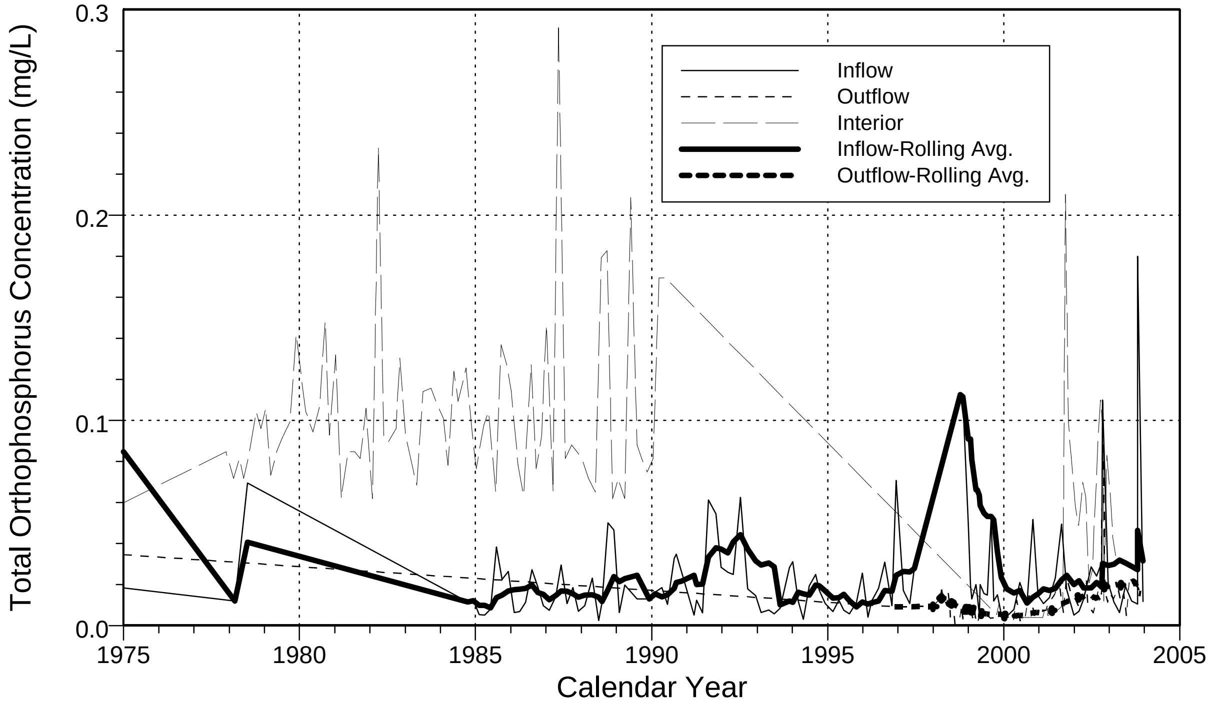


Figure 3-5: Long-term Total Nitrogen at Crescent Lake

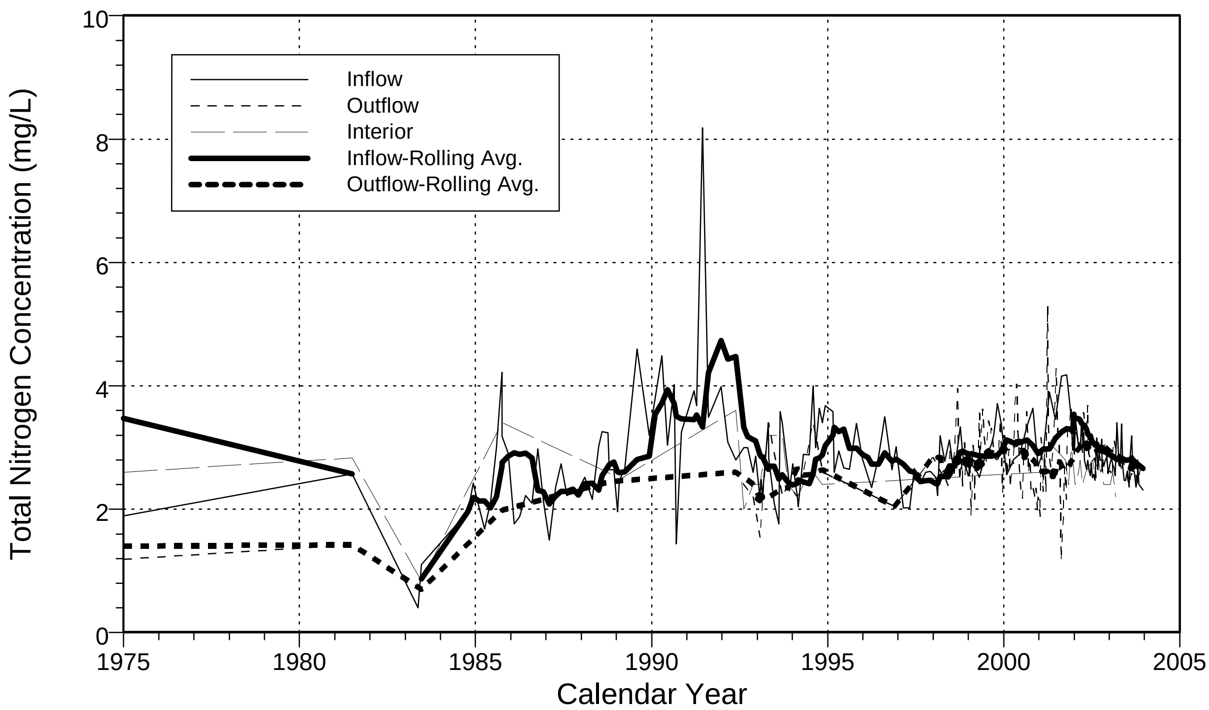


Figure 3-6: Long-term pH at Crescent Lake

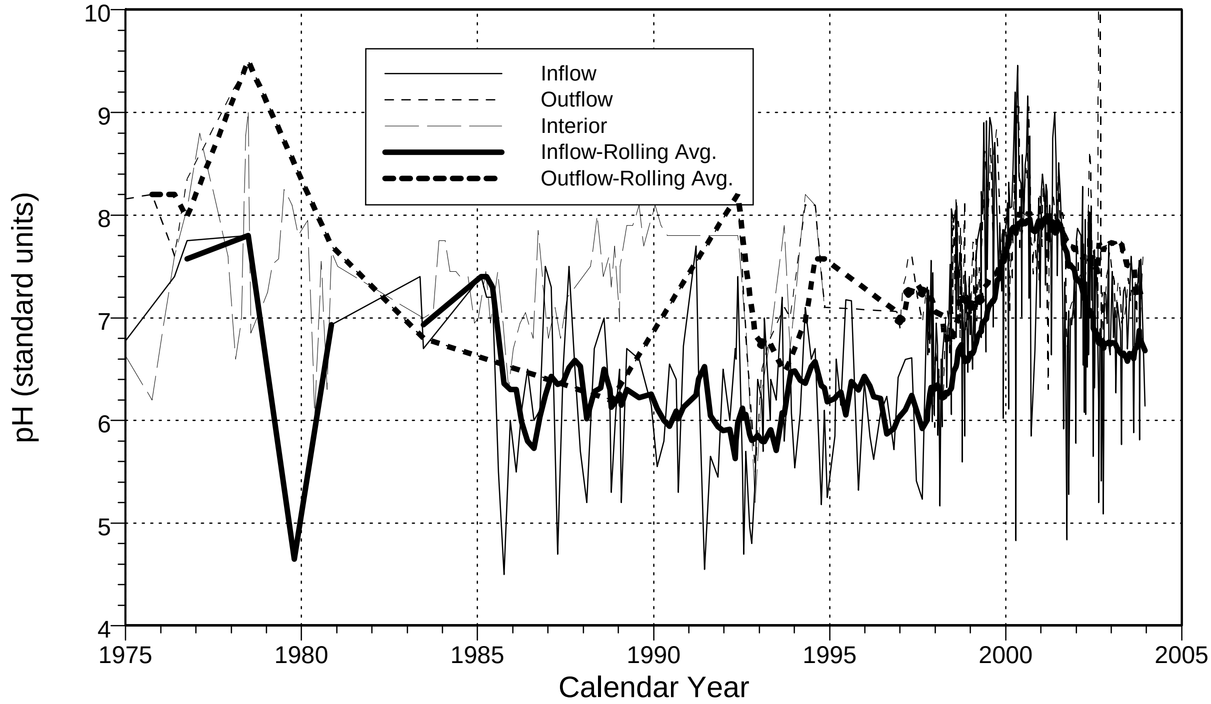


Figure 3-7: Long-term Total Calcium at Crescent Lake

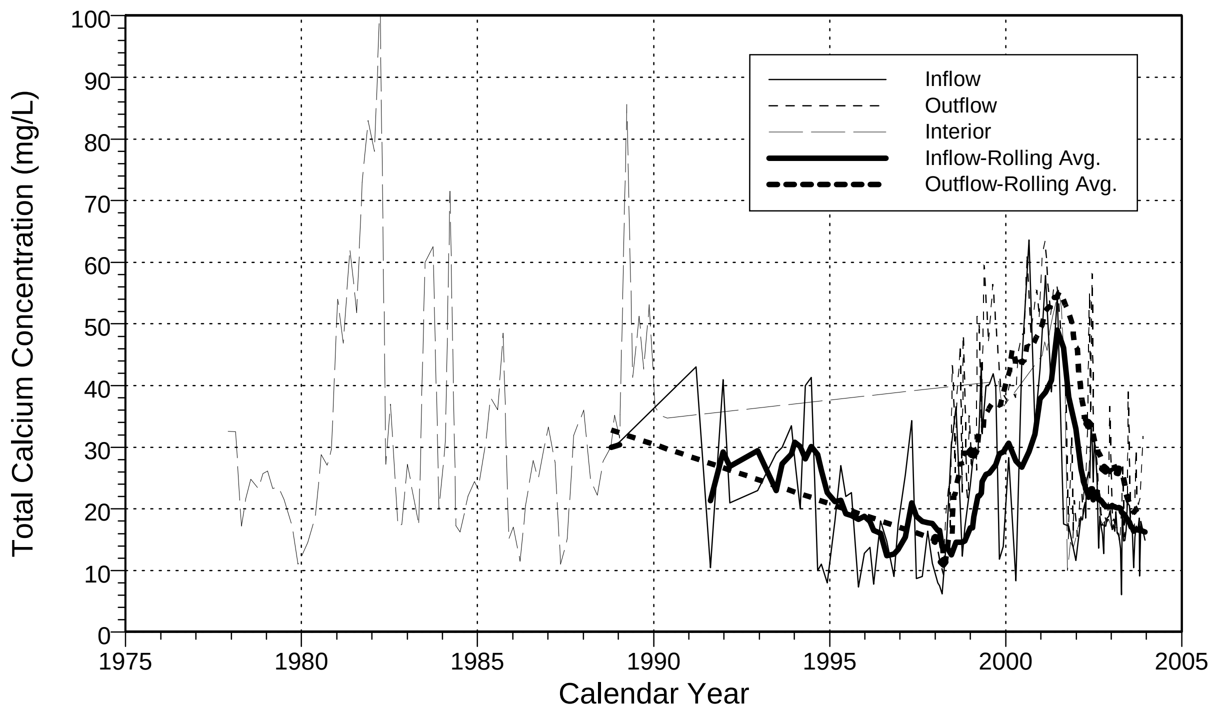


Figure 3-8: Long-term Water Surface Elevation at Crescent Lake

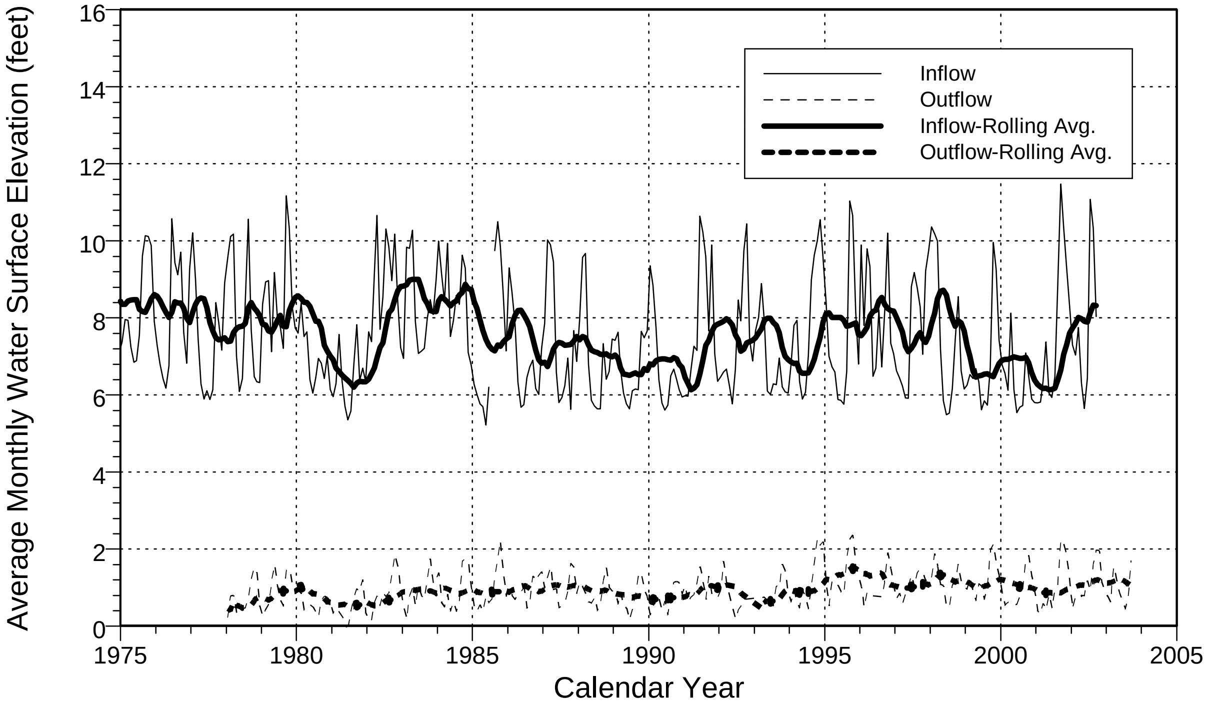
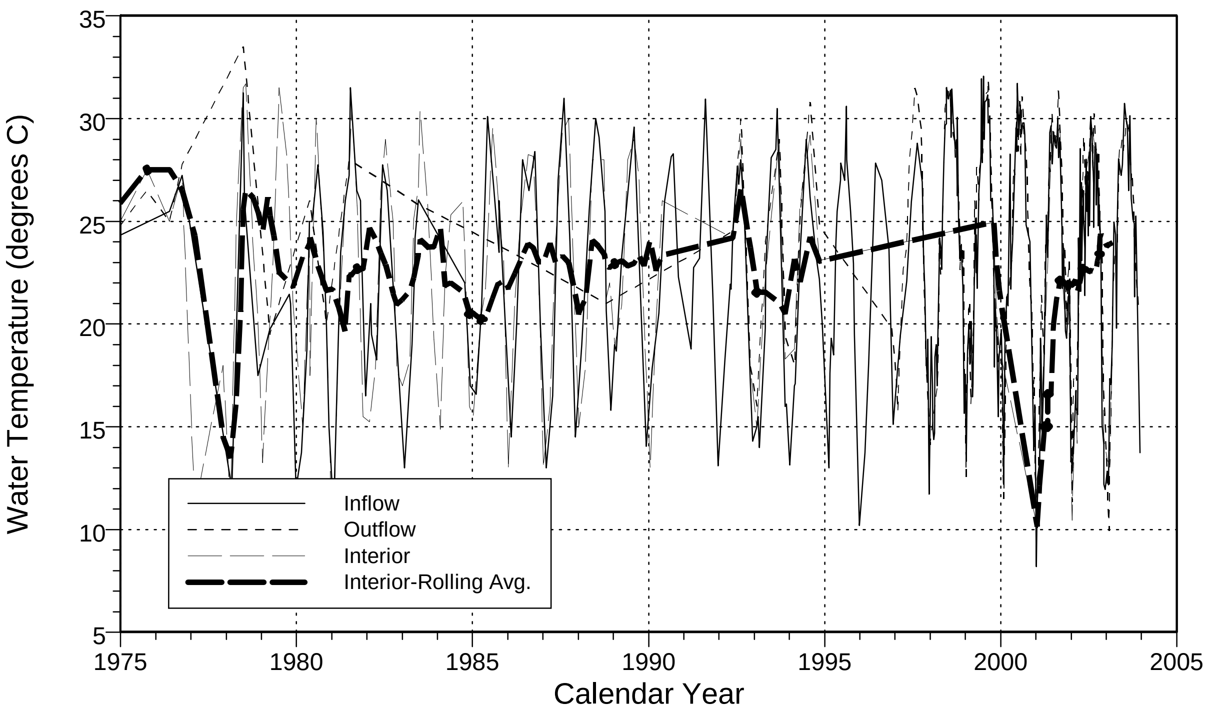


Figure 3-9: Long-term Water Temperature at Crescent Lake



After the analysis period was selected, the time series graphs for flow rate and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 3-10 through 3-11, better show the availability of these critical data during the analysis period. Table 3-2 includes descriptive statistics for key monitoring parameters at Crescent Lake. This table lists the total number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will note that relatively few non-detect samples occurred for the more significant parameters listed in Table 3-2 and none during the selected analysis period. For non-detect samples, the value reported is normally the applicable detection limit and these detection limit values were included in the associated statistics when they occurred.

3.3 WATER BALANCE

A daily water balance for Crescent Lake was developed for water years (WY) 1997–2003. This water balance included estimates of the following quantities for each day during the analysis period.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

Figure 3-10: Analysis Period Flow at Crescent Lake

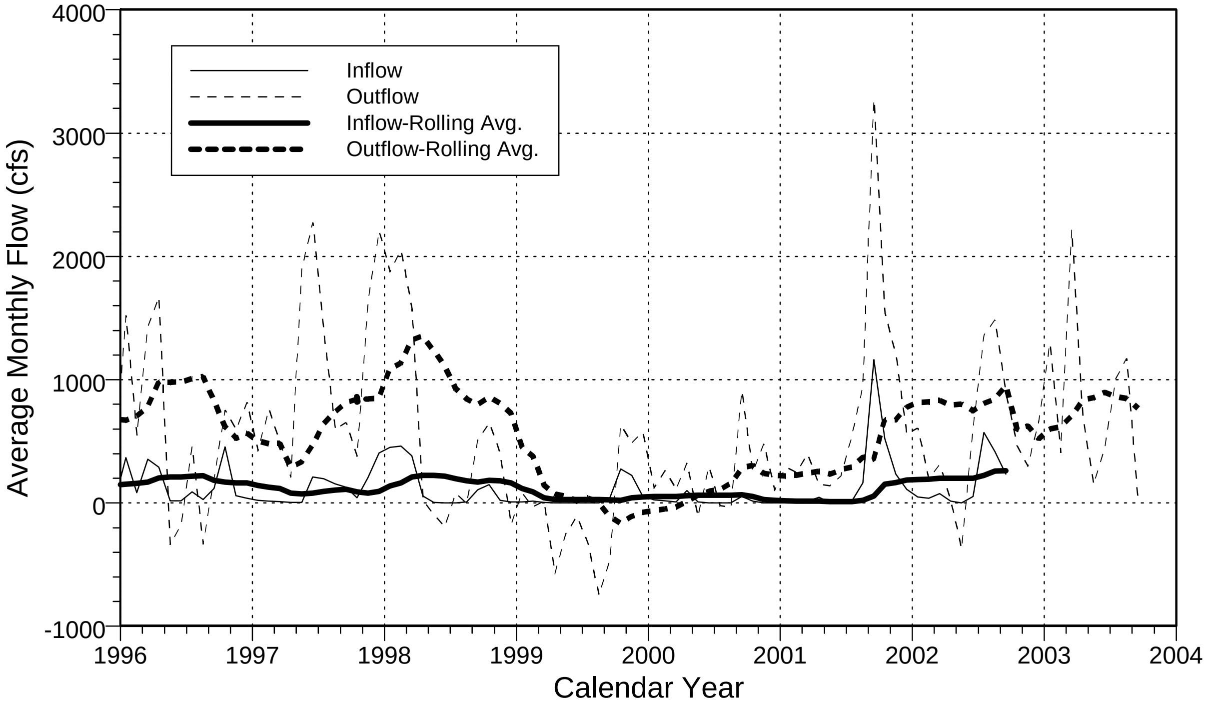


Figure 3-11: Analysis Period Phosphorus at Crescent Lake

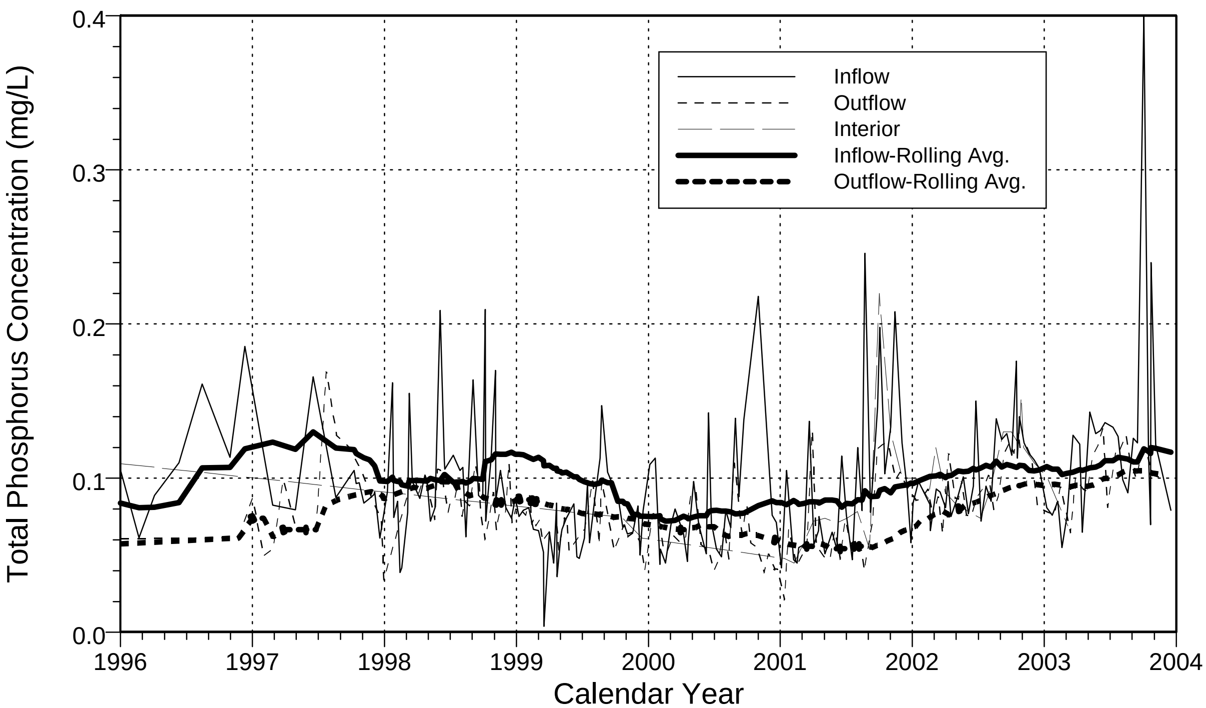


Table 3-2: Crescent Lake Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	127	0	22.015	5.970	64.800
		Outside	47	0	21.078	6.000	65.000
		Total	174	0	21.762	5.970	65.000
Calcium (mg/L)	Outflow	Inside	138	0	33.476	9.310	64.281
		Outside	5	0	25.544	20.232	32.800
		Total	143	0	33.199	9.310	64.281
Calcium (mg/L)	Interior	Inside	51	0	26.895	9.970	55.500
		Outside	137	0	33.336	10.900	114.000
		Total	188	0	31.589	9.970	114.000
Elevation (feet)	Inflow	Inside	4,244	0	7.312	4.170	15.260
		Outside	23,055	0	8.065	4.130	14.860
		Total	27,299	0	7.948	4.130	15.260
Elevation (feet)	Outflow	Inside	2,450	0	1.079	-0.090	3.230
		Outside	5,837	0	0.898	-1.050	3.080
		Total	8,287	0	0.952	-1.050	3.230
Flow (cfs)	Inflow	Inside	4,382	0	113.928	0.000	5,210.000
		Outside	24,473	0	102.540	0.000	2,759.000
		Total	28,855	0	104.270	0.000	5,210.000
Flow (cfs)	Outflow	Inside	2,491	0	541.607	-8,340.000	10,600.000
		Outside	4,117	0	490.360	-6,400.000	8,570.000
		Total	6,608	0	509.679	-8,340.000	10,600.000
Orthophosphorus (mg/L)	Inflow	Inside	65	0	0.033	0.004	0.160
		Outside	99	2	0.032	0.003	0.520
		Total	164	2	0.033	0.003	0.520
Orthophosphorus (mg/L)	Outflow	Inside	83	0	0.011	0.001	0.097
		Outside	8	0	0.035	0.014	0.055
		Total	91	0	0.013	0.001	0.097
Orthophosphorus (mg/L)	Interior	Inside	46	0	0.070	0.004	0.210
		Outside	146	0	0.094	0.023	0.346
		Total	192	0	0.088	0.004	0.346
pH	Inflow	Inside	241	0	6.995	4.670	9.460
		Outside	139	0	6.212	4.400	9.050

POR: Inside=Within analysis period (10/1/1996-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 3-2: Crescent Lake Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Inflow	Total	380	0	6.708	4.400	9.460
pH	Outflow	Inside	556	0	7.536	5.930	9.160
		Outside	39	0	7.478	5.500	9.500
		Total	595	0	7.532	5.500	9.500
pH	Interior	Outside	148	0	7.399	4.400	9.500
		Total	148	0	7.399	4.400	9.500
Phosphorus (mg/L)	Inflow	Inside	228	1	0.098	0.004	0.254
		Outside	147	1	0.106	0.001	0.630
		Total	375	2	0.101	0.001	0.630
Phosphorus (mg/L)	Outflow	Inside	203	0	0.081	0.019	0.173
		Outside	22	0	0.102	0.034	0.410
		Total	225	0	0.083	0.019	0.410
Phosphorus (mg/L)	Interior	Inside	50	0	0.107	0.042	0.220
		Outside	77	1	0.143	0.020	0.490
		Total	127	1	0.129	0.020	0.490
Temperature (deg C)	Inflow	Inside	268	0	22.889	8.210	32.070
		Outside	210	0	21.910	10.200	34.000
		Total	478	0	22.459	8.210	34.000
Temperature (deg C)	Outflow	Inside	563	0	23.809	9.860	32.880
		Outside	44	0	23.828	16.000	33.500
		Total	607	0	23.810	9.860	33.500
Temperature (deg C)	Interior	Inside	98	0	22.895	9.890	29.700
		Outside	313	0	22.590	8.000	34.500
		Total	411	0	22.663	8.000	34.500
Total Nitrogen (mg/L)	Inflow	Inside	151	0	2.881	1.400	4.180
		Outside	141	0	2.897	0.400	11.420
		Total	292	0	2.889	0.400	11.420
Total Nitrogen (mg/L)	Outflow	Inside	181	0	2.822	1.160	5.380
		Outside	24	0	2.126	0.700	3.400
		Total	205	0	2.740	0.700	5.380
Total Nitrogen (mg/L)	Interior	Inside	42	0	2.619	2.200	3.000
		Outside	53	0	2.528	0.680	5.280

POR: Inside=Within analysis period (10/1/1996-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 3-2: Crescent Lake Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Total Nitrogen (mg/L)	Interior	Total	95	0	2.568	0.680	5.280

POR: Inside=Within analysis period (10/1/1996-9/30/2003); Outside=Outside analysis period; Total=All available data.

3.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage; however, no tables or graphs of lake elevation vs. surface area were found for Crescent Lake. Therefore, a constant lake area of 17,448 acres was adopted for use in the water balance (USEPA, 1977a). The inaccuracies introduced by this simplifying assumption are not considered significant because the lake elevation only fluctuates over a narrow range and most of these errors will tend to balance out over time.

3.3.2 Inflow

The U.S. Geological Survey (USGS) has stream gages on two tributary streams upstream of Crescent Lake. These stations, listed previously in Table 3-1, are on Middle Haw Creek (No. 02244320) and Little Haw Creek (No. 02244420). The gaged inflow to Crescent Lake was calculated as the sum of the discharge at these two gages. No data were available from these two gages for WY 2003 so these values were estimated using the results of regression analyses with the Dunns Creek gage [Q_{in} (cfs) = 41.1 + 0.231Q_{out}, R^2 = .303]

The Middle Haw Creek and Little Haw Creek gages have contributing drainage areas of 78.3 and 93.0 square miles, respectively, but the total watershed area of Crescent Lake is approximately 470.7 square miles. Therefore, no recorded discharge exists for nearly 300 square miles of the Crescent Lake watershed. The ungaged inflow to Crescent Lake was initially estimated from the records at the two above stream gages using a straight drainage area ratio but later adjusted as described below in Section 3.3.7.

3.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Crescent Lake can represent a significant lake inflow. Rainfall depths at Crescent Lake over the period of record were estimated from records maintained by the National Oceanic and Atmospheric Administration (NOAA) for Crescent City (Station No. 8-1978) (NOAA, 2002). Crescent City is located on the west shore of Crescent Lake. Missing data values from this station were filled in with data from Hastings ARC (Station No. 8-3874), which is located about 15 miles north of the lake. The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Crescent Lake by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

3.3.4 Evaporation Depth and Volume

No evaporation data for Crescent Lake were located during Task 2 so lake evaporation was estimated from pan evaporation data available at Lisbon, Florida (NOAA, 2002). This climate station (No. 8-5076) is located about 43 miles southwest of Crescent Lake. Water will evaporate faster from an evaporation pan than a lake because it is a much smaller body of water and will heat up much more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Crescent Lake vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value represenative of the evaporation over the entire period is available. In order to smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. As discussed in the previous section, no pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Crescent Lake were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

3.3.5 Outflow

Dunns Creek is the outlet from Crescent Lake. The USGS maintains a stream gage on Dunns Creek (No. 02244440), which is located about five miles downstream of the lake proper near the confluence of Dunns Creek and the St. Johns River. Review of the data for this gage shows that the flow in Dunns Creek reverses at times, with water flowing upstream from the St. Johns River to Crescent Lake. The records at this stream gage were used to estimate the gaged outflow from Crescent Lake. Because Crescent Lake has no other outlets, ungaged outflow was assumed to always be zero.

3.3.6 Elevation and Change in Storage

No long-term daily stage or water surface elevation data were located for Crescent Lake. However, the USGS does record daily gage height data, which is the basis for the corresponding discharge estimates, at the three stream gages previously mentioned. Using the corresponding gage datum, gage height records can be converted to water surface elevations at the gage location. For lack of better data, the estimated elevations in Dunns Creek at the gage downstream of the lake were used as a surrogate for actual lake elevation data. The day-to-day changes in these gage heights were assumed to be representative of the changes in lake elevation also. The corresponding changes in lake storage were then estimated as the products of these gage height changes and the lake surface area. The available gage height readings are mean daily values and as such, are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation was estimated as the average of the gage heights for the current and following day.

While no specific bathymetric data were obtained from Crescent Lake, the total water depth was sometimes recorded when water samples were collected. Comparison of these depth readings and the corresponding water surface elevations at the Dunns Creek gage for the same days yields an average difference of approximately 8.9 feet (that is, the lake bottom elevation is estimated to be -8.9 feet). Estimates of daily lake depth were developed using this relationship.

3.3.7 Imbalance

Theoretically, the sum of all lake inflows (gaged inflow + ungaged inflow + precipitation volume) less all outflows (gaged outflow + ungaged outflow + evaporation) should equal the computed change in storage each day. In practice however, this never occurred. One reason for this imbalance is that no data on exchanges of groundwater between Crescent Lake and the surficial aquifer were available so any such exchanges are not represented in this water balance. Because of the inaccuracies in these methods, an imbalance quantity was calculated for each day. These imbalances are positive on some days (too much inflow or positive storage change) and negative on others (too much outflow or negative storage change). Totaling these imbalances over the entire seven-year period of record indicated that, in general, the estimated inflows exceeded measured outflows. To improve the quality of the overall water balance for Crescent Lake, ungaged inflows (as initially estimated using a drainage area ratio) were adjusted downward by approximately one third (33 percent).

Table 3-3 presents an annual summary of the Crescent Lake water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 3-3: Crescent Lake Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1997	342,634	78,327	54,600	488,838	2,355	-120,829
1998	554,054	91,079	49,020	599,675	-8,375	-1,279
1999	65,990	64,223	50,732	-92,608	13,609	158,479
2000	201,363	70,897	57,716	212,011	3,490	-957
2001	370,513	76,350	52,677	422,007	-3,315	-19,197
2002	615,226	73,352	60,092	509,605	-12,039	130,921
2003	384,245	79,071	61,876	536,458	3,141	-138,160
Total	2,534,025	533,298	386,713	2,675,986	-1,134	8,979

3.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Crescent Lake using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the analysis period.

- Inflow TP concentration and mass flux
- Wet and dry phosphorus deposition load to the lake
- Outflow TP concentration and mass flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

3.4.1 Inflow TP Concentration and Flux

During the selected period of record (WY 1997–2003), inflow TP concentration data are available for 182 days. This sampling rate yields an average sample frequency of once every two weeks. Table 3-4 lists the specific stations and number of available samples within the analysis period at each station.

Table 3-4: TP Monitoring Stations at Crescent Lake

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	14857	SJB-LL-1037	1
	3518	CRESCENT LK BY MARKER NO.9	15
SJRWMD	20030411	CRESCENT LAKE AT MARKER 9	20
	HAW	HAW CREEK MOUTH AT DEAD LAKE	53
	SAVCRL2I	Crescent Lake site #2 inside grassbed	139
Interior Stations			
FDEP	14830	SJB-LL-1002	1
	14831	SJB-LL-1003	1
	14832	SJB-LL-1004	1
	14835	SJB-LL-1008	1
	14836	SJB-LL-1010	1
	14837	SJB-LL-1011	1
	14839	SJB-LL-1013	1
	14841	SJB-LL-1016	1
	14842	SJB-LL-1017	1
	14843	SJB-LL-1018	1
	14847	SJB-LL-1024	1
	14848	SJB-LL-1026	1
	14849	SJB-LL-1027	1
	14850	SJB-LL-1028	1
	14851	SJB-LL-1029	1
	14852	SJB-LL-1030	1
	14853	SJB-LL-1031	1
	14855	SJB-LL-1035	1
	14856	SJB-LL-1036	1
	7886	CRESCENT LAKE MIDDLE	33
Outflow Stations			
FDEP	14262	SJB-LR-1004	1
	14274	SJB-LR-1025	1
	14845	SJB-LL-1020	1
SJRWMD	CRESLM	Crescent Lake at Outlet to Dunns Creek	88
	DUNNSCRK	Dunns Cr Midway betw Crescent L & SJR	113

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of inflow rate, julian day and monthly precipitation as independent variables. Julian day was selected as an independent variable because it can be used to represent seasonality. Monthly precipitation was used as an independent variable because it can be used as a surrogate for the amount of storm water that enters the watershed upstream of the lake. Storm water discharges, particularly from agricultural areas, may have higher phosphorus concentrations. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variables: Julian day (J) and common logarithm of inflow rate in cfs (log Q).
- Model: log [TP] = -1.235 + 0.001 J + 0.041 log Q
- Coefficient of determination (R^2): .128

Even this "best" model does not have a very good fit but any model with an R^2 over .100 may be worthy of consideration. Therefore, this model was used to help estimate inflow TP concentrations.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less valid.

At Crescent Lake, missing inflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based on the interpolation method and best regression model. Once these estimates of daily inflow TP concentrations were developed, the phosphorus influx to Crescent Lake was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance (with appropriate unit conversions to yield influx estimates in grams).

3.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Crescent Lake is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 µg/m^2 while direct precipitation to the lake (wet deposition) is assumed to have a TP concentration of 9.39 µg/L (Ahn & James, 2001). Therefore, the daily phosphorus influx from deposition was calculated as the sum of these two components.

3.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Crescent Lake were identical to those used for lake inflow. During the selected period of record (WY 1997–2003), outflow TP concentration data are available for 159 days. This yields an average sample frequency of once every 16 days. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, none of the available independent variables met the criteria for inclusion in the resultant model so no regression model was produced. Therefore, the outflow TP concentration estimates were developed using the simple straight-line interpolation process described above.

Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Crescent Lake was estimated for each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

3.4.4 Net Phosphorus Retention

The net phosphorus mass retention in Crescent Lake was estimated as the total influx from inflow and direct deposition less the discharge flux in the outflow. As such, these net retention values include the phosphorus retained or discharged because of changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Crescent Lake is shown in Table 3-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

Table 3-5: Crescent Lake Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1997	54,047	3,095	53,451	3,691
1998	68,133	3,242	54,472	16,903
1999	9,843	2,931	-9,161	21,935
2000	26,292	3,015	16,435	12,871
2001	60,798	3,072	42,966	20,904
2002	97,063	3,037	63,020	37,080
2003	52,780	3,103	62,858	-6,974
Total	368,956	21,496	284,041	106,411

3.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Crescent Lake were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. These monthly data sets include the following data values:

- Average water surface area (hectares, ha)
- Total inflow and outflow volumes (cubic meters, m^3)
- Total mass flux of phosphorus in, out and retained in the lake (grams, g)
- Flow-weighted average inflow and outflow phosphorus concentrations (milligrams per liter, mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (meters per year, m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

3.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 3-12. From review of this graph, it is not apparent there is a linear relationship between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of zero.

3.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. The only models with R^2 significantly above zero used hydraulic loading rate (R^2 = .856) and temperature (R^2 = .144). Figure 3-13 is a scatter diagram of settling rate vs. hydraulic loading rate.

3.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Crescent Lake from the Florida Department of Environmental Protection's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

A total of 58 species of wetland and aquatic plants were recorded for Crescent Lake during the BIPM surveys. These included 43 species of emergent wetland plants, eight species of floating aquatic plants, and five species of submerged aquatic plants. Dominant emergent species included cattails (*Typha* spp.), bulrush *(Scirpus* spp.), sawgrass (*Cladium jamaicense*), and grasses (*Panicum hemitomon* and

Figure 3-12: Retention Efficiency vs. Hydraulic Loading Rate at Crescent Lake

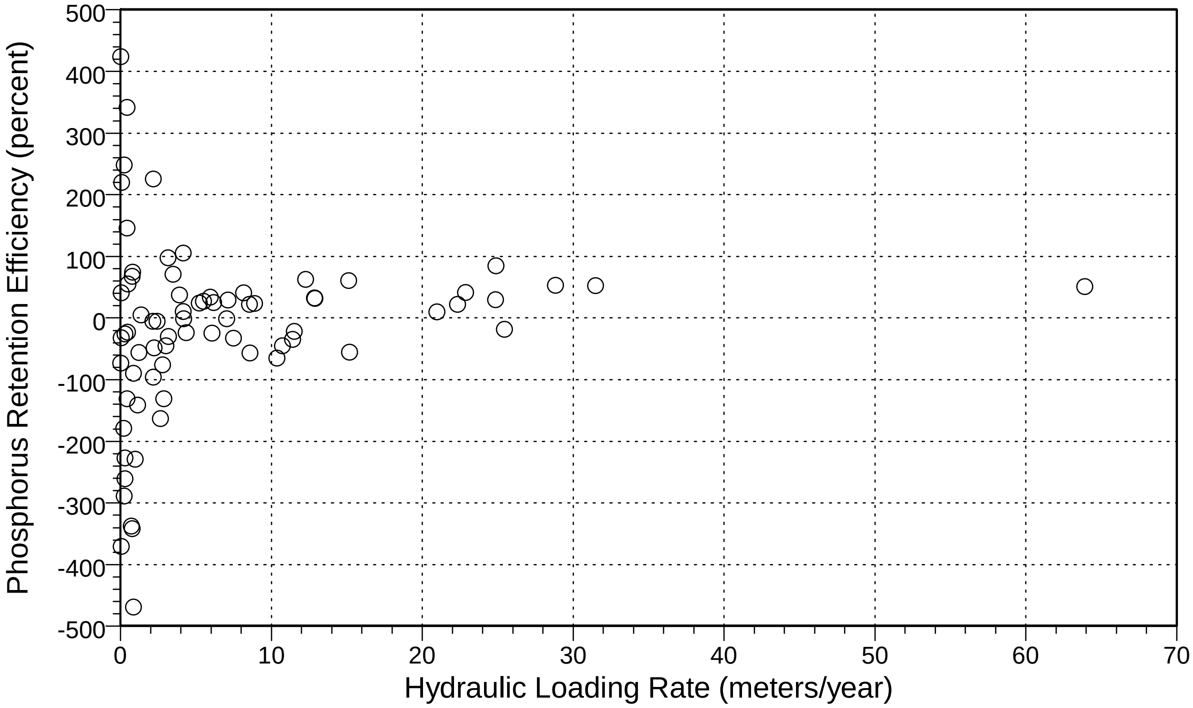
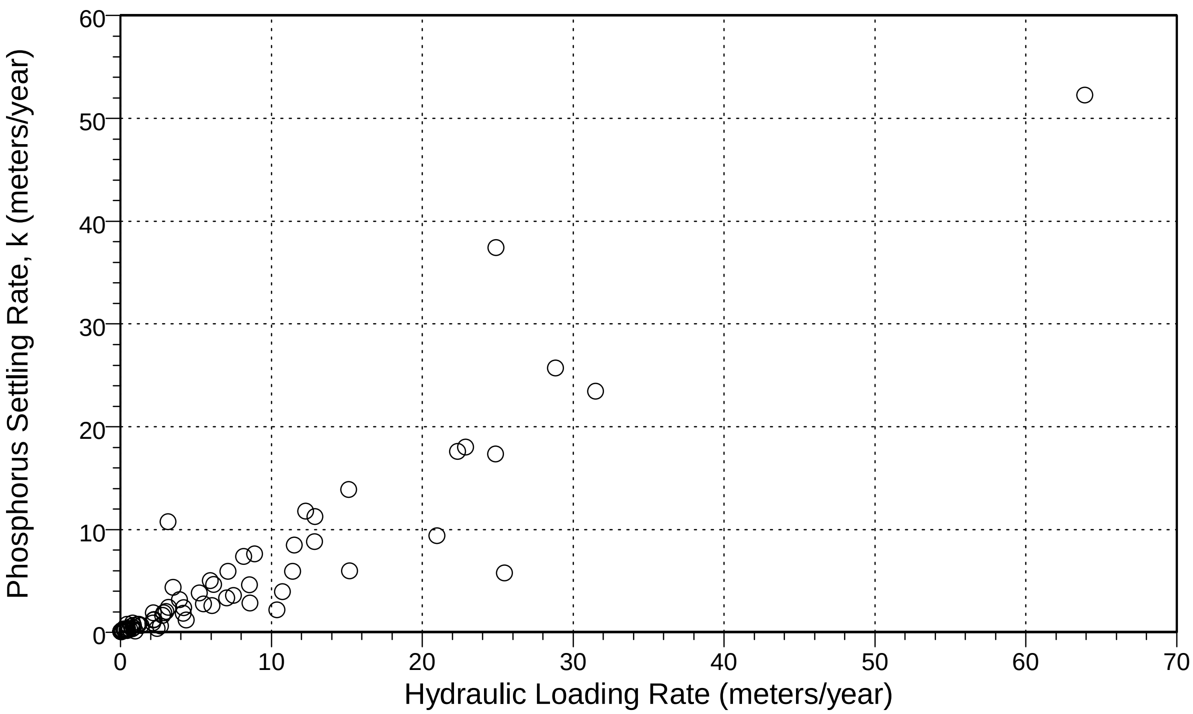


Figure 3-13: Settling Rate vs. Hydraulic Loading Rate at Crescent Lake



Paspalidium geminatum). Dominant floating species included water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), duckweed (*Lemna* spp.), and water fern (*Salvinia minima*). Dominant submerged aquatics included hydrilla (*Hydrilla verticillata*), eelgrass (*Vallisneria americana*), and coontail (*Ceratophyllum demersum*).

Table 3-6 summarizes the estimated cover by vegetation type for Crescent Lake for the period from 1982 through 2003. The average cover by vegetation type was emergent – 517 acres, floating – 247 acres, and submerged – 211 acres. These estimates of plant cover show that plants occupy a very small fraction of the estimated 17,086-acre surface area of Crescent Lake.

Table 3-6: Crescent Lake Vegetation Data

Survey	Vegetation Coverage by Type (acres)		
Month	Emergent	Floatin g	Submerged
Nov-82	553	1230	280
Oct-83	455	648	210
Jul-84	474	70.5	157
May-86	620	85.0	165
Jun-88	702	56.0	179
Jun-90	663	31.8	210
Oct-92	537	34.0	565
Aug-95	422	53.6	130
Aug-03	228	14.2	4.0
Average	517	247	211
Median	537	56.0	179
Maximum	702	1230	565
Minimum	228	14.2	4.0

* * * * *

4 LAKE GEORGE

4 LAKE GEORGE

Lake George is located in the northwestern corner of Volusia County but also extends into Putnam County. Jacksonville is about 65 miles north of Lake George and Orlando is about 48 miles south (Figure 1-1). Lake George is one of a number of natural lakes on the St. Johns River and is the second largest lake in Florida. The data collected for Lake George and the analyses completed with these data are described in the balance of this chapter.

4.1 DATA SOURCES

The data for Lake George were collected from a number of sources. These sources are listed in Table 4-1 along with a listing of the individual sample stations obtained from each source. For each sample station, this table also lists its absolute location (latitude/longitude coordinates) and location relative to Lake George. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 4-1 shows the locations of these monitoring stations.

4.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations

Table 4-1: Lake George Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	20010160	ST JOHNS R AT MARKER 19	29.20083	81.56092
	20010164	L GEO NW CRN 150 YDS E SALT SPRG	29.32447	81.67928
	20010454	Juniper Creek 100 yards upstream of Highway 19	29.21361	81.65556
Outflow	20010165	ST JOHN R CHAN MARKER 72	29.37800	81.62822
	20010166	L GEORGE NW SECTOR	29.35678	81.65483
Interior	20010161	LK GEO AT MARKER 13	29.22983	81.58533
	20010162	L GEORGE AT MARKER #9	29.27639	81.59792
	20010163	L GEORGE AT MARKER #4 & 5	29.33497	81.61636
	20010167	SJR above Oklawaha @ marker 60,1/2 mi s. of Little	29.43178	81.67542
	20010335	Silver Glenn Springs run where the run meets Lake	29.24836	81.63506
	20010358	Silver Glenn Springs at main boil.	29.24578	81.64345
	20030519	SJR above Oklawaha @ marker 65	29.41945	81.65356
	20030520	SJR above Oklawaha @ Marker 59	29.43361	81.68330
	22640			
	22665			
	23274			
	3515	ST. JOHNS RIVER AT HWY 40 NEAR ASTOR	29.16806	81.52361
	9687	SILVER GLEN SPRINGS	29.24584	81.64347
Florida Game and Fresh Water Fish Commission (FGFWF)				
Inflow	GFCCR0058	LAKE GEORGE SOUTH END NEAR JUNIPER RU	29.20472	81.61003
	GFCCR0179	ST. JOHNS RIVER CM 22 AT ENTRANCE TO CR	29.19000	81.55556
	GFCCR0180	LAKE GEORGE JUST OUTSIDE BOAT FENDERS	29.21000	81.58028
Outflow	GFCCR0057	LAKE GEORGE SOUTH OF DRAYTON ISLAND	29.35689	81.62850
	GFCCR0181	LAKE GEORGE FLASHING LIGHT AT L. GEORG	29.37111	81.62361
Florida LAKEWATCH (LakeWatch)				
Inflow	MAR-SIVERG	Marion-Silver Glen-1	29.24486	81.64325
	MAR-SIVERG	Marion-Silver Glen-2	29.24486	81.64325
	MAR-SIVERG	Marion-Silver Glen-3	29.24486	81.64325
	SILVER GLEN	LAKE SILVER GLENN1 IN MARION CO.-SEE NO	29.24486	81.64325
	SILVER GLEN	LAKE SILVER GLENN2 IN MARION CO.-SEE NO	29.24486	81.64325
	SILVER GLEN	LAKE SILVER GLENN3 IN MARION CO.-SEE NO	29.24486	81.64325
Interior	GEORGE107-1	GEORGE LAKE IN PUTNAM CO-SEE NOTE	29.30583	81.59333
	GEORGE107-2	GEORGE LAKE IN PUTNAM CO-SEE NOTE	29.30583	81.59333
	GEORGE107-3	GEORGE LAKE IN PUTNAM CO-SEE NOTE	29.30583	81.59333

Table 4-1: Lake George Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Interior	PUT-GEORGE	Putnam-George-1	29.30583	81.59333
	PUT-GEORGE	Putnam-George-2	29.30583	81.59333
	PUT-GEORGE	Putnam-George-3	29.30583	81.59333
	PUT-GEORGE	Putnam-George East-1	29.29839	81.57345
	PUT-GEORGE	Putnam-George East-2	29.29839	81.57345
	PUT-GEORGE	Putnam-George East-3	29.29839	81.57345
	PUT-GEORGE	Putnam-George South-1	29.23939	81.58344
	PUT-GEORGE	Putnam-George South-2	29.23939	81.58344
	PUT-GEORGE	Putnam-George South-3	29.23939	81.58344
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	82150	Daytona Beach	29.19028	81.06361
	82158	Daytona Beach WSO Airport	29.18333	81.05000
	82229	Deland	29.06667	81.28333
	83321	Gainesville	29.63333	82.36667
	83322	Gainesville	29.68333	82.50000
	83326	Gainesville Muni Arpt	29.68333	82.26667
Saint Johns River Water Management District (SJRWMD)				
Inflow	JUNRUN	JUNIPER CREEK AT HWY 19	29.21278	81.65528
	LGI	LAKE GEORGE AT INLET	29.21000	81.58028
	SJR40	ST JOHNS RIVER @ HWY 40 NEAR ASTOR	29.16722	81.52361
Outflow	20030373	ST JOHNS RIVER AT CM 72	29.37764	81.62769
	LG11	SJR WEST OF DRAYTON ISLAND EAST BANK	29.38333	81.65028
	LG12	SJR btw Drayton Isl and Hog Isl, Mid Channel	29.37842	81.65105
	LG13	SJR WEST OF DRAYTON ISLAND WEST BANK	29.38333	81.65833
	MSJFGF	Middle St Johns R Near Ft Gates Ferry	29.42992	81.66789
Interior	LAG	LAKE GEORGE AT M 9	29.25494	81.59116
	LEO	LAKE GEORGE 50 M WEST OF CM'S 4 & 5	29.33472	81.61611
U.S. Forest Service (USFS)				
Inflow	50205	SALT SPRINGS REC AREA	29.35056	81.73222
	50206	SALT SPRINGS REC AREA	29.35056	81.73222
	50208	SILVER GLENN SPRINGS	29.24500	81.64361
	50209	SILVER GLENN SPRINGS	29.24500	81.64361
	50523	CEMETARY LAKE	29.20222	81.60917
U.S. Geological Survey (USGS)				
Inflow	2236125	ST. JOHNS RIVER AT ASTOR, FLA.	29.16667	81.52222

Table 4-1: Lake George Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Outflow	2244040	St. Johns R at Buffalo Bluff nr Satsuma, Fla	29.59611	81.68333
US EPA--Storet (US EPA)				
Outflow	1210A1	ST JOHNS RIVER	29.38333	81.64167
Interior	121001	LAKE GEORGE	29.21528	81.58056
	121002	LAKE GEORGE	29.25000	81.58334
	121004	LAKE GEORGE	29.33333	81.60555
	121005	LAKE GEORGE	29.32083	81.65278
Volusia County, Florida (Volusia Co)				
Inflow	SJ27	ST. JOHNS RIVER 0.5 MI. SOUTH OF HWY 40 - A	29.16806	81.52361
	SJ28	ST. JOHNS RIVER AT CM 19	29.20111	81.56250
	SJ29	LAKE GEORGE AT CM 9	29.25528	81.59111
	VC-065	St. John's River, about 1/2 mile S. of S.R.40	29.16806	81.52361
	VC-066	St. John's River, at CM 19	29.20111	81.56250
Interior	VC-067	St. John's River, at center of Lake George, at CM	29.25528	81.59111

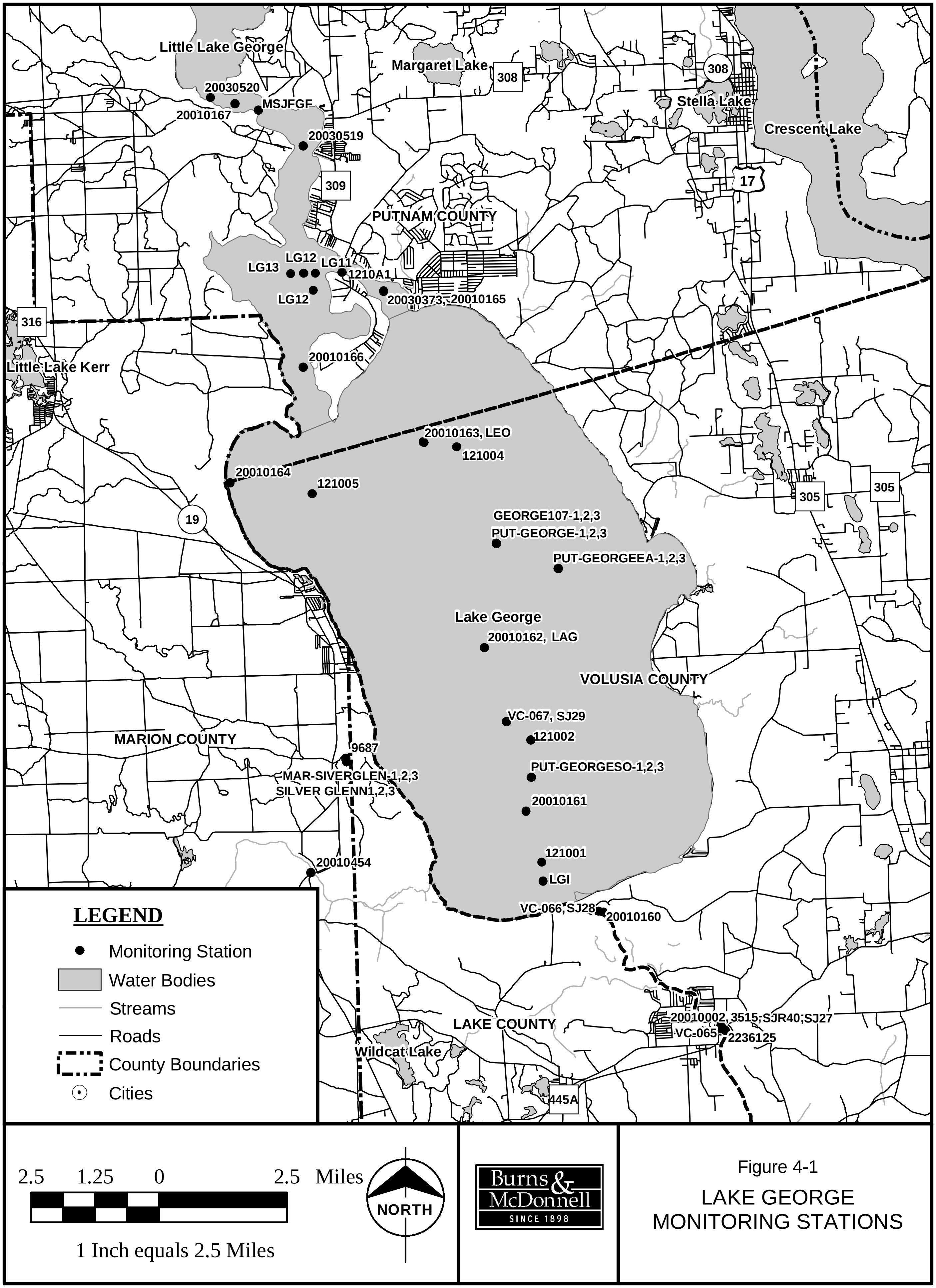


Figure 4-1

LAKE GEORGE MONITORING STATIONS

- Total nitrogen concentrations
- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station represents a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 4-2 through 4-9 contain the time series graphs for Lake George for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data are available back to the early 1970s for Lake George. For the most part, relatively few water quality monitoring data are available for this lake before 1975. The most recent data available are for late 2003. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the WQIR project are flow and phosphorus concentration data for use in calculating flow and phosphorus balances at Lake George. The graphs of available flow and phosphorus concentration data are shown in Figures 4-2 and 4-3, respectively. These figures show that flow data are available continuously only since about 1994. For this reason, a period of record of 1994–2003 (2/1/1994–9/30/2003) was selected for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are generally more prevalent during this same period.

After the analysis period was selected, the time series graphs for flow rate and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 4-10 through 4-11, better show the availability of data during the analysis period. Table 4-2 includes

Figure 4-2: Long-term Flow at Lake George

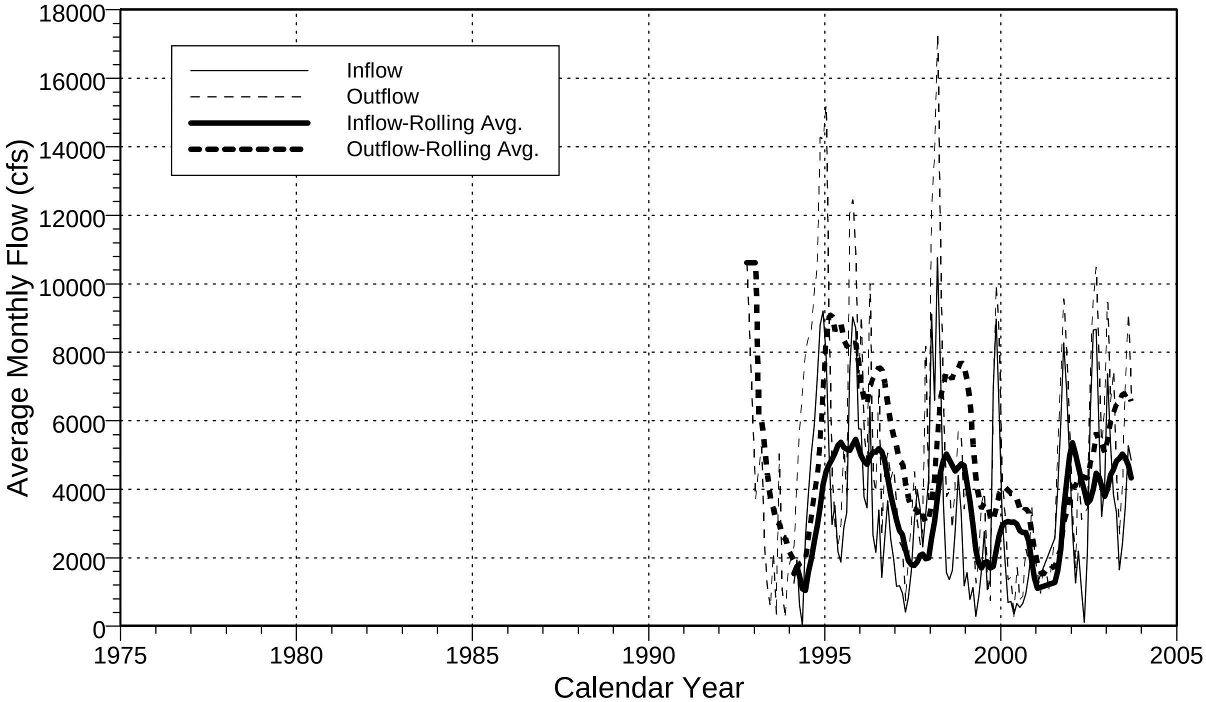


Figure 4-3: Long-term Total Phosphorus at Lake George

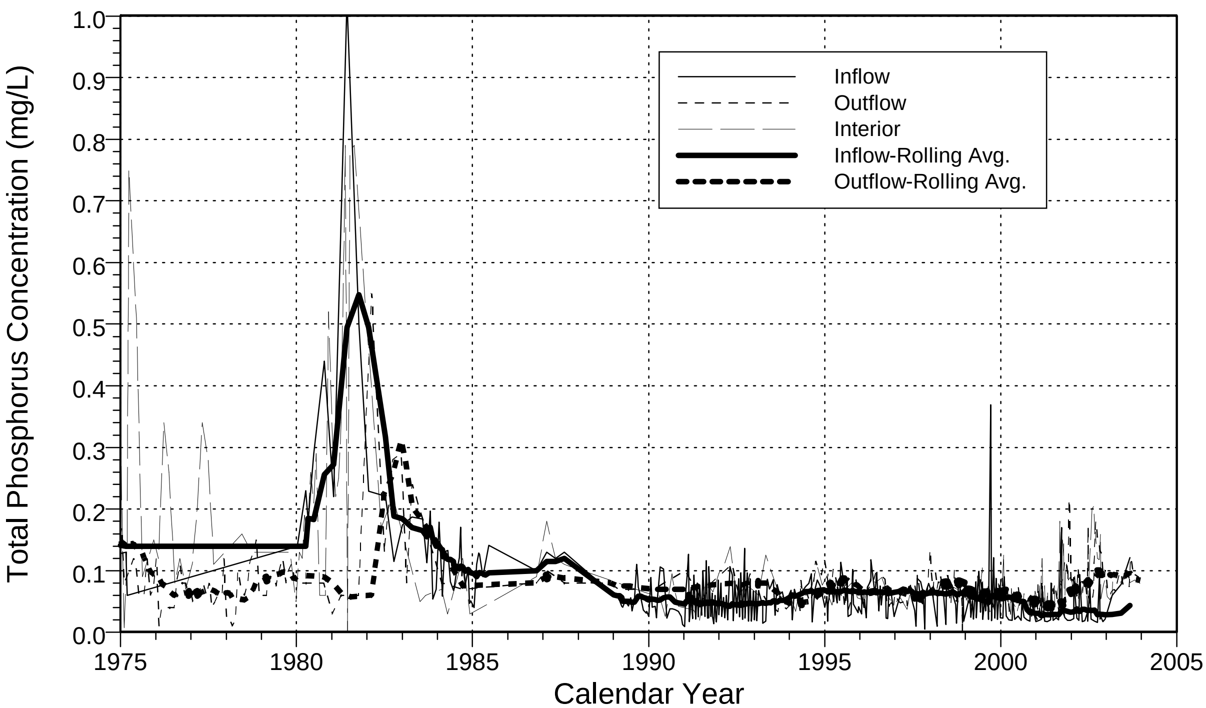


Figure 4-4: Long-term Orthophosphorus at Lake George

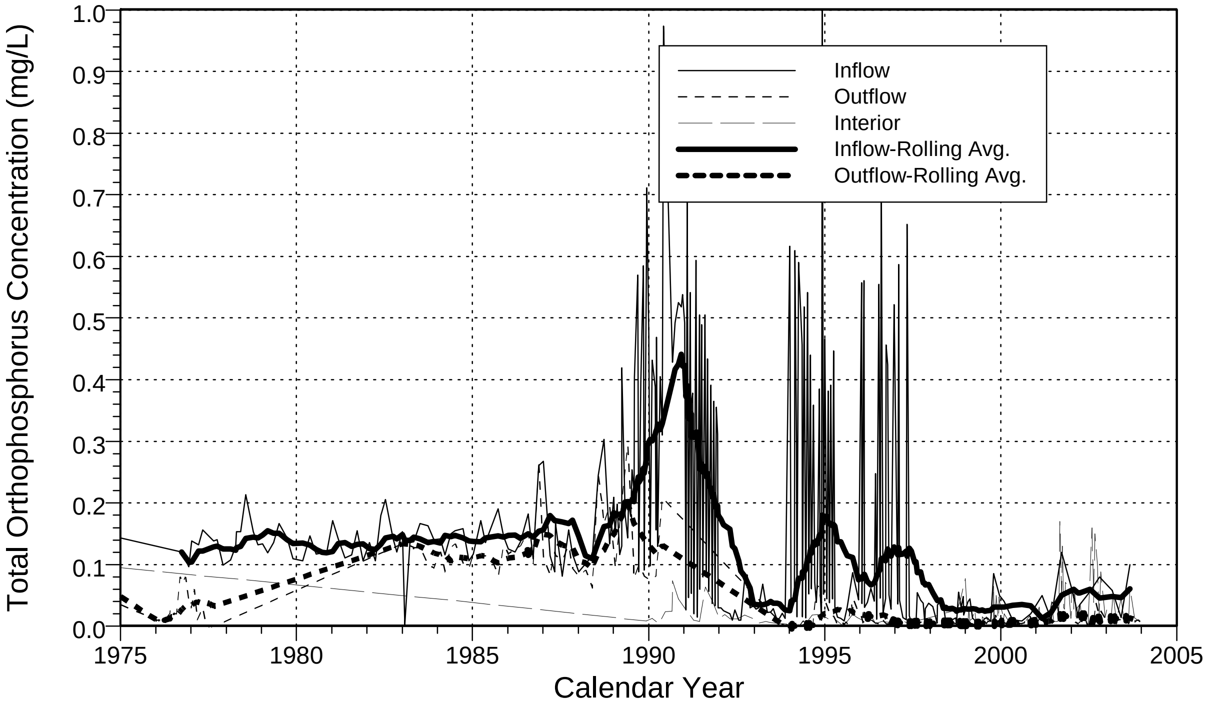


Figure 4-5: Long-term Total Nitrogen at Lake George

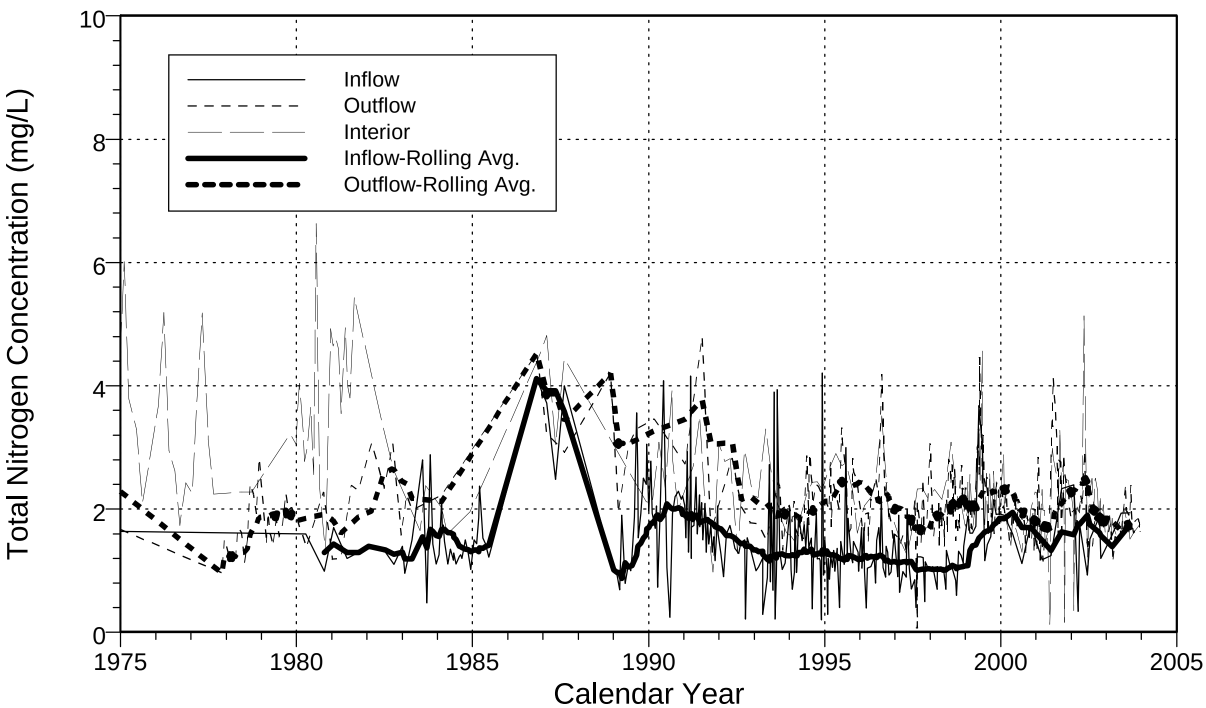


Figure 4-6: Long-term pH at Lake George

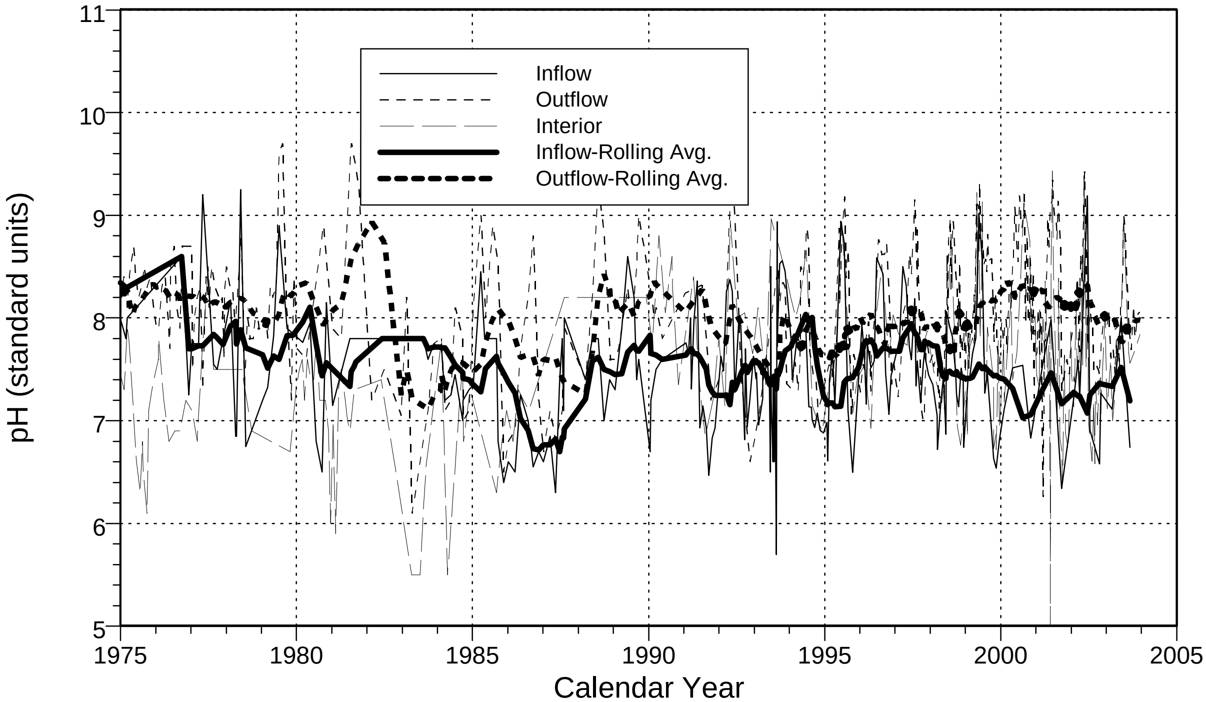


Figure 4-7: Long-term Total Calcium at Lake George

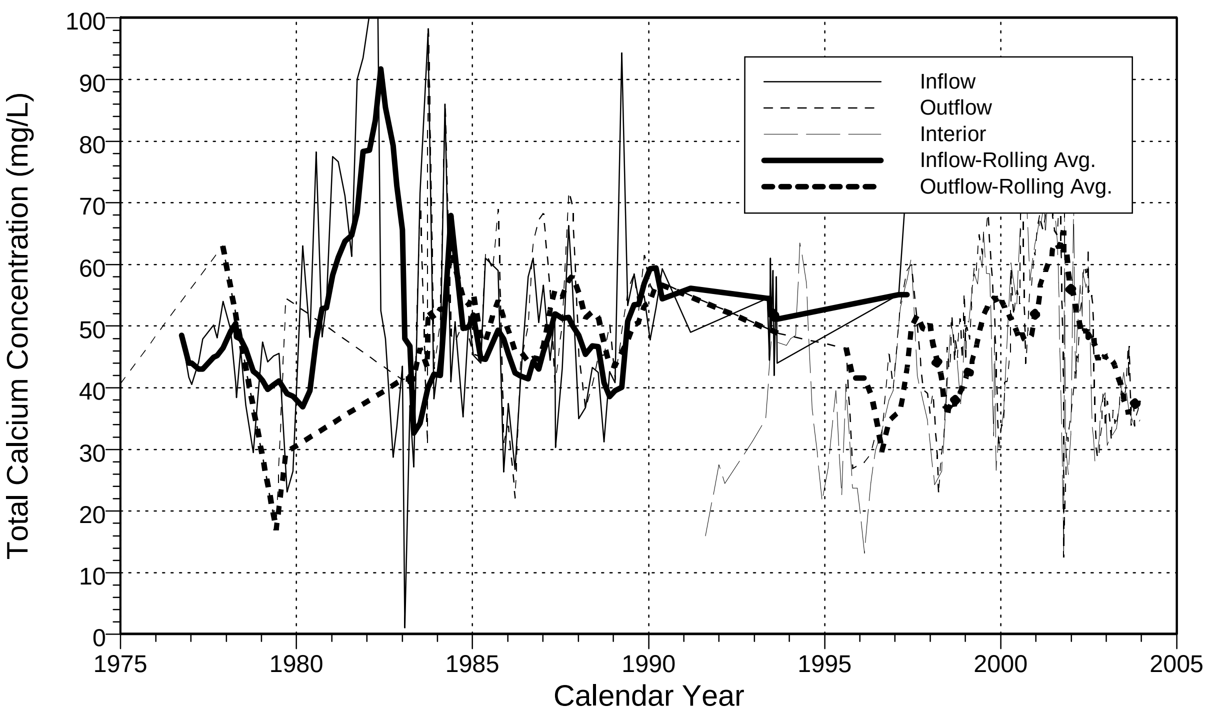


Figure 4-8: Long-term Water Surface Elevation at Lake George

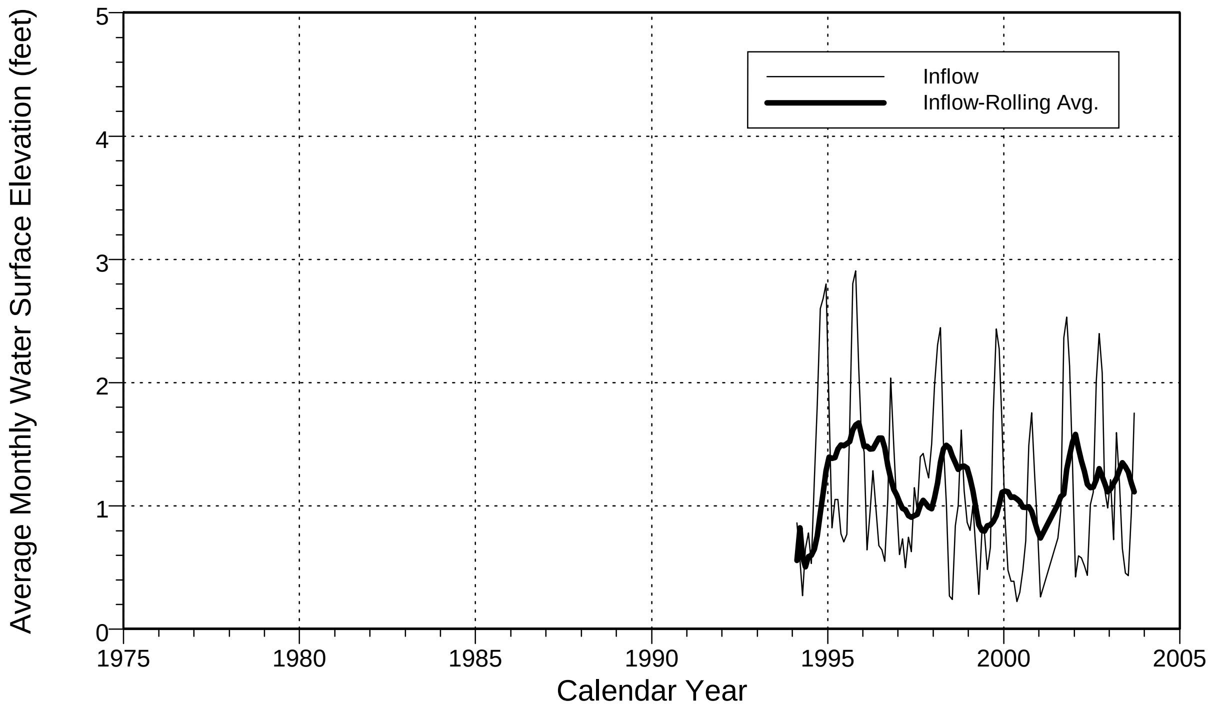
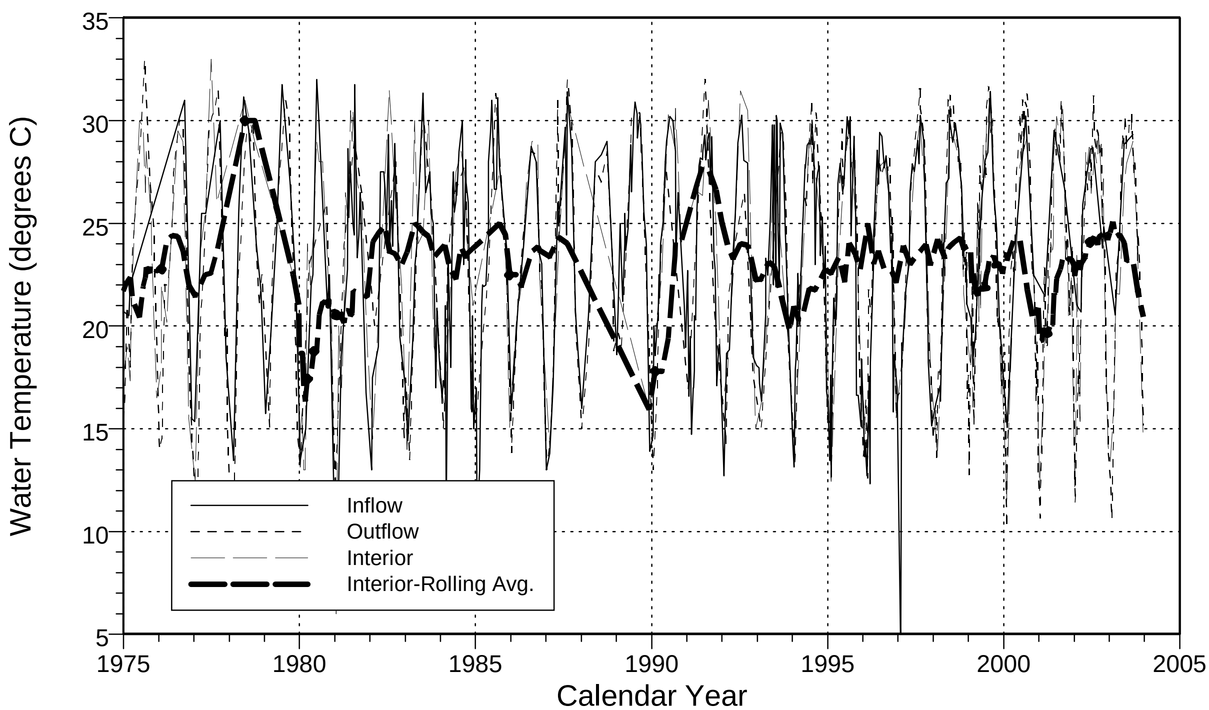


Figure 4-9: Long-term Water Temperature at Lake George



descriptive statistics for key monitoring parameters at Lake George. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will note that relatively few non-detect samples occurred for the more significant parameters listed in Table 4-2. For these non-detect samples, the reported value was normally the applicable detention limit. These detention limit values were included in subsequent statistics and analyses when they occurred.

4.3 WATER BALANCE

A daily water balance for Lake George was developed for February 1994–September 2003. This water balance included estimates of the following quantities for each day during the period of record.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

4.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage; however, no tables or graphs of lake elevation vs. surface area were found for Lake George. Therefore, a constant lake area of 46,000 acres was adopted for use in the water balance

Figure 4-10: Analysis Period Flow at Lake George

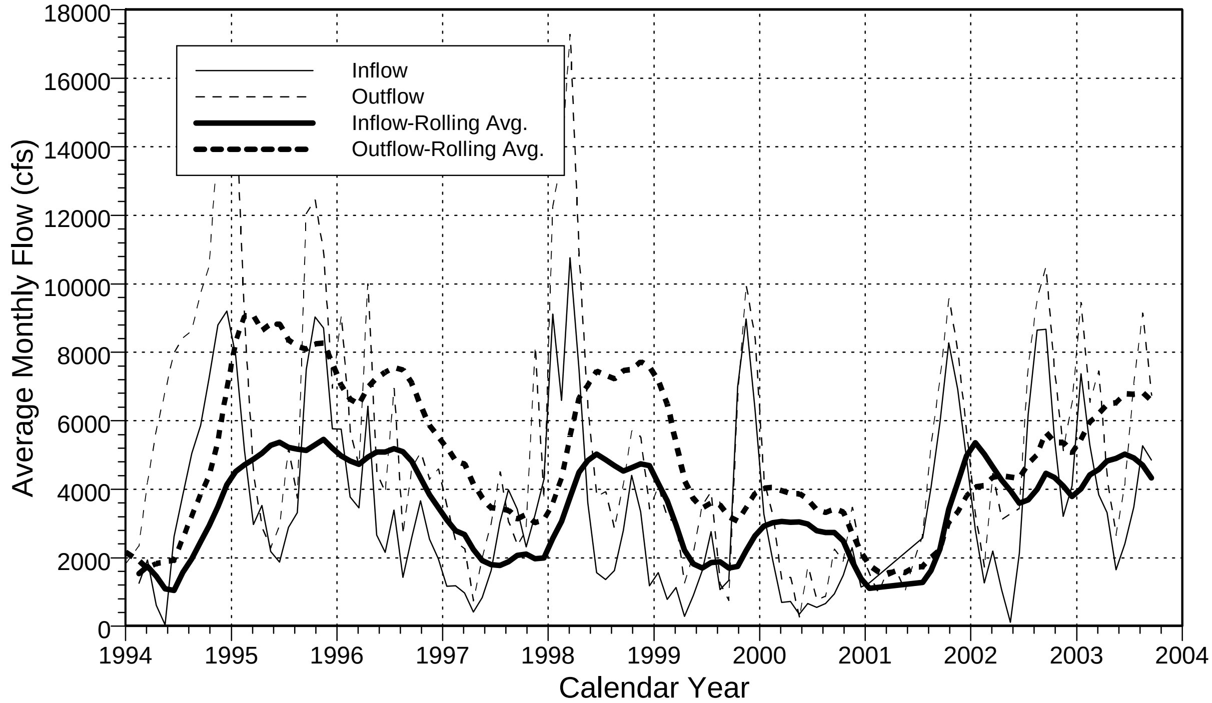


Figure 4-11: Analysis Period Total Phosphorus at Lake George

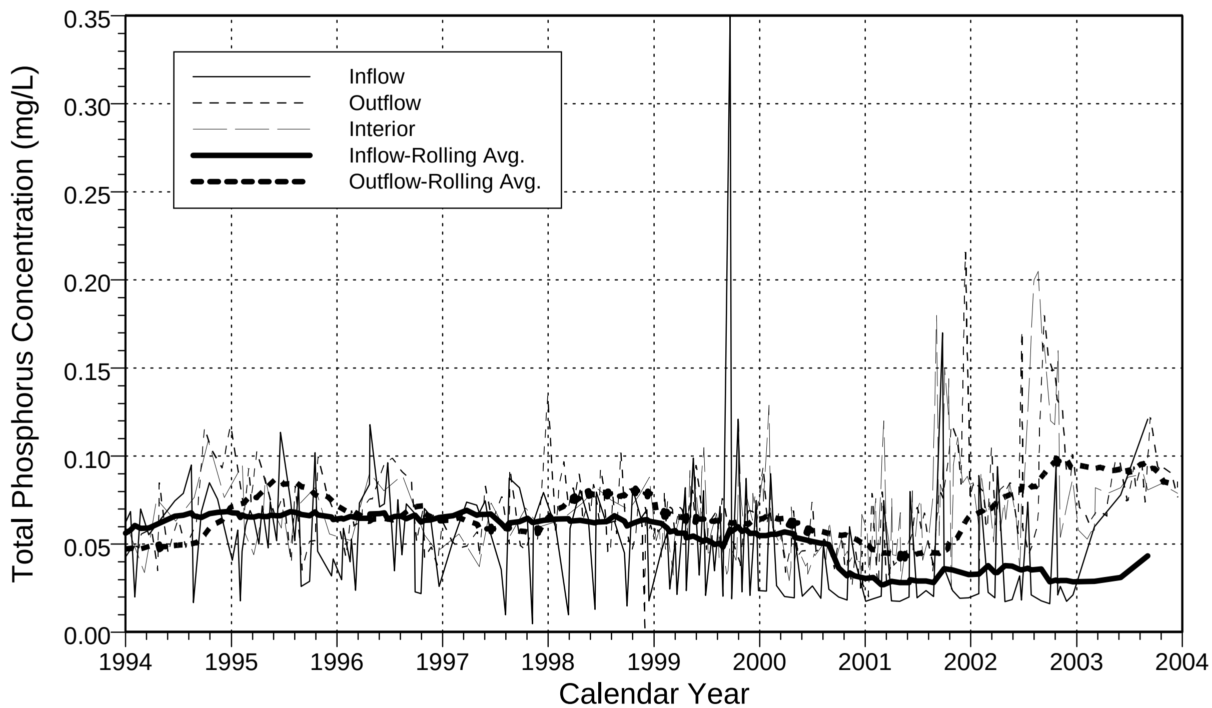


Table 4-2: Lake George Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	2	0	64.950	55.100	74.800
		Outside	155	0	51.221	0.750	154.000
		Total	157	0	51.396	0.750	154.000
Calcium (mg/L)	Outflow	Inside	153	0	46.574	12.533	80.800
		Outside	60	0	49.035	16.930	99.000
		Total	213	0	47.267	12.533	99.000
Calcium (mg/L)	Interior	Inside	187	0	46.143	4.200	80.400
		Outside	21	0	35.054	14.000	49.000
		Total	208	0	45.024	4.200	80.400
Elevation (feet)	Inflow	Inside	3,304	0	1.162	-0.120	3.870
		Total	3,304	0	1.162	-0.120	3.870
Flow (cfs)	Inflow	Inside	3,342	0	3,563.812	-6,180.000	11,700.000
		Total	3,342	0	3,563.812	-6,180.000	11,700.000
Flow (cfs)	Outflow	Inside	3,490	0	5,241.394	-23,900.000	23,400.000
		Outside	387	0	2,323.928	-15,800.000	14,800.000
		Total	3,877	0	4,950.174	-23,900.000	23,400.000
Orthophosphorus (mg/L)	Inflow	Inside	249	3	0.081	0.002	1.363
		Outside	280	0	0.152	0.003	0.973
		Total	529	3	0.119	0.002	1.363
Orthophosphorus (mg/L)	Outflow	Inside	243	1	0.012	0.000	0.075
		Outside	88	5	0.079	0.001	0.293
		Total	331	6	0.030	0.000	0.293
Orthophosphorus (mg/L)	Interior	Inside	115	3	0.026	0.001	0.170
		Outside	56	5	0.042	0.001	0.124
		Total	171	8	0.031	0.001	0.170
pH	Inflow	Inside	384	0	7.459	6.250	9.190
		Outside	497	0	7.493	5.700	9.300
		Total	881	0	7.478	5.700	9.300
pH	Outflow	Inside	873	0	8.056	6.210	9.490
		Outside	295	0	8.057	6.100	9.900
		Total	1,168	0	8.057	6.100	9.900

POR: Inside=Within analysis period (2/1/1994-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 4-2: Lake George Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Interior	Inside	231	0	7.624	6.170	9.430
		Outside	95	0	7.949	6.800	9.200
		Total	326	0	7.719	6.170	9.430
Phosphorus (mg/L)	Inflow	Inside	392	3	0.052	0.005	0.660
		Outside	351	0	0.065	0.009	1.030
		Total	743	3	0.058	0.005	1.030
Phosphorus (mg/L)	Outflow	Inside	356	0	0.070	0.001	0.216
		Outside	155	1	0.092	0.010	0.550
		Total	511	1	0.077	0.001	0.550
Phosphorus (mg/L)	Interior	Inside	422	0	0.064	0.006	0.205
		Outside	82	1	0.097	0.005	0.206
		Total	504	1	0.069	0.005	0.206
Temperature (deg C)	Inflow	Inside	387	0	23.402	1.300	31.960
		Outside	657	0	23.186	7.000	33.000
		Total	1,044	0	23.266	1.300	33.000
Temperature (deg C)	Outflow	Inside	866	0	23.724	10.010	31.850
		Outside	268	0	22.641	10.000	33.000
		Total	1,134	0	23.468	10.000	33.000
Temperature (deg C)	Interior	Inside	231	0	23.263	11.500	31.500
		Outside	85	0	22.623	13.400	31.700
		Total	316	0	23.090	11.500	31.700
Total Nitrogen (mg/L)	Inflow	Inside	650	0	1.378	0.200	4.900
		Outside	450	0	1.539	0.180	6.082
		Total	1,100	0	1.444	0.180	6.082
Total Nitrogen (mg/L)	Outflow	Inside	896	0	2.052	0.054	6.700
		Outside	244	0	2.073	0.852	7.400
		Total	1,140	0	2.057	0.054	7.400
Total Nitrogen (mg/L)	Interior	Inside	571	0	2.098	0.000	6.440
		Outside	176	0	2.546	0.980	5.560
		Total	747	0	2.204	0.000	6.440

POR: Inside=Within analysis period (2/1/1994-9/30/2003); Outside=Outside analysis period; Total=All available data.

(USEPA, 1977b). The inaccuracies introduced by this simplifying assumption are not considered to be too significant as the lake elevation only fluctuates over a narrow range and most of these errors will tend to balance out over time.

4.3.2 Inflow

The USGS has a stream gage on the St. Johns River near Astor (No. 02236125), approximately four miles upstream of Lake George. The gaged inflow to Lake George was calculated from the records for this gage.

The Astor gage has a contributing drainage area of 3,410 square miles but the total watershed area of Lake George is approximately 3,688 square miles. Therefore, the discharge for about 278 square miles of the Lake George watershed is not recorded. The ungaged inflow to Lake George was initially estimated from the records at the above stream gage using a straight drainage area ratio but later adjusted as described below in Section 4.3.7.

4.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Lake George can represent a significant lake inflow. Rainfall depths at Lake George over the period of record were estimated from NOAA records for Crescent City (Station No. 8-1978) (NOAA, 2002). Crescent City is located about six miles northeast of Lake George The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Lake George by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

4.3.4 Evaporation Depth and Volume

No evaporation data for Lake George were located during Task 2 so lake evaporation was estimated from pan evaporation data available at Lisbon, Florida (NOAA, 2002). This climate station (No. 8-5076) is located about 26 miles southwest of Lake George. Water will evaporate faster from an evaporation pan than a lake because a pan is a much smaller body of water and will heat up much more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Lake George vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value representative of the evaporation over the entire period is available. To smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. No pan evaporation data from Lisbon were available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Lake George were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

4.3.5 Outflow

Lake George is on the main stem of the St. Johns River. The USGS maintains a stream gage on the river downstream of Lake George at Buffalo Bluff (No. 02244040), which is located about 13 miles downstream of the lake. However, this gage is also downstream of the mouth of the Ocklawaha River, a major tributary of the St. Johns River. Flow in the Ocklawaha River is recorded by the USGS at Rodman Dam (No. 02243960). The outflow from Lake George was calculated as the difference between the flow recorded at the Buffalo Bluff and Rodman Dam gages. Because Lake George has no other outlets, ungaged outflow was assumed to always be zero.

4.3.6 Elevation and Change in Storage

No long-term daily stage or water surface elevation data were located for Lake George. However, the USGS does record daily gage height data, which is the basis for the corresponding discharge estimates, at the Astor stream gage previously mentioned. Using the corresponding gage datum, gage height records can be converted to water surface elevations at the gage location. For lack of better data, the estimated elevations in the St. Johns River recorded at the Astor gage upstream of the lake were used as a surrogate for actual lake elevation data. The day-to-day changes in these gage heights were assumed to be representative of the changes in lake surface elevation. The corresponding changes in lake storage were then estimated as the products of these lake stage changes and the lake surface area. The available gage height readings are mean daily values and as such, are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation was estimated as the average of the gage heights for the current and following day.

While no specific bathymetric data were obtained for Lake George, the total water depth was sometimes recorded when water samples were collected. Comparison of these depth readings and the corresponding water surface elevations at the Astor gage on the same days yields a median estimate of -10.3 feet for the bottom elevation of Lake George. Estimates of daily lake depth were developed using this relationship.

4.3.7 Imbalance

Theoretically, the sum of all lake inflows (gaged inflow + ungaged inflow + precipitation volume) less all outflows (gaged outflow + ungaged outflow + evaporation) should equal the computed change in storage each day. In practice however, this never occurred. One reason for this is that no data on exchanges of groundwater between Lake George and the surficial aquifer were available so any such exchanges are not represented in this water balance. Because of the inaccuracies in these methods an imbalance quantity was calculated for each day. These imbalances are positive on some days (too much inflow or positive storage change) and negative on others (too much outflow or negative storage change). Totaling these imbalances over the entire period of record indicated that, in general, the estimated outflows exceeded measured inflows. To improve the quality of these estimates, ungaged inflows were adjusted upward by 75 percent.

Table 4-3 presents an annual summary of the Lake George water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

4.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Lake George using the daily water balance and available data on total phosphorus (TP) concentrations in the lake’s inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the analysis period.

- Inflow TP concentration and mass flux
- Wet and dry phosphorus deposition load to the lake

Table 4-3: Lake George Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1994	1,347,368	166,527	110,930	2,080,058	36,110	-713,202
1995	4,311,099	211,892	144,327	4,844,910	63,710	-529,057
1996	3,812,568	182,992	160,494	3,669,067	-90,390	248,090
1997	1,716,351	209,070	143,948	1,642,455	12,190	122,154
1998	3,769,644	213,358	146,944	3,619,702	8,970	207,387
1999	1,411,316	174,905	133,751	1,529,836	28,060	-105,425
2000	2,222,973	186,913	152,163	2,066,087	-5,520	206,979
2001	1,163,618	102,323	56,017	1,143,354	63,250	3,320
2002	3,684,728	194,077	158,426	3,315,709	-40,250	444,920
2003	3,466,275	208,462	163,131	3,462,117	-3,220	52,709
Total	26,905,940	1,850,521	1,370,130	27,373,294	72,910	-62,127

- Outflow TP concentration and mass flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

4.4.1 Inflow TP Concentration and Flux

During the selected period of record (February 1994–September 2003), inflow TP concentration data are available on 158 days. This sampling rate yields an average sample frequency of once every 22 days. Table 4-4 lists the specific stations and number of available samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentrations on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise regression procedure, none of the independent variables met the criteria for inclusion in the model, which indicates that no significant relationship exists between TP concentration and these variables. These models therefore are not useful in this analysis.

Table 4-4: TP Monitoring Stations at Lake George

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	20010164	L GEO NW CRN 150 YDS E SALT SPRG	2
	20010454	Juniper Creek 100 yards upstream of Highway 19	7
LakeWatc	MAR-SIVERG	Marion-Silver Glen-1	46
	MAR-SIVERG	Marion-Silver Glen-2	47
	MAR-SIVERG	Marion-Silver Glen-3	47
Volusia C	SJ27	ST. JOHNS RIVER 0.5 MI. SOUTH OF HWY 40 - ASTO	83
	SJ28	ST. JOHNS RIVER AT CM 19	53
	SJ29	LAKE GEORGE AT CM 9	49
	VC-065	St. John's River, about 1/2 mile S. of S.R.40	30
	VC-066	St. John's River, at CM 19	29
Interior Stations			
FDEP	20010163	L GEORGE AT MARKER #4 & 5	2
	20010167	SJR above Oklawaha @ marker 60,1/2 mi s. of Little	5
	20030519	SJR above Oklawaha @ marker 65	5
	20030520	SJR above Oklawaha @ Marker 59	5
	3515	ST. JOHNS RIVER AT HWY 40 NEAR ASTOR	44
	9687	SILVER GLEN SPRINGS	4
LakeWatc	GEORGE107-1	GEORGE LAKE IN PUTNAM CO-SEE NOTE	6
	GEORGE107-2	GEORGE LAKE IN PUTNAM CO-SEE NOTE	6
	GEORGE107-3	GEORGE LAKE IN PUTNAM CO-SEE NOTE	6
	PUT-GEORGE	Putnam-George-1	6
	PUT-GEORGE	Putnam-George-2	6
	PUT-GEORGE	Putnam-George-3	6
	PUT-GEORGE	Putnam-George East-1	35
	PUT-GEORGE	Putnam-George East-2	35
	PUT-GEORGE	Putnam-George East-3	35
	PUT-GEORGE	Putnam-George South-1	31
	PUT-GEORGE	Putnam-George South-2	34
	PUT-GEORGE	Putnam-George South-3	34
SJRWMD	LAG	LAKE GEORGE AT M 9	62
	LEO	LAKE GEORGE 50 M WEST OF CM'S 4 & 5	29
Volusia C	VC-067	St. John's River, at center of Lake George, at CM	26
Outflow Stations			
SJRWMD	20030373	ST JOHNS RIVER AT CM 72	60

Table 4-4: TP Monitoring Stations at Lake George

Agency	Station	Station Name	Number of Samples
SJRWMD	LG11	SJR WEST OF DRAYTON ISLAND EAST BANK	26
	LG12	SJR btw Drayton Isl and Hog Isl, Mid Channel	166
	LG13	SJR WEST OF DRAYTON ISLAND WEST BANK	27
	MSJFGF	Middle St Johns R Near Ft Gates Ferry	79

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less valid. For lack of a good alternative, this latter method was used to estimate inflow TP concentrations.

Once estimates of daily inflow TP concentrations were developed, the phosphorus influx to Lake George was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance.

4.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Lake George is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 µg/m^2 while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn & James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

4.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Lake George were identical to those used for lake inflow. During the selected period of record (9.66 years), there are 291 days with outflow TP concentration data available. This yields an average sample frequency of once every 12 days. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentrations on missing days. Using a stepwise regression procedure, the best linear model had a R^2 of only .057 so it was not used in subsequent estimates.

Therefore, the simple straight-line interpolation process described above was used to estimate missing outflow TP concentrations between actual sample dates. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Lake George was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

4.4.4 Net Phosphorus Retention

The net phosphorus retention in Lake George was estimated as total influx in inflow and precipitation less discharge flux in outflow. As such, these net retention values include the phosphorus retained or discharged due to changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Lake George is shown in Table 4-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

Table 4-5: Lake George Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1994	108,793	5,136	168,331	-54,402
1995	312,237	8,222	523,099	-202,640
1996	273,347	7,903	338,989	-57,740
1997	118,596	8,189	111,279	15,505
1998	260,740	8,239	315,777	-46,798
1999	102,758	7,793	112,109	-1,558
2000	138,183	7,948	154,433	-8,302
2001	83,931	4,140	76,621	11,450
2002	119,864	8,015	412,569	-284,689
2003	238,109	8,182	388,523	-108,410
Total	1,756,557	73,766	2,601,730	-737,585

Review of Table 4-5 indicates that Lake George is a net exporter of phosphorus in most years (that is, more phosphorus goes out then comes in). These results are counterintuitive and should be subjected to additional scrutiny before they are accepted as valid.

4.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Lake George were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. These monthly data sets include the following data values:

- Average water surface area (ha)
- Total inflow and outflow volumes (m^3)
- Total mass flux of phosphorus in, out and retained in the lake (g)
- Flow-weighted average inflow and outflow phosphorus concentrations (mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

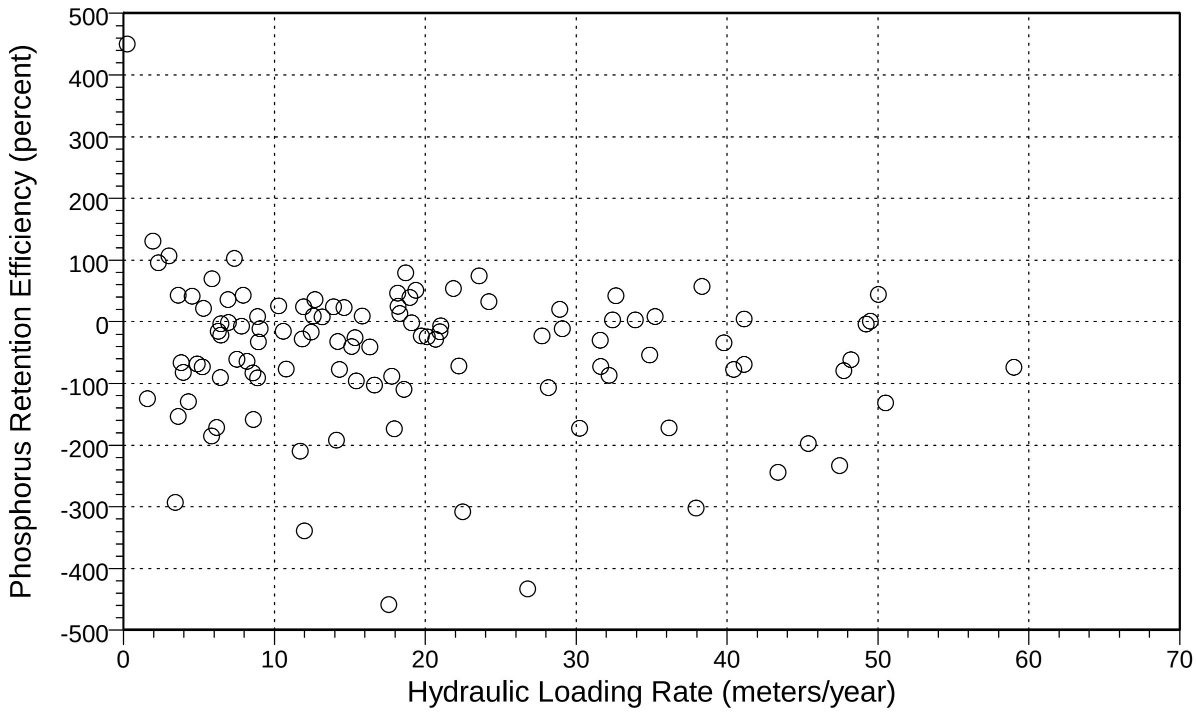
4.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 4-12. From review of this graph, it is not apparent there is a linear relationship between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .063. Also, consistent with the data plotted in Figure 4-12, the slope of this linear model is negative.

4.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate (q), calcium concentration, pH, temperature and depth were all selected as independent variables. A scatter diagram of k vs. q is included in Figure 4-13. The corresponding regression model has a R^2 of .002. The model with the best fit (R^2 = .015) was obtained with pH as the independent variable.

Figure 4-12: Retention Efficiency vs. Hydraulic Loading Rate at Lake George



4.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Lake George from DEP's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

A total of 75 species of wetland and aquatic plants were recorded for Lake George during the BIPM surveys. These included 51 species of emergent wetland plants, eight species of floating aquatic plants, and 16 species of submerged aquatic plants. Dominant emergent wetland species included Mexican water lily (*Nympahea mexicana*), common reed (*Phragmites australis*), cattails, and pennywort (*Hydrocotyle* spp.). Dominant floating species included water hyacinth, duckweed, and filamentous algae. Dominant submerged aquatics included eelgrass, hydrilla, and coontail.

Table 4-6 summarizes the estimated cover by vegetation type for Lake George for the period from 1982 through 2003. The average cover by vegetation type was emergent – 1,253 acres, floating – 633 acres, and submerged – 1,415 acres. These estimated plant coverages show that plants occupy a very small fraction of the estimated 44,486-acre surface area of Lake George.

Table 4-6: Lake George Vegetation Data

Survey Month	Vegetation Coverage by Type (acres)		
	Emergent	Floatin g	Submerged
Oct-82	571	347	411
Oct-83	741	935	383
Nov-84	942	757	1,241
Oct-86	1,659	885	1,804
Aug-88	1,914	985	2,290
Jun-90	2,199	562	2,714
Jul-92	1,564	485	1,755
Aug-95	855	122	976
Aug-03	835	615	1,157
Average	1,253	633	1,415
Median	942	615	1,241
Maximum	2,199	985	2,714
Minimum	571	122	383

* * * * *

5 LAKE HARNEY

5 LAKE HARNEY

Lake Harney is located approximately 18 miles northeast of Orlando on the border between Volusia and Seminole counties (Figure 1-1). Lake Harney is one of a number of natural lakes on the St. Johns River. The data collected for Lake Harney and the analyses completed with these data are described in the balance of this chapter.

5.1 DATA SOURCES

The data for Lake Harney were collected from a number of sources. These sources are listed in Table 5-1 along with a listing of the individual sample stations obtained from each source. For each sample station, this table also lists its absolute location (latitude/longitude coordinates) and location relative to Lake Harney. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 5-1 shows the locations of these monitoring stations.

5.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 5-1: Lake Harney Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	20010012	ST JOHNS R AT FLA HWY NO 46	28.71361	81.04755
	20010533	SJR upstream of Econ River	28.69939	81.02000
Outflow	20010008	ST JOHNS R AT EFF END OF L HARNE	28.79097	81.05764
	20010482	ST JOHNS RIVER AT LAKE HARNEY	28.78333	81.05500
Interior	20010026	Lake Harney, Center of Lake	28.75833	81.05997
	20010378	LAKE HARNEY SOUTH OF CENTER	28.73631	81.05247
	20010481	LAKE HARNEY, CENTER	28.75611	81.05500
Florida Game and Fresh Water Fish Commission (FGFWF)				
Inflow	GFCCR0174	ST. JOHNS RIVER AT SR 46 BR. SOUTH OF L. HA	28.71389	81.03555
Outflow	03080101-180	St. Johns River Station 34	28.78611	81.05667
	GFCCR0188	ST. JOHNS RIVER EXIT TO LAKE HARNEY	28.78611	81.05666
Florida LAKEWATCH (LakeWatch)				
Inflow	SEM-ST-RIVE	Seminole-St. John's River-1-1	28.71117	81.04234
Interior	HARNEY1	HARNEY IN VOLUSIA CO.-SEE NOTE	28.75444	81.05167
	HARNEY2	HARNEY IN VOLUSIA CO.-SEE NOTE	28.75444	81.05167
	HARNEY3	HARNEY IN VOLUSIA CO.-SEE NOTE	28.75444	81.05167
	VOL-HARNE	Volusia-Harney-1	28.75444	81.05167
	VOL-HARNE	Volusia-Harney-2	28.75444	81.05167
	VOL-HARNE	Volusia-Harney-3	28.75444	81.05167
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	87982	Sanform Experiment Stn	28.80000	81.23333
	88942	Titusville	28.61667	80.81667
Saint Johns River Water Management District (SJRWMD)				
Inflow	ILH	LAKE HARNEY NEAR INLET	28.73361	81.04500
	LHI	INLET OF LAKE HARNEY	28.73139	81.04305
	SRN	Lake Harney Inflow	28.72211	81.04540
Outflow	SJR-OLH	Lake Harney Outfall - St. Johns River	28.79403	81.06010
Interior	BBS	ST JOHNS RIVER AT USGS GAGE AT SR 46	28.71389	81.03555
Seminole County, Florida (Seminole Co)				
Interior	40106	ST. JOHNS RIVER, S.R. 46 BRIDGE	28.71417	81.03472

Table 5-1: Lake Harney Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Interior	40501	LAKE HARNEY, SE QUADRANT.	28.74333	81.04305
	40502	LAKE HARNEY, SW QUADRANT	28.75528	81.07639
	40503	LAKE HARNEY, NW QUADRANT.	28.77444	81.06250
	40504	LAKE HARNEY, NE QUADRANT.	28.77611	81.03750
	40758	ST. JOHNS RIVER, OFF OSCEOLA FISH CAMP.	28.79194	81.05972
U.S. Army Corps of Engineers (COE)				
Inflow	3SJR10020	SAINT JOHNS RIVER AT HIGHWAY 46	28.71417	81.03584
U.S. Geological Survey (USGS)				
Inflow	2234000	ST. JOHNS RIVER ABOVE LAKE HARNEY NR G	28.71389	81.03555
Volusia County, Florida (Volusia Co)				
Inflow	SJ02	ST. JOHNS RIVER AT SOUTHERN END LAKE HA	28.72639	81.03861
	VC-041	St. John's River, at southern end of Lake Harney	28.72639	81.03861
Outflow	VC-043	St. Johns River, N of Lake Harney @ Old Osceola Fi	28.79333	81.05861
Interior	SJ03	LAKE HARNEY - CENTER OF THE LAKE	28.76306	81.05722
	VC-042	St. Johns River, center of Lake Harney	28.76306	81.05722

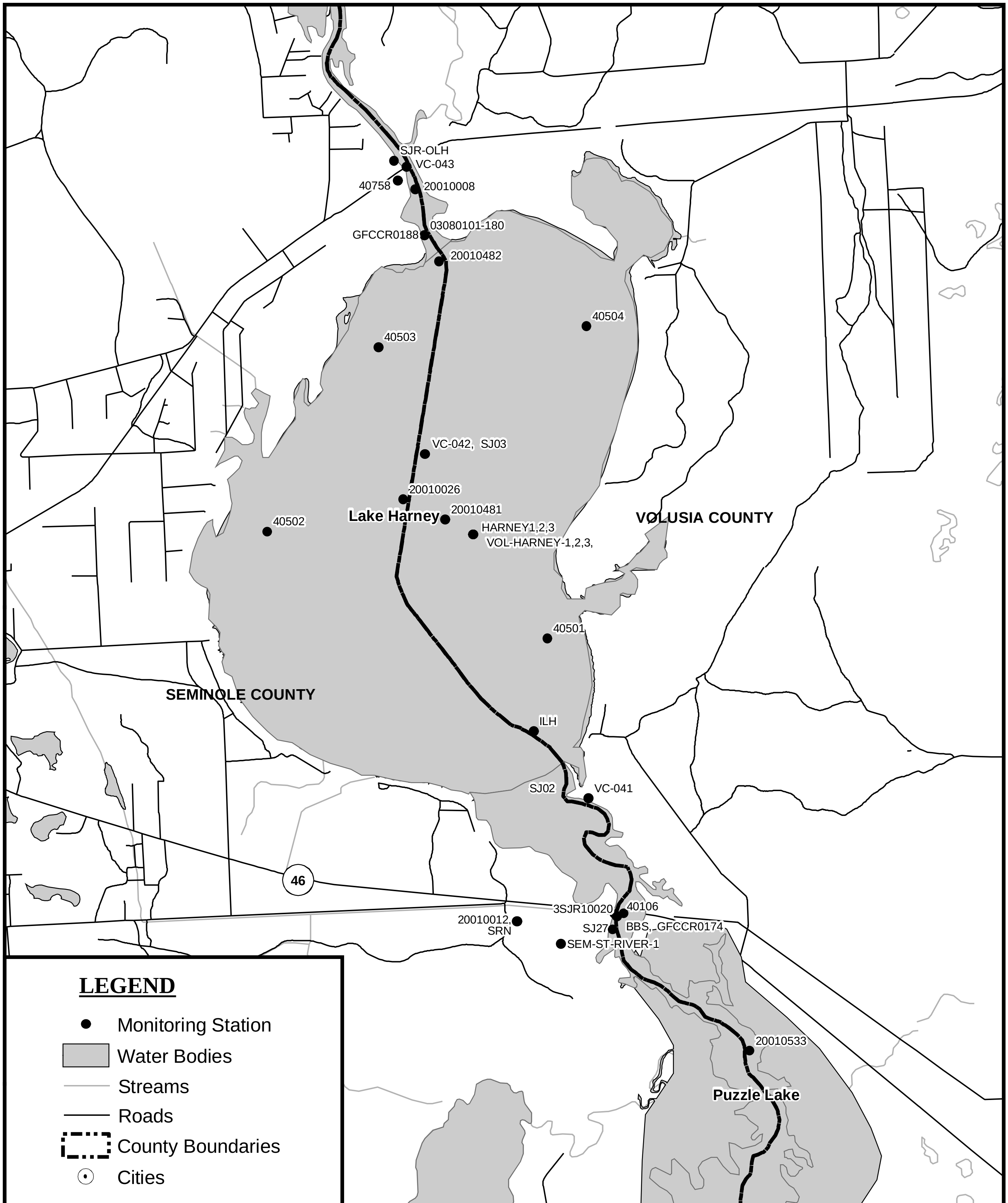


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Figure 5-1
LAKE HARNEY
MONITORING STATIONS

- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station represents a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 5-2 through 5-9 contain the time series graphs for Lake Harney for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow rate and phosphorus concentration data for use in calculating water and phosphorus balances at Lake Harney. The graphs of available flow and phosphorus concentration data are shown in Figures 5-2 and 5-3, respectively. These figures show that flow data are available continuously only since about 1982 but the densest collection of TP data are available only after 1990. For this reason, a period of record of WY 1991–2003 (10/1/1990–9/30/2003) was selected for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are generally more prevalent during this same period.

After the analysis period was selected, the time series graphs for flow rate and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 5-10 and 5-11, better show the availability of data during this critical period. Table 5-2 includes descriptive statistics for key monitoring parameters at Lake Harney. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative

Figure 5-2: Long-term Flow at Lake Harney

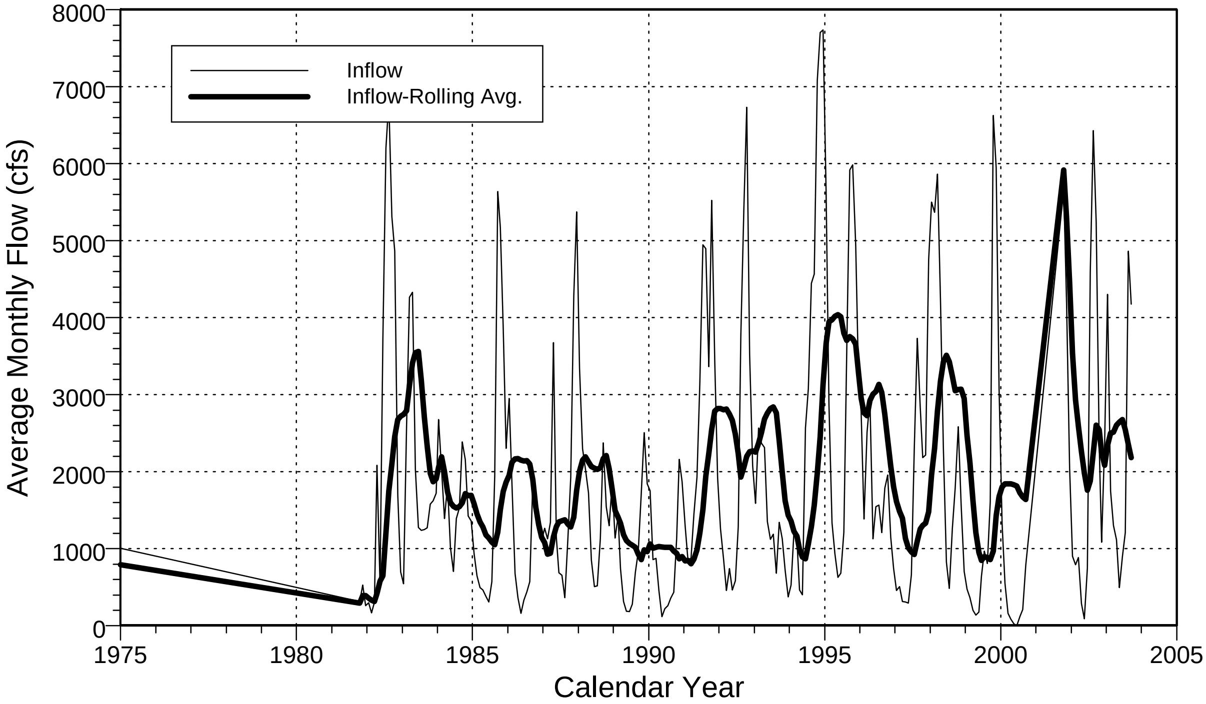

Figure 5-3: Long-term Total Phosphorus at Lake Harney

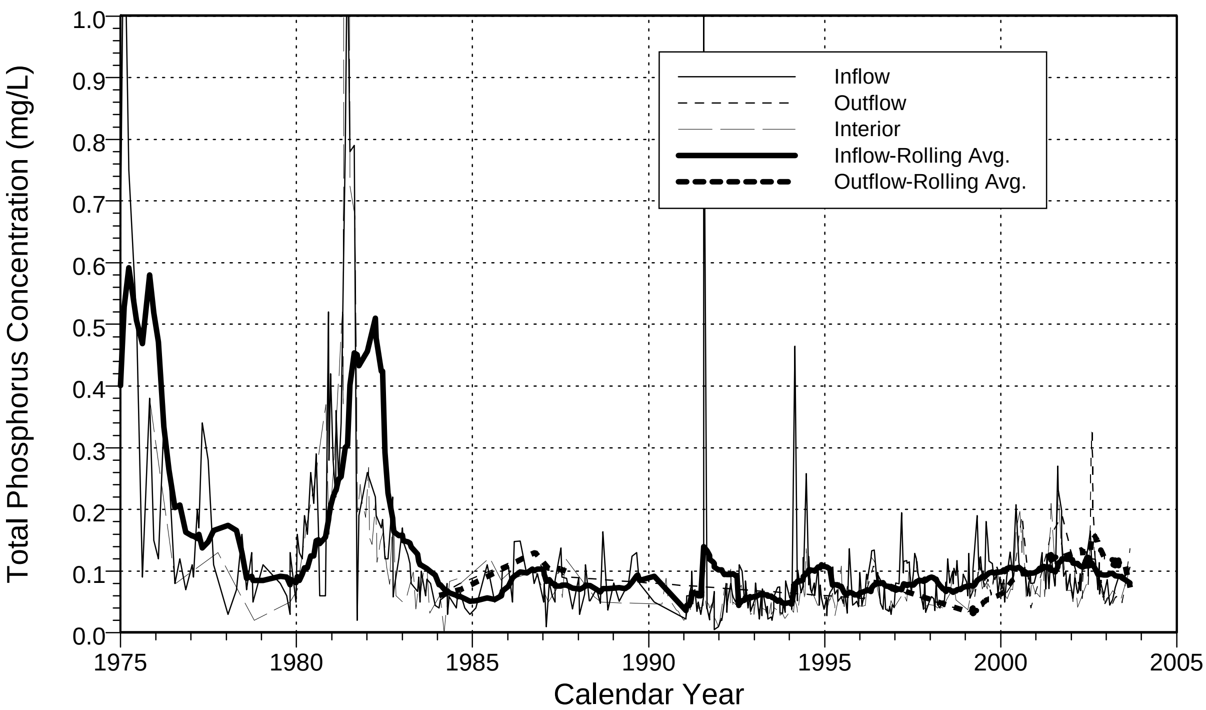

Figure 5-4: Long-term Orthophosphorus at Lake Harney

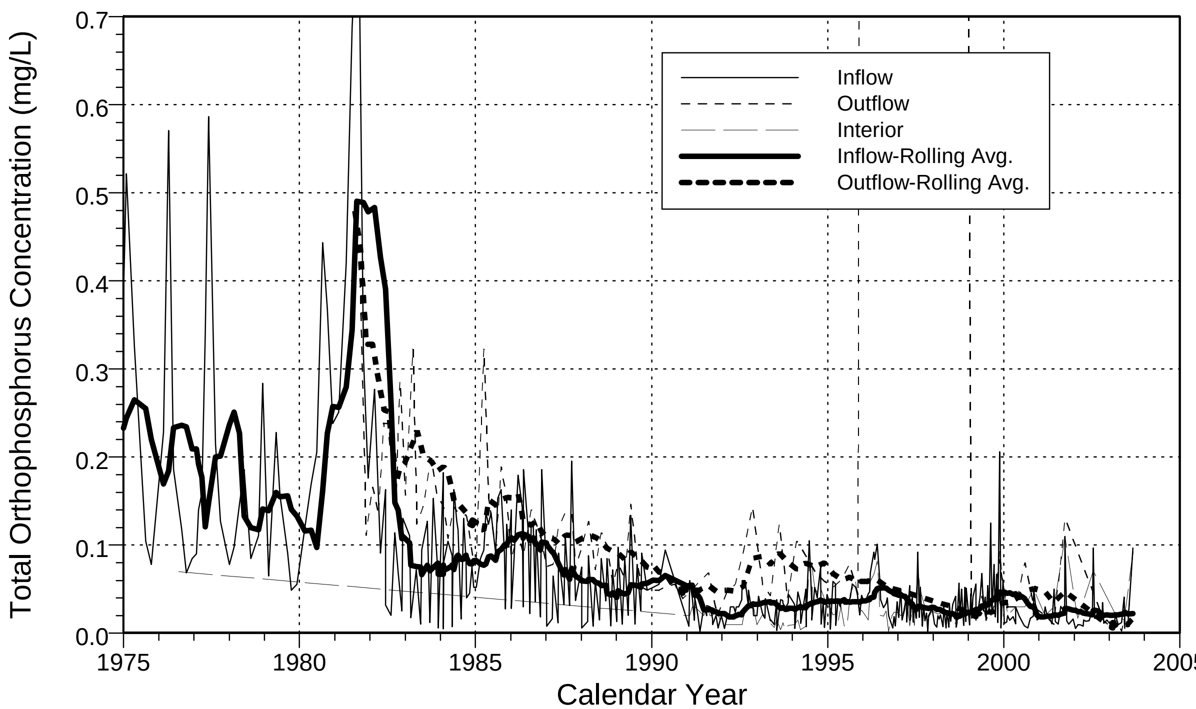

Figure 5-5: Long-term Total Nitrogen at Lake Harney

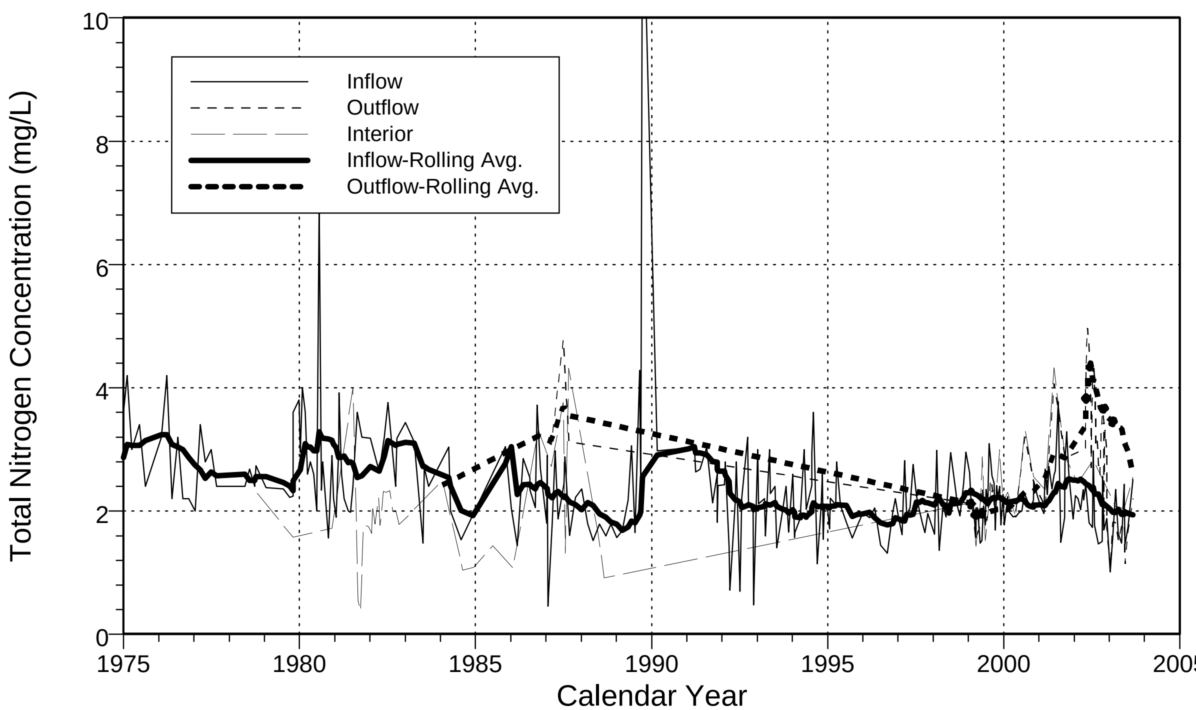

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Figure 5-6: Long-term pH at Lake Harney

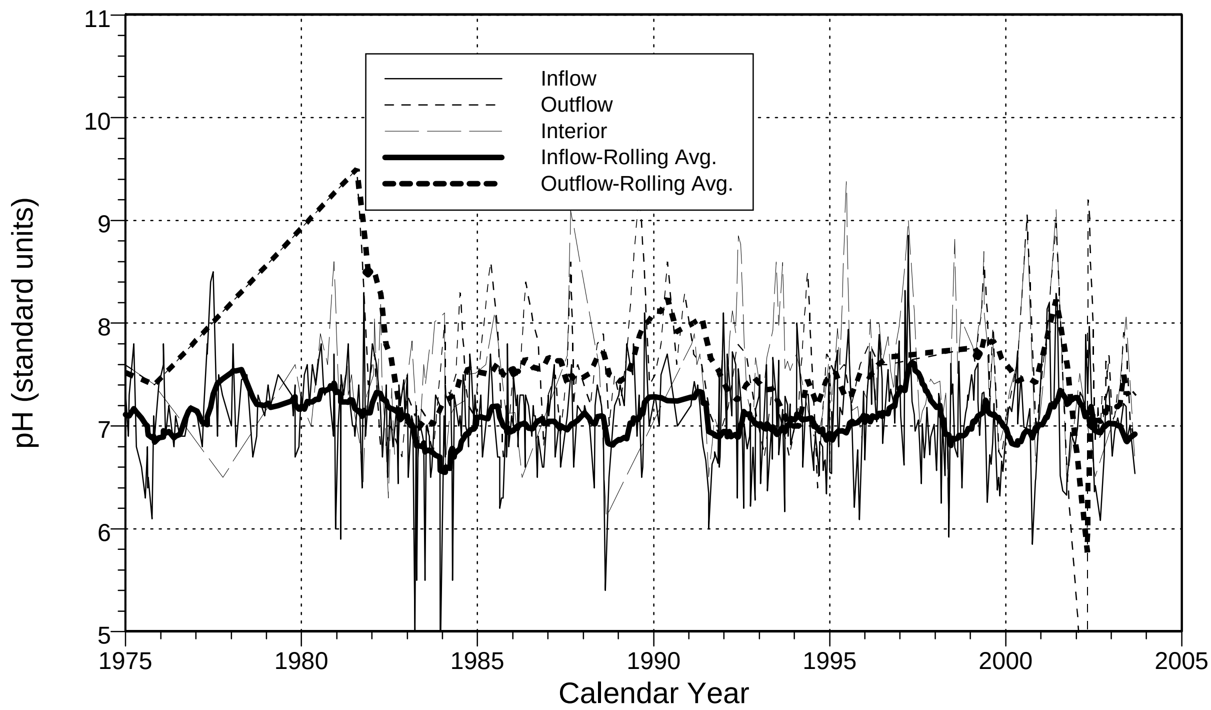


Figure 5-7: Long-term Total Calcium at Lake Harney

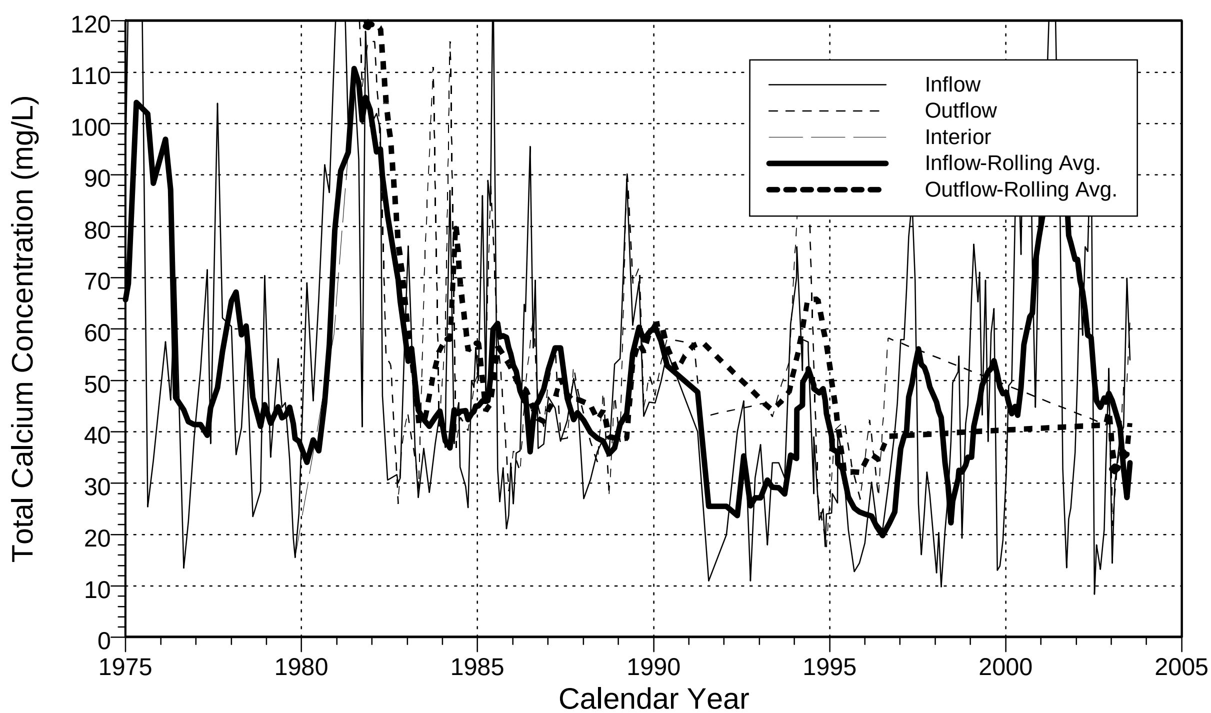


Figure 5-8: Long-term Water Surface Elevation at Lake Harney

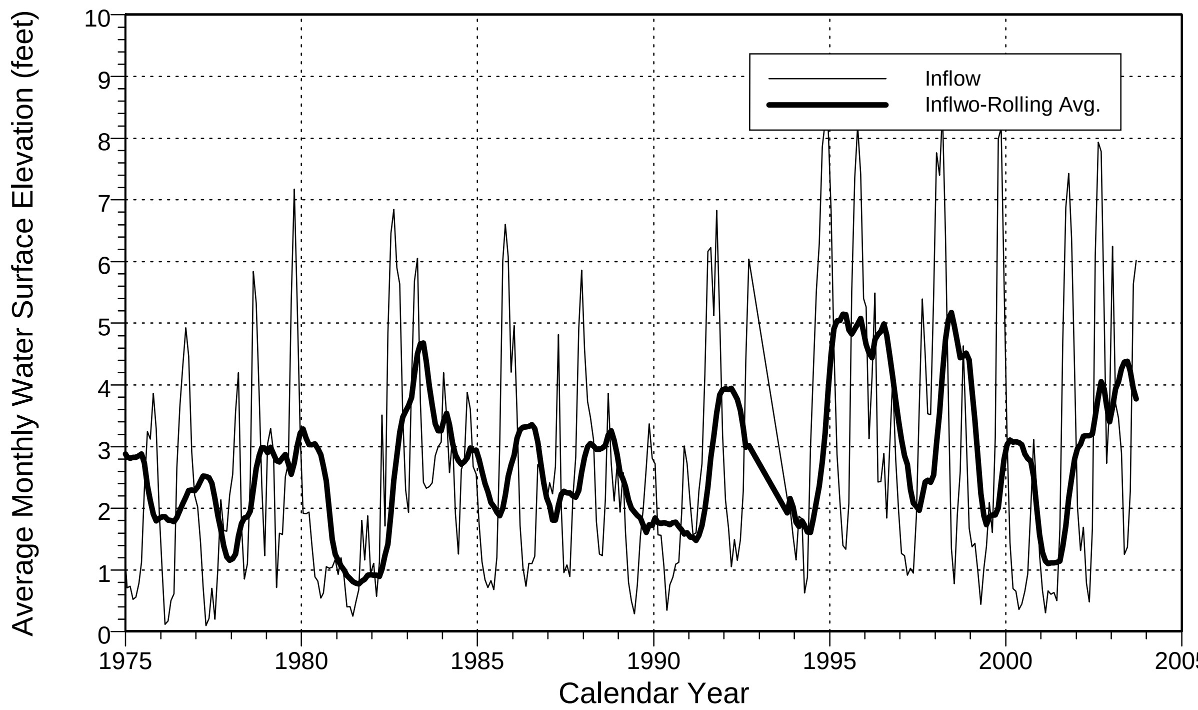
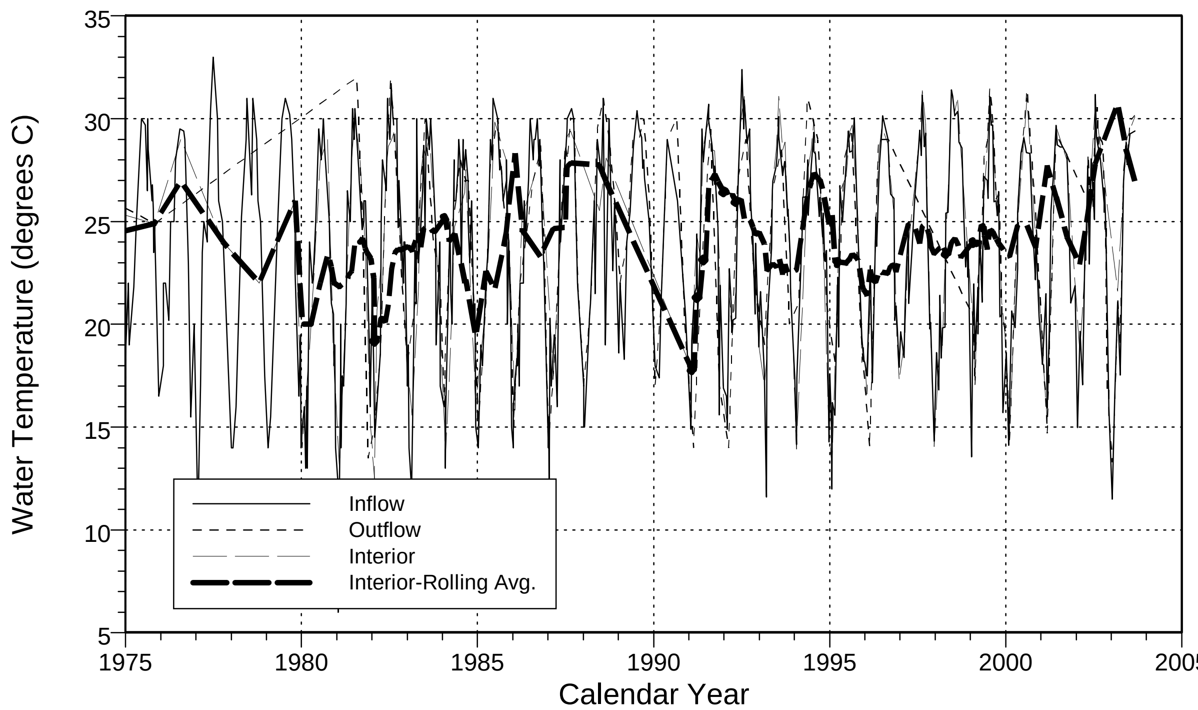


Figure 5-9: Long-term Water Temperature at Lake Harney



location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will note that relatively few non-detect samples occurred for the more significant parameters listed in Table 5-2. For non-detect samples, the value reported is normally the applicable detection limit and these detection limits were included in the associated statistics when they occurred.

5.3 WATER BALANCE

A daily water balance for Lake Harney was developed for WY 1991–2003. This water balance included estimates of the following quantities for each day during the analysis period.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

5.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage; however, no tables or graphs of lake elevation vs. surface area were found for Lake Harney. Therefore, a constant lake area of 7,392 acres was adopted for use in the water balance (USEPA, 1977). The inaccuracies introduced by this simplifying assumption are not considered to be

Figure 5-10: Analysis Period Flow at Lake Harney

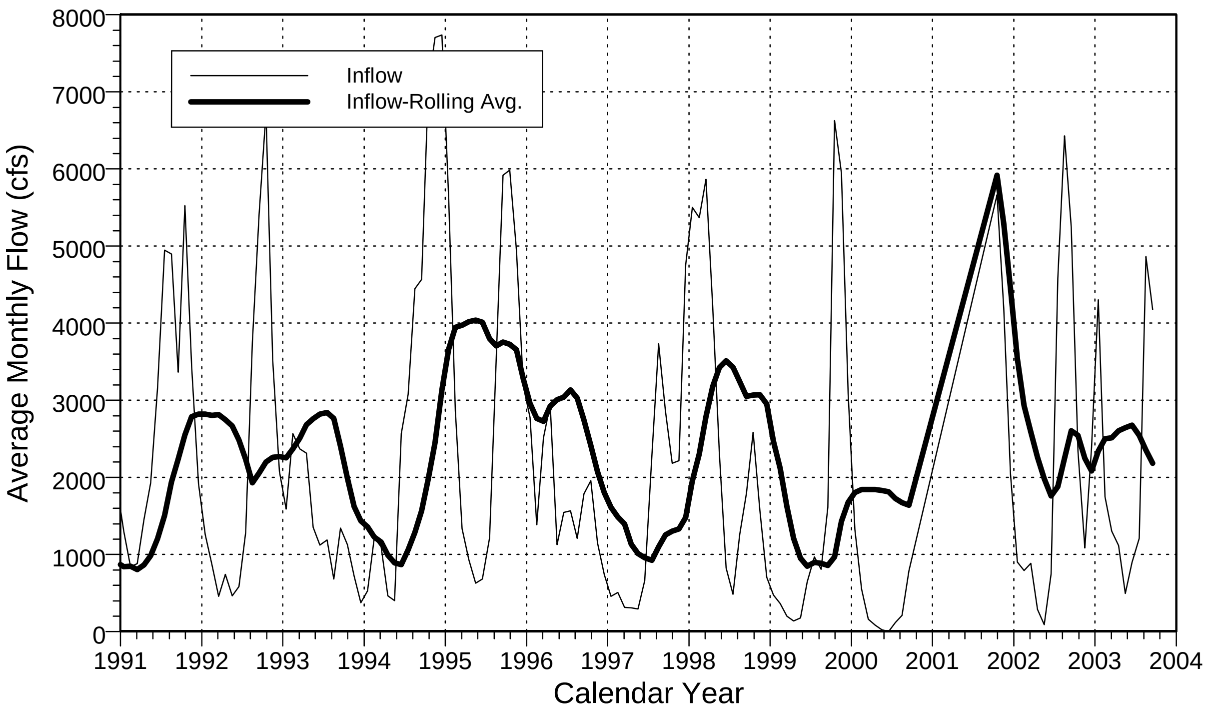


Figure 5-11: Analysis Period Total Phosphorus at Lake Harney

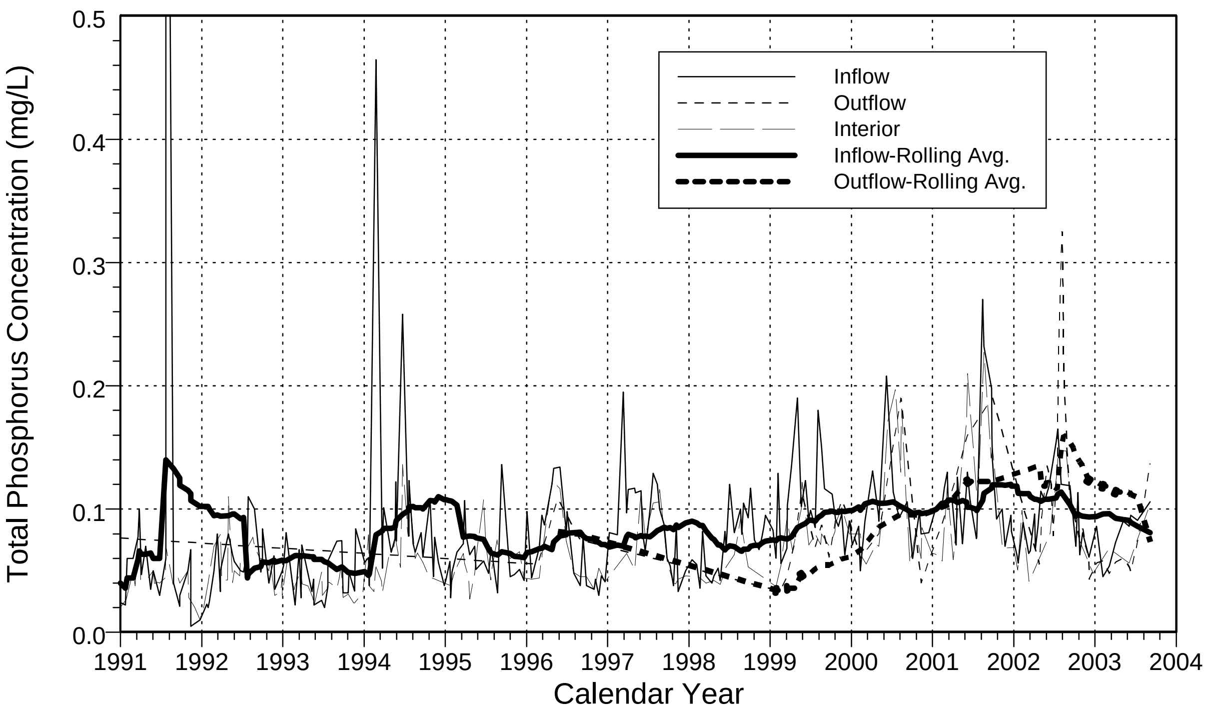


Table 5-2: Lake Harney Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	142	0	46.421	8.400	139.076
		Outside	120	0	54.847	13.500	231.100
		Total	262	0	50.281	8.400	231.100
Calcium (mg/L)	Outflow	Inside	34	0	44.174	17.600	93.900
		Outside	54	0	56.761	26.000	135.000
		Total	88	0	51.898	17.600	135.000
Calcium (mg/L)	Interior	Outside	3	0	56.400	15.600	94.600
		Total	3	0	56.400	15.600	94.600
Elevation (feet)	Inflow	Inside	4,286	0	3.269	0.030	9.440
		Outside	17,863	0	2.677	-0.380	10.600
		Total	22,149	0	2.792	-0.380	10.600
Flow (cfs)	Inflow	Inside	4,383	0	2,202.804	-77.000	9,880.000
		Outside	3,323	0	1,604.313	55.000	7,650.000
		Total	7,706	0	1,944.721	-77.000	9,880.000
Orthophosphorus (mg/L)	Inflow	Inside	245	1	0.031	0.002	0.206
		Outside	187	0	0.182	0.005	1.337
		Total	432	1	0.096	0.002	1.337
Orthophosphorus (mg/L)	Outflow	Inside	57	0	0.046	0.001	0.143
		Outside	54	0	0.138	0.049	0.479
		Total	111	0	0.091	0.001	0.479
Orthophosphorus (mg/L)	Interior	Inside	117	0	0.029	0.002	0.110
		Outside	1	0	0.070	0.070	0.070
		Total	118	0	0.029	0.002	0.110
pH	Inflow	Inside	351	0	7.060	5.850	8.870
		Outside	443	0	7.139	4.600	8.700
		Total	794	0	7.104	4.600	8.870
pH	Outflow	Inside	78	0	7.514	6.400	9.200
		Outside	76	0	7.624	6.700	9.500
		Total	154	0	7.569	6.400	9.500
pH	Interior	Inside	214	0	7.450	5.930	9.490
		Outside	214	0	7.347	4.600	9.400
		Total	428	0	7.399	4.600	9.490

POR: Inside=Within analysis period (10/1/1990-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 5-2: Lake Harney Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Phosphorus (mg/L)	Inflow	Inside	298	1	0.085	0.005	1.130
		Outside	179	1	0.268	0.010	9.980
		Total	477	2	0.154	0.005	9.980
Phosphorus (mg/L)	Outflow	Inside	77	0	0.097	0.024	0.330
		Outside	6	0	0.090	0.060	0.130
		Total	83	0	0.097	0.024	0.330
Phosphorus (mg/L)	Interior	Inside	562	0	0.059	0.006	0.231
		Outside	233	0	0.141	0.001	8.000
		Total	795	0	0.083	0.001	8.000
Temperature (deg C)	Inflow	Inside	339	0	23.674	11.510	32.400
		Outside	474	0	23.643	6.000	33.000
		Total	813	0	23.656	6.000	33.000
Temperature (deg C)	Outflow	Inside	82	0	23.933	13.290	31.470
		Outside	80	0	24.330	13.500	32.000
		Total	162	0	24.129	13.290	32.000
Temperature (deg C)	Interior	Inside	216	0	24.036	13.050	32.230
		Outside	240	0	23.678	12.000	31.500
		Total	456	0	23.848	12.000	32.230
Total Nitrogen (mg/L)	Inflow	Inside	552	0	2.153	0.480	5.660
		Outside	152	0	2.495	0.460	12.700
		Total	704	0	2.227	0.460	12.700
Total Nitrogen (mg/L)	Outflow	Inside	307	0	2.900	0.810	5.600
		Outside	5	0	3.324	2.420	4.780
		Total	312	0	2.907	0.810	5.600
Total Nitrogen (mg/L)	Interior	Inside	118	0	2.415	0.962	5.740
		Outside	242	0	1.768	0.376	4.320
		Total	360	0	1.980	0.376	5.740

POR: Inside=Within analysis period (10/1/1990-9/30/2003); Outside=Outside analysis period; Total=All available data.

significant as the lake elevation only fluctuates over a narrow range and most of these errors will tend to balance out over time.

5.3.2 Inflow

The USGS operates a stream gage on the St. Johns River above Lake Harney near Geneva (No. 02234000), approximately 15 miles upstream of the lake. The gaged inflow to Lake Harney was calculated from the records for this gage.

The Geneva gage has a contributing drainage area of 2,043 square miles but the total area of the Lake Harney watershed is approximately 2,105 square miles. Therefore, no recorded discharge exists for about 62 square miles of the Lake Harney watershed. The ungaged inflow to Lake Harney was estimated from the records at the above stream gage using a straight drainage area ratio.

5.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Lake Harney can represent a significant lake inflow. Rainfall depths at Lake Harney over the period of record were estimated from NOAA records for the Sanford Experiment Station (Station No. 8-7982) (NOAA, 2002). This station is located about ten miles northwest of Lake Harney. The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Lake Harney by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

5.3.4 Evaporation Depth and Volume

No evaporation data for Lake Harney were located during Task 2 so lake evaporation was estimated from pan evaporation data available at Lisbon, Florida (NOAA, 2002). This climate station (No. 8-5076) is located about 43 miles west of Lake Harney. Water will evaporate faster from an evaporation pan than a lake because the pan is a much smaller body of water and will heat up much more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Lake Harney vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value representative of the evaporation over the entire interval is available. To smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. As discussed in the previous section, no pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Lake Harney were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

5.3.5 Outflow

No USGS or other stream gages are located close downstream of Lake Harney. The nearest downstream gaging station is downstream of Lake Monroe so no records of Lake Harney outflow are available. Therefore, the gaged outflow from Lake Harney was set to zero for the entire period of record. The ungaged outflow from Lake Harney was calculated by difference as described below in Section 5.3.7.

5.3.6 Elevation and Change in Storage

No long-term daily stage or water surface elevation data were located for Lake Harney. However, the USGS does record daily gage height data, which is the basis for the corresponding discharge estimates, at the Geneva gage. Using the corresponding gage datum, gage height records can be converted to water surface elevations at the gage location, which is located about 15 miles upstream of the lake. For lack of a better alternative, these estimated water surface elevations were used as a surrogate for actual lake elevation data. The day-to-day changes in these elevations were assumed to be representative of the changes in lake elevation. The corresponding changes in lake storage were then estimated as the products of these water level changes and the lake surface area. The available gage height readings are mean daily values and are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation was estimated as the average of the gage heights for the current and following day.

While no specific bathymetric data were obtained from Lake Harney, the total water depth was sometimes recorded when water samples were collected. Comparison of these depth readings and the corresponding water surface elevations at the Geneva gage for the same days yields a median estimate of -5.9 feet for the

the lake bottom elevation. Estimates of daily lake depth were developed using this estimated lake bottom elevation.

5.3.7 Imbalance

No discharge records exist for Lake Harney so lake discharge (ungaged outflow) was set equal to the computed difference between the other inflow and outflow variables in the flow balance (gaged inflow + ungaged inflow + precipitation volume - evaporation).

Table 5-3 presents an annual summary of the Lake Harney water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 5-3: Lake Harney Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1991	1,734,362	34,550	25,880	1,714,018	29,014	0
1992	1,596,043	28,454	25,103	1,591,411	7,983	0
1993	1,660,151	18,115	25,140	1,653,126	0	0
1994	1,273,471	29,218	24,461	1,211,125	40,176	0
1995	2,805,001	32,214	23,193	2,745,483	-13,232	0
1996	1,922,491	32,471	25,791	1,965,059	-35,888	0
1997	948,807	23,115	23,132	941,438	3,622	0
1998	2,265,475	29,777	23,613	2,261,761	8,612	0
1999	635,633	18,317	21,493	621,609	-2,513	0
2000	1,176,754	21,230	24,452	1,195,183	-26,020	0
2002	1,980,559	29,405	25,458	1,950,982	33,523	0
2003	1,608,101	31,167	26,214	1,620,261	-7,207	0
Total	19,606,847	328,033	293,931	19,471,456	38,069	0

5.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Lake Harney using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the analysis period.

- Inflow TP concentration and flux

- Direct phosphorus deposition load to lake
- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

5.4.1 Inflow TP Concentration and Flux

During the selected 12-year period of record (WY 1991–2003), inflow TP concentration data are available for 260 days. This yields an average sample frequency of once every 17 days, or approximately twice monthly. Table 5-4 lists the specific stations and numbers of available samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of the inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (long [TP])
- Independent variables: Monthly precipitation in inches (P) and common logarithm of inflow rate in cfs (log Q)
- Model: log [TP] = -0.830 + 0.025 P – 0.126 log Q
- Coefficient of determination (R^2): .090

Even the model with the best fit accounts for only 9 percent of the variations in inflow TP concentrations but it was still used to aid in estimating missing TP concentrations.

Table 5-4: TP Monitoring Stations at Lake Harney

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	20010012	ST JOHNS R AT FLA HWY NO 46	18
LakeWatc	SEM-ST-RIVE	Seminole-St. John's River-1-1	14
SJRWMD	ILH	LAKE HARNEY NEAR INLET	1
	SRN	Lake Harney Inflow	148
Volusia C	SJ02	ST. JOHNS RIVER AT SOUTHERN END LAKE HARNE	89
	VC-041	St. John's River, at southern end of Lake Harney	28
Interior Stations			
LakeWatc	HARNEY1	HARNEY IN VOLUSIA CO.-SEE NOTE	54
	HARNEY2	HARNEY IN VOLUSIA CO.-SEE NOTE	54
	HARNEY3	HARNEY IN VOLUSIA CO.-SEE NOTE	54
	VOL-HARNE	Volusia-Harney-1	92
	VOL-HARNE	Volusia-Harney-2	92
	VOL-HARNE	Volusia-Harney-3	90
Volusia C	SJ03	LAKE HARNEY - CENTER OF THE LAKE	97
	VC-042	St. Johns River, center of Lake Harney	29
Outflow Stations			
FDEP	20010008	ST JOHNS R AT EFF END OF L HARNE	35
FGFWF	03080101-180	St. Johns River Station 34	3
SJRWMD	SJR-OLH	Lake Harney Outfall - St. Johns River	11
Volusia C	VC-043	St. Johns River, N of Lake Harney @ Old Osceola Fi	28

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less certain.

At Lake Harney, missing inflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based on the interpolation method and selected regression model. Once these estimates of daily inflow TP concentrations were developed, the phosphorus influx to Lake Harney was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance.

5.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Lake Harney is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 $\mu g/m^2$ while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn & James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

5.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Lake Harney were identical to those used for lake inflow. During the selected period of record, outflow TP concentration data are available for only 51 days with the earliest collected on 19 February 1996. This sampling rate yields an average sample frequency of once every 86 days, or approximately quarterly. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on days with missing data. Using a stepwise procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (long [TP])
- Independent variable: Monthly precipitation in inches (P)
- Model: log [TP] = -1.252 + 0.044 P

- Coefficient of determination (R^2): .200

The regression model with monthly precipitation as the independent variable has a relatively good fit (R^2 = .200). This model was used in subsequent estimates of outflow TP concentration.

The second method used to estimate outflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less valid.

At Lake Harney, missing outflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based on the interpolation method and selected regression model. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Lake Harney was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance. Since no outflow phosphorus concentrations are available before February 1996, the outflow phosphorus mass flux is undetermined before this date.

5.4.4 Net Phosphorus Retention

The net phosphorus retention in Lake Harney was estimated as total influx from inflow and deposition less discharge flux in outflow (when available). As such, these net retention values include the phosphorus retained or discharged due to changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Lake Harney is shown in Table 5-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

5.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Lake Harney were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and

Table 5-5: Lake Harney Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1991	254,185	1,327	194,495	61,017
1992	123,250	1,259	161,946	-37,437
1993	117,239	1,137	143,422	-25,047
1994	155,695	1,265	125,638	28,565
1995	231,370	1,300	251,820	-25,872
1996	165,199	1,305	188,548	-22,043
1997	93,875	1,195	90,326	4,298
1998	173,271	1,272	190,399	-16,009
1999	66,982	1,139	48,343	18,156
2000	111,618	1,175	130,662	-18,272
2002	216,602	1,267	302,219	-84,350
2003	130,734	1,288	140,699	-8,784
Total	1,840,019	14,929	1,968,518	-125,778

other monitoring data was used in these analyses. These monthly data sets include the following data values:

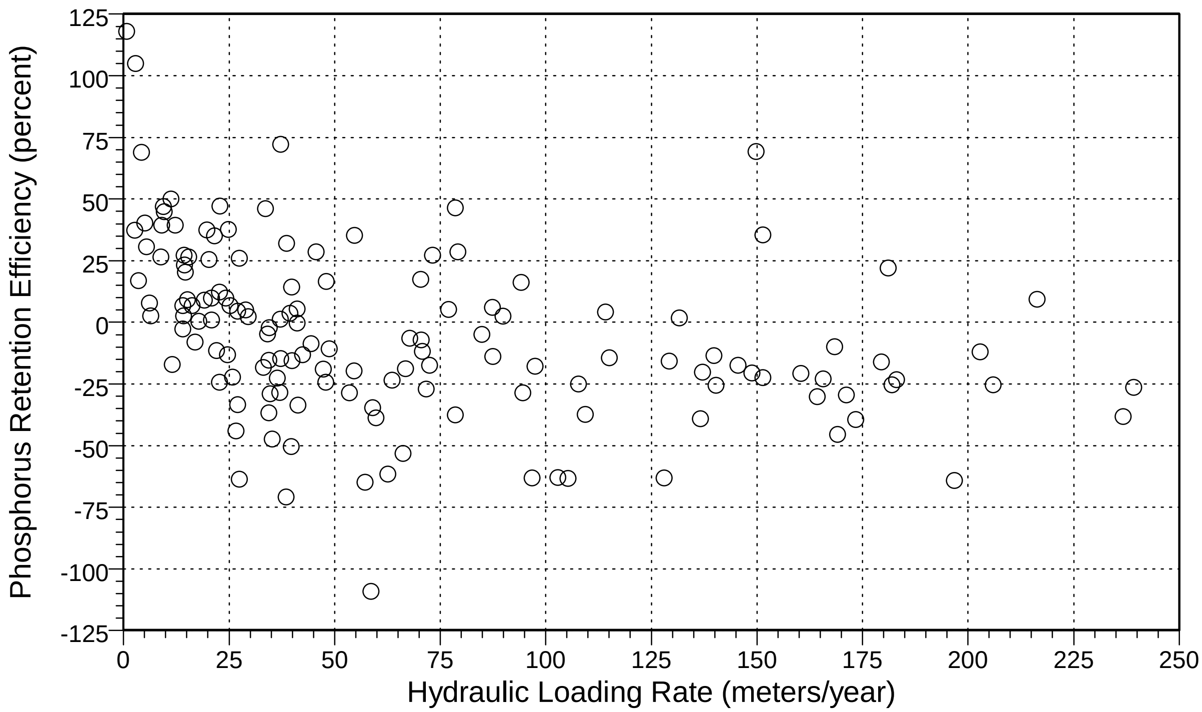
- Average water surface area (ha)
- Total inflow and outflow volumes (m^3)
- Total mass flux of phosphorus in, out and retained in the lake (g)
- Flow-weighted average inflow and outflow phosphorus concentrations (mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate, q (m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

5.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 5-12. From review of this graph, it is not apparent a linear relationship exists between these variables. A regression analysis using these two variables confirms this observation. The resulting linear model has a R^2 of .041.

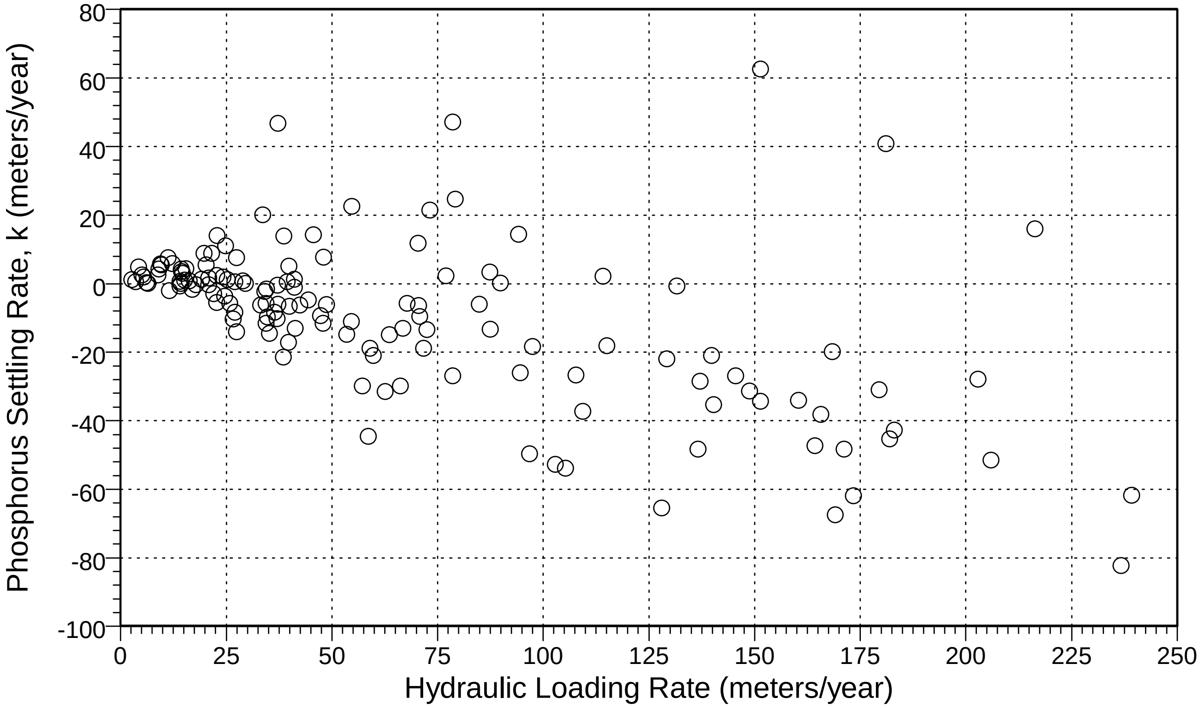
Figure 5-12: Retention Efficiency vs. Hydraulic Loading Rate at Lake Harney



5.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. Figure 5-13 is a scatter diagram of settling rate vs. hydraulic loading rate. The resultant linear model with hydraulic loading rate as the independent variable has a R^2 of .172.

Figure 5-13: Settling Rate vs. Hydraulic Loading Rate at Lake Harney



5.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Lake Harney from the DEP's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

A total of 71 species of wetland and aquatic plants were recorded for Lake Harney during the BIPM surveys. These included 51 species of emergent wetland plants, eight species of floating aquatic plants, and 12 species of submerged aquatic plants. Dominant emergent wetland species included the grasses *Paspalum distichum* and *Echinochloa* spp., pennywort, and spikerush (*Eleocharis* spp.). There were no floating aquatic plants of particular concern in the lake. Dominant submerged aquatics included eelgrass, hydrilla, southern naiad (*Najas guadalupensis*), and coontail.

Table 5-6 summarizes the estimated cover by vegetation type for Lake Harney for the period from 1982 through 2003. The average cover by vegetation type was emergent – 352 acres, floating – 123 acres, and submerged – 916 acres. These estimated plant coverages show that plants occupy a relatively small fraction of the estimated 5,905-acre surface area of Lake Harney.

Table 5-6: Lake Harney Vegetation Data

Survey	Vegetation Coverage by Type (acres)		
Month	Emergent	Floating	Submerged
Oct-82	76	56	60
Oct-83	153	208	41
Nov-84	275	102	54
Aug-86	301	330	1,620
Sep-88	476	244	1,685
Oct-90	516	45	1,705
Oct-92	328	15	1,506
Jun-95	868	60	1,561
Oct-03	172	46	8.6
Average	352	123	916
Median	301	60	1,506
Maximum	868	330	1,705
Minimum	76	15	8.6

* * * * *

6 LAKE ISTOKPOGA

6 LAKE ISTOKPOGA

Lake Istokpoga is located near the center of Highland County, approximately 25 miles northwest of Lake Okeechobee (Figure 1-1). Lake Istokpoga is located within the South Florida Water Management District. The data collected and the analyses completed for Lake Istokpoga are described in the balance of this chapter.

6.1 DATA SOURCES

The data for Lake Istokpoga were collected from a number of sources. These sources are listed in Table 6-1 along with a listing of the individual sample stations obtained from each source. For each sampling station, this table also lists its absolute location (latitude/longitude coordinates) and location relative to Lake Istokpoga. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 6-1 shows the locations of these monitoring stations.

6.2 DATA SUMMARY

Some of the monitoring stations for Lake Istokpoga have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 6-1: Lake Istokpoga Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	7395	SFA-HS-1038	27.43833	81.31722
	8754	SFA-LL-1009	27.42413	81.26674
Outflow	26010502	Lake Istokpoga	27.30972	81.29639
	3503	LAKE ISTOKPOGA AT S68 C.R. 621	27.32921	81.25201
	7390	SFA-HS-1033	27.31889	81.27139
	7391	SFA-HS-1034	27.31333	81.27055
South Florida Water Management District (SFWMD)				
Inflow	ARBK700A	Arbuckle Creek at 700A		
	ARBKSR98	Arbuckle Creek at SR98	27.39655	81.29680
Outflow	ISTKC621	Istokpoga Canal at CR 621	27.38067	81.20400
	S-68	S-68 SPILLWAY ON CANAL C-41A LAKE ISTOK	27.33003	81.25422
	S-68 TW	S-68 Tailwater	27.33003	81.25422
Interior	1NORTH	Lake Istokpoga Northwest		
	2NORTH	Lake Istokpoga-Arbuckle Creek		
	3NORTH	Lake Istokpoag-Northwest		
	GRASSY1	L Istokpoga-South of Grassy Is		
	GRASSY2	L Istokpoga-East of Grassy Is		
	GRASSY3	Lake Istokpoga-East of Grassy Is		
	GRASSY4	L Istokpoga-East of Grassy Is		
	ISLAND1	L Istokpoga-N End of Channel between Islands		
	ISLAND2	L Istokpoga-Mid of Channel between Islands		
	ISLAND3	L Istokpoga-S End of Channel between Islands		
	ISTK1	ISTK1	27.43250	80.73167
	ISTK2	ISTK2	27.41556	80.70889
	ISTK3	L Istokpoga-0.25 Mile E of Josephine Creek	27.39655	81.33475
	ISTK4	L Istokpoga-Halfway btwn Bumblebee Is and W Shore	27.34453	81.31105
	ISTK5	L Istokpoga-0.5 Mile from S End	27.30839	81.28788
	ISTK6	L Istokpoga-Halfway btwn Canal and Big Island	27.38236	81.24344
	ISTK6S		27.35858	81.24077
	ISTK7	L Istokpoga-Btwn Big Is and L Grassy Is	27.39833	81.27914
	S65EAST	L Istokpoga-E of S68		
	S65W	L Istokpoga-W of S68		
Exterior-D	S-70	S-70	27.11866	81.15729
	S-70 TW	S-70 Tailwater	27.11866	81.15729
	S-83	S-83	27.27143	81.19228

Table 6-1: Lake Istokpoga Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Exterior-D	S-83 TW	S-83 Tailwater	27.27143	81.19228
	S-84	S-84	27.21614	80.97339
	S-84 Kiss	S-84 Kissimmee	27.21614	80.97339
	S-84 Kiss TW	S-84 Kissimmee Tailwater	27.21614	80.97339
	S-84 TW	S-84 Tailwater	27.21614	80.97339
U.S. Geological Survey (USGS)				
Inflow	2257000	Fisheating Creek At Palmdale, Fla	26.96222	81.12083
	2270500	ARBUCKLE CR NE DE SOTO FL	27.44222	81.29750
	2271500	JOSEPHINE CREEK NEAR DE SOTO CITY FL	27.37389	81.39361
	2271700	LAKE ISTOKPOGA NR DE SOTO CITY, FLA.	27.44083	81.26167

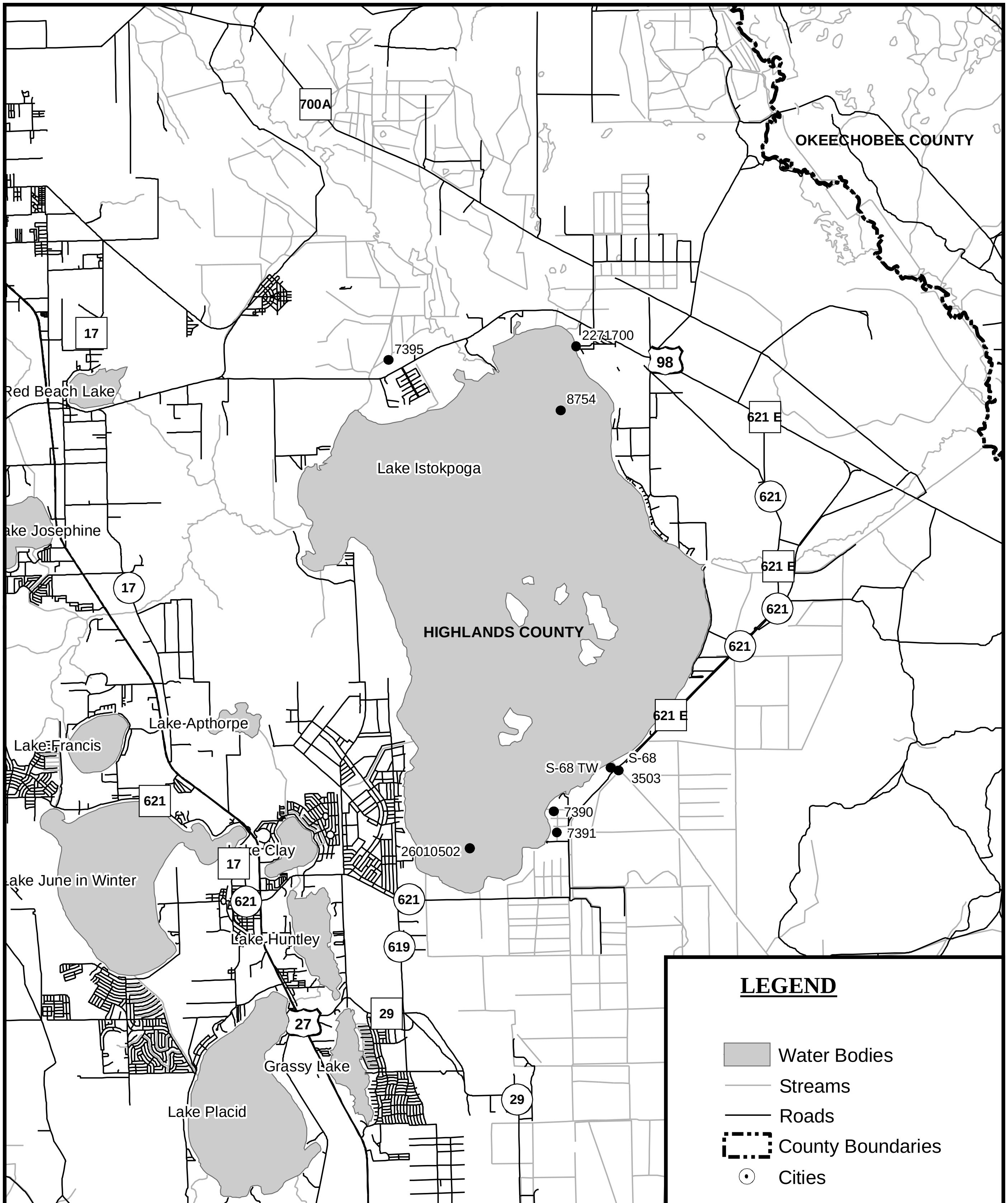


Figure 6-1

LAKE ISTOKPOGA MONITORING STATIONS

- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station is representative of a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 6-2 through 6-9 contain the time series graphs for Lake Istokpoga for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data, principally flow data, are available back to the early 1960s for Lake Istokpoga. For the most part, there are relatively few water quality monitoring data available for this lake before 1988. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow rate and phosphorus concentration data for calculating water and phosphorus balances at Lake Istokpoga. The graphs of available flow and phosphorus concentration data are shown in Figures 6-2 and 6-3, respectively. From review of these figures, flow data are shown to be available since before 1975 but TP data only since about 1988. Based on the availability of TP data, a period of record of calendar years 1989–2003 was selected for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are generally more prevalent during this same period.

After the analysis period was selected, the time series graphs for flow and TP concentration were replotted with an expanded time scale that covers only this period. These graphs, respectively Figures 6-10 and 6-11, better show the availability of data during this critical period. Table 6-2 includes descriptive

Figure 6-2: Long-term Flow at Lake Istokpoga

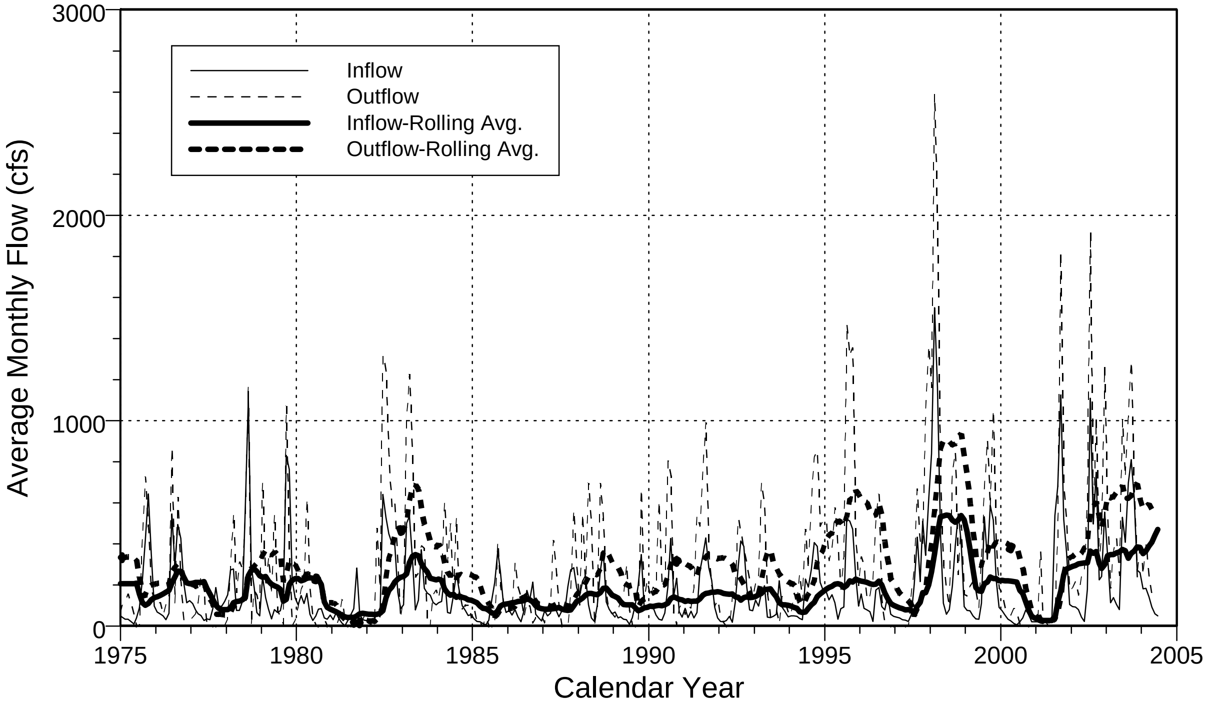


Figure 6-3: Long-term Total Phosphorus at Lake Istokpoga

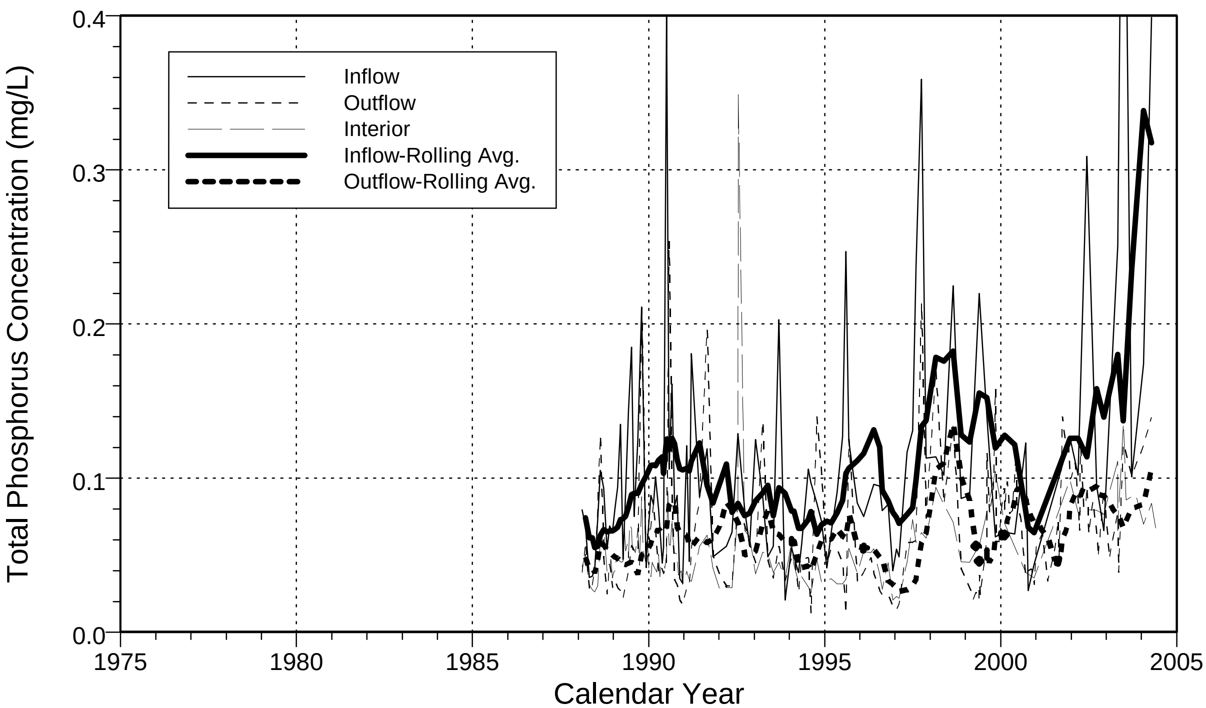


Figure 6-4: Long-term Orthophosphorus at Lake Istokpoga

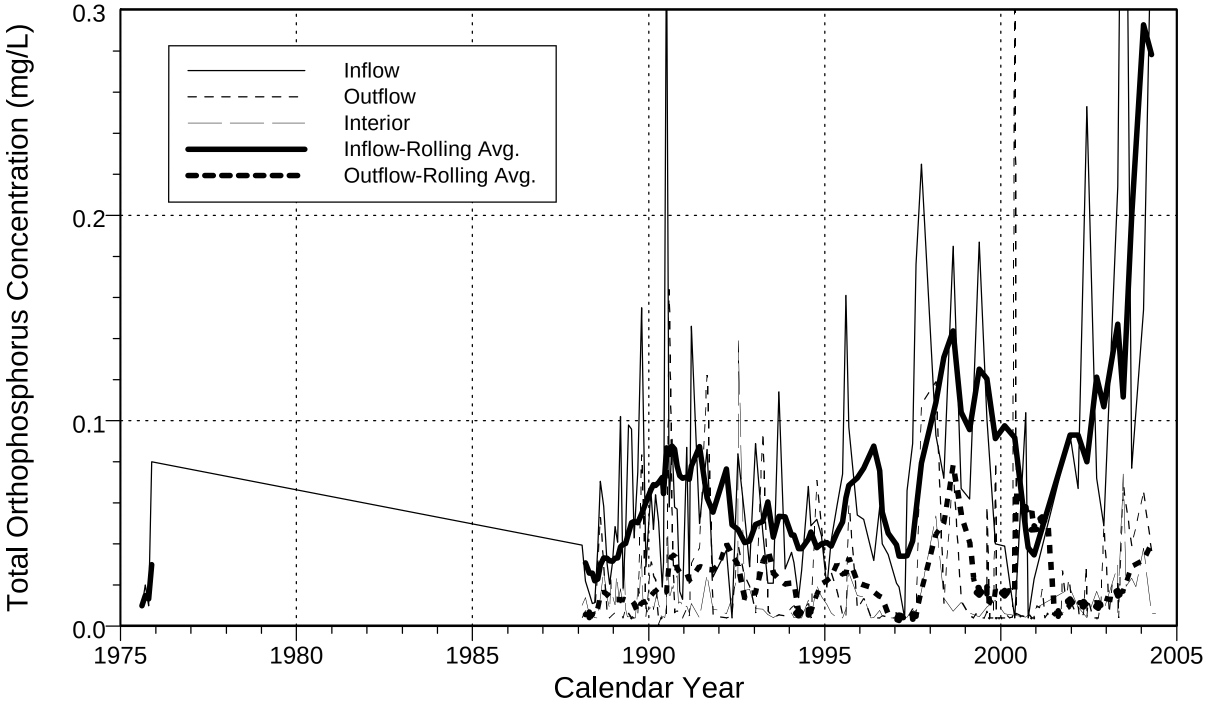


Figure 6-5: Long-term Total Nitrogen at Lake Istokpoga

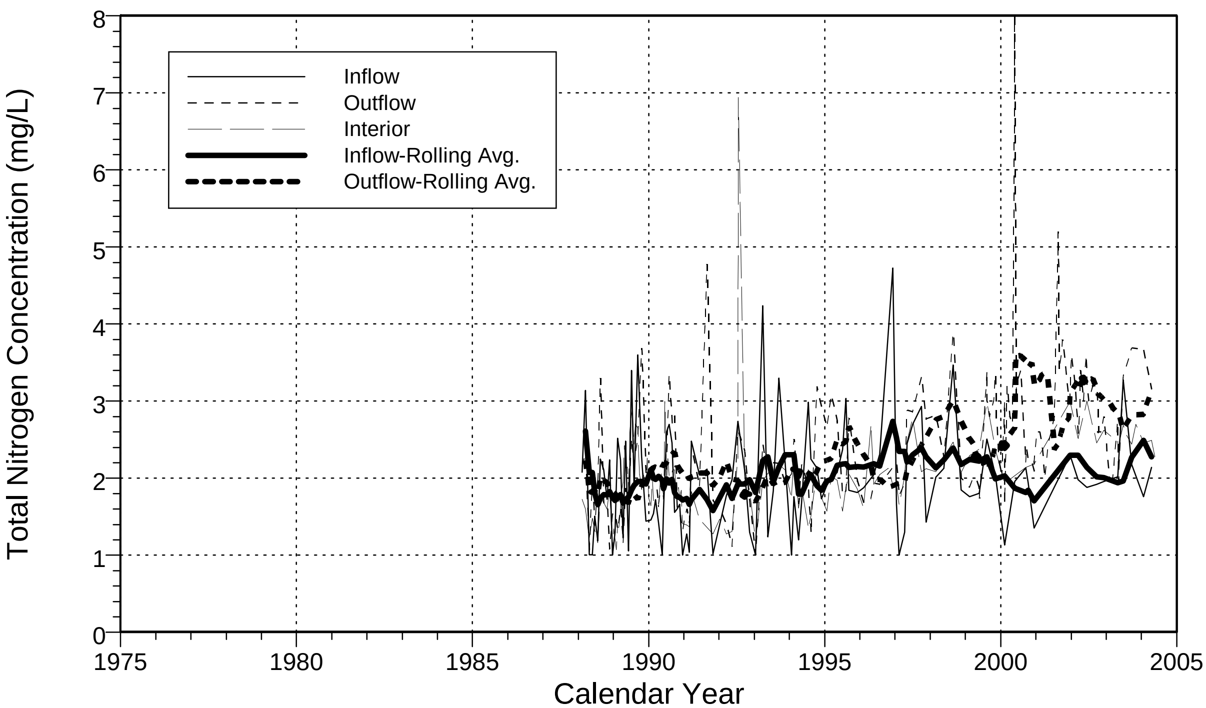


Figure 6-6: Long-term pH at Lake Istokpoga

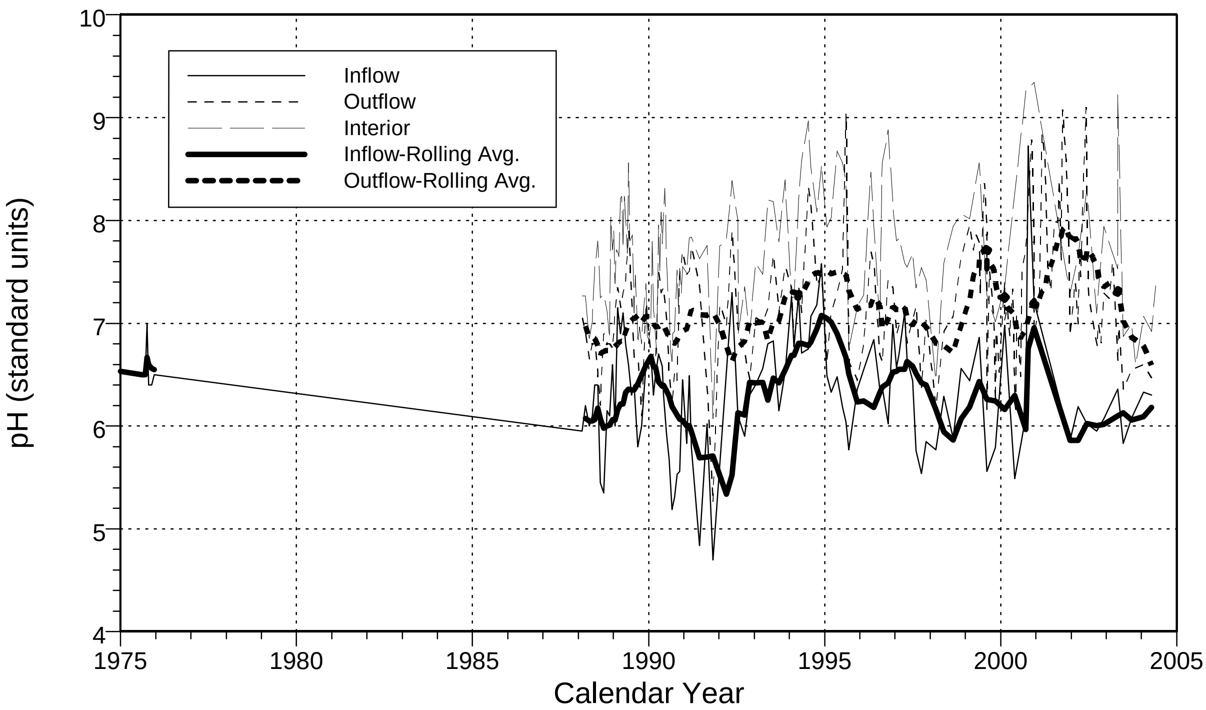


Figure 6-7: Long-term Total Calcium at Lake Istokpoga

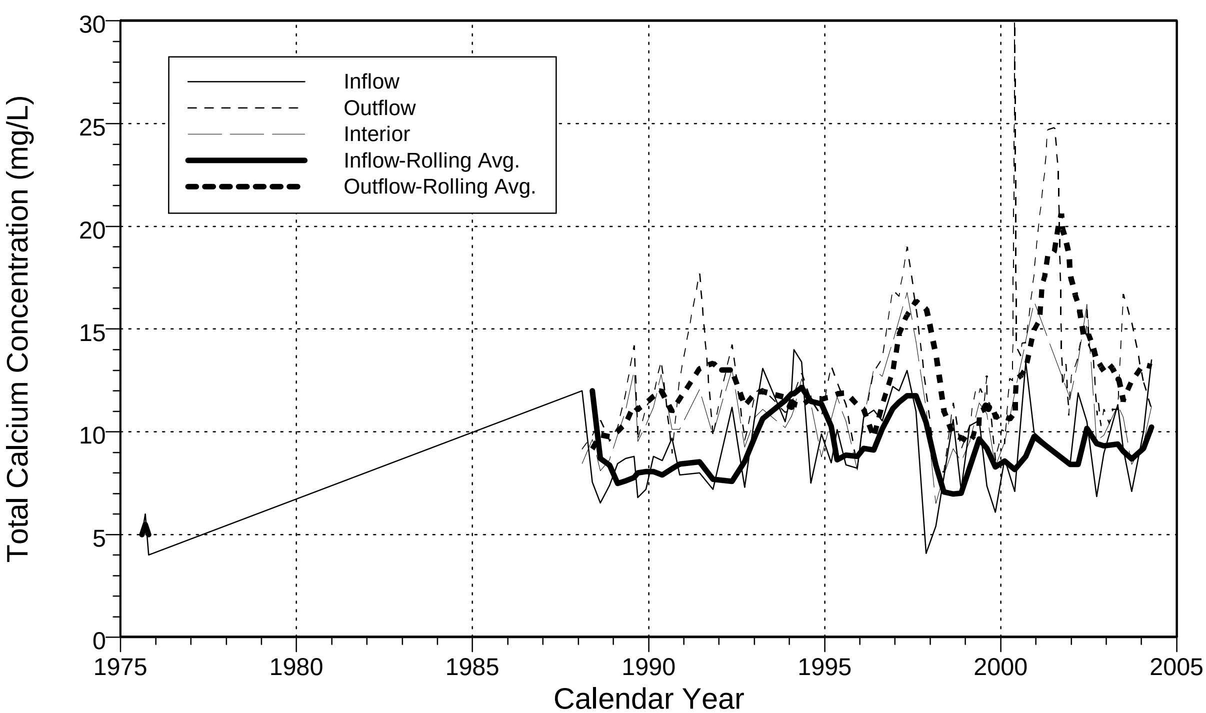


Figure 6-8: Long-term Water Surface Elevation at Lake Istokpoga

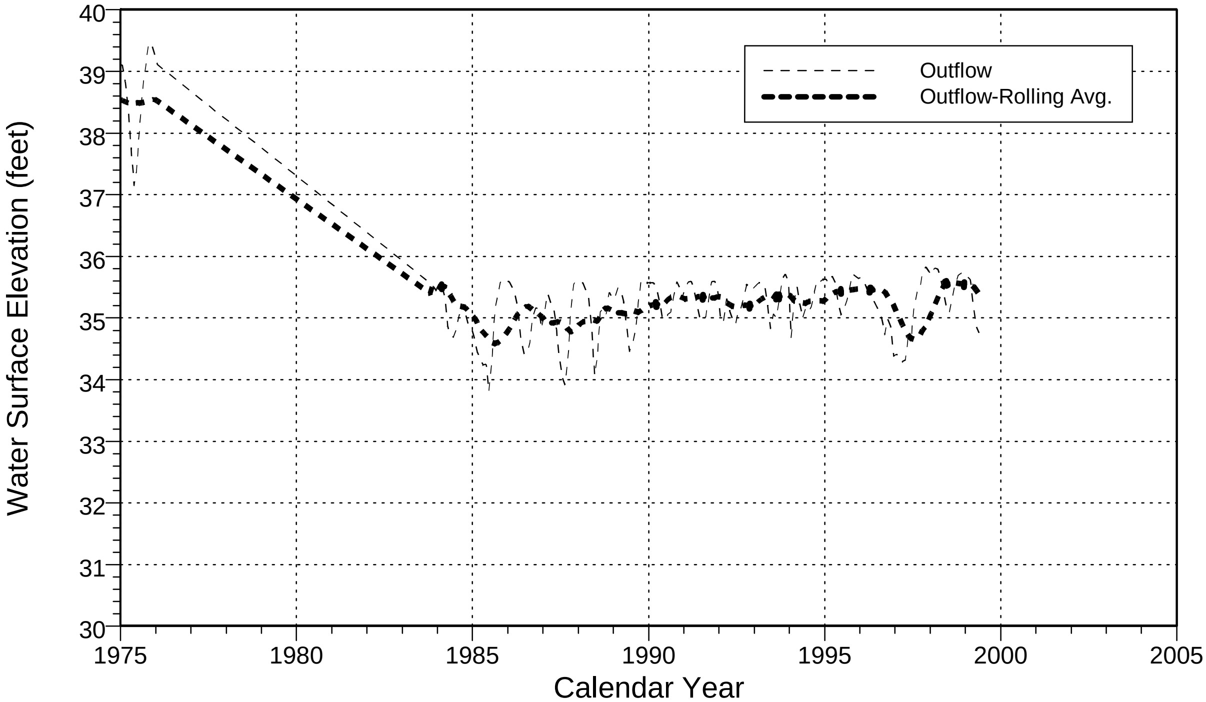
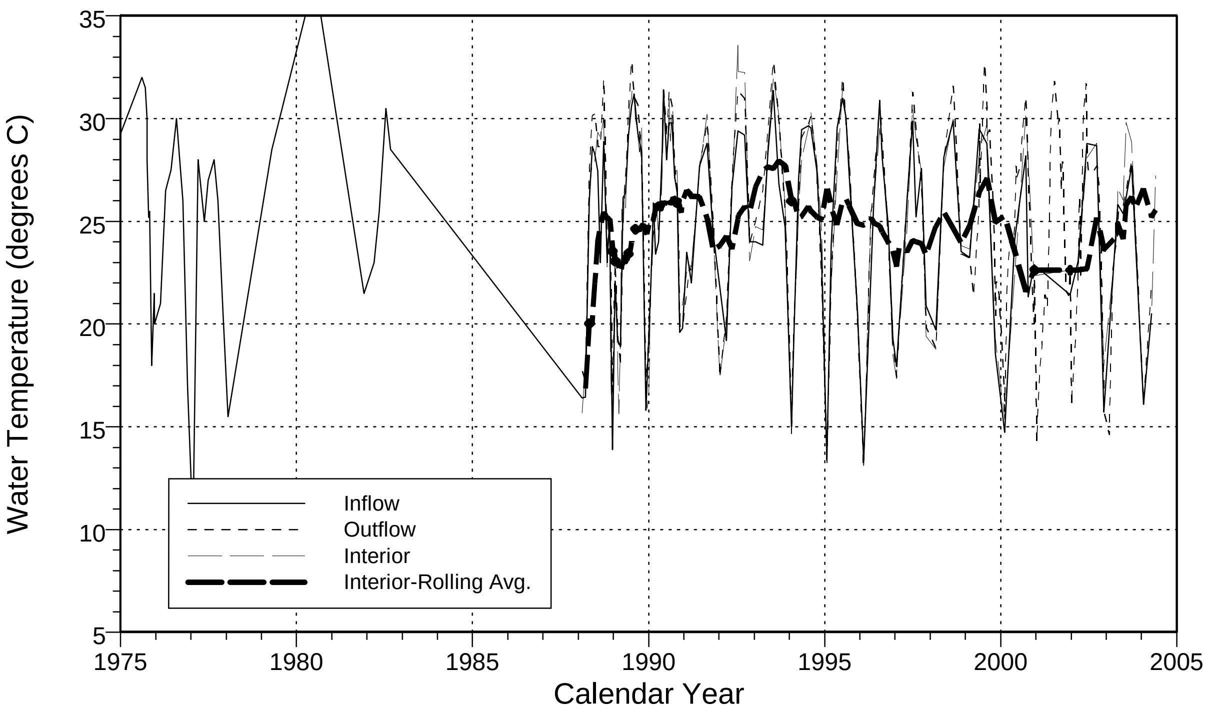


Figure 6-9: Long-term Water Temperature at Lake Istokpoga



statistics for key monitoring parameters at Lake Istokpoga. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will note that relatively few non-detect samples occurred for the more significant parameters listed in Table 6-2 except for orthophosphorus.

6.3 WATER BALANCE

A daily water balance for Lake Istokpoga was developed for WY 1989–2003. This water balance included estimates of the following quantities for each day during the period of record.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

6.3.1 Surface Area

Using data obtained from Corps design memoranda for Lake Istokpoga, a polynomial regression equation for surface area vs. elevation was developed. This equation, which is shown below, was used to estimate the surface area (A) of Lake Istokpoga from recorded stage or water surface elevation data at S-68 (E).

$$A = 1000\left(-0.030E^2 + 3.877E - 78.159\right) \quad \left[R^2 = .971\right]$$

Figure 6-10: Analysis Period Water Surface Elevation at Lake Istokpoga

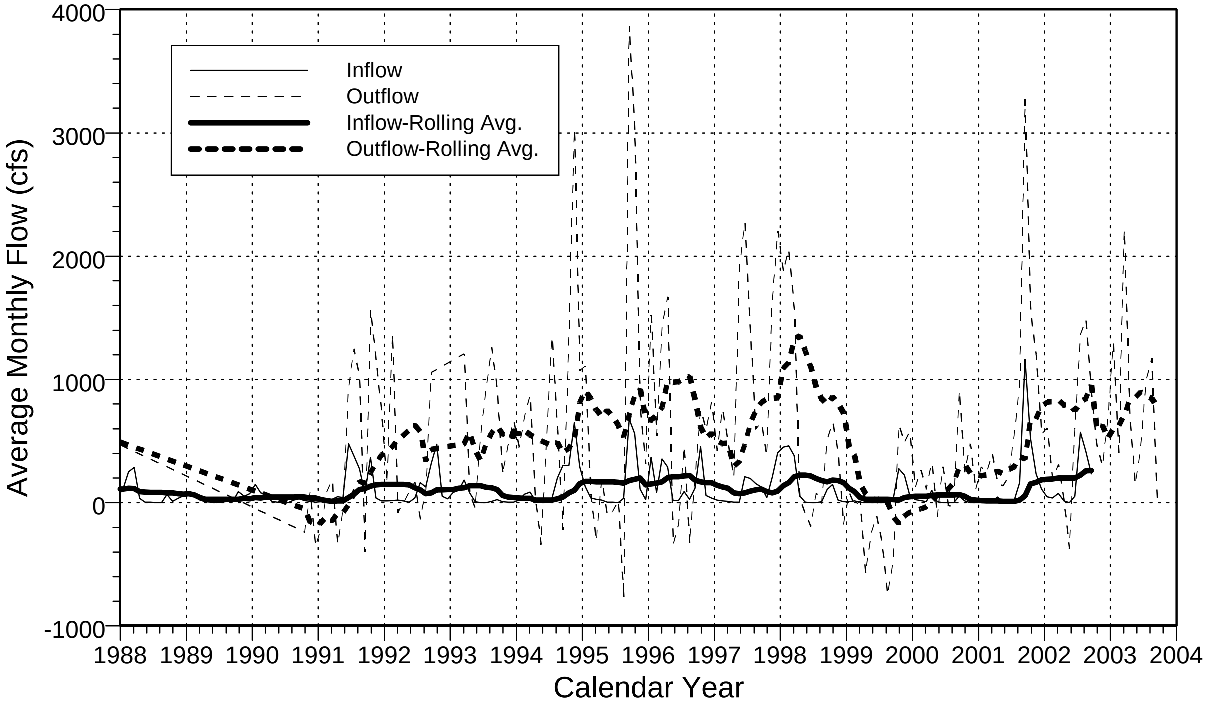


Figure 6-11: Analysis Period Total Phosphorus at Lake Istokpoga

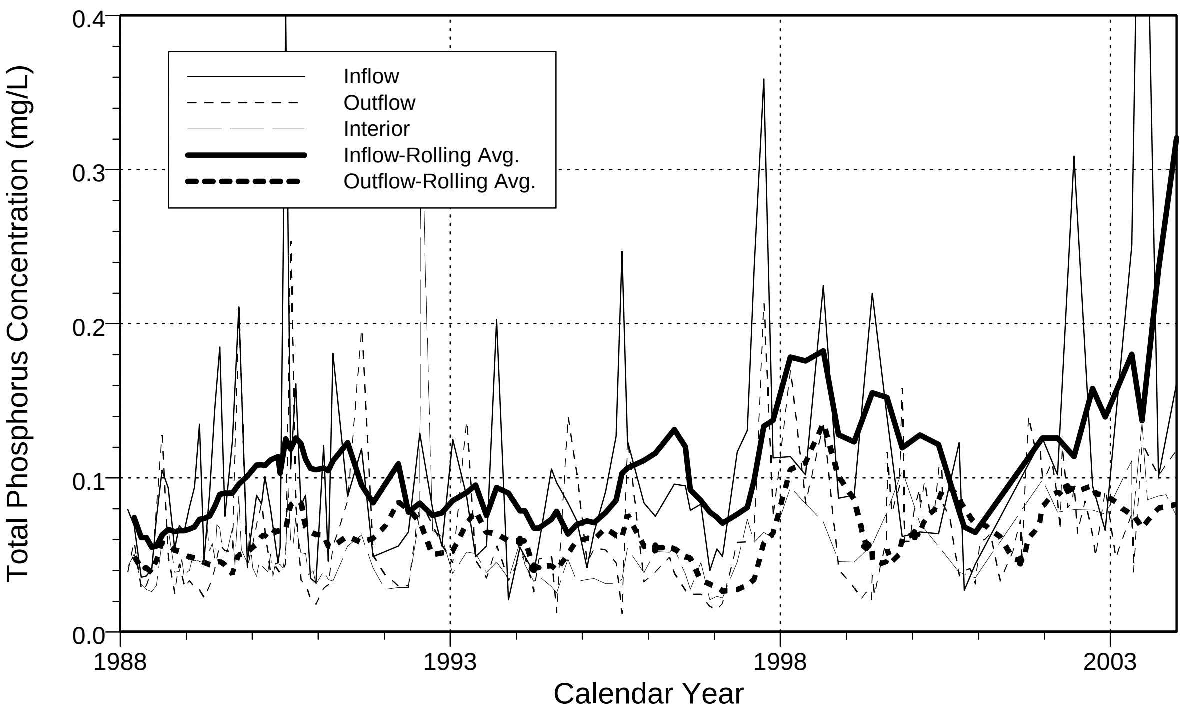


Table 6-2: Lake Istokpoga Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	45	0	9.590	4.100	14.000
		Outside	22	0	8.227	4.000	13.500
		Total	67	0	9.142	4.000	14.000
Calcium (mg/L)	Outflow	Inside	135	0	13.075	6.900	32.900
		Outside	28	0	10.982	7.500	15.400
		Total	163	0	12.715	6.900	32.900
Calcium (mg/L)	Interior	Inside	351	0	11.110	4.700	19.400
		Outside	98	0	10.099	5.900	14.600
		Total	449	0	10.890	4.700	19.400
Elevation (feet)	Outflow	Inside	6,296	0	35.303	29.530	39.740
		Outside	19,507	0	37.645	28.620	42.900
		Total	25,803	0	37.074	28.620	42.900
Flow (cfs)	Inflow	Inside	11,741	2	229.171	-29.000	4,620.000
		Outside		0	209.428	0.000	7,180.000
		Total		2	214.502	-29.000	7,180.000
Flow (cfs)	Outflow	Inside	4,526	0	391.445	0.000	4,166.750
		Outside	7,056	0	230.192	0.000	3,271.300
		Total	11,582	0	293.206	0.000	4,166.750
Orthophosphorus (mg/L)	Inflow	Inside	68	4	0.074	0.004	0.587
		Outside	53	0	0.059	0.005	0.365
		Total	121	4	0.068	0.004	0.587
Orthophosphorus (mg/L)	Outflow	Inside	188	62	0.023	0.004	0.530
		Outside	66	31	0.020	0.001	0.324
		Total	254	93	0.022	0.001	0.530
Orthophosphorus (mg/L)	Interior	Inside	578	153	0.013	0.003	0.482
		Outside	409	131	0.014	0.001	0.340
		Total	987	284	0.013	0.001	0.482
pH	Inflow	Inside	72	0	6.373	4.700	8.810
		Outside	58	0	6.305	5.190	7.200
		Total	130	0	6.343	4.700	8.810
pH	Outflow	Inside	205	0	7.229	5.000	9.310
		Outside	68	0	6.871	4.690	8.400

POR: Inside=Within analysis period (10/1/1990-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 6-2: Lake Istokpoga Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Outflow	Total	273	0	7.140	4.690	9.310
pH	Interior	Inside	577	0	7.725	5.200	10.000
		Outside	417	0	7.361	5.430	9.900
		Total	994	0	7.572	5.200	10.000
Phosphorus (mg/L)	Inflow	Inside	69	0	0.111	0.021	0.664
		Outside	49	0	0.098	0.033	0.410
		Total	118	0	0.106	0.021	0.664
Phosphorus (mg/L)	Outflow	Inside	185	0	0.066	0.008	0.386
		Outside	68	0	0.063	0.015	0.469
		Total	253	0	0.065	0.008	0.469
Phosphorus (mg/L)	Interior	Inside	579	0	0.056	0.010	0.477
		Outside	416	0	0.054	0.009	0.211
		Total	995	0	0.055	0.009	0.477
Temperature (deg C)	Inflow	Inside	72	0	24.564	13.380	31.370
		Outside	87	0	24.441	10.000	37.000
		Total	159	0	24.497	10.000	37.000
Temperature (deg C)	Outflow	Inside	205	0	24.450	12.860	32.960
		Outside	68	0	25.574	15.300	33.600
		Total	273	0	24.729	12.860	33.600
Temperature (deg C)	Interior	Inside	589	0	24.839	11.960	38.000
		Outside	417	0	25.093	13.700	32.600
		Total	1,006	0	24.945	11.960	38.000
Total Nitrogen (mg/L)	Inflow	Inside	67	0	2.027	1.000	4.730
		Outside	49	0	1.861	1.000	3.860
		Total	116	0	1.957	1.000	4.730
Total Nitrogen (mg/L)	Outflow	Inside	195	0	2.528	1.000	9.600
		Outside	66	0	2.084	1.000	5.620
		Total	261	0	2.416	1.000	9.600
Total Nitrogen (mg/L)	Interior	Inside	562	0	2.047	1.000	6.940
		Outside	411	0	1.939	1.000	8.460
		Total	973	0	2.002	1.000	8.460

POR: Inside=Within analysis period (10/1/1990-9/30/2003); Outside=Outside analysis period; Total=All available data.

6.3.2 Inflow

The USGS has stream gages on three tributaries of Lake Istokpoga. These gages are located on Josephine Creek near DeSoto City (No. 02271500), Arbuckle Creek near DeSoto City (No. 02270500), and Fisheating Creek at Palmdale (No. 02256500). These three gages have drainage areas of respectively 379, 109 and 311 square miles. The gaged inflow to Lake Istokpoga was calculated as the sum of the recorded discharges at each of these gages.

The ungaged inflow to Lake Istokpoga was initially set to zero but later estimated as discussed in Section 6.3.7.

6.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Lake Istokpoga can represent a significant lake inflow. Daily rainfall amounts at Lake Istokpoga over the period of record were estimated from records collected by SFWMD at the S-68 outfall structure. This station is located on the southeastern shore of Lake Istokpoga. The water volume contributed to Lake Istokpoga by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

6.3.4 Evaporation Depth and Volume

No evaporation data for Lake Istokpoga was located during Task 2 so lake evaporation was estimated from pan evaporation data available at Moore Haven Lock 1 (NOAA, 2002). This climate station (No. 8-5895) is located about 34 miles south of Lake Istokpoga, on the western shore of Lake Okeechobee. Water will evaporate faster from an evaporation pan than a lake because a pan is a much smaller body of water and will heat up much more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Lake Istokpoga vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Moore Haven is generally daily but regular short periods occurred when only a cumulative value representative of the evaporation over the entire interval is available. In order to smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. No pan evaporation data are available for 2002 so long-term pan evaporation averages by month were used as substitutes for these missing months. Evaporation losses from Lake Istokpoga were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

6.3.5 Outflow

The principal discharge structure from Lake Istokpoga is Structure S-68. SFWMD has recorded the discharge from the lake at this structure since 1972. The gaged outflow from Lake Istokpoga was estimated from these discharge records. The ungaged outflow from Lake Istokpoga was set equal to zero.

6.3.6 Elevation and Change in Storage

The only elevation records available for Lake Istokpoga are the headwater elevation readings taken at S-68. These headwater elevations were used as an indication of lake stage but are unavailable after May 1999. A constant lake elevation of 40 feet was used in place of missing values. The day-to-day changes in these headwater elevations were assumed to be representative of the changes in lake elevation also. The corresponding changes in lake storage were then estimated as the products of these stage changes and the lake surface area. The available elevation readings are mean daily values and as such, are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation was estimated as the average of the elevations for the current and following day.

Using data obtained from Corps design memoranda for Lake Istokpoga, a polynomial regression equation for mean lake depth vs. elevation was developed. This equation, which is shown below, was used to estimate the mean depth (D) of Lake Istokpoga from recorded stage or water surface elevation data at S-68 (E).

$$D = 0.694E - 21.598 \quad \left[R^2 = .995\right]$$

6.3.7 Imbalance

Theoretically, the sum of all lake inflows (gaged inflow + ungaged inflow + precipitation volume) less all outflows (gaged outflow + ungaged outflow + evaporation) should equal the computed change in storage each day. However, this balance never occurred in practice. The ungaged inflow and outflow quantities were adjusted accordingly to eliminate these imbalances.

Table 6-3 presents an annual summary of the Lake Istokpoga water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 6-3: Lake Istokpoga Water Balance Summary (acre-feet)

Calendar Year	Inflow	Precipitation	Deposition	Outflow	Change In Storage	Imbalance
1989	584,908	88,577	141,302	515,608	27,601	0
1990	545,228	69,467	134,769	491,023	-39,838	0
1991	660,995	112,523	129,948	642,414	-12,631	0
1992	437,321	112,377	120,183	371,639	7,580	0
1993	531,482	85,536	119,441	433,793	35,529	0
1994	718,898	107,978	115,620	704,841	6,414	0
1995	883,482	99,221	120,003	874,368	-11,668	0
1996	617,183	61,306	129,081	616,476	-67,068	0
1997	877,267	105,807	120,439	791,646	70,989	0
1998	1,418,669	118,760	124,816	1,397,960	14,653	0
1999	852,099	88,817	121,519	774,766	44,632	0
2000	161,500	57,285	135,671	83,114	0	0
2001	706,942	83,726	135,496	655,172	0	0
2002	804,485	124,727	135,231	793,981	0	0
Total	9,800,459	1,316,107	1,783,520	9,146,801	76,193	0

6.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Lake Istokpoga using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the period of record.

- Inflow TP concentration and flux
- Direct phosphorus deposition load to lake

- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

6.4.1 Inflow TP Concentration and Flux

During the selected 14-year period of record (CY 1989–2002), inflow TP concentration data are available for 87 days. This yields a sampling frequency of approximately once every two months. Table 6-4 lists the specific stations and number of available samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variables: Monthly precipitation in inches (P) and common logarithm of inflow rate in cfs (log Q)
- Model: log [TP] = -1.478 + 0.42 P + 0.107 log Q
- Coefficient of determination (R2): .344

This model accounts for approximately one third of the variations in the measured TP concentrations, which is fairly good for this type of data. Therefore, this model will be used to help estimate inflow TP concentrations.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample

Table 6-4: TP Monitoring Stations at Lake Istokpoga

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	7395	SFA-HS-1038	1
	8754	SFA-LL-1009	1
SFWMD	ARBKSR98	Arbuckle Creek at SR98	67
Interior Stations			
SFWMD	1NORTH	Lake Istokpoga Northwest	2
	2NORTH	Lake Istokpoga-Arbuckle Creek	2
	3NORTH	Lake Istokpoag-Northwest	2
	GRASSY1	L Istokpoga-South of Grassy Is	1
	GRASSY2	L Istokpoga-East of Grassy Is	2
	GRASSY3	Lake Istokpoga-East of Grassy Is	2
	GRASSY4	L Istokpoga-East of Grassy Is	2
	ISLAND1	L Istokpoga-N End of Channel between Islands	2
	ISLAND2	L Istokpoga-Mid of Channel between Islands	2
	ISLAND3	L Istokpoga-S End of Channel between Islands	2
	ISTK1	ISTK1	69
	ISTK2	ISTK2	70
	ISTK3	L Istokpoga-0.25 Mile E of Josephine Creek	71
	ISTK4	L Istokpoga-Halfway btwn Bumblebee Is and W Shore	71
	ISTK5	L Istokpoga-0.5 Mile from S End	71
	ISTK6	L Istokpoga-Halfway btwn Canal and Big Island	69
	ISTK6S		69
	ISTK7	L Istokpoga-Btwn Big Is and L Grassy Is	66
	S65EAST	L Istokpoga-E of S68	2
	S65W	L Istokpoga-W of S68	2
Outflow Stations			
FDEP	26010502	Lake Istokpoga	1
	3503	LAKE ISTOKPOGA AT S68 C.R. 621	52
	7390	SFA-HS-1033	2
	7391	SFA-HS-1034	4
SFWMD	ISTKC621	Istokpoga Canal at CR 621	67
	S-68	S-68 SPILLWAY ON CANAL C-41A LAKE ISTOKPOG	68

dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less certain with this method.

At Lake Istokpoga, missing inflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based the interpolation method and best regression model. Once these estimates of TP concentrations were developed, the phosphorus mass influx to Lake Istokpoga was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance.

6.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Lake Istokpoga is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 µg/m^2 while direct precipitation to the lake (wet deposition) is assumed to have a TP concentration of 9.39 µg/L (Ahn & James, 2001). Therefore, the daily phosphorus influx from deposition was calculated as the sum of these two components.

6.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Lake Istokpoga were identical to those used for lake inflow. During the selected period of record (CY 1989–2002), outflow TP concentration data are available for 133 days. This yields an average sample frequency of once every 39 days. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Outflow TP concentration in mg/L ([TP])
- Independent variables: Outflow rate in cfs (Q) and total monthly precipitation in inches (P)
- Model: [TP] = 0.050 + 1.8E-5 Q + 0.003 P
- Coefficient of determination (R^2): .117

Even this "best" model does not have a very good fit but any model with an R^2 over .100 may be worthy of consideration. Therefore, this model was used to help estimate outflow TP concentrations. The estimates generated from this regression model were averaged with estimates developed using the simple straight-line interpolation process described above.

Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Lake Istokpoga was estimated for each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

6.4.4 Net Phosphorus Retention

The net phosphorus retention in Lake Istokpoga was estimated as the total mass influx from inflow and deposition less discharge flux. As such, these net retention values include the phosphorus retained or discharged because of changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Lake Istokpoga is shown in Table 6-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

6.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Lake Istokpoga were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. These monthly data sets include the following data values:

- Total inflow and outflow volumes (m^3)
- Total mass flux of phosphorus in, out and retained in lake (g)
- Flow-weighted average inflow and outflow phosphorus concentrations (mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (m/yr)
- Net phosphorus settling rate, k (m/yr)

Table 6-5: Lake Istokpoga Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1989	48,926	3,240	20,687	31,287
1990	92,796	4,436	61,855	34,839
1991	81,545	4,710	58,972	22,936
1992	55,377	4,667	31,859	9,414
1993	56,810	4,420	33,941	22,583
1994	65,894	4,424	42,794	27,524
1995	121,121	4,738	84,350	41,509
1996	70,463	4,288	48,745	26,006
1997	106,301	4,378	40,931	69,748
1998	251,648	4,910	224,429	32,128
1999	136,282	4,511	59,387	81,406
2000	30,203	4,423	24,026	10,600
2001	79,095	4,574	51,884	31,786
2002	144,342	4,841	81,576	67,606
2003	24,076	1,230	20,476	4,831
Total	1,364,877	63,789	885,911	514,201

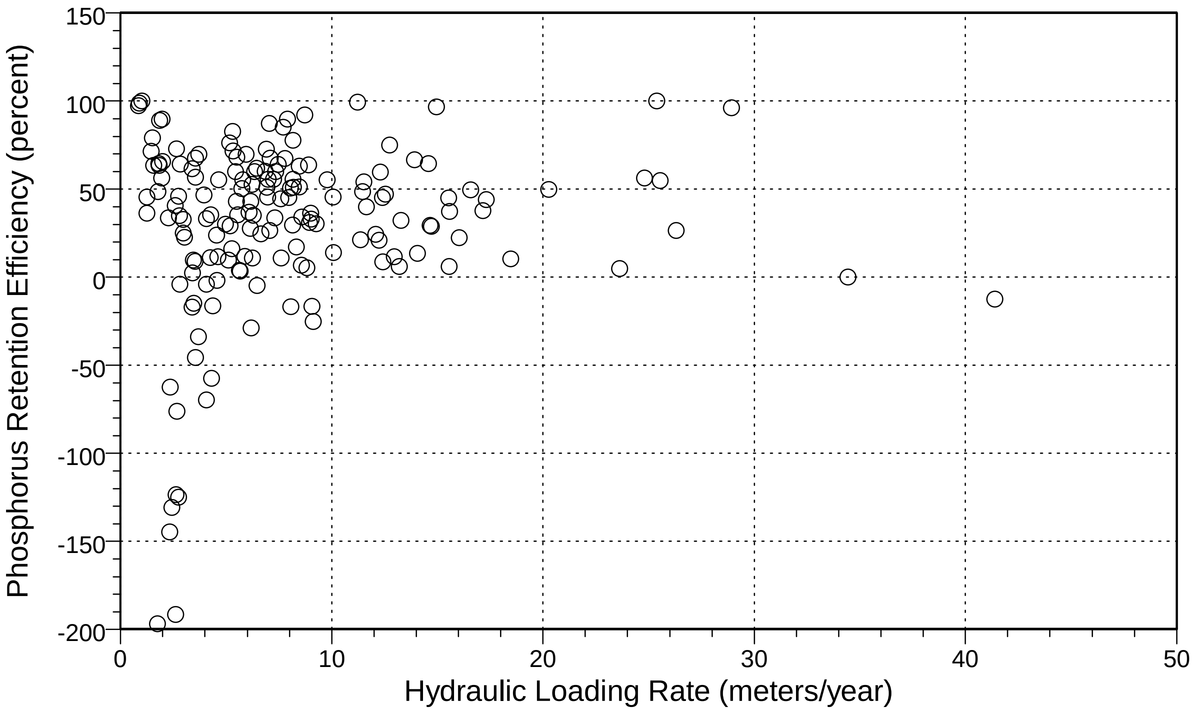
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (or surrogate such as water surface elevation or gage height) (meters)

Not all of these data are available in every month during the period of record.

6.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 6-12. From review of this graph, it is not apparent a linear relationship exists between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .020.

Figure 6-12: Retention Efficiency vs. Hydraulic Loading Rate at Lake Istokpoga



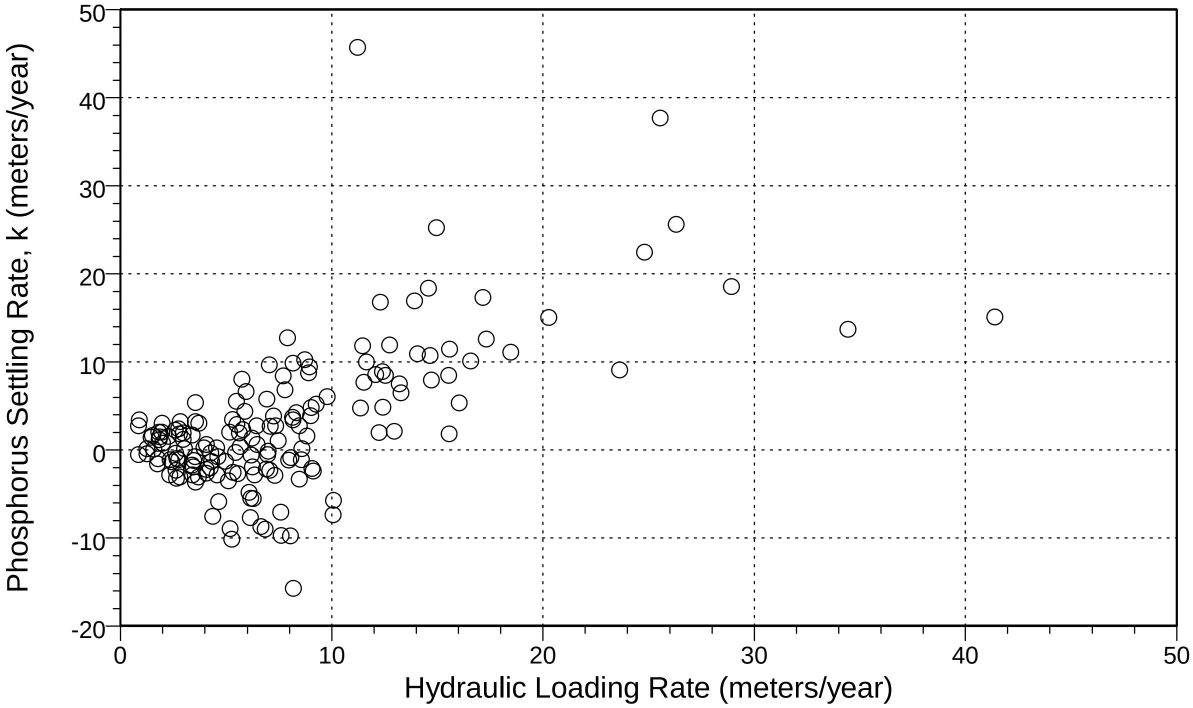
6.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. The only models with R^2 significantly above zero used hydraulic loading rate (R^2 = .383) and temperature (R^2 = .168) as the independent variables. Figure 6-13 is a scatter diagram of settling rate vs. hydraulic loading rate.

A multiple regression analysis was also performed using all of the independent variables listed in the previous paragraph. Using a stepwise procedure, three of these variables were selected to yield a model with the best overall fit. This regression model is described below.

- Independent variable: Phosphorus settling rate in meters/year (k)

Figure 6-13: Settling Rate (k) vs. Hydraulic Loading Rate at Lake Istokpoga



- Dependent variables: Hydraulic loading rate in meters/year (q), temperature in degrees C (T), mean depth in meters (D)
- Model: k = -52.151 + 0.704 q + 0.849 T + 17.166 D
- Coefficient of determination (R^2): .687

6.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Lake Istokpoga from the DEP's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

A total of 77 species of wetland and aquatic plants were recorded for Lake Istokpoga during the BIPM surveys. These included 51 species of emergent wetland plants, 11 species of floating aquatic plants, and 15 species of submerged aquatic plants. Dominant emergent wetland species included cattails, pickerelweed, bulrush, and primrose willow (*Ludwidgia* spp.). The dominant floating species was water hyacinth. Dominant submerged aquatics were hydrilla and pondweed.

Table 6-6 summarizes the estimated cover by vegetation type for Lake Istokpoga for the period from 1982 through 2003. The average cover by vegetation type was emergent – 2,962 acres, floating – 400 acres, and submerged – 5,434 acres. These estimates of plant cover show that plants occupy a significant fraction of the estimated 23,965-acre surface area of Lake Istokpoga.

Table 6-6: Lake Istokpoga Vegetation Data

Survey Month	Vegetative Coverage by Type (acres)		
	Emergent	Floating	Submerged
Nov-82	1,517	522	306
Aug-83	2,908	896	518
Oct-84	2,752	416	573
Oct-86	2,280	723	1055
Oct-88	2,689	602	13,052
Oct-90	3,949	83	8,762
Oct-92	4,262	90	3,209
Oct-95	4,036	110	19,139
Oct-03	2,263	155	2,293
Average	2,962	400	5,434
Median	2,752	416	2,293
Maximum	4,262	896	19,139
Minimum	1,517	83	306

* * * * *

7 LAKE JESSUP

7 LAKE JESSUP

Lake Jessup is located in Seminole County, about 13 miles northeast of central Orlando (Figure 1-1). Lake Jessup is a large, shallow natural lake located adjacent to the St. Johns River. The data collected for Lake Jessup and the analyses completed with these data are described in the balance of this chapter.

7.1 DATA SOURCES

The data for Lake Jessup were collected from a number of sources. These sources are listed in Table 7-1 along with a listing of the individual sample stations obtained from each source. For each sampling station, this table also lists its absolute location (latitude/longitude coordinates) and location relative to Lake Jessup. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 7-1 shows the locations of these monitoring stations.

7.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 7-1: Lake Jessup Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	20010028	HOWELL CR AT ENTRANCE TO L JESSU	28.70000	81.25164
	20010051	SALT CREEK AT PACKARD AVE. NEAR OVIED	28.71428	81.16695
	20010090	SWEETWATER CREEK 0.15 MI. S. OF HOWARD	28.69678	81.20897
	20010127	SHORTCUT CANAL 100 YDS. DOWNSTREAM H	28.69986	81.19881
	20010177	L JESSUP S SANFORD AVE CANAL	28.72553	81.26444
	20010178	L JESSUP E SOLDIER & GEE CR	28.71633	81.28889
	20010180	LAKE JESSUP N HOWELL CR	28.70169	81.25214
	20010182	L JESSUP S MOUTH OF PHELPS CREEK	28.74111	81.22858
	20010184	Soldier Creek 100 yards downstream of S.R. Highway	28.71861	81.30856
	20010185	Gee Creek at S.R. Highway 419	28.70347	81.29044
	20010187	L JESSUP, US CNL TO AT SIPES AVE	28.74931	81.23209
	20010188	SANFORD AVE CANAL WOODEN BRID	28.72736	81.26427
	20010245	L JESSUP 1 1/2 MI S OF SR 46 BRG	28.76289	81.18078
	20010257	SOLDIER CR 200 YDS UPSTRM OF S41	28.71861	81.30903
	20010294	ELDER SPRINGS RUN AT MYRTLE AVE. - SANF	28.73461	81.26625
	20010354	BLACK SWEETWATER CREEK AT HOWARD AV	28.69936	81.18425
Outflow	20010024	ST JOHNS R CONF WITH L JESSUP	28.78583	81.18056
	20010485	LAKE JESSUP NEAR SR 46 BRIDGE	28.78278	81.18166
	SJRJESSUP1	ST JOHNS RIV IN GOVNMT CUT NORTH OF LA	28.78611	81.17944
	SJRJESSUP8	LAKE JESSUP STATION OW-SJR-1	28.78472	81.16889
Interior	20010029	LAKE JESSUP, CENTER OF LAKE	28.72206	81.21794
	20010031	L JESSUP AT HILEYS FISH CMP HW41	28.70172	81.23833
	20010179	W END L JESSUP E SOLDIER CR	28.71519	81.27280
	20010181	LAKE JESSUP SW SECTOR	28.71028	81.23917
	20010183	LAKE JESSUP NE SECTOR	28.73508	81.19542
	20010259	SHEOAH GOLF CR UPSTR CONF SOLD	28.71786	81.30959
	SJRJESSUP2	LAKE JESSUP IN 4FT HOLE OF GRASSY POINT	28.76806	81.17445
	SJRJESSUP3	LK JESSUP IN 7FT HOLE B/T SEEVEE ISL & LON	28.73528	81.18667
	SJRJESSUP4	LK JESSUP B/T WHITE'S LANDING & BIRD ISLA	28.70583	81.23695
	SJRJESSUP5	LK JESSUP B/T CALDWELL FLDS & NEW BALL	28.70944	81.26250
	SJRJESSUP6	LK JESSUP IN 4FT HOLE OFF CENTER OF FAR	28.71389	81.27734
	SJRJESSUP7	LK JESSUP B/T MARL BED POINT & LONG POIN	28.73944	81.21416
Unknown	23279			
Florida Game and Fresh Water Fish Commission (FGFWF)				
Inflow	GFCCR0189	LAKE JESSUP AT SR 46 BRIDGE	28.78556	81.18056

Table 7-1: Lake Jessup Monitoring Stations

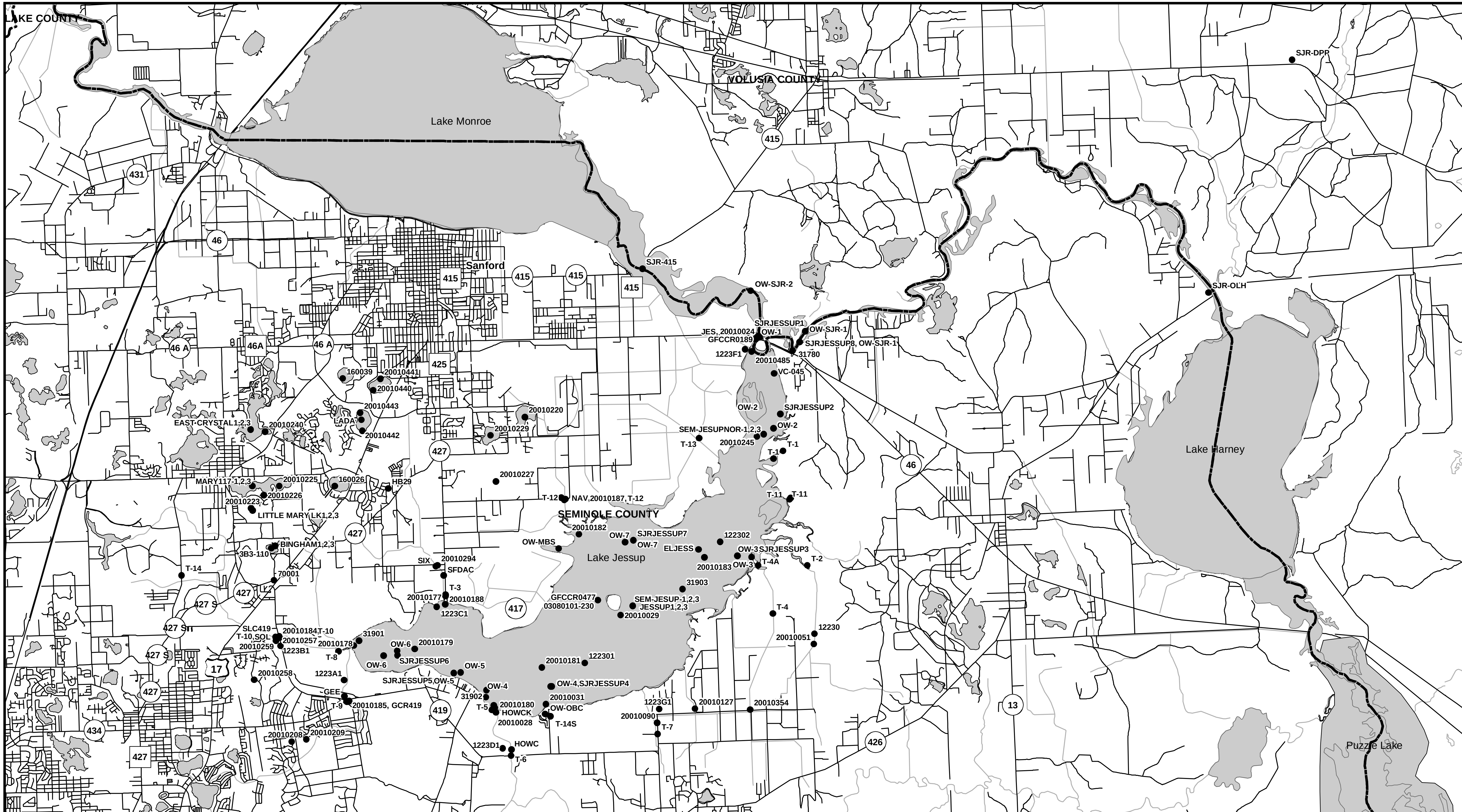
Relative Loc.	Station	Station Name	Latitude	Longitude
Outflow	GFCCR0477	LAKE JESSUP MID LAKE	28.72567	81.22392
Interior	03080101-230	St. Johns River Station 45	28.72567	81.22392
Florida LAKEWATCH (LakeWatch)				
Interior	JESSUP1	JESSUP IN SEMINOLE CO.-SEE NOTE	28.72417	81.21472
	JESSUP2	JESSUP IN SEMINOLE CO.-SEE NOTE	28.72417	81.21472
	JESSUP3	JESSUP IN SEMINOLE CO.-SEE NOTE	28.72417	81.21472
	SEM-JESUP-1	Seminole-Jesup-1	28.72417	81.21472
	SEM-JESUP-2	Seminole-Jesup-2	28.72417	81.21472
	SEM-JESUP-3	Seminole-Jesup-3	28.72417	81.21472
	SEM-JESUPN	Seminole-Jesup North-1	28.76344	81.17889
	SEM-JESUPN	Seminole-Jesup North-2	28.76344	81.17889
	SEM-JESUPN	Seminole-Jesup North-3	28.76344	81.17889
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	87982	Sanform Experiment Stn	28.80000	81.23333
	88942	Titusville	28.61667	80.81667
Saint Johns River Water Management District (SJRWMD)				
Inflow	GCR419	GEE CREEK AT SR 419	28.70333	81.29111
	HOWCK	HOWELL CREEK AT MOUTH LAKE JESSUP	28.70111	81.25195
	OW-MBS	LAKE JESSUP MARL BED SLOUGH SITE	28.73789	81.23397
	OW-OBC	ORANGE BOAT CLUB WEST OF EXPRESS WAY	28.69944	81.23861
	SFDAC	SANFORD AVE CANAL AT MECCA HAMMOCK	28.73222	81.26472
	SLC419	SOLDIER CREEK AT SR 419	28.71861	81.30917
	T-1	Rotten Egg Slough on the East side of Lake Jesup	28.75769	81.17653
	T-10	Soldier Creek at SR419 off West End of Lake Jesup	28.71875	81.30898
	T-11	Marsh west of Sanford Effluent site spray fields	28.74845	81.17220
	T-12	Phelps Creek Delta at Pineway Rd north of Lk Jesup	28.74914	81.23219
	T-13	Chub Creek Delta inside Naked Place NE of Lk Jesup	28.76283	81.19614
	T-14	Soldiers Creek east side Lake Mary Rd	28.73361	81.33417
	T-14S	Clifton Spgs nr Orange Boat Club & west of bridge	28.69889	81.23722
	T-2	Salt Creek Delta on Upper East side of Lake Jesup	28.73267	81.16817
	T-3	Six Mile Creek at Sanford Ave Canal NE of Lk Jesup	28.72777	81.26432
	T-4	Sweetwater Creek west end Palm Ave east of Jesup	28.72161	81.17761
	T-4A	Sweetwater Creek delta by Lake Jesup	28.73290	81.18118
	T-5	Howell Creek Delta on SW end of Lake Jesup	28.70067	81.25267
	T-6	Howell Creek at SR434 So of Whites Lodge on Jesup	28.68986	81.24783
	T-7	Sweetwater Ck at DeLeon and Cress run upstm fr Jes	28.69422	81.20885

Table 7-1: Lake Jessup Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Inflow	T-8	Gee and Soldier Creek Delta west of Lake Jesup	28.71508	81.29305
	T-9	Gee Creek at SR419 off SW End of Lake Jesup	28.70339	81.29114
Outflow	OW-1	SJR in Government Cut N of Lk Jesup & SR46	28.78639	81.17975
	OW-SJR-1	Mid SJR east of Barge Canal & east of JJ Fish Camp	28.78725	81.16730
	OW-SJR-2	Mid SJR between Lakes Jesup and Monroe	28.79693	81.18148
	SJR-415	St. Johns River at 415 Bridge	28.80262	81.21015
Interior	ELJESS	LAKE JESSUP EAST LOBE NEAR MECCA HAM	28.73694	81.19695
	OW-2	Lk Jesup off Grassy Point	28.76477	81.17630
	OW-3	Lk Jesup betwn Seevee Island & Long Point	28.73492	81.18286
	OW-4	Lk Jesup W of bridge btwn Whites Lndg & Bird Islan	28.70528	81.25401
	OW-5	Lk Jesup between Caldwell Fields	28.70956	81.26072
	OW-6	Lk Jesup off center of Far W Arm	28.71490	81.27745
	OW-7	Lk Jesup betwn Marl Bed and Long Point	28.73906	81.21636
Seminole County, Florida (Seminole Co)				
Inflow	31901	LAKE JESSUP, MOUTH OF SOLDIERS CREEK.	28.71750	81.28750
	31902	LAKE JESSUP, MOUTH OF HOWELL CREEK.	28.70361	81.25417
	GEE	Gee Creek	28.70460	81.29170
	HOWC	Howell Creek	28.69130	81.24770
	NAV	Navy Canal at Pineway	28.74940	81.23190
	SIX	Six Mile Creek at Myrtle	28.73440	81.26670
	SOL	Soldiers Creek	28.71880	81.30960
Outflow	31780	ST. JOHNS RIVER, MARINA ISLE	28.78278	81.17083
	JES	St John's/Jesup Confluence	28.78580	81.18030
Interior	31903	LAKE JESSUP, OFF BIRD ISLAND.	28.72778	81.20139
U.S. Geological Survey (USGS)				
Inflow	2234344	HOWELL CREEK AT SR434 NR OVIEDO,FL	28.68972	81.24778
	2234384	SOLDIER CREEK NR LONGWOOD, FLA.	28.71861	81.30889
	2234400	GEE CREEK NR LONGWOOD, FLA.	28.70333	81.29028
Outflow	2234435	LAKE JESUP OUTLET NR SANFORD	28.78583	81.18056
US EPA--Storet (US EPA)				
Inflow	12230	SALT CREEK	28.71667	81.16666
	1223A1	GEE CREEK	28.70833	81.29166
	1223B1	SOLDIER CREEK	28.71667	81.30833
	1223C1	UNNAMED CREEK	28.72500	81.26667

Table 7-1: Lake Jessup Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Inflow	1223D1	HOWELL CREEK	28.69167	81.25000
	1223G1	SWEETWATER CREEK	28.70000	81.20834
Outflow	1223F1	ST JOHNS RIVER	28.78333	81.18333
Interior	122301	LAKE JESSUP	28.71111	81.22778
	122302	LAKE JESSUP	28.73861	81.19111
Volusia County, Florida (Volusia Co)				
Outflow	VC-045	St. John's River, at Lake Jessup, S. of S.R.46	28.77750	81.17583



1.5 0.75 0 1.5 Miles

NORTH

1 Inch equals 1.5 Miles

LEGEND

- Monitoring Station
- Cities
- Streams
- Roads
- Water Bodies
- County Boundaries

Burns & McDonnell SINCE 1898

Figure 7-1

LAKE JESSUP MONITORING STATIONS

- pH
- Total or dissolved calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station represents a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 7-2 through 7-9 contain the time series graphs for Lake Jessup for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data, principally flow data, are available back to the early 1970s for Lake Jessup. For the most part, relatively few water quality monitoring data are available for this lake before 1990. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow and phosphorus concentration data for use in calculating water and phosphorus balances at Lake Jessup. The graphs of available flow and phosphorus concentration data are shown in Figures 7-2 and 7-3, respectively. Figure 7-2 shows that lake outflow data are available only since 1993 and the most intensive water quality sampling has also occurred since this time (Figure 7-3). For this reason, water years 1995–2003 (10/1/1994–9/30/2003) were selected as the period of record for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are most prevalent during this same period.

After the analysis period was selected, the time series graphs for flow rate and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 7-10

Figure 7-2: Long-term Flow at Lake Jessup

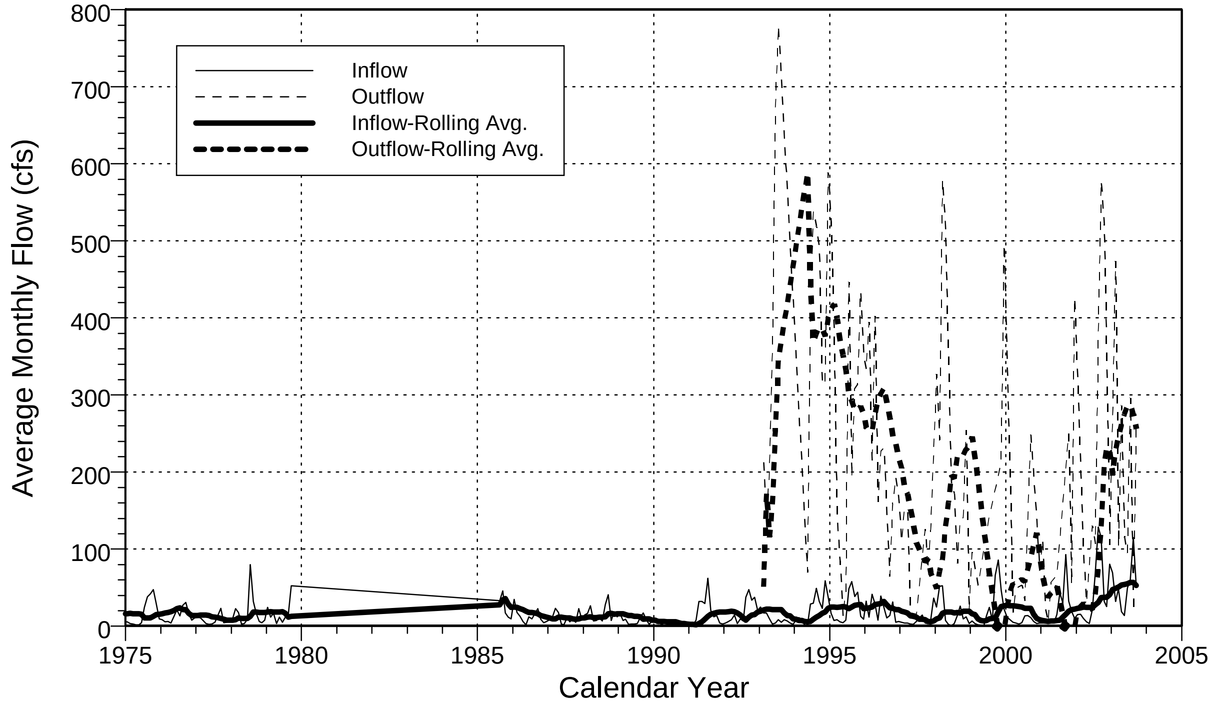


Figure 7-3: Long-term Total Phosphorus at Lake Jessup

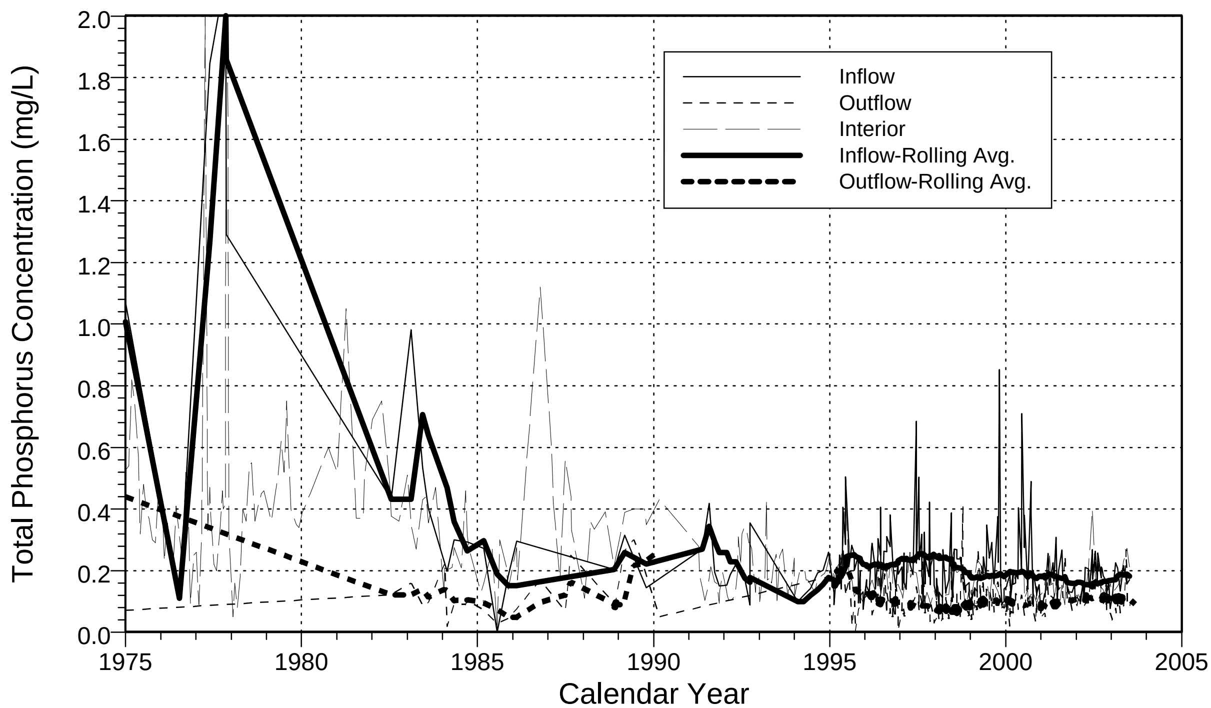


Figure 7-4: Long-term Orthophosphorus at Lake Jessup

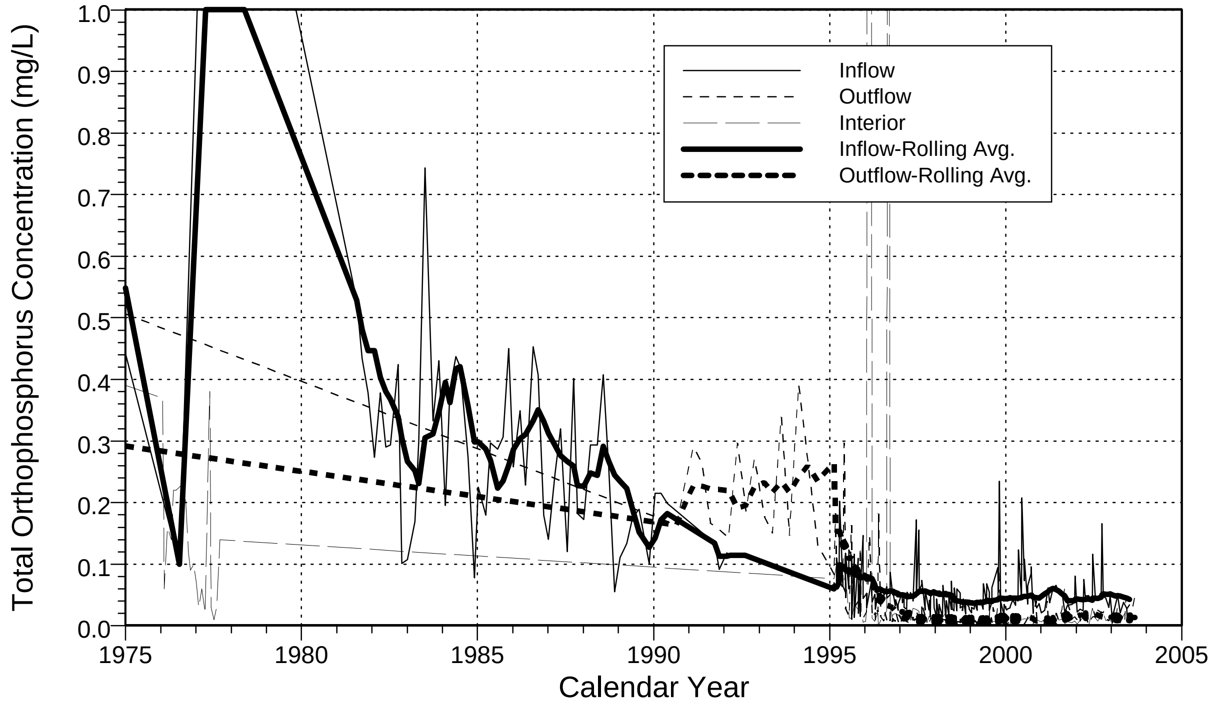


Figure 7-5: Long-term Total Nitrogen at Lake Jessup

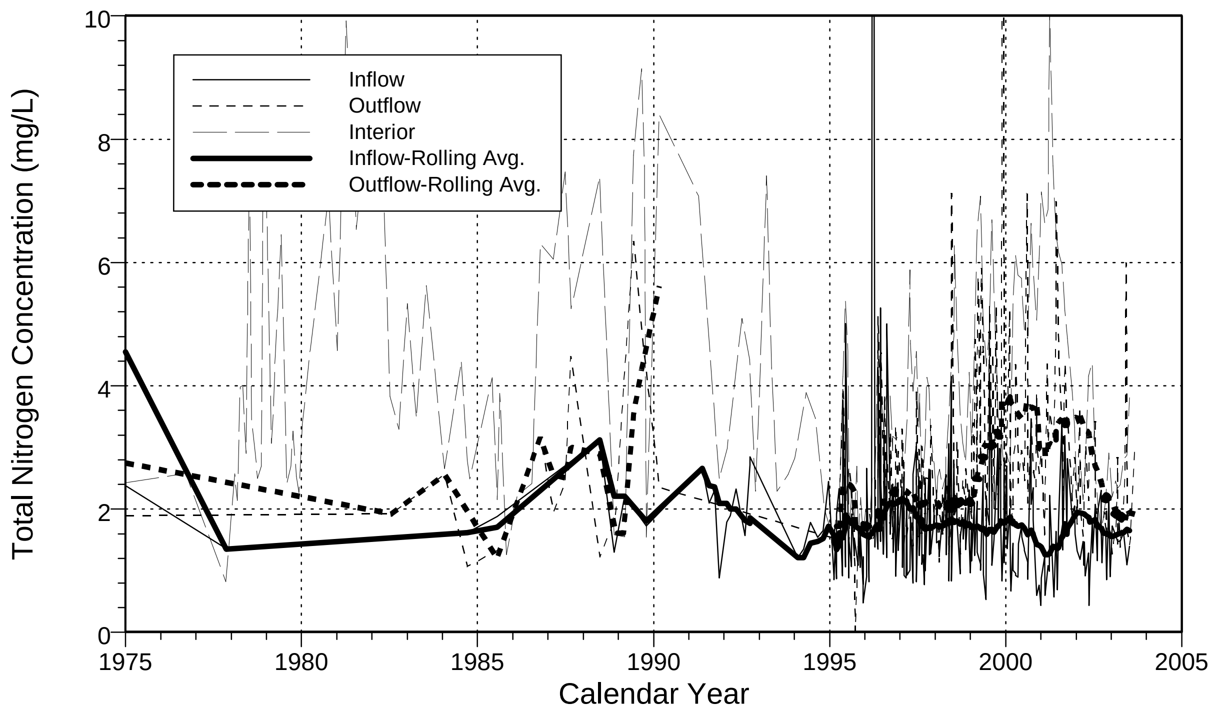


Figure 7-6: Long-term pH at Lake Jessup

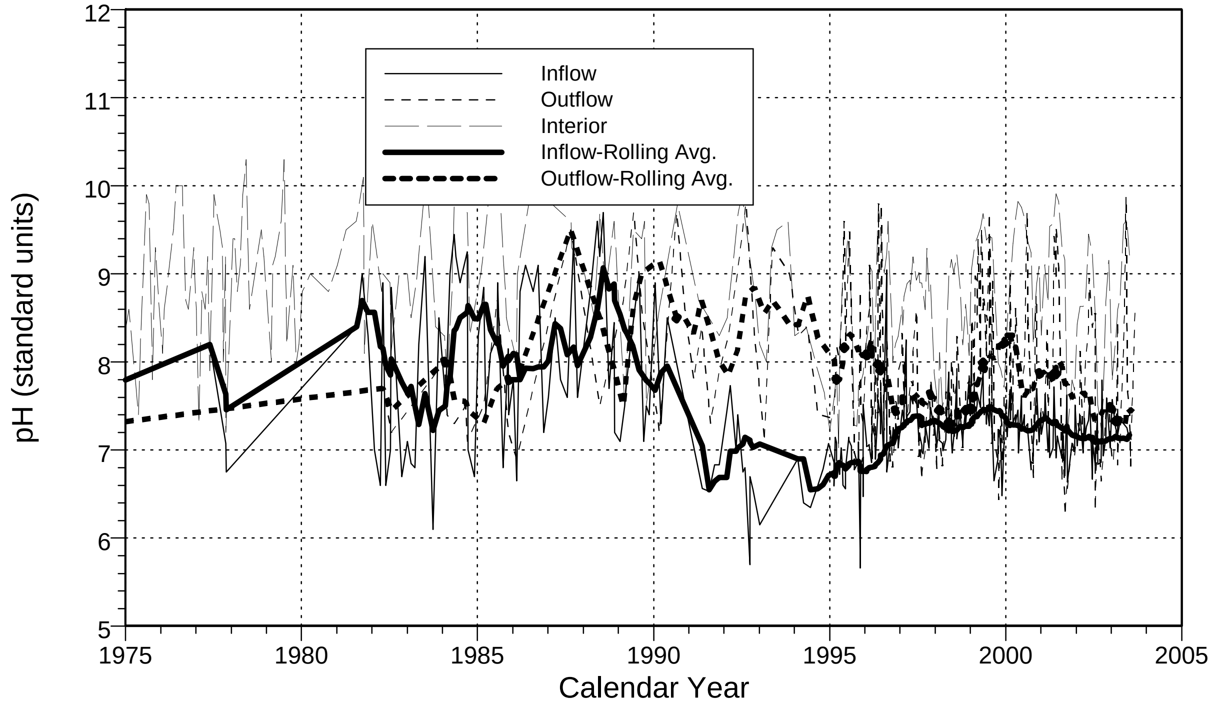


Figure 7-7: Long-term Total Calcium at Lake Jessup

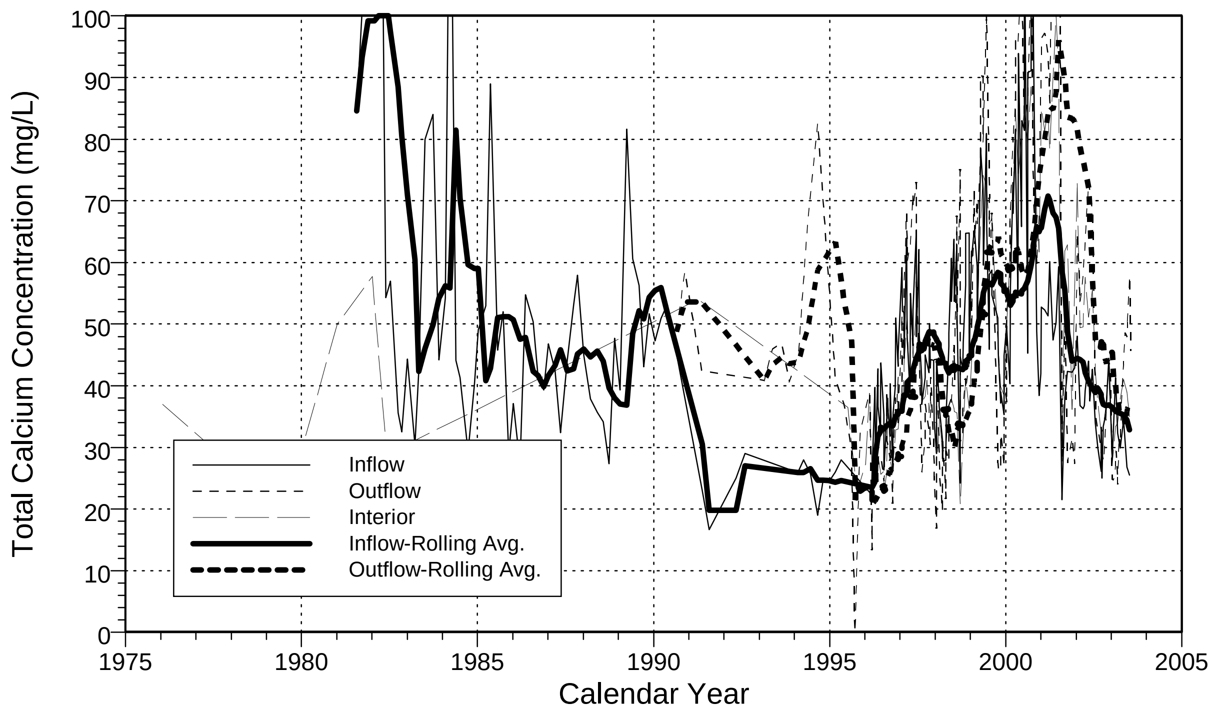


Figure 7-8: Long-term Water Surface Elevation at Lake Jessup

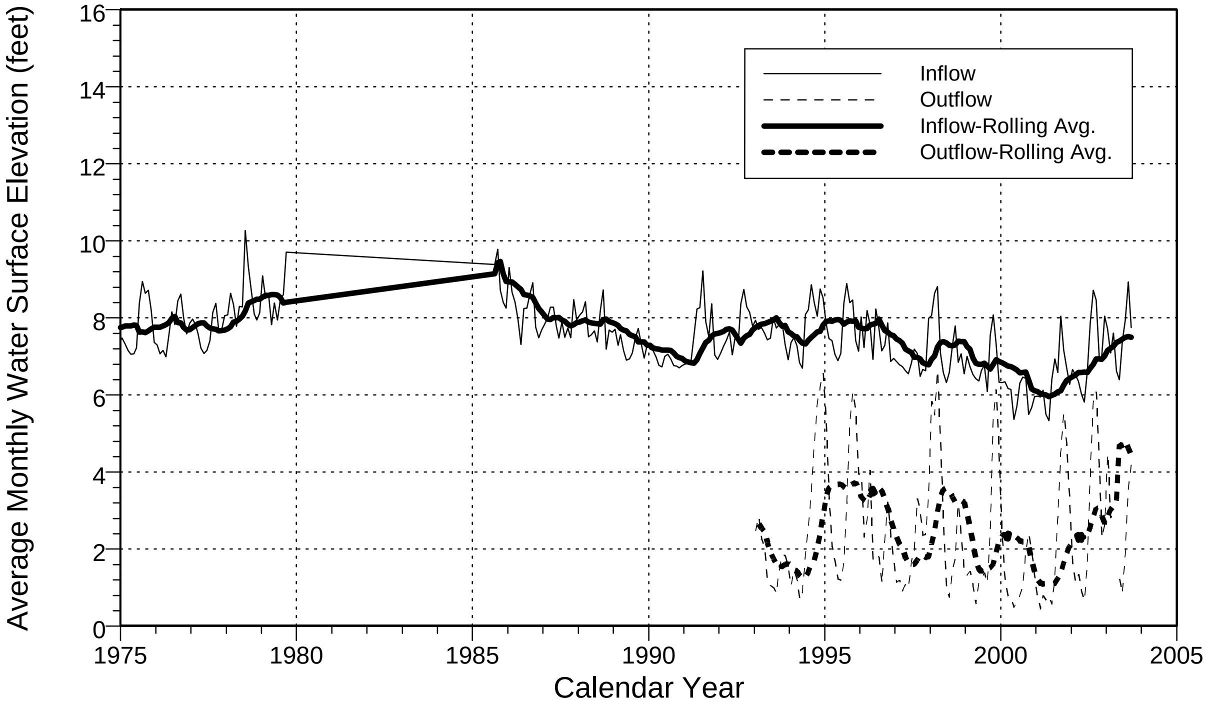
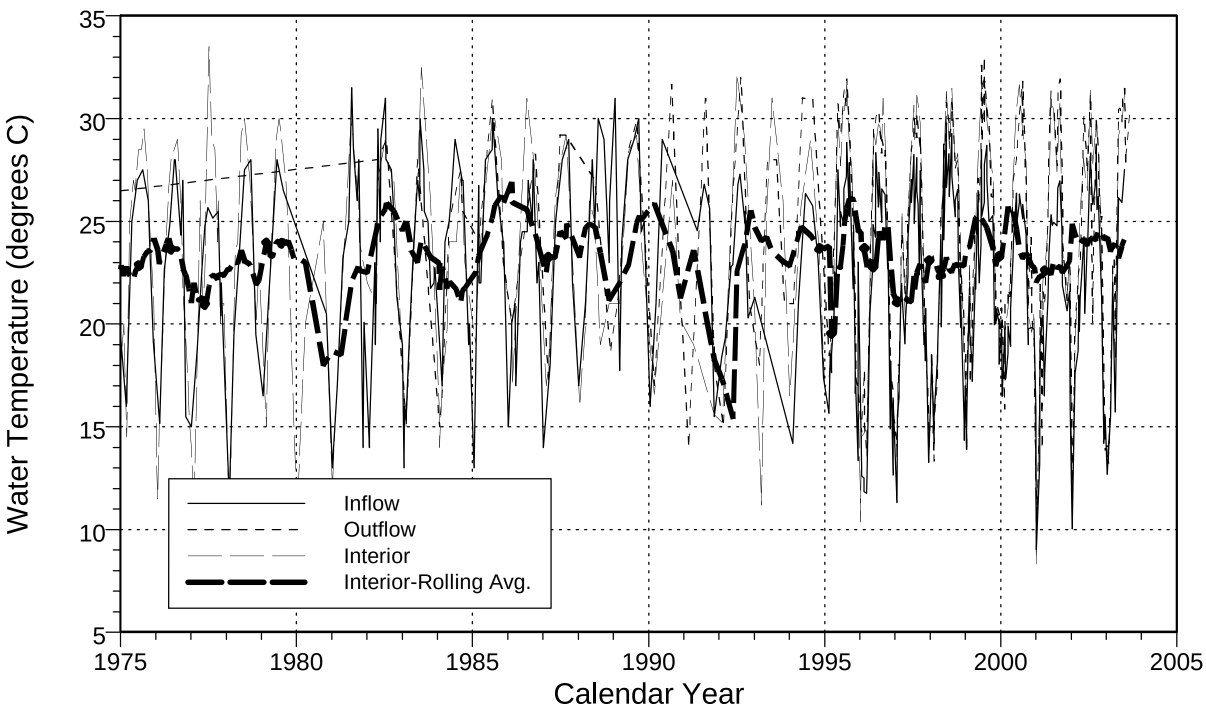


Figure 7-9: Long-term Water Temperature at Lake Jessup



through 7-11, better show the availability of data during this critical period. Table 7-2 includes descriptive statistics for key monitoring parameters at Lake Jessup. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will notice that relatively few non-detect samples occurred for the more significant parameters listed in Table 7-2.

7.3 WATER BALANCE

A daily water balance for Lake Jessup was developed for WY 1995–2003. This water balance included estimates of the following quantities for each day during the period of record.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

7.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage but a constant lake area of 13,110 acres was adopted for use in the water balance. This area estimate is based on an average of monthly data for 1995 from Parsons Engineering Science,

Figure 7-10: Analysis Period Flow at Lake Jessup

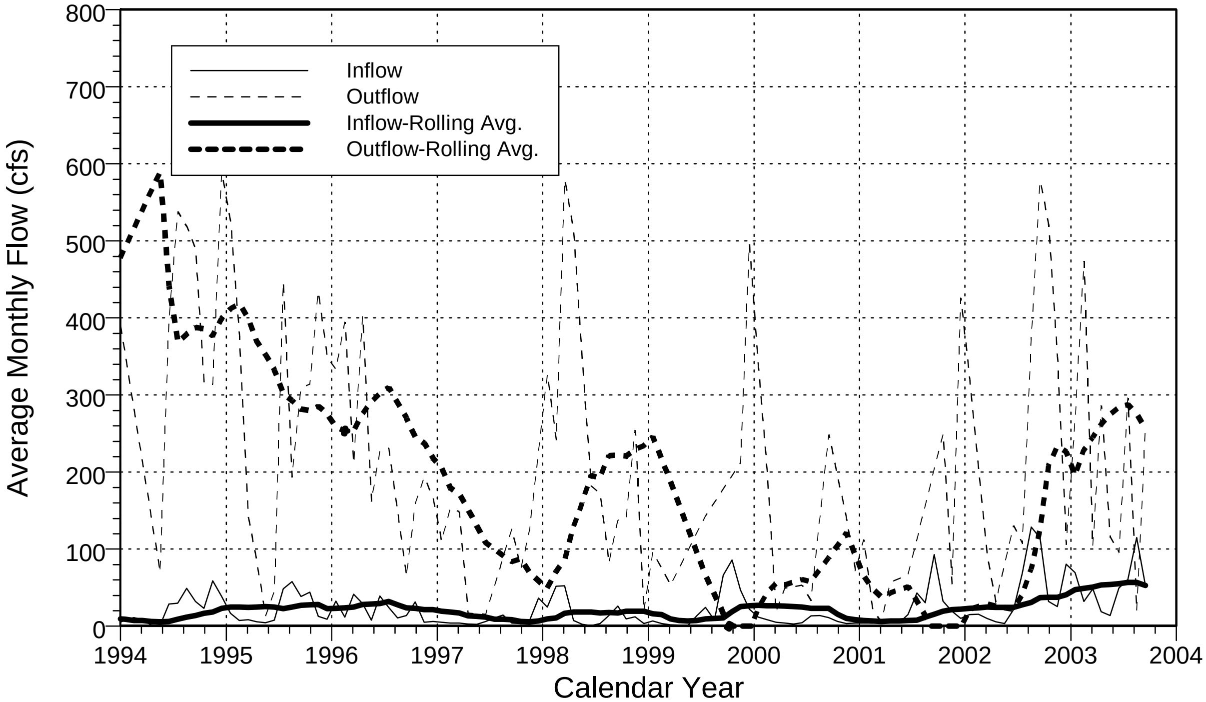


Figure 7-11: Analysis Period Total Phosphorus at Lake Jessup

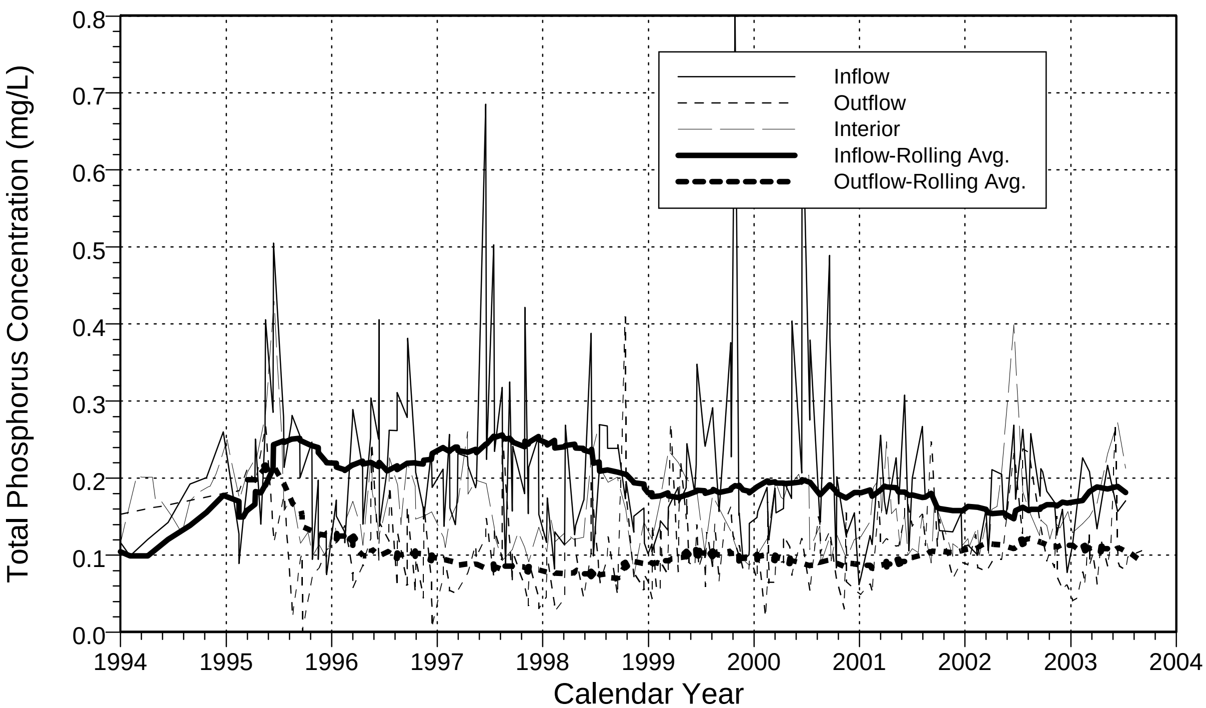


Table 7-2: Lake Jessup Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	902	0	46.480	1.260	197.300
		Outside	70	0	47.949	16.000	169.000
		Total	972	0	46.586	1.260	197.300
Calcium (mg/L)	Outflow	Inside	252	0	50.115	0.040	190.000
		Outside	10	0	51.800	40.600	82.600
		Total	262	0	50.179	0.040	190.000
Calcium (mg/L)	Interior	Inside	482	0	45.931	0.082	139.000
		Outside	9	0	36.126	20.230	57.700
		Total	491	0	45.751	0.082	139.000
Elevation (feet)	Inflow	Inside	7,677	0	7.044	4.420	14.760
		Outside	10,659	0	7.765	5.690	14.430
		Total	18,336	0	7.463	4.420	14.760
Elevation (feet)	Outflow	Inside	3,213	0	2.554	0.240	7.290
		Outside	536	0	1.696	0.390	5.230
		Total	3,749	0	2.431	0.240	7.290
Flow (cfs)	Inflow	Inside	8,137	0	25.378	0.110	629.000
		Outside	11,143	0	13.452	0.160	573.000
		Total	19,280	0	18.485	0.110	629.000
Flow (cfs)	Outflow	Inside	3,287	0	149.206	-2,940.000	1,890.000
		Outside	289	0	373.323	-959.000	1,010.000
		Total	3,576	0	167.318	-2,940.000	1,890.000
Orthophosphorus (mg/L)	Inflow	Inside	790	0	0.048	0.000	0.877
		Outside	143	0	0.554	0.025	4.500
		Total	933	0	0.126	0.000	4.500
Orthophosphorus (mg/L)	Outflow	Inside	269	0	0.017	0.000	0.297
		Outside	30	0	0.255	0.130	0.550
		Total	299	0	0.041	0.000	0.550
Orthophosphorus (mg/L)	Interior	Inside	506	0	0.023	0.000	3.000
		Outside	27	0	0.179	0.010	0.430
		Total	533	0	0.031	0.000	3.000
pH	Inflow	Inside	1,197	0	7.208	5.360	9.710
		Outside	224	0	7.659	5.700	9.800

POR: Inside=Within analysis period (10/1/1994-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 7-2: Lake Jessup Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Inflow	Total	1,421	0	7.279	5.360	9.800
pH	Outflow	Inside	884	0	7.673	6.150	9.880
		Outside	66	0	8.048	6.500	9.800
		Total	950	0	7.699	6.150	9.880
pH	Interior	Inside	1,333	0	8.627	6.590	10.160
		Outside	293	0	8.881	6.300	10.400
		Total	1,626	0	8.673	6.300	10.400
Phosphorus (mg/L)	Inflow	Inside	1,270	0	0.203	0.007	3.880
		Outside	153	0	0.823	0.002	4.900
		Total	1,423	0	0.269	0.002	4.900
Phosphorus (mg/L)	Outflow	Inside	353	1	0.097	0.001	0.495
		Outside	36	0	0.230	0.018	0.720
		Total	389	1	0.110	0.001	0.720
Phosphorus (mg/L)	Interior	Inside	658	0	0.157	0.021	0.747
		Outside	393	0	0.284	0.050	5.660
		Total	1,051	0	0.205	0.021	5.660
Temperature (deg C)	Inflow	Inside	1,191	0	21.429	9.020	34.040
		Outside	344	0	22.115	9.200	31.500
		Total	1,535	0	21.583	9.020	34.040
Temperature (deg C)	Outflow	Inside	886	0	23.217	9.270	33.380
		Outside	83	0	23.835	8.000	32.000
		Total	969	0	23.270	8.000	33.380
Temperature (deg C)	Interior	Inside	1,320	0	23.115	8.040	34.140
		Outside	180	0	22.741	10.800	33.500
		Total	1,500	0	23.070	8.040	34.140
Total Nitrogen (mg/L)	Inflow	Inside	2,903	0	1.745	0.060	23.200
		Outside	355	0	4.278	0.620	37.970
		Total	3,258	0	2.021	0.060	37.970
Total Nitrogen (mg/L)	Outflow	Inside	872	0	2.669	0.004	46.500
		Outside	81	0	3.351	1.070	12.600
		Total	953	0	2.727	0.004	46.500
Total Nitrogen (mg/L)	Interior	Inside	1,520	0	3.755	1.040	16.100

POR: Inside=Within analysis period (10/1/1994-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 7-2: Lake Jessup Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Total Nitrogen (mg/L)	Interior	Outside	225	0	4.423	0.820	14.880
		Total	1,745	0	3.841	0.820	16.100

POR: Inside=Within analysis period (10/1/1994-9/30/2003); Outside=Outside analysis period; Total=All available data.

Inc. (2000). The inaccuracies introduced by this simplifying assumption are not considered to be significant as most of these errors will tend to balance out over time.

7.3.2 Inflow

The USGS operates three gages on streams upstream of Lake Jessup. These three stations, listed previously in Table 7-1, are on Howell Creek (No. 02234344), Soldier Creek (No. 02234384), and Gee Creek (No. 02234400). The gaged inflow to Lake Jessup was calculated as the sum of the discharge at these three gages.

The Howell, Soldier and Gee Creek gages have a combined contributing drainage area of 86 square miles (52, 21.2 and 12.8 square miles, respectively). The total watershed of Lake Jessup however is approximately 150 square miles. From detailed analyses for 1995, Parsons (2000) estimated the ungaged inflow to Lake Jessup to be approximately 64 percent of the gaged inflow. Therefore, the ungaged inflow to Lake Jessup was initially estimated from the total discharge at the three above stream gages times 0.64.

7.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Lake Jessup can represent a significant lake inflow. Rainfall depths at Lake Jessup over the period of record were estimated from records maintained by NOAA for the Sanford Experiment Station (Station No. 8-7982) (NOAA, 2002). This station is located approximately four miles north of Lake Jessup. The period of record for these precipitation data ended in 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Lake Jessup by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

7.3.4 Evaporation Depth and Volume

No evaporation data for Lake Jessup were located during Task 2 so lake evaporation was estimated from pan evaporation data available at Lisbon, Florida (NOAA, 2002). This climate station (No. 8-5076) is located about 32 miles west-northwest of Lake Jessup. Water will evaporate faster from an evaporation pan than a lake because a pan is a much smaller body of water and will heat up much more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Lake Jessup vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value for the entire interval is available. To smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. No pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Lake Jessup were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

7.3.5 Outflow

The outlet from Lake Jessup is located adjacent to the St. Johns River. The USGS maintains a stream gage at this location (No. 02234435). Review of the data for this gage shows that the flow at this gage reverses at times, with water flowing from the St. Johns River into Lake Jessup. The records at this stream gage were used to estimate the gaged outflow from Lake Jessup. Ungaged outflow was assumed to always be zero because Lake Jessup has no other outlets.

7.3.6 Elevation and Change in Storage

No long-term daily stage or water surface elevation data were located for Lake Jessup. However, the USGS does record daily gage height data, which is the basis for the corresponding discharge estimates, at each of the stream gages previously mentioned. Using the corresponding gage datum, gage height records can be converted to water surface elevations at the gage location. For lack of better data, the estimated elevations at the Lake Jessup outlet gage were used as a surrogate for actual lake elevation data. The day-to-day changes in these elevations were assumed to be representative of the changes in lake elevation also. The corresponding changes in lake storage were then estimated as the products of these stage changes and the lake surface area. The available gage height readings are mean daily values and are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation was estimated as the average of the gage heights for the current and following day.

The bottom elevation of Lake Jessup was estimated by comparison of depth readings recorded when water samples were collected and the corresponding estimates of stream elevation at the outlet gage. Using a median value, the bottom elevation of Lake Jessup is estimated to be -2.9 feet. This bottom elevation estimate was used to develop lake depth estimates for the entire analysis period.

7.3.7 Imbalance

Theoretically, the sum of all lake inflows (gaged inflow + ungaged inflow + precipitation volume) less all outflows (gaged outflow + ungaged outflow + evaporation) should equal the computed change in storage each day. However, this equality never occurred in practice. Because of the inaccuracies in these methods an imbalance quantity was calculated for each day. These imbalances are positive on some days (too much inflow or positive storage change) and negative on others (too much outflow or negative storage change). Totaling these imbalances over the entire seven-year period of record indicated that, in general, the estimated inflows exceeded measured outflows. To improve the quality of these estimates, ungaged inflows were adjusted downward by 6 percent.

Table 7-3 presents an annual summary of the Lake Jessup water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 7-3: Lake Jessup Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1995	134,246	71,417	41,133	202,422	3,474	-40,561
1996	113,275	71,985	45,741	188,055	-49,687	1,531
1997	40,736	51,229	41,025	59,840	4,195	-13,322
1998	90,790	65,872	41,879	159,238	8,063	-52,517
1999	47,532	40,608	38,119	16,123	6,358	27,540
2000	69,288	47,065	43,367	70,564	-22,287	24,709
2001	66,390	53,948	39,580	-36,113	27,203	85,776
2002	133,269	53,597	45,151	139,576	-12,782	15,044
2003	178,759	55,276	46,492	173,068	-17,240	31,715
Total	874,285	510,997	382,488	972,773	-52,702	79,916

7.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Lake Jessup using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the period of record.

- Inflow TP concentration and flux

- Direct deposition load to Lake Jessup
- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

7.4.1 Inflow TP Concentration and Flux

During the selected period of record (WY 1995–2003), inflow TP concentration data are available for 206 days for an average sample frequency of once every 16 days. Table 7-4 lists the specific stations and numbers of available samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of the inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variables: Monthly precipitation in inches (P) and common logarithm of inflow rate in cfs (log Q)
- Model: log [TP] = -0.741 + 0.027 P – 0.056 log Q
- Coefficient of determination (R^2): .175

Table 7-4: TP Monitoring Stations at Lake Jessup

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	20010051	SALT CREEK AT PACKARD AVE. NEAR OVIEDO	1
	20010090	SWEETWATER CREEK 0.15 MI. S. OF HOWARD AVE.	1
	20010127	SHORTCUT CANAL 100 YDS. DOWNSTREAM HOWA	1
	20010184	Soldier Creek 100 yards downstream of S.R. Highway	9
	20010185	Gee Creek at S.R. Highway 419	7
	20010187	L JESSUP, US CNL TO AT SIPES AVE	1
	20010294	ELDER SPRINGS RUN AT MYRTLE AVE. - SANFORD	1
	20010354	BLACK SWEETWATER CREEK AT HOWARD AVE.	1
Seminole	GEE	Gee Creek	56
	HOWC	Howell Creek	54
	NAV	Navy Canal at Pineway	15
	SIX	Six Mile Creek at Myrtle	15
	SOL	Soldiers Creek	56
SJRWMD	GCR419	GEE CREEK AT SR 419	5
	OW-MBS	LAKE JESSUP MARL BED SLOUGH SITE	5
	OW-OBC	ORANGE BOAT CLUB WEST OF EXPRESS WAY	2
	SLC419	SOLDIER CREEK AT SR 419	5
	T-1	Rotten Egg Slough on the East side of Lake Jesup	60
	T-10	Soldier Creek at SR419 off West End of Lake Jesup	61
	T-11	Marsh west of Sanford Effluent site spray fields	43
	T-12	Phelps Creek Delta at Pineway Rd north of Lk Jesup	63
	T-13	Chub Creek Delta inside Naked Place NE of Lk Jesup	41
	T-14	Soldiers Creek east side Lake Mary Rd	1
	T-14S	Clifton Spgs nr Orange Boat Club & west of bridge	1
	T-2	Salt Creek Delta on Upper East side of Lake Jesup	64
	T-3	Six Mile Creek at Sanford Ave Canal NE of Lk Jesup	96
	T-4	Sweetwater Creek west end Palm Ave east of Jesup	91
	T-4A	Sweetwater Creek delta by Lake Jesup	25
	T-5	Howell Creek Delta on SW end of Lake Jesup	111
	T-6	Howell Creek at SR434 So of Whites Lodge on Jesup	64
	T-7	Sweetwater Ck at DeLeon and Cress run upstm fr Jes	101
	T-8	Gee and Soldier Creek Delta west of Lake Jesup	152
	T-9	Gee Creek at SR419 off SW End of Lake Jesup	61
Interior Stations			
FDEP	20010183	LAKE JESSUP NE SECTOR	16
FGFWF	03080101-230	St. Johns River Station 45	3

Table 7-4: TP Monitoring Stations at Lake Jessup

Agency	Station	Station Name	Number of Samples
LakeWatc	JESSUP2	JESSUP IN SEMINOLE CO.-SEE NOTE	2
	JESSUP3	JESSUP IN SEMINOLE CO.-SEE NOTE	2
	SEM-JESUP-1	Seminole-Jesup-1	6
	SEM-JESUP-2	Seminole-Jesup-2	8
	SEM-JESUP-3	Seminole-Jesup-3	8
	SEM-JESUPN	Seminole-Jesup North-1	19
	SEM-JESUPN	Seminole-Jesup North-2	19
	SEM-JESUPN	Seminole-Jesup North-3	19
SJRWMD	OW-2	Lk Jesup off Grassy Point	104
	OW-3	Lk Jesup betwn Seevee Island & Long Point	63
	OW-4	Lk Jesup W of bridge btwn Whites Lndg & Bird Islan	105
	OW-5	Lk Jesup between Caldwell Fields	81
	OW-6	Lk Jesup off center of Far W Arm	133
	OW-7	Lk Jesup betwn Marl Bed and Long Point	70
Outflow Stations			
Seminole	JES	St John's/Jesup Confluence	66
SJRWMD	OW-1	SJR in Government Cut N of Lk Jesup & SR46	64
	OW-SJR-1	Mid SJR east of Barge Canal & east of JJ Fish Camp	92
	OW-SJR-2	Mid SJR between Lakes Jesup and Monroe	91
	SJR-415	St. Johns River at 415 Bridge	12
Volusia C	VC-045	St. John's River, at Lake Jessup, S. of S.R.46	29

This "best" regression model was used to help estimate inflow TP concentrations to Lake Jessup.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less reliable.

At Lake Jessup, missing inflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based on the interpolation method and the regression model. Once these estimates of daily inflow TP concentrations were developed, the phosphorus influx to Lake Jessup was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance.

7.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Lake Jessup is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 $\mu g/m^2$ while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn & James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

7.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Lake Jessup were identical to those used for lake inflow. During the selected period of record (WY 1995–2003), outflow TP concentration data are available for 196 days, yielding an average sample frequency of once every 17 days. Both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, none of the independent variables met the criteria for inclusion in the model, which indicates that no significant relationship exists between outflow TP concentration and these independent variables. No regression model was therefore used to help estimate outflow TP concentrations.

Therefore, the simple straight-line interpolation process described above was used to estimate missing outflow TP concentrations between actual sample dates. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Lake Jessup was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

7.4.4 Net Phosphorus Retention

The net phosphorus retention in Lake Jessup was estimated as total influx in inflow and deposition less discharge flux in outflow. As such, these net retention values include the phosphorus retained or discharged due to changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Lake Jessup is shown in Table 7-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

Table 7-5: Lake Jessup Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1995	38,001	2,471	39,747	724
1996	30,002	2,482	24,182	8,301
1997	11,487	2,237	5,567	8,156
1998	21,454	2,407	16,490	7,371
1999	12,799	2,114	2,249	12,664
2000	21,836	2,193	5,867	18,163
2001	17,357	2,269	-8,492	28,117
2002	31,977	2,264	23,393	10,848
2003	22,989	2,284	17,267	9,297
Total	207,901	20,721	126,271	103,643

7.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Lake Jessup were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. These monthly data sets include the following data values:

- Average water surface area (ha)
- Total inflow and outflow volumes (m^3)
- Total mass flux of phosphorus in, out and retained in the lake (g)
- Flow-weighted average inflow and outflow phosphorus concentrations (mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

7.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 7-12. From review of this graph, it is not apparent a significant linear relationship exists between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .020.

7.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. A scatter diagram for settling rate vs. hydraulic loading rate is shown in Figure 7-13. A regression model for these variables has a R^2 of .533. The next best model is with calcium concentration as the independent variable (R^2 = .164).

Figure 7-12: Retention Efficiency vs. Hydraulic Loading Rate at Lake Jessup

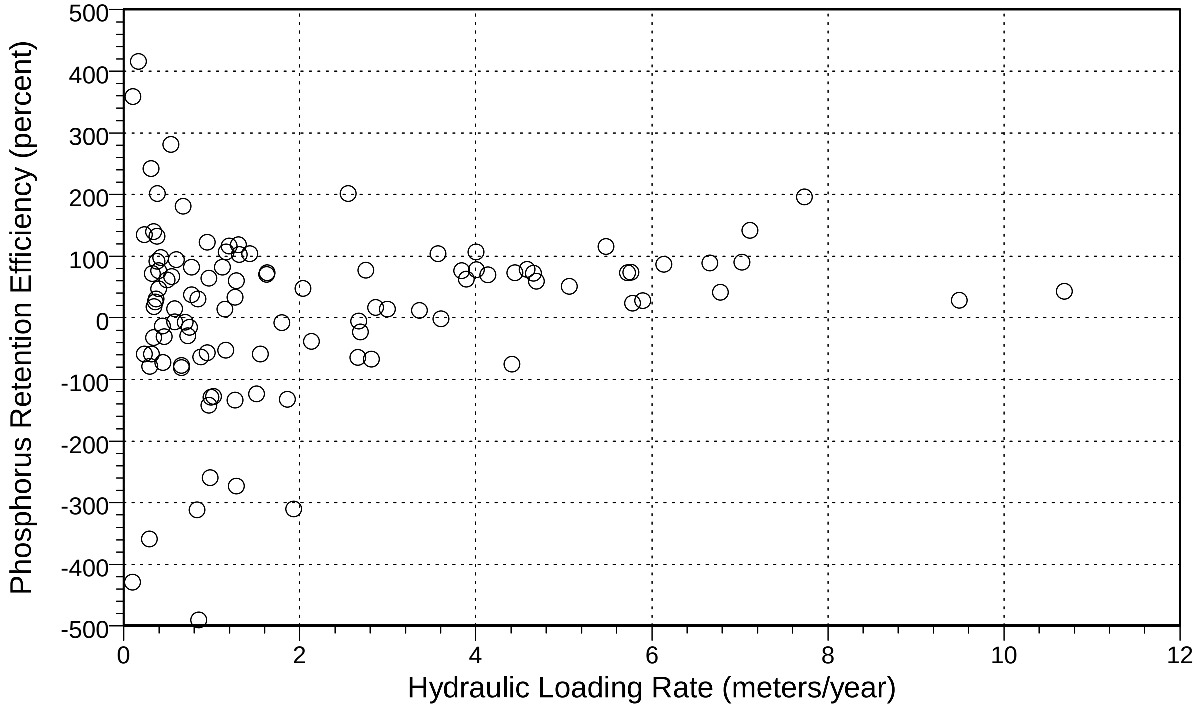
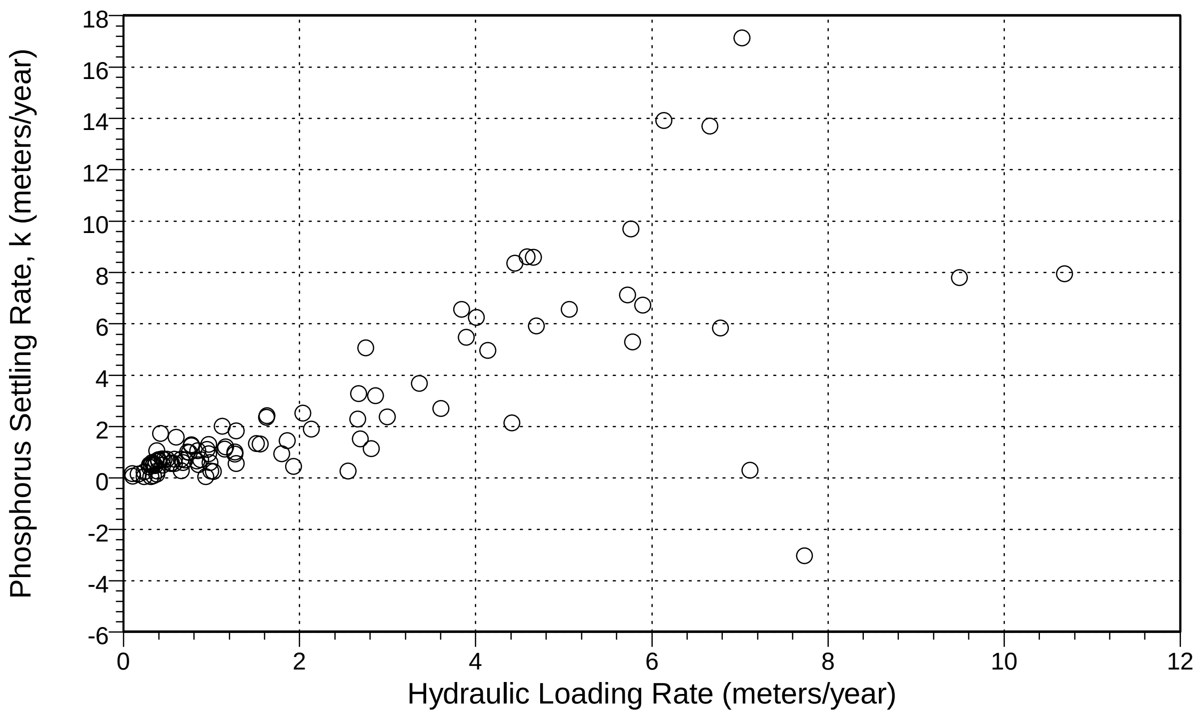


Figure 7-13: Settling Rate vs. Hydraulic Loading Rate at Lake Jessup



7.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Lake Jessup from the DEP's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

A total of 58 species of wetland and aquatic plants were recorded for Lake Jessup during the BIPM surveys. These included 44 species of emergent wetland plants, 7 species of floating aquatic plants, and 7 species of submerged aquatic plants. Dominant emergent wetland species included common reed, cattails, and pennywort. The dominant floating species was filamentous algae. There was very little submerged aquatic vegetation present in Lake Jessup.

Table 7-6 summarizes the estimated cover by vegetation type for Lake Jessup for the period from 1983 through 2003. The average cover by vegetation type was emergent – 737 acres, floating – 156 acres, and submerged – 4 acres. These estimated plant coverages show that plants occupy a very small fraction of the estimated 8,013-acre surface area of Lake Jessup.

Table 7-6: Lake Jessup Vegetation Data

Survey Month	Vegetation Coverage by Type (acres)		
	Emergent	Floating	Submerged
Oct-83	625	445	5.5
Nov-84	990	330	14.0
Aug-86	1,066	121	3.0
Sep-88	1,161	155	2.0
Sep-90	871	110	0.3
Aug-92	809	67	5.2
May-95	187	8.9	0.6
Aug-03	183	14.0	0.8
Average	737	156	3.9
Median	840	115	2.5
Maximum	1,161	445	14
Minimum	183	8.9	0.3

* * * * *

8 LAKE THONOTOSASSA

8 LAKE THONOTOSASSA

Lake Thonotosassa is located in Hillsbourgh County, approximately 12 miles northeast of central Tampa (Figure 1-1). Lake Thonotosassa is within the Southwest Florida Water Management District (SWFWMD). The data collected for Lake Thonotosassa and the analyses completed with these data are described in the balance of this chapter.

8.1 DATA SOURCES

The data for Lake Thonotosassa were collected from a number of sources. These sources are listed in Table 8-1 along with a listing of the individual sample stations obtained from each source. For each sampling station, this table also lists the station's absolute location (latitude/longitude coordinates) and location relative to Lake Thonotosassa. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 8-1 shows the locations of these monitoring stations.

8.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 8-1: Lake Thonotosassa Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	24030014	L THONOTOSASSA MOUTH BAKER CR	28.05186	82.27108
	24030034	BAKER CRK AT THNTSSA PLNT CTY RD	28.04639	82.26778
Outflow	24030029	L THONOTOSASSA MOUTH FLINT CR	28.06806	82.26806
	24030030	L THONOTOSASSA BTW CTR L FLINT C	28.06933	82.27314
Interior	24030015	L THONOTOSASSA 30 FT FRM SE SHOR	28.05400	82.27114
	24030016	L THONOTOSASSA 50 FT FRM SE SHOR	28.05461	82.27203
	24030017	L THONOTOSASSA 400 FT FR BAKER CR	28.05381	82.27219
	24030018	L THONOTOSASSA 200 FT FR SE SHORE	28.05072	82.27394
	24030019	L THONOTOSASSA 400 FT FRM S SHOR	28.05083	82.27725
	24030020	L THONOTOSASSA 400 FT FRM S HOR	28.05175	82.28067
	24030021	L THONOTOSASSA 1000 FT OUT BAKER CR	28.05369	82.27403
	24030022	L THONOTOSASSA CENTER L	28.06114	82.27908
	24030023	L THONOTOSASSA FR REESE BCH DOCK	28.05306	82.28447
	24030024	L THONOTOSASSA REESE BCH	28.05306	82.28447
	24030025	L THONOTOSASSA 300 FT FR W SHORE	28.05778	82.28486
	24030026	L THONOTOSASSA 400 FT FR NW SHORE	28.06342	82.28486
	24030031	L THONOTOSASSA 300 FT FR W SHORE	28.06778	82.26917
	24030033	L THONOTOSASSA 300 FT FRM W SHOR	28.05717	82.27322
	24030124	L34P - LAKE THONOTOSASSA	28.04944	82.27694
Florida LAKEWATCH (LakeWatch)				
Interior	Thonotosassa	Thonotosassa (Hillsborough Co) Florida LAKEWATC	28.06417	82.28139
Hillsborough County, Florida (Hills. Co)				
Outflow	118	Lake Thonotosassa at mouth of Flint Creek		
Interior	135	Lake Thonotasassa center		
Southwest Florida Water Management District (SWFWMD)				
Inflow	FLO-20	BAKER CANAL	28.02529	82.26338
	FLO-389	FLINT CRK UPSTREAM	28.06808	82.26788
	RNF-407	BAKER CANAL	28.02529	82.26342
Interior	RNF-21	LK THONOTOSASSA FLINT CRK	28.04974	82.27897
	STA-242	LAKE THONOTOSASSA (REG)	28.04972	82.27896
Exterior-U	FLO-88	FLINT CRK DOWNSTREAM LT1	28.06819	82.26756
	RNF-69	DOVER ET	28.01502	82.23231

Table 8-1: Lake Thonotosassa Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
U.S. Geological Survey (USGS)				
Inflow	02303271	BAKER CREEK NEAR THONOTOSASSA FL	28.04778	82.26778
	280313082162	LK THONOTOSASSA SITE14 (TOP) AT THONOT	28.05361	82.27389
Outflow	02303300	FLINT CREEK NEAR THONOTOSASSA FL	28.06778	82.26778
	2303300	FLINT CREEK NEAR THONOTOSASSA FL	28.06778	82.26788
	280405082162	LK THONOTOSASSA SITE10 (TOP) AT THONOT	28.06806	82.27361
Interior	02303290	LAKE THONOTOSASSA NEAR THONOTOSASSA	28.05917	82.28584
	280313082165	LK THONOTOSASSA SITE15 (TOP) AT THONOT	28.05361	82.28056
	280338082162	LK THONOTOSASSA SITE13 (TOP) AT THONOT	28.06056	82.27417
	280338082165	LK THONOTOSASSA SITE12 (TOP) AT THONOT	28.06056	82.28250
	280405082164	LK THONOTOSASSA SITE11 (TOP) AT THONOT	28.06806	82.27944
Unknown	2.8031308216e			
	2.8031308217e			
	2.8033808216e			
	2.8033808217e			
	2.8040508216e			
Exterior-D	2303313	CAMPBELL BRANCH NEAR THONOTASSSSA FL	28.05250	82.24944
	2303330	HILLSBOROUGH R AT MORRIS BR NEAR THON	28.09722	82.31250
	2303351	MORRIS BRIDGE BACKWASH POND OUTFLOW	28.12167	82.37194

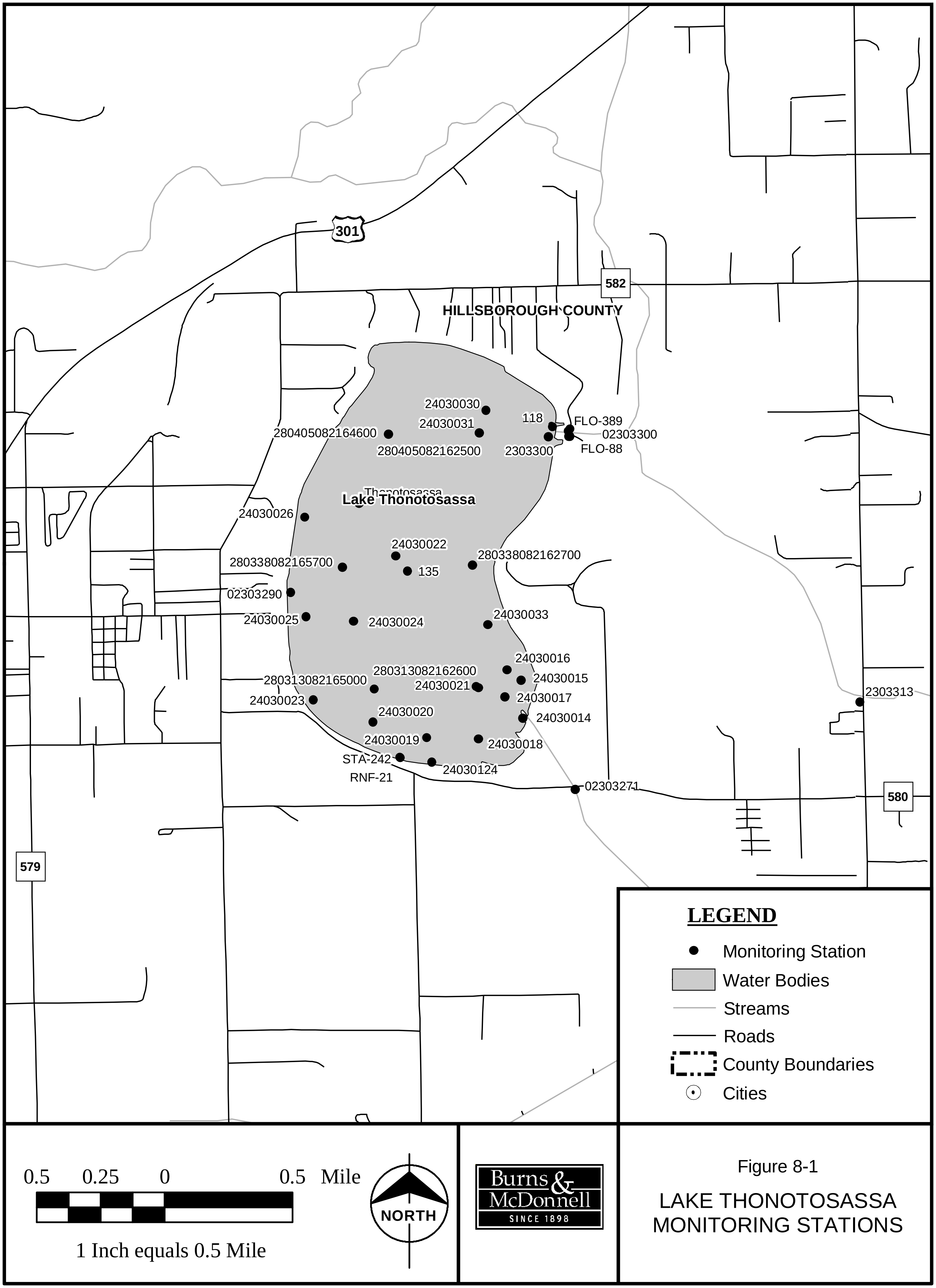


Figure 8-1

LAKE THONOTOSASSA MONITORING STATIONS

- pH
- Total or dissolved calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station represents a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 8-2 through 8-9 contain the time series graphs for Lake Thonotosassa for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data, principally flow data, are available back to the early 1950s for Lake Thonotosassa. For the most part, relatively few water quality monitoring data available for this lake before 1975. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow rate and phosphorus concentration data for use in calculating water and phosphorus balances at Lake Thonotosassa. The graphs of available flow and phosphorus concentration data are shown in Figures 8-2 and 8-3, respectively. Figure 8-2 shows that lake outflow data are unavailable after WY 1991. This potential data site is the only one in this study without recent inflow and/or outflow data. Water years 1981–1991 (10/1/1980–9/30/1991) were selected as the period of record for subsequent analyses. Unfortunately, the time series graphs for the other key monitoring parameters show most of these data were collected after 1991 so they do not coincide with the selected analysis period.

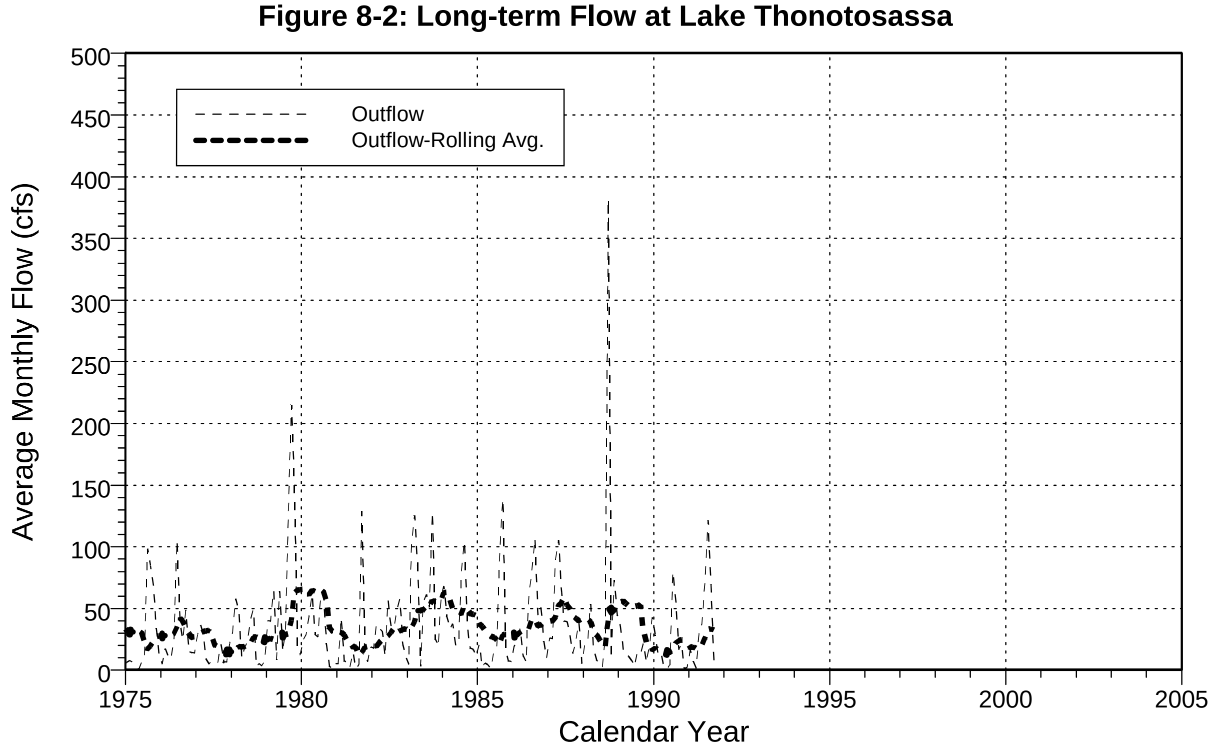


Figure 8-2: Long-term Flow at Lake Thonotosassa
Average Monthly Flow (cfs)
Calendar Year
Outflow
Outflow-Rolling Avg.
0
50
100
150
200
250
300
350
400
450
500
1975
1980
1985
1990
1995
2000
2005

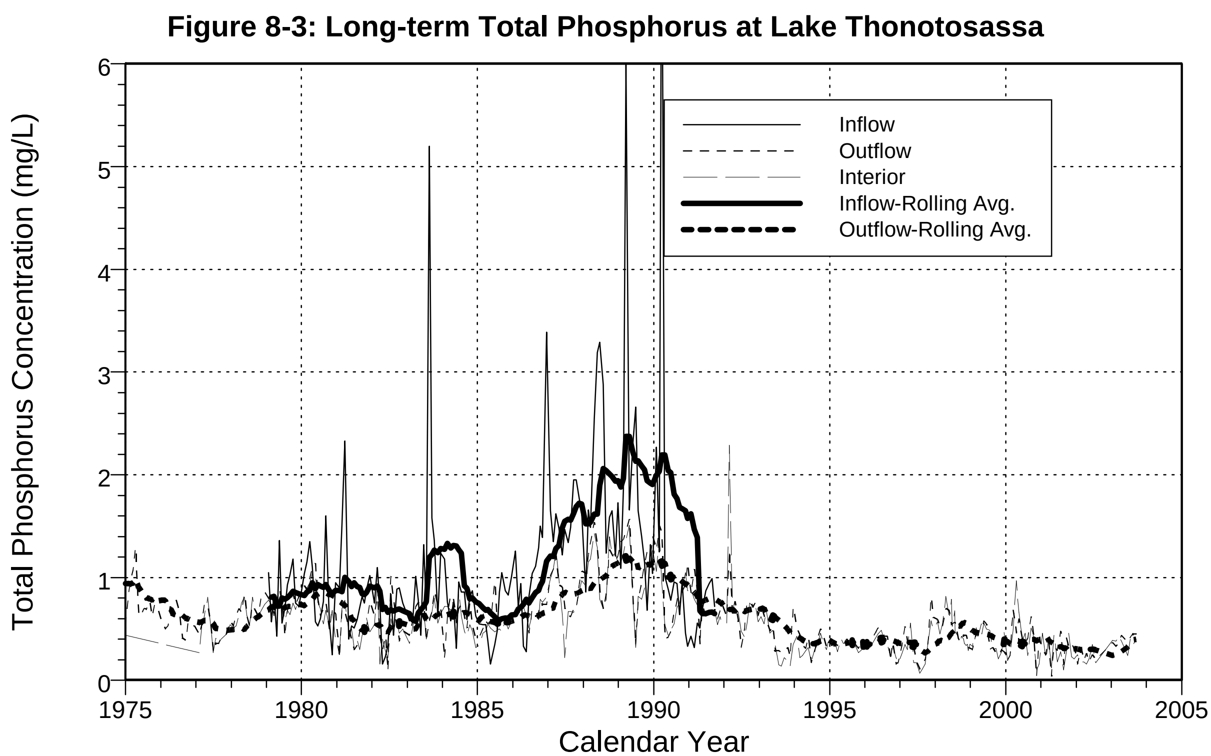


Figure 8-3: Long-term Total Phosphorus at Lake Thonotosassa
Total Phosphorus Concentration (mg/L)
Calendar Year
Inflow
Outflow
Interior
Inflow-Rolling Avg.
Outflow-Rolling Avg.
0
1
2
3
4
5
6
1975
1980
1985
1990
1995
2000
2005

Figure 8-4: Long-term Orthophosphorus at Lake Thonotosassa

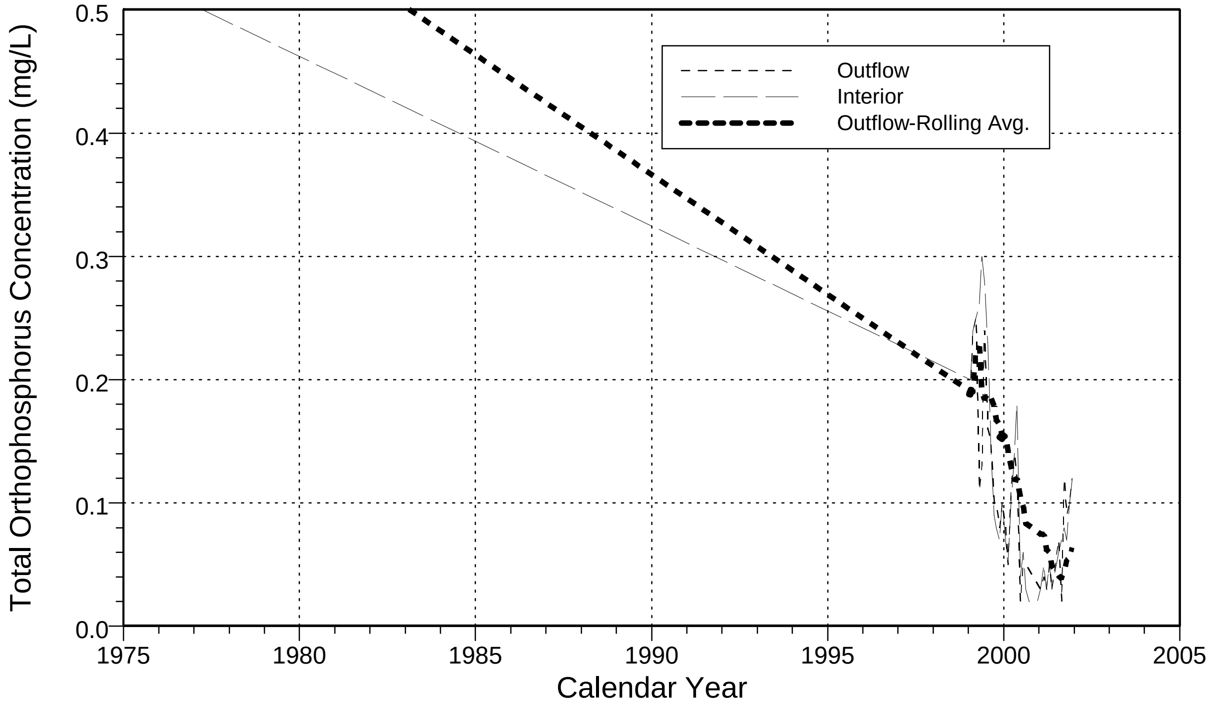


Figure 8-5: Long-term Total Nitrogen at Lake Thonotosassa

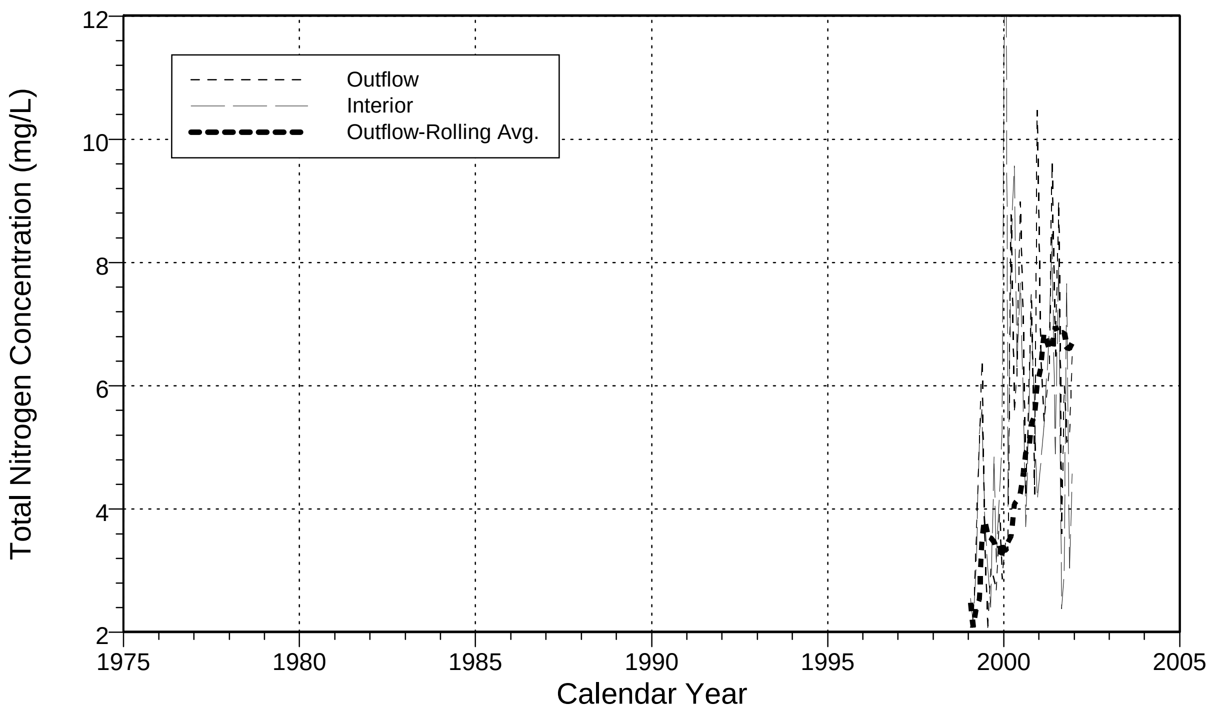


Figure 8-6: Long-term pH at Lake Thonotosassa

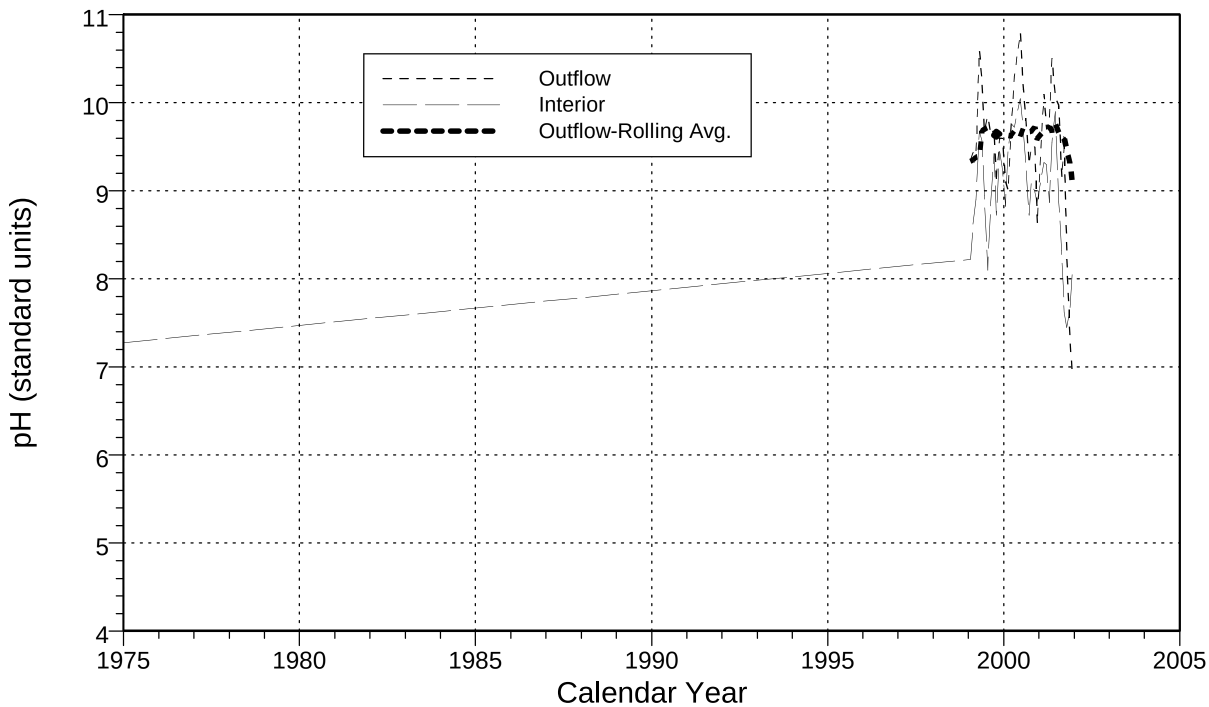


Figure 8-7: Long-term Total Calcium at Lake Thonotosassa

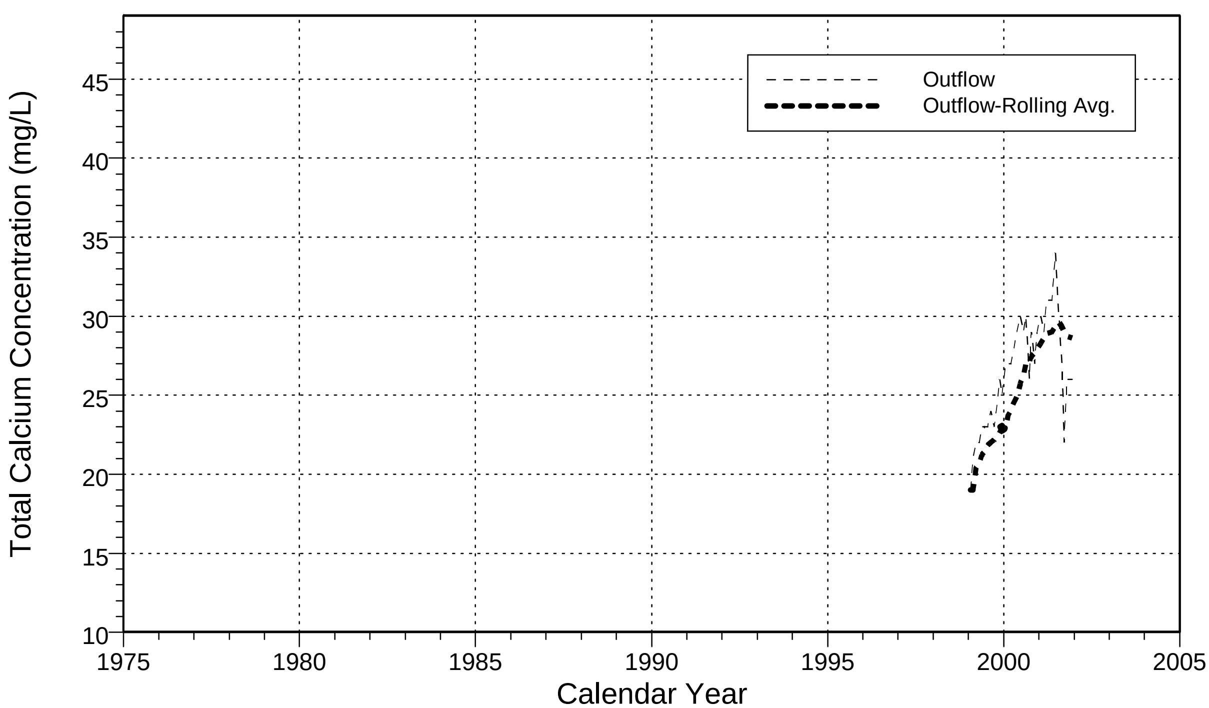


Figure 8-8: Long-term Water Surface Elevation at Lake Thonotosassa

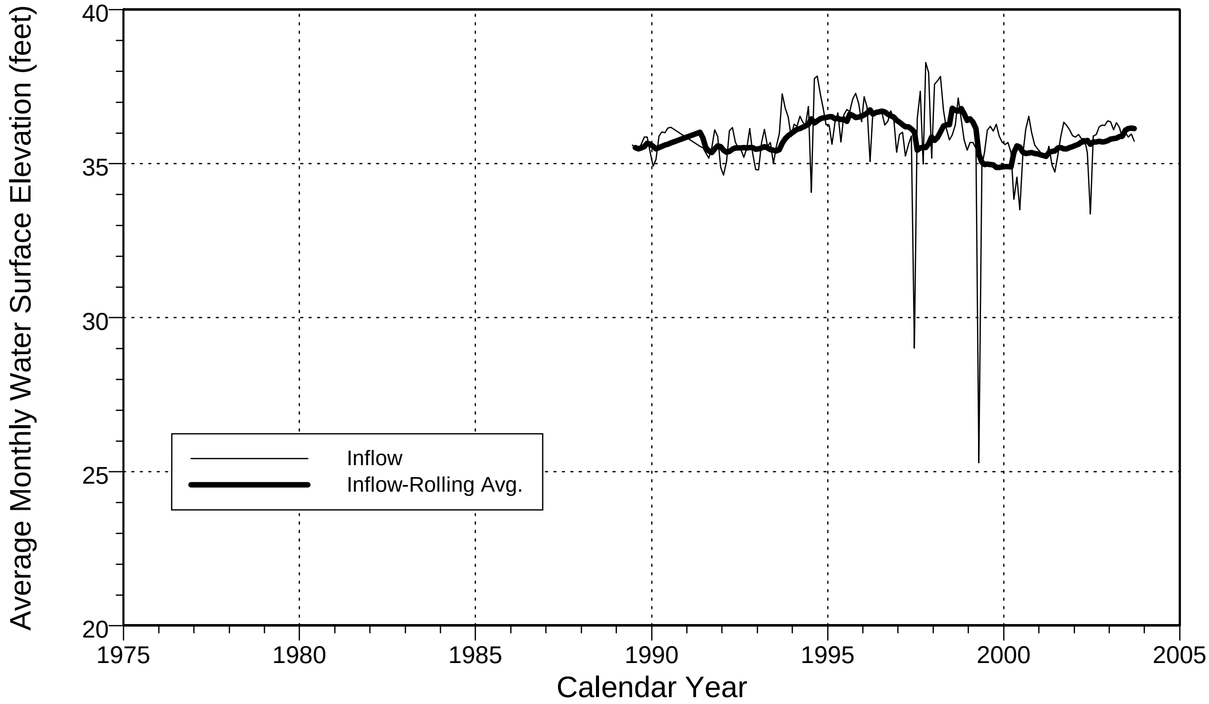
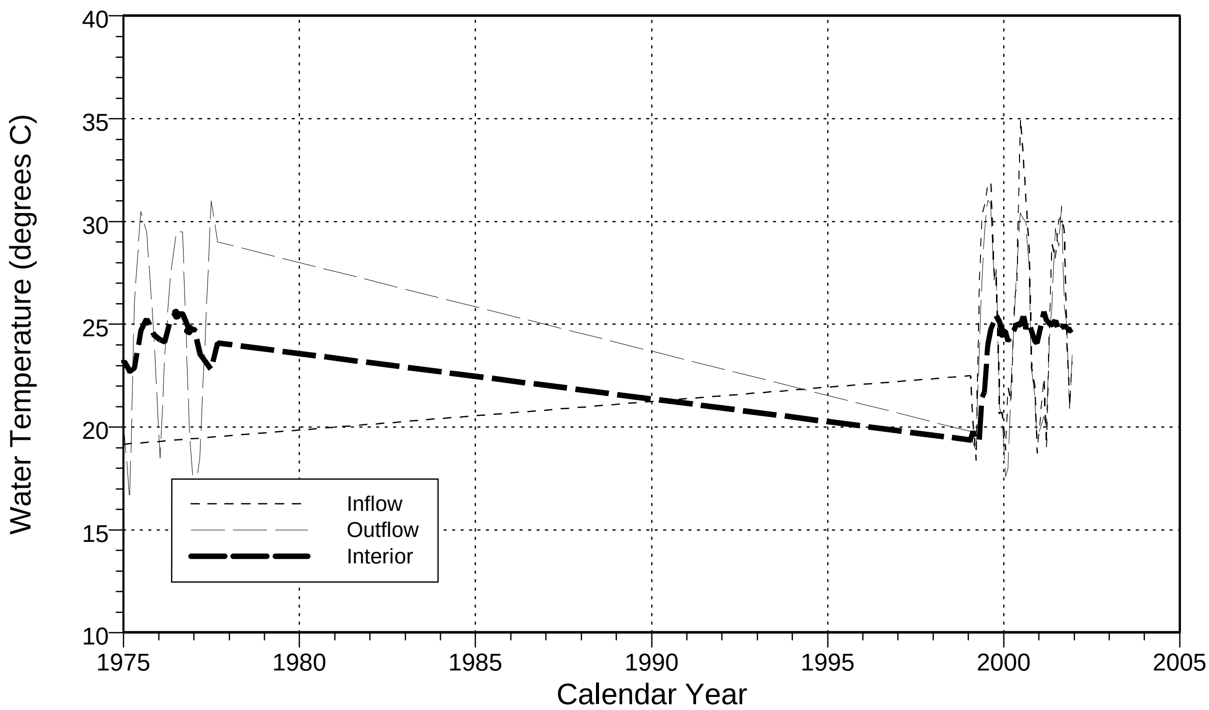


Figure 8-9: Long-term Water Temperature at Lake Thonotosassa



After the analysis period was selected, the time series graphs for flow and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 8-10 and 8-11, better show the availability of data during this critical period. Table 8-2 includes descriptive statistics for key monitoring parameters at Lake Thonotosassa. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period.

8.3 WATER BALANCE

A daily water balance for Lake Thonotosassa was developed for WY 1981–1991. This water balance includes estimates of the following quantities for each day during the period of record.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

8.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage; however, no lake elevation vs. surface area data were found for this lake during Task 2. Therefore, a constant lake area of 819 acres was adopted for use in the water balance (Dynamac

Figure 8-10: Analysis Period Flow at Lake Thonotosassa

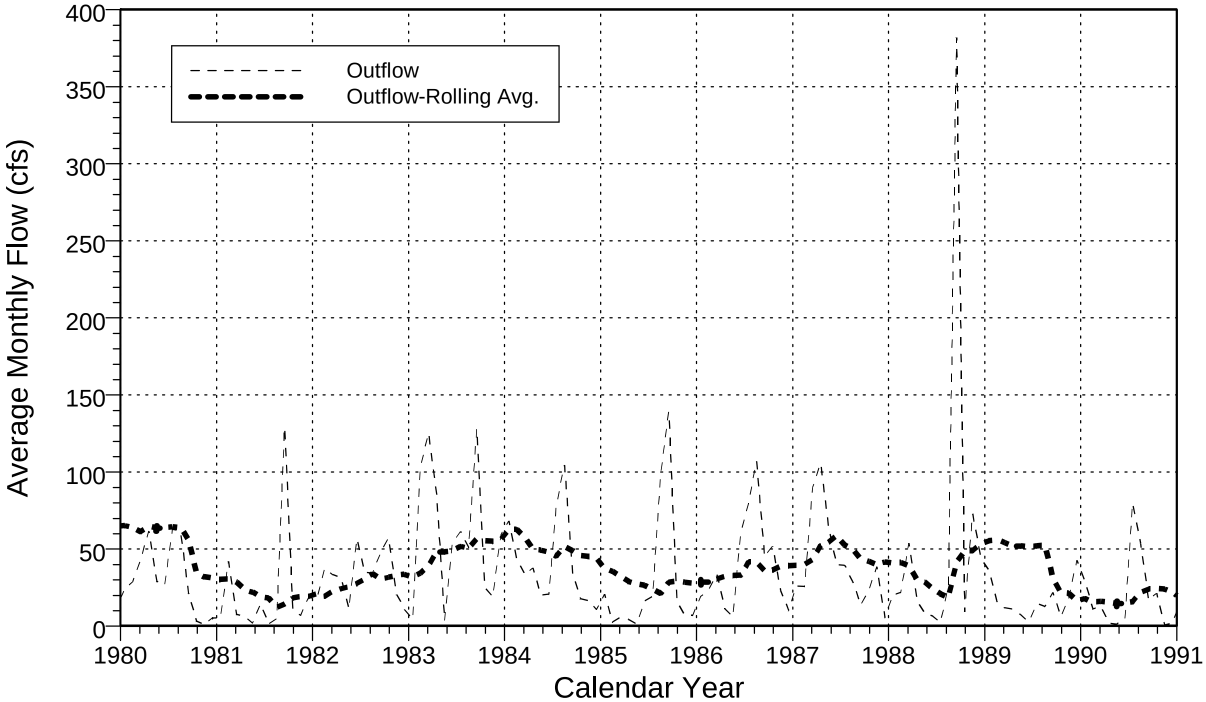


Figure 8-11: Analysis Period Total Phosphorus at Lake Thonotosassa

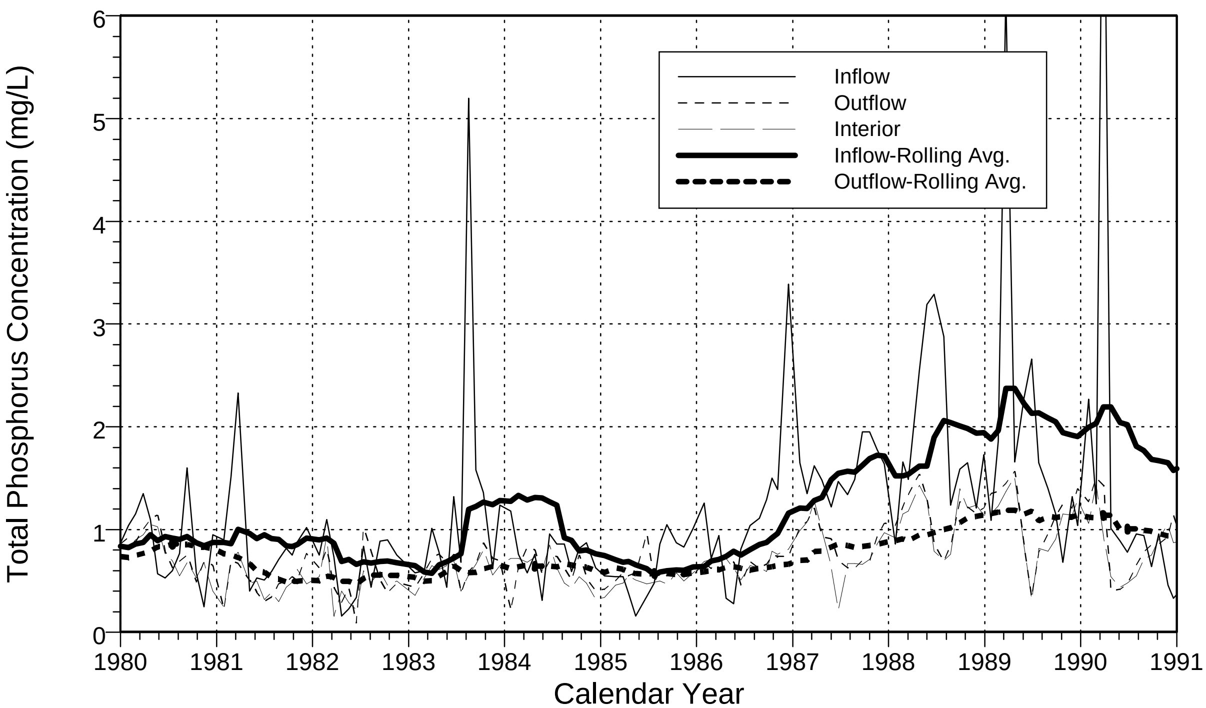


Table 8-2: Lake Thonotosassa Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Outflow	Outside	66	0	26.394	19.000	34.000
		Total	66	0	26.394	19.000	34.000
Elevation (feet)	Inflow	Inside	475	0	35.595	34.763	36.295
		Outside	8,024	0	35.912	0.000	42.700
		Total	8,499	0	35.894	0.000	42.700
Elevation (feet)	Interior	Inside	4,017	0	35.937	34.260	38.720
		Outside	5,514	0	35.253	33.670	38.550
		Total	9,531	0	35.542	33.670	38.720
Flow (cfs)	Outflow	Inside	8,034	0	35.007	0.090	941.000
		Outside	8,561	0	37.916	0.000	588.000
		Total	16,595	0	36.508	0.000	941.000
Orthophosphorus (mg/L)	Inflow	Outside	1	0	0.717	0.717	0.717
		Total	1	0	0.717	0.717	0.717
Orthophosphorus (mg/L)	Outflow	Outside	63	5	0.113	0.020	0.750
		Total	63	5	0.113	0.020	0.750
Orthophosphorus (mg/L)	Interior	Outside	74	4	0.185	0.020	0.750
		Total	74	4	0.185	0.020	0.750
pH	Outflow	Outside	98	0	9.450	6.900	10.800
		Total	98	0	9.450	6.900	10.800
pH	Interior	Outside	139	0	8.918	6.300	10.800
		Total	139	0	8.918	6.300	10.800
Phosphorus (mg/L)	Inflow	Inside	131	0	1.198	0.160	8.960
		Outside	33	0	0.878	0.430	1.600
		Total	164	0	1.134	0.160	8.960
Phosphorus (mg/L)	Outflow	Inside	433	0	0.739	0.090	1.570
		Outside	545	0	0.522	0.040	1.860
		Total	978	0	0.618	0.040	1.860
Phosphorus (mg/L)	Interior	Inside	262	0	0.708	0.160	1.510
		Outside	541	0	0.519	0.070	2.700
		Total	803	0	0.581	0.070	2.700

POR: Inside=Within analysis period (10/1/1980-9/30/1991); Outside=Outside analysis period; Total=All available data.

Table 8-2: Lake Thonotosassa Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Temperature (deg C)	Inflow	Outside	1	0	20.000	20.000	20.000
		Total	1	0	20.000	20.000	20.000
Temperature (deg C)	Outflow	Outside	104	0	25.562	17.500	35.000
		Total	104	0	25.562	17.500	35.000
Temperature (deg C)	Interior	Outside	182	0	24.579	14.500	33.200
		Total	182	0	24.579	14.500	33.200
Total Nitrogen (mg/L)	Outflow	Outside	208	0	5.286	1.224	12.568
		Total	208	0	5.286	1.224	12.568
Total Nitrogen (mg/L)	Interior	Outside	191	0	5.319	1.316	18.600
		Total	191	0	5.319	1.316	18.600

POR: Inside=Within analysis period (10/1/1980-9/30/1991); Outside=Outside analysis period; Total=All available data.

Corporation, 1992). The inaccuracies introduced by this simplifying assumption are not considered to be significant as the lake elevation only fluctuates over a narrow range and most of these errors will tend to balance out over time.

8.3.2 Inflow

No recorded inflow data exist for Lake Thonotosassa. Therefore, gaged inflow to Lake Thonotosassa was set to zero. The ungaged inflow to the lake was estimated by difference as discussed in Section 8.3.7.

8.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Lake Thonotosassa can represent a significant lake inflow. Rainfall depths at Lake Thonotosassa over the period of record were estimated from records maintained by NOAA for the Tampa Airport (Station No. 8-8788) (NOAA, 2002). This station is located approximately 18 miles southwest of Lake Thonotosassa. The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Lake Thonotosassa by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

8.3.4 Evaporation Depth and Volume

No evaporation data for Lake Thonotosassa were located during Task 2 so lake evaporation was estimated from pan evaporation data available at the Lake Alfred Experiment Station (NOAA, 2002). This climate station (No. 8-4707) is located about 34 miles east of Lake Thonotosassa. Water will evaporate faster from an evaporation pan than a lake because a pan is a much smaller body of water and will heat up more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the Lake Thonotosassa vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value representative of the evaporation over the entire interval is available. To smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. No pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Lake Thonotosassa were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

8.3.5 Outflow

The outlet from Lake Thonotosassa is Flint Creek, a tributary of the Hillsborough River. The USGS maintains a stream gage on Flint Creek (No. 02303300). The records at this stream gage were used to estimate the gaged outflow from Lake Thonotosassa. Because Lake Thonotosassa has no other outlets, ungaged outflow was assumed to always be zero.

8.3.6 Elevation and Change in Storage

The only long-term elevation-type data available for Lake Thonotosassa are the gage height readings available for the Flint Creek gage. The gage heights recorded at this gage were used as a surrogate for actual lake elevation data. The day-to-day changes in these gage heights were assumed to be representative of the changes in lake elevation. The corresponding changes in lake storage were then estimated as the products of these gage height changes and the lake surface area. The available gage height readings are mean daily values and, as such, are probably more representative of midday values then end-of-day ones. Therefore, the end-of-day lake elevation each day was estimated as the average of the gage heights for the current and following day.

While no specific bathymetric data were available for Lake Thonotosassa, the 2003 surface water improvement and management (SWIM) plan for the lake reports the average lake stage and depth are respectively 10.8 and 2.5 meters (SWFWMD, 2003). From these data, the average lake bottom elevation is estimated to be 27.2 feet.

8.3.7 Imbalance

Theoretically, the sum of all lake inflows (gaged inflow + ungaged inflow + precipitation volume) less all outflows (gaged outflow + ungaged outflow + evaporation) should equal the computed change in storage each day. However, because no gaged inflow data are available for Lake Thonotosassa, calculating daily imbalances at this lake was not possible. For lack of a better alternative, the ungaged inflow to Lake Thonotosassa was estimated as the difference of the other water balance terms.

Table 8-3 presents an annual summary of the Lake Thonotosassa water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 8-3: Lake Thonotosassa Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1981	15,055	2,599	4,349	13,141	164	0
1982	21,330	3,874	3,765	20,489	950	0
1983	41,300	3,863	3,678	42,149	-663	0
1984	34,217	2,749	3,911	33,051	4	0
1985	23,154	2,657	4,344	21,332	135	0
1986	25,838	2,577	4,209	25,226	-1,020	0
1987	33,534	3,263	4,001	31,269	1,527	0
1988	35,444	3,538	3,912	36,196	-1,126	0
1989	17,569	2,891	4,045	15,829	586	0
1990	16,932	2,680	3,997	16,855	-1,241	0
1991	26,594	2,985	3,690	23,382	2,523	0
Total	290,968	33,676	43,900	278,921	1,839	0

8.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Lake Thonotosassa using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the period of record.

- Inflow TP concentration and flux
- Direct deposition to Lake Thonotosassa
- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

8.4.1 Inflow TP Concentration and Flux

During the selected period of record (WY 1981–1991), inflow TP concentration data are available for 131 days at Lake Thonotosassa, yielding an average sample frequency of once every 31 days, or approximately monthly. Table 8-4 lists the specific stations and numbers of available samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was regression analysis using inflow TP concentration or its log transform as the dependent variable, and julian day and monthly precipitation as independent variables. No recorded inflow to Lake Thonotosassa exists so inflow could not be used as an independent variable. Using a stepwise regression procedure, none of the available independent variables met the minimum significance criteria for inclusion in the model. Therefore, no significant linear relationship exists between these variables.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less valid. Because the regression results were unsatisfactory, this latter method was used to estimate inflow TP concentrations.

Once estimates of daily inflow TP concentrations were developed, the phosphorus mass influx to Lake Thonotosassa was estimated each day as the product of these daily concentrations and the corresponding inflow volume estimate previously developed for the water balance.

8.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Lake Thonotosassa is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 $\mu g/m^2$ while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn

Table 8-4: TP Monitoring Stations at Lake Thonotosassa

Agency	Station	Station Name	Number of Samples
Inflow Stations			
FDEP	24030034	BAKER CRK AT THNTSSA PLNT CTY RD	131
Interior Stations			
Hills. Co	135	Lake Thonotasassa center	262
Outflow Stations			
FDEP	24030029	L THONOTOSASSA MOUTH FLINT CR	171
Hills. Co	118	Lake Thonotosassa at mouth of Flint Creek	262

& James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

8.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Lake Thonotosassa were identical to those used for lake inflow. During the selected period of record (WY 1981–1991), outflow TP concentration data are available for 131 days, yielding an average sample frequency of about once every 31 days. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, none of the available independent variables met the minimum significance criteria for inclusion in the model. Therefore, no significant linear relationship exists between these variables.

Without a suitable regression model, outflow TP concentrations were estimated using a simple straight-line interpolation process. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Lake Thonotosassa was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

8.4.4 Net Phosphorus Retention

The net phosphorus retention in Lake Thonotosassa was estimated as total influx in inflow and deposition less discharge flux in outflow. As such, these net retention values include the phosphorus retained or discharged because of changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Lake Thonotosassa is shown in Table 8-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

8.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Lake Thonotosassa were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. These monthly data sets include the following data values:

Table 8-5: Lake Thonotosassa Phosphorus Balance Summary (kg)

Water Year	Inflow	Direct Deposition	Outflow	Net Retention
1981	16,688	133	7,924	8,897
1982	18,066	148	14,118	4,096
1983	69,742	147	31,779	38,111
1984	37,931	135	25,668	12,397
1985	22,062	133	15,064	7,132
1986	30,193	133	19,171	11,155
1987	65,090	140	35,204	30,027
1988	66,864	144	49,156	17,852
1989	37,110	136	22,997	14,249
1990	21,129	134	19,781	1,482
1991	24,388	137	19,272	5,261
Total	409,263	1,520	260,132	150,659

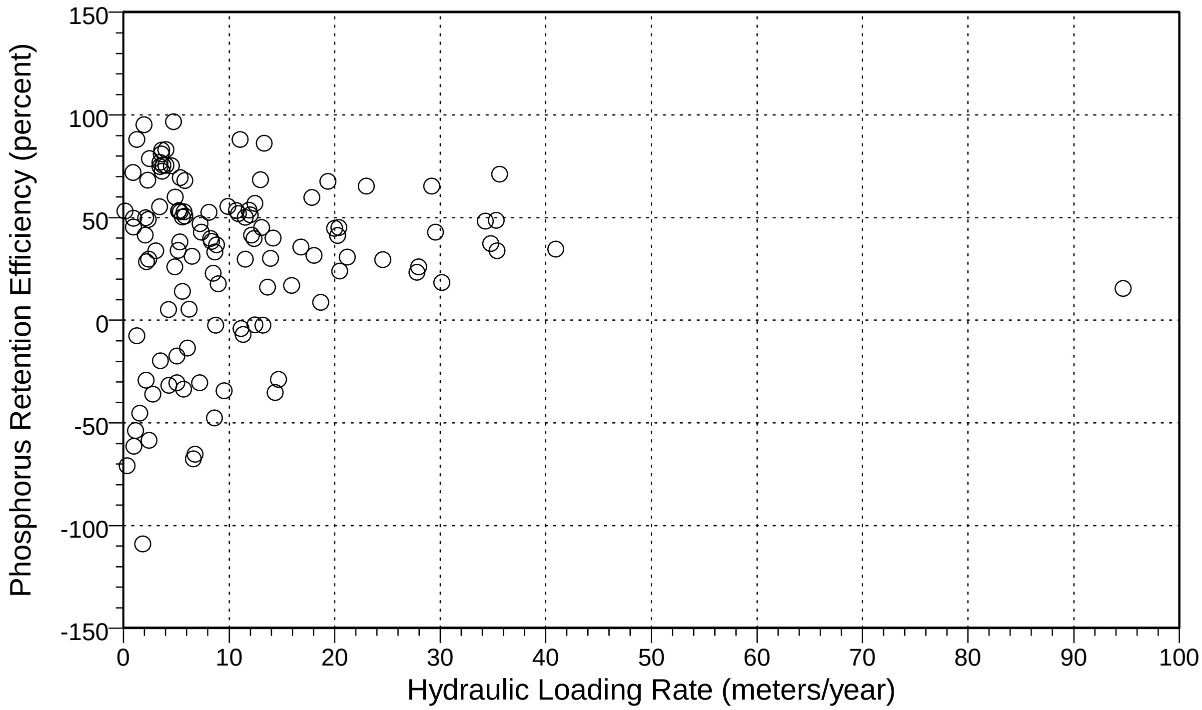
- Average water surface area (ha)
- Total inflow and outflow volumes (m^3)
- Total mass flux of phosphorus in, out and retained in the lake (g)
- Flow-weighted average inflow and outflow phosphorus concentrations (mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

8.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 8-12. From review of this graph, it is not apparent a linear relationship between exists these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .002.

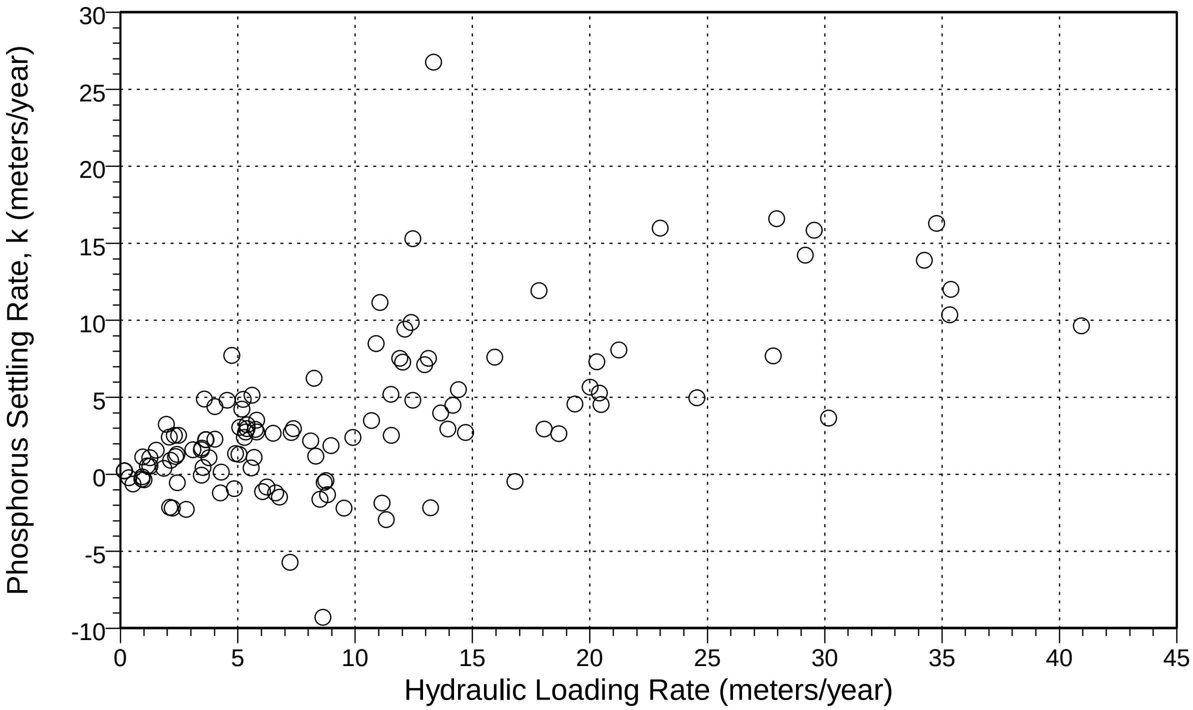
Figure 8-12: Retention Efficiency vs. Hydraulic Loading Rate at Lake Thonotosassa



8.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. Figure 8-13 is a scatter diagram of settling rate vs. hydraulic loading rate. The linear regression model between these two variables has a R^2 of .445. The only other independent variable with a significant linear relationship to the phosphorus settling rate is depth (R^2 = .406).

Figure 8-13: Settling Rate vs. Hydraulic Loading Rate at Lake Thonotosassa



8.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Lake Thonotosassa from the DEP's Bureau of Invasive Plant Management (BIPM). A total of 32 species of wetland and aquatic plants were recorded for Lake Thonotosassa during the BIPM surveys. These included 23 species of emergent wetland plants, 5 species of floating aquatic plants, and 4 species of submerged aquatic plants. With the exception of relatively small patches of cattails and bulrush, none of these plants were dominant in this lake.

Table 8-6 summarizes the estimated cover by vegetation type for Lake Thonotosassa for the period from 1986 through 2003. The average cover by vegetation type was emergent – 10.6 acres, floating – 2.1 acres, and submerged – 0.3 acres. These estimated plant coverages show that plants occupy a relatively small fraction of the estimated 847-acre surface area of Lake Thonotosassa.

* * * * *

Table 8-6
Lake Thonotosassa Vegetation Data

Survey Month	Vegetation Coverage by Type (acres)		
	Emergent	Floating	Submerged
Oct-86	4.9	1.4	
Sep-88	6.1	2.6	0.1
Sep-90	8.7	0.3	0.3
Jul-92	10.2	0.3	0.1
Aug-95	11.4	0.3	0.2
Aug-03	22.5	7.4	0.8
Average	10.6	2.1	0.3
Median	9.5	0.9	0.2
Maximum	22.5	7.4	0.8
Minimum	4.9	0.3	0.1

9 RODMAN RESERVOIR

9 RODMAN RESERVOIR

Rodman Reservoir is located on the Ocklawaha River just upstream of its confluence with the St. Johns River. The reservoir, also known as Ocklawaha Lake, is split between Marion and Putnam counties, and is located approximately 25 miles southeast of Gainesville (Figure 1-1). Rodman Reservoir, which was built as part of the now defunct Cross Florida Barge Canal project, is the only potential data site that is an actual man-made reservoir. The data collected for Rodman Reservoir and the analyses completed with these data are described in the balance of this chapter.

9.1 DATA SOURCES

The data for Rodman Reservoir were collected from a number of sources. These sources are listed in Table 9-1 along with a listing of the individual sample stations obtained from each source. For each sampling station, this table also lists its absolute location (latitude/longitude coordinates) and location relative to Rodman Reservoir. Relative locations were assigned to each monitoring station based on whether the station's data represent inflow, outflow, interior, or external conditions. Figure 9-1 shows the locations of these monitoring stations.

9.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations

Table 9-1: Rodman Reservoir Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Inflow	20020003	MILLS CREEK AT NE 148TH TERRACE BRIDGE	29.40131	81.93042
	20020006	ORANGE CR AT SR 315 NR ORNG SPRG	29.51375	81.93547
	20020012	OKLAWAHA RIVER AT SR 316	29.37292	81.90173
	20020084	LIT ORANGE CR N CONF ORANGE CR.	29.52269	81.94044
	20020144	DEEP CREEK AT S.R. 315 BRIDGE	29.57030	81.87794
	20020147	OCKLAWAHA RIVER UPSTREAM OF PINEY ISL	29.35122	81.88958
	20020404	ORANGE CREEK 50 YDS. UP FROM HWY. 21	29.50861	81.94889
	20020415	OKLAWAHA RIVER AT SUNDAY BLUFF	29.33917	81.88472
	20020434	RODMAN RESERVOIR AT SR 310	29.54194	81.83556
	3517	OKLAWAHA RIVER AT S.R 316	29.37306	81.90166
	7453	SJD-HS-1015	29.33400	81.88840
	7479	SJR-HS-1066	29.36722	81.89806
	8058	SJD-LS-1001	29.51445	81.92999
	8103	SJD-LS-1027	29.58417	81.87139
	8110	SJD-LS-1037	29.40111	81.92860
	8132	SJD-LS-1054	29.50682	81.95311
	8703	SJD-LS-1039	29.58529	81.87140
	8719	SJD-SL-1022	29.58314	81.89170
Outflow	20020068	OCKLAWAHA RIVER 1.1 MI. DOWNSTREAM RO	29.49472	81.79372
	20020071	OKLAWAHA R. DWNSTRM OF RODMAN DA	29.48611	81.78841
	20020078	RODMAN POOL 100 YRDS ABOVE DAM	29.51067	81.80875
	20020314	OKLAWAHA AT RODMAN DAM DNSTR SDE	29.50667	81.81139
	20020439	OKLAWAHA RIVER AT FOREST SERVICE ROA	29.47250	81.77084
	7452	SJD-HS-1009	29.49861	81.79806
	7470	SJD-HS-1114	29.49650	81.79660
	7476	SJD-HS-1059	29.49861	81.79916
	7963	SJD-LL-1023	29.51350	81.80690
	8068	SJD-LS-1005	29.50282	81.80839
	8072	SJD-LS-1006	29.49503	81.80072
	8098	SJD-LS-1019	29.49728	81.79794
Interior	2002031	OKLAWAHA R CEDAR FERRY MIDSTR	29.51472	81.86528
	20020311	OKLAWAHA R AT TOBACO PATCH LANDN	29.43050	81.92597
	20020312	OKLAWAHA R ORANGE FER NFS RD 77	29.50306	81.91250
	20020436	RODMAN RESERVOIR MIDDLE OF EAST END	29.51500	81.82667
	20020437	RODMAN RESERVOIR MIDDLE FROM EAST TO	29.51694	81.87194
	21162			
	22902			

Table 9-1: Rodman Reservoir Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Game and Fresh Water Fish Commission (FGFWF)				
Inflow	GFCCR0212	RODMAN RESERVOIR ORANGE SPRINGS COVE	29.50811	81.91666
	GFCCR0213	RODMAN RESERVOIR AT DEEP CREEK COVE B	29.54489	81.83642
	GFCCR0264	OKLAWAHA RIVER AT EUREKA BRIDGE	29.37161	81.90122
	GFCCR0265	RODMAN RESERVIOR AT MOUTH OF OKLAWA	29.38108	81.89814
	GFCCR0267	ORANGE CREEK AT HIGHWAY 315 BRIDGE	29.51350	81.93520
Outflow	GFCCR0214	OKLAWAHA RIVER IN RODMAN RESERVOIR T	29.50542	81.80400
	GFCCR0269	RODMAN RESERVOIR AT DAM	29.50947	81.81172
Interior	GFCCR0211	RODMAN RESERVOIR MID CHANNEL AT PAYN	29.44189	81.92592
	GFCCR0266	RODMAN RESERVIOR AT TREE CRUSHER	29.47297	81.91666
	GFCCR0268	RODMAN RESERVOIR AT CHANNEL MARKER 2	29.53650	81.83334
Florida LAKEWATCH (LakeWatch)				
Outflow	PUT-RODMA	Putnam-Rodman-out 1-1	29.50778	81.80583
	PUT-RODMA	Putnam-Rodman-out 2-1	29.52778	81.79889
Interior	PUT-RODMA	Putnam-Rodman-1	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-2	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-3	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-4	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-5	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-6	29.52667	81.84125
	PUT-RODMA	Putnam-Rodman-out 3-1	29.50833	81.91617
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	82915	Federal Point	29.75000	81.53333
	83321	Gainesville	29.63333	82.36667
	83322	Gainesville	29.68333	82.50000
	83326	Gainesville Muni Arpt	29.68333	82.26667
	86753	Palatka	29.65000	81.65000
Saint Johns River Water Management District (SJRWMD)				
Inflow	20020012	OKLAWAHA_RIVER_AT_SR_316	29.37306	81.90166
U.S. Army Corps of Engineers (COE)				
Inflow	3CFB10001	DEEP CREEK AT HIGHWAY 310	29.54222	81.85472
	3CFB10003	ORANGE CREEK AT SR 315	29.51361	81.93584
	3CFB10004	OKLAWAHA RIVER AT SR 316 (EUREKA)	29.37306	81.90195

Table 9-1: Rodman Reservoir Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Outflow	3CFB10005	OKLAWAHA RIVER ABOVE DAM	29.51000	81.80695
Interior	3CFB10006	LAKE OKLAWAHA AT KENWOOD BAY	29.52194	81.87695
	3CFB10007	LAKE OKLAWAHA AT POWERLINE	29.49944	81.91250
	3CFB10008	LAKE OKLAWAHA AT PAYNES LANDING	29.44500	81.92500
	3CFB10009	LAKE OKLAWAHA AT GASLINE	29.51722	81.86583
	3CFB10010	LAKE OKLAWAHA AT MARKER 15	29.52194	81.83028
U.S. Geological Survey (USGS)				
Inflow	2240500	OCKLAWAHA RIVER AT EUREKA,FLA.	29.37222	81.90278
	2243000	ORANGE CREEK AT ORANGE SPRINGS, FLA.	29.50944	81.94639
	2243300	Little Orange Creek near Johnson, FL	29.54111	81.95333
Outflow	2243960	OCKLAWAHA R AT RODMAN DAM NR ORANG	29.50833	81.80417
	2244032	CROSS FL BARGE CA AT BUCKMAN LOCK NR	29.54583	81.72639
US EPA--Storet (US EPA)				
Inflow	111665	OKLAWAHA R ORANGE FERRY FISH CP	29.48333	81.90000
	111680	OKLAWAHA R FLA 316 E OF EUREKA	29.50000	81.86667
	3C133011L	SWEETWATER CREEK	29.56056	81.80861
	3C133011U	SWEETWATER CREEK	29.57250	81.80833
	3C133013L	NO NAME	29.46583	81.92917
	3C133013U	NO NAME	29.46389	81.94056
Outflow	111610	DEEP CREEK FLA 310 W OF RODMAN	29.50000	81.80000

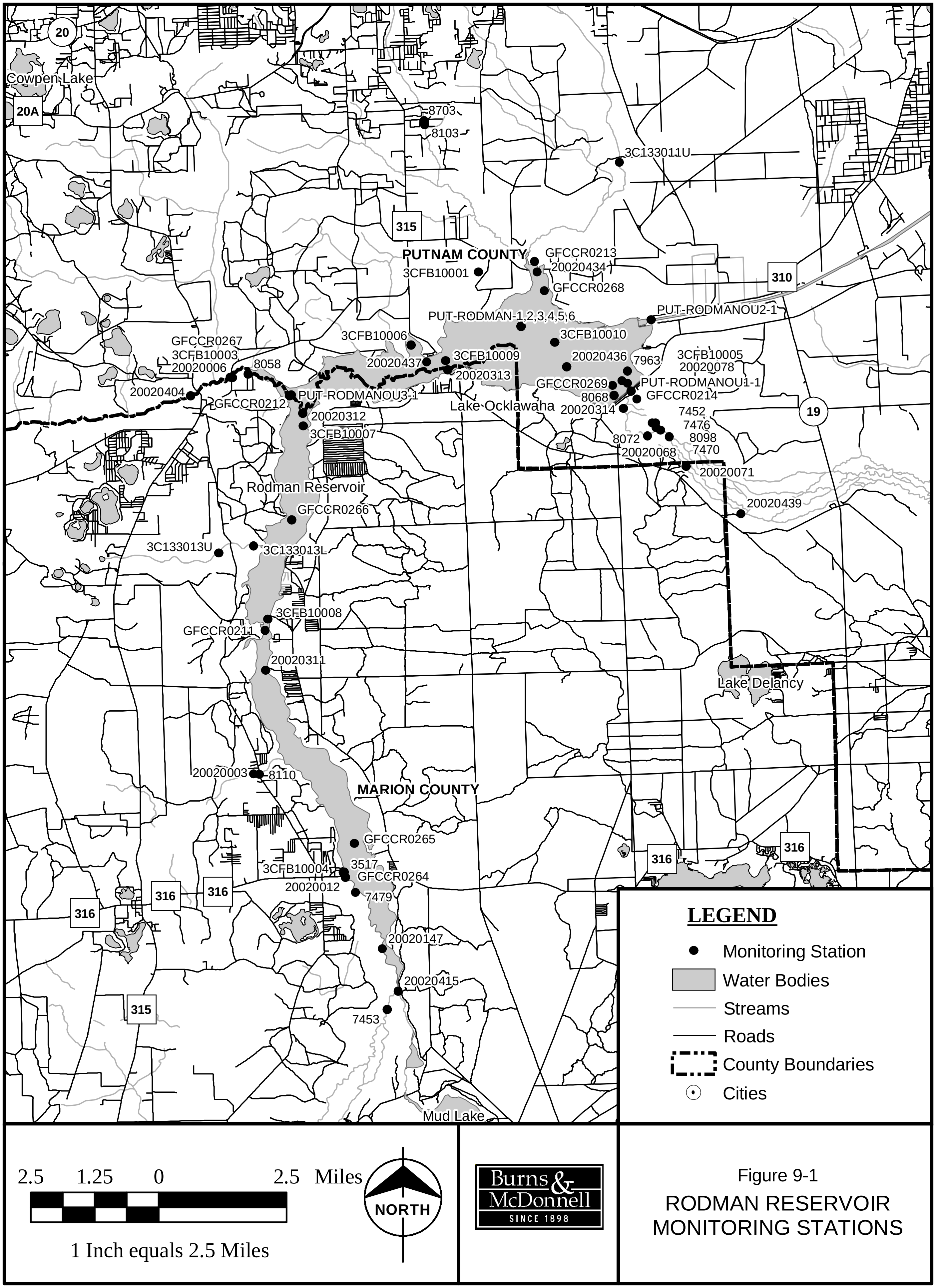


Figure 9-1
RODMAN RESERVOIR MONITORING STATIONS

- Total nitrogen concentrations
- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station is representative of a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 9-2 through 9-9 contain the time series graphs for Rodman Reservoir for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005. Also shown on these time series graphs are lines showing annual (365-day) rolling averages for inflow and outflow. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow and phosphorus concentration data for use in calculating water and phosphorus balances at Rodman Reservoir. The graphs of available flow and phosphorus concentration data are shown in Figures 9-2 and 9-3, respectively. Water years 1981–2003 (10/1/1980–9/30/1991) were selected as the period of record for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are most prevalent during this same period.

After the analysis period was selected, the time series graphs for flow rate and phosphorus concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 9-10 and 9-11, better show the availability of data during this critical period. Table 9-2 includes descriptive statistics for key monitoring parameters at Rodman Reservoir. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative

Figure 9-2: Long-term Flow at Rodman Reservoir

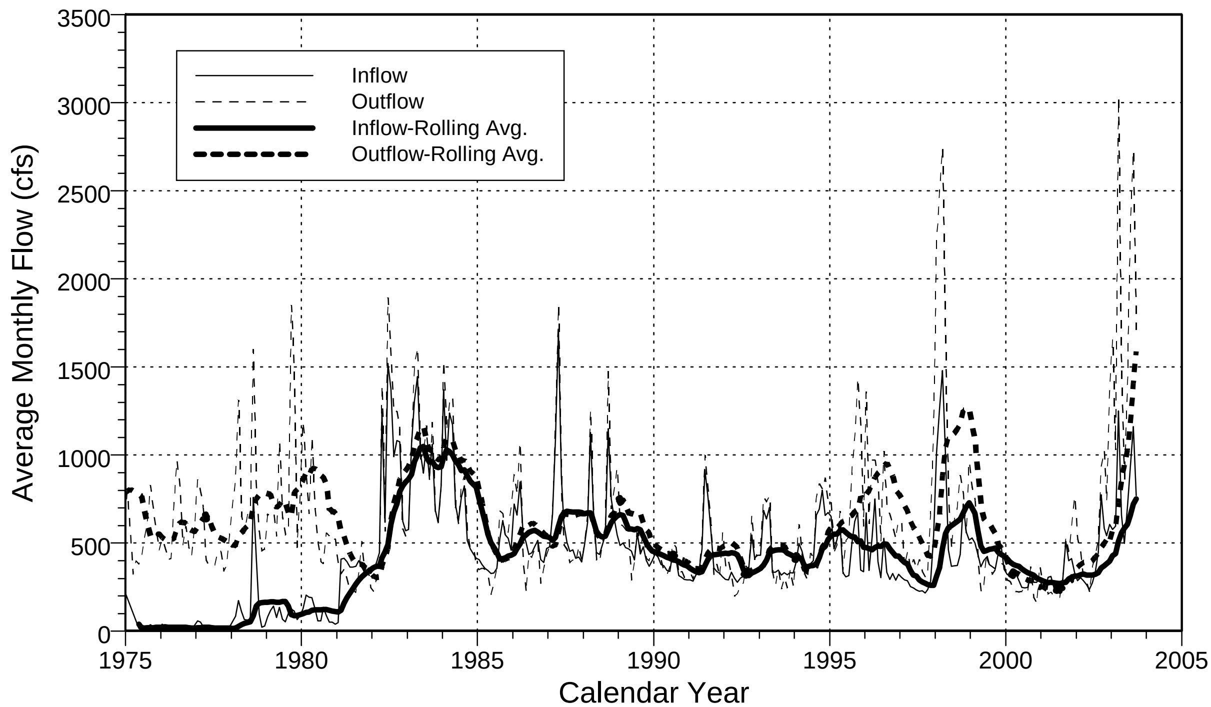
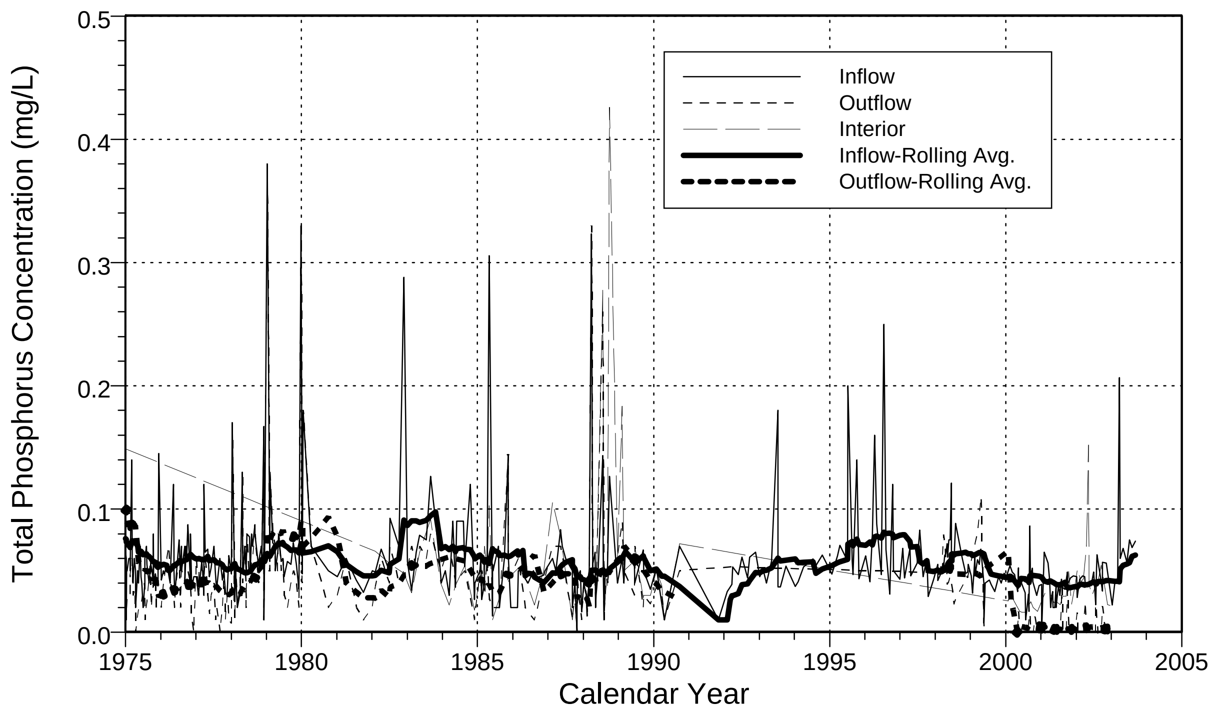


Figure 9-3: Long-term Total Phosphorus at Rodman Reservoir



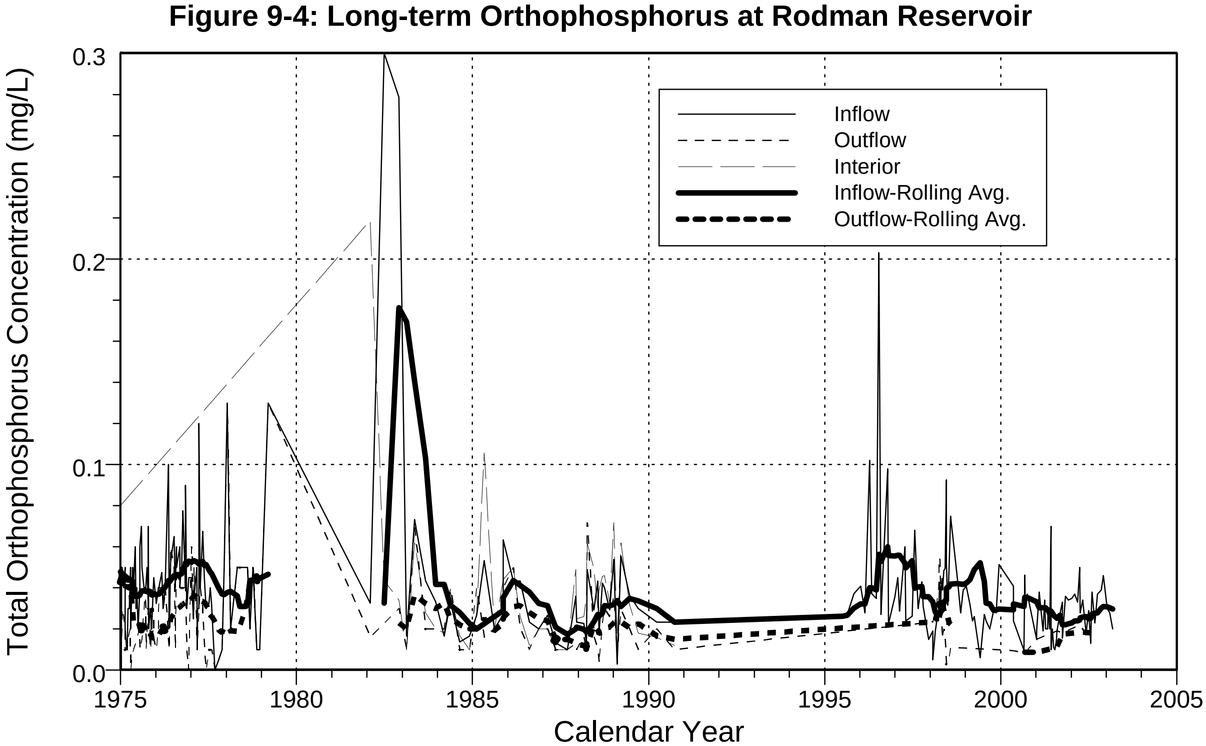


Figure 9-4: Long-term Orthophosphorus at Rodman Reservoir
Total Orthophosphorus Concentration (mg/L)
Calendar Year
Inflow
Outflow
Interior
Inflow-Rolling Avg.
Outflow-Rolling Avg.
0.0
0.1
0.2
0.3
1975
1980
1985
1990
1995
2000
2005

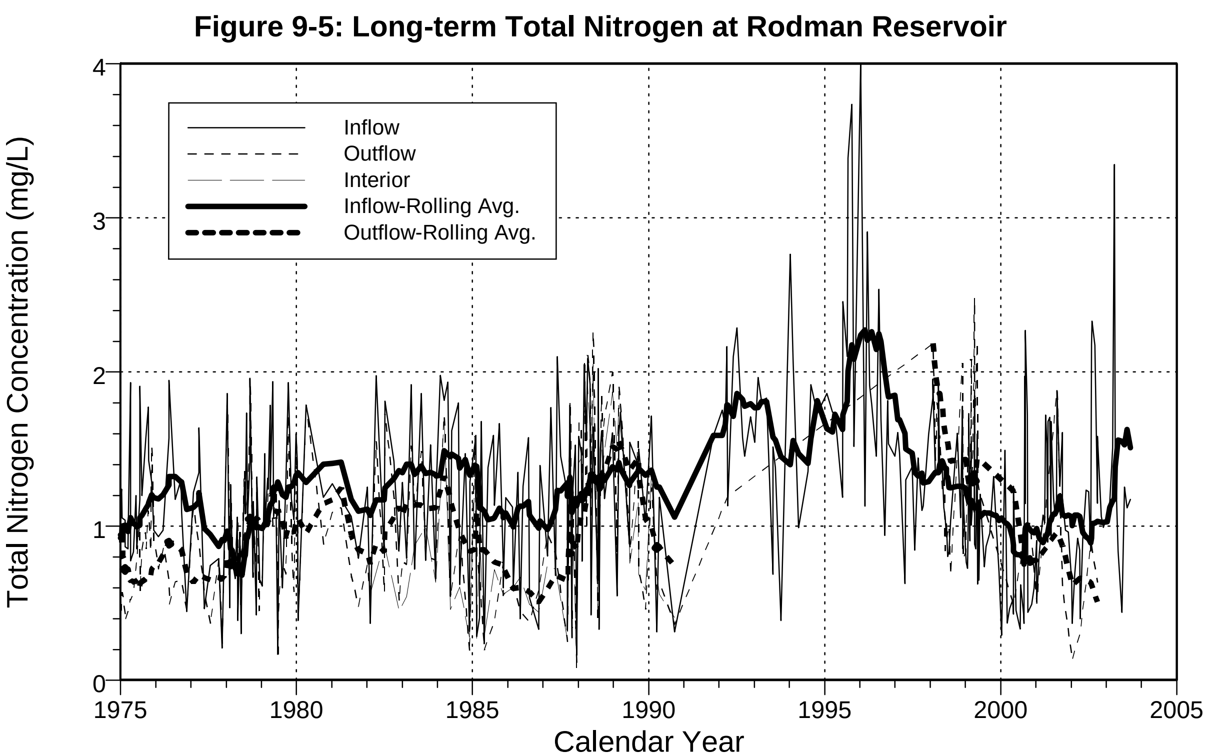


Figure 9-5: Long-term Total Nitrogen at Rodman Reservoir
Total Nitrogen Concentration (mg/L)
Calendar Year
Inflow
Outflow
Interior
Inflow-Rolling Avg.
Outflow-Rolling Avg.
0
1
2
3
4
1975
1980
1985
1990
1995
2000
2005

Figure 9-6: Long-term pH at Rodman Reservoir

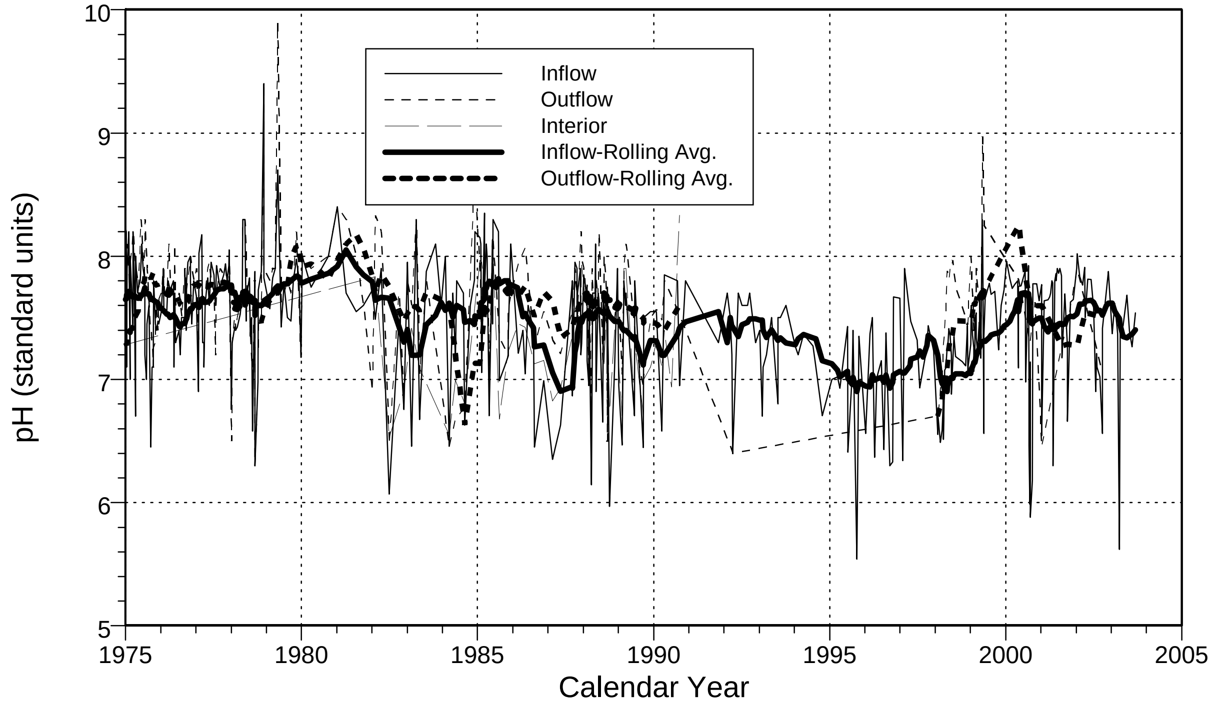


Figure 9-7: Long-term Total Calcium at Rodman Reservoir

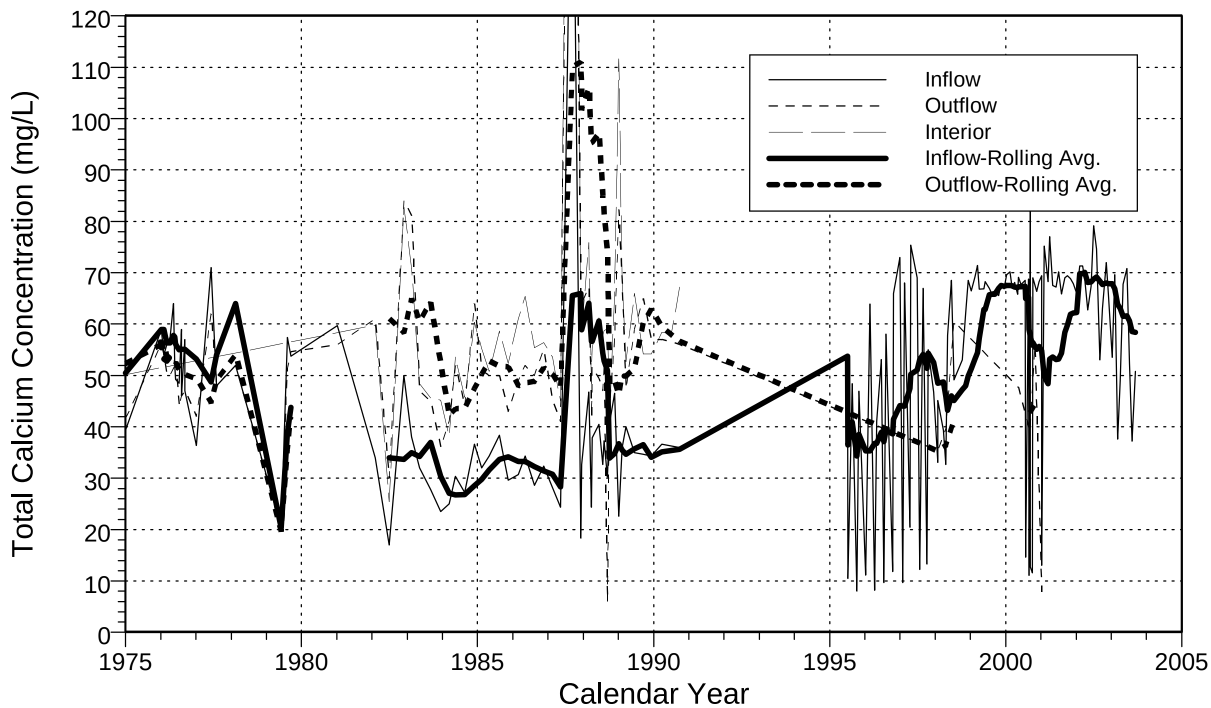


Figure 9-8: Long-term Water Surface Elevation at Rodman Reservoir

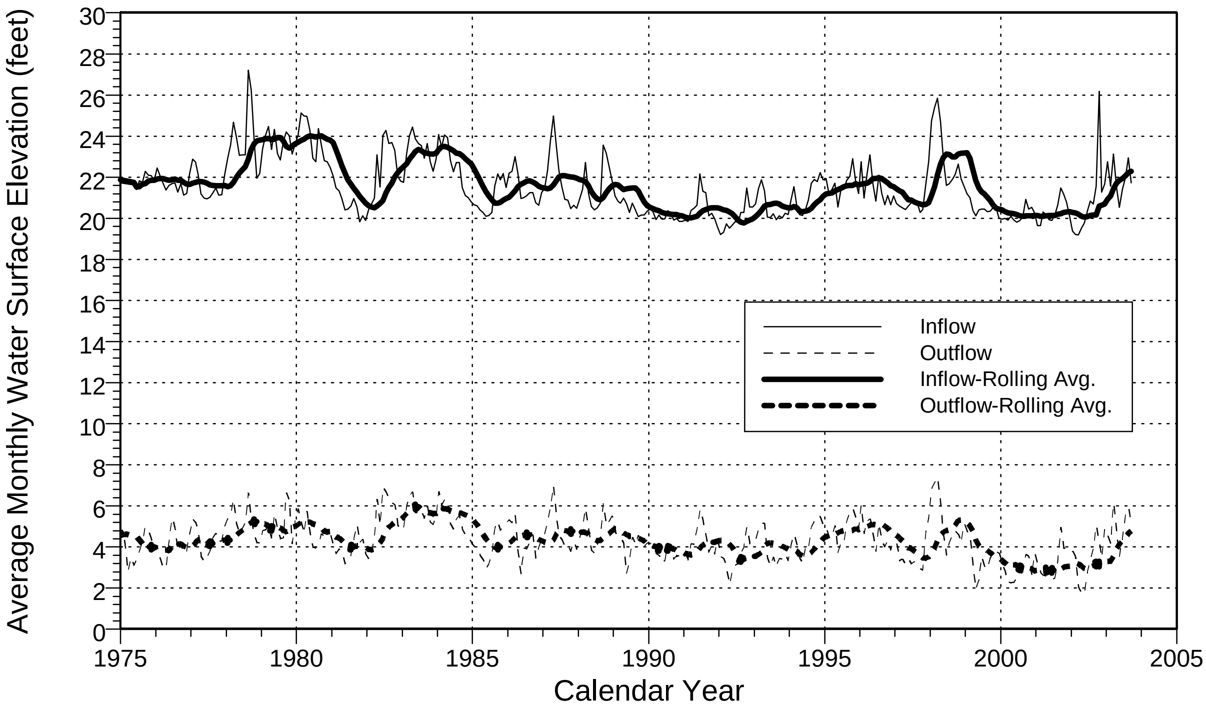
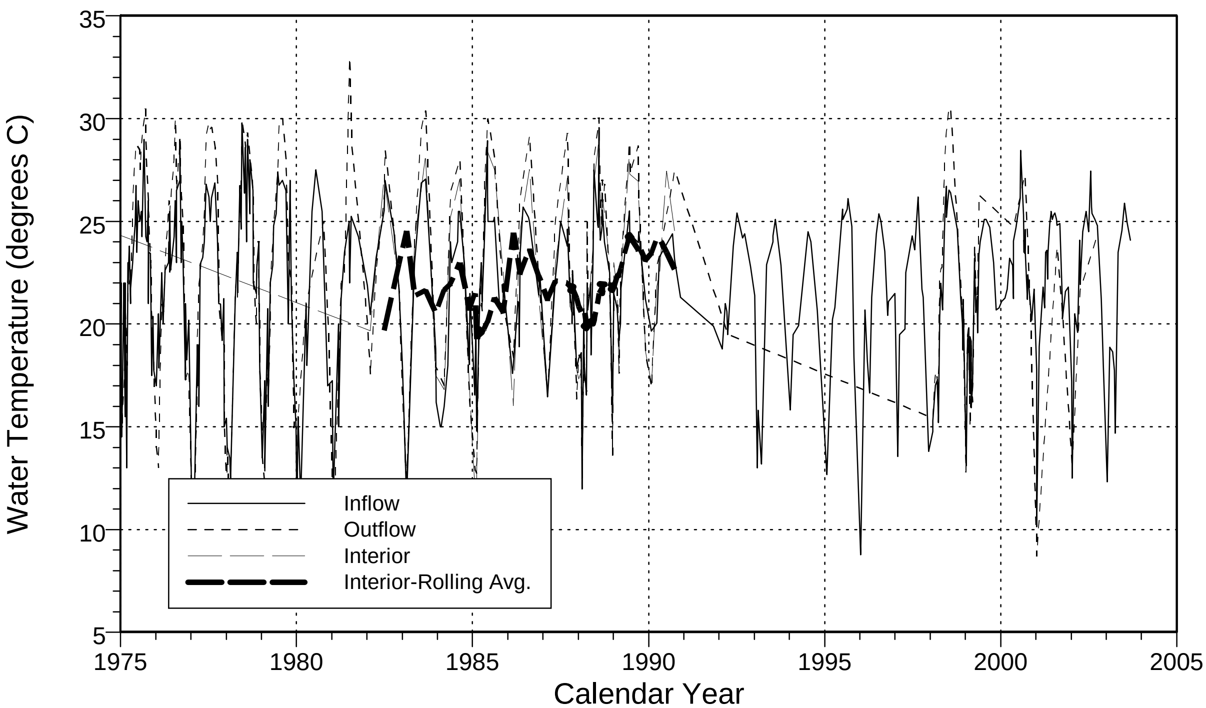


Figure 9-9: Long-term Water Temperature at Rodman Reservoir



location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. For non-detect samples, the value reported is generally the applicable detection limit and these values were included in the associated statistics when then occurred.

9.3 WATER BALANCE

A daily water balance for Rodman Reservoir was developed for WY 1981–2003. This water balance included estimates of the following quantities for each day during the analysis period.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Lake elevation
- Lake depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

9.3.1 Surface Area

The surface area of a lake is a function of stage, expanding and contracting respectively with increases or decreases in lake stage; however, no lake elevation vs. surface area data were found for Rodman Reservoir during Task 2. Therefore, a constant lake area of 5,980 acres was adopted for use in the water balance (SJRWMD, 1994). The inaccuracies introduced by this simplifying assumption are not considered to be significant as the lake elevation only fluctuates over a narrow range and most of these errors will tend to balance out over time.

Figure 9-10: Analysis Period Flow at Rodman Reservoir

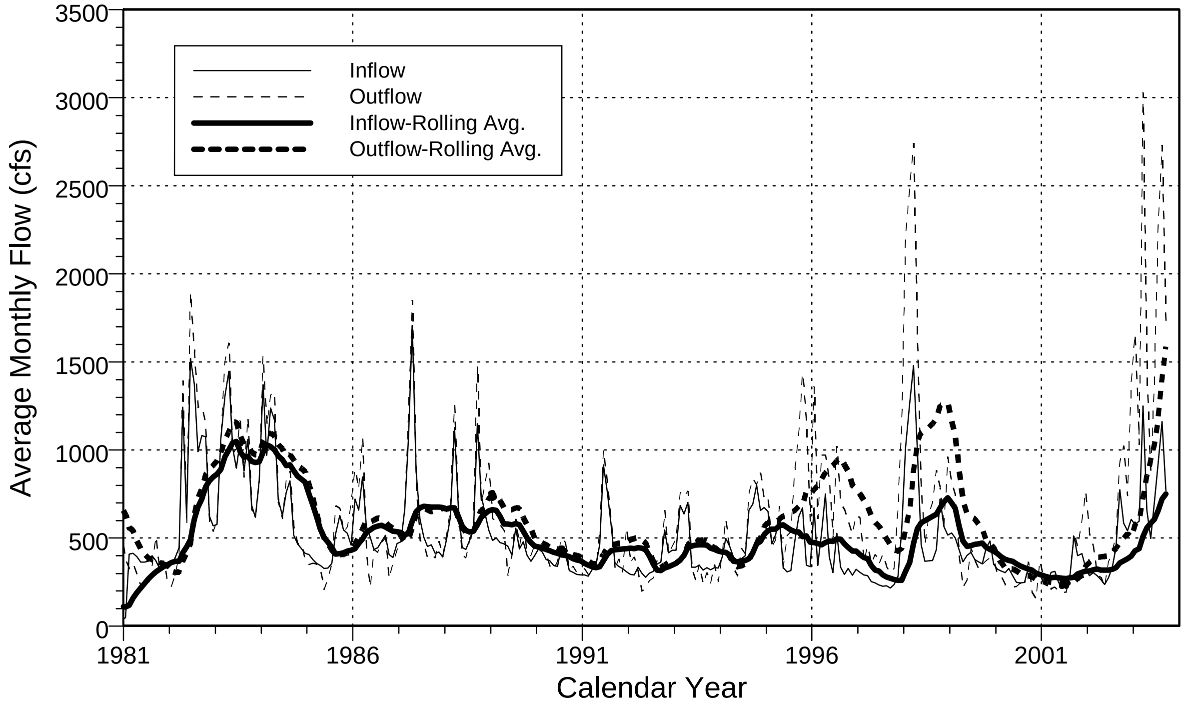


Figure 9-11: Analysis Period Total Phosphorus at Rodman Reservoir

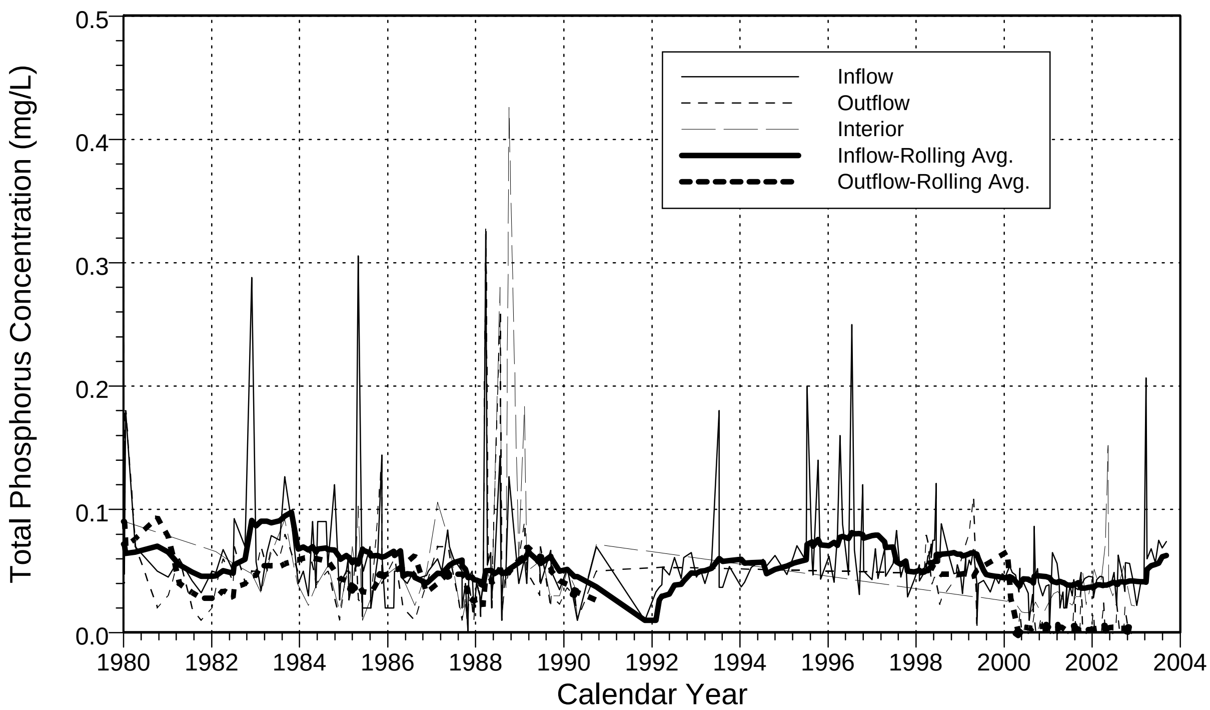


Table 9-2: Rodman Reservoir Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	456	0	51.701	3.500	362.000
		Outside	203	0	43.798	4.900	74.800
		Total	659	0	49.267	3.500	362.000
Calcium (mg/L)	Outflow	Inside	65	0	52.875	5.900	299.000
		Outside	88	0	49.419	17.200	62.000
		Total	153	0	50.888	5.900	299.000
Calcium (mg/L)	Interior	Inside	172	0	63.095	12.000	373.000
		Outside	46	0	57.087	42.000	69.900
		Total	218	0	61.828	12.000	373.000
Elevation (feet)	Inflow	Inside	15,795	0	21.246	17.370	58.810
		Outside	15,444	0	18.172	2.970	29.410
		Total	31,239	0	19.726	2.970	58.810
Elevation (feet)	Outflow	Inside	8,106	0	4.290	0.730	9.640
		Outside	4,110	0	4.754	1.960	9.450
		Total	12,216	0	4.446	0.730	9.640
Flow (cfs)	Inflow	Inside	17,812	0	512.897	1.000	6,110.000
		Outside	16,780	0	542.206	2.000	6,060.000
		Total		0	527.115	1.000	6,110.000
Flow (cfs)	Outflow	Inside	16,251	0	610.937	0.000	8,610.000
		Outside	8,538	0	844.682	0.000	9,560.000
		Total	24,789	0	691.445	0.000	9,560.000
Orthophosphorus (mg/L)	Inflow	Inside	360	4	0.038	0.001	0.756
		Outside	426	0	0.055	0.005	0.400
		Total	786	4	0.047	0.001	0.756
Orthophosphorus (mg/L)	Outflow	Inside	70	2	0.020	0.003	0.072
		Outside	239	0	0.043	0.003	0.400
		Total	309	2	0.038	0.003	0.400
Orthophosphorus (mg/L)	Interior	Inside	162	0	0.036	0.001	1.000
		Outside	52	0	0.059	0.020	0.554
		Total	214	0	0.041	0.001	1.000
pH	Inflow	Inside	1,376	0	7.406	4.060	8.970
		Outside	718	0	7.634	5.200	9.900

POR: Inside=Within analysis period (1/1/1981-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 9-2: Rodman Reservoir Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Inflow	Total	2,094	0	7.484	4.060	9.900
pH	Outflow	Inside	238	0	7.637	3.100	8.970
		Outside	411	0	7.693	6.000	9.900
		Total	649	0	7.673	3.100	9.900
pH	Interior	Inside	419	0	7.440	6.320	10.310
		Outside	60	0	7.496	5.900	8.100
		Total	479	0	7.447	5.900	10.310
Phosphorus (mg/L)	Inflow	Inside	869	20	0.056	0.010	0.765
		Outside	407	0	0.065	0.010	0.400
		Total	1,276	20	0.059	0.010	0.765
Phosphorus (mg/L)	Outflow	Inside	207	7	0.036	0.005	0.330
		Outside	265	0	0.063	0.003	0.400
		Total	472	7	0.051	0.003	0.400
Phosphorus (mg/L)	Interior	Inside	444	16	0.050	0.006	0.970
		Outside	3	0	0.167	0.140	0.210
		Total	447	16	0.051	0.006	0.970
Temperature (deg C)	Inflow	Inside	1,094	0	21.371	8.700	30.530
		Outside	980	0	21.945	9.000	31.000
		Total	2,074	0	21.642	8.700	31.000
Temperature (deg C)	Outflow	Inside	171	0	22.044	8.700	33.000
		Outside	587	0	23.098	9.000	31.500
		Total	758	0	22.860	8.700	33.000
Temperature (deg C)	Interior	Inside	233	0	22.064	9.900	30.070
		Outside	147	0	22.587	12.500	30.000
		Total	380	0	22.266	9.900	30.070
Total Nitrogen (mg/L)	Inflow	Inside	2,601	0	1.275	0.000	5.608
		Outside	450	0	1.176	0.090	3.240
		Total	3,051	0	1.260	0.000	5.608
Total Nitrogen (mg/L)	Outflow	Inside	421	0	1.122	0.060	2.720
		Outside	283	0	0.896	0.170	2.400
		Total	704	0	1.031	0.060	2.720
Total Nitrogen (mg/L)	Interior	Inside	498	0	0.963	0.010	5.400

POR: Inside=Within analysis period (1/1/1981-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 9-2: Rodman Reservoir Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Total Nitrogen (mg/L)	Interior	Total	498	0	0.963	0.010	5.400

POR: Inside=Within analysis period (1/1/1981-9/30/2003); Outside=Outside analysis period; Total=All available data.

9.3.2 Inflow

The USGS maintains gages on three streams upstream of Rodman Reservoir. These three stations, listed previously in Table 9-1, are Ocklawaha River at Eureka (No. 02240500), Orange Creek at Orange Springs (No. 02243000), and Little Orange Creek (No. 02243300). The gaged inflow to Rodman Reservoir was calculated as the sum of the discharge at these three gages. Flow records for the Little Orange Creek gage are available only from 24 May 1995–30 September 1998.

The Eureka, Orange Creek and Little Orange Creek gages have contributing drainage areas of 1,367, 1,119, and 42.6 square miles, respectively, for a total drainage area of 2,528.6 square miles. The total watershed area of Rodman Reservoir is approximately 2,747 square miles. The ungaged inflow to Rodman Reservoir was initially estimated from the total discharge at the three above stream gages using a drainage area ratio.

9.3.3 Precipitation Depth and Volume

The precipitation that falls directly on Rodman Reservoir can represent a significant lake inflow. Rainfall depths at Rodman Reservoir over the period of record were estimated from records maintained by NOAA for Crescent City (Station No. 8-1978) (NOAA, 2002). This station is located approximately 20 miles southwest of Rodman Reservoir. The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to Rodman Reservoir by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

9.3.4 Evaporation Depth and Volume

No evaporation data for Rodman Reservoir was located during Task 2 so lake evaporation was estimated from pan evaporation data available at Lisbon (NOAA, 2002). This climate station (No. 8-5076) is located about 43 miles south of Rodman Reservoir. The pan coefficient for the Rodman Reservoir vicinity is estimated to be 76 percent (NOAA, 1982).

The recording frequency for the pan evaporation data at Lisbon is generally daily but regular short periods of a few days occurred when only a cumulative value that represents the evaporation over the entire interval is available. To smooth out these periods, the pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. No pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from Rodman Reservoir were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and lake surface area.

9.3.5 Outflow

Rodman Reservoir has two outlets: the Ocklawaha River and the Cross Florida Barge Canal. The USGS maintains stream gaging stations on both of these outlets: Nos. 02243960 and 02244032, respectively. Both of these waterways join the St. Johns River less than ten miles downstream of Rodman Reservoir. The sum of the records at these two stream gages was used to estimate the gaged outflow from Rodman Reservoir. Ungaged outflow was assumed to always be zero.

9.3.6 Elevation and Change in Storage

The gage heights recorded at the Eureka gage were used as a surrogate for actual lake elevation data. This gage is at the upper end of Rodman Reservoir so the water surface elevations at this location are expected to be somewhat higher than rest of the reservoir. The long-term average gage height at Eureka is approximately 19.22 feet as compared to a normal pool elevation of 18.0 feet in the reservoir. The daily water surface elevations of Rodman Reservoir were estimated as the gage heights at Eureka less 2.22 feet. From these estimates, the day-to-day changes in lake storage were estimated as the products of the corresponding reservoir elevation changes and the reservoir surface area.

Very few total water depth readings are available for Rodman Reservoir but the average reservoir depth has been reported as 8.4 feet (Parsons, 2000). Using the estimed reservoir elevation data, an average lake bottom of 9.5 feet was determined to yield average water depths of about 8.5 feet.

9.3.7 Imbalance

Using all of the above assumptions, a water balance for each day during the period of record was calculated and any resulting imbalances determined. Over the entire period of record, reservoir outflow exceeds inflow by about 600,000 acre-feet. In order to make these quantities more closely balance, the estimates of ungaged inflow to Rodman Reservoir were increase by a factor of two.

Table 9-3 presents an annual summary of the Rodman Reservoir water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 9-3: Rodman Reservoir Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1981	389,432	14,322	18,409	301,917	-2,063	85,492
1982	1,198,891	29,716	20,561	1,178,127	20,721	9,197
1983	1,596,847	28,490	20,444	1,475,359	-6,578	136,112
1984	1,429,026	27,598	21,470	1,329,237	-4,545	110,461
1985	620,685	21,184	21,626	588,018	628	31,597
1986	894,688	23,018	22,451	844,505	-4,545	55,295
1987	1,110,530	21,269	19,687	942,483	1,017	168,612
1988	906,551	24,373	20,652	928,022	9,568	-27,319
1989	796,385	19,829	22,508	852,601	-7,086	-51,933
1990	566,464	19,847	22,716	593,988	-5,860	-24,532
1991	644,530	24,305	20,936	672,799	1,226	-26,056
1992	467,255	25,083	20,308	481,119	150	-9,547
1993	681,405	27,377	20,338	693,594	-1,286	-3,864
1994	649,513	29,942	19,789	643,369	12,110	4,189
1995	945,280	27,546	18,762	981,306	-8,252	-18,680
1996	1,079,410	23,789	20,864	1,314,446	-23,501	-210,308
1997	625,706	27,179	18,713	646,758	-957	-12,286
1998	1,650,265	27,737	19,103	1,764,052	6,638	-111,791
1999	699,822	22,738	17,388	750,704	7,535	-52,452
2000	479,852	24,299	19,781	417,739	-120	66,606
2001	430,856	26,280	18,054	375,979	-658	62,955
2002	537,288	25,230	20,595	701,296	24,040	-182,321
2003	1,108,117	27,100	21,207	1,170,135	9,448	-66,787
Total	19,508,798	568,251	466,364	19,647,553	27,628	-67,358

9.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for Rodman Reservoir using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the period of record.

- Inflow TP concentration and flux
- Direct phosphorus deposition to Rodman Reservoir
- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

9.4.1 Inflow TP Concentration and Flux

During the selected period of record (WY 1981–2003), inflow TP concentration data are available for 263 days at Rodman Reservoir, yielding an average sample frequency of once every 32 days, or approximately monthly. Table 9-4 lists the specific stations and numbers of available TP samples within the analysis period at each station.

Two different methods were tried to estimate the inflow TP concentration on missing days. The first method was through regression analysis using inflow TP concentration or its log transform as the dependent variable, and the inflow rate, log transform of the inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variable: Common logarithm of inflow rate in cfs (log Q)
- Model: log [TP] = -2.496 +0.359 log Q
- Coefficient of determination (R^2): .119

Table 9-4: TP Monitoring Stations at Rodman Reservoir

Agency	Station	Station Name	Number of Samples
Inflow Stations			
COE	3CFB10001	DEEP CREEK AT HIGHWAY 310	31
	3CFB10003	ORANGE CREEK AT SR 315	31
	3CFB10004	OKLAWAHA RIVER AT SR 316 (EUREKA)	31
FDEP	20020003	MILLS CREEK AT NE 148TH TERRACE BRIDGE	1
	20020006	ORANGE CR AT SR 315 NR ORNG SPRG	148
	20020012	OKLAWAHA RIVER AT SR 316	207
	20020084	LIT ORANGE CR N CONF ORANGE CR.	50
	20020144	DEEP CREEK AT S.R. 315 BRIDGE	8
	20020147	OCKLAWAHA RIVER UPSTREAM OF PINEY ISLAND	1
	20020404	ORANGE CREEK 50 YDS. UP FROM HWY. 21	55
	20020415	OKLAWAHA RIVER AT SUNDAY BLUFF	14
	20020434	RODMAN RESERVOIR AT SR 310	56
	3517	OKLAWAHA RIVER AT S.R 316	45
	7453	SJD-HS-1015	1
	7479	SJR-HS-1066	1
	8058	SJD-LS-1001	1
	8103	SJD-LS-1027	1
	8110	SJD-LS-1037	1
	8132	SJD-LS-1054	1
	8703	SJD-LS-1039	1
	8719	SJD-SL-1022	1
SJRWMD	20020012	OKLAWAHA_RIVER_AT_SR_316	186
USGS	2240500	OCKLAWAHA RIVER AT EUREKA,FLA.	8
Interior Stations			
COE	3CFB10006	LAKE OKLAWAHA AT KENWOOD BAY	30
	3CFB10007	LAKE OKLAWAHA AT POWERLINE	31
	3CFB10008	LAKE OKLAWAHA AT PAYNES LANDING	31
	3CFB10009	LAKE OKLAWAHA AT GASLINE	30
	3CFB10010	LAKE OKLAWAHA AT MARKER 15	29
FDEP	2002031	OKLAWAHA R CEDAR FERRY MIDSTR	19
	20020311	OKLAWAHA R AT TOBACO PATCH LANDN	19
	20020312	OKLAWAHA R ORANGE FER NFS RD 77	19
	20020436	RODMAN RESERVOIR MIDDLE OF EAST END	4
	20020437	RODMAN RESERVOIR MIDDLE FROM EAST TO WE	6
LakeWatc	PUT-RODMA	Putnam-Rodman-1	36

Table 9-4: TP Monitoring Stations at Rodman Reservoir

Agency	Station	Station Name	Number of Samples
LakeWatc	PUT-RODMA	Putnam-Rodman-2	35
	PUT-RODMA	Putnam-Rodman-3	35
	PUT-RODMA	Putnam-Rodman-4	35
	PUT-RODMA	Putnam-Rodman-5	35
	PUT-RODMA	Putnam-Rodman-6	36
	PUT-RODMA	Putnam-Rodman-out 3-1	16
Outflow Stations			
COE	3CFB10005	OKLAWAHA RIVER ABOVE DAM	31
FDEP	20020068	OCKLAWAHA RIVER 1.1 MI. DOWNSTREAM RODM	52
	20020071	OKLAWAHA R. DWNSTRM OF RODMAN DA	24
	20020314	OKLAWAHA AT RODMAN DAM DNSTR SDE	19
	20020439	OKLAWAHA RIVER AT FOREST SERVICE ROAD 77	6
	7452	SJD-HS-1009	1
	7470	SJD-HS-1114	1
	7476	SJD-HS-1059	1
	7963	SJD-LL-1023	1
	8068	SJD-LS-1005	2
	8072	SJD-LS-1006	1
	8098	SJD-LS-1019	1
LakeWatc	PUT-RODMA	Putnam-Rodman-out 1-1	36
	PUT-RODMA	Putnam-Rodman-out 2-1	36

Even this “best” model does not have a very good fit but any model with a R^2 over .100 may be worthy of consideration. Therefore, this model was used to help estimate inflow TP concentrations.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less reliable.

At Rodman Reservoir, missing inflow TP concentrations were estimated using a combination of the two methods. Each missing value was estimated as the average of estimates based on the interpolation method and best regression model. Once these estimates of daily inflow TP concentrations were developed, the phosphorus influx to Rodman Reservoir was estimated each day as the product of these daily concentrations and the corresponding inflow volume previously developed for the water balance.

9.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to Rodman Reservoir is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 $\mu g/m^2$ while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn & James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

9.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from Rodman Reservoir were identical to those used for lake inflow. During the selected period of record (WY 1981–2003), outflow TP concentration data are available for 132 days, yielding an average sample frequency of about once every 62 days. Again, both regression analyses and the interpolation methods were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of outflow TP concentration in mg/L (log [TP])

- Independent variables: Common logarithm of inflow rate in cfs (log Q), julian day (J), and total monthly precipitation in inches (P)
- Model: log [TP] = -2.929 +0.490 log Q – 0.001 J – 0.019 P
- Coefficient of determination (R^2): .292

This regression model for outflow TP concentration has a significantly better fit than most of the other regression models developed in this study. Therefore, this model was used to help estimate outflow TP concentrations.

The second method used to estimate outflow TP concentrations was a simple straight-line interpolation process described above. The outflow TP concentration estimates used in the phosphorus balance were calculated as the average of the estimates from these two methods. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from Rodman Reservoir was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

9.4.4 Net Phosphorus Retention

The net phosphorus retention in Rodman Reservoir was estimated as total influx in inflow and deposition less discharge flux in outflow. As such, these net retention values include the phosphorus retained or discharged because of changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for Rodman Reservoir is shown in Table 9-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

9.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for Rodman Reservoir were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. This monthly data set includes the following data values:

Table 9-5: Rodman Reservoir Phosphorus Balance Summary (kg)

Water Year	Inflow	Precipitation	Outflow	Net Retention
1981	19,998	665	9,556	11,107
1982	85,432	1,094	55,003	31,523
1983	138,286	1,080	81,589	57,777
1984	98,570	1,071	71,159	28,483
1985	39,345	995	18,958	21,383
1986	47,747	1,016	37,410	11,353
1987	71,850	996	50,826	22,020
1988	70,119	1,034	62,427	8,726
1989	50,992	979	39,385	12,587
1990	26,025	980	17,866	9,138
1991	30,214	1,031	29,695	1,551
1992	20,494	1,042	20,617	919
1993	40,803	1,067	32,147	9,723
1994	35,490	1,097	28,089	8,497
1995	64,871	1,069	44,568	21,372
1996	89,430	1,027	64,181	26,276
1997	35,816	1,065	27,186	9,695
1998	112,242	1,071	100,083	13,230
1999	37,240	1,013	31,681	6,573
2000	22,454	1,033	7,553	15,934
2001	18,763	1,054	7,482	12,336
2002	25,985	1,042	19,705	7,321
2003	71,267	1,064	3,639	6,723
Total	1,253,433	23,586	860,803	354,248

- Average water surface area (hectares, ha)
- Total inflow and outflow volumes (cubic meters, m^3)
- Total mass flux of phosphorus in, out and retained in the lake (grams, g)
- Flow-weighted average inflow and outflow phosphorus concentrations (milligrams per liter, mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (meters per year, m/yr)
- Net phosphorus settling rate, k (m/yr)

- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

9.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 9-12. From review of this graph, it is not apparent there is a linear relationship between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .028.

9.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. Figure 9-13 is a scatter diagram of settling rate vs. hydraulic loading rate. The corresponding regression model has a R^2 of .554. The other model with a R^2 significantly above zero (R^2 = .530) has depth as the independent variable.

9.6 VEGETATION DATA

Aquatic and wetland plant community data are available for Rodman Reservoir from the DEP's Bureau of Invasive Plant Management (BIPM). BIPM conducts periodic surveys of cover of wetland and aquatic plants for many water bodies in the state to assess both the need for and effectiveness of their aquatic plant management activities. Total areas of individual emergent, floating, and submerged macrophyte species are estimated by BIPM. Available plant community data from this source are summarized below to provide a quantitative indicator of the importance of wetland and aquatic plant communities in this lake.

Figure 9-12: Retention Efficiency vs. Hydraulic Loading Rate at Rodman Reservoir

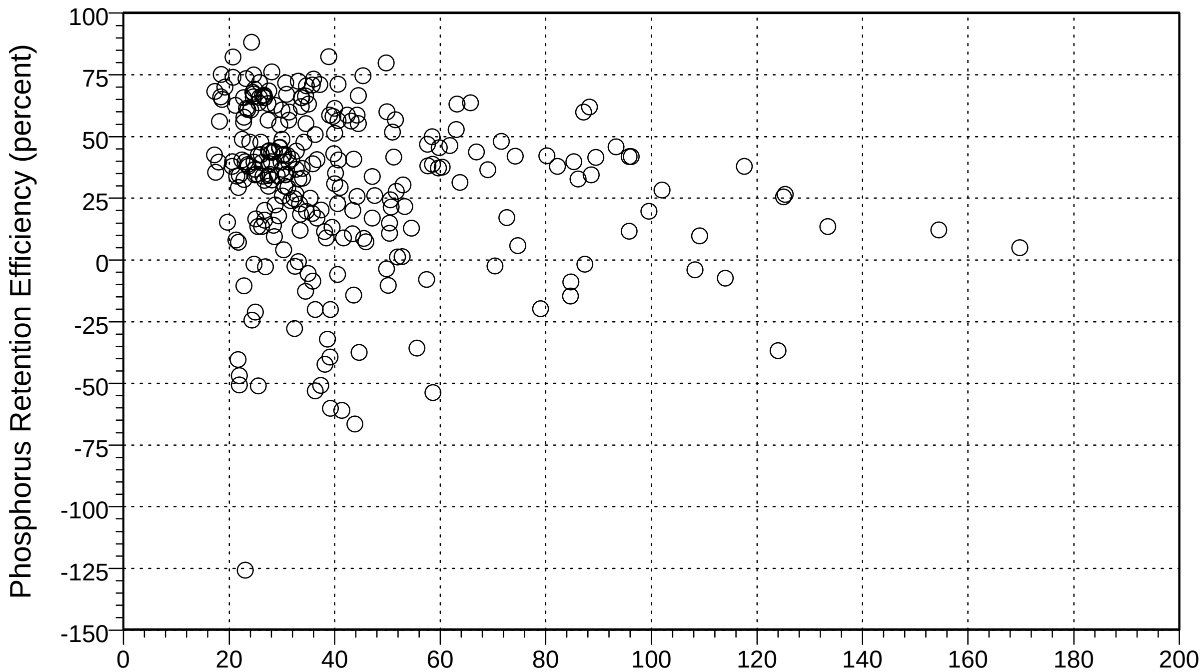
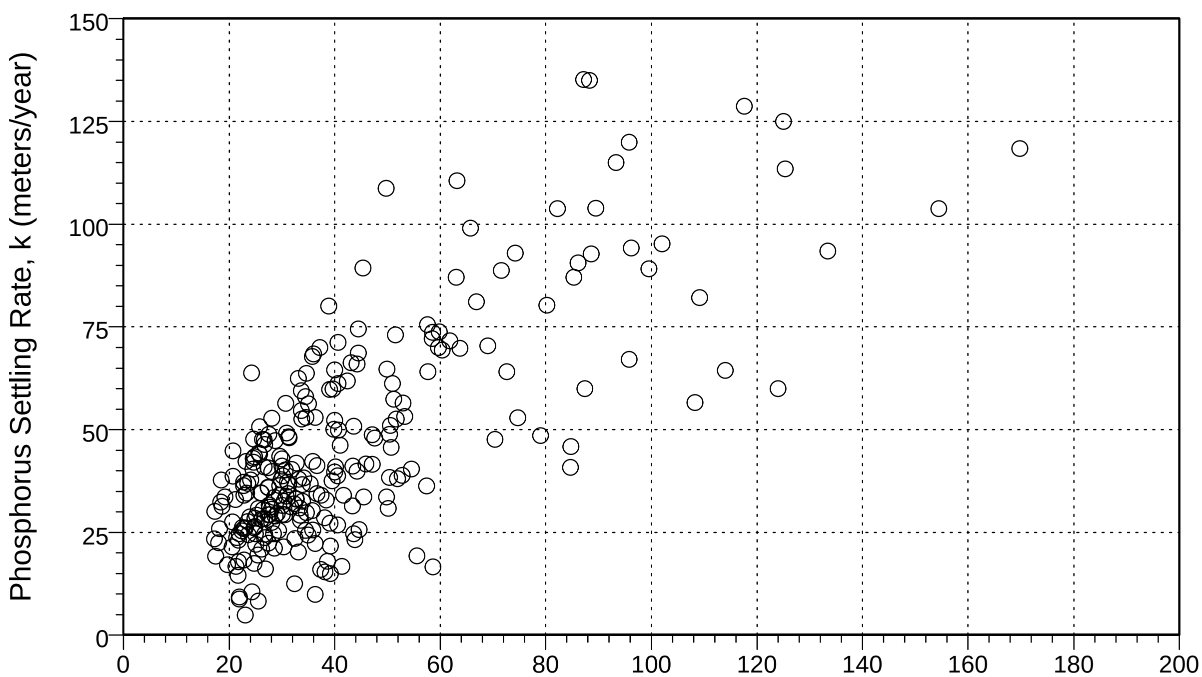


Figure 9-13: Settling Rate vs. Hydraulic Loading Rate at Rodman Reservoir



A total of 69 species of wetland and aquatic plants were recorded in Rodman Reservoir during the BIPM surveys. These included 46 species of emergent wetland plants, 10 species of floating aquatic plants, and 13 species of submerged aquatic plants. Dominant emergent wetland species included smartweeds (*Polygonum* spp.), pickerelweed (*Pontederia cordata*), cattails, alligatorweed (*Alternanthera philoxeroides*), and pennywort. Dominant floating species included water lettuce, duckweed, and filamentous algae. Dominant submerged aquatics included hydrilla, coontail, eelgrass, and pondweed (*Potamogeton illinoensis*).

Table 9-6 summarizes the estimated cover by vegetation type in the Rodman Reservoir for the period from 1982 through 2003. The average cover by vegetation type was emergent – 1,104 acres, floating – 1,246 acres, and submerged – 3,325 acres. These estimated plant coverages show that plants largely fill the estimated 3,857-acre surface area of the Rodman Reservoir.

Table 9-6: Rodman Reservoir Vegetation Data

Survey	Vegetation Coverage by Type (acres)		
Month	Emergent	Floating	Submerged
Sep-82	804	1174	2646
Oct-83	555	1821	2580
Oct-84	586	1315	4577
Oct-86	715	830	4192
Nov-88	920	680	3871
Oct-90	877	676	3470
Oct-92	2526	888	4181
Oct-95	2248	2083	1772
Oct-03	705	1750	2635
Average	1104	1246	3325
Median	804	1174	3470
Maximum	2526	2083	4577
Minimum	555	676	1772

* * * * *

10 St. Johns Marsh Conservation Area

10 ST. JOHNS MARSH CONSERVATION AREA

The St. Johns Marsh Conservation Area (CA) is located in Brevard County approximately ten miles west of Melbourne. This conservation area is near the headwaters of the St. Johns River (Figure 1-1) and contains two small lakes: Lake Hellen Blazes and Sawgrass Lake. The data collected for the St. Johns Marsh CA and the analyses completed with these data are described in the balance of this chapter.

10.1 DATA SOURCES

The data for the St. Johns Marsh CA were collected from a number of sources. These sources are listed in Table 10-1 along with a listing of the individual sample stations obtained from each source. For each sampling station, this table also lists the station's absolute location (latitude/longitude coordinates) and location relative to the CA. Relative locations were assigned to each monitoring station based on whether the station's data are representative of inflow, outflow, interior, or external conditions. Figure 10-1 shows the locations of these monitoring stations.

10.2 DATA SUMMARY

Some of the monitoring stations discussed in the previous paragraph have data available for dozens of hydrologic and water quality parameters; however, only selected parameters are of primary interest in this analysis. These parameters are listed below:

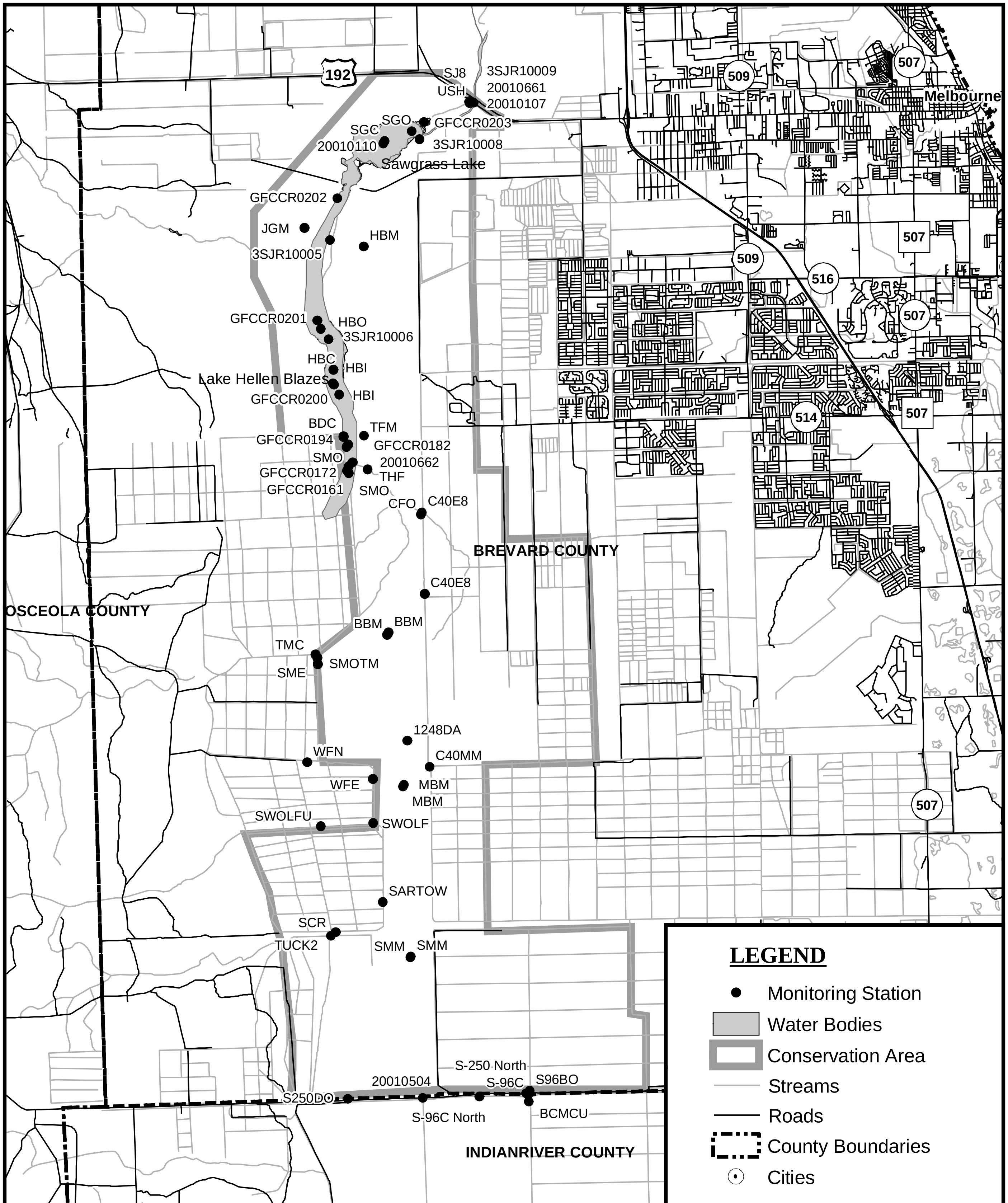
- Flow
- Total phosphorus concentrations
- Total orthophosphorus concentrations
- Total nitrogen concentrations

Table 10-1: St. Johns Marsh Conservation Area Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Florida Department of Environmental Protection (FDEP)				
Outflow	20010662	THREE FORKS RUN ON ST JOHNS RIVER	27.99500	80.79166
Exterior-D	20010118	ST JOHNS R TO SAWGRASS L	28.06275	80.79000
	20010119	ST JOHNS R TO L HELLEN BLAZES	28.00056	80.79278
	20010504	WESTERN TERMINAT OF LAT M CANAL	27.82264	80.77456
Florida Game and Fresh Water Fish Commission (FGFWF)				
Outflow	GFCCR0161	SOUTH MORMON OUTSIDE CANAL UPSTREAM	27.98750	80.79166
	GFCCR0172	3-FORKS RUN APPROX. 300 FT UPSTREAM	27.99028	80.79056
	GFCCR0182	SOUTH MORMON OUTSIDE CANAL DOWNSTR	27.99444	80.79222
	GFCCR0200	ST. JOHNS RIVER ENTRANCE TO LAKE HELL N'	28.01111	80.79583
Exterior-U	GFCCR0194	BULLDOZER CANAL APPROX. 100 FT IN FROM	27.99722	80.79305
Exterior-D	GFCCR0201	ST. JOHNS RIVER EXIT OF LAKE HELL N' BLAZ	28.02778	80.80000
	GFCCR0228	DEVILS GARDEN SPRING	28.08333	80.76250
National Oceanic and Atmospheric Administration (NOAA)				
Unknown	85612	Melbourne Airport	28.10000	80.63333
Saint Johns River Water Management District (SJRWMD)				
Inflow	BCMCU	Upstream (south) of S-96C in M canal in BCMCA	27.82100	80.74316
	S-250 North		27.82268	80.75786
	S-96C		27.82311	80.74381
	S-96C North		27.82278	80.74336
Outflow	HBI	Lake Hell N Blazes inlet	28.00821	80.79396
	SMO	South Mormon Outside Canal 100 yd upstm fr SJR	27.98935	80.79168
	THF	ST JOHNS RIVER IN THREE FORKS AREA	27.98833	80.78611
Interior	BBM	SJMCA at Big Bend Marsh telemetry station	27.94533	80.78119
	C40E8	Canal 40 Upstream of E-8 plug	27.95526	80.77007
	C40MM	CANAL 40 400M N OF S-256 NR MULBERRY MO	27.90972	80.77000
	CFO	CANAL 40 100 YDS SOUTH OF CONF W/ THREE	27.97611	80.77055
	MARYAC	MARY A CANAL UPSTREAM OF CONF W/ C-40	27.82528	80.76972
	MBM	Mulberry Marsh in SJMCA 800 m west of C40	27.90518	80.77777
	SMM	Six Mile Marsh in SJMCA 700 m West of C40	27.85998	80.77708
Exterior-U	BDC	BULLDOZER CANAL 100 YDS UPSTR CONF W/	27.99694	80.79305
Exterior-D	HBC	LAKE HELL'N BLAZES AT CENTER	28.01472	80.79556
	HBO	ST JOHNS RIVER AT EXIT OF LAKE HELL'N BL	28.02556	80.79889

Table 10-1: St. Johns Marsh Conservation Area Monitoring Stations

Relative Loc.	Station	Station Name	Latitude	Longitude
Exterior-D	JGM	JANE GREEN MARSH W OF SJR (B/T HL'N BLZ	28.05222	80.80305
	SARTOW	SARTORI WEST IN CANAL UPSTM OF PUMP	27.87444	80.78497
	SCR	SIX MILE CREEK IN CANAL 50 YDS FROM FAR	27.86686	80.79928
	SME	S MORMON EXT 50 YDS S OF CONF W/TEN MIL	27.93917	80.80250
	SMOTM	S MORMON OUTSIDE CANAL AB TEN MILE CA	27.93750	80.80250
	SWOLF	S. WOLF CREEK IN CANAL AT NE CORNER SAT	27.89528	80.78722
	SWOLFU	SOUTH WOLF CRK DWNSTM FROM PUMP AT	27.89489	80.80275
	TFM	THREE FORKS MARSH E OF BULLDOZER CANA	27.99722	80.78694
	TMC	TEN MI CNL 100 YDS W OF CONF W/S MORMO	27.94000	80.80305
	TUCK2	PUMP AT NORTH END OF TUCKER PROPERTY	27.86589	80.80061
	WFE	WILLOWBRK FARMS E-- 100 YDS S OF BEND IN	27.90694	80.78694
	WFN	WILLOWBRK FRMS N-- B/T CULVERTS & CONF	27.91167	80.80639
U.S. Army Corps of Engineers (COE)				
Exterior-D	3SJR10005	ST JOHNS R ABOVE LK HELLEN BLAZES	28.04889	80.79556
	3SJR10006	LAKE HELLEN BLAZES NEAR OUTLET	28.02278	80.79667
U.S. Geological Survey (USGS)				
Inflow	2231600	JANE GREEN CREEK NEAR DEER PARK, FLA.	28.07417	80.88834
Outflow	2232000	ST. JOHNS RIVER NEAR MELBOURNE FLA	28.08444	80.75222
US EPA--Storet (US EPA)				
Interior	1248DA	LARGO	27.91667	80.77639



2.5 1.25 0 2.5 Miles

1 Inch equals 2.5 Miles

NORTH

Burns & McDonnell
SINCE 1898

Figure 10-1
ST. JOHNS MARSH CONSERVATION AREA MONITORING STATIONS

- pH
- Total calcium concentrations
- Water depth (reported as stream depth, water surface elevations, gage heights, or stage)
- Water temperature

For daily time series data (principally flow and water surface elevations), monthly averages were calculated from the available data for each relative location. For constituent concentration data where more than one monitoring station represents a given relative location (inflow, outflow, etc.), the data for these stations were averaged for each sample date to yield a single average value for that date and relative location. These average data were plotted against time by relative location to give a visual indication of available periods of record, sampling frequency and overall data richness.

Figures 10-2 through 10-9 contain the time series graphs for the St. Johns Marsh CA for the selected monitoring parameters listed above. These graphs share a common time scale of 1975 to 2005, although some data, principally flow data, are available earlier than 1975. For the most part, relatively few water quality monitoring data are available for this CA before 1980. Also shown on these time series graphs for inflow and outflow are lines showing annual (365-day) rolling averages. These rolling average lines can give an indication of long-term trends.

The most critical data needed for the purposes of the WQIR project are flow and phosphorus concentration data for use in calculating water and phosphorus balances at the CA. The graphs of available flow and phosphorus concentration data are shown in Figures 10-2 and 10-3, respectively. The limiting data at this site is inflow TP concentration data, which is only available starting in January 1997. For this reason, WY 1997–2003 (10/1/1996–9/30/2003) were selected as the period of record for subsequent analyses. The time series graphs for the other key monitoring parameters also show these data are most prevalent during this same period.

After the analysis period was selected, the time series graphs for flow rates and TP concentration were replotted with an expanded time scale that covers only this period. These graphs, Figures 10-10 and 10-11, better show the availability of data during this critical period. Table 10-2 includes descriptive

Figure 10-2: Long-term Flow at St. Johns Marsh Conservation Area

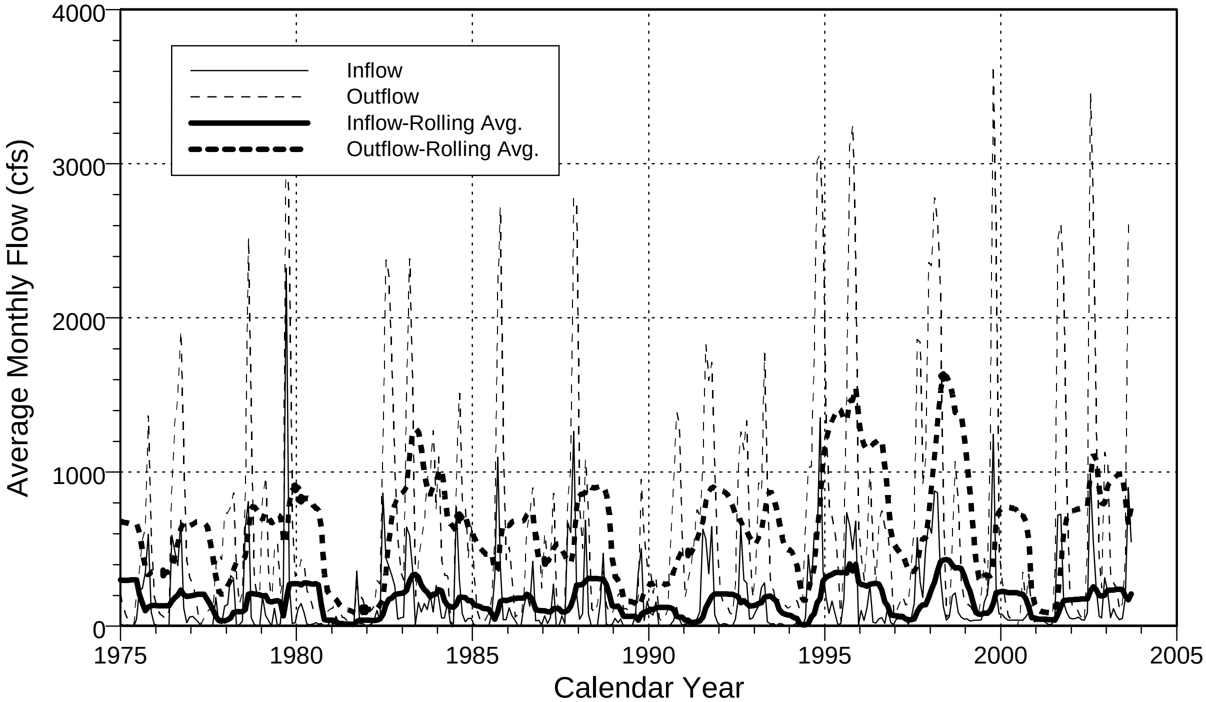


Figure 10-3: Long-term Total Phosphorus at St. Johns Marsh Conservation Area

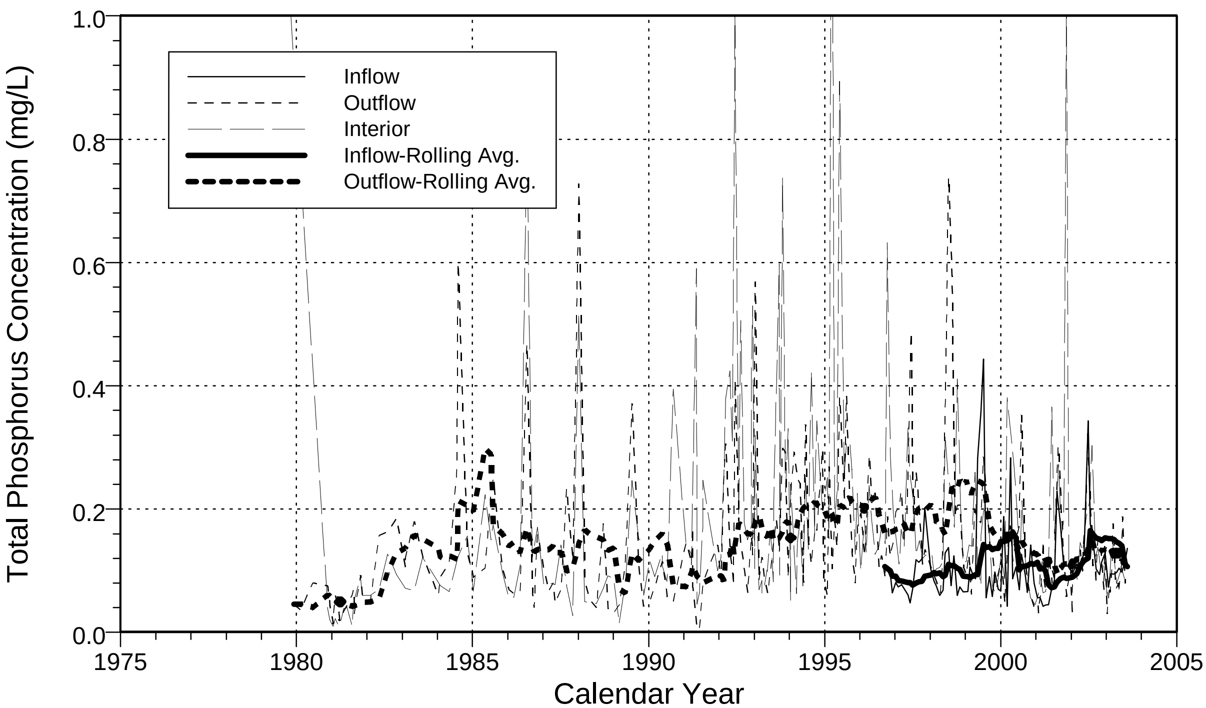


Figure 10-4: Long-term Orthophosphorus at St. Johns Marsh Conservation Area

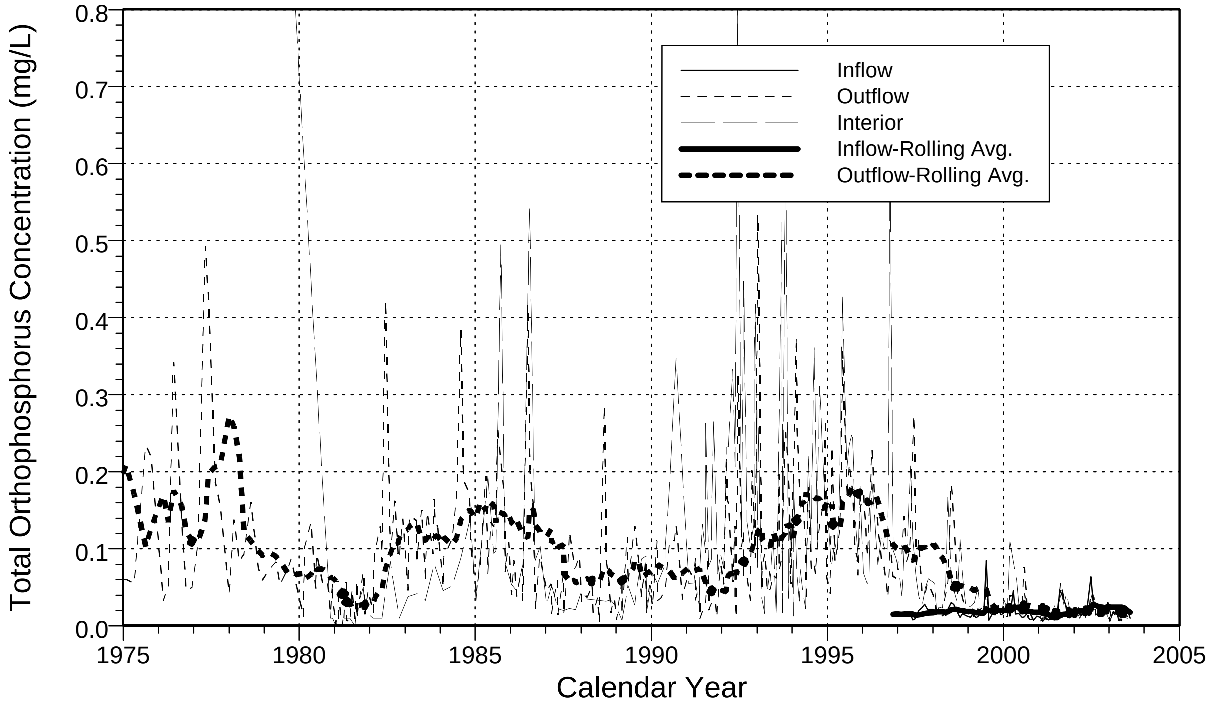


Figure 10-5: Long-term Total Nitrogen at St. Johns Marsh Conservation Area

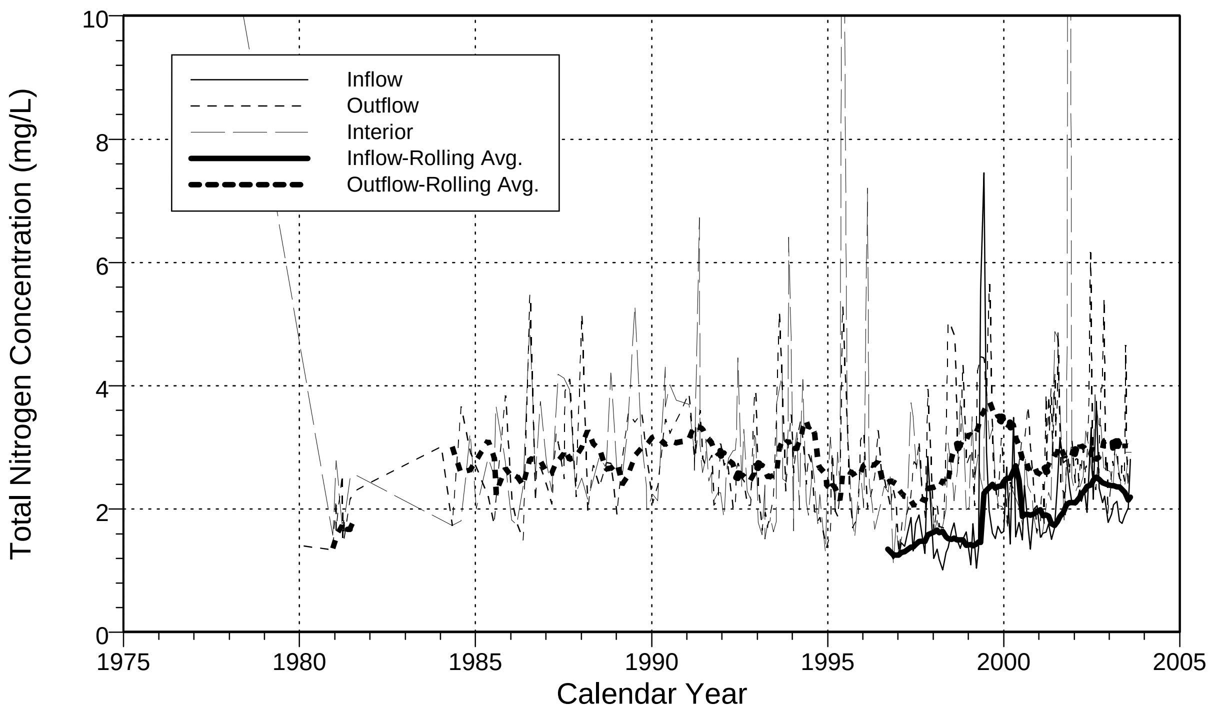


Figure 10-6: Long-term pH at St. Johns Marsh Conservation Area

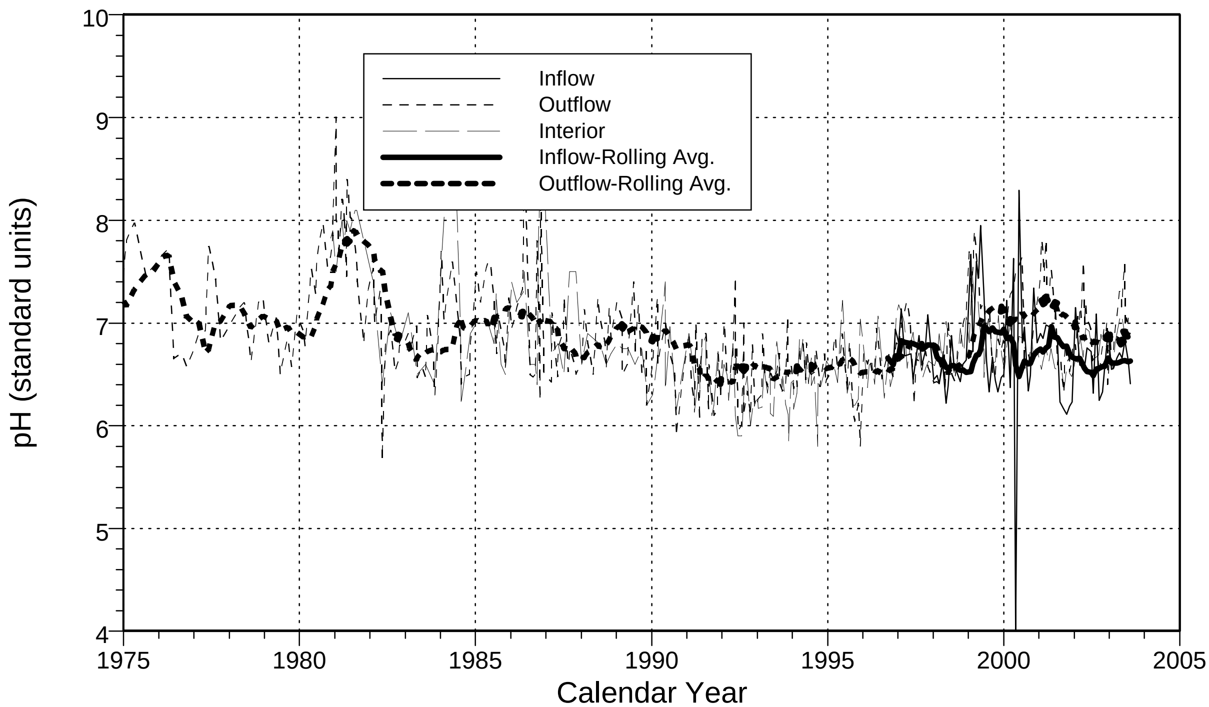


Figure 10-7: Long-term Total Calcium at St. Johns Marsh Conservation Area

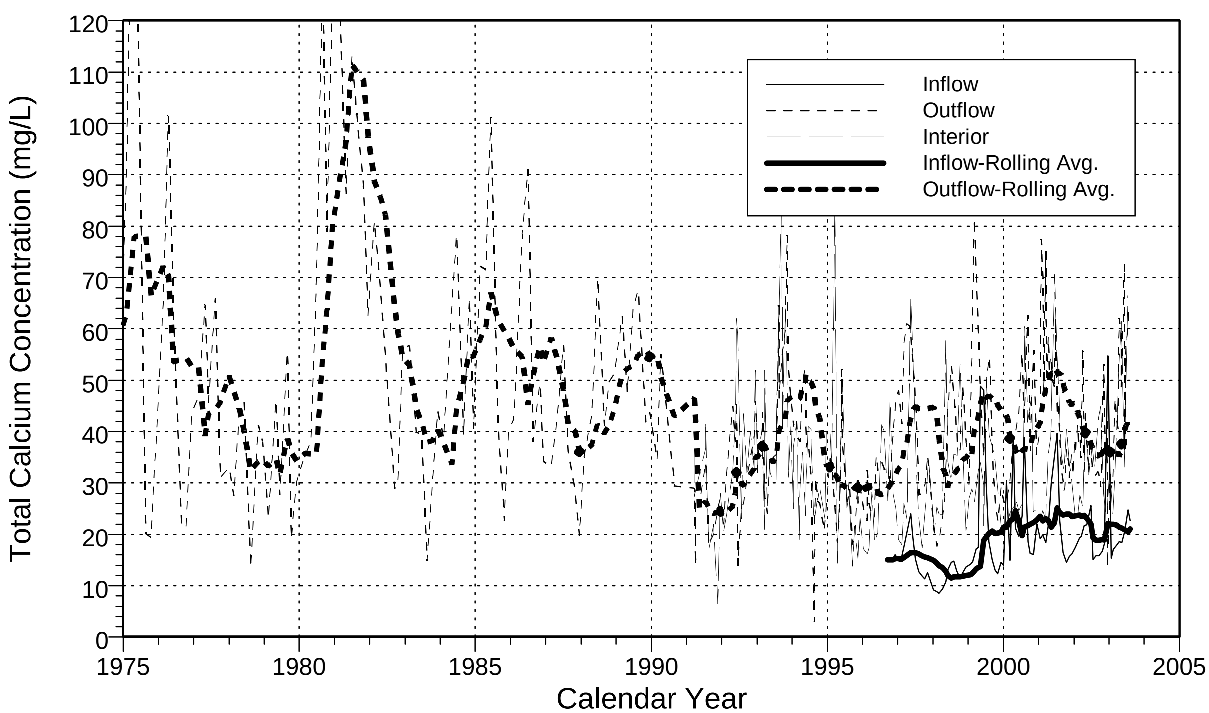


Figure 10-8: Long-term Water Surface Elevation at St. Johns Marsh Conservation Area

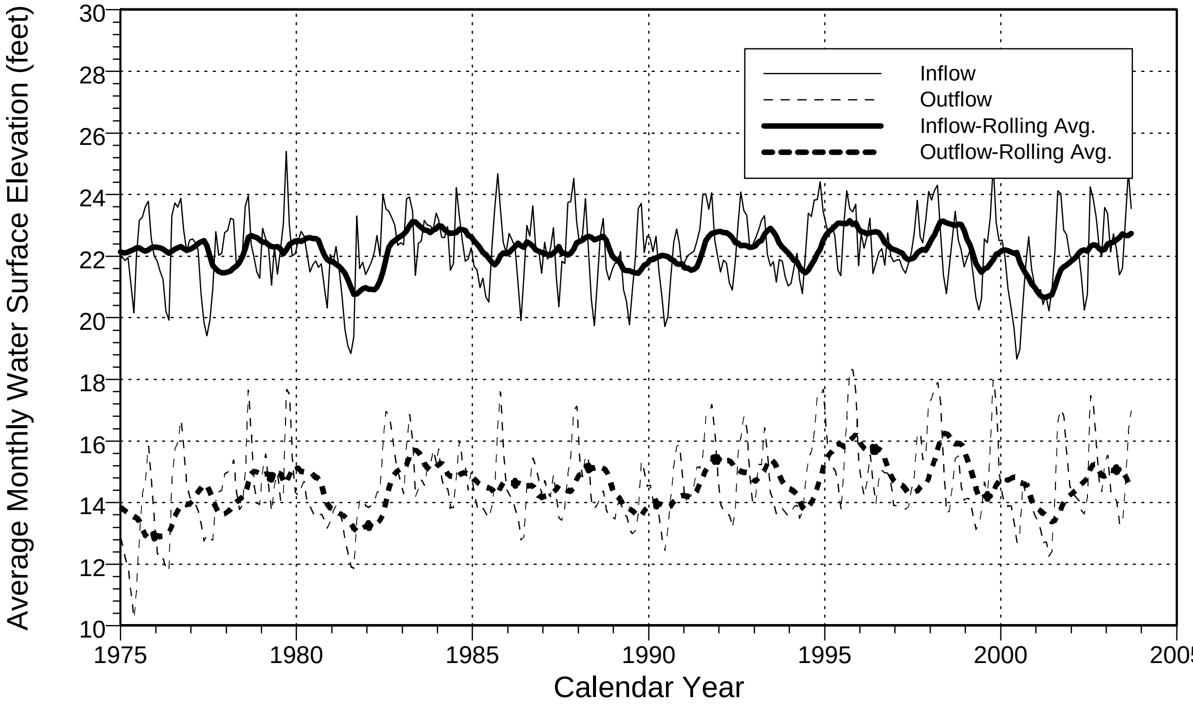
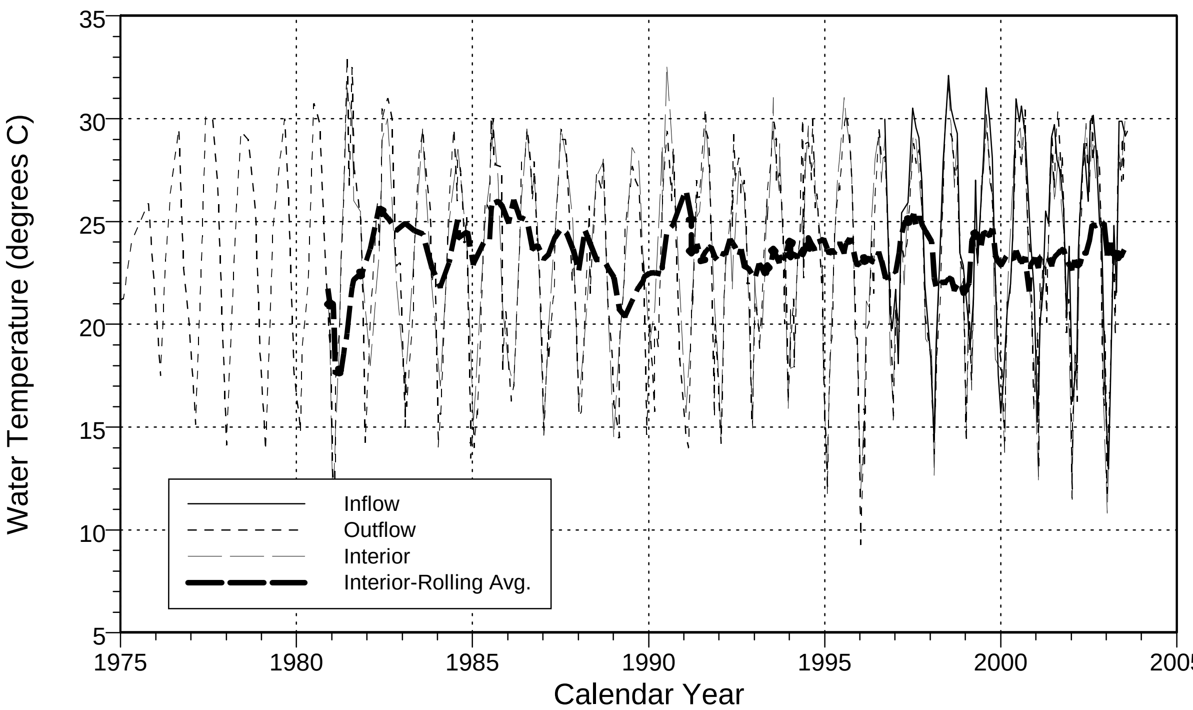


Figure 10-9: Long-term Water Temperature at St. Johns Marsh Conservation Area



statistics for key monitoring parameters at St. Johns Marsh CA. This table lists the number of samples; number of non-detect samples; and mean, minimum and maximum values for each parameter and relative location. These statistics are further broken down by period of record, whether they occur inside or outside of the selected analysis period. Readers will note that relatively few non-detect samples occurred at this data site. The values reported for these non-detect samples were typically the applicable detection limits and these detection limit values were included in the associated statistics when they occurred.

10.3 WATER BALANCE

A daily water balance for St. Johns Marsh CA was developed for WY 1997–2003. This water balance included estimates of the following quantities for each day during the period of record.

- Surface area
- Gaged and ungaged inflow
- Precipitation depth and volume
- Evaporation depth and volume
- Gaged and ungaged outflow
- Water surface elevation
- Water depth
- Storage change
- Imbalance

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

10.3.1 Surface Area

The St. Johns Marsh CA includes both open water and marsh areas, totaling about 23,200 acres. No specific information on the surface area of these combined areas as a function of stage is available. Therefore, a constant surface area of 23,200 acres was adopted for use in the water balance.

Figure 10-10: Analysis Period Flow at St. Johns Marsh Conservation Area

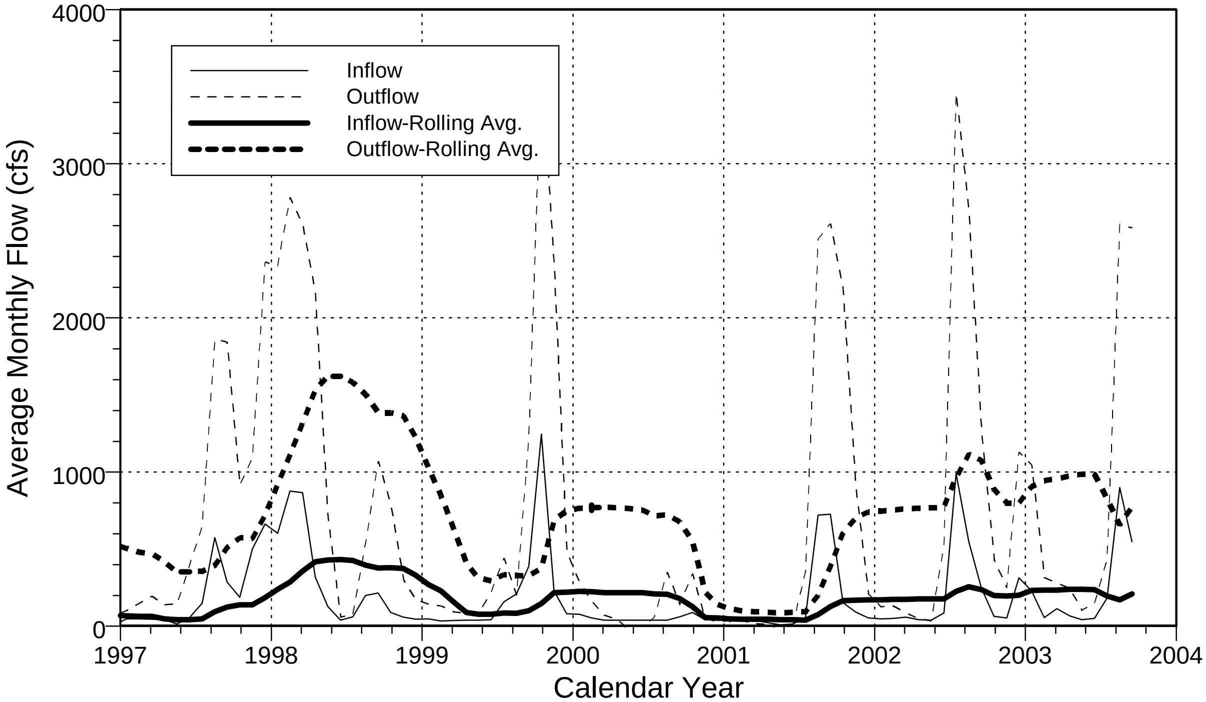


Figure 10-11: Analysis Period Total Phosphorus at St. Johns Marsh Conservation Area

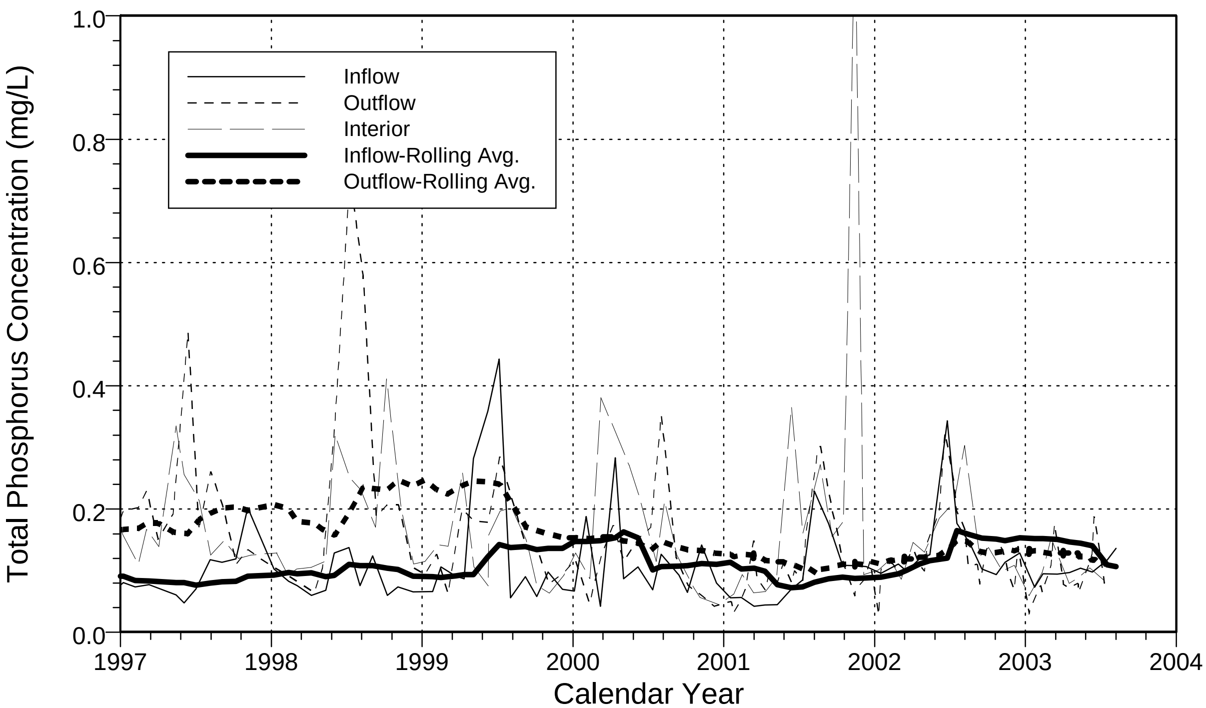


Table 10-2: St. Johns Marsh Conservation Area Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Calcium (mg/L)	Inflow	Inside	90	0	19.380	8.490	54.784
		Outside	4	0	15.250	15.000	16.000
		Total	94	0	19.204	8.490	54.784
Calcium (mg/L)	Outflow	Inside	183	0	41.619	0.001	84.300
		Outside	496	0	49.124	3.000	255.000
		Total	679	0	47.101	0.001	255.000
Calcium (mg/L)	Interior	Inside	149	0	32.996	14.620	70.617
		Outside	140	0	33.768	3.800	190.000
		Total	289	0	33.370	3.800	190.000
Elevation (feet)	Inflow	Inside	2,354	0	22.124	18.460	25.950
		Outside	15,629	0	22.397	18.610	29.270
		Total	17,983	0	22.361	18.460	29.270
Elevation (feet)	Outflow	Inside	2,461	0	14.712	12.030	19.100
		Outside	20,807	0	15.189	9.990	20.830
		Total	23,268	0	15.138	9.990	20.830
Flow (cfs)	Inflow	Inside	4,798	0	199.683	0.000	2,880.000
		Outside	15,798	0	216.893	0.000	17,000.000
		Total	20,596	0	212.884	0.000	17,000.000
Flow (cfs)	Outflow	Inside	2,464	0	752.794	-79.000	5,340.000
		Outside	20,912	0	674.477	-118.000	18,000.000
		Total	23,376	0	682.732	-118.000	18,000.000
Orthophosphorus (mg/L)	Inflow	Inside	78	0	0.019	0.007	0.085
		Outside	2	0	0.016	0.015	0.016
		Total	80	0	0.019	0.007	0.085
Orthophosphorus (mg/L)	Outflow	Inside	178	0	0.043	0.001	0.466
		Outside	718	1	0.102	0.001	0.783
		Total	896	1	0.090	0.001	0.783
Orthophosphorus (mg/L)	Interior	Inside	144	0	0.038	0.002	0.314
		Outside	294	0	0.384	0.002	7.700
		Total	438	0	0.270	0.002	7.700
pH	Inflow	Inside	88	0	6.699	3.870	8.290
		Outside	4	0	6.680	6.560	6.940

POR: Inside=Within analysis period (1/1/1997-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 10-2: St. Johns Marsh Conservation Area Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
pH	Inflow	Total	92	0	6.698	3.870	8.290
pH	Outflow	Inside	183	0	6.939	6.130	7.910
		Outside	644	0	6.972	5.300	9.600
		Total	827	0	6.964	5.300	9.600
pH	Interior	Inside	149	0	6.744	6.250	7.780
		Outside	240	0	6.619	5.800	9.400
		Total	389	0	6.667	5.800	9.400
Phosphorus (mg/L)	Inflow	Inside	90	0	0.112	0.040	0.443
		Outside	4	0	0.091	0.064	0.116
		Total	94	0	0.111	0.040	0.443
Phosphorus (mg/L)	Outflow	Inside	183	0	0.157	0.028	0.935
		Outside	225	2	0.133	0.005	0.728
		Total	408	2	0.144	0.005	0.935
Phosphorus (mg/L)	Interior	Inside	149	0	0.176	0.032	4.424
		Outside	237	0	0.591	0.009	8.300
		Total	386	0	0.431	0.009	8.300
Temperature (deg C)	Inflow	Inside	90	0	24.822	12.970	32.100
		Outside	4	0	22.710	19.800	29.980
		Total	94	0	24.732	12.970	32.100
Temperature (deg C)	Outflow	Inside	182	0	23.785	11.550	30.690
		Outside	669	0	23.105	9.000	34.000
		Total	851	0	23.250	9.000	34.000
Temperature (deg C)	Interior	Inside	149	0	23.202	10.150	31.610
		Outside	247	0	23.460	9.910	32.900
		Total	396	0	23.363	9.910	32.900
Total Nitrogen (mg/L)	Inflow	Inside	246	0	2.004	0.760	11.180
		Outside	10	0	1.254	0.700	2.020
		Total	256	0	1.974	0.700	11.180
Total Nitrogen (mg/L)	Outflow	Inside	507	0	2.915	0.576	9.248
		Outside	524	0	2.623	0.260	9.580
		Total	1,031	0	2.766	0.260	9.580
Total Nitrogen (mg/L)	Interior	Inside	407	0	3.153	0.934	131.648

POR: Inside=Within analysis period (1/1/1997-9/30/2003); Outside=Outside analysis period; Total=All available data.

Table 10-2: St. Johns Marsh Conservation Area Monitoring Data Statistics

Parameter	Relative Loc.	POR	Number	Nondetect	Mean	Minimum	Maximum
Total Nitrogen (mg/L)	Interior	Outside	702	0	3.753	0.950	48.000
		Total	1,109	0	3.533	0.934	131.648

POR: Inside=Within analysis period (1/1/1997-9/30/2003); Outside=Outside analysis period; Total=All available data.

10.3.2 Inflow

The St. Johns Marsh CA has two sources of inflow: Jane Green Creek and Structure S-96. The USGS maintains a gaging station on Jane Green Creek (No. 02231600) and SJRWMD keeps records of discharge at S-96. The gaged inflow to the CA was calculated as the sum of the discharge at these two locations.

The ungaged inflow to this CA was initially set to zero and later adjusted as described in Section 10.3.7.

10.3.3 Precipitation Depth and Volume

The precipitation that falls directly on St. Johns Marsh CA can represent a significant lake inflow. Rainfall depths at the St. Johns Marsh CA over the period of record were estimated from records maintained by NOAA for Melbourne Airport (Station No. 8-5612) (NOAA, 2002). This station is located approximately ten miles east of the St. Johns Marsh CA. The NOAA data source used to obtain precipitation data includes data only through the end of 2001. Rainfall amounts for 2002 and 2003 were estimated from long-term averages for each day of the year. The water volume contributed to St. Johns Marsh CA by precipitation was calculated as the product of the estimated rainfall depth each day and the constant lake area discussed above.

10.3.4 Evaporation Depth and Volume

No evaporation data for St. Johns Marsh CA were located during Task 2 so lake evaporation was estimated from pan evaporation data available at Vero Beach (Station No. 8-9210), Fort Pierce (Station No. 8-3209), and Lake Alfred (Station No. 8-4707). Vero Beach is the closest of these three stations at a distance of approximately 30 miles from the CA. The records at this station were given preference but the records at the other two stations were used to fill in missing data. The Fort Pierce and Lake Alfred stations are progressively farther away from the CA — approximately 44 and 57 miles, respectively. Water will evaporate faster from an evaporation pan than a lake because a pan is a much smaller body of water and will heat up more rapidly than a lake. Therefore, pan evaporation data must be multiplied by a pan coefficient to estimate lake evaporation. The pan coefficient for the St. Johns Marsh CA vicinity is estimated to be 76 percent (NOAA, 1982).

The available pan evaporation data were totaled by month and then the monthly totals were distributed evenly to each day of the respective month. As discussed in the previous section, no pan evaporation data are available for 2002 or 2003 so long-term pan evaporation averages by month were used as substitutes for missing months. Evaporation losses from St. Johns Marsh CA were then estimated as the product of the estimated daily pan evaporation depth, pan coefficient and water surface area.

10.3.5 Outflow

The principal outlet from the St. Johns Marsh CA is the St. Johns River. The USGS maintains a stream gage on the St. Johns River at the northern (downstream) boundary of the CA. This gage, St. Johns River near Melbourne, FL (No. 02232000), has a period of record going back into the 1930s. The records at this stream gage were used to estimate the gaged outflow from St. Johns Marsh CA. Ungaged outflow was assumed to always be zero because the CA has no other significant outlets.

10.3.6 Elevation and Change in Storage

The water surface elevations recorded at the CA outlet (Melbourne gage) were used as a surrogate for actual water surface elevation data. The day-to-day changes in these elevations were assumed to be representative of the changes in CA stage. The corresponding changes in storage were then estimated as the products of these elevation changes and the CA surface area. The available elevation readings are mean daily values and as such, are probably more representative of midday values then end-of-day ones. Therefore, end-of-day lake elevations were estimated as the averages of the recorded elevations for the current and following days.

10.3.7 Imbalance

Using all of the above assumptions, a water balance for each day during the analysis period was calculated and any resulting imbalances determined. With the above assumptions, the CA outflow exceeded inflow over the entire period of record. In order to make these quantities more closely balance, the estimates of ungaged inflow to St. Johns Marsh CA were calculated as 80 percent of the gaged inflow to the area.

Table 10-3 presents an annual summary of the St. Johns Marsh CA water balance. An expanded version of the water balance, with monthly data, is included in Appendix A.

Table 10-3: St. Johns Marsh CA Water Balance Summary (acre-feet)

Water Year	Inflow	Precipitation	Evaporation	Outflow	Change In Storage	Imbalance
1997	277,549	89,852	63,225	330,762	41,644	-68,230
1998	1,006,045	119,654	64,900	1,001,808	9,976	49,014
1999	251,508	99,386	68,779	232,951	10,672	38,492
2000	436,589	107,184	79,094	458,329	-50,460	56,809
2001	389,340	116,960	67,325	362,943	79,460	33,015
2002	522,264	97,735	90,022	712,013	-58,580	-118,240
2003	530,503	96,784	84,355	580,306	20,996	-58,370
Total	3,413,797	727,554	517,701	3,679,111	53,708	-67,509

10.4 PHOSPHORUS BALANCE

A phosphorus balance was developed for St. Johns Marsh CA using the daily water balance and available data on total phosphorus (TP) concentrations in the lake's inflow and outflow. This phosphorus balance included estimates of the following quantities for each day during the period of record.

- Inflow TP concentration and flux
- Direct phosphorus deposition to the St. Johns Marsh CA
- Outflow TP concentration and flux
- Net phosphorus retention

Described below for each of these parameters are the assumptions and methods used to develop these estimates.

10.4.1 Inflow TP Concentration and Flux

During the selected analysis period (WY 1997–2003), inflow TP concentration data are available for 78 days at the St. Johns Marsh CA, yielding an average sample frequency of once every 32 days, or approximately monthly. Table 10-4 lists the specific stations and numbers of available TP concentration samples within the analysis period at each station.

Two different methods were used to estimate the inflow TP concentration on missing days. The first method used was regression analyses using inflow TP concentration and its log transform as the dependent variable, and the inflow rate, log transform of the inflow rate, julian day and monthly precipitation as independent variables. Using a stepwise regression procedure, the linear model with the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variable: Inflow rate in cfs (Q)
- Model: log [TP] = -1.041 + 9.8E-5 Q
- Coefficient of determination (R^2): .054

With an R^2 of only .054, this "best" model only explains about 5 percent of the variations in TP concentrations so it was not used to estimate missing TP values.

The second method used to estimate inflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. As the time interval between sample dates increases, the resulting estimates are assumed to become less and less reliable. Because the regression results were unsatisfactory, missing inflow TP concentrations were estimated using this latter method exclusively. Once estimates of daily inflow TP concentrations were developed, the phosphorus mass influx to the St. Johns Marsh CA was estimated each day as the product of these daily concentrations and the corresponding inflow volume estimates previously developed for the water balance.

10.4.2 Direct Phosphorus Deposition

Direct phosphorus deposition to the St. Johns Marsh CA is composed of two components: wet deposition and dry deposition. Dry deposition is assumed to occur continuously at a daily rate of 84.88 $\mu g/m^2$ while direct precipitation to the lake (wet deposition) is assumed to have a TP composition of 9.39 µg/L (Ahn

Table 10-4: TP Monitoring Stations at St. Johns Marsh Conservation Area

Agency	Station	Station Name	Number of Samples
Inflow Stations			
SJRWMD	BCMCU	Upstream (south) of S-96C in M canal in BCMCA	90
Interior Stations			
SJRWMD	BBM	SJMCA at Big Bend Marsh telemetry station	23
	C40E8	Canal 40 Upstream of E-8 plug	91
	C40MM	CANAL 40 400M N OF S-256 NR MULBERRY MOUND	3
	MBM	Mulberry Marsh in SJMCA 800 m west of C40	21
	SMM	Six Mile Marsh in SJMCA 700 m West of C40	11
Outflow Stations			
SJRWMD	HBI	Lake Hell N Blazes inlet	86
	SMO	South Mormon Outside Canal 100 yd upstm fr SJR	97

& James, 2001). Therefore, daily phosphorus influx from deposition was calculated as the sum of these two components.

10.4.3 Outflow TP Concentration and Flux

The methods used to develop daily estimates of outflow TP concentration and flux from St. Johns Marsh CA were identical to those used for lake inflow. During the selected analysis period (WY 1997–2003), outflow TP concentration data are available for 110 days. This yields an average sample frequency of about once every 23 days. Again, both regression analyses and the interpolation method were tried to estimate the outflow TP concentration on missing days. Using a stepwise regression procedure, the linear model determined to have the best fit is described below:

- Dependent variable: Common logarithm of inflow TP concentration in mg/L (log [TP])
- Independent variable: Total monthly precipitation in inches (P)
- Model: log [TP] = -1.052 + 0.030 P
- Coefficient of determination (R^2): .140

Any regression model for TP concentrations with an R^2 over .100 is worthy of consideration so this "best" model was used the help estimate missing TP values.

The second method used to estimate outflow TP concentrations was a simple straight-line interpolation process. With this method, TP concentrations are assumed to vary linearly with time between sample dates. Outflow TP concentration rates each day were estimated as the averages of the estimates from the regression model and interpolation method. Once estimates of daily outflow TP concentrations were developed, the phosphorus discharge flux from St. Johns Marsh CA was estimated each day as the product of these daily concentrations and the corresponding outflow volume previously developed for the water balance.

10.4.4 Net Phosphorus Retention

The net phosphorus retention in St. Johns Marsh CA was estimated as total influx in inflow and deposition less discharge flux in outflow. As such, these net retention values include the phosphorus retained or discharged because of changes in lake storage plus that intercepted by lake vegetation or that settles out into lake sediments. An annual summary of the phosphorus balance for St. Johns Marsh CA is shown in Table 10-5. An expanded version of this phosphorus balance, with monthly data, is included in Appendix B.

Table 10-5: St. Johns Marsh CA Phosphorus Balance Summary (kg)

Water Year	Inflow	Deposition	Outflow	Net Retention
1997	35,712	3,216	76,534	-37,606
1998	125,851	4,295	154,164	-24,019
1999	41,318	4,060	48,663	-3,284
2000	46,596	4,158	77,507	-26,753
2001	80,206	4,263	91,650	-3,120
2002	107,504	4,041	124,980	-13,370
2003	38,988	4,030	31,097	1,452
Total	476,175	28,063	604,596	-106,701

10.5 DATA SET ANALYSIS

After the daily flow and phosphorus balances for the St. Johns Marsh CA were completed, these data were used to explore the relationships between the retention of phosphorus and other characteristics of the lake, such as hydraulic loading rate. A monthly data set derived from the daily water and phosphorus balances, and other monitoring data was used in these analyses. This monthly data set includes the following data values:

- Average water surface area (hectares, ha)
- Total inflow and outflow volumes (cubic meters, m^3)
- Total mass flux of phosphorus in, out and retained in the lake (grams, g)
- Flow-weighted average inflow and outflow phosphorus concentrations (milligrams per liter, mg/L)
- Phosphorus retention efficiency (percent)
- Hydraulic loading rate (meters per year, m/yr)
- Net phosphorus settling rate, k (m/yr)
- Flow-weighted average calcium (Ca) concentration in lake interior (mg/L)

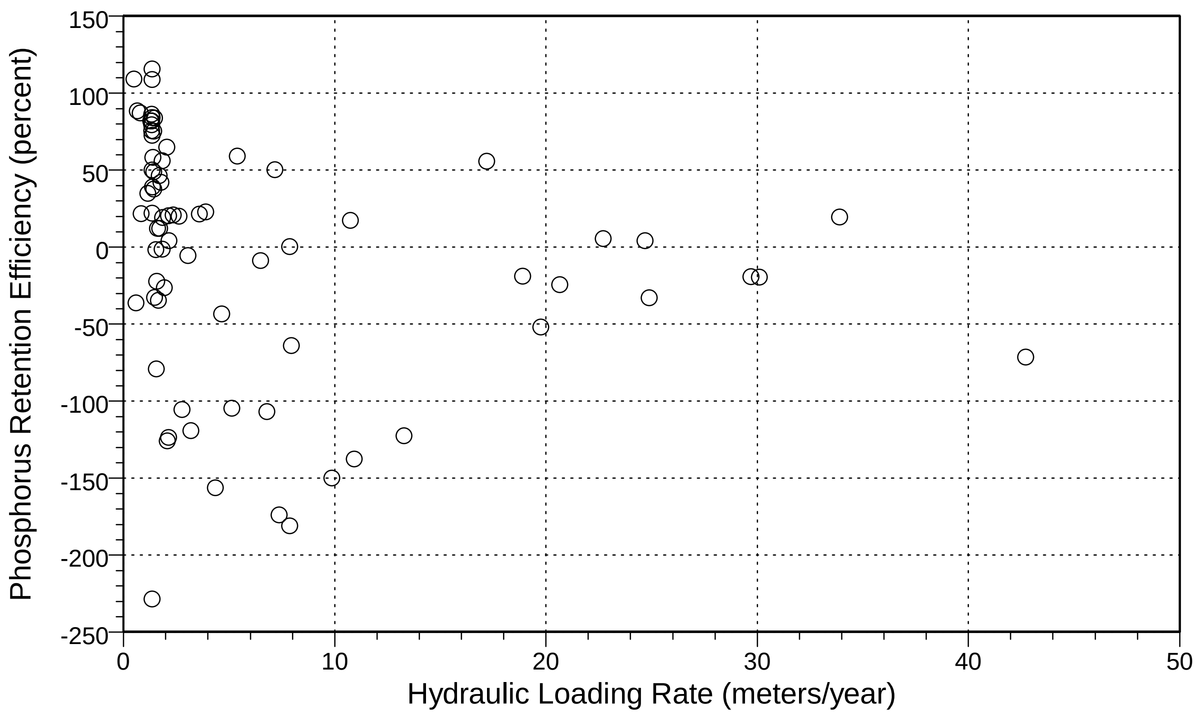
- Average pH in lake interior (standard units)
- Average water temperature (degrees C)
- Average water depth (meters)

Not all of these data are available for every month during the selected analysis period.

10.5.1 Phosphorus Retention Efficiency vs. Hydraulic Loading Rate

A scatter diagram of the monthly values for phosphorus retention efficiency plotted against the hydraulic loading rate is included in Figure 10-12. From review of this graph, it is not apparent a linear relationship exists between these variables. A regression analysis using phosphorus retention efficiency as the dependent variable and hydraulic loading rate as the independent variable confirms this observation. The resulting linear model has a R^2 of .006.

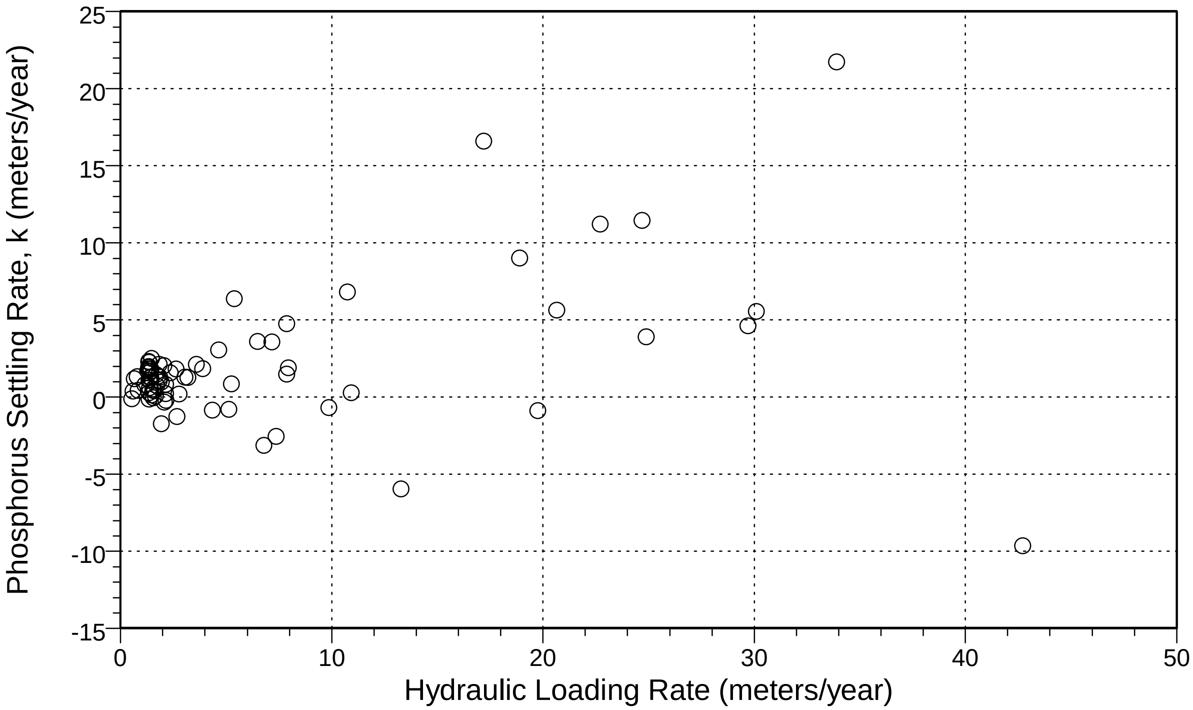
Figure 10-12: Retention Efficiency vs. Hydraulic Loading Rate at St. Johns Marsh CA



10.5.2 Regression Analyses for Phosphorus Settling Rate (k)

Regression analyses with the phosphorus settling rate (k) as the dependent variable were also completed. In these analyses, the hydraulic loading rate, calcium concentration, pH, temperature and depth were all selected as independent variables. Figure 10-13 is a scatter diagram of settling rate vs. hydraulic loading rate. The regression model with these variables has a R^2 of .136. None of the regression models with the other independent variables have R^2 significantly above zero.

Figure 10-13: Settling Rate vs. Hydraulic Loading Rate at St. Johns Marsh CA



10.6 VEGETATION DATA

No vegetation cover data from BIPM are available for the St. Johns Marsh CA.

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11 SUMMARY AND RECOMMENDATIONS

11 SUMMARY AND RECOMMENDATIONS

A summary of the analyses completed for each potential data site is presented in this report section along with recommendations for future studies.

11.1 PERIODS OF RECORD

In Task 3, detailed analyses were conducted on the eight potential (good-rated) data sites identified in Task 2. These analyses included development of water and phosphorus balances for each water body, and exploration of relationships between phosphorus retention in the lakes and other key variables. Table 11-1 contains a list of the eight potential data sites and the selected periods of record for their respective water and phosphorus balances.

Table 11-1: Analysis Periods of Record

Site Name	Water Balance		Phosphorus Balance	
	Date Range	Years	Date Range	Years
Crescent Lake	10/01/1996–09/30/2003	7.0	10/01/1996–09/30/2003	7.0
Lake George	02/20/1994–09/30/2003	9.6	02/20/1994–09/03/2003	9.5
Lake Harney	10/01/1990–09/30/2003	13.0	10/01/1990–09/04/2003	12.9
Lake Istokpoga	01/01/1989–12/31/2002	14.0	01/01/1989–12/31/2002	14.0
Lake Jessup	10/01/1994–09/30/2003	9.0	01/01/1994–07/09/2003	8.8
Lake Thonotosassa	10/01/1980–09/30/1991	11.0	10/01/1980–09/25/1991	11.0
Rodman Reservoir	01/31/1981–09/30/2003	22.7	01/31/1981–12/18/2003	21.9
St. Johns Marsh CA	01/01/1997–09/30/2003	6.7	01/01/1997–07/15/2003	6.5

The periods of record selected for each data site, for both the water and phosphorus balances, were selected based primarily on the availability of inflow and outflow sampling data for total phosphorus (TP). Some of these data sites have flow records extending back into the 1930s so much longer periods of record for the water balances alone are generally possible.

The chief goal of this study is to estimate the amount of phosphorus retained in a lake or reservoir and the factors that may affect the relative amounts that are retained. In order to develop credible estimates of phosphorus retention, phosphorus concentration data in both the inflow and outflow are necessary. The periods of record for the phosphorus balances at some lakes were limited due to the absence of either or both inflow and outflow phosphorus concentration data. The water balance at Lake Thonotosassa is limited to the period when inflow and outflow rate data are available. No records of lake inflow or outflow at this lake are available after October 1991.

11.2 PHYSICAL, CHEMICAL AND VEGETATIVE COVER DATA

A summary of the average physical and chemical characteristics of the eight potential data sites is presented in Table 11-2. This table lists comparative size data for each lake (average depth, surface area, volume and contributing watershed) and an average of available interior sampling data for the most significant parameters (total phosphorus, calcium, and total nitrogen concentrations plus pH and temperature). Also listed in this table are averages for vegetative cover by type: emergent, floating or submerged.

Six of the eight data sites are natural lakes and only two are man-made: Rodman Reservoir and the St. Johns Marsh Conservation Area. The largest of the eight water bodies in all physiographic categories is Lake George. Lake George and the other data site located on the main stem of the St. Johns River, Lake Harney, have the largest average flow-through hydrology and larger contributing watersheds.

The interior chemical characteristics of the eight data sites are similar with a few exceptions. Both the average interior TP and TN concentrations at Lake Thonotosassa are higher than at all of the other data sites. These higher readings are believed to be largely a consequence of this data site’s earlier analysis period. The analysis period for Lake Thonotosassa spans from 1980 to 1991 and does not include the last decade as do the analysis periods for the other data sites. During the early portion of the Lake

Table 11-2: Summary of Average Physical, Chemical and Vegetative Data

Data Site	Physiographic Data: Depth[1] (feet)	Area[1] (acres)	Volume (ac-ft)	Watershed (miles^2)	Discharge[1] (cfs)	Interior Chemical/Physical Data[2]: TP (mg/L)	Ca (mg/L)	TN (mg/L)	pH (SU)	Temp. (deg. C)	Vegetative Cover (%): Emer.	Float.	Sub.
Crescent Lake	11.2	17,450	114,500	470	528	0.129	31.6	2.57	7.4	22.7	3.0	1.4	1.2
Lake George	17.7	46,000	452,800	3,760	4,170	0.069	45	2.2	7.7	23.1	2.7	1.4	3.1
Lake Harney	9.3	7,392	46,000 [3]	2,105	2,250	0.083	56.4	1.98	7.4	23.8	4.8	1.7	12.4
Lake Istokpoga	5.6	27,640	103,000 [3]	990	945	0.055	10.9	2	7.6	24.9	10.7	1.4	19.7
Lake Jessup	7.6	13,110	67,000 [3]	150	149	0.205	45.8	3.84	8.7	23.1	5.6	1.2	0.0
Lake Thonotosassa	5.1	819	2,800 [3]	60	35	0.581	N/A	5.32	8.9	24.6	1.3	0.3	0.0
Rodman Reservoir	8.5	5,980	34,000 [3]	2,747	1,200	0.051	61.8	0.96	7.4	22.3	18.5	20.8	55.6
St. Johns Marsh CA	3.1	23,200	58,000 [3]	968	753	0.431	33.4	3.53	6.7	23.4	N/A[4]	N/A[4]	N/A[4]

1. Average of estimates for corresponding data in water balance.
2. Average of data from all internal monitoring stations for data site.
3. Estimated as product of average depth and surface area times adjustment of 0.67 for natural lakes and 0.80 for conservation areas.
4. N/A = not available.

Thonotosassa analysis period (through 1983), the lake was still receiving wastewater treatment plant effluent, as were some of the other lakes such as Lake Jessup. With the cessation of these discharges, the water quality of Lake Thonotosassa has improved significantly in recent years.

The nutrient loading history of these data sites may prove to be a significant factor in determining their suitability as calibration data sets. Because of past wastewater inflows, the bottom of Lake Jessup is reported to be covered with a layer of nutrient-rich organic muck up to eight feet thick (Parsons Engineering Science, 2000). As a man-made impoundment, the proposed EAA storage reservoir site should not have similar characteristics and this reservoir's nutrient assimilation capacity may be significantly different than a natural lake with a history of wastewater inflow.

The vegetative cover statistics in Table 11-2 show that most of these lake systems have generally little cover. The most obvious exception is Rodman Reservoir; on average, this reservoir has nearly 95 percent coverage. Lake Istokpoga also has a significant amount of vegetative cover with nearly one third coverage on average. For water bodies with a significant amount of vegetative cover, such as Rodman Reservoir and Lake Istokpoga, submerged vegetation accounts for over half of the total coverage.

As the primary focus of this study, the total phosphorus loadings of the eight data sites are further characterized in Table 11-3. This table summarizes the available sampling data for TP during the identified analysis period at each data site.

As one of the most intensively studied lakes in Florida, Table 11-3 shows that Lake Jessup has the most available TP samples with nearly 2,300 collected during this lake's 9-year analysis period. Rodman Reservoir has the second highest number of TP samples with over 1,500 samples available. The fewest numbers of TP samples are available at Crescent Lake and the St. Johns Marsh CA, which is why these lakes also have the shortest analysis periods.

The TP concentration statistics in Table 11-3 show one unexpected result. The concentrations of phosphorus discharges from three of the sites — Lake George, Lake Harney and the St. Johns Marsh CA — are higher than those entering the lake. Comparing average TP concentrations values, these outflow concentrations are respectively about 35, 14 and 40 percent higher than the corresponding inflow

Table 11-3: Summary of TP Sample Data[1]

Data Site	Relative Location	No. of Monitoring Stations	No. of TP Samples: Total	No. of TP Samples: Non-detect	TP Concentration (mg/L): Average	TP Concentration (mg/L): Median	TP Concentration (mg/L): Minimum	TP Concentration (mg/L): Maximum
Crescent Lake	Inflow	5	228	1	0.098	0.088	0.004	0.254
	Interior	20	50	0	0.107	0.107	0.042	0.220
	Outflow	5	203	0	0.081	0.078	0.019	0.173
Lake George	Inflow	10	393	3	0.052	0.050	0.005	0.660
	Interior	21	422	0	0.064	0.061	0.006	0.205
	Outflow	5	356	0	0.070	0.069	0.001	0.216
Lake Harney	Inflow	5	298	1	0.085	0.082	0.005	1.130
	Interior	8	562	0	0.059	0.056	0.006	0.231
	Outflow	4	77	0	0.097	0.084	0.024	0.330
Lake Istokpoga	Inflow	5	69	0	0.111	0.084	0.021	0.664
	Interior	20	579	0	0.056	0.048	0.010	0.477
	Outflow	5	185	0	0.066	0.046	0.008	0.386
Lake Jessup	Inflow	33	1270	0	0.203	0.157	0.007	3.880
	Interior	16	658	0	0.157	0.162	0.021	0.747
	Outflow	6	353	1	0.097	0.090	0.001	0.495
Lake Thonotosassa	Inflow	1	131	0	1.198	0.054	0.160	8.960
	Interior	1	262	0	0.708	0.096	0.160	1.510
	Outflow	2	433	0	0.739	0.058	0.090	1.570
Rodman Reservoir	Inflow	23	871	20	0.056	0.050	0.010	0.765
	Interior	17	444	16	0.050	0.031	0.006	0.970
	Outflow	14	207	7	0.036	0.040	0.005	0.330
St. Johns Marsh CA	Inflow	1	90	0	0.112	0.095	0.040	0.443
	Interior	5	149	0	0.176	0.141	0.032	4.424
	Outflow	2	183	0	0.157	0.112	0.028	0.935

1. Station and sample counts, and TP concentration statistics are based on samples collected during analysis period for each site only.

concentrations. The TP sampling data used in this study were those data that were readily available from an electronic repository, such as USEPA’s STORET system. Therefore, these water bodies may have significant phosphorus loadings, from tributaries or groundwater inflows, where no sampling has occurred.

11.3 PHOSPHORUS LOADING CHARACTERISTICS

The daily water and phosphorus balances at each of the eight potential data sites were used to develop average annual loading rates for water and phosphorus. These data are presented in Table 11-4, which presents estimates of average annual phosphorus inflow and outflow from each water body and the amount of phosphorus retained.

Perhaps the most significant data in Table 11-4 are the estimates of TP retention. These data show that three of these data sites — Lakes George and Harney, and the St. Johns Marsh CA — are all net exporters of phosphorus. This conclusion is most evident at Lake George, which has a calculated retention efficiency of -42 percent (that is, this lake discharges 42 percent more phosphorus than the amount that comes in). As discussed above, these lakes may have additional unmonitored inflows that could explain this anomaly. Finding large lakes such as these three that are net exporters of phosphorus is an unexpected finding and additional investigation should be conducted to confirm these results.

The highest phosphorus settling rate was found at Rodman Reservoir (14.19 m/yr). This settling rate is approximately 3.5 times higher than the next highest value (4.05 m/yr at Lake Thonotosassa) and is believed to be largely a consequence of the high portion of vegetative cover at Rodman Reservoir. This reservoir has an average vegetative coverage of nearly 95 percent. Rodman Reservoir is also rather long and narrow (that is, has a large length to width ratio) compared to the other data sites. As such, the flow through this reservoir is similar to true plug flow while the other lakes are believed to be fairly well mixed by wind action.

The results of these investigations appear to be similar to those obtained by other investigators. Walker and Havens (2003) reported a net phosphorous settling rate of 3.2 m/yr at Lake Istokpoga compared to a rate of 2.88 m/yr obtained in the current study. Knight, Gu, Clarke and Newman (2003) obtained a significantly different settling rate for Lake Istokpoga (0.02 m/yr) but more comparable values for

Table 11-4: Average Annual TP Removal Performance[1]

Data Set	Area (ha)	Inflow Volume (Mm³/yr)	Inflow TP Load (Mg/yr)	Inflow TP Conc. (mg/L)	Atmospheric Deposition (Mg/yr)	Outflow Volume (Mm³/yr)	Outflow TP Load (Mg/yr)	Outflow TP Conc. (mg/L)	TP Retention Load (Mg/yr)	TP Retention Effic. (%)	Hydraulic Loading (m/yr)	Settling Rate (k) (m/yr)
Crescent Lake	7,061	446.7	52.7	0.118	3.1	471.7	40.6	0.086	15.2	28.8	6.33	2.00
Lake George	18,616	3,650.4	195.3	0.054	8.1	3,720.1	285.4	0.077	-82.0	-42.0	19.61	-7.07
Lake Harney	2,992	2,001.4	154.0	0.077	1.2	2,000.6	165.9	0.083	-10.6	-6.9	66.90	-4.98
Lake Istokpoga	11,193	886.1	100.1	0.113	4.5	843.4	66.2	0.079	38.4	38.4	7.92	2.88
Lake Jessup	5,306	114.1	23.7	0.208	2.3	132.8	14.2	0.107	11.8	49.9	2.15	1.43
Lake Thonotosassa	331	32.7	37.3	1.140	0.1	31.3	23.7	0.756	13.7	36.8	9.86	4.05
Rodman Reservoir	2,420	1,047.6	54.5	0.052	1.0	1,049.6	39.3	0.037	16.2	29.7	43.29	14.19
St. Johns Marsh CA	9,389	601.6	73.2	0.122	4.1	643.4	94.0	0.146	-16.7	-22.9	6.41	-1.18

1. Unit abbreviations: ha-hectares; Mm^3/yr-million cubic meters per year; Mg/yr-million grams per year; mg/L-milligrams per liter; m/yr-meters per year.

Rodman Reservoir (9.42 m/yr) and Lake Harney (-4.92 m/yr). These latter two values for Rodman Reservoir and Lake Harney are comparable to settling rates of 14.19 and -4.99 m/yr, respectively, shown in Table 11-4.

11.4 RECOMMENDATIONS FOR FURTHER STUDY

The data collected for the eight potential data sites and the data sets constructed from these data should prove useful for future model calibrations efforts; however, none of these potential data sites have proven to be very similar to the proposed EAA storage reservoir(s), which was one of the primary goals of the WQIR study. Therefore, further effort to identify and collect data for more similar water bodies (if available) is recommended. An outline of these recommended study efforts is presented below:

1. Most of the 36 candidate water bodies identified in Task 2 are natural lakes and very few are actually man-made impoundments. Additional efforts should be expended to identify man-made reservoirs and water management areas in central and south Florida that are physically and operationally similar to the proposed EAA storage reservoir(s).

2. For the man-made impoundments that were identified in Task 2, the study team's efforts to collect useful data for these impoundments were largely unfruitful. For these and any other representative impoundments identified in Item 1 above, site visits and interviews with the managers of these impoundments should be conducted. These site visits and interviews will attempt to better define the similarity of these water bodies to the proposed EAA storage reservoir(s). The questions asked and data collected will ascertain current operating rules, existing data collection activities, management challenges and lessons learned. If as expected, the existing data resources and ongoing monitoring efforts fall short of providing all of the data needed for model calibration, facility managers will be consulted about their willingness to authorize access for additional monitoring activities.

3. The information and data collected during the site visit and interview process will be used to rank the applicability of each data site investigated. The five top-ranked reservoirs or management areas should be selected for detailed monitoring. A brief technical report that presents the results of Items 1 through 3 should be prepared for review and comment by the District and other cooperating agencies.

4. After the list of recommended reservoirs is approved, a detailed monitoring plan should be developed for each of the five reservoirs or management areas. The monitoring plan will be designed to characterize each reservoir's hydrology, water chemistry, and biology. Monitoring should include estimation of all inflows and outflows, water level monitoring, estimates of storage volume, measurement of a wide variety of water quality parameters, plant community and cover mapping, and rapid assessment of wildlife populations. The draft monitoring plans for each reservoir will be submitted to the District for approval.

5. A minimum one-year sampling program is recommended for each of the selected reservoirs. As an option, the monitoring program can be extended for up to two additional years. All monitoring data should be imported into a database for easy retrieval and QA/QC checks. Annual monitoring reports will be prepared and submitted to the District.

6. At the end of the monitoring program, a final report should be prepared that summarizes the monitoring data and provides design guidance for future CERP reservoir design efforts. The final report should summarize all of the results and findings of the monitoring program and tie in related work from other published sources.

The additional study items described above should be initiated as soon as practicable so this information is available in a timely fashion to assist with future CERP reservoir design. With a one-year monitoring program, the total elapsed time for these additional studies is estimated to be 22 months, increasing to 46 months for a three-year monitoring program.

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12 REFERENCES AND BIBLIOGRAPHY

12 REFERENCES AND BIBLIOGRAPHY

This section contains a list of the references cited in this report and a bibliography of technical reports that are available for the potential water bodies.

12.1 REFERENCES CITED

The following entries are the citations for the references cited in this report.

Ahn, H. & James, R. (2001). Variability, uncertainty, and sensitivity of phosphorus deposition load estimates in South Florida. *Air, Water, and Soil Pollution, 126,* 37-51.

Burns & McDonnell Engineering Company. (2003). *Everglades Protection Area tributary basins: Long term plan for achieving water quality goals* (Project No. 32233). Kansas City: Author.

Burns & McDonnell Engineering Company. (2004, May). *Water quality impacts of reservoirs: Task 2–Identification of data sites and data acquisition* (Project No. 35106). Kansas City: Author.

Corps of Engineers and South Florida Water Management District. (no date). *The Comprehensive Everglades Restoration Plan (CERP).* Retrieved 15 March 2004 from http://www.evergladesplan.org/about/rest_plan.cfm.

Dynamac Corporation. (1992, August). *Diagnostic feasibility study of Lake Thonotosassa, draft final report.* Prepared for Southwest Florida Water Management District (Contract No. 22-131). Rockville, MD: Author.

Knight, R., Gu, B., Clarke, R., & Newman, J. (2003). Long-term phosphorus removal in Florida aquatic systems dominated by submerged aquatic vegetation. *Ecological Engineering 20*, 45-63.

Parsons Engineering Science, Inc. (2000, November). *Lake Jesup water and nutrient budget report.*

Southwest Florida Water Management District. (2003, February). *Lake Thonotosassa surface water improvement and management (SWIM) plan*. Brooksville, FL: Author

U.S. Environmental Protection Agency. (1977a). *Report on Crescent Lake, Flagler and Putnam counties, Florida* (Working Paper No. 246). Corvallis, OR: Office of Research and Development.

U.S. Environmental Protection Agency. (1977b). *Report on Lake George, Putnam and Volusia counties, Florida* (Working Paper No. 251). Corvallis, OR: Office of Research and Development.

U.S. Geological Survey. (2002). *National Water Information System [Database].* Available from U.S. Geological Survey web site, http://water.usgs.gov

Walker, W. & Havens, K. (2002). Development and application of a phosphorus balance model for Lake Istokpoga, Florida. *Lake and Reservoir Management 19(1)*, 79-91.

12.2 BIBLIOGRAPHY

The following listing is a bibliography of available technical reports that may contain information pertinent to the WQIR study. These entries are ordered by the potential data site they apply to.

12.2.1 Crescent Lake

Dobberfuhl, D. & Trahan, N. (2003). *Distribution of submerged aquatic vegetation in the lower St. John's River* (Prof. Paper SJ2003-PP1). Palatka, FL: St. Johns River Water Management District. [electronic PDF submitted]

Frydenborg, R., Lurding, K. & Ross, L. (1990). *Biological water quality characteristics of the Crescent Lake basin, Florida*. State of Florida Department of Environmental Regulation. [partial hardcopy onfile]

Water & Air Research, Inc. (2000). *Benthic macroinvertebrate data from 148 surface water sites within the St. Johns River Water Management District* (SJ2000-SP7). Gainesville, FL: Author. [electronic PDF submitted]

12.2.2 Lake George

Alvarez, L. (1991). *Fish/wildlife habitat assessment of the Lake George basin* (SJ92-SP7). Palatka, FL: St. Johns River Water Management District. [electronic PDF submitted]

Marzolf, E. (2000). *Temporal trends and correlations in ambient water quality in the upper St. Johns River basin; 1979 – 1998* (TM No. 40). Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

U.S. Geological Survey. (2002). *Subsurface characterization of selected water bodies in the St. Johns River Water Management District, Northeast Florida - Lake George.* Available at http://coastal.er.usgs.gov/ publications/ofr/00-180/sectiond/drayton-intro.html.

Water & Air Research, Inc. (2000). *Benthic macroinvertebrate data from 148 surface water sites within the St. Johns River Water Management District* (SJ2000-SP7). Gainesville, FL: Author. [electronic PDF submitted]

12.2.3 Lake Harney

Keller, T., Martinez, M., DaSilva, M. & Lippincott, C. (2004). *Middle St. Johns River basin water quality status and trends: 2002* (SJ2004-1). Palatka, FL: St. Johns River Water Management District. [electronic PDF submitted]

Kinner, P. (1987). *Seminole County wetlands vegetation inventory*. (SJ 88-4 Part 2-14). Palatka, FL: St. Johns Water Management District. [hardcopy onfile]

Marzolf, E. (2000). *Temporal trends and correlations in ambient water quality in the upper St. Johns River basin; 1979 - 1998* (TM No. 40). Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

USGS. (2002). *Subsurface characterization of selected water bodies in the St. Johns River Water Management District, Northeast Florida - Lake Harney*. Available online at http://coastal.er.usgs.gov/ publications/ofr/00-180/sectione/harney-intro.html.

12.2.4 Lake Istokpoga

Searcy, H. (1993). *Lake Istokpoga feasibility study (Contract C-3019) final report.* Lindahl, Browning, Ferrari & Hellstorm, Inc. and Tomasello Consulting Engineers, Inc. [hardcopy onfile]

U.S. Army Corps of Engineers. (1958). *Central and southern Florida project: For flood control and other purposes, Part II. Kissimmee River basin and related areas.* Jacksonville, FL: Author. [hardcopy onfile]

U.S. Environmental Protection Agency (USEPA). (1977). *National eutrophication survey working paper series: report on Lake Istokpoga, Highlands County, Florida* (Working Paper No. 258). 1977. Corvallis, OR: Corvallis Environmental Research Lab. [hardcopy on file]

12.2.5 Lake Jessup

Brezonik, P. & Fox, J. (1976). *Analysis of eutrophication and water quality factors in the middle St. Johns River basin* (ENV-07-76-02). Gainesville, FL: Camp Dresser & McKee, Inc.; University of Florida, Department of Environmental Engineering Sciences. [partial hardcopy onfile]

Cable, J., Schelske, C., Hansen, P., Kenney, W. & Whitmore, T. (1997). *Sediment and nutrient deposition in Lake Jessup, Florida (USA)* (SJ98-SP18). Gainesville, FL: Department of Fisheries and Aquatic Sciences, University of Florida. [electronic PDF submitted]

Keesecker, D. (1992). *Lake Jessup restoration diagnostic evaluation water budget and nutrient budget* (SJ92-SP16). Gainesville, FL: Water & Air Research, Inc. [electronic PDF submitted]

Keller, T., Martinez, M., DaSilva, M. & Lippincott, C. (2004). *Middle St. Johns River basin water quality status and trends: 2002* (SJ2004-1). Palatka, FL: St. Johns River Water Management District. [electronic PDF submitted]

Kinner, P. (1987). *Seminole County wetlands vegetation inventory* (SJ 88-4 Part 2-14). Palatka, FL: St. Johns Water Management District. [hardcopy onfile]

Osborne, J. (2002). *Zooplankton populations dynamics in Lakes Jessup and Washington* (SJ2002-SP7). Orlando, FL: Department of Biology, University of Central Florida. [electronic PDF submitted]

St. Johns River Water Management District. (2003). *Lake Jesup.* Available online at http://sjr.state.fl.us/programs/ acq_restoration/s_water/msjr/ljesup_sb.html.

USGS. (2002). *Subsurface characterization of selected water bodies in the St. Johns River Water Management District, Northeast Florida - Lake Jessup.* Available online at http://coastal.er.usgs.gov/ publications/ofr/00-180/sectione/jessup-intro.html.

Water & Air Research, Inc. (2000). *Benthic macroinvertebrate data from 148 surface water sites within the St. Johns River Water Management District* (SJ2000-SP7). Gainesville, FL: Author [electronic PDF submitted]

12.2.6 Lake Thonotosassa

Dames & Moore. (1994). *Linked watershed/waterbody model initial application to Lake Thonotosassa watershed.* Tampa, FL: Author. [electronic PDF submitted]

Southwest Florida Water Management District. (1990). *Lake Thonotosassa SWIM plan.* Brooksville, FL: Author. [electronic PDF submitted]

Southwest Florida Water Management District. (2002). *Lake Thonotosassa surface water improvement and management (SWIM) plan "455 Draft"*. Brooksville, FL: Author. [hardcopy on file]

Southwest Florida Water Management District. (1995). *Surface water improvement and management (SWIM) plan for Lake Thonotosassa.* Brooksville, FL: SWIM Section. [electronic PDF submitted]

Southwest Florida Water Management District. (1997). *Surface water improvement and management (SWIM) priority water bodies.* Brooksville, FL: SWIM Section. [hardcopy on file]

University of South Florida. (2001). *Lake assessment document: Lake Thonotosassa.* Tampa, FL: Florida Center for Community Design, Research School of Architecture, Community Design. [electronic PDF submitted]

12.2.7 Rodman Reservoir (Ocklawaha Lake)

U.S. Department of Agriculture (1973). *Forest Service environmental statement - proposal for Oklawaha River.* [partial hardcopy onfile]

Barnard, T., Poppleton, J., Chou, I. & Danek, L. (1994). *Modeling of floodplain forest succession in Rodman Reservoir under river restoration and partial reservoir retention alternatives - Volume 17 (Part 1 of 2), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Gainesville, FL: Environmental Consulting & Technology, Inc. [hardcopy onfile]

Bryan, J. & Warr, K. (1994). *Birds of Rodman Reservoir and the lower Ocklawaha River - Volume 19, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Palatka, FL: St. John's River Water Management District.. [hardcopy onfile]

Camp Dresser & McKee, Inc. (1976). *A study of water management alternatives for the middle Oklawaha River basin.* Boston, MA: Author [hardcopy onfile]

Continental Shelf Associates, Inc. (1994). *An analysis of fish populations in Rodman Reservoir and the lower Ocklawaha River - Volume 15, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Jupiter, FL: Continental Shelf Associates, Inc. [hardcopy onfile]

Crum, L. (1954). *The Ocklawaha River*. Master of Arts Florida State University. [hardcopy onfile]

Danek, L., Bonds, J. & Arcuri, A. (1994). *Sediment characteristics, toxics analysis, and seepbank studies for Rodman Reservoir - Volume 7. (ECT No. 94-326-0400), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Oclawaha River.* Gainesville, FL: Environmental Consulting & Technology, Inc. [hardcopy onfile]

Danek, L., Tomlinson, M., Barnard, M. & TenBroeck, B. (1994). *Bathymetry and sediment thickness mapping of Rodman Reservoir - Volume 3 (Part 1 of 2) (ECT No. 93-575), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Gainesville, FL: Environmental Consulting and Technology, Inc. [hardcopy onfile]

Danek, L., Tomlinson, M., Barnard, M. & TenBroeck, B. (1994). *Bathymetry and sediment thickness mapping of Rodman Reservoir - Volume 3 (Part 2 of 2) (ECT No. 93-575), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Gainesville, FL: Environmental Consulting and Technology, Inc. [hardcopy onfile]

Department of Environmental Protection. (1995). *Environmental and economic efficacy studies of complete restoration of the Ocklawaha River; partial restoration of the Ocklawaha River; total retention of the Rodman Reservoir; and partial retention of the Rodman Reservoir.* [hardcopy onfile]

Florida Defenders of the Environment. (1987). *An Outstanding Florida Water petition for the Oklawaha River.* Gainesville, FL: Author. [hardcopy onfile]

Florida Department of Environmental Protection. (1994). *Management and characteristics of aquatic plant communities in Rodman Reservoir, Marion and Putnam counties, Florida from 1969-1994 and for the proposed restoration alternatives - Volume 16, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Bureau of Aquatic Plant Management. [hardcopy onfile]

Florida Department of Environmental Protection. (1995). *A socio-economic study of the Rodman Reservoir - Volume 1.* [hardcopy onfile]

Florida Department of Environmental Protection. (1995). *A socio-economic study of the Rodman Reservoir - Volume 2.* [hardcopy onfile]

Holcomb, S., Goolsby, D., Williamson, G., Tebo, L., Heinen, E. & Traina, P. (1972). *Water quality review - Rodman Reservoir/Oklawaha River.* Florida Fish and Wildlife Conservation Commission. [hardcopy onfile]

Jordan, F. (1994). *Current status of the southern tessellated darter (Etheostoma Olmstedi Maculaticeps) and the bluenose shiner (Pteronotropis welaka) in the Ocklawaha River system - Volume 13, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Jacksonville, FL: Department of Biology and Marine Science, Jacksonville University. [hardcopy onfile]

Jordan, F. (1994). *Ocklawaha River migratory fish assessment - Volume 14, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Jacksonville, FL: Department of Biology and Marine Science, Jacksonville University. [hardcopy onfile]

St. Johns River Water Management District. (1994). *Bathymetry and thickness mapping of Rodman Reservoir - Volume 3 (Part 1 of 2), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Palatka, FL: Author. [hardcopy onfile]

Tomlinson, M., Shuman, J., Danek, L., Barnard, T. & Warr, K.. (1997). *The unique challenges of studying Rodman Reservoir (Ocklawaha River).* Florida Lake Management Society [1997 Annual Meeting Proceedings]. [hardcopy onfile]

Tomlinson, M., Danek, L. & Barnard, T.. (1994). *Characteristics of the Ocklawaha River floodplain under Rodman Reservoir - Volume 8. (ECT No. 94326-0400), Environmental studies concerning four alternatives for the Rodman Reservoir and the lower Ocklawaha River.* Gainesville, FL: Environmental Consulting & Technology, Inc. [hardcopy onfile]

Tomlinson, M., Chou, I. & Danek, L.. (1994). *Surface water quality and alternatives analysis for Rodman Reservoir - Volume 11 (ECT No. 94326-0600&0700), Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha.* Gainesville, FL: Environmental Consulting & Technology, Inc. [hardcopy onfile]

Warr, K., Shuman, J., Bryan, J. & Lasi, M. (1994). *Analysis of habitats in Rodman Reservoir and the lower Ocklawaha River under four river restoration and reservoir retention alternatives - Volume 20, Environmental studies concerning four alternatives for Rodman Reservoir and the lower Oclawaha River.* Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Warr, K., Miller, R. & Bryan, J. (1994). *An analysis of threatened and endangered species, candidate species, and species of special concern in the lower Ocklawaha River basin - Volume 18. Environmental studies concerning four alternatives for Rodman Reservoir and the lower Ocklawaha River.* Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Water & Air Research, Inc. (2000). *Benthic macroinvertebrate data from 148 surface water sites within the St. Johns River Water Management District* (SJ2000-SP7). Gainesville, FL: Author [electronic PDF submitted]

12.2.8 St. Johns Marsh Conservation Area

Marzolf, E. (2000). *Temporal trends and correlations in ambient water quality in the upper St. Johns River basin; 1979 - 1998* (TM No. 40). Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Miller, S., Borah, A., Lee, M., Lowe, E. & Rao, D. (1996). *Environmental management plan for the upper St. Johns River basin project.* Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Miller, S., Tremwell, T. & Minno, M. (2003). *2003 interim environmental water management plan for the upper St. Johns River basin project* (TM No. 48. 2003). Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Sewell, C. (2001). *Survey of wading birds utilization of the upper St. John's River basin* (SJ2001-SP6). Vero Beach, FL: Author. [electronic PDF submitted]

Sterling, M. & Padera, C. (1998). *The upper St. Johns River basin project: The environmental transformation of a public flood control project* (Prof. Paper SJ98-PP1). Palatka, FL: St. Johns River Water Management District. [electronic PDF submitted]

12.2.9 Miscellaneous

Florida Department of Environmental Protection. (2002). *Florida's water quality assessment 2002 305(b) Report.* Tallahassee, FL: Author. [hardcopy on file]

Florida LAKEWATCH. (2003). *Florida LAKEWATCH annual data summaries 2002.* Gainesville, FL: Department of Fisheries and Aquatic Sciences & Institute of Food and Agriculatural Sciences, University of Florida. [electronic PDF submitted]

Gant, R. (1990). *Lake levels project annual report.* Brooksville, FL: Environmental Section, Southwest Florida Water Management District. [electronic PDF submitted]

Gant, R. (1993). *Lake levels project annual report.* Brooksville, FL: Environmental Section, Southwest Florida Water Management District. [electronic PDF submitted]

Gant, R. (1996). *Lake levels project annual report.* Brooksville, FL: Environmental Section, Southwest Florida Water Management District. [electronic PDF submitted]

Gibson, G., Carlson, R., Simpson, J., Smeltzer, E., Gerritson, J., Chapra, S., Heiskary, S., Jones, J. & Kennedy, R. (2000). *Nutrient criteria technical guidance manual: Lakes and reservoirs, first edition.* Washington, DC: Office of Water & Office of Science and Technology, United States Environmental Protection Agency. [hardcopy on file]

Highlands Today. (2002). *Guide to area lakes and ways to preserve them.* [hardcopy on file]

Hillsborough Co., FL. (1998). *Surface water quality, 1995-1997.* Environmental Protection Commission of Hillsborough County. [hardcopy on file]

Huber, W., Brezonik, P., Heaney, J., Dickinson, R., Preston, S., Dwornik, D. & Demaio, M. (1982). *A classification of Florida lakes - Water Resources Research Center, Publication No. 72.* Gainesville, FL: Department of Environmental Engineering Sciences, University of Florida. [hardcopy on file]

Lowe, E. & Battoe, L. (2003). *Bibliographical listing version 6 for the Division of Environmental Sciences.* Palatka, FL: St. Johns River Water Management District. [hardcopy onfile]

Ritter, P. (2003). *Lake Okeechobee basin survey reports Vol. III, Arbuckle Creek, Josephine Creek.* Okeechobee Service Center. [hardcopy on file]

Romie, K. (2000). *Water chemistry of lakes in the Southwest Florida Water Management District.* Environmental Section, Resource Management Department. [electronic PDF submitted]

Southwest Florida Water Management District. (1989). *Highlands Ridge work group report, first draft.* Brooksville, FL: Author. [hardcopy on file]

Southwest Florida Water Management District. (2002). *Surface water improvement and management (SWIM) 2001 Annual Report, Covering the period from January 1, 2001 to December 31, 2001.* Brooksville, FL: Author. [hardcopy on file]

Southwest Florida Water Management District. (2000). *Aquifer characteristics within the Southwest Florida Water Management District.* Brooksville, FL: Technical Services Department Resource Regulation. [electronic PDF submitted]

U.S. Environmental Protection Agency (1978). *A compendium of lake and reservoir data collected by the national eutrophication survey in eastern, north-central, and southeastern United States.* Corvallis, OR: Corvallis Environmental Research Lab. [hardcopy on file]

Walker, W. & Kadlec, R. (2003). *Dynamic model for stormwater treatment areas.* Available online at http://www.wwwalker.net/dmsta/index2.htm.

Walker, W. (1998). *STA & reservoir performance measures for the Everglades restudy*. Available online at http://www.wwwalker.net/restudy/introd.htm.

Walker, W. (1995). Design basin for Everglades stormwater treatment area. *Water Resources Bulletin: 31:4,* 671-685. [electronic PDF submitted]

Walker, W. (no date). Phosphorus removal by urban runoff detention basins. *Lake and Reservoir Management: Vol. 3*, North American Lake Management Society.

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Appendix A

MONTHLY WATER BALANCES

Appendix A: Monthly Water Balances

Crescent Lake									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1996	10	120,892	6.10	8,869	1.70	2,475	26,920	21,636	83,141
	11	14,993	1.04	1,512	1.46	2,122	35,115	-4,711	-16,021
	12	10,553	3.55	5,162	1.37	1,989	45,330	-6,456	-25,149
1997	1	5,925	2.70	3,926	1.08	1,569	15,011	2,443	-9,172
	2	3,748	1.10	1,599	1.47	2,144	36,159	-8,462	-24,493
	3	2,988	3.85	5,598	3.00	4,365	29,877	-1,483	-24,173
	4	1,364	4.34	6,310	4.54	6,608	12,258	14,831	-26,022
	5	1,149	3.05	4,435	5.12	7,448	15,055	-1,309	-15,610
	6	54,175	12.80	18,611	4.64	6,752	112,768	-9,858	-37,282
	7	52,182	6.90	10,033	5.49	7,989	85,190	-5,496	-25,468
	8	41,499	5.57	8,099	4.32	6,288	36,543	5,845	921
	9	33,166	2.87	4,173	3.34	4,851	38,612	-4,624	-1,500
	10	10,895	2.92	4,246	1.70	2,475	23,094	7,677	-18,106
	11	53,672	4.08	5,932	2.80	4,067	96,922	-12,737	-28,647
	12	108,494	13.02	18,931	1.01	1,470	135,574	1,309	-12,878
1998	1	120,763	2.35	3,417	1.09	1,580	115,230	7,764	-3,973
	2	111,621	10.12	14,714	1.31	1,901	113,970	6,107	3,794
	3	101,863	2.80	4,071	2.90	4,221	96,478	-18,669	23,904
	4	14,834	0.15	218	4.61	6,697	1,431	1,396	5,529
	5	1,132	2.00	2,908	4.89	7,116	-5,935	-7,939	10,797
	6	197	0.45	654	5.86	8,520	-11,605	-6,456	10,393
	7	136	8.05	11,705	4.77	6,929	4,654	-5,758	6,016

Appendix A: Monthly Water Balances

Crescent Lake									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1998	8	2,425	7.70	11,196	0.00	0	-371	10,294	3,697
	9	28,022	9.00	13,086	2.78	4,044	30,232	8,637	-1,805
	10	39,587	2.37	3,446	1.92	2,796	39,995	-262	504
	11	5,424	4.35	6,325	1.00	1,459	23,665	-8,724	-4,650
	12	2,177	1.20	1,745	1.00	1,459	-10,881	6,630	6,714
1999	1	2,244	4.90	7,125	1.06	1,536	5,234	7,939	-5,341
	2	3,359	1.49	2,166	1.37	1,989	-1,719	-9,160	14,415
	3	1,522	1.23	1,788	2.88	4,188	867	-4,536	2,792
	4	332	1.92	2,792	4.77	6,929	-34,278	14,918	15,555
	5	142	3.21	4,667	4.71	6,851	-15,370	-15,005	28,334
	6	203	5.29	7,692	3.97	5,779	-6,514	-7,415	16,044
	7	486	4.19	6,092	5.20	7,558	-20,150	7,154	12,016
	8	269	6.12	8,898	4.31	6,266	-46,032	17,361	31,574
	9	10,245	7.90	11,487	2.70	3,923	-27,423	4,711	40,521
	10	73,455	3.54	5,147	1.69	2,464	38,902	-5,060	42,296
	11	57,690	2.13	3,097	1.28	1,868	28,946	2,268	27,706
	12	14,581	1.41	2,050	0.78	1,138	35,270	-22,595	2,817
2000	1	6,693	1.92	2,792	1.03	1,492	7,500	1,221	-728
	2	4,388	0.52	756	1.34	1,945	14,987	-3,839	-7,949
	3	2,164	3.44	5,002	2.85	4,144	6,549	7,677	-11,205
	4	25,903	2.62	3,809	5.07	7,371	19,285	-3,315	6,372
	5	2,190	1.06	1,541	6.24	9,072	-7,154	8,637	-6,824

Appendix A: Monthly Water Balances

Crescent Lake									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2000	6	210	8.23	11,966	6.86	9,967	17,371	-15,529	367
	7	232	7.76	11,283	4.92	7,161	-1,435	7,677	-1,888
	8	378	6.12	8,898	4.71	6,851	-2,490	12,737	-7,822
	9	13,480	10.01	14,555	2.92	4,243	54,280	13,609	-44,098
	10	4,151	1.09	1,585	1.96	2,851	15,181	-10,033	-2,264
	11	599	1.36	1,977	1.71	2,486	28,393	-16,663	-11,640
	12	280	0.40	582	1.03	1,492	6,153	-6,979	197
2001	1	237	1.63	2,370	1.06	1,536	17,722	-5,758	-10,894
	2	287	1.22	1,774	1.32	1,923	13,503	7,503	-20,868
	3	3,755	5.27	7,663	2.36	3,426	24,316	785	-17,109
	4	11,442	1.46	2,123	4.64	6,741	8,891	3,839	-5,905
	5	1,509	1.59	2,312	5.56	8,089	8,561	3,053	-15,191
	6	1,025	8.67	12,606	4.73	6,884	12,849	3,315	-9,417
	7	3,561	9.75	14,177	4.40	6,398	33,505	12,301	-33,077
	8	43,135	9.08	13,202	4.64	6,741	58,056	-5,234	-3,697
	9	300,533	10.99	15,979	2.83	4,111	194,876	10,556	110,670
	10	140,071	0.83	1,207	2.07	3,006	94,612	-15,616	59,277
	11	60,644	4.07	5,918	1.63	2,365	71,550	-13,260	5,908
	12	30,053	0.00	0	1.58	2,293	33,971	-4,362	-1,849
2002	1	12,855	2.98	4,338	1.67	2,434	37,307	-7,328	-15,220
	2	9,433	3.35	4,868	2.12	3,082	10,800	6,543	-6,124
	3	20,281	4.13	6,004	3.56	5,176	19,107	872	1,130

Appendix A: Monthly Water Balances

Crescent Lake

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2002	4	3,764	2.73	3,977	4.83	7,016	1,283	-5,583	5,025
	5	476	3.66	5,317	5.42	7,883	-22,939	12,388	8,460
	6	13,157	6.78	9,862	5.03	7,319	35,849	-10,556	-9,593
	7	152,925	7.38	10,736	5.04	7,321	83,437	3,490	69,413
	8	111,134	7.28	10,579	4.62	6,717	91,357	15,354	8,285
	9	60,433	7.25	10,548	3.77	5,479	53,272	6,020	6,210
	10	25,424	3.83	5,565	2.95	4,294	28,473	-9,335	7,558
	11	18,373	2.37	3,439	1.97	2,862	17,714	-19,367	20,604
	12	34,585	2.64	3,839	1.58	2,293	40,717	9,335	-13,921
2003	1	50,320	2.98	4,338	1.67	2,434	79,603	-6,020	-21,360
	2	19,133	3.35	4,868	2.12	3,082	22,514	8,811	-10,406
	3	73,782	4.13	6,004	3.56	5,176	136,181	4,624	-66,195
	4	28,484	2.73	3,977	4.83	7,016	41,568	-2,966	-13,157
	5	16,916	3.66	5,317	5.42	7,883	9,247	-14,482	19,584
	6	19,736	6.78	9,862	5.03	7,319	26,285	4,188	-8,193
	7	36,327	7.38	10,736	5.04	7,321	61,496	-4,885	-16,869
	8	41,639	7.28	10,579	4.62	6,717	72,089	12,388	-38,976
	9	19,527	7.25	10,548	3.77	5,479	573	20,850	3,172

Appendix A: Monthly Water Balances

Lake George									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1994	2	29,527	0.55	2,108	0.48	1,826	22,316	-1,150	8,644
	3	118,150	2.40	9,200	2.68	10,267	147,830	-40,480	9,733
	4	31,127	0.75	2,875	3.50	13,417	220,582	2,760	-202,756
	5	3,014	3.15	12,075	5.50	21,093	-55,012	32,660	16,348
	6	177,400	10.20	39,100	4.63	17,742	422,999	-30,820	-193,422
	7	234,011	9.85	37,758	4.26	16,316	404,523	10,120	-159,189
	8	355,221	9.09	34,852	4.29	16,460	436,846	29,210	-92,443
	9	398,918	7.45	28,558	3.60	13,809	479,974	33,810	-100,117
	10	509,770	5.61	21,502	1.50	5,768	546,930	28,290	-49,717
	11	597,754	6.10	23,383	1.12	4,283	745,462	12,650	-141,258
	12	646,845	4.98	19,103	1.32	5,069	785,885	-3,220	-121,787
1995	1	555,507	1.16	4,462	1.41	5,390	846,331	-68,540	-223,212
	2	325,689	1.18	4,542	1.41	5,390	441,951	-20,700	-96,410
	3	209,261	1.62	6,218	3.02	11,595	213,090	11,270	-20,476
	4	240,289	3.85	14,758	4.29	16,431	91,563	-11,730	158,783
	5	153,053	2.85	10,925	5.61	21,500	100,034	-690	43,134
	6	127,624	6.31	24,171	4.35	16,664	114,627	10,120	10,384
	7	202,689	2.85	10,925	5.27	20,219	254,156	11,960	-71,823
	8	232,803	8.24	31,587	4.58	17,538	118,871	93,380	34,600
	9	509,815	10.52	40,317	3.78	14,479	586,009	920	-51,276
	10	634,175	6.95	26,642	2.05	7,866	589,567	-13,570	76,954
	11	591,838	1.09	4,178	1.97	7,544	509,835	-37,950	116,587
	12	405,060	1.03	3,955	1.43	5,477	353,945	-11,270	60,863

Appendix A: Monthly Water Balances

Lake George									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1996	1	404,607	1.48	5,685	1.17	4,487	390,982	-20,240	35,063
	2	248,018	1.55	5,942	1.88	7,225	257,528	-35,420	24,626
	3	243,145	7.55	28,942	2.83	10,867	168,403	48,300	44,517
	4	436,858	1.25	4,792	4.64	17,800	479,504	-24,610	-31,045
	5	187,435	2.85	10,925	5.80	22,229	172,298	0	3,834
	6	146,893	8.98	34,423	5.08	19,490	171,548	17,480	-35,502
	7	238,159	5.36	20,555	6.29	24,093	301,734	-59,110	-8,003
	8	100,193	4.79	18,362	5.08	19,490	78,666	44,620	-24,222
	9	176,187	4.85	18,592	3.63	13,926	195,057	1,380	-15,584
	10	257,811	6.10	23,383	1.70	6,526	238,756	21,160	14,752
	11	172,486	1.04	3,987	1.46	5,594	192,484	-16,330	-5,275
	12	138,226	4.50	17,234	1.37	5,244	205,031	-23,460	-31,355
1997	1	82,463	2.70	10,350	1.08	4,137	139,545	5,750	-56,620
	2	74,655	1.10	4,217	1.47	5,652	96,819	-16,100	-7,500
	3	68,071	3.85	14,758	3.00	11,508	83,637	-3,450	-8,866
	4	28,566	4.34	16,637	4.54	17,422	1,833	35,420	-9,471
	5	58,295	3.05	11,692	5.12	19,636	72,018	-1,150	-20,517
	6	110,696	12.80	49,067	4.64	17,800	135,459	-4,600	11,103
	7	212,956	6.90	26,450	5.49	21,063	227,478	-9,430	294
	8	280,111	5.29	20,295	4.32	16,577	145,470	26,220	112,139
	9	232,017	2.87	11,002	3.34	12,790	103,924	-1,840	123,470
	10	162,500	3.83	14,672	1.70	6,526	130,750	10,810	29,086

Appendix A: Monthly Water Balances

Lake George									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1997	11	220,299	2.80	10,719	2.80	10,721	407,062	-27,370	-159,395
	12	301,991	6.41	24,591	1.01	3,875	85,377	54,280	183,050
1998	1	640,997	2.35	9,008	1.09	4,166	482,233	1,150	162,456
	2	418,273	10.12	38,793	1.31	5,011	483,503	31,970	-63,417
	3	755,793	2.80	10,733	2.90	11,129	725,883	-31,050	60,565
	4	509,838	0.15	575	4.61	17,655	450,833	-33,580	75,505
	5	252,981	2.00	7,667	4.89	18,762	291,995	-27,830	-22,279
	6	106,609	0.45	1,725	5.86	22,462	170,112	-20,240	-64,000
	7	96,283	8.05	30,858	4.77	18,267	163,041	-16,560	-37,606
	8	113,878	7.70	29,517	4.62	17,708	88,481	28,060	9,146
	9	190,200	9.00	34,500	2.78	10,663	140,432	39,330	34,276
	10	310,073	3.83	14,672	1.92	7,371	254,674	-6,900	69,600
	11	227,096	4.35	16,675	1.00	3,846	263,391	-25,990	2,524
	12	82,589	1.20	4,600	1.00	3,846	91,525	16,100	-24,281
1999	1	109,868	4.90	18,783	1.06	4,050	150,772	-2,300	-23,870
	2	49,801	1.49	5,712	1.37	5,244	92,928	920	-43,579
	3	79,135	1.23	4,715	2.88	11,042	137,387	-28,750	-35,828
	4	19,813	1.92	7,360	4.77	18,267	48,294	26,910	-66,297
	5	62,606	3.21	12,305	4.71	18,063	98,053	-24,840	-16,364
	6	110,193	5.29	20,278	3.97	15,237	158,348	-1,150	-41,964
	7	193,804	4.19	16,062	5.20	19,927	195,842	460	-6,363
	8	75,203	6.12	23,460	4.31	16,519	35,982	38,410	7,752

Appendix A: Monthly Water Balances

Lake George									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1999	9	91,134	7.90	30,283	2.70	10,342	2,640	35,190	73,245
	10	491,276	3.54	13,570	1.69	6,497	362,846	23,000	112,503
	11	610,196	2.13	8,165	1.28	4,924	547,067	-14,030	80,401
	12	446,785	1.41	5,405	0.78	3,001	470,104	-49,450	38,358
2000	1	229,993	1.92	7,360	1.03	3,933	224,259	-2,760	11,920
	2	126,962	0.52	1,993	1.34	5,127	153,824	-24,840	-5,156
	3	48,833	3.44	13,187	2.85	10,925	53,669	10,350	-12,924
	4	49,109	2.62	10,043	5.07	19,432	57,882	-10,810	-7,351
	5	25,105	1.06	4,063	6.24	23,918	-13,020	10,350	7,920
	6	44,975	8.23	31,548	6.86	26,278	76,219	-27,830	1,857
	7	38,457	7.76	29,747	4.92	18,878	16,606	28,060	4,660
	8	46,657	6.12	23,460	4.71	18,063	25,755	24,610	1,689
	9	64,623	10.01	38,372	2.92	11,187	90,875	27,830	-26,897
	10	104,730	1.09	4,178	1.96	7,516	92,995	-1,840	10,237
	11	155,930	1.36	5,213	1.71	6,555	188,630	-46,000	11,958
	12	80,445	0.40	1,533	1.03	3,933	81,183	-7,360	4,222
2001	1	63,186	0.43	1,648	0.75	2,874	36,724	-16,100	41,337
	7	69,988	3.34	12,814	1.70	6,530	86,791	30,360	-40,878
	8	284,779	9.08	34,807	4.64	17,771	291,088	1,610	9,117
	9	404,559	10.99	42,128	2.83	10,838	365,942	102,580	-32,673
	10	581,503	0.83	3,182	2.07	7,924	532,449	-39,560	83,872
	11	470,402	4.07	15,602	1.63	6,235	407,024	-35,190	107,935

Appendix A: Monthly Water Balances

Lake George									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2001	12	343,277	0.18	691	1.58	6,046	254,253	-28,060	111,728
2002	1	197,861	2.98	11,436	1.67	6,418	134,723	-23,920	92,076
	2	80,103	3.35	12,835	2.12	8,125	43,821	23,920	17,072
	3	153,751	4.13	15,829	3.56	13,646	238,538	-13,800	-68,804
	4	72,484	2.73	10,484	4.83	18,498	152,376	-9,660	-78,246
	5	8,508	3.66	14,017	5.42	20,784	-58,671	31,050	29,363
	6	145,198	6.78	26,000	5.03	19,296	160,479	-7,590	-987
	7	434,456	7.38	28,303	5.04	19,302	414,936	13,110	15,411
	8	607,885	7.28	27,891	4.62	17,708	522,591	42,550	52,926
	9	589,300	7.25	27,808	3.77	14,445	513,189	6,900	82,574
	10	387,200	3.83	14,672	2.95	11,320	396,605	-30,360	24,308
	11	218,123	2.37	9,067	1.97	7,544	261,166	-43,700	2,180
	12	287,875	2.64	10,121	1.58	6,046	315,386	140,296,090	-140,319,525
2003	1	518,156	2.98	11,436	1.67	6,418	479,546	-140,284,130	140,327,758
	2	336,500	3.35	12,835	2.12	8,125	305,661	6,210	29,339
	3	269,368	4.13	15,829	3.56	13,646	272,450	32,890	-33,789
	4	225,466	2.73	10,484	4.83	18,498	168,805	-27,370	76,017
	5	115,859	3.66	14,017	5.42	20,784	109,910	-37,030	36,212
	6	163,162	6.78	26,000	5.03	19,296	164,509	14,950	-9,593
	7	244,505	7.38	28,303	5.04	19,302	294,030	-11,960	-28,564
	8	370,270	7.28	27,891	4.62	17,708	395,464	40,250	-55,262
	9	329,791	7.25	27,808	3.77	14,445	298,586	40,940	3,629

Appendix A: Monthly Water Balances

Lake Harney									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1990	10	71,590	4.08	2,513	2.86	1,760	62,363	9,979	0
	11	131,893	1.02	626	1.85	1,138	128,683	2,698	0
	12	117,826	0.46	286	1.49	918	122,369	-5,174	0
1991	1	81,699	1.32	813	1.99	1,227	83,947	-2,661	0
	2	48,061	1.07	660	2.12	1,306	55,066	-7,651	0
	3	55,626	7.23	4,455	3.61	2,224	49,208	8,649	0
	4	88,456	5.81	3,578	5.29	3,258	79,276	9,499	0
	5	121,421	6.15	3,790	4.54	2,800	118,161	4,250	0
	6	192,711	9.13	5,623	3.91	2,411	189,676	6,246	0
	7	311,685	13.28	8,180	4.51	2,781	302,042	15,043	0
	8	308,435	2.85	1,754	5.05	3,113	314,985	-7,909	0
	9	204,960	3.69	2,272	4.78	2,945	208,242	-3,955	0
	10	347,985	3.86	2,380	2.25	1,386	342,659	6,320	0
	11	209,640	0.34	212	1.16	712	223,592	-14,451	0
	12	120,664	0.69	424	0.97	599	132,796	-12,308	0
1992	1	79,277	1.54	951	1.38	852	85,068	-5,692	0
	2	51,223	5.75	3,543	1.46	899	55,752	-1,885	0
	3	28,863	1.74	1,069	2.90	1,784	30,367	-2,218	0
	4	45,234	2.83	1,745	4.71	2,903	40,897	3,179	0
	5	29,270	2.77	1,705	5.75	3,544	29,870	-2,439	0
	6	35,662	5.63	3,469	6.62	4,078	31,283	3,770	0
	7	81,244	3.59	2,213	5.27	3,249	75,995	4,213	0

Appendix A: Monthly Water Balances

Lake Harney									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1992	8	236,872	12.24	7,540	4.01	2,467	212,376	29,568	0
	9	330,109	5.20	3,203	4.27	2,631	330,755	-74	0
	10	424,017	3.66	2,257	2.71	1,671	424,602	0	0
	11	214,730	1.50	922	1.58	974	214,678	0	0
	12	131,000	0.54	335	1.06	651	130,684	0	0
1993	1	100,323	4.21	2,592	1.12	693	102,222	0	0
	2	146,173	2.65	1,631	1.62	997	146,807	0	0
	3	149,302	2.72	1,676	2.55	1,573	149,404	0	0
	4	141,136	1.38	848	4.77	2,935	139,048	0	0
	5	85,132	3.19	1,963	5.65	3,483	83,613	0	0
	6	68,547	2.13	1,311	6.06	3,731	66,126	0	0
	7	74,935	2.05	1,262	5.12	3,155	73,041	0	0
	8	42,914	2.26	1,392	4.56	2,809	41,497	0	0
	9	81,943	3.13	1,927	4.01	2,467	81,403	0	0
	10	70,940	3.06	1,882	2.31	1,423	63,249	5,840	0
	11	43,895	0.38	232	1.84	1,133	46,801	-3,807	0
	12	23,746	1.24	764	0.80	492	32,815	-8,796	0
1994	1	33,432	5.06	3,114	1.98	1,222	31,666	3,659	0
	2	69,323	1.90	1,173	1.48	913	62,708	6,875	0
	3	69,323	2.78	1,715	3.61	2,224	79,274	-10,460	0
	4	28,412	0.67	414	4.77	2,940	25,606	-370	0
	5	25,374	1.76	1,084	5.50	3,389	18,706	3,548	0

Appendix A: Monthly Water Balances

Lake Harney									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1994	6	156,505	8.20	5,051	4.63	2,851	135,531	23,174	0
	7	193,869	6.96	4,287	4.89	3,010	188,852	74	0
	8	280,179	8.33	5,130	4.29	2,645	256,344	9,388	0
	9	278,473	7.10	4,371	3.60	2,219	269,574	11,051	0
	10	446,321	2.48	1,528	1.50	927	421,236	-4,250	0
	11	469,437	7.26	4,470	1.12	688	436,558	11,716	0
	12	487,292	4.38	2,696	1.32	815	496,343	-7,170	0
1995	1	355,277	1.95	1,202	1.41	866	356,354	-14,932	0
	2	162,601	0.81	498	1.41	866	178,606	-16,373	0
	3	84,157	1.66	1,025	3.02	1,863	87,929	-6,764	0
	4	57,200	2.33	1,434	4.29	2,640	59,041	-4,657	0
	5	39,574	2.63	1,621	5.61	3,455	37,119	-591	0
	6	41,573	7.39	4,553	4.35	2,678	36,302	5,914	0
	7	76,570	8.02	4,943	5.27	3,249	74,901	3,363	0
	8	224,338	10.08	6,209	4.58	2,818	205,272	15,967	0
	9	360,660	3.30	2,035	3.78	2,327	355,822	4,546	0
	10	376,890	5.90	3,637	2.05	1,264	373,904	5,359	0
	11	301,671	1.82	1,124	1.97	1,212	315,183	-13,601	0
	12	200,592	1.54	951	1.43	880	216,815	-16,152	0
1996	1	174,824	4.60	2,834	1.17	721	179,154	-2,218	0
	2	81,754	1.04	641	1.88	1,161	97,312	-16,078	0
	3	158,412	8.95	5,514	2.83	1,746	130,690	31,490	0

Appendix A: Monthly Water Balances

Lake Harney

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1996	4	179,145	1.49	917	4.64	2,860	194,609	-17,408	0
	5	70,994	3.38	2,080	5.80	3,572	83,621	-14,119	0
	6	94,357	11.15	6,870	5.08	3,132	87,782	10,312	0
	7	98,641	3.46	2,129	6.29	3,872	108,319	-11,421	0
	8	76,332	4.41	2,715	5.08	3,132	72,626	3,289	0
	9	108,878	4.97	3,060	3.63	2,238	105,044	4,657	0
	10	123,134	4.79	2,952	1.70	1,049	117,793	7,244	0
	11	70,292	0.24	148	1.46	899	81,072	-11,532	0
	12	46,767	1.78	1,099	1.37	843	51,791	-4,768	0
1997	1	28,932	1.30	798	1.08	665	32,022	-2,957	0
	2	28,745	0.59	362	1.47	908	29,086	-887	0
	3	19,874	2.28	1,404	3.00	1,849	19,171	259	0
	4	18,798	1.97	1,212	4.54	2,800	15,326	1,885	0
	5	18,655	1.87	1,153	5.12	3,155	17,465	-813	0
	6	40,322	4.86	2,996	4.64	2,860	32,733	7,725	0
	7	144,162	7.70	4,741	5.49	3,385	129,074	12,714	0
	8	235,064	8.04	4,953	4.32	2,664	235,394	1,959	0
	9	174,063	2.10	1,296	3.34	2,055	180,511	-7,207	0
	10	137,612	3.93	2,420	1.70	1,049	143,862	-4,879	0
	11	135,108	1.10	680	2.80	1,723	134,398	-333	0
	12	299,477	7.26	4,475	1.01	623	265,297	38,032	0
1998	1	346,603	2.16	1,331	1.09	669	358,759	-11,495	0

Appendix A: Monthly Water Balances

Lake Harney

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1998	2	305,489	8.21	5,056	1.31	805	295,548	14,193	0
	3	369,496	4.64	2,858	2.90	1,788	378,476	-7,909	0
	4	257,368	0.18	108	4.61	2,837	273,969	-19,330	0
	5	145,064	0.24	148	4.89	3,015	161,269	-19,071	0
	6	50,232	2.15	1,326	5.86	3,610	62,326	-14,377	0
	7	30,502	6.93	4,268	4.77	2,935	29,829	739	0
	8	79,510	5.22	3,218	4.62	2,846	69,607	10,275	0
	9	109,013	6.31	3,890	2.78	1,713	88,422	22,767	0
	10	162,932	1.57	966	1.92	1,184	170,807	-8,094	0
	11	95,678	1.07	660	1.00	618	108,324	-12,603	0
	12	44,370	0.28	172	1.00	618	48,840	-4,916	0
1999	1	29,734	3.10	1,907	1.06	651	33,984	-2,994	0
	2	20,897	0.29	177	1.37	843	18,125	2,107	0
	3	12,717	1.17	719	2.88	1,774	18,944	-7,281	0
	4	8,568	2.15	1,326	4.77	2,935	5,221	1,737	0
	5	11,229	1.58	971	4.71	2,903	10,221	-924	0
	6	39,324	4.74	2,922	3.97	2,448	25,568	14,230	0
	7	60,915	4.22	2,602	5.20	3,202	67,707	-7,392	0
	8	51,075	1.77	1,089	4.31	2,654	47,884	1,626	0
	9	98,194	7.80	4,805	2.70	1,662	65,984	21,991	0
	10	417,537	6.70	4,125	1.69	1,044	399,366	21,252	0
	11	362,448	2.32	1,429	1.28	791	376,872	-13,786	0
	12	194,600	1.80	1,109	0.78	482	213,891	-18,665	0

Appendix A: Monthly Water Balances

Lake Harney									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2000	1	83,266	0.85	522	1.03	632	94,415	-14,895	0
	2	32,650	0.56	345	1.34	824	41,115	-8,944	0
	3	10,362	0.47	291	2.85	1,756	9,636	-739	0
	4	5,340	1.18	729	5.07	3,123	5,571	-2,624	0
	5	1,544	0.16	99	6.24	3,844	-390	-1,811	0
	6	65	2.79	1,720	6.86	4,223	-3,473	1,035	0
	7	7,377	7.66	4,721	4.92	3,034	5,406	3,659	0
	8	13,370	3.94	2,425	4.71	2,903	10,305	2,587	0
	9	48,195	6.03	3,716	2.92	1,798	42,469	6,912	0
2001	10	357,004	2.08	1,284	2.07	1,273	323,454	33,560	0
	11	254,996	3.00	1,848	1.63	1,002	263,678	-7,836	0
	12	128,843	0.30	182	1.58	972	150,785	-22,730	0
2002	1	56,452	2.76	1,698	1.67	1,031	68,133	-11,014	0
	2	45,164	3.07	1,893	2.12	1,306	36,512	9,240	0
	3	55,600	3.96	2,437	3.56	2,193	67,524	-11,679	0
	4	17,674	2.30	1,414	4.83	2,972	17,447	-1,331	0
	5	5,827	3.21	1,977	5.42	3,340	805	3,659	0
	6	45,554	6.68	4,116	5.03	3,101	27,054	19,515	0
	7	288,873	6.88	4,240	5.04	3,102	265,803	24,209	0
	8	405,125	7.18	4,422	4.62	2,846	397,831	8,870	0
	9	319,445	6.32	3,894	3.77	2,321	331,957	-10,940	0
	10	147,534	3.82	2,354	2.95	1,819	171,649	-23,580	0

Appendix A: Monthly Water Balances

Lake Harney									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2002	11	66,067	2.18	1,343	1.97	1,212	78,653	-12,456	0
	12	150,620	2.24	1,380	1.58	972	123,641	27,387	0
2003	1	271,038	2.76	1,698	1.67	1,031	277,138	-5,433	0
	2	99,595	3.07	1,893	2.12	1,306	115,780	-15,597	0
	3	82,010	3.96	2,437	3.56	2,193	72,386	9,868	0
	4	67,963	2.30	1,414	4.83	2,972	82,814	-16,410	0
	5	31,296	3.21	1,977	5.42	3,340	36,549	-6,616	0
	6	54,748	6.68	4,116	5.03	3,101	45,452	10,312	0
	7	76,403	6.88	4,240	5.04	3,102	73,143	4,398	0
	8	306,302	7.18	4,422	4.62	2,846	283,411	24,468	0
	9	254,524	6.32	3,894	3.77	2,321	259,645	-3,548	0

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1989	1	39,852	1.37	3,176	5.53	12,732	17,309	12,987	0
	2	43,061	0.46	1,066	5.89	13,629	49,880	-19,383	0
	3	41,875	1.45	3,343	5.76	13,249	40,158	-8,189	0
	4	26,998	3.29	7,394	5.31	12,013	63,411	-41,032	0
	5	29,440	2.81	6,046	6.51	14,069	96,971	-75,555	0
	6	18,793	2.44	4,996	5.78	11,904	46,991	-35,105	0
	7	36,903	8.27	17,049	6.15	12,729	22,578	18,646	0
	8	61,993	7.53	15,898	5.65	12,026	8,774	57,091	0
	9	106,207	2.96	6,596	5.05	11,354	4,896	96,940	0
	10	92,283	6.53	15,252	5.02	11,787	87,536	18,851	0
	11	32,305	0.60	1,400	3.88	9,058	24,086	561	0
	12	55,198	2.72	6,360	2.89	6,752	53,018	1,788	0
1990	1	38,887	0.56	1,314	3.71	8,682	35,061	-3,541	0
	2	51,377	2.39	5,575	3.94	9,177	42,341	5,435	0
	3	18,156	0.47	1,077	6.31	14,617	46,263	-41,647	0
	4	41,829	1.28	2,922	5.97	13,595	58,690	-27,533	0
	5	18,265	2.15	4,683	6.42	14,084	57,183	-51,720	0
	6	54,654	6.82	14,910	6.21	13,615	22,236	33,713	0
	7	68,634	6.27	13,900	5.17	11,452	85,456	-14,373	0
	8	116,521	4.69	10,547	6.08	13,637	73,810	39,621	0
	9	51,841	3.68	8,405	5.39	12,252	11,680	36,314	0
	10	38,626	1.99	4,646	3.94	9,224	0	30,887	0
	11	22,096	0.17	389	3.43	7,988	25,257	-33,007	0

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1990	12	24,340	0.48	1,099	2.81	6,446	33,047	-13,986	0
1991	1	63,051	5.81	13,306	3.09	7,124	31,744	37,489	0
	2	44,196	1.00	2,323	3.75	8,746	48,704	-10,931	0
	3	66,112	3.45	8,038	5.25	12,277	49,503	12,369	0
	4	25,411	3.27	7,578	5.41	12,537	57,769	-37,317	0
	5	19,558	7.56	16,879	6.03	13,496	94,793	-71,851	0
	6	55,340	4.38	9,562	6.23	13,579	41,265	-3,729	0
	7	82,759	6.68	14,581	5.56	12,124	70,337	14,878	0
	8	118,266	9.32	20,506	5.54	12,224	96,980	29,568	0
	9	72,142	5.24	11,933	4.87	11,109	30,607	42,359	0
	10	56,438	1.99	4,603	4.99	11,627	27,531	21,884	0
	11	30,623	1.13	2,618	3.69	8,580	41,298	-16,636	0
	12	27,097	0.26	597	2.85	6,526	51,883	-30,714	0
1992	1	31,844	1.15	2,577	2.70	6,067	50,801	-21,582	0
	2	44,550	5.96	13,277	3.49	7,788	28,410	23,327	0
	3	39,584	1.50	3,369	4.69	10,549	50,504	-18,100	0
	4	58,229	3.50	7,792	5.08	11,368	47,557	7,096	0
	5	6,256	1.10	2,394	6.72	14,807	54,108	-60,265	0
	6	44,339	14.24	31,115	5.18	11,292	34,715	52,969	0
	7	62,161	2.20	4,864	5.57	12,318	81,724	-28,301	0
	8	50,969	10.81	24,182	4.61	10,296		28,764	
	9	46,102	5.42	12,336	5.11	11,604		41,098	

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1992	10	23,572	2.93	6,779	4.72	10,925		8,472	
	11	9,505	1.25	2,867	3.42	7,872		-10,911	
	12	20,210	0.36	823	2.32	5,297	23,819	-14,987	0
1993	1	56,310	3.25	7,491	2.76	6,321	39,318	18,162	0
	2	55,514	3.10	7,202	3.30	7,622	38,882	16,212	0
	3	70,826	4.22	9,874	4.16	9,664	89,274	-18,238	0
	4	65,801	2.90	6,751	5.67	13,112	75,857	-20,500	0
	5	12,322	1.25	2,741	6.54	14,553	46,232	-53,888	0
	6	9,391	2.60	5,678	5.91	12,834	1,836	-15,607	0
	7	38,949	5.64	12,393	5.51	12,091	10,881	28,370	0
	8	28,894	7.70	16,937	5.00	10,959	37,346	-2,474	0
	9	81,952	3.50	7,964	4.67	10,535	1,284	78,097	0
	10	42,904	2.65	6,164	3.94	9,187	26,111	13,770	0
	11	42,107	0.50	1,175	2.96	6,951	35,209	1,123	0
	12	26,513	0.50	1,164	2.41	5,613	31,564	-9,499	0
1994	1	51,853	1.40	3,268	2.80	6,544	47,460	1,117	0
	2	35,812	1.70	3,960	3.15	7,299	37,930	-5,457	0
	3	58,774	1.45	3,396	5.03	11,630	62,970	-12,430	0
	4	19,634	4.85	11,032	5.35	12,158	54,844	-36,336	0
	5	17,158	0.50	1,089	6.10	13,440	61,696	-56,889	0
	6	82,406	10.85	24,035	5.31	11,748	73,665	21,028	0
	7	57,524	2.50	5,532	4.92	10,861	32,674	19,521	0

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Lake Istokpoga

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1994	8	60,605	4.20	9,343	4.70	10,438	54,957	4,553	0
	9	122,633	6.75	15,510	3.37	7,701	75,320	55,122	0
	10	101,052	2.25	5,239	4.33	10,102	75,339	20,849	0
	11	60,841	8.10	18,654	3.52	8,201	74,661	-3,367	0
	12	50,606	2.95	6,920	2.35	5,498	53,325	-1,297	0
1995	1	66,674	1.45	3,380	2.51	5,847	64,804	-596	0
	2	70,795	1.65	3,829	2.64	6,128	68,776	-280	0
	3	67,199	1.90	4,473	4.34	10,171	56,522	4,979	0
	4	46,439	4.20	9,831	5.72	13,269	85,692	-42,690	0
	5	20,477	2.40	5,384	6.51	14,488	74,502	-63,130	0
	6	45,549	6.65	14,570	5.65	12,352	34,745	13,021	0
	7	43,745	5.93	13,081	4.93	10,837	36,493	9,497	0
	8	183,927	6.22	13,632	5.40	11,984	183,575	2,000	0
	9	149,032	5.81	13,275	4.72	10,730	91,298	60,279	0
	10	114,106	6.35	14,800	4.13	9,616	108,046	11,243	0
	11	52,420	1.10	2,569	3.42	7,994	37,670	9,325	0
	12	23,119	0.17	397	2.82	6,586	32,246	-15,316	0
1996	1	66,045	1.70	3,979	2.91	6,800	51,100	12,124	0
	2	45,335	1.90	4,445	3.85	8,937	62,317	-21,474	0
	3	77,585	2.25	5,198	5.08	11,725	66,266	4,792	0
	4	34,133	0.95	2,206	5.62	12,952	55,733	-32,346	0
	5	25,996	5.40	12,064	5.59	12,510	55,042	-29,492	0

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Lake Istokpoga

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1996	6	64,587	4.83	10,765	5.21	11,544	73,307	-9,499	0
	7	66,095	4.54	10,004	6.57	14,403	83,868	-22,172	0
	8	54,465	1.51	3,293	5.78	12,603	37,006	8,149	0
	9	23,930	2.02	4,410	5.65	12,335	19,474	-3,469	0
	10	58,502	1.53	3,371	4.59	10,166	12,332	39,376	0
	11	44,036	0.05	112	3.88	8,660	49,344	-13,856	0
	12	56,475	0.65	1,458	2.90	6,447	50,687	800	0
1997	1	47,172	0.87	1,943	2.96	6,598	33,814	8,703	0
	2	41,350	1.06	2,368	3.53	7,859	49,308	-13,449	0
	3	38,175	1.05	2,313	5.27	11,618	45,186	-16,317	0
	4	57,569	4.35	9,490	5.32	11,573	49,462	6,024	0
	5	34,224	4.57	10,093	6.15	13,536	27,573	3,209	0
	6	49,948	4.14	9,157	5.37	11,869	39,754	7,482	0
	7	65,833	6.13	13,619	5.34	11,825	54,911	12,716	0
	8	110,026	6.78	15,215	5.02	11,333	86,955	26,953	0
	9	93,764	8.70	20,168	4.75	10,809	45,476	57,647	0
	10	103,884	0.41	961	4.82	11,272	107,349	-13,776	0
	11	91,701	2.80	6,586	2.76	6,473	93,006	-1,192	0
	12	143,620	5.97	13,895	2.44	5,674	158,852	-7,011	0
1998	1	182,760	4.86	11,277	2.74	6,349	188,285	-597	0
	2	288,545	7.64	17,885	2.90	6,704	329,612	-29,885	0
	3	266,683	4.87	11,415	4.62	10,709	246,400	20,988	0

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1998	4	116,805	1.20	2,809	5.46	12,671	111,456	-4,514	0
	5	32,763	0.66	1,492	6.45	14,665	64,853	-45,264	0
	6	17,360	4.25	9,352	6.99	15,393	62,612	-51,293	0
	7	51,573	8.42	18,214	5.34	11,625	29,019	29,143	0
	8	93,083	7.91	17,578	5.87	13,034	76,080	21,547	0
	9	127,367	6.86	15,621	4.03	9,161	107,657	26,171	0
	10	108,485	1.47	3,453	4.94	11,522	63,628	36,789	0
	11	87,952	3.66	8,585	3.12	7,281	82,526	6,730	0
	12	45,293	0.46	1,078	2.43	5,702	35,832	4,838	0
1999	1	54,348	1.05	2,464	3.25	7,583	55,258	-6,029	0
	2	32,037	0.11	249	2.90	6,747	50,196	-24,658	0
	3	34,881	1.09	2,465	5.03	11,410	79,750	-53,814	0
	4	24,788	0.26	556	5.75	12,492	69,934	-57,083	0
	5	221,659	2.52	5,552	6.08	13,939	27,056	186,215	0
	6	27,607	8.01	19,305	4.35	10,495	36,416	0	0
	7	99,005	2.81	6,772	5.27	12,712	93,065	0	0
	8	72,007	10.30	24,824	4.35	10,495	86,335	0	0
	9	114,754	4.33	10,436	3.96	9,543	115,647	0	0
	10	106,251	4.96	11,954	3.88	9,341	108,864	0	0
	11	43,920	0.55	1,326	3.62	8,719	36,527	0	0
	12	20,843	1.21	2,916	3.34	8,041	15,718	0	0
2000	1	18,351	1.07	2,579	3.00	7,235	13,694	0	0

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2000	2	13,645	0.16	386	3.56	8,572	5,458	0	0
	3	14,740	0.71	1,711	4.42	10,660	5,791	0	0
	4	15,598	1.94	4,676	5.72	13,792	6,482	0	0
	5	21,305	0.45	1,082	7.07	17,034	5,352	0	0
	6	13,865	3.81	9,182	5.94	14,305	8,743	0	0
	7	10,029	5.94	14,316	5.34	12,858	11,487	0	0
	8	12,260	2.68	6,459	5.66	13,646	5,073	0	0
	9	15,171	4.70	11,327	4.61	11,118	15,380	0	0
	10	11,638	2.07	4,989	4.69	11,301	5,325	0	0
	11	7,964	0.07	169	3.37	8,133	0	0	0
	12	6,934	0.17	410	2.91	7,015	329	0	0
2001	1	7,146	0.11	265	3.02	7,290	121	0	0
	2	29,606	0.00	0	3.86	9,305	20,301	0	0
	3	12,622	2.66	6,411	4.99	12,034	6,998	0	0
	4	15,337	1.18	2,844	6.56	15,807	2,374	0	0
	5	14,922	2.07	4,989	6.95	16,741	3,170	0	0
	6	9,751	6.42	15,473	5.46	13,170	12,054	0	0
	7	99,832	6.42	15,473	5.03	12,126	103,179	0	0
	8	125,488	2.55	6,146	5.43	13,096	118,538	0	0
	9	205,053	10.25	24,703	3.94	9,488	220,269	0	0
	10	100,090	2.47	5,953	4.66	11,236	94,807	0	0
	11	64,903	0.47	1,133	3.34	8,059	57,976	0	0
	12	22,191	0.14	337	2.96	7,143	15,385	0	0

Appendix A: Monthly Water Balances

Lake Istokpoga									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2002	1	22,514	1.52	3,663	2.96	7,129	19,048	0	0
	2	21,633	1.76	4,242	3.40	8,201	17,674	0	0
	3	22,814	0.51	1,234	4.98	11,998	12,050	0	0
	4	27,668	0.33	795	5.90	14,214	14,249	0	0
	5	29,859	2.59	6,242	6.46	15,568	20,533	0	0
	6	44,881	14.24	34,320	5.65	13,610	65,590	0	0
	7	205,767	7.11	17,136	5.58	13,444	209,459	0	0
	8	92,245	6.40	15,425	5.41	13,042	94,627	0	0
	9	133,658	5.97	14,388	4.87	11,744	136,302	0	0
	10	44,280	2.29	5,519	4.66	11,236	38,563	0	0
	11	45,930	3.67	8,845	3.43	8,264	46,511	0	0
	12	113,237	5.36	12,918	2.81	6,779	119,375	0	0

Appendix A: Monthly Water Balances

Lake Jessup									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1994	10	10,269	3.10	3,387	1.50	1,644	19,430	2,884	-10,303
	11	23,958	9.07	9,909	1.12	1,221	18,694	19,075	-5,123
	12	16,098	5.47	5,976	1.32	1,445	36,188	-13,176	-2,384
1995	1	7,055	2.44	2,666	1.41	1,536	32,285	-23,991	-109
	2	3,078	1.01	1,103	1.41	1,536	20,926	-23,336	5,055
	3	3,624	2.08	2,272	3.02	3,305	8,703	-9,767	3,656
	4	2,324	2.91	3,179	4.29	4,683	5,023	-5,899	1,696
	5	1,985	3.29	3,594	5.61	6,128	756	852	-2,194
	6	3,413	9.24	10,095	4.35	4,749	2,700	6,883	-571
	7	21,104	10.03	10,958	5.27	5,762	27,491	8,521	-9,123
	8	25,649	12.60	13,766	4.58	4,998	11,859	33,365	-10,808
	9	15,692	4.13	4,512	3.78	4,127	18,367	8,063	-10,353
	10	16,985	7.38	8,063	2.05	2,242	19,313	12,258	-8,765
	11	5,338	2.28	2,491	1.97	2,150	25,847	-20,583	415
	12	3,585	1.93	2,109	1.43	1,561	21,469	-19,272	1,935
1996	1	13,168	5.75	6,282	1.17	1,279	20,501	-1,377	-953
	2	4,367	1.30	1,420	1.88	2,059	22,707	-25,433	6,455
	3	16,739	11.19	12,225	2.83	3,097	12,978	40,707	-27,818
	4	11,871	1.86	2,032	4.64	5,073	23,942	-19,993	4,880
	5	3,191	4.22	4,610	5.80	6,335	9,952	-20,189	11,703
	6	16,558	13.94	15,229	5.08	5,555	13,511	12,258	464
	7	10,940	4.32	4,720	6.29	6,867	14,194	-17,502	12,499

Appendix A: Monthly Water Balances

Lake Jessup									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1996	8	4,788	5.51	6,020	5.08	5,555	-203	6,031	-575
	9	5,747	6.21	6,784	3.63	3,969	3,843	3,409	1,293
	10	14,014	5.99	6,544	1.70	1,860	9,797	13,044	-4,143
	11	2,318	0.30	328	1.46	1,594	11,494	-14,028	3,586
	12	2,720	2.23	2,436	1.37	1,495	10,208	-8,063	1,516
1997	1	2,112	1.62	1,770	1.08	1,179	6,764	-2,294	-1,767
	2	1,509	0.72	789	1.47	1,611	8,499	-2,032	-5,781
	3	1,603	2.85	3,114	3.00	3,280	9,138	-721	-6,980
	4	1,326	2.46	2,688	4.54	4,965	1,012	6,162	-8,125
	5	1,241	2.34	2,556	5.12	5,596	-1,417	-918	536
	6	2,715	6.08	6,642	4.64	5,073	893	2,425	966
	7	4,375	9.62	10,510	5.49	6,003	-1,473	13,176	-2,820
	8	5,232	10.05	10,980	4.32	4,724	-2,577	6,686	7,151
	9	1,571	2.63	2,873	3.34	3,645	7,503	-9,243	2,538
	10	1,335	4.91	5,364	1.70	1,860	4,558	-1,966	2,247
	11	2,730	1.38	1,508	2.80	3,056	7,452	-3,540	-2,730
	12	14,615	9.08	9,920	1.01	1,104	-8,059	47,720	-16,231
1998	1	10,446	2.70	2,950	1.09	1,187	20,116	-8,259	352
	2	20,233	10.26	11,209	1.31	1,428	13,402	19,206	-2,595
	3	21,525	5.80	6,337	2.90	3,172	35,611	-8,587	-2,335
	4	3,009	0.22	240	4.61	5,032	30,587	-31,005	-1,364
	5	1,067	0.30	328	4.89	5,347	20,965	-24,712	-205

Appendix A: Monthly Water Balances

Lake Jessup									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1998	6	359	2.69	2,939	5.86	6,402	10,836	-13,503	-436
	7	1,084	8.66	9,461	4.77	5,206	10,594	-3,540	-1,715
	8	4,676	6.53	7,134	4.62	5,047	5,013	14,028	-12,277
	9	9,712	7.76	8,483	2.78	3,039	8,162	22,221	-15,227
	10	3,725	1.96	2,141	1.92	2,101	8,654	-4,851	-38
	11	4,100	1.34	1,464	1.00	1,096	15,162	-15,601	4,907
	12	1,456	0.35	382	1.00	1,096	1,157	-1,180	766
1999	1	2,559	3.87	4,228	1.06	1,154	5,923	-4,457	4,168
	2	1,262	0.36	393	1.37	1,495	-3,441	4,326	-725
	3	851	1.46	1,595	2.88	3,147	3,267	-11,209	7,242
	4	596	2.69	2,939	4.77	5,206	-5,334	2,819	845
	5	383	1.97	2,152	4.71	5,148	-2,289	-2,556	2,232
	6	3,352	5.93	6,479	3.97	4,342	-1,456	14,421	-7,477
	7	7,432	5.28	5,768	5.20	5,679	8,817	-10,685	9,389
	8	2,464	2.21	2,414	4.31	4,708	-6,337	5,834	674
	9	19,352	9.75	10,652	2.70	2,948	-7,999	29,498	5,558
	10	25,974	8.37	9,144	1.69	1,852	-27,185	37,298	23,155
	11	13,754	2.90	3,168	1.28	1,403	12,615	-15,994	18,898
	12	6,788	2.25	2,458	0.78	855	30,476	-26,023	3,938
2000	1	3,537	1.06	1,158	1.03	1,121	20,731	-20,452	3,295
	2	2,478	0.70	765	1.34	1,461	11,492	-11,209	1,498
	3	1,537	0.59	645	2.85	3,114	1,095	-328	-1,699

Appendix A: Monthly Water Balances

Lake Jessup

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2000	4	1,271	1.48	1,617	5.07	5,538	2,928	-3,867	-1,710
	5	848	0.20	219	6.24	6,817	-888	-1,901	-2,961
	6	1,395	3.49	3,813	6.86	7,489	3,148	-721	-4,708
	7	4,100	9.58	10,466	4.92	5,380	2,032	7,145	9
	8	4,252	4.92	5,375	4.71	5,148	-668	5,703	-556
	9	3,354	7.54	8,237	2.92	3,188	14,789	8,063	-14,449
	10	1,948	1.42	1,551	1.96	2,142	-11,472	5,834	6,995
	11	1,119	1.19	1,300	1.71	1,868	8,293	-13,110	5,368
	12	1,258	0.66	721	1.03	1,121	4,434	-3,671	95
2001	1	1,232	0.57	623	1.06	1,154	6,920	-8,063	1,843
	2	1,071	0.31	339	1.32	1,445	1,250	-459	-826
	3	2,190	6.80	7,429	2.36	2,574	325	9,374	-2,653
	4	2,048	2.01	2,196	4.64	5,065	3,392	-10,357	6,144
	5	1,377	1.58	1,726	5.56	6,078	-1,519	2,360	-3,815
	6	4,474	4.10	4,479	4.73	5,173	3,925	2,491	-2,636
	7	13,046	11.48	12,542	4.40	4,807	-939	17,633	4,086
	8	9,306	9.27	10,127	4.64	5,065	-16,235	11,537	19,067
	9	27,321	9.99	10,914	2.83	3,089	-34,487	13,634	52,108
	10	9,819	2.58	2,823	2.07	2,258	15,341	-15,404	10,446
	11	5,758	3.75	4,097	1.63	1,777	3,268	-7,473	12,282
	12	3,037	0.37	404	1.58	1,723	26,208	-29,301	4,811
2002	1	4,616	2.76	3,012	1.67	1,829	19,703	-15,142	1,238

Appendix A: Monthly Water Balances

Lake Jessup									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2002	2	4,304	3.07	3,357	2.12	2,316	-1,494	8,653	-1,814
	3	3,069	3.96	4,322	3.56	3,889	5,712	-9,243	7,031
	4	1,744	2.30	2,508	4.83	5,272	1,863	-1,377	-1,506
	5	1,128	3.21	3,506	5.42	5,923	-2,579	6,883	-5,593
	6	6,349	6.68	7,301	5.03	5,499	7,753	15,208	-14,686
	7	20,890	6.88	7,519	5.04	5,501	6,555	26,351	-9,998
	8	39,018	7.18	7,842	4.62	5,047	22,881	19,272	-339
	9	33,537	6.32	6,906	3.77	4,117	34,364	-11,209	13,172
	10	9,704	3.82	4,175	2.95	3,226	32,039	-30,809	9,422
	11	7,539	2.18	2,381	1.97	2,150	20,807	-18,354	5,317
	12	24,318	2.24	2,448	1.58	1,723	6,502	28,908	-10,367
2003	1	21,043	2.76	3,012	1.67	1,829	16,459	-1,442	7,209
	2	8,802	3.07	3,357	2.12	2,316	26,321	-20,976	4,499
	3	14,632	3.96	4,322	3.56	3,889	6,361	14,093	-5,391
	4	5,490	2.30	2,508	4.83	5,272	17,036	-19,468	5,159
	5	4,195	3.21	3,506	5.42	5,923	7,109	-9,439	4,109
	6	14,617	6.68	7,301	5.03	5,499	5,681	5,309,157	-5,298,419
	7	18,369	6.88	7,519	5.04	5,501	18,222	-5,294,801	5,296,966
	8	34,754	7.18	7,842	4.62	5,047	1,200	28,252	8,097
	9	15,296	6.32	6,906	3.77	4,117	15,330	-2,360	5,115

Appendix A: Monthly Water Balances

Lake Thonotosassa									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1980	10	-60	1.27	87	4.54	310	196	-479	0
	11	79	2.68	183	2.77	189	77	-4	0
	12	791	0.37	25	2.30	157	328	332	0
1981	1	564	0.44	30	3.92	268	334	-8	0
	2	2,244	5.34	364	4.58	313	2,349	-53	0
	3	917	1.70	116	6.35	433	461	139	0
	4	886	0.00	0	7.11	485	385	16	0
	5	-28	1.68	115	8.01	547	125	-586	0
	6	1,166	9.37	640	6.63	452	854	500	0
	7	34	1.65	113	6.79	464	72	-389	0
	8	787	7.71	526	5.76	393	289	631	0
	9	7,676	5.87	401	4.97	339	7,672	66	0
	10	1,325	0.87	59	4.58	312	679	393	0
	11	-167	0.43	29	3.27	223	417	-778	0
	12	1,849	3.58	244	2.49	170	1,145	778	0
1982	1	420	1.93	132	2.87	196	1,090	-733	0
	2	2,375	2.15	147	3.45	235	2,078	209	0
	3	2,628	3.07	210	4.59	313	2,053	471	0
	4	1,932	2.01	137	5.56	380	1,890	-201	0
	5	970	5.04	344	6.24	426	692	197	0
	6	3,010	8.45	577	5.30	362	3,384	-160	0
	7	2,584	10.89	743	6.29	429	2,132	766	0

Appendix A: Monthly Water Balances

Lake Thonotosassa									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1982	8	1,509	7.50	512	5.91	404	2,112	-495	0
	9	2,895	10.85	741	4.61	315	2,817	504	0
	10	2,765	2.30	157	4.01	274	3,529	-880	0
	11	1,177	0.93	63	3.02	206	1,222	-188	0
	12	263	1.33	91	2.76	188	665	-500	0
1983	1	858	1.31	90	2.09	143	281	524	0
	2	6,214	7.28	497	2.69	184	5,724	803	0
	3	9,335	7.05	481	4.86	331	7,716	1,769	0
	4	3,247	2.90	198	5.81	397	5,034	-1,986	0
	5	-704	4.22	288	6.40	437	208	-1,061	0
	6	4,417	6.97	476	5.73	391	3,232	1,269	0
	7	2,825	6.42	438	6.50	443	3,774	-954	0
	8	3,040	9.19	627	5.65	386	3,134	147	0
	9	7,863	6.70	457	4.35	297	7,630	393	0
	10	1,485	1.87	128	4.24	289	1,540	-217	0
	11	1,229	2.41	164	3.11	212	1,140	41	0
	12	5,246	4.75	324	2.03	138	3,630	1,802	0
1984	1	2,841	1.69	115	2.35	160	4,188	-1,392	0
	2	3,024	3.39	231	3.69	252	2,491	512	0
	3	1,544	1.39	95	4.77	326	2,054	-741	0
	4	2,103	1.65	112	5.87	400	2,245	-430	0
	5	1,938	3.31	226	6.17	421	1,235	508	0

Appendix A: Monthly Water Balances

Lake Thonotosassa									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1984	6	1,606	2.19	149	6.10	416	1,236	102	0
	7	5,602	7.35	501	6.51	444	4,836	823	0
	8	6,344	5.98	408	6.16	420	6,418	-86	0
	9	1,256	4.30	294	6.32	431	2,036	-917	0
	10	802	0.42	29	5.41	369	1,092	-631	0
	11	1,271	0.80	54	3.56	243	992	90	0
	12	547	0.11	7	2.96	202	659	-307	0
1985	1	2,257	2.13	146	3.31	226	1,280	897	0
	2	-517	2.14	146	3.86	263	152	-786	0
	3	785	1.88	128	6.45	440	346	127	0
	4	222	1.10	75	5.89	402	251	-356	0
	5	478	0.34	23	7.81	533	87	-119	0
	6	1,906	6.54	446	7.54	515	961	876	0
	7	1,421	6.88	469	6.25	427	1,181	283	0
	8	7,812	7.79	532	5.18	354	6,057	1,933	0
	9	6,172	8.81	601	5.43	370	8,274	-1,871	0
	10	487	2.21	151	4.89	334	972	-667	0
	11	520	1.07	73	3.59	245	434	-86	0
	12	832	1.16	79	3.12	213	424	274	0
1986	1	1,324	2.44	167	3.02	206	1,195	90	0
	2	1,519	1.55	106	3.79	259	1,300	66	0
	3	2,046	4.35	297	5.06	345	2,071	-74	0

Appendix A: Monthly Water Balances

Lake Thonotosassa

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1986	4	533	1.09	74	7.03	480	680	-553	0
	5	638	2.58	176	7.96	543	386	-115	0
	6	6,441	5.11	349	5.98	408	3,633	2,748	0
	7	3,636	6.61	451	6.08	415	4,876	-1,204	0
	8	6,741	5.66	386	5.82	397	6,587	143	0
	9	1,122	3.93	268	5.33	364	2,669	-1,642	0
	10	4,067	6.34	433	5.18	354	3,188	958	0
	11	1,153	0.58	39	3.30	225	1,373	-405	0
	12	814	1.03	70	2.60	177	613	94	0
1987	1	1,277	3.35	229	2.75	188	1,592	-274	0
	2	2,202	1.57	107	3.03	207	1,422	680	0
	3	8,058	11.82	807	4.85	331	5,532	3,002	0
	4	3,176	0.53	36	6.54	446	6,292	-3,526	0
	5	4,629	2.98	204	6.86	468	3,898	467	0
	6	2,654	3.49	238	6.93	473	2,370	49	0
	7	1,882	6.46	441	5.83	398	2,416	-491	0
	8	1,181	7.53	514	5.58	381	1,769	-455	0
	9	2,442	2.13	145	5.17	353	805	1,429	0
	10	349	1.59	109	4.36	298	1,413	-1,253	0
	11	2,628	4.44	303	2.83	193	2,291	446	0
	12	-295	0.54	37	2.78	190	334	-782	0
1988	1	1,978	2.83	193	2.39	163	1,242	766	0

Appendix A: Monthly Water Balances

Lake Thonotosassa									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1988	2	916	1.51	103	3.46	236	1,250	-467	0
	3	4,117	4.17	285	5.05	344	3,312	745	0
	4	1,191	1.28	87	6.32	432	978	-131	0
	5	524	1.39	95	6.82	466	502	-348	0
	6	210	5.30	362	6.47	441	384	-254	0
	7	-28	3.80	259	6.15	420	147	-336	0
	8	2,957	11.34	774	5.66	386	1,609	1,736	0
	9	20,896	13.65	932	5.01	342	22,735	-1,249	0
	10	1,117	0.22	15	4.89	334	590	209	0
	11	4,121	6.04	412	3.09	211	4,338	-16	0
	12	3,181	1.68	115	2.54	173	2,741	381	0
1989	1	2,542	1.61	110	3.07	210	2,242	201	0
	2	36	0.48	33	3.86	263	903	-1,097	0
	3	1,035	1.79	122	4.92	336	735	86	0
	4	1,189	0.85	58	6.09	415	659	172	0
	5	285	0.36	25	7.55	516	470	-676	0
	6	1,046	6.84	467	6.22	424	171	917	0
	7	476	8.74	596	5.81	397	893	-217	0
	8	703	7.56	516	6.25	427	784	8	0
	9	1,837	6.20	423	4.97	339	1,303	618	0
	10	-638	2.02	138	4.50	307	380	-1,188	0
	11	1,949	2.13	145	3.44	235	1,065	794	0
	12	3,015	4.76	325	2.14	146	2,620	573	0

Appendix A: Monthly Water Balances

Lake Thonotosassa

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1990	1	1,151	0.60	41	3.23	220	1,753	-782	0
	2	1,001	4.65	317	4.07	278	611	430	0
	3	-36	0.43	30	5.56	379	774	-1,159	0
	4	430	1.61	110	5.88	401	109	29	0
	5	285	1.88	129	7.17	489	80	-156	0
	6	802	5.01	342	6.68	456	254	434	0
	7	4,841	10.40	710	5.22	356	4,904	291	0
	8	4,654	3.57	244	5.37	367	3,306	1,224	0
	9	-521	2.21	151	5.30	362	1,000	-1,732	0
	10	1,383	2.76	188	4.51	308	1,308	-45	0
	11	201	0.74	50	3.44	234	41	-25	0
	12	503	0.23	16	2.82	192	134	192	0
1991	1	1,646	2.36	161	2.80	191	973	643	0
	2	109	0.40	27	3.43	234	382	-479	0
	3	214	4.35	297	4.60	314	90	106	0
	4	4,273	1.68	114	5.39	368	1,746	2,273	0
	5	3,710	6.90	471	5.45	372	2,322	1,503	0
	6	4,520	3.75	256	5.97	407	4,287	82	0
	7	8,071	9.40	641	5.14	351	7,490	872	0
	8	2,840	7.65	522	4.93	337	4,278	-1,253	0
	9	-876	3.52	240	5.60	382	329	-1,347	0

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1981	1	1,438	0.00	0	0.05	25	1,531	0	-119
	2	51,362	3.97	1,978	2.44	1,216	36,270	3,857	11,998
	3	54,483	3.38	1,684	3.86	1,924	43,662	1,704	8,877
	4	49,006	0.13	65	5.28	2,632	34,681	-2,571	14,329
	5	45,588	0.60	299	5.91	2,943	28,500	-568	15,012
	6	44,143	1.78	887	5.96	2,969	28,249	30	13,782
	7	46,850	6.10	3,040	5.06	2,522	27,110	1,196	19,061
	8	51,204	10.53	5,247	4.82	2,401	41,116	1,495	11,439
	9	45,358	2.25	1,121	3.56	1,776	60,798	-7,206	-8,888
	10	40,891	1.70	847	3.46	1,723	39,164	-1,106	1,958
	11	41,348	4.92	2,452	1.53	761	44,084	-1,166	121
	12	41,143	3.18	1,585	1.27	632	30,599	1,196	10,300
1982	1	44,386	2.65	1,321	1.88	939	27,802	3,947	13,018
	2	44,435	1.46	728	2.31	1,151	33,180	2,422	8,409
	3	56,426	6.90	3,439	3.74	1,863	49,559	5,621	2,821
	4	160,380	8.03	4,002	4.04	2,011	166,109	3,080	-6,818
	5	78,538	1.71	852	5.08	2,530	69,991	7,086	-217
	6	201,543	9.35	4,659	4.58	2,280	225,432	7,355	-28,864
	7	195,851	8.88	4,425	4.86	2,420	191,128	-6,339	13,067
	8	143,493	4.38	2,183	4.76	2,371	152,579	-8,581	-693
	9	150,456	6.47	3,224	3.77	1,879	148,500	7,206	-3,905
	10	145,205	4.04	2,013	2.74	1,367	141,584	-9,777	14,044
	11	80,172	1.13	563	1.39	693	69,092	-1,076	12,026

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1982	12	75,568	1.73	862	1.16	579	65,986	-1,106	10,971
1983	1	75,853	3.39	1,689	1.04	519	73,133	2,123	1,768
	2	127,469	5.09	2,537	1.65	822	119,500	10,764	-1,080
	3	181,784	6.39	3,184	3.47	1,727	185,599	1,764	-4,122
	4	202,071	3.95	1,968	4.52	2,253	191,448	-3,857	14,195
	5	160,260	3.28	1,635	5.69	2,837	120,157	-8,581	47,483
	6	137,492	10.37	5,168	5.26	2,621	120,151	4,276	15,613
	7	147,566	7.27	3,623	5.69	2,837	143,609	-2,213	6,955
	8	119,183	5.75	2,865	4.92	2,454	103,797	30	15,767
	9	144,223	4.78	2,382	3.48	1,735	141,302	1,076	2,492
	10	97,395	4.30	2,143	3.14	1,564	81,483	-3,857	20,347
	11	82,465	2.37	1,181	1.66	826	72,976	0	9,845
	12	115,011	5.24	2,611	0.87	432	99,005	12,379	5,807
1984	1	189,845	2.30	1,146	1.34	667	188,610	-179	1,894
	2	131,879	3.75	1,869	2.41	1,201	131,258	-299	1,588
	3	180,256	2.58	1,286	4.29	2,140	161,195	-4,814	23,021
	4	164,371	3.05	1,520	4.64	2,310	158,323	-3,259	8,518
	5	102,982	4.65	2,317	5.28	2,632	86,378	-1,854	18,142
	6	82,988	3.48	1,734	4.70	2,341	72,633	-1,435	11,185
	7	104,945	8.90	4,435	4.92	2,450	102,196	9,030	-4,296
	8	111,370	6.18	3,080	5.13	2,556	108,353	-9,418	12,959
	9	65,518	8.58	4,276	4.72	2,352	66,827	-837	1,452

Appendix A: Monthly Water Balances

Rodman Reservoir

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1984	10	59,650	0.95	473	3.58	1,784	57,396	-2,990	3,934
	11	54,284	1.80	897	1.69	845	55,972	-927	-709
	12	52,248	0.15	75	1.42	708	45,802	-329	6,142
1985	1	50,964	0.50	249	1.13	564	43,033	-359	7,974
	2	43,008	0.70	349	2.65	1,322	39,745	-867	3,158
	3	44,589	2.10	1,047	4.23	2,106	43,357	-658	831
	4	41,554	2.45	1,221	4.17	2,079	37,265	-269	3,699
	5	40,483	2.20	1,096	6.75	3,363	25,448	-508	13,276
	6	39,725	5.91	2,945	5.12	2,553	32,442	1,615	6,062
	7	44,463	7.76	3,867	4.77	2,378	43,803	748	1,402
	8	68,432	9.79	4,879	4.12	2,053	84,171	6,458	-19,371
	9	81,284	8.20	4,086	3.75	1,871	79,585	-1,286	5,200
	10	72,242	5.99	2,985	3.53	1,757	65,496	-149	8,123
	11	71,309	0.60	299	1.65	822	67,164	-2,990	6,612
	12	62,278	0.40	199	1.26	629	87,156	-5,591	-19,715
1986	1	97,693	4.67	2,327	1.42	708	109,646	4,096	-14,431
	2	83,578	1.75	872	2.22	1,106	86,412	-1,017	-2,051
	3	124,378	3.20	1,595	3.69	1,841	132,050	2,601	-10,519
	4	80,506	2.55	1,271	5.45	2,716	48,625	-4,365	34,802
	5	64,729	1.80	897	6.35	3,166	26,987	2,811	32,662
	6	54,288	7.91	3,942	5.63	2,806	51,822	-1,076	4,677
	7	57,707	7.25	3,613	5.15	2,568	51,564	3,947	3,241

Appendix A: Monthly Water Balances

Rodman Reservoir

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1986	8	61,952	8.32	4,146	4.80	2,390	58,253	419	5,037
	9	64,027	1.75	872	3.90	1,943	59,330	-3,229	6,855
	10	51,408	2.60	1,296	2.50	1,246	33,137	1,076	17,244
	11	47,693	1.90	947	1.17	583	42,063	508	5,484
	12	61,078	2.90	1,445	1.58	786	53,345	120	8,272
1987	1	63,484	1.65	822	1.41	704	59,345	-718	4,974
	2	82,081	5.53	2,756	1.71	852	75,404	8,043	538
	3	159,536	10.40	5,183	2.99	1,492	148,306	17,970	-3,049
	4	248,943	0.20	100	4.85	2,416	220,520	-17,133	43,238
	5	133,529	1.95	972	4.89	2,439	99,168	-4,933	37,828
	6	82,110	3.65	1,819	4.45	2,216	58,118	0	23,596
	7	66,602	4.50	2,243	5.04	2,509	57,201	-3,588	12,722
	8	57,501	4.65	2,317	4.96	2,469	47,603	-269	10,014
	9	56,566	2.75	1,370	3.96	1,973	48,272	-60	7,751
	10	51,723	1.15	573	2.70	1,345	47,804	-1,047	4,195
	11	51,324	4.17	2,078	1.34	667	57,463	-120	-4,608
	12	49,293	2.00	997	1.16	579	48,524	-538	1,725
1988	1	62,430	7.24	3,608	1.32	659	62,842	7,445	-4,909
	2	73,412	3.90	1,944	1.88	935	75,975	-1,824	269
	3	145,531	5.95	2,965	3.96	1,973	154,590	8,193	-16,259
	4	81,812	0.70	349	4.72	2,352	77,389	-11,422	13,842
	5	55,906	2.55	1,271	5.94	2,958	49,714	-957	5,462

Appendix A: Monthly Water Balances

Rodman Reservoir

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1988	6	52,306	3.00	1,495	5.14	2,560	46,320	1,017	3,905
	7	60,548	5.86	2,920	5.27	2,625	61,470	2,213	-2,839
	8	67,878	4.25	2,118	4.93	2,458	69,997	867	-3,326
	9	154,388	8.14	4,056	3.09	1,541	175,936	5,741	-24,774
	10	109,446	0.80	399	2.52	1,257	85,553	-2,571	25,605
	11	85,331	3.40	1,694	1.43	712	95,611	-3,349	-5,950
	12	74,399	2.00	997	1.34	667	113,942	-5,322	-33,891
1989	1	63,586	3.20	1,595	1.66	826	75,174	-1,346	-9,473
	2	58,130	0.65	324	2.05	1,023	66,226	-1,525	-7,270
	3	61,077	4.20	2,093	3.75	1,871	71,034	-1,405	-8,329
	4	57,080	1.75	872	5.12	2,553	65,145	2,482	-12,228
	5	56,268	2.25	1,121	5.97	2,973	35,609	0	18,807
	6	48,572	7.30	3,638	5.51	2,746	47,250	4,694	-2,604
	7	69,404	3.39	1,689	6.31	3,143	74,801	-1,435	-5,415
	8	54,572	4.04	2,013	5.50	2,742	55,567	-419	-1,305
	9	58,521	6.81	3,394	4.01	1,996	66,689	3,110	-9,880
	10	50,068	4.36	2,173	2.56	1,276	50,991	-3,648	3,621
	11	44,277	1.51	752	1.56	776	47,708	-598	-2,858
	12	49,740	3.30	1,645	1.22	606	57,590	1,226	-8,037
1990	1	54,461	3.10	1,545	1.46	727	56,182	-209	-694
	2	47,671	4.28	2,133	2.14	1,064	50,182	1,764	-3,206
	3	47,298	3.43	1,709	4.77	2,378	50,005	-2,721	-655

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1990	4	44,629	3.72	1,854	4.83	2,405	39,784	-299	4,593
	5	42,498	2.52	1,256	6.37	3,174	39,344	-1,405	2,641
	6	40,702	4.15	2,068	5.52	2,750	43,698	4,066	-7,744
	7	55,353	5.29	2,635	5.17	2,575	61,557	1,375	-7,520
	8	51,855	3.34	1,664	5.02	2,500	59,101	-3,977	-4,105
	9	37,911	0.83	414	4.99	2,484	37,845	-1,435	-569
	10	37,992	3.83	1,907	2.86	1,424	41,820	0	-3,275
	11	35,377	2.37	1,179	1.85	920	36,456	359	-1,180
	12	36,303	0.50	249	1.49	742	37,896	-957	-1,130
1991	1	36,343	3.84	1,914	1.99	992	40,417	688	-3,841
	2	32,042	0.51	254	2.12	1,057	32,795	-1,346	-210
	3	41,190	4.22	2,103	3.61	1,799	45,350	1,674	-5,531
	4	42,175	5.56	2,770	5.29	2,636	40,411	4,724	-2,826
	5	58,193	7.60	3,787	4.54	2,265	65,867	5,113	-11,265
	6	113,392	5.97	2,975	3.91	1,950	119,133	6,728	-11,444
	7	95,594	4.91	2,447	4.51	2,250	99,725	-5,920	1,986
	8	72,614	3.45	1,717	5.05	2,519	74,713	70,983	-73,884
	9	43,317	6.03	3,003	4.78	2,382	38,216	-80,820	86,542
	10	42,526	2.85	1,420	2.25	1,121	46,963	-1,047	-2,950
	11	39,272	0.90	449	1.16	576	36,420	-658	3,382
	12	38,414	0.95	473	0.97	485	69,086	-8,432	-22,251
1992	1	36,566	3.51	1,749	1.38	689	44,170	-837	-5,706

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1992	2	34,261	1.85	922	1.46	727	45,203	329	-11,077
	3	42,428	4.13	2,058	2.90	1,443	37,855	2,571	2,617
	4	36,225	2.73	1,363	4.71	2,348	23,476	4,037	7,727
	5	34,325	3.66	1,822	5.75	2,867	26,305	-598	7,574
	6	36,139	10.36	5,163	6.62	3,299	30,835	5,262	1,455
	7	38,450	7.38	3,679	5.27	2,628	33,535	-3,349	9,315
	8	44,523	5.73	2,855	4.01	1,996	45,779	2,422	-2,818
	9	44,126	6.28	3,130	4.27	2,128	41,492	449	3,186
	10	72,297	0.78	388	2.71	1,352	81,197	2,033	-11,898
	11	50,481	5.00	2,492	1.58	788	48,367	2,452	1,366
	12	53,900	0.50	249	1.06	526	55,761	-2,841	702
1993	1	54,167	6.15	3,065	1.12	561	61,450	3,917	-8,696
	2	78,106	4.10	2,043	1.62	807	84,446	2,302	-7,406
	3	82,958	4.60	2,292	2.55	1,273	90,329	6,189	-12,541
	4	85,098	0.37	183	4.77	2,375	91,377	-12,737	4,268
	5	41,488	5.11	2,544	5.65	2,818	41,203	-1,555	1,567
	6	40,070	4.59	2,287	6.06	3,019	30,920	1,196	7,222
	7	43,333	7.40	3,686	5.12	2,553	43,051	-1,047	2,462
	8	39,401	6.25	3,115	4.56	2,272	29,415	30	10,798
	9	40,105	10.10	5,033	4.01	1,996	36,077	-1,226	8,291
	10	39,855	6.57	3,275	2.31	1,151	29,990	2,422	9,567
	11	40,369	0.26	130	1.84	917	41,647	-2,302	238
	12	41,217	1.30	648	0.80	398	30,809	1,286	9,372

Appendix A: Monthly Water Balances

Rodman Reservoir

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1994	1	50,545	6.61	3,294	1.98	988	49,902	7,804	-4,856
	2	59,027	0.95	473	1.48	739	67,394	-4,694	-3,938
	3	57,663	3.10	1,545	3.61	1,799	53,351	-179	4,237
	4	47,038	0.75	374	4.77	2,378	38,700	-1,525	7,859
	5	46,028	3.15	1,570	5.50	2,742	34,909	-658	10,605
	6	46,319	10.20	5,083	4.63	2,306	52,899	-419	-3,385
	7	51,358	10.65	5,307	4.89	2,435	50,834	2,243	1,153
	8	84,266	9.09	4,531	4.29	2,140	93,257	7,535	-14,134
	9	85,827	7.45	3,713	3.60	1,795	99,675	598	-12,529
	10	100,635	5.61	2,795	1.50	750	98,828	0	3,852
	11	81,227	6.10	3,040	1.12	557	103,702	0	-19,992
	12	86,136	4.98	2,483	1.32	659	88,806	1,106	-1,512
1995	1	83,523	1.16	580	1.41	701	90,065	-2,482	-4,181
	2	53,841	1.18	590	1.41	701	49,805	-2,631	6,557
	3	66,665	1.62	808	3.02	1,507	60,135	5,532	299
	4	76,711	3.85	1,919	4.29	2,136	81,037	-9,718	5,174
	5	47,611	2.85	1,420	5.61	2,795	40,038	1,017	5,181
	6	64,763	6.31	3,142	4.35	2,166	61,156	9,927	-5,344
	7	65,074	2.85	1,420	5.27	2,628	65,823	-9,299	7,342
	8	99,428	8.24	4,106	4.58	2,280	110,815	8,073	-17,763
	9	119,668	10.52	5,241	3.78	1,882	131,096	-9,777	1,708
	10	136,869	6.95	3,463	2.05	1,023	176,563	1,914	-39,166

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1995	11	70,658	1.09	543	1.97	981	138,184	-8,372	-59,593
	12	67,627	1.03	514	1.43	712	73,204	-1,047	-4,728
1996	1	131,602	1.48	739	1.17	583	167,306	-11,661	-24,720
	2	63,150	1.55	772	1.88	939	70,096	-7,983	871
	3	106,212	7.55	3,762	2.83	1,413	119,657	18,777	-29,873
	4	142,287	1.25	623	4.64	2,314	115,736	-1,854	25,849
	5	76,472	2.85	1,420	5.80	2,890	102,631	-11,422	-16,207
	6	57,838	8.98	4,475	5.08	2,534	60,385	8,641	-9,247
	7	105,234	5.36	2,672	6.29	3,132	125,863	-7,744	-13,345
	8	65,883	4.79	2,387	5.08	2,534	86,001	-209	-20,055
	9	55,578	4.85	2,417	3.63	1,810	78,821	-2,542	-20,095
	10	66,326	6.10	3,040	1.70	848	72,869	1,615	-5,966
	11	53,987	1.04	518	1.46	727	62,202	-449	-7,975
	12	63,920	4.50	2,240	1.37	682	77,328	-419	-11,431
1997	1	59,704	2.70	1,346	1.08	538	75,971	-2,960	-12,499
	2	51,106	1.10	548	1.47	735	40,451	1,644	8,824
	3	55,567	3.85	1,919	3.00	1,496	55,634	-777	1,133
	4	48,551	4.34	2,163	4.54	2,265	42,248	2,422	3,779
	5	48,948	3.05	1,520	5.12	2,553	50,150	-3,797	1,563
	6	44,655	12.80	6,379	4.64	2,314	41,954	688	6,077
	7	44,025	6.90	3,439	5.49	2,738	50,160	0	-5,435
	8	46,705	5.29	2,638	4.32	2,155	41,566	0	5,623

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1997	9	42,212	2.87	1,430	3.34	1,663	36,226	1,076	4,021
	10	46,799	3.83	1,907	1.70	848	40,385	2,542	4,931
	11	58,606	2.80	1,393	2.80	1,394	79,265	-3,977	-16,683
	12	120,926	6.41	3,197	1.01	504	141,673	20,810	-38,865
1998	1	206,543	2.35	1,171	1.09	542	271,743	-5,053	-59,518
	2	255,386	10.12	5,043	1.31	651	276,920	7,864	-25,006
	3	343,744	2.80	1,395	2.90	1,447	337,456	-4,066	10,303
	4	214,983	0.15	75	4.61	2,295	196,274	-6,399	22,887
	5	96,094	2.00	997	4.89	2,439	95,524	-8,432	7,559
	6	68,411	0.45	224	5.86	2,920	55,258	598	9,860
	7	71,885	8.05	4,012	4.77	2,375	77,927	-2,243	-2,162
	8	74,123	7.70	3,837	4.62	2,302	86,178	-807	-9,713
	9	92,765	9.00	4,485	2.78	1,386	105,447	5,801	-15,384
	10	99,618	3.83	1,907	1.92	958	96,446	-2,691	6,812
	11	70,339	4.35	2,168	1.00	500	65,587	598	5,822
	12	65,127	1.20	598	1.00	500	118,304	0	-53,079
1999	1	68,900	4.90	2,442	1.06	526	100,692	4,246	-33,508
	2	58,997	1.49	743	1.37	682	82,413	-4,963	-18,392
	3	55,244	1.23	613	2.88	1,435	48,704	-1,375	7,093
	4	44,301	1.92	957	4.77	2,375	26,440	4,634	11,809
	5	50,017	3.21	1,600	4.71	2,348	32,333	3,528	13,408
	6	50,438	5.29	2,636	3.97	1,981	52,546	-3,110	1,657

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1999	7	47,841	4.19	2,088	5.20	2,591	45,874	-688	2,153
	8	45,921	6.12	3,050	4.31	2,147	39,685	957	6,182
	9	43,079	7.90	3,937	2.70	1,345	41,679	6,399	-2,406
	10	55,235	3.54	1,764	1.69	845	45,808	-5,442	15,789
	11	58,099	2.13	1,061	1.28	640	46,209	-1,824	14,135
	12	43,826	1.41	703	0.78	390	45,856	-2,721	1,003
2000	1	40,156	1.92	957	1.03	511	35,730	897	3,975
	2	36,670	0.52	259	1.34	667	32,539	-419	4,142
	3	37,889	3.44	1,714	2.85	1,420	29,236	1,794	7,152
	4	39,447	2.62	1,306	5.07	2,526	26,852	-299	11,309
	5	35,381	1.06	528	6.24	3,109	27,330	-837	6,307
	6	29,860	8.23	4,101	6.86	3,416	26,884	-150	3,810
	7	30,691	7.76	3,867	4.92	2,454	29,885	-60	2,279
	8	31,090	6.12	3,050	4.71	2,348	27,751	150	3,891
	9	41,508	10.01	4,988	2.92	1,454	43,658	8,791	-7,186
	10	34,570	1.09	543	1.96	977	23,637	-1,465	11,964
	11	33,464	1.36	678	1.71	852	18,419	777	13,643
	12	37,836	0.40	199	1.03	511	45,685	-8,791	630
2001	1	30,021	1.63	812	1.06	526	33,511	-3,080	-124
	2	25,963	1.22	608	1.32	659	32,602	1,166	-7,857
	3	38,661	5.27	2,626	2.36	1,174	25,876	4,993	9,047
	4	37,562	1.53	763	4.64	2,310	26,565	-897	10,348

Appendix A: Monthly Water Balances

Rodman Reservoir

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2001	5	30,338	1.59	792	5.56	2,772	24,756	-1,914	5,357
	6	27,955	8.67	4,321	4.73	2,360	22,493	-419	7,842
	7	31,973	9.90	4,935	4.40	2,193	23,823	3,110	7,782
	8	37,980	9.08	4,525	4.64	2,310	35,149	-1,316	6,361
	9	64,534	10.99	5,477	2.83	1,409	63,463	7,176	-2,038
	10	50,319	0.83	414	2.07	1,030	55,313	-478	-5,132
	11	49,458	4.07	2,028	1.63	810	71,230	1,555	-22,315
	12	41,632	0.18	90	1.58	786	94,094	-837	-51,024
2002	1	36,140	2.98	1,487	1.67	834	64,157	179	-27,544
	2	34,305	3.35	1,669	2.12	1,056	50,579	-1,106	-14,554
	3	35,729	4.13	2,058	3.56	1,774	36,002	2,751	-2,740
	4	31,763	2.73	1,363	4.83	2,405	32,922	6,548	-8,748
	5	29,167	3.66	1,822	5.42	2,702	27,168	3,767	-2,647
	6	33,287	6.78	3,380	5.03	2,508	43,482	3,140	-12,462
	7	43,496	7.38	3,679	5.04	2,509	51,874	2,721	-9,928
	8	57,628	7.28	3,626	4.62	2,302	63,705	3,229	-7,983
	9	94,362	7.25	3,615	3.77	1,878	110,771	2,571	-17,243
	10	73,737	3.83	1,907	2.95	1,472	63,039	-4,634	15,769
	11	65,585	2.37	1,179	1.97	981	44,007	658	21,118
	12	77,972	2.64	1,316	1.58	786	85,476	1,375	-8,349
2003	1	75,318	2.98	1,487	1.67	834	102,127	0	-26,157
	2	68,396	3.35	1,669	2.12	1,056	57,197	13,485	-2,406

Appendix A: Monthly Water Balances

Rodman Reservoir									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2003	3	160,266	4.13	2,058	3.56	1,774	186,347	2,183	-27,980
	4	80,885	2.73	1,363	4.83	2,405	86,553	-7,714	1,004
	5	61,568	3.66	1,822	5.42	2,702	52,925	1,256	6,027
	6	85,724	6.78	3,380	5.03	2,508	81,876	11,362	-6,642
	7	115,991	7.38	3,679	5.04	2,509	140,906	149	-23,894
	8	148,973	7.28	3,626	4.62	2,302	167,762	-1,286	-16,180
	9	93,702	7.25	3,615	3.77	1,878	101,921	-7,385	904

Appendix A: Monthly Water Balances

St. Johns Marsh Conservation Area									
Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1997	1	10,472	2.01	3,881	1.89	3,659	6,214	-812	5,292
	2	9,683	1.84	3,553	2.31	4,467	8,138	-348	979
	3	10,023	1.70	3,282	3.97	7,670	11,923	-1,044	-5,243
	4	9,178	5.25	10,143	4.29	8,302	8,297	1,508	1,215
	5	3,517	4.86	9,405	4.07	7,876	8,783	4,988	-8,725
	6	12,140	5.83	11,264	5.39	10,418	23,459	12,412	-22,884
	7	33,200	7.04	13,618	3.63	7,009	39,915	15,312	-15,419
	8	127,683	9.18	17,749	3.02	5,848	114,426	27,724	-2,566
	9	61,655	8.77	16,957	4.13	7,978	109,607	-18,096	-20,878
	10	41,897	3.49	6,740	3.16	6,112	56,204	-18,096	4,417
	11	107,514	5.94	11,482	1.63	3,159	64,889	43,152	7,796
	12	146,759	6.58	12,720	1.54	2,968	145,230	20,416	-9,135
1998	1	133,402	5.42	10,474	2.58	4,996	143,782	-3,364	-1,537
	2	175,703	6.12	11,828	2.11	4,070	154,532	19,140	9,788
	3	191,865	4.95	9,566	7.30	14,120	160,264	-5,568	32,614
	4	68,274	0.34	650	5.85	11,314	128,569	-46,516	-24,442
	5	28,137	0.95	1,845	1.16	2,233	43,710	-44,080	28,119
	6	8,602	0.25	476	2.05	3,967	3,499	-18,676	20,288
	7	13,947	9.16	17,716	2.12	4,099	4,444	10,324	12,796
	8	43,914	8.19	15,835	3.22	6,230	32,995	27,840	-7,316
	9	46,031	10.51	20,321	0.84	1,631	63,691	25,404	-24,374
	10	17,291	2.09	4,047	0.89	1,719	48,379	-35,264	6,504
	11	12,917	5.60	10,824	1.97	3,806	17,921	-10,788	12,803

Appendix A: Monthly Water Balances

St. Johns Marsh Conservation Area

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
1998	12	10,138	2.56	4,948	2.25	4,349	10,570	-3,712	3,879
1999	1	9,965	2.31	4,461	2.16	4,173	8,775	4,524	-3,046
	2	3,424	0.45	866	2.42	4,687	7,250	-8,352	705
	3	7,445	0.66	1,272	3.63	7,009	5,740	-11,484	7,452
	4	8,509	1.31	2,526	3.65	7,053	4,814	-4,988	4,156
	5	8,744	6.55	12,672	4.25	8,214	5,135	1,740	6,327
	6	8,958	5.64	10,897	3.75	7,244	13,029	34,220	-34,639
	7	34,813	1.25	2,424	4.41	8,522	27,154	-12,180	13,741
	8	46,243	6.10	11,795	3.12	6,024	12,222	19,140	20,651
	9	83,062	16.89	32,655	3.09	5,980	71,962	37,816	-41
	10	275,898	13.53	26,151	2.28	4,408	223,835	47,328	26,478
	11	49,205	2.54	4,908	3.94	7,626	139,819	-64,844	-28,487
	12	17,905	2.42	4,678	1.69	3,277	29,542	-29,812	19,576
2000	1	17,041	2.10	4,055	2.30	4,437	17,614	-12,064	11,108
	2	11,040	0.40	769	2.65	5,128	9,445	-6,148	3,384
	3	8,984	2.16	4,172	3.60	6,965	4,363	5,220	-3,392
	4	8,478	2.70	5,213	4.04	7,802	2,472	-6,264	9,680
	5	8,744	0.52	1,014	4.83	9,330	-1,446	-17,516	19,390
	6	8,461	7.12	13,758	4.42	8,537	-689	-6,380	20,752
	7	8,744	6.60	12,767	3.89	7,523	3,633	35,496	-25,140
	8	8,762	4.51	8,721	3.97	7,685	21,525	5,336	-17,063
	9	13,327	10.85	20,978	3.30	6,377	8,218	-812	20,523

Appendix A: Monthly Water Balances

St. Johns Marsh Conservation Area

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2000	10	19,722	5.75	11,110	2.96	5,730	20,779	-4,176	8,499
	11	9,230	0.54	1,044	2.19	4,232	2,910	-8,236	11,341
	12	8,671	0.24	464	2.14	4,144	1,793	-5,568	8,766
2001	1	8,572	0.51	986	2.03	3,923	2,175	-4,756	8,216
	2	7,776	1.50	2,900	2.69	5,201	1,922	-8,120	11,673
	3	8,378	2.89	5,587	3.34	6,465	1,011	-2,552	9,041
	4	4,639	1.40	2,707	4.46	8,625	579	-9,280	6,779
	5	1,860	6.77	13,089	3.88	7,494	-503	-6,612	8,450
	6	2,727	8.38	16,201	4.04	7,802	619	18,328	-4,567
	7	2,627	11.25	21,750	3.99	7,714	21,741	58,116	-23,213
	8	159,558	7.22	13,959	1.09	2,101	154,532	32,132	-15,249
	9	155,581	14.05	27,163	2.01	3,894	155,385	20,184	3,281
	10	33,960	5.42	10,479	5.51	10,653	134,301	-36,772	-63,743
	11	19,997	4.91	9,493	2.42	4,687	54,367	-29,116	-448
	12	11,932	0.59	1,141	2.71	5,231	12,865	-13,572	8,549
2002	1	10,875	2.33	4,496	2.03	3,929	7,736	-2,088	5,794
	2	10,357	2.68	5,178	2.66	5,150	7,206	5,104	-1,925
	3	13,296	3.18	6,146	4.00	7,728	5,215	-12,528	19,027
	4	8,984	2.22	4,290	4.78	9,232	2,872	-4,872	6,042
	5	8,643	3.97	7,681	5.03	9,731	2,175	-1,624	6,041
	6	13,585	5.91	11,436	4.57	8,836	31,043	65,772	-75,414
	7	218,988	5.69	10,992	4.69	9,063	212,688	30,624	-22,395

Appendix A: Monthly Water Balances

St. Johns Marsh Conservation Area

Year	Month	Inflow (ac-ft)	Prec. Depth (in)	Prec. Vol. (ac-ft)	Evap Depth (in)	Evap Vol (ac-ft)	Outflow (ac-ft)	Stor. Chng. (ac-ft)	Imbalance (ac-ft)
2002	8	122,013	5.90	11,415	4.33	8,364	165,818	-26,796	-13,958
	9	49,634	7.75	14,990	3.84	7,419	75,727	-32,712	14,190
	10	13,717	5.44	10,509	3.34	6,462	26,406	-14,152	5,509
	11	11,489	3.02	5,848	2.42	4,687	14,713	-6,032	3,969
	12	69,434	1.97	3,805	1.94	3,754	69,566	36,076	-36,157
2003	1	50,858	2.33	4,496	2.03	3,929	64,500	-24,592	11,516
	2	11,264	2.68	5,178	2.66	5,150	17,453	-15,428	9,267
	3	25,127	3.18	6,146	4.00	7,728	17,205	8,700	-2,359
	4	14,706	2.22	4,290	4.78	9,232	14,628	-18,096	13,231
	5	9,265	3.97	7,681	5.03	9,731	6,300	-26,332	27,247
	6	10,679	5.91	11,436	4.57	8,836	8,777	43,152	-38,650
	7	40,287	5.69	10,992	4.69	9,063	26,775	12,528	2,912
	8	199,438	5.90	11,415	4.33	8,364	160,205	58,232	-15,948
	9	74,240	7.75	14,990	3.84	7,419	153,779	-33,060	-38,907

Appendix B

MONTHLY PHOSPHORUS BALANCES

Appendix B: Monthly Phosphorus Balances

Crescent Lake									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1996	10	0.138	20,632,726	0.020	2,024,997	18,607,728	90.19	24.88	48.28
	11	0.152	2,807,345	0.052	2,719,461	87,884	3.13	3.19	3.39
	12	0.184	2,398,656	0.069	4,244,629	-1,845,973	-76.96	2.17	2.15
1997	1	0.135	986,210	0.053	1,153,355	-167,145	-16.95	1.22	1.15
	2	0.127	586,052	0.050	2,343,490	-1,757,438	-299.88	0.85	0.79
	3	0.148	546,747	0.081	3,109,912	-2,563,165	-468.80	0.62	0.37
	4	0.231	389,406	0.065	1,026,863	-637,457	-163.70	0.29	0.37
	5	0.269	381,495	0.065	1,249,425	-867,930	-227.51	0.24	0.34
	6	0.139	9,287,719	0.055	9,402,956	-115,237	-1.24	11.52	10.61
	7	0.129	8,291,988	0.107	14,371,937	-6,079,949	-73.32	10.74	2.03
	8	0.116	5,926,294	0.087	5,998,273	-71,979	-1.21	8.54	2.40
	9	0.120	4,907,627	0.087	5,806,118	-898,490	-18.31	7.05	2.24
	10	0.135	1,810,993	0.089	3,081,709	-1,270,716	-70.17	2.24	0.93
	11	0.125	8,263,631	0.074	11,171,753	-2,908,122	-35.19	11.42	5.90
	12	0.127	16,993,308	0.045	10,260,714	6,732,594	39.62	22.33	23.25
1998	1	0.094	14,006,777	0.030	6,421,834	7,584,943	54.15	24.86	28.01
	2	0.075	10,316,655	0.053	10,895,043	-578,388	-5.61	25.44	8.61
	3	0.098	12,294,842	0.062	11,001,608	1,293,234	10.52	20.97	9.50
	4	0.101	1,839,026	0.008	84,517	1,754,509	95.40	3.16	7.87
	5	0.245	342,255	0.079	-530,628	872,883	255.04	0.23	0.26
	6	0.891	216,894	0.075	-1,064,988	1,281,882	591.02	0.04	0.10
	7	2.013	338,389	0.101	589,635	-251,245	-74.25	0.03	0.08

Appendix B: Monthly Phosphorus Balances

Crescent Lake									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1998	8	0.221	659,818	0.268	246,570	413,248	62.63	0.50	-0.10
	9	0.124	4,292,803	0.043	2,314,310	1,978,493	46.09	5.96	6.25
	10	0.138	6,725,206	0.047	3,383,028	3,342,177	49.70	8.15	8.74
	11	0.160	1,071,640	0.072	2,321,205	-1,249,565	-116.60	1.15	0.92
	12	0.189	508,291	0.103	-1,258,043	1,766,333	347.50	0.45	0.27
1999	1	0.170	471,673	0.062	481,542	-9,869	-2.09	0.46	0.46
	2	0.120	495,784	-0.168	35,663	460,121	92.81	0.77	
	3	0.173	324,219	0.074	142,483	181,737	56.05	0.31	0.27
	4	0.585	239,385	0.060	-2,527,217	2,766,602	1,155.71	0.07	0.16
	5	1.440	253,102	0.073	-1,377,445	1,630,548	644.22	0.03	0.09
	6	1.146	286,609	0.043	-340,982	627,592	218.97	0.04	0.14
	7	0.512	306,680	0.084	-2,052,881	2,359,561	769.39	0.10	0.18
	8	0.976	324,450	0.089	-5,051,809	5,376,259	1,657.04	0.06	0.13
	9	0.140	1,767,300	0.104	-2,916,394	4,683,695	265.02	2.18	0.64
	10	0.115	10,426,662	0.034	3,084,697	7,341,965	70.42	15.12	18.26
	11	0.114	8,102,238	0.033	2,250,293	5,851,945	72.23	12.27	15.25
	12	0.129	2,320,542	0.047	2,426,854	-106,312	-4.58	3.00	3.04
2000	1	0.112	922,201	0.044	569,135	353,066	38.29	1.38	1.30
	2	0.097	524,399	0.057	1,188,515	-664,115	-126.64	0.97	0.52
	3	0.167	446,761	0.049	452,445	-5,684	-1.27	0.45	0.55
	4	0.083	2,654,936	0.040	1,538,344	1,116,592	42.06	5.51	4.03
	5	0.163	440,864	0.046	-351,753	792,617	179.79	0.45	0.57

Appendix B: Monthly Phosphorus Balances

Crescent Lake

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2000	6	1.310	339,364	0.046	998,284	-658,920	-194.16	0.04	0.15
	7	1.185	338,621	-0.048	79,354	259,267	76.57	0.05	
	8	0.714	333,076	0.156	-446,833	779,909	234.15	0.08	0.12
	9	0.148	2,456,893	0.062	4,646,074	-2,189,181	-89.10	2.87	2.48
	10	0.194	994,852	0.054	1,128,573	-133,720	-13.44	0.85	1.10
	11	0.423	312,641	0.048	1,701,788	-1,389,147	-444.33	0.13	0.28
	12	0.660	228,199	0.029	223,900	4,299	1.88	0.06	0.18
2001	1	0.799	233,426	0.049	1,080,307	-846,881	-362.81	0.05	0.14
	2	0.592	209,250	0.050	834,041	-624,791	-298.59	0.07	0.16
	3	0.153	707,741	0.090	2,875,775	-2,168,033	-306.33	0.77	0.41
	4	0.091	1,277,659	0.060	1,040,508	237,151	18.56	2.43	1.02
	5	0.186	346,138	0.065	738,236	-392,098	-113.28	0.31	0.33
	6	0.352	445,363	0.055	902,011	-456,648	-102.53	0.22	0.41
	7	0.174	765,827	0.059	2,567,243	-1,801,415	-235.22	0.73	0.79
	8	0.136	7,225,921	0.041	3,981,294	3,244,627	44.90	8.88	10.54
	9	0.138	51,123,002	0.063	25,891,884	25,231,117	49.35	63.92	50.10
	10	0.154	26,682,696	0.072	14,174,209	12,508,487	46.88	28.83	21.92
	11	0.168	12,536,589	0.075	9,168,810	3,367,779	26.86	12.90	10.42
	12	0.139	5,138,226	0.067	3,961,561	1,176,665	22.90	6.19	4.48
2002	1	0.098	1,557,322	0.074	3,972,008	-2,414,686	-155.05	2.65	0.73
	2	0.099	1,155,831	0.062	1,154,801	1,030	0.09	2.15	1.02
	3	0.097	2,439,047	0.057	2,004,656	434,392	17.81	4.17	2.23

Appendix B: Monthly Phosphorus Balances

Crescent Lake									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2002	4	0.133	619,124	0.092	343,598	275,526	44.50	0.80	0.29
	5	0.509	298,584	0.093	-2,595,110	2,893,694	969.14	0.10	0.17
	6	0.140	2,279,502	0.073	3,765,690	-1,486,188	-65.20	2.80	1.84
	7	0.107	20,240,956	0.052	9,902,442	10,338,514	51.08	31.48	22.70
	8	0.125	17,130,478	0.054	9,474,026	7,656,452	44.69	22.87	19.24
	9	0.134	10,021,750	0.077	7,692,975	2,328,775	23.24	12.85	7.18
	10	0.146	4,573,373	0.086	4,287,314	286,059	6.25	5.23	2.73
	11	0.145	3,288,163	0.079	2,546,366	741,797	22.56	3.91	2.38
	12	0.140	5,978,911	0.055	3,825,176	2,153,734	36.02	7.12	6.69
2003	1	0.083	5,147,779	0.060	7,656,048	-2,508,269	-48.73	10.36	3.29
	2	0.085	2,007,896	0.063	2,430,149	-422,253	-21.03	4.36	1.32
	3	0.102	9,255,376	0.062	13,004,349	-3,748,973	-40.51	15.19	7.53
	4	0.112	3,919,539	0.074	4,972,865	-1,053,325	-26.87	6.06	2.51
	5	0.129	2,682,094	0.054	1,130,072	1,552,022	57.87	3.48	3.03
	6	0.132	3,223,578	0.084	3,670,291	-446,714	-13.86	4.20	1.90
	7	0.129	5,774,950	0.088	8,458,039	-2,683,089	-46.46	7.48	2.88
	8	0.117	6,026,921	0.096	10,765,974	-4,739,053	-78.63	8.57	1.75
	9	0.166	4,004,718	0.009	111,025	3,893,692	97.23	4.15	11.93

Appendix B: Monthly Phosphorus Balances

Lake George

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1994	2	0.073	2,648,333	0.026	1,519,888	1,128,445	42.61	7.94	8.29
	3	0.064	9,310,761	0.035	10,886,417	-1,575,656	-16.92	12.43	7.44
	4	0.071	2,734,578	0.035	10,748,701	-8,014,124	-293.07	3.42	2.42
	5	0.234	870,306	0.047	-3,045,387	3,915,693	449.92	0.24	0.38
	6	0.078	17,174,370	0.043	30,457,624	-13,283,254	-77.34	14.31	8.71
	7	0.083	24,006,913	0.037	27,904,035	-3,897,123	-16.23	20.98	16.92
	8	0.061	26,600,240	0.035	32,729,119	-6,128,879	-23.04	27.73	14.89
	9	0.062	30,583,447	0.056	57,130,933	-26,547,486	-86.80	32.18	3.43
	10	0.083	51,931,590	0.057	69,682,442	-17,750,852	-34.18	39.80	14.84
	11	0.074	54,429,224	0.056	87,849,322	-33,420,098	-61.40	48.22	13.20
	12	0.055	43,858,508	0.061	101,611,287	-57,752,779	-131.68	50.50	-5.20
1995	1	0.046	31,857,252	0.067	109,532,562	-77,675,311	-243.82	43.37	-15.61
	2	0.052	20,809,093	0.048	42,976,774	-22,167,681	-106.53	28.15	2.19
	3	0.065	16,905,239	0.049	23,757,229	-6,851,990	-40.53	16.34	4.87
	4	0.063	18,708,592	0.025	9,162,676	9,545,916	51.02	19.38	18.26
	5	0.063	11,883,886	0.031	8,986,827	2,897,059	24.38	11.95	8.41
	6	0.086	13,487,377	0.036	9,982,337	3,505,039	25.99	10.30	9.00
	7	0.083	20,671,600	0.035	18,686,750	1,984,849	9.60	15.82	13.56
	8	0.060	17,197,441	0.023	9,192,482	8,004,958	46.55	18.17	17.31
	9	0.030	18,718,325	0.025	31,677,827	-12,959,502	-69.23	41.13	7.37
	10	0.066	51,940,629	0.036	51,345,986	594,643	1.14	49.51	29.80
	11	0.041	29,849,136	0.042	53,623,888	-23,774,752	-79.65	47.75	-1.62
	12	0.037	18,735,807	0.037	32,342,476	-13,606,669	-72.62	31.62	0.41

Appendix B: Monthly Phosphorus Balances

Lake George

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1996	1	0.042	20,868,338	0.029	27,034,195	-6,165,857	-29.55	31.59	11.11
	2	0.047	14,225,992	0.031	18,257,829	-4,031,837	-28.34	20.70	8.27
	3	0.070	20,853,790	0.027	12,564,006	8,289,785	39.75	18.98	18.15
	4	0.089	48,109,078	0.041	43,920,673	4,188,405	8.71	35.24	27.16
	5	0.094	21,723,901	0.040	16,708,438	5,015,464	23.09	14.63	12.40
	6	0.087	15,726,632	0.054	20,086,374	-4,359,742	-27.72	11.85	5.57
	7	0.059	17,246,739	0.057	36,112,725	-18,865,986	-109.39	18.59	0.42
	8	0.067	8,231,019	0.043	8,835,818	-604,799	-7.35	7.82	3.41
	9	0.063	13,738,600	0.042	18,156,923	-4,418,323	-32.16	14.21	5.76
	10	0.046	14,622,340	0.032	18,142,653	-3,520,313	-24.07	20.13	7.50
	11	0.066	14,141,493	0.025	10,724,965	3,416,528	24.16	13.91	13.43
	12	0.041	6,979,971	0.031	12,304,332	-5,324,360	-76.28	10.79	3.14
1997	1	0.047	4,742,958	0.035	9,040,739	-4,297,781	-90.61	6.44	1.92
	2	0.062	5,701,731	0.029	5,897,405	-195,674	-3.43	6.45	4.79
	3	0.077	6,471,358	0.029	5,050,834	1,420,524	21.95	5.31	5.27
	4	0.092	3,240,340	0.004	139,446	3,100,895	95.70	2.30	7.11
	5	0.079	5,650,330	0.022	3,300,826	2,349,504	41.58	4.55	5.85
	6	0.059	8,108,534	0.037	10,727,756	-2,619,223	-32.30	8.93	4.12
	7	0.038	10,103,393	0.040	20,443,434	-10,340,041	-102.34	16.63	-0.67
	8	0.066	22,809,465	0.022	10,449,797	12,359,667	54.19	21.87	24.34
	9	0.085	24,212,606	0.013	5,056,874	19,155,732	79.11	18.72	34.55
	10	0.063	12,671,696	0.024	8,067,354	4,604,342	36.34	12.69	12.31

Appendix B: Monthly Phosphorus Balances

Lake George

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1997	11	0.053	14,470,615	0.037	27,282,042	-12,811,427	-88.53	17.77	6.53
	12	0.077	28,644,129	0.017	7,218,214	21,425,916	74.80	23.58	35.95
1998	1	0.065	51,519,573	0.022	28,809,565	22,710,008	44.08	50.04	53.46
	2	0.038	19,488,185	0.051	53,053,497	-33,565,311	-172.23	36.15	-10.59
	3	0.043	40,174,255	0.041	69,715,916	-29,541,660	-73.53	59.00	3.31
	4	0.076	47,782,683	0.041	45,689,810	2,092,873	4.38	41.13	25.08
	5	0.065	20,322,080	0.039	24,982,058	-4,659,979	-22.93	19.75	9.90
	6	0.049	6,416,046	0.051	16,570,380	-10,154,334	-158.26	8.60	-0.38
	7	0.071	8,453,257	0.045	13,612,322	-5,159,064	-61.03	7.52	3.51
	8	0.066	9,292,405	0.037	8,522,494	769,911	8.29	8.89	5.23
	9	0.042	9,743,509	0.032	12,252,957	-2,509,449	-25.76	15.34	3.82
	10	0.063	23,996,082	0.025	16,109,619	7,886,463	32.87	24.21	22.44
	11	0.070	19,691,872	0.030	16,989,431	2,702,440	13.72	18.32	15.72
	12	0.054	5,459,348	0.033	6,650,491	-1,191,143	-21.82	6.45	3.14
1999	1	0.044	5,973,353	0.036	10,908,817	-4,935,464	-82.62	8.58	1.78
	2	0.059	3,617,220	0.049	8,298,424	-4,681,204	-129.41	4.30	0.77
	3	0.042	4,076,592	0.043	11,064,868	-6,988,276	-171.42	6.18	-0.24
	4	0.071	1,732,675	0.048	3,895,505	-2,162,830	-124.83	1.60	0.62
	5	0.084	6,465,201	0.058	10,897,749	-4,432,548	-68.56	4.89	1.81
	6	0.044	5,924,786	0.036	11,332,251	-5,407,464	-91.27	8.89	1.69
	7	0.044	10,468,297	0.033	14,703,581	-4,235,284	-40.46	15.13	4.46
	8	0.059	5,489,272	0.013	1,681,073	3,808,200	69.38	5.87	8.73

Appendix B: Monthly Phosphorus Balances

Lake George									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1999	9	0.157	17,656,379	-0.004	-422,433	18,078,811	102.39	7.35	
	10	0.074	45,109,573	0.020	19,307,912	25,801,662	57.20	38.35	50.90
	11	0.054	40,548,226	0.032	42,088,709	-1,540,482	-3.80	49.23	26.32
	12	0.048	26,380,877	0.038	40,539,780	-14,158,903	-53.67	34.88	7.90
2000	1	0.029	8,247,475	0.043	22,542,405	-14,294,930	-173.32	17.96	-7.01
	2	0.067	10,548,841	0.037	12,197,600	-1,648,760	-15.63	10.60	6.26
	3	0.034	2,072,845	0.029	3,448,277	-1,375,432	-66.35	3.81	0.65
	4	0.029	1,769,636	0.026	3,220,894	-1,451,258	-82.01	3.96	0.48
	5	0.061	1,877,408	-0.053	-584,711	2,462,120	131.14	1.96	
	6	0.040	2,238,093	0.040	5,667,434	-3,429,341	-153.23	3.63	0.05
	7	0.038	1,808,205	-0.002	-123,176	1,931,381	106.81	3.00	
	8	0.052	2,967,485	0.021	1,691,062	1,276,423	43.01	3.64	3.34
	9	0.032	2,562,208	0.024	4,436,864	-1,874,656	-73.17	5.21	1.44
	10	0.024	3,093,861	0.022	5,088,187	-1,994,326	-64.46	8.18	0.57
	11	0.050	9,535,024	0.022	8,624,360	910,665	9.55	12.58	10.50
	12	0.032	3,182,357	0.020	3,673,747	-491,390	-15.44	6.28	3.08
2001	1	0.023	1,777,186	0.016	1,795,506	-18,321	-1.03	6.95	2.54
	7	0.027	2,338,761	0.037	6,830,792	-4,492,031	-192.07	14.12	-4.55
	8	0.028	9,695,182	0.025	16,665,143	-6,969,961	-71.89	22.23	2.20
	9	0.117	58,448,177	0.038	33,942,799	24,505,378	41.93	32.64	36.55
	10	0.031	21,981,915	0.051	65,337,256	-43,355,342	-197.23	45.40	-23.00
	11	0.022	12,673,094	0.050	50,925,076	-38,251,983	-301.84	37.95	-31.75

Appendix B: Monthly Phosphorus Balances

Lake George

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2001	12	0.021	8,799,778	0.069	46,915,945	-38,116,167	-433.15	26.80	-31.99
2002	1	0.029	7,162,906	0.037	14,011,446	-6,848,540	-95.61	15.45	-3.53
	2	0.056	5,560,290	0.025	3,562,890	1,997,400	35.92	6.92	5.52
	3	0.030	5,661,728	0.054	24,849,823	-19,188,095	-338.91	12.00	-7.11
	4	0.059	5,291,857	0.057	15,092,462	-9,800,605	-185.20	5.85	0.25
	5	0.074	780,110	0.091	-5,761,629	6,541,738	838.57	0.66	-0.14
	6	0.032	5,810,886	0.051	18,009,113	-12,198,228	-209.92	11.71	-5.25
	7	0.048	25,595,001	0.025	24,845,854	749,147	2.93	33.92	21.51
	8	0.020	15,244,715	0.039	50,825,267	-35,580,552	-233.40	47.46	-31.00
	9	0.018	13,317,453	0.082	103,955,609	-90,638,156	-680.60	47.54	-71.19
	10	0.054	25,642,788	0.077	69,993,480	-44,350,692	-172.96	30.23	-10.96
	11	0.024	6,539,699	0.066	36,530,419	-29,990,720	-458.59	17.60	-17.45
	12	0.025	8,777,706	0.051	35,838,533	-27,060,827	-308.29	22.47	-16.37
2003	1	0.037	23,863,485	0.037	42,244,997	-18,381,511	-77.03	40.45	0.69
	2	0.052	21,562,561	0.032	24,058,347	-2,495,786	-11.57	29.09	13.64
	3	0.065	21,480,523	0.037	22,891,987	-1,411,465	-6.57	21.03	12.01
	4	0.070	19,481,409	0.032	14,632,315	4,849,093	24.89	18.19	14.02
	5	0.079	11,249,377	0.048	12,508,235	-1,258,858	-11.19	9.05	4.48
	6	0.089	17,944,090	0.044	16,494,871	1,449,219	8.08	13.16	9.44
	7	0.101	30,518,916	0.050	31,081,745	-562,829	-1.84	19.09	13.61
	8	0.115	52,463,186	0.047	41,832,185	10,631,001	20.26	28.91	25.75
	9	0.122	6,043,816	0.056	5,870,323	173,492	2.87	32.40	25.19

Appendix B: Monthly Phosphorus Balances

Lake Harney									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1990	10	0.055	4,818,772	0.072	6,216,287	-1,397,515	-29.00	34.78	-9.69
	11	0.044	7,185,385	0.069	11,009,519	-3,824,134	-53.22	66.21	-29.83
	12	0.043	6,185,873	0.072	10,190,133	-4,004,260	-64.73	57.24	-29.89
1991	1	0.048	4,821,154	0.074	7,247,598	-2,426,444	-50.33	39.69	-17.13
	2	0.065	3,838,899	0.081	4,689,365	-850,466	-22.15	25.85	-5.77
	3	0.089	6,097,788	0.087	5,818,908	278,880	4.57	27.02	0.62
	4	0.072	7,904,818	0.081	8,594,942	-690,125	-8.73	44.41	-4.78
	5	0.065	9,693,131	0.089	13,047,409	-3,354,278	-34.60	58.99	-18.89
	6	0.065	15,450,167	0.109	25,201,401	-9,751,235	-63.11	96.74	-49.64
	7	0.217	83,339,054	0.143	53,811,875	29,527,178	35.43	151.42	62.63
	8	0.247	93,990,249	0.078	28,811,368	65,178,881	69.35	149.85	173.61
	9	0.048	12,186,325	0.080	19,855,984	-7,669,659	-62.94	102.89	-52.68
	10	0.053	22,621,850	0.079	32,905,101	-10,283,251	-45.46	169.06	-67.38
	11	0.043	11,028,952	0.071	18,001,440	-6,972,488	-63.22	105.24	-53.88
	12	0.035	5,177,860	0.074	10,832,074	-5,654,214	-109.20	58.62	-44.58
1992	1	0.043	4,219,064	0.075	7,205,564	-2,986,500	-70.79	38.52	-21.49
	2	0.065	4,099,719	0.096	5,906,708	-1,806,990	-44.08	26.60	-10.33
	3	0.071	2,516,924	0.074	2,583,806	-66,882	-2.66	14.02	-0.67
	4	0.075	4,176,602	0.067	3,667,146	509,457	12.20	22.71	2.42
	5	0.076	2,737,943	0.076	2,664,419	73,524	2.69	14.22	0.06
	6	0.075	3,278,405	0.076	3,264,342	14,063	0.43	17.90	-0.35
	7	0.073	7,315,223	0.072	7,046,349	268,875	3.68	39.47	0.54

Appendix B: Monthly Phosphorus Balances

Lake Harney									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1992	8	0.103	30,125,829	0.121	34,429,749	-4,303,920	-14.29	115.08	-18.11
	9	0.067	27,210,446	0.084	33,439,441	-6,228,995	-22.89	165.72	-38.11
	10	0.060	31,307,887	0.077	39,259,827	-7,951,940	-25.40	206.00	-51.53
	11	0.053	14,148,899	0.068	17,688,409	-3,539,510	-25.02	107.80	-26.64
	12	0.051	8,309,710	0.065	10,257,584	-1,947,875	-23.44	63.64	-14.92
1993	1	0.071	8,742,277	0.080	9,673,542	-931,266	-10.65	48.74	-6.10
	2	0.051	9,259,549	0.072	12,731,955	-3,472,406	-37.50	78.62	-26.91
	3	0.060	11,045,742	0.072	12,974,259	-1,928,516	-17.46	72.53	-13.40
	4	0.058	10,066,925	0.066	11,242,548	-1,175,623	-11.68	70.85	-9.51
	5	0.053	5,546,449	0.072	7,410,614	-1,864,165	-33.61	41.36	-12.97
	6	0.048	4,044,736	0.067	5,525,848	-1,481,112	-36.62	34.41	-11.56
	7	0.054	4,945,616	0.067	6,062,797	-1,117,181	-22.59	36.41	-8.28
	8	0.073	3,850,546	0.067	3,473,362	377,184	9.80	20.85	1.65
	9	0.070	7,107,167	0.072	7,121,663	-14,496	-0.20	41.14	-1.06
	10	0.056	4,762,046	0.067	5,497,656	-735,610	-15.45	34.43	-5.77
	11	0.059	3,173,696	0.067	3,536,313	-362,617	-11.43	22.04	-2.89
	12	0.075	2,204,461	0.090	2,579,282	-374,821	-17.00	11.54	-2.05
1994	1	0.080	3,292,418	0.076	3,066,683	225,735	6.86	16.24	0.78
	2	0.213	18,236,852	0.061	5,071,875	13,164,977	72.19	37.29	46.83
	3	0.146	12,448,707	0.080	6,707,929	5,740,778	46.12	33.68	20.06
	4	0.078	2,657,423	0.058	1,934,733	722,690	27.20	14.37	4.22
	5	0.082	2,460,377	0.051	1,490,442	969,936	39.42	12.27	5.87

Appendix B: Monthly Phosphorus Balances

Lake Harney									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1994	6	0.154	29,712,621	0.084	15,909,995	13,802,626	46.45	78.57	47.20
	7	0.105	24,309,912	0.090	20,369,602	3,940,310	16.21	94.15	14.41
	8	0.077	25,180,102	0.095	30,253,756	-5,073,654	-20.15	137.16	-28.45
	9	0.075	25,764,345	0.087	29,220,172	-3,455,827	-13.41	139.80	-20.93
	10	0.074	37,963,288	0.069	34,423,661	3,539,627	9.32	216.33	16.02
	11	0.069	37,698,709	0.089	47,636,632	-9,937,923	-26.36	239.24	-61.68
	12	0.054	32,578,708	0.077	45,019,202	-12,440,494	-38.19	236.74	-82.21
1995	1	0.052	21,682,395	0.068	28,071,613	-6,389,219	-29.47	171.22	-48.30
	2	0.058	11,600,734	0.067	13,211,928	-1,611,194	-13.89	87.46	-13.26
	3	0.071	7,174,986	0.069	6,784,796	390,190	5.44	41.14	1.32
	4	0.072	4,964,592	0.070	4,710,808	253,783	5.11	28.91	0.83
	5	0.070	3,298,935	0.065	3,004,173	294,762	8.94	19.20	1.35
	6	0.080	3,985,195	0.081	3,944,426	40,769	1.02	20.90	-0.28
	7	0.078	7,402,448	0.092	8,482,845	-1,080,397	-14.60	37.20	-5.95
	8	0.073	19,585,523	0.103	26,904,862	-7,319,339	-37.37	109.32	-37.32
	9	0.085	38,012,540	0.068	29,624,857	8,387,683	22.07	181.06	40.82
	10	0.064	29,591,682	0.080	36,486,991	-6,895,310	-23.30	183.10	-42.72
	11	0.053	19,586,625	0.066	23,991,990	-4,405,366	-22.49	151.45	-34.33
	12	0.056	13,752,119	0.067	16,207,595	-2,455,475	-17.86	97.45	-18.33
1996	1	0.071	15,241,312	0.076	15,976,616	-735,304	-4.82	84.93	-5.94
	2	0.062	6,270,766	0.072	7,092,060	-821,294	-13.10	42.46	-6.22
	3	0.092	17,950,051	0.089	17,019,389	930,662	5.18	76.96	2.26

Appendix B: Monthly Phosphorus Balances

Lake Harney

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1996	4	0.085	18,711,407	0.084	18,230,370	481,037	2.57	89.93	0.25
	5	0.105	9,182,622	0.110	9,372,693	-190,070	-2.07	34.49	-1.53
	6	0.106	12,364,669	0.129	14,701,142	-2,336,473	-18.90	47.37	-9.33
	7	0.074	9,049,983	0.095	11,256,482	-2,206,499	-24.38	47.92	-11.60
	8	0.061	5,780,286	0.081	7,420,902	-1,640,615	-28.38	37.08	-10.13
	9	0.067	9,022,558	0.082	10,791,345	-1,768,787	-19.60	54.66	-11.09
	10	0.056	8,558,058	0.080	11,878,114	-3,320,056	-38.79	59.82	-20.91
	11	0.050	4,368,259	0.076	6,433,514	-2,065,255	-47.28	35.29	-14.50
	12	0.061	3,516,184	0.078	4,372,991	-856,807	-24.37	22.72	-5.50
1997	1	0.079	2,801,953	0.075	2,611,560	190,394	6.80	14.06	0.67
	2	0.087	3,083,789	0.065	2,266,347	817,442	26.51	15.46	4.41
	3	0.119	2,924,074	0.067	1,611,202	1,312,871	44.90	9.66	5.54
	4	0.102	2,364,406	0.055	1,254,368	1,110,038	46.95	9.44	5.80
	5	0.101	2,322,168	0.063	1,407,302	914,865	39.40	9.06	4.33
	6	0.083	4,135,701	0.063	3,083,978	1,051,722	25.43	20.24	5.48
	7	0.101	17,540,812	0.086	14,487,045	3,053,767	17.41	70.45	11.80
	8	0.097	28,024,296	0.095	26,843,207	1,181,089	4.21	114.20	2.20
	9	0.070	14,983,925	0.067	14,076,188	907,737	6.06	87.38	3.38
	10	0.061	10,394,418	0.074	12,340,908	-1,946,490	-18.73	66.86	-13.03
	11	0.055	9,106,044	0.059	9,686,649	-580,605	-6.38	67.83	-5.76
	12	0.064	23,610,693	0.077	27,740,582	-4,129,889	-17.49	145.49	-26.92
1998	1	0.057	24,396,901	0.064	26,808,379	-2,411,479	-9.88	168.39	-19.89

Appendix B: Monthly Phosphorus Balances

Lake Harney

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1998	2	0.066	25,003,526	0.088	32,552,789	-7,549,263	-30.19	164.32	-47.27
	3	0.061	27,824,130	0.073	32,278,476	-4,454,346	-16.01	179.51	-30.94
	4	0.048	15,229,575	0.057	17,625,692	-2,396,117	-15.73	129.20	-21.96
	5	0.054	9,598,364	0.059	10,275,945	-677,582	-7.06	70.48	-6.40
	6	0.076	4,709,849	0.073	4,390,941	318,908	6.77	25.22	1.19
	7	0.100	3,596,641	0.082	2,866,934	729,707	20.29	14.63	3.00
	8	0.088	8,616,115	0.061	5,859,826	2,756,289	31.99	38.63	13.97
	9	0.092	12,304,596	0.061	7,972,280	4,332,316	35.21	54.73	22.52
	10	0.077	15,394,729	0.056	11,000,321	4,394,408	28.54	79.16	24.72
	11	0.068	7,990,458	0.058	6,668,572	1,321,885	16.54	48.03	7.68
	12	0.079	4,350,592	0.053	2,821,266	1,529,327	35.15	21.56	8.82
1999	1	0.083	3,037,733	0.065	2,330,828	706,905	23.27	14.45	3.50
	2	0.081	2,085,713	0.041	1,040,149	1,045,564	50.13	11.24	7.57
	3	0.088	1,376,280	0.083	1,269,556	106,725	7.75	6.18	0.37
	4	0.130	1,370,391	0.041	425,437	944,954	68.96	4.30	4.93
	5	0.114	1,584,752	0.081	1,099,524	485,228	30.62	5.46	1.88
	6	0.093	4,529,680	0.060	2,827,050	1,702,630	37.59	19.74	8.84
	7	0.092	6,897,661	0.092	6,734,796	162,865	2.36	29.59	0.06
	8	0.112	7,038,771	0.071	4,387,184	2,651,588	37.67	24.81	11.14
	9	0.104	10,842,486	0.076	7,738,529	3,103,957	28.63	45.67	14.31
	10	0.085	43,552,619	0.097	48,776,162	-5,223,543	-11.99	202.85	-27.81
	11	0.072	32,177,028	0.092	40,312,176	-8,135,148	-25.28	181.96	-45.35
	12	0.069	16,505,534	0.091	21,217,669	-4,712,135	-28.55	94.54	-26.00

Appendix B: Monthly Phosphorus Balances

Lake Harney

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2000	1	0.070	6,909,078	0.083	7,983,018	-1,073,940	-15.54	39.97	-6.63
	2	0.071	2,852,442	0.078	3,081,146	-228,704	-8.02	16.96	-1.70
	3	0.098	1,248,777	0.060	745,095	503,682	40.33	5.03	2.49
	4	0.115	757,148	0.074	474,001	283,147	37.40	2.68	1.19
	5	0.139	265,573	-0.026	-47,932	313,505	118.05	0.75	
	6	0.511	40,842	-5.117	-399,275	440,118	1,077.60	0.03	
	7	0.130	1,181,625	0.110	982,058	199,567	16.89	3.58	0.58
	8	0.103	1,697,628	0.103	1,652,531	45,097	2.66	6.50	0.02
	9	0.089	5,202,117	0.103	5,885,773	-683,656	-13.14	24.62	-3.63
2001	10	0.080	35,092,410	0.114	48,943,481	-13,851,071	-39.47	173.44	-61.83
	11	0.074	23,343,720	0.124	38,066,785	-14,723,066	-63.07	128.01	-65.46
	12	0.071	11,351,205	0.118	18,337,187	-6,985,982	-61.54	62.60	-31.47
2002	1	0.071	4,936,358	0.118	8,080,518	-3,144,160	-63.69	27.43	-14.01
	2	0.079	4,374,561	0.073	3,945,354	429,207	9.81	24.29	1.93
	3	0.075	5,173,654	0.103	6,902,915	-1,729,261	-33.42	27.01	-8.38
	4	0.089	1,935,120	0.067	1,422,004	513,116	26.52	8.87	2.52
	5	0.119	854,685	-0.006	-42,977	897,662	105.03	2.83	
	6	0.115	6,447,524	0.062	3,408,472	3,039,052	47.14	22.87	14.04
	7	0.112	40,084,833	0.145	50,324,810	-10,239,976	-25.55	140.34	-35.27
	8	0.097	48,571,515	0.163	79,712,868	-31,141,354	-64.11	196.82	-102.20
	9	0.091	35,703,881	0.112	43,118,025	-7,414,144	-20.77	160.37	-34.08
	10	0.076	13,882,092	0.099	17,626,813	-3,744,721	-26.98	71.68	-18.79

Appendix B: Monthly Phosphorus Balances

Lake Harney									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2002	11	0.073	5,928,984	0.088	7,009,875	-1,080,891	-18.23	33.17	-6.28
	12	0.068	12,603,518	0.051	9,172,296	3,431,223	27.22	73.18	21.51
2003	1	0.068	22,666,031	0.068	22,251,072	414,959	1.83	131.68	-0.71
	2	0.059	7,280,803	0.078	9,361,447	-2,080,644	-28.58	53.57	-14.74
	3	0.070	7,078,162	0.061	6,065,058	1,013,103	14.31	39.84	5.20
	4	0.075	6,272,874	0.080	6,565,540	-292,666	-4.67	34.12	-2.32
	5	0.087	3,361,774	0.081	3,054,786	306,988	9.13	15.20	1.12
	6	0.094	6,330,375	0.071	4,687,939	1,642,436	25.95	27.48	7.62
	7	0.093	8,764,163	0.094	8,655,127	109,036	1.24	37.12	-0.40
	8	0.089	33,712,359	0.110	40,639,188	-6,926,828	-20.55	148.81	-31.35
	9	0.090	4,033,849	0.128	5,609,505	-1,575,656	-39.06	136.60	-48.30

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1989	1	0.080	3,937,882	0.067	931,690	3,006,192	76.34	5.18	0.92
	2	0.084	4,436,455	0.233	2,517,394	1,919,060	43.26	6.17	-6.32
	3	0.099	5,116,017	0.127	2,044,940	3,071,077	60.03	5.45	-1.36
	4	0.078	2,592,545	0.220	3,470,143	-877,599	-33.85	3.69	-3.83
	5	0.094	3,410,822	0.208	5,781,915	-2,371,093	-69.52	4.08	-3.25
	6	0.124	2,872,678	0.436	2,988,214	-115,536	-4.02	2.82	-3.55
	7	0.141	6,416,647	0.275	1,807,135	4,609,512	71.84	5.33	-3.56
	8	0.113	8,666,297	0.041	677,208	7,989,090	92.19	8.72	8.78
	9	0.112	14,524,560	0.017	468,622	14,055,938	96.77	14.95	28.48
	10	0.164	18,231,340	0.148	14,390,835	3,840,505	21.07	12.24	1.31
	11	0.093	3,706,333	0.106	2,390,564	1,315,769	35.50	4.27	-0.55
	12	0.073	4,980,677	0.114	3,659,866	1,320,812	26.52	7.07	-3.13
1990	1	0.078	3,735,509	0.103	2,608,453	1,127,056	30.17	4.97	-1.37
	2	0.087	5,491,318	0.141	3,632,152	1,859,165	33.86	7.30	-3.54
	3	0.090	2,012,664	0.150	3,268,110	-1,255,446	-62.38	2.34	-1.21
	4	0.077	3,997,926	0.077	3,857,745	140,181	3.51	5.68	0.01
	5	0.072	1,598,233	0.193	3,570,906	-1,972,674	-123.43	2.63	-2.59
	6	0.160	10,812,807	0.068	1,585,779	9,227,028	85.33	7.71	6.57
	7	0.208	17,588,309	0.136	12,226,485	5,361,824	30.49	9.27	3.96
	8	0.124	17,890,746	0.082	9,818,120	8,072,626	45.12	15.55	6.57
	9	0.104	6,647,801	0.032	845,509	5,802,292	87.28	7.05	8.42
	10	0.085	1,327,776	0.000	0	1,327,776	100.00	25.39	
	11	0.058	1,297,434	0.125	1,151,568	145,865	11.24	4.25	-3.26

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1990	12	0.056	1,647,473	0.111	1,488,365	159,108	9.66	3.45	-2.34
1991	1	0.106	8,277,529	0.105	1,833,601	6,443,928	77.85	8.17	0.10
	2	0.073	3,971,231	0.201	2,571,187	1,400,045	35.25	6.29	-6.37
	3	0.112	9,133,045	0.189	3,361,787	5,771,258	63.19	8.46	-4.42
	4	0.125	3,914,432	0.232	4,575,364	-660,932	-16.88	3.39	-2.10
	5	0.134	3,244,740	0.185	9,458,715	-6,213,975	-191.51	2.62	-0.83
	6	0.101	5,966,970	0.070	4,190,440	1,776,531	29.77	8.15	2.96
	7	0.119	12,190,182	0.088	9,588,017	2,602,165	21.35	11.36	3.52
	8	0.145	21,135,531	0.117	16,388,401	4,747,129	22.46	16.04	3.47
	9	0.110	9,801,760	0.064	4,364,895	5,436,865	55.47	9.78	5.24
	10	0.078	5,408,208	0.049	2,403,709	3,004,499	55.55	7.25	3.31
	11	0.066	2,484,955	0.126	2,582,432	-97,477	-3.92	4.08	-2.64
	12	0.062	2,070,533	0.190	3,012,862	-942,329	-45.51	3.54	-3.98
1992	1	0.062	2,433,905	0.424	2,826,337	-392,432	-16.12	4.37	-8.39
	2	0.082	4,475,405	0.445	1,783,992	2,691,413	60.14	6.84	-11.59
	3	0.065	3,155,581	0.618	2,641,678	513,904	16.29	5.27	-11.89
	4	0.075	5,366,023	0.378	2,654,419	2,711,604	50.53	8.04	-13.05
	5	0.102	788,011	0.215	3,044,380	-2,256,369	-286.34	0.85	-0.63
	6	0.165	7,108,699	0.188	3,353,361	3,755,338	52.83	6.22	-0.82
	7	0.106	7,981,539	0.094	7,556,083	425,456	5.33	8.82	1.04
	12	0.089	1,959,402	0.091	1,516,195	443,206	22.62	3.04	-0.10
1993	1	0.107	7,431,028	0.084	2,974,680	4,456,348	59.97	7.35	1.76

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1993	2	0.099	6,748,104	0.125	3,696,472	3,051,632	45.22	7.96	-1.92
	3	0.099	8,652,699	0.139	10,816,991	-2,164,292	-25.01	9.13	-3.12
	4	0.087	6,998,572	0.117	8,150,570	-1,151,998	-16.46	9.06	-2.73
	5	0.076	1,061,622	0.203	3,149,308	-2,087,686	-196.65	1.75	-1.71
	6	0.071	427,119	0.119	116,303	310,816	72.77	6.92	-3.60
	7	0.086	4,109,808	0.060	705,153	3,404,655	82.84	5.31	1.92
	8	0.143	5,108,927	0.185	2,725,482	2,383,445	46.65	3.95	-1.00
	9	0.139	14,026,102	0.003	89,397	13,936,705	99.36	11.23	44.27
	10	0.100	5,292,897	0.067	1,683,438	3,609,458	68.19	5.50	2.19
	11	0.058	3,035,121	0.105	1,959,572	1,075,549	35.44	5.55	-3.24
	12	0.056	1,846,751	0.148	1,800,274	46,477	2.52	3.41	-3.29
1994	1	0.062	3,962,507	0.257	2,982,658	979,849	24.73	6.65	-9.46
	2	0.064	2,829,566	0.141	2,553,664	275,902	9.75	5.11	-4.04
	3	0.058	4,219,377	0.244	3,753,483	465,894	11.04	7.61	-10.91
	4	0.083	2,019,142	0.148	3,556,391	-1,537,249	-76.13	2.67	-1.53
	5	0.075	1,580,071	0.271	3,863,840	-2,283,770	-144.54	2.33	-3.01
	6	0.137	13,921,350	0.094	6,380,706	7,540,644	54.17	11.52	4.40
	7	0.096	6,809,159	0.045	2,221,381	4,587,778	67.38	7.79	5.98
	8	0.102	7,649,173	0.038	3,398,570	4,250,603	55.57	8.16	8.00
	9	0.113	17,153,191	0.072	8,640,475	8,512,716	49.63	16.58	7.58
	10	0.087	10,828,052	0.077	9,556,546	1,271,506	11.74	12.97	1.51
	11	0.114	8,580,257	0.150	10,010,763	-1,430,506	-16.67	8.07	-2.19
	12	0.079	4,957,567	0.079	5,192,376	-234,809	-4.74	6.47	0.06

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1995	1	0.063	5,221,530	0.075	4,868,946	352,585	6.75	8.56	-1.45
	2	0.066	5,761,142	0.126	4,955,541	805,601	13.98	10.09	-6.53
	3	0.075	6,216,472	0.080	4,086,943	2,129,529	34.26	8.58	-0.54
	4	0.092	5,278,432	0.115	6,799,049	-1,520,617	-28.81	6.19	-1.38
	5	0.095	2,402,113	0.156	5,404,071	-3,001,958	-124.97	2.75	-1.36
	6	0.122	6,837,545	0.102	2,609,619	4,227,926	61.83	6.44	1.15
	7	0.153	8,246,727	0.062	2,483,476	5,763,251	69.89	5.96	5.35
	8	0.169	38,434,082	0.088	16,800,543	21,633,539	56.29	24.82	16.26
	9	0.126	23,095,205	0.067	11,582,000	11,513,206	49.85	20.27	12.60
	10	0.121	17,017,795	0.069	11,997,305	5,020,489	29.50	14.65	8.29
	11	0.088	5,692,441	0.040	2,780,197	2,912,244	51.16	6.94	5.41
	12	0.082	2,335,621	0.059	1,751,256	584,364	25.02	2.96	0.99
1996	1	0.080	6,512,230	0.064	3,162,298	3,349,932	51.44	8.46	1.89
	2	0.079	4,415,285	0.120	3,932,067	483,219	10.94	6.25	-2.64
	3	0.081	7,734,660	0.192	4,216,990	3,517,671	45.48	10.07	-8.71
	4	0.083	3,491,477	0.166	3,557,463	-65,986	-1.89	4.58	-3.17
	5	0.103	3,295,675	0.181	3,780,039	-484,364	-14.70	3.47	-1.98
	6	0.102	8,114,990	0.079	5,157,381	2,957,610	36.45	9.01	2.24
	7	0.101	8,223,945	0.071	5,503,788	2,720,157	33.08	9.03	3.17
	8	0.080	5,375,424	0.079	1,934,271	3,441,153	64.02	7.47	0.06
	9	0.086	2,541,640	0.080	972,416	1,569,224	61.74	3.39	0.27
	10	0.081	5,814,381	0.026	596,665	5,217,716	89.74	7.91	8.84

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1996	11	0.062	3,352,978	0.243	2,118,675	1,234,303	36.81	6.09	-8.34
	12	0.055	3,834,473	0.294	2,124,930	1,709,543	44.58	7.59	-12.73
1997	1	0.061	3,544,106	0.212	1,414,511	2,129,595	60.09	6.34	-7.90
	2	0.061	3,126,325	0.355	2,260,597	865,727	27.69	6.15	-10.80
	3	0.073	3,434,972	0.519	2,432,176	1,002,796	29.19	5.19	-10.17
	4	0.096	6,829,909	0.772	3,342,885	3,487,024	51.06	8.18	-17.05
	5	0.110	4,637,674	0.409	2,066,920	2,570,754	55.43	4.65	-6.12
	6	0.113	6,985,341	0.128	3,092,264	3,893,077	55.73	6.99	-0.84
	7	0.158	12,861,294	0.069	4,659,317	8,201,977	63.77	8.90	7.45
	8	0.200	27,098,043	0.068	9,578,425	17,519,618	64.65	14.57	15.73
	9	0.252	29,159,122	0.105	7,243,608	21,915,515	75.16	12.74	11.17
	10	0.197	25,184,653	0.117	17,061,884	8,122,768	32.25	13.29	6.92
	11	0.116	13,086,464	0.065	9,885,754	3,200,710	24.46	12.09	7.05
	12	0.126	22,305,431	0.082	19,946,863	2,358,568	10.57	18.48	7.89
1998	1	0.120	27,108,057	0.092	25,741,474	1,366,583	5.04	23.64	6.26
	2	0.144	51,419,448	0.116	57,758,150	-6,338,701	-12.33	41.40	8.92
	3	0.121	39,896,002	0.097	39,810,532	85,470	0.21	34.44	7.78
	4	0.097	13,933,774	0.087	13,080,695	853,080	6.12	15.56	1.72
	5	0.094	3,792,972	0.125	5,968,936	-2,175,965	-57.37	4.31	-1.24
	6	0.129	2,755,687	0.239	6,355,112	-3,599,425	-130.62	2.44	-1.51
	7	0.164	10,411,264	0.130	3,377,975	7,033,289	67.55	7.09	1.62
	8	0.181	20,740,146	0.109	10,959,021	9,781,126	47.16	12.54	6.34

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1998	9	0.165	25,923,413	0.098	14,482,704	11,440,710	44.13	17.32	9.04
	10	0.120	16,004,674	0.037	5,326,769	10,677,905	66.72	13.92	16.29
	11	0.103	11,157,722	0.053	6,680,608	4,477,114	40.13	11.64	7.80
	12	0.081	4,521,808	0.060	2,016,783	2,505,024	55.40	5.78	1.72
1999	1	0.082	5,517,952	0.104	3,009,290	2,508,662	45.46	6.96	-1.63
	2	0.084	3,324,527	0.088	2,526,425	798,103	24.01	4.56	-0.21
	3	0.104	4,469,776	0.140	3,945,887	523,890	11.72	4.60	-1.38
	4	0.122	3,735,334	0.171	3,398,813	336,522	9.01	3.53	-1.18
	5	0.139	38,111,413	0.094	1,380,972	36,730,442	96.38	28.94	11.32
	6	0.180	6,146,370	0.055	2,655,258	3,491,112	56.80	3.54	4.24
	7	0.137	16,781,658	0.039	6,739,640	10,042,019	59.84	12.29	15.38
	8	0.169	14,978,292	0.072	10,308,209	4,670,082	31.18	8.94	7.60
	9	0.113	16,042,949	0.066	11,397,918	4,645,030	28.95	14.72	7.92
	10	0.103	13,437,458	0.064	12,615,969	821,489	6.11	13.19	6.23
	11	0.073	3,933,001	0.048	3,777,328	155,673	3.96	5.64	2.33
	12	0.079	2,036,757	0.034	1,205,635	831,122	40.81	2.59	2.16
2000	1	0.080	1,810,442	0.041	1,199,881	610,561	33.72	2.28	1.50
	2	0.079	1,328,706	0.026	471,788	856,919	64.49	1.81	1.99
	3	0.080	1,447,234	0.040	528,793	918,440	63.46	1.83	1.24
	4	0.082	1,578,093	0.057	539,376	1,038,716	65.82	2.00	0.73
	5	0.070	1,839,314	0.052	496,340	1,342,974	73.01	2.65	0.78
	6	0.094	1,612,596	0.138	828,918	783,678	48.60	1.78	-0.67

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2000	7	0.129	1,598,997	0.178	1,015,153	583,844	36.51	1.25	-0.40
	8	0.115	1,742,401	0.039	361,268	1,381,134	79.27	1.52	1.64
	9	0.121	2,260,262	0.056	985,298	1,274,964	56.41	1.95	1.49
	10	0.077	1,108,050	0.036	314,556	793,493	71.61	1.45	1.10
	11	0.074	724,247	0.000	0	724,247	100.00	1.02	
	12	0.085	724,581	0.004	18,971	705,610	97.38	0.86	2.65
2001	1	0.087	769,465	0.002	8,225	761,240	98.93	0.89	3.52
	2	0.062	2,261,494	0.054	1,507,174	754,319	33.35	4.07	0.58
	3	0.088	1,374,487	0.099	499,792	874,695	63.64	1.57	-0.17
	4	0.082	1,556,957	0.023	157,540	1,399,417	89.88	1.97	2.51
	5	0.089	1,644,556	0.050	180,459	1,464,097	89.03	1.85	1.07
	6	0.131	1,581,262	0.145	859,710	721,552	45.63	1.25	-0.12
	7	0.121	14,945,966	0.066	8,179,292	6,766,673	45.27	12.40	7.60
	8	0.100	15,444,285	0.051	9,664,870	5,779,415	37.42	15.58	10.42
	9	0.164	41,534,419	0.080	30,493,090	11,041,329	26.58	26.31	18.95
	10	0.106	13,028,550	0.070	11,899,632	1,128,918	8.66	12.43	5.18
	11	0.100	8,007,742	0.058	6,630,213	1,377,529	17.20	8.33	4.60
	12	0.105	2,868,964	0.041	1,547,335	1,321,629	46.07	2.76	2.57
2002	1	0.107	2,971,075	0.054	1,933,325	1,037,750	34.93	2.80	1.92
	2	0.103	2,754,073	0.054	1,847,440	906,634	32.92	2.97	1.94
	3	0.100	2,813,859	0.034	1,007,433	1,806,426	64.20	2.83	3.08
	4	0.127	4,343,978	0.052	1,406,752	2,937,225	67.62	3.55	3.19

Appendix B: Monthly Phosphorus Balances

Lake Istokpoga									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2002	5	0.166	6,116,629	0.074	1,845,513	4,271,116	69.83	3.71	2.98
	6	0.291	16,101,230	0.094	7,985,555	8,115,675	50.40	5.76	6.53
	7	0.200	50,782,336	0.058	22,932,416	27,849,920	54.84	25.55	31.82
	8	0.159	18,112,068	0.061	9,313,362	8,798,706	48.58	11.45	10.96
	9	0.129	21,281,688	0.055	13,226,830	8,054,857	37.85	17.15	14.53
	10	0.092	5,013,654	0.038	2,851,386	2,162,269	43.13	5.50	4.85
	11	0.092	5,200,536	0.052	4,576,126	624,410	12.01	5.89	3.32
	12	0.108	15,092,071	0.059	13,048,027	2,044,044	13.54	14.06	8.59

Appendix B: Monthly Phosphorus Balances

Lake Jessup									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1994	10	0.198	2,513,720	0.132	4,195,321	-1,681,601	-66.90	2.81	1.14
	11	0.235	6,957,883	0.100	4,088,324	2,869,559	41.24	6.78	5.84
	12	0.230	4,569,121	0.141	8,004,778	-3,435,656	-75.19	4.41	2.16
1995	1	0.203	1,764,166	0.160	7,238,874	-5,474,709	-310.33	1.93	0.45
	2	0.181	686,526	0.171	4,814,256	-4,127,730	-601.25	0.93	0.05
	3	0.215	961,816	0.163	2,200,727	-1,238,912	-128.81	0.99	0.27
	4	0.252	722,741	0.161	1,282,770	-560,029	-77.49	0.66	0.29
	5	0.311	760,777	0.104	253,164	507,613	66.72	0.54	0.59
	6	0.389	1,635,905	0.100	589,606	1,046,299	63.96	0.97	1.31
	7	0.256	6,670,257	0.102	5,099,466	1,570,791	23.55	5.78	5.30
	8	0.286	9,047,045	0.025	847,280	8,199,765	90.63	7.03	17.13
	9	0.216	4,181,758	0.033	1,132,800	3,048,957	72.91	4.44	8.36
	10	0.228	4,770,868	0.036	1,312,140	3,458,728	72.50	4.65	8.60
	11	0.181	1,194,067	0.074	2,668,281	-1,474,214	-123.46	1.51	1.35
	12	0.176	776,376	0.096	2,790,965	-2,014,589	-259.49	0.98	0.60
1996	1	0.182	2,948,341	0.085	3,007,923	-59,582	-2.02	3.61	2.72
	2	0.179	963,603	0.115	3,594,947	-2,631,344	-273.07	1.28	0.57
	3	0.278	5,746,519	0.043	1,217,003	4,529,516	78.82	4.59	8.61
	4	0.199	2,917,562	0.067	2,561,561	356,002	12.20	3.36	3.68
	5	0.271	1,065,983	0.119	1,742,881	-676,898	-63.50	0.87	0.72
	6	0.267	5,461,582	0.076	2,202,428	3,259,154	59.67	4.69	5.92
	7	0.216	2,919,505	0.098	2,516,734	402,771	13.80	3.00	2.38

Appendix B: Monthly Phosphorus Balances

Lake Jessup

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1996	8	0.280	1,653,531	-0.015	-48,869	1,702,400	102.96	1.31	
	9	0.291	2,065,553	0.068	616,290	1,449,263	70.16	1.63	2.37
	10	0.236	4,074,352	0.043	963,008	3,111,344	76.36	3.84	6.57
	11	0.212	605,712	0.069	1,093,902	-488,191	-80.60	0.66	0.74
	12	0.239	802,771	0.063	924,875	-122,103	-15.21	0.75	0.99
1997	1	0.241	628,689	0.067	668,449	-39,759	-6.32	0.58	0.74
	2	0.248	460,840	0.052	602,597	-141,756	-30.76	0.46	0.72
	3	0.287	567,895	0.052	645,523	-77,629	-13.67	0.44	0.75
	4	0.301	492,944	0.018	40,581	452,363	91.77	0.38	1.06
	5	0.343	524,358	0.258	-210,285	734,643	140.10	0.34	0.10
	6	0.372	1,245,281	0.072	227,302	1,017,979	81.75	0.77	1.26
	7	0.359	1,938,455	-0.214	-314,743	2,253,198	116.24	1.20	
	8	0.279	1,800,895	-0.099	-75,056	1,875,951	104.17	1.43	
	9	0.300	581,510	0.096	1,001,109	-419,599	-72.16	0.44	0.51
	10	0.358	590,045	0.062	408,266	181,779	30.81	0.37	0.64
	11	0.262	880,792	0.049	552,143	328,649	37.31	0.77	1.29
	12	0.218	3,928,478	-0.265	-278,504	4,206,981	107.09	4.00	
1998	1	0.165	2,121,732	0.054	1,758,489	363,243	17.12	2.86	3.20
	2	0.196	4,886,787	0.020	642,492	4,244,295	86.85	6.14	13.93
	3	0.188	4,983,882	0.060	3,603,190	1,380,692	27.70	5.90	6.73
	4	0.200	741,989	0.110	4,379,568	-3,637,579	-490.25	0.85	0.51
	5	0.271	356,836	0.061	1,638,370	-1,281,535	-359.14	0.29	0.43

Appendix B: Monthly Phosphorus Balances

Lake Jessup									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1998	6	0.612	271,151	0.105	1,434,639	-1,163,487	-429.09	0.10	0.18
	7	0.437	584,423	0.075	1,043,333	-458,910	-78.52	0.30	0.52
	8	0.274	1,581,515	0.065	634,667	946,848	59.87	1.28	1.84
	9	0.245	2,933,393	0.039	673,627	2,259,765	77.04	2.75	5.07
	10	0.213	977,486	0.165	2,221,756	-1,244,270	-127.29	1.02	0.26
	11	0.184	929,695	0.065	1,419,805	-490,110	-52.72	1.16	1.20
	12	0.229	411,032	0.038	95,244	315,787	76.83	0.40	0.72
1999	1	0.212	670,282	0.078	717,942	-47,660	-7.11	0.70	0.70
	2	0.232	361,066	0.112	-367,986	729,052	201.92	0.38	0.28
	3	0.317	333,385	0.113	529,313	-195,928	-58.77	0.23	0.24
	4	0.415	304,996	0.157	-963,633	1,268,629	415.95	0.17	0.16
	5	0.546	257,669	0.263	-667,007	924,676	358.86	0.10	0.08
	6	0.304	1,258,768	-0.394	-285,737	1,544,505	122.70	0.95	
	7	0.254	2,323,811	0.073	1,207,718	1,116,094	48.03	2.04	2.52
	8	0.267	810,728	0.110	-654,951	1,465,679	180.79	0.67	0.60
	9	0.263	6,274,194	-0.214	-1,003,322	7,277,515	115.99	5.48	
	10	0.346	11,096,090	0.332	-4,640,892	15,736,982	141.82	7.12	0.31
	11	0.212	3,596,689	0.052	1,345,381	2,251,308	62.59	3.89	5.48
	12	0.165	1,378,556	0.075	3,199,109	-1,820,553	-132.06	1.86	1.46
2000	1	0.193	842,831	0.072	2,036,607	-1,193,776	-141.64	0.97	0.95
	2	0.206	629,066	0.051	813,216	-184,150	-29.27	0.73	1.02
	3	0.239	453,612	0.004	9,486	444,126	97.91	0.42	1.75

Appendix B: Monthly Phosphorus Balances

Lake Jessup									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2000	4	0.273	428,375	0.070	317,746	110,628	25.83	0.36	0.49
	5	0.368	384,660	0.293	-133,990	518,650	134.83	0.23	0.05
	6	0.434	746,021	0.080	396,360	349,661	46.87	0.39	0.67
	7	0.337	1,706,509	0.056	310,553	1,395,955	81.80	1.12	2.03
	8	0.248	1,299,695	-0.037	-88,296	1,387,991	106.79	1.16	
	9	0.355	1,467,634	0.111	2,301,342	-833,708	-56.81	0.95	1.10
	10	0.234	561,050	0.080	-1,016,729	1,577,778	281.22	0.53	0.57
	11	0.263	362,960	0.052	577,076	-214,116	-58.99	0.32	0.51
	12	0.236	366,232	0.047	300,303	65,930	18.00	0.34	0.56
2001	1	0.224	339,796	0.047	449,359	-109,564	-32.24	0.34	0.52
	2	0.247	325,987	0.039	91,424	234,563	71.95	0.32	0.60
	3	0.296	799,983	0.021	42,965	757,018	94.63	0.60	1.59
	4	0.235	594,358	0.088	506,018	88,341	14.86	0.58	0.57
	5	0.292	495,948	0.192	-161,059	657,007	132.48	0.38	0.16
	6	0.225	1,243,766	0.101	831,923	411,844	33.11	1.27	1.01
	7	0.273	4,393,782	-0.020	-176,397	4,570,179	104.01	3.57	
	8	0.252	2,896,476	0.227	-2,951,070	5,847,546	201.88	2.55	0.27
	9	0.215	7,244,839	0.318	-6,985,976	14,230,816	196.43	7.73	-3.02
	10	0.163	1,968,665	0.092	2,419,573	-450,907	-22.90	2.69	1.53
	11	0.183	1,299,012	0.041	345,054	953,958	73.44	1.63	2.43
	12	0.183	684,580	0.081	2,814,603	-2,130,023	-311.14	0.83	0.67
2002	1	0.173	982,931	0.083	2,297,435	-1,314,504	-133.73	1.26	0.93

Appendix B: Monthly Phosphorus Balances

Lake Jessup									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2002	2	0.177	937,917	-0.124	-172,740	1,110,656	118.42	1.31	
	3	0.217	819,933	0.061	567,391	252,541	30.80	0.84	1.07
	4	0.269	579,423	0.062	222,417	357,006	61.61	0.49	0.73
	5	0.315	438,186	0.267	-623,761	1,061,948	242.35	0.31	0.05
	6	0.236	1,850,892	0.139	1,998,756	-147,864	-7.99	1.80	0.95
	7	0.226	5,830,224	0.065	1,550,431	4,279,793	73.41	5.72	7.12
	8	0.217	10,453,632	0.103	5,945,587	4,508,045	43.12	10.69	7.95
	9	0.203	8,396,250	0.089	6,028,652	2,367,598	28.20	9.49	7.81
	10	0.197	2,352,616	0.083	3,868,405	-1,515,790	-64.43	2.66	2.30
	11	0.172	1,601,407	0.071	2,213,957	-612,550	-38.25	2.13	1.90
	12	0.131	3,940,861	0.017	441,955	3,498,906	88.79	6.66	13.70
2003	1	0.149	3,877,138	0.028	1,002,075	2,875,063	74.15	5.76	9.71
	2	0.208	2,261,596	0.061	2,376,997	-115,401	-5.10	2.67	3.29
	3	0.187	3,368,373	0.039	738,418	2,629,954	78.08	4.01	6.26
	4	0.189	1,278,885	0.081	2,031,882	-752,997	-58.88	1.55	1.32
	5	0.223	1,152,579	0.083	994,173	158,406	13.74	1.15	1.13
	6	0.195	3,522,830	0.059	1,057,539	2,465,290	69.98	4.14	4.97
	7	0.198	1,307,766	0.054	641,387	666,380	50.96	5.06	6.57

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1980	10	2.042	-151,498	0.552	133,514	-285,012	188.13	-0.26	-0.34
	11	0.380	36,840	0.665	62,938	-26,098	-70.84	0.36	-0.20
	12	0.966	942,595	0.587	237,326	705,269	74.82	3.47	1.73
1981	1	0.931	647,071	0.333	137,166	509,905	78.80	2.47	2.54
	2	1.117	3,093,369	0.511	1,482,062	1,611,307	52.09	10.90	8.51
	3	2.014	2,277,755	0.675	383,337	1,894,417	83.17	4.02	4.40
	4	1.014	1,107,969	0.571	270,973	836,996	75.54	4.02	2.30
	5	-0.311	10,888	0.502	77,461	-66,573	-611.42	-0.12	
	6	0.537	772,947	0.341	358,933	414,014	53.56	5.28	2.41
	7	1.410	58,994	0.312	27,609	31,385	53.20	0.15	0.22
	8	0.691	670,761	0.433	154,555	516,206	76.96	3.45	1.61
	9	0.777	7,352,615	0.486	4,597,728	2,754,887	37.47	34.78	16.31
	10	0.833	1,360,745	0.518	433,914	926,832	68.11	5.81	2.76
	11	0.718	-148,184	0.569	292,987	-441,171	297.72	-0.76	-0.18
	12	0.939	2,140,700	0.717	1,012,299	1,128,402	52.71	8.11	2.19
1982	1	0.817	423,448	0.658	884,884	-461,436	-108.97	1.84	0.40
	2	0.968	2,835,825	0.776	1,988,833	846,992	29.87	11.53	2.55
	3	0.861	2,789,505	0.548	1,388,479	1,401,026	50.22	11.52	5.20
	4	0.312	744,138	0.327	762,327	-18,189	-2.44	8.76	-0.40
	5	0.269	321,776	0.357	304,892	16,884	5.25	4.26	-1.21
	6	0.341	1,265,903	0.254	1,061,187	204,716	16.17	13.64	4.00
	7	0.685	2,184,889	0.887	2,333,892	-149,003	-6.82	11.33	-2.93

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1982	8	0.621	1,155,369	0.743	1,935,791	-780,422	-67.55	6.62	-1.19
	9	0.879	3,139,588	0.495	1,718,409	1,421,179	45.27	13.12	7.55
	10	0.890	3,035,217	0.408	1,777,419	1,257,798	41.44	12.12	9.44
	11	0.781	1,134,203	0.465	700,904	433,300	38.20	5.33	2.77
	12	0.761	247,262	0.463	379,999	-132,737	-53.68	1.15	0.57
1983	1	0.600	635,402	0.449	155,673	479,729	75.50	3.76	1.09
	2	0.591	4,531,948	0.524	3,697,504	834,444	18.41	30.17	3.66
	3	0.844	9,719,516	0.667	6,344,005	3,375,511	34.73	40.93	9.67
	4	0.889	3,562,278	0.739	4,586,110	-1,023,831	-28.74	14.71	2.73
	5	0.733	-636,805	0.732	187,655	-824,459	129.47	-3.09	0.00
	6	0.963	5,247,526	0.726	2,892,873	2,354,653	44.87	20.01	5.67
	7	1.147	3,997,539	0.517	2,407,319	1,590,221	39.78	12.39	9.87
	8	4.340	16,273,873	0.582	2,249,244	14,024,629	86.18	13.33	26.79
	9	2.283	22,141,500	0.680	6,400,030	15,741,470	71.09	35.63	43.15
	10	1.250	2,289,026	0.828	1,572,584	716,442	31.30	6.51	2.68
	11	0.789	1,195,427	0.731	1,027,682	167,745	14.03	5.57	0.42
	12	1.214	7,852,437	0.605	2,710,508	5,141,929	65.48	23.00	16.00
1984	1	1.187	4,159,879	0.347	1,792,714	2,367,165	56.90	12.46	15.32
	2	0.798	2,975,646	0.581	1,784,489	1,191,157	40.03	14.17	4.50
	3	0.616	1,173,287	0.765	1,937,903	-764,616	-65.17	6.77	-1.46
	4	0.646	1,674,582	0.812	2,248,044	-573,462	-34.25	9.53	-2.18
	5	0.539	1,287,903	0.651	992,431	295,471	22.94	8.50	-1.61

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1984	6	0.994	1,969,127	0.683	1,041,367	927,759	47.12	7.27	2.73
	7	0.877	6,058,731	0.716	4,269,789	1,788,942	29.53	24.56	4.99
	8	0.816	6,383,410	0.618	4,894,393	1,489,017	23.33	27.82	7.71
	9	0.675	1,046,138	0.556	1,396,448	-350,311	-33.49	5.69	1.10
	10	0.805	796,035	0.708	953,076	-157,041	-19.73	3.52	0.45
	11	0.851	1,333,352	0.513	627,308	706,044	52.95	5.76	2.92
	12	0.709	477,948	0.413	335,757	142,191	29.75	2.40	1.30
1985	1	0.556	1,548,692	0.437	689,505	859,187	55.48	9.90	2.40
	2	0.535	-340,795	0.475	89,304	-430,099	126.20	-2.51	-0.30
	3	0.548	530,603	0.555	236,901	293,701	55.35	3.44	-0.04
	4	0.393	107,368	0.560	173,250	-65,883	-61.36	1.00	-0.36
	5	0.221	130,274	0.611	65,269	65,004	49.90	2.09	-2.13
	6	0.309	725,974	0.903	1,070,304	-344,330	-47.43	8.64	-9.26
	7	0.505	885,367	0.575	837,371	47,996	5.42	6.23	-0.81
	8	0.862	8,302,007	0.574	4,288,192	4,013,816	48.35	34.26	13.91
	9	1.011	7,698,799	0.558	5,697,539	2,001,261	25.99	27.96	16.62
	10	0.907	544,624	0.587	703,862	-159,239	-29.24	2.13	0.93
	11	0.901	577,775	0.550	294,087	283,688	49.10	2.36	1.16
	12	1.054	1,081,726	0.564	295,071	786,654	72.72	3.65	2.28
1986	1	1.177	1,922,714	0.642	945,460	977,254	50.83	5.81	3.52
	2	0.963	1,804,727	0.642	1,029,388	775,339	42.96	7.37	2.99
	3	0.853	2,152,218	0.692	1,766,996	385,222	17.90	8.97	1.88

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1986	4	0.574	377,422	0.713	598,124	-220,702	-58.48	2.42	-0.52
	5	0.299	235,481	0.672	319,923	-84,442	-35.86	2.80	-2.26
	6	0.822	6,527,231	0.504	2,260,133	4,267,098	65.37	29.18	14.24
	7	0.978	4,386,914	0.606	3,644,242	742,672	16.93	15.94	7.64
	8	1.093	9,088,185	0.639	5,191,562	3,896,623	42.88	29.56	15.87
	9	1.175	1,626,550	0.645	2,121,834	-495,284	-30.45	5.08	3.05
	10	1.448	7,264,933	0.741	2,913,915	4,351,018	59.89	17.83	11.95
	11	1.881	2,675,449	0.740	1,253,105	1,422,344	53.16	5.22	4.87
	12	3.061	3,075,552	0.774	585,049	2,490,503	80.98	3.57	4.91
1987	1	2.402	3,783,257	0.957	1,879,230	1,904,027	50.33	5.60	5.15
	2	1.471	3,995,409	1.061	1,861,487	2,133,922	53.41	10.69	3.49
	3	1.545	15,352,544	1.152	7,862,010	7,490,534	48.79	35.33	10.36
	4	1.556	6,094,203	1.062	8,239,899	-2,145,696	-35.21	14.39	5.50
	5	1.308	7,470,368	0.912	4,384,184	3,086,184	41.31	20.30	7.33
	6	1.396	4,572,135	0.761	2,224,864	2,347,271	51.34	12.03	7.30
	7	1.408	3,268,167	0.659	1,964,733	1,303,434	39.88	8.25	6.26
	8	1.416	2,062,904	0.624	1,361,021	701,884	34.02	5.18	4.25
	9	1.865	5,615,631	0.679	674,149	4,941,482	88.00	11.06	11.18
	10	1.960	843,385	0.703	1,224,387	-381,002	-45.18	1.53	1.57
	11	1.783	5,777,677	0.946	2,673,058	3,104,619	53.73	11.91	7.54
	12	2.003	-727,913	1.049	432,622	-1,160,535	159.43	-1.29	-0.84
1988	1	0.986	2,404,858	1.046	1,602,699	802,159	33.36	8.67	-0.51

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1988	2	1.202	1,357,835	1.160	1,787,570	-429,735	-31.65	4.29	0.15
	3	1.590	8,074,400	1.350	5,513,994	2,560,406	31.71	18.05	2.96
	4	2.594	3,812,736	1.490	1,797,834	2,014,901	52.85	5.40	2.99
	5	3.970	2,566,384	1.318	815,551	1,750,833	68.22	2.30	2.53
	6	3.322	859,745	0.991	469,352	390,392	45.41	0.95	1.15
	7	4.123	-143,844	0.751	136,170	-280,014	194.66	-0.12	-0.21
	8	1.509	5,505,253	0.871	1,728,606	3,776,648	68.60	12.97	7.13
	9	1.423	36,677,692	1.104	30,974,033	5,703,659	15.55	94.68	23.99
	10	1.628	2,244,184	1.234	897,849	1,346,335	59.99	4.90	1.36
	11	1.350	6,864,570	1.171	6,265,445	599,125	8.73	18.67	2.66
	12	1.472	5,776,969	1.192	4,028,894	1,748,075	30.26	13.95	2.95
1989	1	1.127	3,534,592	1.330	3,678,561	-143,969	-4.07	11.15	-1.85
	2	5.189	230,909	1.363	1,518,250	-1,287,341	-557.51	0.18	0.23
	3	4.121	5,262,190	1.426	1,293,887	3,968,302	75.41	4.54	4.82
	4	2.794	4,096,561	1.535	1,248,284	2,848,277	69.53	5.39	3.22
	5	1.831	643,564	1.195	692,397	-48,833	-7.59	1.25	0.53
	6	2.575	3,321,152	0.505	106,183	3,214,969	96.80	4.74	7.72
	7	1.992	1,169,874	0.621	683,387	486,488	41.58	2.09	2.43
	8	1.510	1,309,903	0.896	866,352	443,550	33.86	3.08	1.61
	9	1.232	2,791,597	1.068	1,717,208	1,074,389	38.49	8.33	1.18
	10	1.082	-851,706	1.172	549,575	-1,401,281	164.53	-2.80	0.23
	11	1.055	2,536,801	1.221	1,604,568	932,233	36.75	8.83	-1.29
	12	1.155	4,297,180	1.360	4,394,586	-97,406	-2.27	13.22	-2.15

Appendix B: Monthly Phosphorus Balances

Lake Thonotosassa

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1990	1	1.723	2,445,454	1.328	2,872,904	-427,449	-17.48	5.05	1.31
	2	1.186	1,464,100	1.438	1,082,670	381,430	26.05	4.86	-0.93
	3	46.978	-2,068,170	1.476	1,408,420	-3,476,590	168.10	-0.16	-0.54
	4	3.945	2,090,791	0.737	99,232	1,991,559	95.25	1.95	3.26
	5	0.970	340,919	0.411	40,564	300,355	88.10	1.25	1.07
	6	0.851	841,866	0.457	142,910	698,956	83.02	3.63	2.26
	7	0.875	5,223,415	0.597	3,613,890	1,609,525	30.81	21.23	8.09
	8	0.948	5,444,181	0.732	2,984,075	2,460,106	45.19	20.41	5.29
	9	0.781	-501,718	0.800	987,366	-1,489,083	296.80	-2.36	0.06
	10	0.714	1,217,051	0.856	1,381,230	-164,178	-13.49	6.06	-1.10
	11	0.663	164,204	0.905	45,987	118,217	71.99	0.91	-0.28
	12	0.400	248,445	1.076	177,587	70,858	28.52	2.21	-2.18
1991	1	0.405	822,409	0.893	1,072,117	-249,707	-30.36	7.22	-5.71
	2	0.303	40,907	0.951	448,070	-407,163	-995.33	0.53	-0.61
	3	0.795	209,620	0.943	105,281	104,339	49.78	0.94	-0.16
	4	0.524	2,759,068	0.413	890,722	1,868,346	67.72	19.36	4.57
	5	0.669	3,063,468	0.688	1,966,001	1,097,467	35.82	16.81	-0.45
	6	0.814	4,539,605	0.652	3,449,868	1,089,738	24.01	20.48	4.54
	7	0.912	9,079,724	0.650	6,001,438	3,078,287	33.90	35.39	12.01
	8	0.968	3,389,255	0.657	3,465,653	-76,398	-2.25	12.45	4.83
	9	0.919	-1,010,445	0.653	258,739	-1,269,184	125.61	-4.85	-1.65

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1981	1	0.043	75,452	0.018	63,258	12,194	16.16	26.76	23.70
	2	0.045	2,858,280	0.015	1,495,442	1,362,838	47.68	34.15	38.24
	3	0.047	3,177,733	0.017	2,010,085	1,167,648	36.74	32.72	33.13
	4	0.048	2,888,203	0.016	1,653,834	1,234,370	42.74	30.41	32.60
	5	0.045	2,527,682	0.012	1,093,968	1,433,714	56.72	27.38	36.00
	6	0.042	2,313,264	0.010	849,385	1,463,879	63.28	27.39	40.72
	7	0.040	2,336,820	0.006	556,018	1,780,802	76.21	28.14	52.78
	8	0.039	2,468,512	0.006	696,558	1,771,954	71.78	30.75	56.39
	9	0.036	2,016,911	0.009	1,137,743	879,168	43.59	28.15	39.77
	10	0.035	1,776,244	0.006	601,431	1,174,813	66.14	24.56	42.97
	11	0.039	1,968,969	0.007	716,132	1,252,837	63.63	25.66	44.35
	12	0.041	2,090,132	0.006	522,158	1,567,974	75.02	24.71	47.77
1982	1	0.043	2,353,599	0.009	807,414	1,546,184	65.69	26.66	40.97
	2	0.045	2,466,274	0.014	1,344,523	1,121,751	45.48	29.54	34.01
	3	0.051	3,516,784	0.017	2,211,017	1,305,767	37.13	33.89	36.60
	4	0.063	12,389,318	0.026	9,945,418	2,443,901	19.73	99.53	89.14
	5	0.051	4,950,604	0.018	3,278,956	1,671,649	33.77	47.17	48.82
	6	0.057	14,111,840	0.021	10,514,568	3,597,272	25.49	125.07	125.05
	7	0.072	17,290,224	0.024	10,721,151	6,569,073	37.99	117.62	128.72
	8	0.067	11,817,087	0.023	7,950,622	3,866,466	32.72	86.17	90.66
	9	0.064	11,795,025	0.019	6,389,556	5,405,469	45.83	93.37	114.98
	10	0.079	14,220,866	0.017	5,711,054	8,509,812	59.84	87.20	135.21
	11	0.138	13,644,621	0.016	2,754,590	10,890,030	79.81	49.75	108.70

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1982	12	0.113	10,496,953	0.016	2,651,858	7,845,095	74.74	45.38	89.37
1983	1	0.047	4,365,798	0.022	3,982,129	383,669	8.79	45.55	33.61
	2	0.045	7,137,314	0.026	7,774,712	-637,398	-8.93	84.75	45.93
	3	0.054	12,159,093	0.026	10,975,954	1,183,140	9.73	109.17	82.17
	4	0.063	15,706,114	0.025	11,516,352	4,189,762	26.68	125.40	113.44
	5	0.064	12,699,043	0.024	7,381,174	5,317,869	41.88	96.24	94.25
	6	0.063	10,670,990	0.023	6,423,547	4,247,443	39.80	85.32	87.06
	7	0.065	11,776,039	0.023	7,703,904	4,072,135	34.58	88.62	92.74
	8	0.079	11,685,571	0.023	6,059,541	5,626,030	48.15	71.57	88.70
	9	0.083	14,802,871	0.026	8,653,888	6,148,983	41.54	89.50	103.88
	10	0.070	8,395,407	0.020	4,198,310	4,197,098	49.99	58.49	72.17
	11	0.056	5,736,231	0.018	3,341,436	2,394,795	41.75	51.17	57.41
	12	0.046	6,571,033	0.017	4,168,366	2,402,667	36.56	69.07	70.38
1984	1	0.051	11,973,702	0.029	12,869,909	-896,207	-7.48	114.01	64.46
	2	0.046	7,548,555	0.029	8,648,701	-1,100,146	-14.57	84.66	40.83
	3	0.047	10,490,866	0.028	10,898,837	-407,971	-3.89	108.25	56.62
	4	0.065	13,189,674	0.026	9,459,285	3,730,389	28.28	102.00	95.27
	5	0.053	6,680,204	0.016	3,583,491	3,096,713	46.36	61.84	71.69
	6	0.067	6,814,397	0.016	2,942,208	3,872,189	56.82	51.50	73.08
	7	0.068	8,840,616	0.017	4,162,365	4,678,252	52.92	63.02	87.13
	8	0.060	8,299,949	0.018	4,669,477	3,630,472	43.74	66.88	81.16
	9	0.063	5,101,093	0.014	2,216,297	2,884,796	56.55	40.66	61.28

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1984	10	0.073	5,358,952	0.011	1,557,549	3,801,403	70.94	35.82	67.82
	11	0.046	3,057,838	0.008	1,045,104	2,012,735	65.82	33.69	59.53
	12	0.040	2,577,610	0.009	1,035,265	1,542,345	59.84	31.38	48.02
1985	1	0.043	2,729,146	0.017	1,914,419	814,727	29.85	30.61	29.30
	2	0.037	1,984,590	0.018	1,799,148	185,441	9.34	28.60	21.20
	3	0.043	2,387,980	0.015	1,617,522	770,459	32.26	26.78	28.42
	4	0.088	4,517,148	0.016	1,541,510	2,975,638	65.87	25.79	44.07
	5	0.104	5,187,514	0.008	608,320	4,579,194	88.27	24.31	63.87
	6	0.043	2,123,287	0.008	695,413	1,427,874	67.25	24.65	42.12
	7	0.050	2,756,631	0.008	917,337	1,839,293	66.72	26.70	47.57
	8	0.039	3,267,201	0.013	2,310,151	957,051	29.29	41.10	46.21
	9	0.044	4,392,688	0.020	3,916,252	476,435	10.85	50.44	38.37
	10	0.062	5,509,441	0.030	4,919,250	590,190	10.71	43.38	31.46
	11	0.062	5,467,952	0.025	4,061,386	1,406,566	25.72	44.25	39.97
	12	0.030	2,339,570	0.020	3,529,206	-1,189,636	-50.85	37.40	16.02
1986	1	0.033	3,975,904	0.025	6,112,011	-2,136,107	-53.73	58.67	16.60
	2	0.036	3,698,380	0.025	5,021,892	-1,323,512	-35.79	55.57	19.29
	3	0.049	7,539,992	0.024	7,104,266	435,725	5.78	74.69	52.95
	4	0.045	4,502,433	0.012	1,794,391	2,708,043	60.15	49.96	64.71
	5	0.041	3,299,462	0.005	580,765	2,718,697	82.40	38.87	80.09
	6	0.041	2,715,831	0.008	1,027,795	1,688,036	62.16	33.69	54.61
	7	0.043	3,074,292	0.007	903,500	2,170,793	70.61	34.66	63.71

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1986	8	0.043	3,280,222	0.007	949,629	2,330,593	71.05	37.20	69.97
	9	0.043	3,359,453	0.009	1,405,626	1,953,826	58.16	39.73	59.91
	10	0.042	2,646,388	0.008	870,720	1,775,668	67.10	30.87	49.22
	11	0.042	2,487,170	0.012	1,350,743	1,136,426	45.69	29.60	36.43
	12	0.046	3,443,756	0.015	2,042,138	1,401,618	40.70	36.68	41.25
1987	1	0.048	3,734,542	0.023	3,305,942	428,600	11.48	38.12	28.55
	2	0.052	5,225,581	0.025	4,553,352	672,230	12.86	54.57	40.42
	3	0.053	10,483,696	0.026	9,255,167	1,228,529	11.72	95.81	67.16
	4	0.063	19,221,970	0.032	16,881,351	2,340,619	12.18	154.48	103.75
	5	0.062	10,286,141	0.023	5,938,916	4,347,225	42.26	80.19	80.26
	6	0.054	5,424,118	0.016	2,612,872	2,811,246	51.83	50.95	61.21
	7	0.049	4,046,670	0.013	1,970,211	2,076,460	51.31	40.00	52.27
	8	0.046	3,289,316	0.009	1,102,890	2,186,426	66.47	34.53	58.07
	9	0.037	2,556,896	0.007	941,813	1,615,083	63.17	35.10	56.26
	10	0.039	2,480,195	0.012	1,427,874	1,052,321	42.43	31.06	37.29
	11	0.043	2,719,688	0.012	1,609,200	1,110,488	40.83	31.85	40.35
	12	0.034	2,046,938	0.008	926,903	1,120,035	54.72	29.60	43.49
1988	1	0.038	2,936,090	0.015	2,342,398	593,692	20.22	37.49	34.07
	2	0.037	3,306,063	0.015	2,745,029	561,034	16.97	47.13	41.52
	3	0.131	23,603,057	0.066	24,003,895	-400,838	-1.70	87.40	59.98
	4	0.058	5,865,547	0.024	4,604,896	1,260,651	21.49	50.77	45.69
	5	0.041	2,814,994	0.018	2,294,971	520,023	18.47	33.57	28.00

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1988	6	0.058	3,767,235	0.040	4,816,813	-1,049,578	-27.86	32.46	12.48
	7	0.071	5,307,519	0.054	8,123,527	-2,816,007	-53.06	36.36	9.91
	8	0.042	3,531,682	0.012	2,099,261	1,432,421	40.56	40.76	49.96
	9	0.067	12,773,771	0.019	7,432,205	5,341,566	41.82	95.81	120.00
	10	0.078	10,558,258	0.017	3,836,440	6,721,818	63.66	65.73	99.06
	11	0.060	6,340,556	0.021	4,419,973	1,920,583	30.29	52.95	56.49
	12	0.044	4,083,404	0.025	5,613,438	-1,530,034	-37.47	44.68	25.68
1989	1	0.045	3,559,558	0.030	5,062,709	-1,503,151	-42.23	38.19	15.37
	2	0.046	3,296,436	0.029	4,354,089	-1,057,654	-32.08	38.65	17.96
	3	0.052	3,881,132	0.020	3,221,555	659,576	16.99	36.68	34.44
	4	0.052	3,643,397	0.018	2,732,876	910,521	24.99	35.42	36.78
	5	0.049	3,400,754	0.010	1,166,946	2,233,807	65.69	33.79	52.58
	6	0.044	2,608,961	0.016	1,932,841	676,120	25.92	30.14	29.39
	7	0.045	3,841,015	0.020	3,500,347	340,669	8.87	41.68	34.09
	8	0.048	3,254,029	0.013	1,819,560	1,434,469	44.08	32.77	41.86
	9	0.049	3,503,940	0.011	1,723,805	1,780,135	50.80	36.32	52.99
	10	0.041	2,541,651	0.010	1,297,234	1,244,417	48.96	30.07	41.20
	11	0.037	2,029,142	0.010	1,136,983	892,159	43.97	27.48	35.88
	12	0.039	2,405,583	0.011	1,450,674	954,909	39.70	29.87	37.91
1990	1	0.044	2,941,663	0.016	2,152,017	789,645	26.84	32.71	33.24
	2	0.041	2,428,065	0.015	1,844,720	583,344	24.03	31.70	31.23
	3	0.034	1,956,388	0.014	1,681,821	274,567	14.03	28.40	24.62

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1990	4	0.026	1,435,047	0.009	938,444	496,603	34.61	27.70	29.30
	5	0.028	1,445,360	0.008	830,561	614,799	42.54	25.52	30.81
	6	0.034	1,694,857	0.011	1,104,694	590,163	34.82	25.26	29.17
	7	0.041	2,797,344	0.013	1,880,916	916,428	32.76	33.24	37.95
	8	0.046	2,962,984	0.015	2,095,015	867,969	29.29	31.14	34.41
	9	0.051	2,366,099	0.016	1,452,673	913,426	38.60	23.53	27.71
	10	0.051	2,403,135	0.017	1,620,722	782,414	32.56	22.82	25.87
	11	0.049	2,124,768	0.016	1,396,319	728,449	34.28	21.95	24.71
	12	0.046	2,066,814	0.016	1,459,937	606,876	29.36	21.80	23.09
1991	1	0.044	1,983,779	0.020	1,839,816	143,962	7.26	21.83	17.86
	2	0.042	1,643,192	0.019	1,511,763	131,429	8.00	21.30	16.69
	3	0.040	2,049,468	0.020	2,085,102	-35,634	-1.74	24.74	17.46
	4	0.038	1,999,088	0.017	1,726,932	272,156	13.61	26.17	20.97
	5	0.038	2,714,935	0.019	2,864,972	-150,037	-5.53	34.95	24.36
	6	0.040	5,609,766	0.020	5,745,260	-135,494	-2.42	70.37	47.65
	7	0.036	4,280,060	0.019	4,616,731	-336,671	-7.87	57.41	36.27
	8	0.032	2,904,978	0.018	3,320,816	-415,838	-14.31	43.61	24.64
	9	0.027	1,465,633	0.015	1,506,538	-40,906	-2.79	26.88	16.10
	10	0.025	1,288,066	0.018	1,944,817	-656,751	-50.99	25.54	8.28
	11	0.024	1,173,454	0.016	1,460,296	-286,842	-24.44	24.37	10.57
	12	0.028	1,316,864	0.022	2,972,698	-1,655,834	-125.74	23.07	4.89
1992	1	0.032	1,436,147	0.021	2,108,944	-672,797	-46.85	21.96	8.86

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1992	2	0.035	1,466,857	0.023	2,209,324	-742,468	-50.62	21.99	9.30
	3	0.038	2,004,224	0.018	1,733,344	270,880	13.52	25.48	19.56
	4	0.043	1,934,695	0.014	989,464	945,231	48.86	22.48	26.17
	5	0.042	1,759,838	0.015	1,091,016	668,822	38.00	20.61	21.48
	6	0.046	2,037,232	0.015	1,212,878	824,354	40.46	22.43	25.35
	7	0.047	2,237,224	0.015	1,345,772	891,453	39.85	23.09	26.14
	8	0.043	2,355,756	0.017	1,884,865	470,892	19.99	26.74	24.53
	9	0.046	2,525,718	0.016	1,663,390	862,328	34.14	27.38	29.36
	10	0.052	4,672,513	0.020	3,735,186	937,328	20.06	43.42	41.11
	11	0.051	3,195,273	0.016	1,930,423	1,264,850	39.59	31.33	36.58
	12	0.046	3,075,755	0.017	2,312,104	763,650	24.83	32.37	32.02
1993	1	0.043	2,886,392	0.021	2,962,459	-76,066	-2.64	32.53	23.50
	2	0.046	4,476,849	0.022	4,426,657	50,192	1.12	51.93	38.10
	3	0.043	4,421,397	0.022	4,584,840	-163,444	-3.70	49.82	33.68
	4	0.047	4,973,093	0.023	4,902,783	70,310	1.41	52.81	38.92
	5	0.054	2,766,647	0.017	1,750,721	1,015,927	36.72	24.92	28.51
	6	0.083	4,097,465	0.014	1,261,959	2,835,507	69.20	24.87	43.43
	7	0.062	3,340,165	0.016	1,748,751	1,591,414	47.64	26.02	34.66
	8	0.038	1,842,131	0.013	1,141,931	700,199	38.01	23.66	24.45
	9	0.043	2,122,311	0.015	1,389,215	733,096	34.54	24.89	26.39
	10	0.044	2,167,985	0.013	1,132,772	1,035,213	47.75	23.93	28.84
	11	0.041	2,046,604	0.017	1,706,802	339,801	16.60	25.05	22.10
	12	0.039	1,960,660	0.013	1,182,632	778,029	39.68	24.75	26.16

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1994	1	0.038	2,398,821	0.019	2,298,677	100,144	4.17	30.35	21.46
	2	0.041	3,002,051	0.024	3,606,125	-604,075	-20.12	39.25	21.65
	3	0.044	3,128,261	0.019	2,513,275	614,986	19.66	34.63	29.78
	4	0.045	2,638,751	0.016	1,737,581	901,170	34.15	29.19	29.62
	5	0.047	2,640,433	0.015	1,468,987	1,171,446	44.37	27.64	31.73
	6	0.048	2,765,419	0.018	2,146,651	618,768	22.38	28.74	28.97
	7	0.049	3,084,588	0.016	2,013,916	1,070,672	34.71	30.84	33.80
	8	0.051	5,249,404	0.018	3,972,393	1,277,011	24.33	50.61	51.02
	9	0.052	5,503,631	0.019	4,309,321	1,194,310	21.70	53.26	53.24
	10	0.055	6,813,199	0.017	4,247,198	2,566,001	37.66	60.44	69.35
	11	0.051	5,152,287	0.019	4,385,443	766,844	14.88	50.41	48.88
	12	0.049	5,186,499	0.018	3,745,805	1,440,693	27.78	51.73	52.59
1995	1	0.046	4,751,727	0.025	5,245,290	-493,563	-10.39	50.16	30.85
	2	0.046	3,065,491	0.020	2,487,119	578,372	18.87	35.80	30.36
	3	0.051	4,178,911	0.019	2,889,869	1,289,042	30.85	40.03	39.77
	4	0.056	5,330,003	0.021	3,937,026	1,392,977	26.13	47.60	47.96
	5	0.052	3,027,005	0.016	1,699,110	1,327,895	43.87	28.59	33.49
	6	0.051	4,037,288	0.018	2,613,446	1,423,842	35.27	40.19	40.97
	7	0.089	7,128,359	0.019	2,944,020	4,184,339	58.70	39.08	59.85
	8	0.062	7,633,781	0.019	4,791,674	2,842,106	37.23	59.71	69.96
	9	0.065	9,635,366	0.019	5,581,994	4,053,372	42.07	74.26	93.02
	10	0.076	12,805,023	0.021	7,949,725	4,855,297	37.92	82.20	103.82

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1995	11	0.044	3,828,285	0.026	6,371,932	-2,543,647	-66.44	43.85	23.28
	12	0.048	3,998,611	0.018	3,085,572	913,038	22.83	40.61	38.76
1996	1	0.054	8,807,450	0.029	10,549,592	-1,742,142	-19.78	79.03	48.55
	2	0.043	3,376,701	0.022	3,572,334	-195,633	-5.79	40.54	26.81
	3	0.066	8,699,505	0.022	5,961,478	2,738,027	31.47	63.78	69.84
	4	0.092	16,205,298	0.020	6,172,250	10,033,048	61.91	88.30	134.99
	5	0.060	5,681,865	0.024	5,264,300	417,565	7.35	45.92	41.71
	6	0.057	4,041,608	0.017	2,465,366	1,576,242	39.00	35.89	42.31
	7	0.122	15,895,787	0.021	5,855,672	10,040,115	63.16	63.20	110.59
	8	0.052	4,219,672	0.020	3,665,271	554,400	13.14	39.57	37.55
	9	0.042	2,897,512	0.020	3,267,414	-369,902	-12.77	34.49	25.49
	10	0.062	5,086,791	0.018	2,899,456	2,187,336	43.00	39.83	50.17
	11	0.043	2,857,361	0.018	2,513,940	343,421	12.02	33.50	29.25
	12	0.042	3,330,467	0.018	3,030,886	299,581	9.00	38.39	32.89
1997	1	0.048	3,556,062	0.024	3,863,893	-307,831	-8.66	35.85	25.58
	2	0.044	2,802,779	0.017	1,872,176	930,602	33.20	33.98	32.56
	3	0.047	3,227,016	0.019	2,498,208	728,808	22.58	33.37	30.93
	4	0.047	2,834,990	0.017	1,793,299	1,041,690	36.74	30.13	31.57
	5	0.043	2,613,906	0.018	2,147,519	466,387	17.84	29.40	25.47
	6	0.047	2,573,363	0.015	1,569,014	1,004,349	39.03	27.71	31.14
	7	0.056	3,016,756	0.017	1,991,087	1,025,668	34.00	26.44	30.54
	8	0.047	2,681,760	0.016	1,616,190	1,065,570	39.73	28.05	30.63

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1997	9	0.044	2,299,354	0.015	1,389,866	909,488	39.55	26.20	28.26
	10	0.039	2,260,677	0.015	1,527,407	733,270	32.44	28.10	27.41
	11	0.037	2,677,165	0.020	3,213,722	-536,556	-20.04	36.37	22.34
	12	0.048	7,166,614	0.020	5,939,832	1,226,783	17.12	72.62	64.16
1998	1	0.054	13,706,482	0.033	18,748,265	-5,041,783	-36.78	124.04	60.05
	2	0.055	17,435,075	0.028	16,568,978	866,097	4.97	169.80	118.47
	3	0.059	25,207,646	0.034	25,851,070	-643,424	-2.55	206.43	113.31
	4	0.060	15,959,615	0.030	13,809,493	2,150,122	13.47	133.41	93.46
	5	0.058	6,832,135	0.019	4,229,678	2,602,457	38.09	57.71	64.13
	6	0.061	5,114,161	0.014	2,109,562	3,004,600	58.75	42.45	61.84
	7	0.055	4,881,343	0.012	2,136,196	2,745,146	56.24	43.17	66.34
	8	0.062	5,627,217	0.013	2,520,567	3,106,650	55.21	44.51	68.69
	9	0.056	6,444,719	0.015	3,427,870	3,016,849	46.81	57.57	75.58
	10	0.052	6,361,367	0.015	3,465,806	2,895,561	45.52	59.82	73.78
	11	0.045	3,936,767	0.014	2,327,021	1,609,745	40.89	43.65	50.80
	12	0.046	3,687,514	0.023	5,136,684	-1,449,170	-39.30	39.11	27.23
1999	1	0.044	3,710,491	0.029	5,973,962	-2,263,471	-61.00	41.38	16.75
	2	0.047	3,394,324	0.032	5,436,837	-2,042,514	-60.17	39.23	14.98
	3	0.047	3,219,697	0.026	3,243,098	-23,401	-0.73	33.18	20.20
	4	0.049	2,678,348	0.022	1,878,271	800,077	29.87	27.49	22.41
	5	0.039	2,387,997	0.009	937,083	1,450,915	60.76	30.04	42.92
	6	0.040	2,475,372	0.009	1,075,113	1,400,260	56.57	31.30	48.29

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1999	7	0.040	2,332,698	0.008	870,517	1,462,181	62.68	28.73	47.31
	8	0.037	2,109,834	0.006	663,733	1,446,100	68.54	27.58	48.86
	9	0.037	1,959,029	0.006	672,710	1,286,319	65.66	26.73	46.43
	10	0.041	2,789,391	0.006	770,624	2,018,767	72.37	33.17	62.48
	11	0.041	2,917,861	0.006	780,833	2,137,029	73.24	36.05	68.45
	12	0.042	2,243,582	0.007	747,555	1,496,027	66.68	26.32	47.65
2000	1	0.042	2,062,618	0.009	810,023	1,252,595	60.73	24.12	37.74
	2	0.044	1,976,664	0.009	770,672	1,205,992	61.01	23.54	36.95
	3	0.042	1,966,038	0.008	673,906	1,292,132	65.72	22.75	37.27
	4	0.039	1,880,025	0.007	603,201	1,276,824	67.92	24.48	40.43
	5	0.037	1,614,955	0.008	603,414	1,011,541	62.64	21.25	33.03
	6	0.037	1,373,516	0.005	339,685	1,033,831	75.27	18.53	37.74
	7	0.031	1,186,718	0.005	402,325	784,393	66.10	18.43	32.37
	8	0.029	1,102,814	0.005	385,687	717,127	65.03	18.67	31.37
	9	0.046	2,373,268	0.006	665,463	1,707,805	71.96	25.76	50.74
	10	0.037	1,598,743	0.006	415,718	1,183,025	74.00	20.76	38.64
	11	0.033	1,374,305	0.004	244,401	1,129,904	82.22	20.77	44.83
	12	0.036	1,687,001	0.007	746,874	940,127	55.73	22.72	36.40
2001	1	0.034	1,272,429	0.010	768,953	503,475	39.57	18.03	22.50
	2	0.047	1,516,550	0.012	870,828	645,722	42.58	17.26	23.48
	3	0.044	2,113,919	0.007	562,535	1,551,384	73.39	23.22	42.27
	4	0.032	1,490,846	0.007	573,797	917,049	61.51	23.31	34.59

Appendix B: Monthly Phosphorus Balances

Rodman Reservoir

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2001	5	0.029	1,067,604	0.007	467,578	600,026	56.20	18.22	25.87
	6	0.032	1,119,538	0.006	354,521	765,017	68.33	17.35	30.11
	7	0.036	1,411,229	0.006	423,061	988,168	70.02	19.20	33.62
	8	0.037	1,728,751	0.008	729,399	999,353	57.81	22.81	34.09
	9	0.043	3,436,489	0.009	1,323,992	2,112,498	61.47	40.05	64.50
	10	0.039	2,444,957	0.011	1,406,966	1,037,991	42.45	30.22	38.79
	11	0.042	2,539,973	0.011	1,664,196	875,777	34.48	30.69	40.23
	12	0.041	2,088,671	0.015	2,528,624	-439,953	-21.06	25.00	24.67
2002	1	0.036	1,595,522	0.018	2,240,248	-644,726	-40.41	21.70	14.61
	2	0.040	1,672,313	0.018	1,847,896	-175,584	-10.50	22.81	18.25
	3	0.040	1,781,238	0.013	1,175,393	605,846	34.01	21.46	23.73
	4	0.037	1,437,380	0.015	1,219,093	218,287	15.19	19.71	17.19
	5	0.036	1,292,747	0.012	832,623	460,125	35.59	17.52	19.21
	6	0.040	1,631,052	0.010	982,047	649,005	39.79	20.66	27.58
	7	0.037	1,977,320	0.010	1,132,554	844,765	42.72	26.12	34.53
	8	0.048	3,416,117	0.010	1,525,599	1,890,518	55.34	34.61	53.04
	9	0.044	5,149,322	0.013	3,150,021	1,999,301	38.83	58.56	73.66
	10	0.049	4,454,597	0.011	1,837,862	2,616,735	58.74	44.28	66.02
	11	0.046	3,746,700	0.008	1,078,271	2,668,429	71.22	40.70	71.20
	12	0.041	2,161,141	0.008	722,906	1,438,236	66.55	44.50	74.55

Appendix B: Monthly Phosphorus Balances

St. Johns Marsh Conservation Area

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1997	1	0.101	1,299,625	0.077	1,141,349	158,276	12.18	1.62	0.44
	2	0.097	1,156,059	0.093	1,555,018	-398,959	-34.51	1.66	0.06
	3	0.098	1,212,804	0.101	2,172,274	-959,470	-79.11	1.55	-0.04
	4	0.100	1,127,911	0.090	1,494,792	-366,880	-32.53	1.47	0.14
	5	0.141	611,140	0.171	2,269,758	-1,658,618	-271.40	0.54	-0.11
	6	0.084	1,265,240	0.206	7,661,100	-6,395,860	-505.51	1.94	-1.73
	7	0.104	4,249,083	0.121	8,692,483	-4,443,401	-104.57	5.14	-0.78
	8	0.119	18,795,040	0.125	28,523,105	-9,728,065	-51.76	19.76	-0.88
	9	0.121	9,211,155	0.130	23,024,275	-13,813,119	-149.96	9.86	-0.68
	10	0.143	7,412,083	0.082	8,059,532	-647,449	-8.74	6.49	3.61
	11	0.178	23,600,086	0.068	10,406,791	13,193,295	55.90	17.20	16.62
	12	0.133	24,125,476	0.081	22,754,161	1,371,315	5.68	22.72	11.21
1998	1	0.100	16,440,396	0.076	20,437,269	-3,996,873	-24.31	20.65	5.64
	2	0.083	17,960,326	0.069	21,429,049	-3,468,723	-19.31	30.11	5.56
	3	0.071	16,727,483	0.061	19,916,254	-3,188,770	-19.06	29.70	4.62
	4	0.065	5,443,413	0.063	12,929,000	-7,485,587	-137.52	10.92	0.29
	5	0.081	2,814,498	0.099	7,212,081	-4,397,583	-156.25	4.36	-0.85
	6	0.156	1,651,553	0.098	1,004,934	646,619	39.15	1.38	0.63
	7	0.138	2,373,297	0.151	2,273,060	100,238	4.22	2.16	-0.20
	8	0.110	5,969,612	0.174	12,337,174	-6,367,562	-106.67	6.80	-3.12
	9	0.099	5,626,920	0.140	15,404,739	-9,777,818	-173.77	7.36	-2.54
	10	0.081	1,720,497	0.128	9,186,755	-7,466,258	-433.96	2.68	-1.24
	11	0.094	1,494,601	0.109	3,372,416	-1,877,814	-125.64	2.07	-0.31

Appendix B: Monthly Phosphorus Balances

St. Johns Marsh Conservation Area

Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
1998	12	0.090	1,128,143	0.069	1,377,685	-249,542	-22.12	1.57	0.42
1999	1	0.091	1,115,723	0.064	1,131,473	-15,750	-1.41	1.54	0.54
	2	0.151	636,859	0.077	866,186	-229,326	-36.01	0.59	0.40
	3	0.121	1,113,998	0.059	723,411	390,587	35.06	1.15	0.82
	4	0.163	1,713,398	0.073	854,229	859,168	50.14	1.36	1.10
	5	0.344	3,706,087	0.082	1,013,142	2,692,945	72.66	1.35	1.94
	6	0.418	4,615,492	0.129	2,873,722	1,741,770	37.74	1.43	1.68
	7	0.347	14,888,313	0.106	6,075,278	8,813,035	59.19	5.39	6.39
	8	0.084	4,793,909	0.051	2,382,822	2,411,087	50.29	7.16	3.58
	9	0.082	8,451,290	0.129	18,805,654	-10,354,364	-122.52	13.29	-5.95
	10	0.079	26,800,670	0.099	45,908,960	-19,108,290	-71.30	42.71	-9.64
	11	0.096	5,801,972	0.079	16,291,058	-10,489,086	-180.78	7.87	1.50
	12	0.083	1,826,169	0.077	3,749,083	-1,922,914	-105.30	2.77	0.20
2000	1	0.130	2,740,934	0.066	2,189,823	551,111	20.11	2.64	1.81
	2	0.152	2,070,561	0.047	909,108	1,161,453	56.09	1.83	2.13
	3	0.137	1,522,737	0.055	634,589	888,147	58.33	1.39	1.27
	4	0.240	2,508,932	0.045	399,103	2,109,829	84.09	1.36	2.27
	5	0.119	1,282,485	-0.048	-201,643	1,484,129	115.72	1.35	
	6	0.133	1,391,587	-0.025	-126,132	1,517,719	109.06	1.35	
	7	0.126	1,361,229	0.101	1,058,815	302,414	22.22	1.35	0.30
	8	0.147	1,589,441	0.160	5,219,176	-3,629,734	-228.37	1.36	-0.12
	9	0.113	1,857,331	0.077	1,475,439	381,891	20.56	2.13	0.83

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St. Johns Marsh Conservation Area									
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2000	10	0.102	2,483,209	0.067	2,614,977	-131,768	-5.31	3.05	1.29
	11	0.147	1,670,116	0.027	267,157	1,402,959	84.00	1.48	2.50
	12	0.103	1,104,242	0.018	148,761	955,481	86.53	1.34	2.33
2001	1	0.083	880,115	0.021	181,086	699,030	79.42	1.33	1.82
	2	0.081	779,403	0.025	189,860	589,543	75.64	1.33	1.59
	3	0.074	764,672	0.020	137,904	626,768	81.97	1.30	1.71
	4	0.088	506,004	0.016	64,911	441,094	87.17	0.79	1.34
	5	0.147	336,520	-0.031	-31,227	367,747	109.28	0.50	
	6	0.158	529,788	0.026	60,560	469,228	88.57	0.65	1.18
	7	0.154	497,413	0.089	388,283	109,131	21.94	0.84	0.45
	8	0.216	42,459,006	0.136	40,689,449	1,769,557	4.17	24.70	11.46
	9	0.166	31,816,303	0.142	42,234,796	-10,418,493	-32.75	24.89	3.93
	10	0.131	5,503,906	0.111	21,035,650	-15,531,745	-282.19	5.26	0.87
	11	0.122	3,012,150	0.082	6,602,103	-3,589,953	-119.18	3.20	1.28
	12	0.123	1,808,684	0.061	1,458,715	349,969	19.35	1.85	1.30
2002	1	0.121	1,622,345	0.051	865,149	757,197	46.67	1.68	1.46
	2	0.129	1,647,070	0.060	953,622	693,448	42.10	1.78	1.37
	3	0.124	2,025,544	0.046	711,312	1,314,232	64.88	2.06	2.04
	4	0.142	1,576,092	0.040	388,283	1,187,809	75.36	1.44	1.82
	5	0.182	1,942,380	0.041	351,093	1,591,287	81.92	1.34	2.00
	6	0.328	5,499,913	0.170	7,876,448	-2,376,536	-43.21	4.66	3.06
	7	0.210	56,726,004	0.111	45,583,827	11,142,177	19.64	33.90	21.76

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St. Johns Marsh Conservation Area									
Year	Month	Inf. Conc. (mg/L)	Influx (g)	Out. Conc. (mg/L)	Outflux (g)	Retention (g)	Ret. Effic. (%)	Hyd. Load. (m/yr)	k (m/yr)
2002	8	0.151	22,718,254	0.094	26,975,544	-4,257,290	-18.74	18.89	9.02
	9	0.119	7,276,177	0.094	11,926,761	-4,650,584	-63.92	7.94	1.90
	10	0.119	2,019,326	0.108	4,512,972	-2,493,646	-123.49	2.12	0.22
	11	0.137	1,934,710	0.075	1,956,822	-22,112	-1.14	1.84	1.10
	12	0.125	10,690,606	0.066	8,831,486	1,859,120	17.39	10.75	6.82
2003	1	0.097	6,072,369	0.053	6,047,856	24,513	0.40	7.87	4.76
	2	0.113	1,564,955	0.068	1,975,965	-411,010	-26.26	1.93	0.99
	3	0.105	3,260,428	0.065	2,515,178	745,250	22.86	3.89	1.85
	4	0.113	2,047,770	0.057	1,615,074	432,695	21.13	2.35	1.59
	5	0.132	1,503,785	0.054	766,922	736,863	49.00	1.43	1.27
	6	0.131	1,721,962	0.083	1,513,674	208,288	12.10	1.71	0.77
	7	0.125	1,733,073	0.069	1,361,128	371,945	21.46	3.59	2.14