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EXECUTIVE SUMMARY

INTRODUCTION

This report was prepared under a contract between Limno-Tech, Inc. (LTI) and the Southwest Florida Water Management District (SWFWMD) for a diagnostic assessment study of the Upper Hillsborough River watershed. The Hillsborough River drains more than 695 mi$^2$ of predominantly agricultural lands in Pasco, Polk, and Hillsborough Counties. The present investigation focused on a 650 mi$^2$ area encompassing the northern and central drainage segments of the Hillsborough River Watershed (Figure E-1). Of particular concern to this investigation is the Hillsborough River reservoir, which is designated as a Class I water based on its use as a potable water supply. Water quality in the reservoir is characterized by low dissolved oxygen, and high concentrations of nutrients and metals. Seasonally occurring algal blooms are mitigated by the routine application of copper sulfate-based algaecide by the City of Tampa.

GOAL

The goal of the investigation was to quantitatively evaluate sources of pollutants within the watershed such that problem areas are identified and ranked, and future efforts effectively directed towards the management of water quality to protect and enhance natural resources. This goal was addressed through the development and application of watershed and reservoir models that describe pollutant generation from the watershed, and the response of the reservoir water quality to those pollutants. In particular, the SWFWMD's Linked Watershed/Waterbody Model (LWWM) served as the primary basis for all modeling analyses.

WATERSHED HYDROLOGIC ANALYSIS

Estimates of hydraulic loadings to the Hillsborough River Reservoir were developed for 1983, 1987, and 1990, selected as years that best represent wet, dry, and average conditions. The estimated loadings compared well with monthly and annual flows observed at the reservoir dam during 1987. The hydrologic model was found to generally over-estimate flows during both 1983 and 1990.

Table E-1 presents a summary of the estimated relative contribution of each major input or loss to the annual hydrologic budget of the reservoir. Pumpage to the reservoir from the Tampa Bypass Canal and Sulphur Springs represent significant inputs during dry years, and water treatment plant withdrawals are significant in all three years examined. The relative percent of net flow over the dam varies significantly among the three years.
Figure E-1. The Upper Hillsborough River Watershed.

Source: GIS layers from Southwest Florida Water Management District.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>1983</th>
<th>1987</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated Total Stream Flow</td>
<td>94.6%</td>
<td>93.5%</td>
<td>75.1%</td>
</tr>
<tr>
<td>Estimated Total Stream Inputs below Fowler Ave.</td>
<td>5.0%</td>
<td>6.0%</td>
<td>9.3%</td>
</tr>
<tr>
<td>Direct Rainfall</td>
<td>0.4%</td>
<td>0.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>TBC Pumpage to Reservoir</td>
<td>no data</td>
<td>no data</td>
<td>13.0%</td>
</tr>
<tr>
<td>Sulphur Springs Pumpage to Reservoir</td>
<td>no data</td>
<td>no data</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

Losses

<table>
<thead>
<tr>
<th></th>
<th>1983</th>
<th>1987</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Treatment Plant Withdrawal</td>
<td>9.6%</td>
<td>17.8%</td>
<td>56.0%</td>
</tr>
<tr>
<td>Direct Evapo-transpiration</td>
<td>0.3%</td>
<td>0.5%</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

Discharge

<table>
<thead>
<tr>
<th></th>
<th>1983</th>
<th>1987</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Net Flow</td>
<td>90.0%</td>
<td>81.7%</td>
<td>42.6%</td>
</tr>
</tbody>
</table>

NUTRIENT LOAD ESTIMATES

Loading estimates were developed for nitrogen and phosphorus (Table E-2). The distribution of monthly loads was observed to vary among the years examined. For 1987, the peak monthly loads were in April. Comparing high and low stream flow seasons (i.e., July through October, and November through June, respectively) during 1987, approximately 21 percent of the phosphorus load was delivered during the high flow season. The nitrogen loading trend during 1987 is generally similar to that of phosphorus.


<table>
<thead>
<tr>
<th>Source of Loading</th>
<th>Total Phosphorus (tons)</th>
<th>Total Nitrogen (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream of Fowler Ave.</td>
<td>194.5</td>
<td>153.8</td>
</tr>
<tr>
<td>Downstream of Fowler Ave.</td>
<td>14.4</td>
<td>18.1</td>
</tr>
<tr>
<td>Tampa Bypass Canal</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Sulphur Springs</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Groundwater</td>
<td>2.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Total load</td>
<td>211.0</td>
<td>176.6</td>
</tr>
</tbody>
</table>

* No available flow data.

WATER QUALITY GOALS AND LOADING TARGETS

Water quality goals were investigated based on the designated uses of the Hillsborough River reservoir (i.e., potable water supply, recreation, and propagation and maintenance of fish and wildlife.) and similar goals developed for Lake Thonotosassa. Preliminary water quality targets were developed, with an emphasis on chlorophyll a and nutrients (Table E-3).
Table E-3. Summary of Preliminary Nutrient and Chlorophyll a Targets for the Hillsborough River Reservoir.

<table>
<thead>
<tr>
<th>Water Quality Parameter</th>
<th>Target Concentration</th>
<th>Justification/Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen</td>
<td>1.0 mg/l</td>
<td>Long-term average under existing conditions, consistent with TBNEP recommendations.</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>0.07 mg/L</td>
<td>Concentration based on model-predicted requirements to meet chlorophyll a target.</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>20.0 µg/L</td>
<td>Corresponds to a FDEP TSI value of 60.</td>
</tr>
</tbody>
</table>

Target loads for phosphorus were estimated by modifying the calibrated Hillsborough River reservoir water quality model to remove the influence of algaecide applications, and running it for 1983, 1987, and 1990. The modeling results indicated an average chlorophyll a concentration goal of 20 µg/L may be attained in the reservoir with an approximate 80 percent reduction in watershed phosphorus loading relative to 1987, which corresponds to an average annual watershed phosphorus load of approximately 34 tons/year.

Based on the TBNEP target of maintaining loads at 1992-94 levels, a target average total annual nitrogen load of approximately 309 tons/year was identified.

LOAD REDUCTION ALLOCATION

Reductions in point source discharges since 1987 have already provided an approximate 48 percent reduction in annual watershed phosphorus loads. The evaluation of future load reduction targets was conducted taking these reductions into account. The resulting target for watershed phosphorus load reductions was 62 percent. The principal source of both phosphorus and nitrogen loading in the watershed was identified as surface runoff. Existing point source discharges appear to be relatively minor sources of nutrients in the watershed.

Attaining a 62 percent reduction in existing watershed phosphorus loading is an ambitious goal. It is advisable to set interim load reduction goals, and provide for periodic reassessment of the progress made and the appropriateness of the goals. Suggested interim phosphorus load reduction goals are provided in Table E-4. It should be noted that the annual phosphorus loads shown in the table are approximations, based on 1987 as an “average” year. Actual loading on any given year will be strongly influenced by precipitation.
Table E-4. Suggested Interim Phosphorus Load Reduction Goals.

<table>
<thead>
<tr>
<th>Years from Initiation of Load Reduction Program</th>
<th>Phosphorus Load Reduction Relative to Current Conditions</th>
<th>Approximate Annual Phosphorus Load (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>72</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
<td>63</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>34</td>
</tr>
</tbody>
</table>

The schedule of interim reductions presented in Table E-4 is intended as a starting point. Implementation will require consensus among the diverse stakeholders in the watershed, and some revisions are likely to be required to ensure that consensus.

IDENTIFICATION OF PRIORITY SUBBASINS

Figures E-2 and E-3 present identified priority ranked subbasins based on runoff unit area loading values for contributions of phosphorus and nitrogen, respectively, from surface runoff. The results indicate that the priority subbasins tend to fall in the more developed areas of Tampa and western Polk County. The identified priority subbasins are relevant for both development of targeted nutrient reduction programs, as well as where trading opportunities might be sought involving reductions in certain existing sources in return for increases in others (e.g., to counteract the influence of urbanization).

RECOMMENDATIONS

The following recommendations are provided for future watershed management efforts, research, model development, and data collection and management:

- A target chlorophyll a concentration of 20 μg/L should be adopted, based on a target TSI of 60, and reflecting the naturally occurring eutrophic conditions in this system. This target will facilitate significant reduction in the Tampa Water Treatment Plant’s need to use algaecide. Once significant phosphorus load reductions have been achieved, and additional monitoring data collected, the feasibility of totally eliminating algaecide applications should be revisited.

- A schedule of interim load reduction targets is recommended, with incremental reduction milestones over a 30-year period leading to attainment of the final goal. This process should include periodic assessment of the progress made and revisiting of the load reduction goals to ensure that they are still appropriate.
Figure E-2. Priority Subbasins Based on Total Estimated Unit Area Loads for Phosphorus from Runoff.
Figure E-3. Priority Subbasins Based on Total Estimated Unit Area Loads for Nitrogen from Runoff.

ESTIMATED ANNUAL TOTAL NITROGEN (TN) AREAL LOADING FROM RUNOFF BY SUBBASIN

Upper Hillsborough River Watershed

Potential TN areal loading

95th PERCENTILE

\( \geq 4.27 \text{ lb/ ac-yr} \)

80th PERCENTILE

3.69 - 4.17 lb/ ac-yr

70th PERCENTILE

3.41 - 3.65 lb/ ac-yr

SWMM model results calculated by Limno-Tech, Inc. Base GIS map layers from Southwest Florida Water Management District.

/ctrw25/5/tae/mapa/small tn runoff.map
• Additional water quality monitoring stations in the reservoir should be added to the ongoing monitoring programs to provide a higher level of spatial and temporal resolution in the characterization of water quality in the reservoir, and in doing so support future modeling efforts.

• The HCEPC and TBSG monitoring programs should be coordinated to assure that comparable methods of sampling and analysis are used. Greater coordination of these programs is likely to result in a superior database of water quality measurements for the reservoir.

• Nutrient levels in the reservoir sediments should be measured as an initial step in characterizing the influence of sediments on the nutrient budget of the reservoir. Additionally, several locations in the reservoir should be measured to assess spatial variability in sediment nutrient levels, because sediments are likely to be accumulating at a faster rate behind the dam. Further consideration of sediment-water interactions should only be undertaken once this information has been collected and analyzed.

• A significant factor reducing the efficiency of this study was a general lack of a clear definition of data availability and quality. Many organizations collect data in this watershed, but the format, quality, completeness, etc. of the data vary significantly. Moreover, the criteria for judging data adequacy relative to the needs of a particular organization may bear little relevance to the data requirements for model development, calibration, and application. In the future, the SWFWMD should precede all watershed studies with a separately funded data identification, compilation, and assessment phase that can serve as a confident basis for planning subsequent modeling activities. In the absence of either adequate data or project resources to conduct a preliminary data characterization step, simpler models should be used as a matter of course.
SECTION 1. INTRODUCTION

This report was prepared under a contract between Limno-Tech, Inc. (LTI) and the South Florida Water Management District (SFWMD) for a diagnostic feasibility study of the Upper Hillsborough River watershed. The overall goal of this study is to develop water quality and pollutant load reduction targets for the management of the Hillsborough River Reservoir. This goal was addressed through the development and application of watershed and reservoir models that describe pollutant generation from the watershed, and the response of the reservoir water quality to those pollutants. A conceptual flow chart of the major elements of the overall study is presented in Figure I-1, below.

![Conceptual Flow Chart](image)

Figure 1-1. Relationship Among the Major Elements of the Upper Hillsborough River Watershed Investigation.

The purpose of this report is to describe the results of the hydrologic and water quality modeling of the upper Hillsborough River watershed and the Hillsborough River reservoir, and from that information describe the development of appropriate water quality and nutrient loading targets. Several previously submitted technical reports have been incorporated into the current document as part of the effort to present a complete documentation of the work conducted.

1.1 BACKGROUND

The Hillsborough River drains more than 695 square miles of predominantly agricultural lands in Pasco, Polk, and Hillsborough Counties. The drainage basin is one of eight that comprise the Tampa Bay watershed. The upper and central portions of the Hillsborough River drainage basin are rural, while the southern-most segment consists of predominantly urban and industrial areas within the City of Tampa (Figure 1-2). Incorporated urban areas within the basin consist of Tampa, Temple Terrace, Plant City, and Zephyrhills.
Figure 1-2. The Upper Hillsborough River Watershed.
Major surface water features in the Hillsborough River Watershed include perennial tributaries (i.e., Big Ditch, Blackwater Creek, and Flint Creek), and a number of intermittent tributary streams (e.g., Indian Creek, Two Hole Branch, New River, etc.). Major impoundments in the watershed consist of the Tampa Reservoir, which was built in 1945 and serves as a source of water for the City of Tampa, and Lake Thonotosassa. The Lake Thonotosassa watershed is the largest of the upper Hillsborough River tributary basins. There are also a number of smaller lakes towards the headwaters of the system.

A key feature in the hydrology of the system is the Tampa Bypass Canal. The Bypass Canal was constructed over a period between 1966 and 1981 as part of the Four River Basins Project, a US Army Corps of Engineers initiative. The purpose of the Bypass Canal is to control flooding in developed areas by diverting water from the Hillsborough River to the Palm River and into Tampa Bay. The history and operating characteristics of the Bypass Canal are thoroughly discussed in Environmental Assessment of the Palm River, Tampa/Hillsborough County, Florida (HDR, 1994).

A comprehensive review of the hydrology, and water quality of the Hillsborough River Watershed is provided by Wolfe and Drew (1990). This reference also presents comprehensive descriptions of flora and fauna of the region. An annotated bibliography on the hydrogeology of the area is presented by Schreuder and Davis (1993).

The present investigation focused on a geographic area encompassing the northern and central drainage segments of the Hillsborough River Watershed. The northern segment consists of all named tributaries and lands upstream of the point where the Hillsborough River passes Fletcher Avenue. This drainage basin is predominantly rural, and includes extensive wetland forests.

The central segment represents lands draining to the Hillsborough River between Fletcher Avenue and the dam at the Tampa Reservoir. This portion of the system is dominated by urban neighborhoods of Temple Terrace and Tampa.

1.2 NATURE OF THE PROBLEM
The Tampa Bay National Estuary Program (TBNEP) concluded that, among the major drainage basins, the Hillsborough River Basin is the largest contributor of suspended solids to the Bay, and represents a significant source of nitrogen and phosphorus loading (Coastal, 1994). To meet resource-based water quality targets established for the Bay by the TBNEP, attention is being directed towards appropriate load reductions in the contributing basins.

In addition, the Hillsborough River is itself a valuable resource that must be protected. The upper Hillsborough basin includes the Hillsborough River State Park, Hillsborough Wildlife Management Area, and the Green Swamp Wildlife Management Area, as well as extensive wetland forests. Of immediate concern to this investigation is the Hillsborough River reservoir, which is designated as a Class I water based on its use as a potable water supply.
Water quality in the Hillsborough River system varies significantly with location, reflecting point and nonpoint sources, as well as characteristics of the drainage courses and the assimilative capacity of the system (Wolfe and Drew, 1990). Water quality in the reservoir is characterized by low dissolved oxygen, and high concentrations of nutrients and metals. Algal blooms are common during the late-spring and early summer when residence time and temperatures are elevated. The magnitude and duration of these blooms are mitigated by the routine application of copper sulfate-based algaecide by the City of Tampa.

The Hillsborough River watershed is of specific interest to several ongoing water quality and environmental management programs, and has been recognized as being a high priority by at least three District programs. The Hillsborough River is a major tributary to Tampa Bay, which is a District SWIM priority waterbody. The District has recently decided to use the Hillsborough River as a pilot for development of a comprehensive surface water management plan (CSWP). The largest tributary watershed within the basin is that of Lake Thonotosassa, which is another SWIM priority waterbody. SWIM Plans were issued for Lake Thonotosassa in 1990 and 1996. In 1992, the District conducted a diagnostic watershed assessment (Dynamac, 1992), and a preliminary evaluation of BMP opportunities throughout the watershed was conducted in 1995.

In addition to the District programs, the Florida Department of Environmental Protection (FDEP) designated the Hillsborough River as a pilot for the development of an ecosystem-based resource management plan, and a Greenways Task Force is active in the watershed. There are also several ongoing related monitoring and management programs being conducted by local agencies within the watershed.

1.3 PROJECT OBJECTIVES

The goal of the investigation was to quantitatively evaluate sources of pollutants within the watershed such that problem areas could be identified and ranked, and future efforts effectively directed towards the management of water quality to protect and enhance natural resources. The following objectives drove the investigation:

- Map locations of existing point and nonpoint pollution sources.
- Map current land-uses in the watershed.
- Refine existing loading estimates for nitrogen, phosphorus, total suspended sediments to the reservoir under current conditions.
- Identify and rank specific subbasins within the watershed that represent problematic sources of loadings to the reservoir.
- Estimate timing and volumes of freshwater inputs to river segments.
- Develop water and nutrient budgets for the selected river segments.
- Develop resource-based water quality targets and associated pollution load reduction goals for the reservoir.
1.4 **REPORT STRUCTURE**

This report is structured as a series of Sections, each of which covers a particular aspect of the investigation. Section 2 presents a characterization of the watershed and reservoir in terms of data that were compiled to support the analyses. Section 3 provides a discussion of the watershed hydrology, as developed through modeling. Section 4 focuses on a characterization of pollutant loads from the watershed to the reservoir. Section 5 describes the adaptation and application of the WASP5 model to the simulation of water quality in the reservoir as a function of hydrologic and pollutant loads. In Section 6, the designated uses and requirements of the reservoir are used as the basis for determining water quality and nutrient loading targets. Priority subbasins in the watershed where management efforts should be focused are identified in Section 7. Finally, Section 8 presents recommendations for future investigations and management activities.
SECTION 2. WATERSHED CHARACTERIZATION

This section presents a summary of available information that was compiled on watershed characteristics and pollutant sources.

2.1 LAND USE AND SOILS

Land use and soils information was obtained from SWFWMD as Arc/Info data files, referenced to 1990. The original data file contained 54 FLUCCS land use classifications.

2.2 POTENTIAL SOURCES OF POLLUTANTS

In addition to overland runoff, other potential sources of pollutants were investigated. Details on the information that was reviewed are presented in the following sub-sections.

2.2.1 NPDES Dischargers

A list of NPDES dischargers in Hillsborough, Polk, and Pasco Counties was obtained from the Florida Department of Environmental Protection’s (FDEP’s) Bureau of Water Facilities Planning and Regulation. Dischargers within the Upper Hillsborough River watershed were identified by mapping facility location and overlaying the watershed boundary coverage provided by SWFWMD. These locations were verified by comparison to lists of NPDES dischargers provided by U.S. EPA and a table in SWFWMD (1995). Quantification of the nutrient loads from permitted NPDES dischargers was based largely on estimated loads to Tampa Bay reported by TBNEP (Coastal, 1994). Table 2-1 presents the final list of NPDES dischargers identified through this process, along with average annual loadings for the period of 1985 - 1991, as reported by the TBNEP, coupled with data on the Plant City WWTP reported by Dynamac (1992). The locations of the listed dischargers are shown in Figure 2-1. As noted in Table 2-1, several of the facilities have either ceased discharging (e.g., Florida Sno-Man), or have significantly changed the nature of their discharges (e.g., the Plant City STP has recently gone to a reuse operation with reduced discharge to Blackwater Creek). With these considerations in mind, the information in Table 2-1 provides a sound basis for characterizing loads from these discharges.

2.2.2 Superfund Sites

A coverage of National Priority List ("Superfund") sites was compiled from several sources: a list in the 1994 Florida Water Quality Assessment 305(b) report, lists of NPL and state sites provided by FDEP, and output from the U.S. EPA’s Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) database. Much disagreement exists among these sources regarding actual location of sites. Locations as mapped are best estimates based only on available sources. Limno-Tech created a new coverage of other CERCLIS sites from an electronic U.S. EPA list of all CERCLIS sites, converting the latitudes and longitudes to UTM zone 17 and clipping to the watershed.
Table 2-1. Summary of NPDES Discharge Permits in the Watershed.

<table>
<thead>
<tr>
<th>Facility Name</th>
<th>Average Loadings (tons/year)&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phosphorus</td>
</tr>
<tr>
<td><strong>Industrial Dischargers</strong></td>
<td></td>
</tr>
<tr>
<td>Alpha Owens Corning</td>
<td>na</td>
</tr>
<tr>
<td>CF Industries, Plant City</td>
<td>6.9</td>
</tr>
<tr>
<td>City of Tampa Waterworks</td>
<td>0.0</td>
</tr>
<tr>
<td>Crystals Int'l-Plant City</td>
<td>0.0</td>
</tr>
<tr>
<td>CSX Transportation - Winston Yard</td>
<td>0.4</td>
</tr>
<tr>
<td>Florida Juice, Inc.</td>
<td>1.1</td>
</tr>
<tr>
<td>Florida Sno-Man&lt;sup&gt;2&lt;/sup&gt;</td>
<td>69.4</td>
</tr>
<tr>
<td>Plaza Materials Corp&lt;sup&gt;3&lt;/sup&gt;</td>
<td>na</td>
</tr>
<tr>
<td><strong>Municipal Dischargers</strong></td>
<td></td>
</tr>
<tr>
<td>Country Meadows WWTP&lt;sup&gt;4&lt;/sup&gt;</td>
<td>0.0</td>
</tr>
<tr>
<td>Pebble Creek Village</td>
<td>0.9</td>
</tr>
<tr>
<td>Plant City STP per Dynamac, 1992</td>
<td>14.7</td>
</tr>
<tr>
<td>Plant City STP per Coastal, 1994&lt;sup&gt;5&lt;/sup&gt;</td>
<td>4.1</td>
</tr>
<tr>
<td>Valrico WWTP&lt;sup&gt;6&lt;/sup&gt;</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:
1. From Coastal (1994) unless otherwise noted
2. No longer discharging
3. Listed by FDEP but not found in Coastal (1994)
4. Underground injection
5. Reflects current NPDES discharge permit with reuse and 2.68 MGD discharge to East Canal
6. Land application via spray irrigation

Although some of the Superfund sites do not actually lie within the Upper Hillsborough River watershed, all of these sites are included because leachate may be transported into the Tampa Reservoir via the Tampa Bypass Canal, or may travel through groundwater to the watershed. The other CERCLIS sites are assumed to be potential sources to the groundwater or the river through leachate.

No information was found to describe specific pollutants of concern or potential transport mechanisms. All NPL and CERCLIS sites are shown in Figure 2-2.

2.2.3 Septic Systems
Pollutant loadings from on-site septic systems in the Upper Hillsborough River were previously estimated by Ayres Associates for the SWFWMD SWIM Department (Ayres, 1995). The estimated annual TN and TP unit area loading by subwatershed from septic systems based on population density and housing type are shown in Figures 2-3 and 2-4, respectively. It should be noted here that there is considerable debate regarding the accuracy of the data shown in Figures 2-3 and 2-4. A central issue in this debate is the concern that the loads shown are substantially greater than those actually delivered to the surface waters in the watershed. This issue is unresolved at the time of this writing.
Figure 2-1. NPDES Permitted Discharges in the Upper Hillsborough River Watershed.

Sources:
3. Base GIS layers from Southwest Florida Water Management District.
Figure 2-2. NPL and CERCLIS Sites in the Hillsborough River Watershed.
Figure 2-3. Estimated Annual Total Phosphorus (TP) Areal Loading from Septic Systems by Subbasin (Ayres, 1995).
ESTIMATED ANNUAL TOTAL NITROGEN (TN) LOADINGS FROM SEPTIC SYSTEMS BY SUBBASIN

Upper Hillsborough River Watershed

Potential TN loadings

- **90TH PERCENTILE**: ≥ 1.11 lb/ac-yr
- **70TH PERCENTILE**: 0.79 - 1.09 lb/ac-yr
- **50TH PERCENTILE**: 0.65 - 0.73 lb/ac-yr

Drainage subbasin boundary

County boundary

POLK

HILLSBOROUGH

PASCO


Figure 2-4. Estimated Annual Total Nitrogen (TN) Loadings from Septic Systems by Subbasin (Ayres, 1995).
Figure 2-5 shows the locations of small wastewater treatment plants such as school or trailer-park operated percolation ponds as reported in SWFWMD [1995], and based on information provided by the FDEP Bureau of Water Facilities Planning and Regulation. No information was identified for quantifying loads from these sources to surface waters.

2.2.4 Land Application Sites for Sludge
Pollutant loadings from land application of sludge were estimated by Ayres Associates (Ayres, 1995). The estimated annual TN and TP unit area load by subbasin from land application sites are shown in Figures 2-6 and 2-7, respectively. As is the case with the septic system loading estimates discussed previously, there is an ongoing debate as to whether the loads shown in these figures are substantially greater than those actually delivered to the surface waters in the watershed.

2.2.5 Other Types of Land Application
Land application of citrus wastes, fish wastes, and poultry processing wastes were also mentioned as potential sources in the Upper Hillsborough River watershed. No information was identified for quantifying loads from these sources to surface waters.

2.2.6 Dairy Farms
A map showing approximate locations of dairy operations and a list of dairy farms received from Mary Sowerby of the University of Florida Cooperative Extension Service and Frank Leteux of FDEP Bureau of Water Facilities Planning and Regulation were used to create an ARC/INFO point coverage. Point attributes include operator identification, estimated farm area, and estimated number of dairy animals. The point coverage was reviewed by the Cooperative Extension Service and also compared to the 1990 land use coverage from SWFWMD. Figure 2-8 shows the location of dairy farms, as well as poultry farms, and beef, cattle, and livestock operations in the Upper Hillsborough River watershed.

All dairy farms were considered potential sources of phosphorus and nitrogen. However, no information was identified for quantifying specific loads from these sources to surface waters.

2.2.7 Poultry Farms
A map from Roger Jacobs of the University of Florida Cooperative Extension Service showing the approximate locations of the two poultry operations in the watershed was used to create an ARC/INFO point coverage. Associated attributes include the approximate size of the facility. Figure 2-8 shows the location of the poultry farms in the Upper Hillsborough River watershed. All poultry farms were considered potential sources of phosphorus and nitrogen. No information was identified for quantifying specific loads from these sources to surface waters.
Figure 2-5. Locations of Small Wastewater Treatment Plants.
Figure 2-6. Estimated Annual Total Phosphorus (TP) Loadings from Land Application by Subbasin (Ayres, 1995).
ESTIMATED ANNUAL TOTAL NITROGEN (TN) LOADINGS FROM LAND APPLICATION BY SUBBASIN

Upper Hillsborough River Watershed

Potential TN loadings

90TH PERCENTILE

\( \geq 5.64 \text{ lb/ac-yr} \)

80TH PERCENTILE

0.58 - 4.52 lb/ac-yr

70TH PERCENTILE

0.006 - 0.45 lb/ac-yr

Drainage subbasin boundary

County boundary

Figure 2-7. Estimated Annual Total Nitrogen (TN) Loadings from Land Application by Subbasin (Ayres, 1995).

2.2.8 Beef, Cattle, and Livestock Operations

The locations of other livestock operations were determined by identifying water use permit area boundaries for appropriate permits in the SWFWMD water use permit polygon coverages (WUPPOLY). Figure 2-8 shows the location of beef, cattle, and livestock operations in the Upper Hillsborough River watershed. No information was identified for specific quantifying loads from these sources.

2.2.9 Citrus Groves

The land-use polygon coverage from SWFWMD was used to identify probable areas under cultivation as citrus groves. Figure 2-9 shows the location of identified citrus groves in the Upper Hillsborough River watershed. Citrus groves are included as potential sources of pesticides and nutrients in the Upper Hillsborough River. No information was identified for quantifying specific loads from these sources.

2.2.10 Strawberry Farms

Strawberry farms were mentioned as potential sources of pollutants to the Upper Hillsborough River watershed. Strawberries are probably the primary crop in the Upper Hillsborough River Watershed, and as such would represent a large portion of the non-citrus agricultural load. However, no accurate locational information was available from the Florida Strawberry Growers Association, and no operational studies were found to support special treatment of these farms, whose nutrient contributions are already represented in the overland runoff calculations.

2.2.11 Fish Farms

Fish farms were identified in initial discussions as potential sources of pollutants to the Upper Hillsborough River watershed. However, based on conversations with Craig Watson (University of Florida Cooperative Extension Service) and Jeff Hilton and Mohammed Kader (FDEP), fish farms in the Upper Hillsborough River watershed raise tropical species which require extremely clean water. Jeff Hilton further stated that there are no discharges from fish farms significant enough to warrant attention, and that no fish farms in the Upper Hillsborough River watershed required NPDES permits. Craig Watson mentioned an EPA study which concluded that not much water was discharged from fish farms, and that the discharged water was of good quality. Fish farms were not considered as potential sources of pollutants.

2.2.12 Silviculture

Silviculture operations were also identified as potential pollutant sources to the Upper Hillsborough River watershed by Kathy Liles (FDEP). Based on conversations with Bob Deu (University of Florida Cooperative Extension Service), silviculture should not be a potential source of pollutants to the river. This conclusion is based on the strictness of permits and because the cultivation is either of cypress, which are raised in controlled wetlands, or of pine trees, which are raised in uplands remote from the water.
Figure 2-8. Locations of Dairy Farms, Poultry Farms, and Beef, Cattle, and Livestock Operations in the Upper Hillsborough River Watershed.

Figure 2-9. Locations of Identified Citrus Groves in the Upper Hillsborough River Watershed.
2.2.13 Other Potential Sources

There were several other potential sources of pollutants to the Upper Hillsborough River watershed that were investigated. These are discussed in the following paragraphs.

**Crystal Springs.** This spring supplies a large portion of the Upper Hillsborough River flow, and has been characterized as having elevated nutrient levels. Water quantity and quality measurements have been collected by USGS and were obtained for potential use in the water and nutrient budget analyses.

**Sulphur Springs.** Flow from this spring is sometimes used by the City of Tampa to augment the Hillsborough River reservoir. The discharge point to the reservoir is on the north shore immediately upstream of the dam. Limited water quantity and quality measurements are available for some years.

**Other Groundwater Sources.** In general, groundwater quality is an areawide concern because of elevated pollutant levels in surficial aquifers. In the absence of sufficient monitoring data to fully quantify the extent of the problem, it has been noted as a concern. It has also been noted that groundwater quality may be affected by several of the other sources that are depicted here, including septic systems and land use [SWFWMD, 1988].

**Tampa Bypass Canal.** The canal is noted as an area of concern because of its connection to the Hillsborough River reservoir and impacts from National Priority List and other CERCLIS (“Superfund”) sites. Limited daily pumping records and monthly water quality data for the canal were available for use in the reservoir hydrologic and nutrient modeling analyses.

2.3 AVAILABLE STREAM FLOW DATA

All available USGS stream discharge data within the watershed were obtained and compiled. Twenty-three USGS stream discharge gaging stations were identified in the upper Hillsborough River Basin (Appendix A). Data from these stations were obtained from two sources: 1) a USGS stream flow data CD ROM purchased from Earthinfo, and 2) data requests submitted to the SWFWMD. Stream discharge data used in this report are available from the District’s SWMM Program.

As discussed in Section 3, three years were selected for use in calibration to represent wet, average, and dry precipitation conditions (i.e., 1983, 1987, and 1990, respectively). Thus, only USGS gage stations where the period of record included these years were suitable for use in the modeling. An additional consideration in the selection of gaging stations was location in the watershed. The objective was to select a subset of available stations that would ensure that different areas of the watershed were adequately represented. Of the twenty-three stations identified, seven were chosen to be used in the hydrologic modeling (Table 2-2 and Figure 2-10).
Figure 2-10. Locations of USGS Stream Monitoring Used in this Investigation.
Table 2-2. Summary of USGS Stream Gaging Stations that Supplied Data used in this Investigation.

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Period of Record</th>
<th>Lat.</th>
<th>Long.</th>
<th>Drainage Area (Mi²)</th>
<th>County</th>
</tr>
</thead>
<tbody>
<tr>
<td>02302500</td>
<td>Blackwater Ck. N. Knights, FL</td>
<td>1951-96</td>
<td>28° 8' 25&quot;</td>
<td>82° 9' 0&quot;</td>
<td>110</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02303000</td>
<td>Hillsborough R. Nr. Zephyrhills, FL</td>
<td>1939-96</td>
<td>28° 8' 59&quot;</td>
<td>82° 13' 57&quot;</td>
<td>220</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02303300</td>
<td>Flint Ck. Nr. Thonotosassa, FL</td>
<td>1956-91</td>
<td>28° 4' 4&quot;</td>
<td>82° 16' 4&quot;</td>
<td>60</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02303330</td>
<td>Hillsborough R. at Morris Bridge Nr. Thonotosassa, FL</td>
<td>1972-96</td>
<td>28° 5' 50&quot;</td>
<td>82° 18' 45&quot;</td>
<td>375</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02303350</td>
<td>Trout Ck. Nr. Sulphur Springs, FL</td>
<td>1974-96</td>
<td>28° 8' 20&quot;</td>
<td>82° 21' 50&quot;</td>
<td>23</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02303420</td>
<td>Cypress Ck. at Worthington Gardens, FL</td>
<td>1974-96</td>
<td>28° 11' 8&quot;</td>
<td>82° 24' 3&quot;</td>
<td>117</td>
<td>Pasco</td>
</tr>
<tr>
<td>02303800</td>
<td>Cypress Ck. Nr. Sulphur Springs, FL</td>
<td>1964-96</td>
<td>28° 5' 20&quot;</td>
<td>82° 24' 33&quot;</td>
<td>160</td>
<td>Hillsborough</td>
</tr>
<tr>
<td>02304500</td>
<td>Hillsborough R. Nr. Tampa, FL</td>
<td>1938-90, 1991-96</td>
<td>28° 1' 25&quot;</td>
<td>82° 25' 41&quot;</td>
<td>650</td>
<td>Hillsborough</td>
</tr>
</tbody>
</table>

2.4 AVAILABLE WATER QUALITY DATA

Water quality monitoring data in the watershed were obtained from three sources, as summarized in the following subsections. Data used in this report are available from the District’s SWMM Program.

2.4.1 Hillsborough County Environmental Protection Commission (HCEPC)

The Hillsborough County Environmental Protection Commission (HCEPC) conducts monthly water quality monitoring at 12 locations in the watershed, as listed in Table 2-3, and shown in Figure 2-11. In general, these stations were monitored monthly, with a varying suite of water quality parameters reported, including phosphorus and nitrogen species at most stations. Unfortunately, total suspended solids (TSS) data were only available for a limited number of stations and dates.

2.4.2 United States Geological Survey (USGS)

Limited water quality monitoring data were available for a subset of the USGS gaging stations in the watershed, as listed in Table 2-4. Water quality monitoring data were available at varying intervals of approximately every two months during the three years of interest (i.e., 1983, 1987, and 1990). Water quality parameters varied among stations, but generally included total nutrients.
Figure 2-11. Locations of Environmental Protection Commission of Hillsborough County Water Quality Monitoring Stations in the Upper Hillsborough River Watershed.
### Table 2-3. Summary of HCEPC Water Quality Monitoring Stations in the Upper Hillsborough River Watershed.

<table>
<thead>
<tr>
<th>Station No.</th>
<th>Description</th>
<th>Period of Data Retrieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>105</td>
<td>Hillsborough River @ SR 585</td>
<td>1/74 - 12/94</td>
</tr>
<tr>
<td>106</td>
<td>Hillsborough River @ SR 582</td>
<td>1/74 - 12/94</td>
</tr>
<tr>
<td>107</td>
<td>Baker Creek @ Thonotosassa Rd.</td>
<td>1/74 - 12/94</td>
</tr>
<tr>
<td>108</td>
<td>Hillsborough River @ US 301</td>
<td>1/74 - 12/94</td>
</tr>
<tr>
<td>118</td>
<td>Lake Thonotosassa @ Flint Creek</td>
<td>1/74 - 12/94</td>
</tr>
<tr>
<td>120</td>
<td>Cypress Creek @ SR 581</td>
<td>5/76 - 12/94</td>
</tr>
<tr>
<td>135</td>
<td>Lake Thonotosassa (center)</td>
<td>2/77 - 12/94</td>
</tr>
<tr>
<td>143</td>
<td>Blackwater Creek @ SR 39</td>
<td>1/88 - 12/94</td>
</tr>
<tr>
<td>145</td>
<td>Trout Creek @ SR 581</td>
<td>1/89 - 12/94</td>
</tr>
<tr>
<td>148</td>
<td>Flint Creek @ US 301</td>
<td>9/89 - 12/94</td>
</tr>
<tr>
<td>149</td>
<td>Mill Creek @ I-4</td>
<td>8/90 - 12/94</td>
</tr>
<tr>
<td>150</td>
<td>Mill Creek @ Alexander St.</td>
<td>10/90 - 12/94</td>
</tr>
</tbody>
</table>

### Table 2-4. Summary of USGS Water Quality Monitoring Stations in the Upper Hillsborough River Watershed.

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Station Name</th>
<th>Water Quality Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>02302500</td>
<td>Blackwater Ck. N. Knights, FL</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>02303000</td>
<td>Hillsborough R. Nr. Zephyrhills, FL</td>
<td>7</td>
</tr>
<tr>
<td></td>
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<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>02303300</td>
<td>Flint Ck. Nr. Thonotosassa, FL</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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<td>6</td>
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<tr>
<td>02303330</td>
<td>Hillsborough R. at Morris Bridge Nr. Thonotosassa, FL</td>
<td>5</td>
</tr>
<tr>
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</tr>
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<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>02303420</td>
<td>Cypress Ck. at Worthington Gardens, FL</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>02303800</td>
<td>Cypress Ck. Nr. Sulphur Springs, FL</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>
2.4.3 City of Tampa

The City of Tampa Bay Study Program collected water quality data at two stations in the Hillsborough River in the immediate vicinity of the Hillsborough River reservoir (Figure 2-12). The first station is located at Busch Ave. (Station 25) and the second is located at the 40th Street Bridge (Station 5). Monthly monitoring data were available from April 1984 through October 1995. Each monitoring event included samples collected at the surface and just off the bottom, and analyzed for nutrients, bacteria, and chlorophyll. TSS data were not available.

The City of Tampa Water Treatment Plant also monitors water quality in the raw water intakes from both the Hillsborough River reservoir and the Tampa Bypass Canal at monthly intervals as part of permit requirements. A wide range of parameters are reported, including total phosphorus, but only a subset of the nitrogen species (i.e., ammonia and nitrate) are reported. Because the data are collected for water supply purposes, the detection limits for nutrients are higher than would be normally found in limnological data (i.e., dl for TP is 0.1 mg/L). Digital data were only available as far back as 1990. Prior to that, the data exist as hard copy sheets in archives files.

2.5 AVAILABLE METEOROLOGICAL DATA

Meteorological data obtained included precipitation and evaporation data from several locations in and in the immediate vicinity of the watershed, as described in the following subsections. Meteorological data used in this report are available from the District’s SWMM Program.

2.5.1 Precipitation

Precipitation data at both daily and hourly intervals were necessary for the hydrologic modeling. Daily rainfall data were obtained for the following five precipitation stations in, or immediately outside of, the Hillsborough River Basin from National Climatic Data Center (NCDC): Plant City, Lakeland, St. Leo, Hillsborough River State Park, and the Tampa International Airport (TIA). Data were also obtained from the University of Florida Institute of Food and Agricultural Sciences (IFAS), precipitation station located in Dover, Florida. The locations of these stations are shown on Figure 2-13.

Precipitation data recorded at hourly intervals were obtained for the Lakeland, St. Leo, and TIA stations. Total daily precipitation recorded at Plant City was converted to hourly precipitation by the SWFWMD, using the hourly rainfall distribution at Lakeland.

2.5.2 Evaporation

Total daily evaporation data, measured at the IFAS Gulf Coast Research and Education Center in Dover, Florida, were supplied by the SWFWMD.
Figure 2-12. City of Tampa Bay Study Program Monitoring Stations in, and Immediately Upstream of, Hillsborough River Reservoir.
Figure 2-13. Locations of Precipitation Monitoring Stations In and Near the Upper Hillsborough River Watershed.
SECTION 3. WATERSHED HYDROLOGIC ANALYSIS

An analysis of watershed hydrology was required to support the estimation of hydraulic and pollutant loadings to the Hillsborough River Reservoir. This section discusses the methods used and the results of the analysis.

3.1 MODELING APPROACH

The hydrologic analysis was based on the selection of a modeling approach and definition of representative years to be evaluated. The results consist of a water budget for the Hillsborough River Reservoir under different representative hydrologic conditions.

3.1.1 Model Description

The original plan for conducting the hydrologic analysis was to apply the SWMM component of the SWFWMD’s linked watershed/waterbody model (LWWM) to the watershed. This model provides simulation of both water quantity and quality, and had several significant advantages relative to the objectives of the investigation. As described in a separate project report (Limno-Tech, Inc., 1997), the results of the SWMM/LWWM application indicated that the model performance was good at large spatial and temporal scales, and under average hydrologic conditions, but tended to underestimate hydraulic loads during wet years, and overestimate them during dry years.

Based on the observed performance and limitations of the SWMM/LWWM implementation, it was decided to take a hybrid approach to estimating hydraulic loadings by using monitoring data wherever possible to develop empirical estimates, supplemented by the SWMM/LWWM wherever monitoring data were inadequate. A schematic depiction of the hydrologic budget of the system, as developed for this investigation, is presented in Figure 3-1. Daily flow monitoring data from USGS stations 02303350 (Trout Creek near Sulphur Springs), 02303330 (Hillsborough River near Morris Bridge), and 02303800 (Cypress Creek near Sulphur Springs) were combined to estimate total flow at Fowler Ave. The three stations drain a total of 558 mi², or approximately 88.6% of the 630 mi² area that drains to the Fowler Ave. station. Flow at Fowler Ave. was estimated by multiplying total flows for the three USGS stations by 1.129 (i.e., 1+0.886).

It should be noted that the Fowler Ave. location was chosen because it corresponds to HCEPC water quality monitoring station 106, data from which provided a basis for estimation of nutrient loads. Originally, the intention had been to use Fletcher Ave. as the point of demarcation between the upper and middle reaches of the Hillsborough River. Fowler Ave. was subsequently used as the boundary for the practical reason that the available monitoring data better supported estimation of loads at this location.
Inputs affecting the reservoir below Fowler Ave. consist of runoff and groundwater inputs from adjacent lands, pumping from the Tampa Bypass Canal and Sulphur Springs, withdrawals by the Tampa Water Treatment Plant, and direct rainfall and evapotranspiration (ET). Runoff and groundwater inputs were estimated using the SWMM/LWWM model, as described by Limno-Tech, Inc. (1997). Available daily pumping records for the Tampa Water Treatment Plant, the Tampa Bypass Canal, and Sulphur Springs were obtained from the City of Tampa and the SWFWMD. Direct rainfall was estimated from daily meteorological records at Tampa International Airport, the closest reporting station. Daily ET was estimated from observations at the IFAS station at Dover.

3.1.2 Selection Of Wet, Dry, And Normal Water Years
An analysis of available daily precipitation data was performed to identify those years that best represent wet, dry, and average conditions in the upper Hillsborough River watershed. Daily rainfall data reported at the Plant City, St. Leo, TIA, Hillsborough River State Park (HRSP), and Lakeland precipitation stations were used to evaluate precipitation conditions throughout the watershed.

Daily precipitation values from 1981 through 1995 were examined in the analysis because this time period could be represented by current (1990) land use conditions in the watershed. From the daily precipitation values, total annual rainfall was calculated. Table 3-1 presents maximum and minimum annual rainfall at the stations examined from the years 1981-1995, as well as average annual rainfall between 1950 and 1995 calculated using the highest resolution data available for each station.
<table>
<thead>
<tr>
<th>Year</th>
<th>Plant City</th>
<th>St. Leo</th>
<th>Tampa Int'l Airport</th>
<th>HRSP</th>
<th>Lakeland</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>39.48</td>
<td>52.4</td>
<td>38.64</td>
<td>51.43</td>
<td>33.4 M</td>
</tr>
<tr>
<td>1982</td>
<td>53.06</td>
<td>69.1</td>
<td>55.81</td>
<td>61.24</td>
<td>63.1</td>
</tr>
<tr>
<td>1983</td>
<td>71.97</td>
<td>72.8</td>
<td>60.87</td>
<td>62.78</td>
<td>64.9</td>
</tr>
<tr>
<td>1984</td>
<td>44.08</td>
<td>42.9</td>
<td>32.31</td>
<td>42.77 M</td>
<td>35.6 M</td>
</tr>
<tr>
<td>1985</td>
<td>50.87</td>
<td>33.2</td>
<td>44.6</td>
<td>41.66 M</td>
<td>35.7</td>
</tr>
<tr>
<td>1986</td>
<td>60.00</td>
<td>46.7</td>
<td>41.6</td>
<td>44.31 M</td>
<td>51.8</td>
</tr>
<tr>
<td>1987</td>
<td>52.91</td>
<td>52.2</td>
<td>49.08</td>
<td>59.28 M</td>
<td>56.9</td>
</tr>
<tr>
<td>1988</td>
<td>57.22</td>
<td>59.7</td>
<td>52.33</td>
<td>61.11</td>
<td>61.8</td>
</tr>
<tr>
<td>1989</td>
<td>44.20</td>
<td>42.4</td>
<td>43.63</td>
<td>40.56</td>
<td>51.6</td>
</tr>
<tr>
<td>1990</td>
<td>39.74</td>
<td>37.1</td>
<td>34.39</td>
<td>48.27</td>
<td>38.7</td>
</tr>
<tr>
<td>1991</td>
<td>51.34</td>
<td>39.3</td>
<td>43.16</td>
<td>46.63</td>
<td>57</td>
</tr>
<tr>
<td>1992</td>
<td>58.70</td>
<td>47.9</td>
<td>34.98</td>
<td>51.69</td>
<td>49.1 M</td>
</tr>
<tr>
<td>1993</td>
<td>44.33</td>
<td>47.56</td>
<td>37.45</td>
<td>41.12</td>
<td>52.38</td>
</tr>
<tr>
<td>1994</td>
<td>64.33</td>
<td>55.78</td>
<td>45.46</td>
<td>56.87</td>
<td>62.94</td>
</tr>
<tr>
<td>1995</td>
<td>51.01</td>
<td>50.41</td>
<td>54.11</td>
<td>INCOMPLETE</td>
<td>59.74</td>
</tr>
</tbody>
</table>

**MAXIMUM RAINFALL** (since 1981)  
71.97  
72.8  
60.87  
62.78  
64.9

**MINIMUM RAINFALL** (since 1981)  
39.48  
33.2  
32.31  
40.56  
35.7

**CALCULATED AVERAGE ANNUAL RAINFALL** (1950 - 95)  
52.72  
54.75  
44.86  
52.97  
49.09

**NOTES:**

1) "M" indicates that there was missing data in that year and that annual totals are therefore not accurate.
2) The annual totals for St. Leo and Lakeland may not correspond with NCDC Summary of the Day data. Annual rainfalls for these stations were obtained from NCDC data with a finer resolution than the Summary of the Day data.
3) Averages do not take into account years with incomplete data.
In interpreting Table 3-1, it should be noted that the resolution of the original data varied among the stations appearing in this table. Hourly rainfall data were reported at the Lakeland, St. Leo, and TIA stations, while only daily totals are reported at the Plant City and HRSP stations. Moreover, there are two rainfall gages at the St. Leo station (Sam McCown, NCDC, pers. comm.). Thus, annual totals shown in Table 3-1 may not exactly correspond with totals calculated from NCDC Summary of the Day data. It should also be noted that there were data gaps during several years at both the Lakeland and HRSP stations, ensuring that the totals shown for those years are underestimates of actual precipitation. Thus, the data from the Plant City, St. Leo, and TIA stations were considered to be the most reliable representations of actual precipitation, and were given the greatest weight in the identification of representative years.

The wettest precipitation year, corresponding to the year with maximum annual rainfall, for all five precipitation stations examined occurred in 1983.

The driest precipitation year for the Plant City station, corresponding to the year with minimum annual rainfall, occurred in 1981. For the St. Leo station, the driest precipitation year occurred in 1985, while the driest conditions for the TIA station occurred in 1984. For the years with complete records at the Lakeland station, the driest year was 1985. The second driest year for all four of these stations occurred in 1990. The data from the HRSP station indicate that the pattern of driest (1989) and second driest (1993) years were different from the other stations.

For the Plant City station, the annual rainfall for the years 1982, 1987, and 1991 corresponded closely to the average annual rainfall for that station. The years 1981, 1987, and 1994 had annual rainfall at the St. Leo station that was comparable to the calculated average. For the TIA station, the years 1985, 1987, and 1994 had annual rainfall close to the average annual rainfall at that station. At the HRSP station, the rainfall in 1987 was closest to the long-term average, although there were some data missing from the records. The years 1981 and 1992 were also similar in magnitude to the long-term average at this station. Finally, at the Lakeland station, the 1992 data were closest to the calculated long-term average, although the records were incomplete for this year. Other years with near-average rainfalls reported at this station were 1986 and 1989.

Because the maximum annual rainfall for all five precipitation stations clearly occurred in 1983, this year was selected to represent a typical wet year in the Hillsborough River watershed. The driest precipitation conditions for the stations occurred in different years. In order to select a year that uniformly represented dry conditions, the year 1990, corresponding to the second driest year for four of the five precipitation stations, was selected. The year 1987 was selected to represent a normal precipitation year. The annual rainfall for four of the five stations in 1987 corresponded closely to the calculated average annual rainfall for each station. Although the selected years do not always correspond to the maximum, minimum, and average rainfall for each of the individual stations, they were chosen because they consistently represent wet, dry, and normal years.
for the stations examined. Selected years and their corresponding annual precipitation are shaded in gray in Table 3-1.

### 3.2 HYDROLOGIC BUDGET

Table 3-2 presents a summary of the hydrologic budget of the Hillsborough River reservoir for the three years of interest. Figure 3-2 presents a comparison of model estimated total monthly flows through the reservoir versus monthly flows observed at USGS station 4500, located at the reservoir dam.

The comparison of model versus observed monthly flows suggests that the flow estimates are consistent in both magnitude and trend with observed flows during 1987, with relative error ranging from 1 to 53 percent in any given month. Annual estimated and observed flows for the year were within 11 percent of each other.

The model generally over-estimates flows during both 1983 and 1990, with a much larger range of relative errors (i.e., 1 - 186 percent). Annual estimated and observed flows for 1983 differed by 40 percent. Observed flows were not available at USGS 4500 for the last three months of 1990, but the observed and estimated flows for the first nine months of that year differed by 56 percent.

Table 3-3 presents a summary of the relative contribution of each major input or loss to the annual water budget of the reservoir. From this table it can be seen that pumpage to the reservoir from the Tampa Bypass Canal and Sulphur Springs represent significant inputs during dry years, and water treatment plant withdrawals are significant in all three years examined. The relative percent of net flow over the dam varies significantly among the three years.

**Table 3-3. Relative Annual Inputs and Losses in the Water Budget of the Hillsborough River Reservoir for 1983, 1987, and 1990.**

<table>
<thead>
<tr>
<th></th>
<th>1983</th>
<th>1987</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Total Stream Flow</td>
<td>94.6%</td>
<td>93.5%</td>
<td>75.1%</td>
</tr>
<tr>
<td>Estimated Total Stream Inputs below Fowler Ave.</td>
<td>5.0%</td>
<td>6.0%</td>
<td>9.3%</td>
</tr>
<tr>
<td>Direct Rainfall</td>
<td>0.4%</td>
<td>0.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>TBC Pumpage to Reservoir</td>
<td>no data</td>
<td>no data</td>
<td>13.0%</td>
</tr>
<tr>
<td>Sulphur Springs Pumpage to Reservoir</td>
<td>no data</td>
<td>no data</td>
<td>1.6%</td>
</tr>
<tr>
<td><strong>Losses:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Treatment Plant Withdrawal</td>
<td>9.6%</td>
<td>17.8%</td>
<td>56.0%</td>
</tr>
<tr>
<td>Direct Evapo-transpiration</td>
<td>0.3%</td>
<td>0.5%</td>
<td>1.4%</td>
</tr>
<tr>
<td><strong>Discharge:</strong></td>
<td>Estimated Dam Overflow</td>
<td>90.0%</td>
<td>81.7%</td>
</tr>
</tbody>
</table>

In interpreting these results, it must be remembered that pumping flows from the Tampa Bypass Canal and Sulphur Springs were not available for 1983 and 1987.
<table>
<thead>
<tr>
<th>Time Period</th>
<th>Total Rainfall (Inches over the Entire Watershed)</th>
<th>Total Flow at Fowler Avenue</th>
<th>Total Stream Flow Inputs below Fowler Ave.</th>
<th>Other Inputs to the Hillsborough River Reservoir</th>
<th>Losses from the Hillsborough River Reservoir</th>
<th>Net Flow Through the Reservoir</th>
<th>Relative Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan-83</td>
<td>2.3</td>
<td>5.49E+07</td>
<td>5.90E+07</td>
<td>1.29E+08</td>
<td>7.22E+06</td>
<td>4.67E+07</td>
<td>42%</td>
</tr>
<tr>
<td>Feb-83</td>
<td>8.9</td>
<td>8.87E+07</td>
<td>8.87E+07</td>
<td>1.97E+08</td>
<td>1.00E+07</td>
<td>7.87E+07</td>
<td>52%</td>
</tr>
<tr>
<td>Mar-83</td>
<td>9.3</td>
<td>9.40E+07</td>
<td>9.40E+07</td>
<td>2.04E+08</td>
<td>1.13E+07</td>
<td>8.27E+07</td>
<td>56%</td>
</tr>
<tr>
<td>Apr-83</td>
<td>3.1</td>
<td>5.07E+08</td>
<td>5.07E+08</td>
<td>1.07E+08</td>
<td>7.63E+07</td>
<td>4.39E+07</td>
<td>41%</td>
</tr>
<tr>
<td>May-83</td>
<td>2.3</td>
<td>6.22E+07</td>
<td>6.22E+07</td>
<td>1.33E+08</td>
<td>7.59E+07</td>
<td>5.76E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Jun-83</td>
<td>9.7</td>
<td>9.40E+07</td>
<td>9.40E+07</td>
<td>2.07E+08</td>
<td>1.14E+07</td>
<td>8.26E+07</td>
<td>52%</td>
</tr>
<tr>
<td>Jul-83</td>
<td>6.9</td>
<td>7.30E+07</td>
<td>7.30E+07</td>
<td>1.54E+08</td>
<td>8.87E+07</td>
<td>5.00E+07</td>
<td>56%</td>
</tr>
<tr>
<td>Aug-83</td>
<td>8.3</td>
<td>8.30E+07</td>
<td>8.30E+07</td>
<td>1.75E+08</td>
<td>1.00E+07</td>
<td>7.30E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Sep-83</td>
<td>8.2</td>
<td>9.28E+07</td>
<td>9.28E+07</td>
<td>2.03E+08</td>
<td>1.12E+07</td>
<td>8.17E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Oct-83</td>
<td>2.3</td>
<td>7.79E+07</td>
<td>7.79E+07</td>
<td>1.59E+08</td>
<td>1.01E+07</td>
<td>6.78E+07</td>
<td>52%</td>
</tr>
<tr>
<td>Nov-83</td>
<td>2.5</td>
<td>8.86E+07</td>
<td>8.86E+07</td>
<td>1.77E+08</td>
<td>1.02E+07</td>
<td>7.85E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Dec-83</td>
<td>6.3</td>
<td>8.42E+08</td>
<td>8.42E+08</td>
<td>1.79E+08</td>
<td>1.04E+07</td>
<td>7.39E+08</td>
<td>41%</td>
</tr>
<tr>
<td>Total:</td>
<td>71.5</td>
<td>2.02E+10</td>
<td>2.02E+10</td>
<td>4.28E+09</td>
<td>2.51E+07</td>
<td>1.70E+10</td>
<td>56%</td>
</tr>
<tr>
<td>Jan-87</td>
<td>3.3</td>
<td>3.73E+08</td>
<td>3.73E+08</td>
<td>7.63E+07</td>
<td>4.26E+07</td>
<td>3.37E+08</td>
<td>42%</td>
</tr>
<tr>
<td>Feb-87</td>
<td>2.9</td>
<td>3.64E+08</td>
<td>3.64E+08</td>
<td>7.60E+07</td>
<td>4.24E+07</td>
<td>3.36E+08</td>
<td>41%</td>
</tr>
<tr>
<td>Mar-87</td>
<td>9.3</td>
<td>9.06E+07</td>
<td>9.06E+07</td>
<td>1.89E+08</td>
<td>1.02E+07</td>
<td>8.04E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Apr-87</td>
<td>0.4</td>
<td>9.02E+07</td>
<td>9.02E+07</td>
<td>1.87E+08</td>
<td>1.02E+07</td>
<td>8.00E+07</td>
<td>41%</td>
</tr>
<tr>
<td>May-87</td>
<td>6.7</td>
<td>6.86E+07</td>
<td>6.86E+07</td>
<td>1.46E+08</td>
<td>1.01E+07</td>
<td>5.85E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Jun-87</td>
<td>5.1</td>
<td>5.41E+07</td>
<td>5.41E+07</td>
<td>1.13E+08</td>
<td>1.00E+07</td>
<td>4.37E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Jul-87</td>
<td>6.3</td>
<td>6.26E+07</td>
<td>6.26E+07</td>
<td>1.30E+08</td>
<td>1.00E+07</td>
<td>5.27E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Aug-87</td>
<td>5.4</td>
<td>7.49E+07</td>
<td>7.49E+07</td>
<td>1.62E+08</td>
<td>1.00E+07</td>
<td>6.49E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Sep-87</td>
<td>5.5</td>
<td>8.77E+07</td>
<td>8.77E+07</td>
<td>1.86E+08</td>
<td>1.00E+07</td>
<td>7.77E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Oct-87</td>
<td>1.8</td>
<td>3.36E+08</td>
<td>3.36E+08</td>
<td>6.80E+07</td>
<td>1.00E+07</td>
<td>2.80E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Nov-87</td>
<td>5.8</td>
<td>7.45E+08</td>
<td>7.45E+08</td>
<td>1.67E+08</td>
<td>1.00E+07</td>
<td>5.84E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Dec-87</td>
<td>0.3</td>
<td>9.45E+07</td>
<td>9.45E+07</td>
<td>2.01E+08</td>
<td>1.00E+07</td>
<td>7.44E+07</td>
<td>41%</td>
</tr>
<tr>
<td>Total:</td>
<td>57.6</td>
<td>3.37E+10</td>
<td>3.37E+10</td>
<td>6.94E+08</td>
<td>1.00E+07</td>
<td>2.94E+10</td>
<td>41%</td>
</tr>
</tbody>
</table>
Figure 3-2. Comparison of Model Estimates of Total Monthly Flow Through the Hillsborough River Reservoir with Observed Monthly Flows at USGS 4500.
SECTION 4. WATERSHED POLLUTANT LOADING ANALYSIS

This section describes the development of pollutant loading estimates.

4.1 NUTRIENT LOADING ESTIMATION APPROACH

The development of pollutant (i.e., phosphorus, nitrogen, and suspended solids) loading estimates followed the same hybrid approach taken for the estimation of hydraulic inputs. Specifically, where suitable water quality monitoring data were available, they were used to calculate empirical estimates of loadings from the represented subbasins. In the absence of appropriate monitoring data, the SWMM/LWWM model was employed to estimate loadings based on flow and characteristic water quality. The details of the computational approaches are provided in the following subsections.

4.1.1 Development of Empirical Loading Estimates

The empirical loading estimates were developed by combining the previously developed flow estimates at Fowler Ave. (see Section 3.1) with monthly water quality monitoring data collected at HCEPC station 106, also located at Fowler Ave. Nutrient loading was estimated using an LTI-developed model, TRBLDEST, which calculates loads using different methods, and provides the user with the option of choosing the best load estimation based on graphic representation and statistical output. For this analysis, the following two load estimation techniques were considered:

1. Minimum Variance Unbiased Estimator (MVUE) - This is a regression estimator technique that performs well where there is a strong exponential relationship between flow and concentration. Performance declines if the data do not display this relationship.

2. Monthly Average (MA) - This technique simply applies the average observed monthly concentration of a constituent to the total flow during the month. The resulting load series is a "step function." This approach works well where data are independent and identically distributed. Where bias occurs, it is always negative (i.e., estimates are lower than observed data).

The selection of load estimation technique was based on adequacy of the data. The MVUE method is only suitable where there is a statistically significant regression relationship between flow and water quality concentrations. Poor regression relationships between flow and nutrient concentrations were generally observed in the monitoring data, which led to the conclusion that the MA method would provide the best loading estimates at all stations.

It should be noted that TSS data were unavailable at HCEPC 106, nor were TSS measurements reported at any of the City of Tampa stations in the immediate vicinity of the reservoir. Thus, loading estimates were only developed for total phosphorus and nitrogen.
4.1.2 Application of SWMM/LWWM

The SWMM/LWWM was calibrated to flow during 1987, as described in the report *Hydrologic Modeling for the Hillsborough River Watershed* (Limno-Tech, Inc., 1997), and then applied to that portion of the watershed that is below Fowler Ave. This drainage area is 20 mi² and comprises approximately 3 percent of the total drainage area of the reservoir. It should also be noted that this area is characterized by urban and suburban development, and may be expected to yield more runoff than other areas with less impervious cover.

The SWMM/LWWM calibration included a separation of flows into baseflow and runoff components. These two flow components were treated differently in generating loading estimates. For baseflows, water quality records collected at HCEPC monitoring station 106 during baseflow periods were averaged to obtain mean total phosphorus (TP) and total nitrogen (TN) concentrations. These concentrations were then applied to estimated baseflows from the drainage areas below Fowler Avenue to estimate baseflow loading. The pollutant loading from runoff in these areas was generated by SWMM/LWWM based on runoff flow and event mean concentrations (EMCs) reported by the TBNEP (Coastal, 1994). The two loading components were then combined into a total estimated monthly loading value.

### 4.2 ESTIMATES OF NUTRIENT INPUTS

Table 4-1 presents a summary of estimated nutrient loads from stream flows and runoff to the Hillsborough River Reservoir for 1983, 1987, and 1990. Estimated loads have been presented separately for the upper and middle segments of the Hillsborough River (i.e., for inputs above and below Fowler Ave. It should be noted that the loads shown in Table 4-1 include both watershed sources and additional potential loads from Tampa Bypass Canal and Sulphur Springs pumping, as well as internal loads from sediment and groundwater fluxes. These additional potential loads are poorly represented by monitoring data, and were estimated subsequently as part of the reservoir water quality modeling (Sec. 5).


<table>
<thead>
<tr>
<th>Source of Loading</th>
<th>Total Phosphorus (tons)</th>
<th>Total Nitrogen (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed Sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upstream of Fowler Ave.</td>
<td>194.5</td>
<td>153.8</td>
</tr>
<tr>
<td>Downstream of Fowler Ave.</td>
<td>14.4</td>
<td>18.1</td>
</tr>
<tr>
<td>Other Sources</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tampa Bypass Canal</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Sulphur Springs</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Groundwater</td>
<td>2.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Total load</td>
<td>211.0</td>
<td>176.6</td>
</tr>
</tbody>
</table>

* No available flow data.
Upper Hillsborough River
Diagnostic Watershed Assessment
Final Project Report

On an annual basis, the magnitude of loading to the two segments of the river were generally consistent with the relative sizes of the drainage areas. As might be expected, the relative contribution of the drainage area contributing to the upper segment was lowest in 1990, the driest of the years examined.

The monthly distribution of watershed phosphorus and nitrogen loads (i.e., loads from runoff and stream baseflows) is presented in Figures 4-1 and 4-2, respectively. The distribution of monthly loads varies among the years examined. For 1987, the peak monthly loads were in April, representing 39 percent of the annual phosphorus load and 28 percent of the annual nitrogen load. Comparing high and low stream flow seasons (i.e., July through October, and November through June, respectively) during 1987, approximately 21 percent of the phosphorus load was delivered during the high flow season. The nitrogen loading trend during 1987 is generally similar to that of phosphorus.

The monthly patterns are different for the other years examined. In particular, peak phosphorus loads occurred during the high stream flow season in both years, with more than half of the annual load being delivered during the months of July through October. Again, the distribution of monthly nitrogen loads followed a generally similar pattern, although peak nitrogen loads during March of 1983 were nearly as great as those observed in September of that year.
Figure 4-1. Monthly Estimated Watershed Phosphorus Loading.
Figure 4-2. Monthly Estimated Watershed Nitrogen Loading.
SECTION 5. RESERVOIR MODELING ANALYSIS

This section describes the adaptation and application of the WASP5 eutrophication model, EUTROS, for simulation of water quality in the Hillsborough River reservoir as a function of nutrient pollutant loads, and hydrologic and environmental conditions.

5.1 BACKGROUND

As discussed in previous sections of this report, the Hillsborough River reservoir exhibits seasonal (late spring and summer) water quality problems of low dissolved oxygen and algal blooms due to the relatively high loading rate of nutrients from external sources. The algal blooms are currently controlled by the City of Tampa through the application of copper sulfate-based algaecide. However, the reservoir is used by the City as a potable water supply, and alternative methods for controlling algal levels are a major management interest. A eutrophication model for the reservoir, as described in this section of the report, was developed to provide the SWFWMD with a tools for evaluating the water quality effects of controlling nutrient loads to the reservoir under conditions where algaecides are not applied. The predicted response of the reservoir to reduced nutrient loads is a key factor in determining an appropriate management approach for meeting water quality goals in the reservoir.

The goal of the eutrophication model development is to quantitatively evaluate the impact of sources of nutrient loads on water quality so that future management efforts are effectively directed to protect and enhance natural resources. Of particular interest is the use of the model to develop resource-based water quality targets and associated nutrient load reduction goals for the reservoir.

The following sections describe the development and application of a WASP5-based, but modified, EUTROS dynamic phytoplankton simulation model for the Hillsborough River reservoir.

5.1.1 Limitations

Several data-related issues introduce significant uncertainty to the application of the WASP5 eutrophication model, EUTROS, to the Hillsborough River reservoir. These data uncertainties restrict, or limit, the ability of the model to accurately predict algal dynamics and the variation of other water quality parameters. The sources of these uncertainties are summarized in the following paragraphs.

Characterization of Nutrient Loads

The ability of EUTROS to predict day-to-day variations in water quality is limited by the lack of adequate upstream data for estimating pollutant loads on a daily basis. Nutrient concentration measurements are available upstream of the reservoir at approximately monthly intervals. Inflows to the reservoir can be highly variable from day to day, and
monthly water quality monitoring provides only a rough characterization of the magnitude of external nutrient loads.

Additionally, only limited information is available to fractionate the upstream phosphorus levels between inorganic (as orthophosphate) and organic forms. Observed values for orthophosphate phosphorus were available for just two sampling dates (both in 1990) over the selected simulation years of 1983, 1987, and 1990. To address this data inadequacy, a regression relationship was developed between total phosphorus and orthophosphate phosphorus using data for 1990 - 1994 at HCEPC 106. The regression resulted in use of a constant split for total phosphorus loads of approximately 90% orthophosphate and 10% organic phosphorus. Any seasonal variability or long term trends in this distribution are not represented in the loads input to the model, so the uncertainty associated in characterizing this split must be considered a model limitation. This limitation is especially relevant when the model is used to forecast the reservoir response to load reductions that may affect the distribution of dissolved and particulate forms of phosphorus.

Characterization of Reservoir Operations

Hillsborough Reservoir water levels (and volumes) appear to be highly variable over relatively short (daily to weekly) time scales. Differences in reported flow measurements between USGS gages, downstream and upstream of the reservoir, fluctuate widely from positive to negative on a daily basis. The differences are often significantly greater than can be accounted for by available information for other sources and losses (i.e. direct runoff, and Tampa Bypass Canal and Sulphur Springs pumpage, Tampa WTP withdrawals, and evaporation) of water to the reservoir. This suggests that dam operations control the storage and release of reservoir water on a daily basis, however no information is currently available to characterize these operations and their effect on reservoir water levels.

Additionally, pumpage rate information for Tampa Bypass Canal and Sulphur Springs water transfers is unavailable for 1983, and 1987, and is only available on a monthly basis for 1990. Unmeasured daily variability and the general lack of information to characterize these pumpages may lead to under- or over-estimation of pollutant loads from these sources, and may also significantly limit the ability of the EUTRO5 model to characterize the day-to-day variability of water quality conditions within the reservoir.

A very significant operations factor which limits the capability of EUTRO5 to accurately predict Hillsborough River Reservoir water quality is the minimal information available describing the application times, locations, and dosage rates of algaecide for the selected model simulation years of 1983, 1987, and 1990. Additionally, it is unknown how the algaecide applications may have disrupted water column and sediment microbial communities and affected biologically-mediated processes, such as nitrification, denitrification, and the oxidation of non-living organic carbon material (represented as CBOD in EUTRO5). The ability of EUTRO5 to accurately predict levels of ammonia,
and nitrite-nitrate nitrogen forms within the reservoir may be limited by these factors. However, the assumption that nitrogen-fixation by blue-green algae can take place under non-dosing conditions reduces the significance of this uncertainty; at least as far as it relates to overall algal production in the reservoir.

5.1.2 Available Monitoring Data

A detailed discussion of available data sets for characterizing water quality conditions in the Hillsborough River and reservoir was presented in Section 2 of this report. Section 4 of this report describes the processing of water quality data collected at stations upstream of the reservoir to estimate pollutant mass loads for the selected average, wet, and dry simulation years (1987, 1983, and 1990, respectively). This report section discusses the sources of information used to characterize environmental (e.g. temperature, wind, solar radiation) and instream water quality conditions for model calibration purposes.

Hydrologic Data

The hybrid approach used to estimate hydraulic loads to the reservoir is presented in Section 3.1 of this report. The USGS station 02304500, just downstream of the reservoir dam, provided daily measurement of outflow from the reservoir.

Measured daily evaporation rates at Dover, Florida are available from August through December in 1983, and for all of 1987, and 1990. Evaporative water losses from the reservoir were estimated from this data and incorporated within the EUTRO5 model on a daily basis. January through July 1983 evaporation were estimated in the EUTRO5 model based on 1987 conditions.

Additionally, managed transfers of water to and from the reservoir also occur. These include: the City of Tampa Hillsborough River Water Treatment Plant withdrawals (daily measurements), and Tampa Bypass Canal and Sulphur Springs transfers (partial record of 1990 monthly volume pumped to the reservoir only).

No information on groundwater seepage rates into or out of the reservoir is available, although this hydrologic factor appears to be relatively significant in the Hillsborough River watershed (Limno-Tech, 1996).

Environmental Data

Specific environmental data, external to the reservoir, are required as forcing conditions for the EUTRO5 model. These environmental forcing conditions include: wind speed, air temperature, and solar radiation. All of this information is available on a daily basis from NOAA's National Climatic Data Center (NCDC) databases. Daily wind speed and air temperature measurements for Tampa Airport were retrieved from the NCDC Summary of the Day-First Order on-line database. Solar radiation measurements were abstracted from the NCDC Solar and Meteorological Surface Observational Network (SAMPSON) database and converted to estimates of incident solar radiation which are suitable for input to the EUTRO5 model.
Water Quality Data

As previously discussed, historical water quality monitoring data for the Hillsborough River reservoir are available from two primary sources: Hillsborough County, and the City of Tampa.

The Hillsborough County Environmental Protection Commission (HCEPC) conducts monthly monitoring at 2 locations in the immediate vicinity of the Hillsborough River reservoir. Station HCEPC 106, located upstream of the reservoir, provides a basis for estimating upstream loads to the reservoir as discussed in Section 4.1.1. Station HCEPC 105, just downstream of the reservoir, provides a relatively reasonable database of water quality measurements which can serve as model calibration targets. The HCEPC water quality parameters relevant to the EUTROS model application include: temperature, dissolved oxygen, chlorophyll a, BOD5, and forms of nitrogen and phosphorus nutrients (with the exception of orthophosphate, in general). However, the dissolved oxygen and chlorophyll a measurements at this location may not be representative of conditions at the end of the reservoir due to the turbulent effects of water flowing out of the dam and into the relatively shallow downstream waters.

Within the reservoir, the City of Tampa’s Bay Study Program water quality data at the 40th Street Bridge (Station 5) is available on a monthly basis for two of the model simulation years, 1987 and 1990. Upstream river data is also available for a station located at Busch Ave. (Station 25). Each monitoring event included samples collected at the surface and just off the bottom. The parameters measured which are relevant to the EUTROS model application include: temperature, dissolved oxygen, Chlorophyll a, and forms of nitrogen and phosphorus nutrients (with the exception of organic nitrogen).

Raw water intake from the Hillsborough River reservoir is monitored by The City of Tampa Water Treatment Plant at monthly intervals. However, only 1990 data was available for use in this study (see Section 4.). Additionally, the detection limits for nutrient forms in this data set are relatively high compared to other data sources utilized.

5.1.3 Reservoir Modeling Approach

The U.S. EPA-supported WASP5 model, EUTRO5, was selected for application to the Hillsborough River reservoir since only minor modifications of this defacto-standard eutrophication model were necessary to meet the study objectives. The EUTRO5 model, and its predecessor versions, have been extensively applied to evaluate dissolved oxygen and eutrophication conditions in water bodies throughout the State of Florida, including Lake Thonotosassa and Lake Okeechobee, and the rest of the United States.

The EUTRO5 model was applied to the Hillsborough River reservoir in order to evaluate the effectiveness of controlling sources of nutrient loads (specifically phosphorus loads) to prevent the proliferation of algae to levels which exceed specific water quality targets for this water body (Section 6).
The selected approach for modeling eutrophication in the reservoir included the following steps:

- Modify the model code for site-specific requirements;
- Select calibration and verification years;
- Develop hydrologic, pollutant load, and environmental forcing functions as time series for input to the model;
- Process the reservoir water quality data for use in model calibration and verification;
- Calibrate and verify the model for the selected simulation years; and
- Apply the model in a predictive mode to evaluate the effectiveness of nutrient load reductions.

Some modifications of the EUTRO5 model code were required in order to allow for the likely occurrence of nitrogen-fixation by blue-green algae, as described in the following section. As an average precipitation year, 1987 was selected as the initial calibration period assuming this period would be the most representative of typical conditions within the reservoir. As model verification years, 1983 and 1987 represent periods of extreme conditions for testing the parameterization of the calibrated model.

The utility of the EUTRO5 model as an effective management tool was also examined through comparison of the model calibration to empirical approaches for predicting the eutrophic status of a reservoir on an seasonal to annual basis. The calibration/verification is followed by predictive management application of EUTRO5 to examine the responsiveness of the reservoir, during the selected average, wet and dry years, to reductions in external phosphorus loads.

### 5.2 WASP MODEL MODIFICATIONS

The mass transport and kinetic process mechanisms represented by the standard EUTRO5 model largely meet the needs for simulating Hillsborough River reservoir eutrophication. However, certain modifications of the model framework are required to meet site-specific considerations. These include:

- Inclusion of nitrogen fixation kinetics, in a simplified fashion, to allow for the effects of nitrogen-fixing blue-green algae dominating primary production under nitrogen limiting conditions.
- Minor model transport changes to better represent the effect of highly variable reservoir levels and volumes.

#### 5.2.1 Kinetics Modifications

The standard EUTRO5 model framework provides no mechanism for nitrogen fixation as a nutrient source for the primary production. Available reservoir historic data are inadequate to serve as a basis for calibrating algal kinetics because algaecides are used to control the growth of algae well below nuisance levels. However, nitrogen-fixing, blue-green algae are the target of control efforts by the City of Tampa (Chris Owens, pers. limno-tech.com).
comm.), and are typically dominant in nearby water bodies such as Lake Thonotosassa (SWFWMD, 1996). Without chemical controls, it is likely that nitrogen-fixing algal species will proliferate given the existing level of phosphorus loading to the reservoir.

Because the purpose of this study is to evaluate the effectiveness of controlling nutrient loads to the reservoir, it is necessary to incorporate the effects of nitrogen fixation within a water quality modeling framework. This is ideally accomplished through development and application of a multi-species, phytoplankton model. However, the existing phytoplankton measurements for the reservoir are extremely limited and do not enumerate species composition. EUTRO5, as a “single”-species eutrophication model, represents phytoplankton levels (as chlorophyll a) as a composite of an entire multi-species algal community. Nitrogen fixation kinetics are best represented within the existing EUTRO5 framework in a simplified fashion, because the actual species composition in a water body will vary as a function of environmental and nutrient limiting factors.

Figure 5-1 provides a schematic representation of the EUTRO5 model framework, as it was modified for this application. The model state variables include: dissolved oxygen, CBOD, Chlorophyll a, and nutrients. Total nitrogen is represented by ammonia, nitrate+nitrite, and organic nitrogen, while total phosphorus is represented by orthophosphate and organic phosphorus forms. A detailed description of the EUTRO5 mass transport (e.g. advection, dispersion, settling, etc.) and kinetic processes (e.g. nitrification, CBOD oxidation, phytoplankton growth and death, etc.) is presented in the WASP5 users’ manual (Ambrose, et al 1995).

Figure 5-1 also depicts a modification to the EUTRO5 framework, showing dissolved gaseous nitrogen as a potential nutrient source for uptake by phytoplankton through direct fixation. This kinetic change to the EUTRO5 model code treats gaseous nitrogen as an infinite nutrient source, and not as a model state variable like other forms of inorganic nitrogen (i.e. ammonia and nitrate+nitrite). The effect of nitrogen fixation is simulated in the modified EUTRO5 by assigning an inorganic nitrogen “trigger” level. Below this “trigger” level, the only source of nitrogen as a nutrient required for algal production is via direct uptake of gaseous nitrogen. The following paragraphs describe the effect of this change on the EUTRO5 kinetic processes.

The growth rate of phytoplankton in EUTRO5 is controlled by temperature, light extinction, and potential nutrient limitation as described by the following equation:

\[
G_{P1} = K_{IC} \cdot X_{RT} \cdot X_{RI} \cdot X_{RN}
\]

where:

- \( G_{P1} \) = phytoplankton specific growth rate (day\(^{-1}\));
- \( K_{IC} \) = maximum phytoplankton growth rate at 20\(^\circ\)C (day\(^{-1}\));
- \( X_{RT} \) = temperature limitation on phytoplankton growth (dimensionless);
- \( X_{RI} \) = light limitation on phytoplankton growth (dimensionless); and
- \( X_{RN} \) = nutrient limitation on phytoplankton growth (dimensionless).
The limiting factors which "correct" the phytoplankton growth rate to reflect site-specific environmental and nutrient conditions are described by the various X terms, as discussed below.

An Arrhenius-type temperature correction is used in EUTRO5 to factor in the dependence of phytoplankton growth rates on water temperature as follows:

\[ X_{RT} = \Theta_{IC}^{(T-20)} \]

where

\[ \Theta_{IC} = \text{temperature correction coefficient (unitless); and} \]
\[ T = \text{water temperature (°C)} \]

A standard correction for light limiting effects on phytoplankton growth, based upon a model developed for the Sacramento-San Joaquin Delta (DiToro et al, 1971), is incorporated in the EUTRO5 model framework as follows:

\[ X_{RL} = \frac{2.718f}{K_{s}H} \left[ \exp(-\alpha_{1}) - \exp(-\alpha_{2}) \right] \]
and 

\[ \alpha_1 = \exp \left( \frac{I_a}{I_s} \exp(-K_e H) \right) ; \quad \alpha_2 = \exp \left( \frac{I_a}{I_s} \right) \]

where

\[ K_e = \text{light extinction coefficient} \ (m^{-1}) \]
\[ = K_e' + 0.0088P_{Chl} + 0.054P_{Chl}^{2/3} \]
\[ K_e' = \text{base light extinction coefficient due to non-algal factors} \ (m^{-1}) \]
\[ P_{Chl} = \text{phytoplankton chlorophyll a concentration} \ (\mu g/L) \]
\[ H = \text{water column depth} \ (m) \]
\[ f = \text{fraction of daylight each day} \ (\text{dimensionless}) \]
\[ I_s = \text{saturating light intensity} \ (\text{langley/day}) \]
\[ I_a = \text{average incident light intensity} \ (\text{langley/day}) \]

Nutrient limiting effects on phytoplankton growth are incorporated within the EUTRO5 model framework through a Michaelis-Menton formulation. This expression employs a "Michaelis" constant which represents the concentration of available nutrient that results in a reduction of the phytoplankton growth rate by 50 percent. Because multiple nutrients are utilized by phytoplankton, the minimum reduction factor is assumed to control nutrient limitation for the Hillsborough River reservoir application of EUTRO5, as follows:

\[ X_{RN} = \min \{R_{CP}; R_{CN}; \cdots\} \]

where

\[ R_{CP} = \text{available phosphorus limitation factor;} \]
\[ R_{CN} = \text{available nitrogen limitation factor;} \]
\[ R_{Cx} = \text{other nutrient limitation factor(s) \ldots e.g. silica.} \]

The reduction effect of phosphorus limitation on phytoplankton growth in standard EUTRO5 is described by the following equation:

\[ R_{CN} = \frac{[DIP]}{[K_{mP} + DIP]} \]

where

\[ R_{CP} = \text{algal growth rate limitation due to phosphorus} \ (\text{dimensionless}) \]
\[ K_{mP} = \text{"Michaelis" phosphorus half-saturation constant} \ (\text{mg P/L}) \]
\[ DIP = \text{dissolved inorganic phosphorus or ortho-phosphate} \ (\text{mg P/L}) \]

The reduction effect of nitrogen limitation on phytoplankton growth in standard EUTRO5 is described by the following equation:

\[ R_{CN} = \frac{[NH_3 + NO_x]}{[K_{mN} + NH_3 + NO_x]} \]

where

\[ R_{CN} = \text{algal growth rate reduction factor} \ (\text{dimensionless}) \]
\[ K_{mN} = \text{"Michaelis" nitrogen half-saturation constant} \ (\text{mg N/L}) \]
The modified Hillsborough River reservoir EUTRO5 model formulation applies this standard growth rate reduction factor until the sum of the available inorganic forms of nitrogen (ammonia and nitrate+nitrite) decline to a preset trigger level ($CN_{\text{min}}$) as follows:

When $NO_x + NH_3 \leq CN_{\text{min}}$

$$R_{CN} = \frac{CN_{\text{min}}}{K_{mN} + CN_{\text{min}}} \quad \text{...N-fixation reduction factor;}$$

otherwise

$$R_{CN} = \frac{[NH_3 + NO_x]}{K_{mN} + NH_3 + NO_x} \quad \text{...standard reduction factor;}$$

where

$$CN_{\text{min}} = \text{nitrogen fixation "trigger" level (mg N/L)}$$

Thus, $CN_{\text{min}}$ is a calibration parameter which may vary depending on site-specific conditions. Additionally, no algal uptake of ammonia or nitrate+nitrate occurs in the modified EUTRO5 while the nitrogen fixation "trigger" is in effect. However, these nutrients are still subject to other loss processes (i.e., nitrification and denitrification) and gains (i.e., external loads, and recycle from phytoplankton death and respiration) under this condition. Separate tracking of phytoplankton production under this condition is also implemented in the modified EUTRO5 in order to provide an indicator of the relative dominance of presumed nitrogen fixation through the growing season and on an annual basis.

No changes to the EUTRO5 kinetics, other than those described above, were implemented in developing the Hillsborough River reservoir eutrophication model. A more detailed discussion of the complete EUTRO5 kinetic formulations is provided in the WASP5 user's manual (Ambrose, et al, 1993).

5.2.2 Transport Modifications

As discussed above, Hillsborough Reservoir water levels (and volumes) appear to be highly variable over relatively short (daily to weekly) time scales. A slight modification of the WASP5-EUTRO5 model transport framework was implemented to account for the change in cross-sectional areas within the reservoir as a function of varying depth.

5.3 CALIBRATION AND VERIFICATION

As discussed above, three one-year periods were selected as calibration and verification targets to test the veracity of the reservoir eutrophication model over an extreme range of hydrologic conditions in the Hillsborough River watershed. The following sections describe the basic development of the EUTRO5 model inputs to represent conditions in
the reservoir for the target simulation years of 1983, 1987 and 1990. Complete calibration
and verification input files are provided in files on diskette as an "electronic" Appendix to
this report.

5.3.1 Approach

The EUTRO5 model was developed using available data to describe the physical and
chemical characteristics of the reservoir, as well as the effects of the external hydrologic
and environmental forcing conditions which "drive" the condition of water quality within
the reservoir. This information, which essentially describes the model development, is
categorized as follows:

- Model Segmentation and Geometry
- Hydraulic Conditions
- External and Loads
- Environmental Conditions
- Initial Conditions
- Eutrophication Kinetic Parameters

The processing and use of information from each of these categories of data to develop
the Hillsborough River reservoir EUTRO5 model is described below.

Model Segmentation and Geometry

The one-dimensional EUTRO5 grid for the Hillsborough River reservoir was selected to
reasonably represent longitudinal gradients in water quality with a minimum number of
model segments. Data representing water quality conditions within the reservoir are
very limited, so sampling locations could not be used as a criteria for discretizing the reservoir.
Additionally, a single segment (i.e. completely mixed) representation of the reservoir was
determined to be inadequate for modeling purposes, because much of the reservoir is
fairly riverine.

A map of the EUTRO5 segmentation for the reservoir is presented in Figure 5-2. Eleven
longitudinal segments are used to represent the reservoir with segment lengths ranging
from 0.80 to 1.15 kilometers. The geometry of the reservoir was determined from
bathymetric survey maps and profiles supplied by the City of Tampa. The channel cross­
sections were discretized at 100 to 250 meter intervals in order to estimate segment
geometry (i.e. surface area, width, etc.) for the EUTRO5 model.

Available information on the variability of water surface levels in the reservoir is
minimal, so an annualized procedure was applied to estimate beginning and end of year
specifically, annual average estimates of reservoir outflows were determined for 1982
through 1990. Year to year variations in reservoir volumes were then estimated based on
the change in annualized outflows. The initial volume for the reservoir at the beginning of
1982 was determined assuming a reservoir water level elevation of 22.5 feet MSB (above
Mean Sea Level) which is equivalent to the spillway elevation of the dam. There is
obvious uncertainty in this approach, but it provides a hydrologic linkage between the
years selected for the model application to represent relative changes in reservoir volume.
Figure 5-2. Hillsborough River Reservoir WASP5 Model Segmentation.
The influence of wet and dry precipitation years is evident from the volume estimates presented in Table 5-1 for the beginning of following years.

Table 5-1. Estimated Hillsborough River Reservoir Start of Year Volumes for 1982 through 1991.

<table>
<thead>
<tr>
<th>Year</th>
<th>Initial Volume (cu. feet.)</th>
<th>Characterization of Selected Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>1.78E+08</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>2.60E+08</td>
<td>wet</td>
</tr>
<tr>
<td>1984</td>
<td>3.06E+08</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>2.96E+08</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>1.84E+08</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>2.08E+08</td>
<td>average</td>
</tr>
<tr>
<td>1988</td>
<td>2.78E+08</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>3.05E+08</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>2.04E+08</td>
<td>dry</td>
</tr>
<tr>
<td>1991</td>
<td>6.75E+07</td>
<td></td>
</tr>
</tbody>
</table>

Hydraulic Conditions

Estimates of hydraulic (water) loads and losses for the reservoir were processed on a daily scale for input to the EUTRO5 model. As described in Section 5.1.2, information on water transfers to and from the reservoir is very limited. Since these transfers cannot be distinguished from possible groundwater seepage, a combined estimate of this hydraulic effect was developed from the existing information on inflow, outflow, and other withdrawals from the reservoir. The approach evaluated the net difference between known gains and losses (including evaporation) of water to the reservoir on a 14-day rolling-average basis for each of the selected simulation years. The net difference in flow was then adjusted to reflect the estimated change in reservoir volume between the beginning and end of each year. This approach allowed reservoir volumes to vary in response to significant flooding or water release events, as measured by upstream and downstream USGS gages. It should be noted that the SWMM-generated runoff predictions were only used to supplement monitored flows to develop the EUTRO5 forcing conditions, as previously discussed (Section 3.1.1, Figure 3-1).

Hydraulic inflows and outflows were routed through the EUTRO5 model segmentation based on proportioning by segment volume and the specific segment location of the transfer within the reservoir. For example, 100% of the upstream flow is routed into segment 1, 95% into segment 2, 89.5% into segment 3, ..., and 0% into segment 11 (the most downstream segment). In similar fashion, measured outflows from the reservoir dam (USGS station 02304500) are routed through the model segments in a reverse manner, with 100% of the outflow leaving segment 11, and 0% leaving segment 1. Table 5-2 presents the relative fractional volumes used in this routing scheme for each model segment. This simplified approach to the hydrologic routing provides a reasonable method for allowing segment volumes to vary in response to flow through the reservoir.
Table 5-2. Hillsborough River Reservoir Segment Volumes Used in Developing the EUTROS5 Flow Routing Scheme.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Volume* (cu. feet)</th>
<th>Volume Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.82E+06</td>
<td>0.050</td>
</tr>
<tr>
<td>2</td>
<td>9.78E+06</td>
<td>0.055</td>
</tr>
<tr>
<td>3</td>
<td>1.84E+07</td>
<td>0.104</td>
</tr>
<tr>
<td>4</td>
<td>1.19E+07</td>
<td>0.067</td>
</tr>
<tr>
<td>5</td>
<td>1.28E+07</td>
<td>0.072</td>
</tr>
<tr>
<td>6</td>
<td>1.54E+07</td>
<td>0.086</td>
</tr>
<tr>
<td>7</td>
<td>1.63E+07</td>
<td>0.092</td>
</tr>
<tr>
<td>8</td>
<td>2.15E+07</td>
<td>0.121</td>
</tr>
<tr>
<td>9</td>
<td>2.21E+07</td>
<td>0.124</td>
</tr>
<tr>
<td>10</td>
<td>1.87E+07</td>
<td>0.105</td>
</tr>
<tr>
<td>11</td>
<td>2.20E+07</td>
<td>0.124</td>
</tr>
</tbody>
</table>

* Determined assuming a surface water elevation of 22.5 feet MSL

Diffuse flow gains and losses of water to the reservoir, such as the SWMM-predicted direct runoff and evaporation, were apportioned according to the segment volume fractions presented in Table 5-2 for the EUTROS5 model simulations.

**External Loads**

The development of estimates for upstream total nitrogen and phosphorus external loads to the reservoir is presented in Section 4 of this report. This same approach was used to generate the daily upstream loads required by the EUTROS5 model. The available water quality data for station HCECP 106 supported the development of load estimates for each of the nitrogen species that EUTROS5 simulates, specifically ammonia, nitrate-nitrite, and organic nitrogen.

The relationship between total phosphorus and orthophosphate phosphorus for 1990-1994 at HCEPC 106 was used characterize the distribution of upstream phosphorus loads between inorganic (as orthophosphate) and organic forms (Figure 5-3).

SWMM generated runoff and baseflow loads downstream of HCECP 106 were generated as described in Section 2.2.

Information on water quality for other potential external loads was relatively limited, as described in Section 2.2.13. Therefore, constant concentrations were assigned to estimate the magnitude of the pollutant loads from these additional sources. Table 5-3 presents a summary of the selected pollutant concentrations. Groundwater phosphorus concentrations were assumed to be similar to runoff EMCs since no site-specific data were available. Reddy (personal communication, 1997) observed porewater phosphorus concentrations in Lake Okeechobee sediments of 0.04 to 0.45 mg/L orthophosphate, and 0.04 to 0.48 mg/L dissolved organic phosphorus.
Figure 5-3. Regression of Orthophosphate and Total Phosphorus Concentrations at HCEPC 106 (1990-1994).

Table 5-3. Summary of Pollutant Concentrations Assumed for Other Potential External Loads.

<table>
<thead>
<tr>
<th>Parameter (mg/L)</th>
<th>Tampa Bypass Canal&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Sulphur Springs&lt;sup&gt;3&lt;/sup&gt;</th>
<th>Unmeasured Water Transfers&lt;sup&gt;4&lt;/sup&gt;</th>
<th>Groundwater&lt;sup&gt;5&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orthophosphate&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.243</td>
<td>0.243</td>
<td>0.243&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0.243</td>
</tr>
<tr>
<td>Organic Phosphorus&lt;sup&gt;1&lt;/sup&gt;</td>
<td>0.027</td>
<td>0.027</td>
<td>0.027</td>
<td>0.027</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.200</td>
<td>0.025</td>
<td>0.150</td>
<td>0.025</td>
</tr>
<tr>
<td>Nitrate+Nitrite</td>
<td>0.200</td>
<td>0.025</td>
<td>0.150</td>
<td>0.025</td>
</tr>
<tr>
<td>Organic Nitrogen</td>
<td>0.600</td>
<td>0.100</td>
<td>1.300</td>
<td>0.100</td>
</tr>
<tr>
<td>Chlorophyll a (ug/L)</td>
<td>20</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>CBOD</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>1</sup> Runoff EMC and a 90% fraction for orthophosphorus.
<sup>2</sup> Nitrogen species estimated from available monthly data.
<sup>3</sup> Nitrogen species estimated assuming relatively “clean” conditions (near detection limits).
<sup>4</sup> Nitrogen runoff EMC assumed with specie split roughly estimated from available upstream data.
<sup>5</sup> Nitrogen species estimated assuming relatively “clean” conditions (near detection limits).

Environmental Conditions

Environmental forcing conditions were developed on a daily basis, where feasible, for the EUTRO5 model simulations. The available environmental data is described in Section 5.1.2, with relevant parameters being wind speed, air temperature, and incident solar radiation. The environmental information for each of the target simulation years was
processed to a daily scale time series as inputs to the EUTRO5 model. Additionally, a
time series of monthly water temperature measurements for the reservoir was developed
for each of the simulation years using field measurements available from the HCEPC
(Station 105) monitoring program.

**Eutrophication Model Parameters**

The parameters which control the eutrophication model processes were determined
through calibration and verification simulations once the physical and chemical
characteristics, and external forcing conditions, described above were specified for each
of the target simulation years.

The primary sources of information used to determine and adjust the model calibration
parameters included: the WASP5 user's manual (Ambrose et al, 1993), Thomann and
Mueller (1987), and Bowie et al (1987). Table 5-4 provides a description of the model
parameters and the values used for the reservoir calibration and verification simulations.
Typical maximum algal growth rates range from 1.5 to 2.5 day\(^{-1}\) (Thomann and Mueller,
1987). For these simulations, an approximate 50 percent reduction in the maximum algal
growth rate was used to represent the effects of algaecide applications to the reservoir. Slightly
different maximum algal growth rates were specified for the 1987 calibration and
the 1983 and 1990 verification simulations (1.0 versus 0.8 per day) to adjust the model
predicted fit to chlorophyll \(a\) data in the reservoir. This adjustment between years can be
considered minimal in light of the lack of information on the timing and magnitude of
algaecide applications to the reservoir. It should also be noted that for all predictive
simulations presented in Section 6, a higher maximum growth rate of 2.0 per day has
been
assumed with the expectation that phytoplankton growth kinetics will respond in a typical
fashion if algaecide applications to the reservoir are halted.

5.3.2 Calibration Results

Of the three target years, 1987 provides the best temporal coverage of reservoir water
quality measurements for comparison to Hillsborough River reservoir EUTRO5 model
predictions. Additionally, as an "average" precipitation year, 1987 should best represent
typical conditions in the watershed, so that calibration of the EUTRO5 model parameters
is less likely to be biased due to any extreme perturbations in factors which effect water
quality in the reservoir. For these reasons, 1987 was selected as the primary calibration
year for the eutrophication simulations.

Figure 5-4 displays a comparison of the temporal trends and variability between the
EUTRO5 predictions and selected water quality parameter measurements for 1987. The
model generally captures magnitude, trends and variability of the water quality
parameters. A number of parameters have data available at two locations: TBSG station
5, located at the 40th Street bridge (compare to model segment 8); and HCEPC station
105, located just downstream of the reservoir spillway (compare to model segment 11).
# Table 5-4. Hillsborough River Reservoir EUTRO5 Model Parameters.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>EUTRO5 Notation</th>
<th>Definition</th>
<th>Units</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{JC}$</td>
<td>KIC</td>
<td>Maximum algal growth rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>1.0 (1987) 0.8 (1983, 1990) 2.0 (untreated)</td>
<td>Thomann and Mueller, 1987; model calibration</td>
</tr>
<tr>
<td>$\Theta_{IC}$</td>
<td>KIT</td>
<td>Growth rate temperature correction</td>
<td>dimensionless</td>
<td>1.07</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$K_{IR}$</td>
<td>KIRC</td>
<td>Algal respiration rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.1</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$\Theta_{IR}$</td>
<td>KIRT</td>
<td>Respiration temperature correction</td>
<td>dimensionless</td>
<td>1.07</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$K_{ID}$</td>
<td>KID</td>
<td>Algal death rate</td>
<td>day$^{-1}$</td>
<td>0.05</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$K_{IG}$</td>
<td>KIG</td>
<td>Zooplankton grazing rate (at 20°C)</td>
<td>gC/mgC-day</td>
<td>0.3</td>
<td>James and Bierman, 1995</td>
</tr>
<tr>
<td>$\Theta_{IG}$</td>
<td>KIGT</td>
<td>Grazing rate temperature correction</td>
<td>dimensionless</td>
<td>1.07</td>
<td>James and Bierman, 1995</td>
</tr>
<tr>
<td>$K_{MN}$</td>
<td>KMNG</td>
<td>Nitrogen half-saturation constant</td>
<td>mg N/L</td>
<td>0.03</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$K_{MP}$</td>
<td>KMPG</td>
<td>Phosphorus half-saturation constant</td>
<td>mg P/L</td>
<td>0.002</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$CN_{min}$</td>
<td>CNMIN</td>
<td>Inorganic N trigger level for N-fixation</td>
<td>mg N/L</td>
<td>0.1</td>
<td>model calibration</td>
</tr>
<tr>
<td>$a_{NC}$</td>
<td>NCRB</td>
<td>Nitrogen:carbon mass ratio</td>
<td>mg N/L</td>
<td>0.2</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$a_{PC}$</td>
<td>PCRB</td>
<td>Phosphorus:carbon mass ratio</td>
<td>mg P/L</td>
<td>0.02</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$a_{P C}$</td>
<td>CCHL</td>
<td>Phosphorus:carbon mass ratio</td>
<td>mg P/L</td>
<td>0.002</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$f_{ON}$</td>
<td>FON</td>
<td>Recycle fraction to organic nitrogen</td>
<td>dimensionless</td>
<td>0.45</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$f_{OP}$</td>
<td>FOP</td>
<td>Recycle fraction to organic phosphorus</td>
<td>dimensionless</td>
<td>0.45</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$I_3$</td>
<td>ISI</td>
<td>Saturation Light Intensity</td>
<td>ly/day</td>
<td>300</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$K_D$</td>
<td>KDT</td>
<td>CBOD decay rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.1</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$\Theta_D$</td>
<td>KDTS</td>
<td>CBOD decay temperature correction</td>
<td>dimensionless</td>
<td>1.047</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$K_{BOD}$</td>
<td>KBOD</td>
<td>Half-saturation for CBOD decay</td>
<td>mg O$_2$/L</td>
<td>1</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$K_{JJ}$</td>
<td>KJ1320C</td>
<td>Nitrification rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.1</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$\Theta_{JJ}$</td>
<td>KJ1320T</td>
<td>Nitrification temperature correction</td>
<td>dimensionless</td>
<td>1.07</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$K_{NN}$</td>
<td>KNIT</td>
<td>Half-saturation constant for nitrification</td>
<td>mg O$_2$/L</td>
<td>2</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$K_{SD}$</td>
<td>K140C</td>
<td>Denitrification rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.1</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$\Theta_{SD}$</td>
<td>K140T</td>
<td>Denitrification temperature correction</td>
<td>dimensionless</td>
<td>1.07</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$K_{NO3}$</td>
<td>KNO3</td>
<td>Half-saturation constant for denitrification</td>
<td>mg O$_2$/L</td>
<td>0.5</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$K_{J1}$</td>
<td>K1013C</td>
<td>Organic N mineralization rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.03</td>
<td>model calibration</td>
</tr>
<tr>
<td>$\Theta_{J1}$</td>
<td>K1013T</td>
<td>ON mineralization temperature correction</td>
<td>dimensionless</td>
<td>1.08</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$K_{KJ}$</td>
<td>K38C</td>
<td>Organic P mineralization rate (at 20°C)</td>
<td>day$^{-1}$</td>
<td>0.03</td>
<td>model calibration</td>
</tr>
<tr>
<td>$\Theta_{KJ}$</td>
<td>K38T</td>
<td>OP mineralization temperature correction</td>
<td>dimensionless</td>
<td>1.08</td>
<td>Bowie et al, 1985</td>
</tr>
<tr>
<td>$K_{NP}$</td>
<td>KMPHY</td>
<td>Algal half-saturation for mineralization</td>
<td>mg C/L</td>
<td>1</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$v_{N1}$</td>
<td>VNET1</td>
<td>Net settling rate for algae</td>
<td>m/day</td>
<td>0.05</td>
<td>James and Bierman, 1995</td>
</tr>
<tr>
<td>$v_{N2}$</td>
<td>VNET2</td>
<td>Net settling rate for particulate material</td>
<td>m/day</td>
<td>0.1</td>
<td>James and Bierman, 1995</td>
</tr>
<tr>
<td>$K_e$</td>
<td>KESG</td>
<td>Background light extinction coefficient</td>
<td>m$^{-1}$</td>
<td>1</td>
<td>Ambrose et al, 1993</td>
</tr>
<tr>
<td>$F_{SOD}$</td>
<td>SOD</td>
<td>Sediment oxygen demand</td>
<td>g O$_2$/m$^2$-day</td>
<td>1.1</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$SOD$</td>
<td>SODTA</td>
<td>SOD temperature correction</td>
<td>dimensionless</td>
<td>1.065</td>
<td>Thomann and Mueller, 1987</td>
</tr>
<tr>
<td>$F_{NH4}$</td>
<td>FNH4</td>
<td>Ammonium flux from sediment</td>
<td>mg N/m$^2$-day</td>
<td>26</td>
<td>model calibration</td>
</tr>
<tr>
<td>$F_{PO4}$</td>
<td>FPO4</td>
<td>Phosphate flux from sediment</td>
<td>mg P/m$^2$-day</td>
<td>2</td>
<td>model calibration</td>
</tr>
</tbody>
</table>
Figure 5-4. 1987 Hillsborough River Reservoir EUTRO5 Calibration Comparison to Data.
Note that chlorophyll $a$ and dissolved oxygen data for HCEPC 105 are not included in these temporal comparison because the dam spillway and the manner in which water is released from the reservoir is likely to have a significant effect on these two parameters. Table 5-5 compares the mean and variance of the model predictions and the data. The large differences between the mean dissolved oxygen concentrations for HCEPC 105 and model segment 11, suggest that the effects of enhanced reaeration as water exits the reservoir dam are significant. Most of the other predicted parameter values compare reasonably well with the water quality measurements in terms of mean and variance, as indicated by the t-test results in Table 5-5.

The predictions for ammonia are an exception to the generally acceptable model results for the 1987 calibration. The large discrepancy between the HCEPC and TBSG data for ammonia cannot be resolved by the model. These systematic differences are not observed in the 1990 data (see Figure 5-6), suggesting that the 1987 ammonia measurements from one of these two field sampling programs are inaccurate. However, no information is currently available to assess the validity of these data. For the purposes of this study, this issue adds additional uncertainty to predicted nitrogen fixation-driven algal production, but the overall effect on algal production in response to phosphorus loading reductions should be minimal. Also note that flow records to estimate Tampa Bypass Canal and Sulphur Springs pollutant loads to the reservoir are unavailable for 1987 and 1983. However, loads from these sources are implicitly included within the "unmeasured water transfers" estimated as part of the estimation of hydraulic loads to the reservoir (Section 5.3.1).

Table 5-5. Paired Two Sample t-Test for Means of EUTRO5 Model Predictions vs. Observed Data - 1987 Calibration Period.

<table>
<thead>
<tr>
<th>EUTRO5 Segment</th>
<th>Station</th>
<th>Parameter</th>
<th>EUTRO5 Mean</th>
<th>Observed Mean</th>
<th>Variance EUTRO5</th>
<th>Variance Observed</th>
<th>Count</th>
<th>P (T&lt;=t)</th>
<th>P&gt;a?</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>TBSG</td>
<td>DO (mg/L)</td>
<td>4.8</td>
<td>4.8</td>
<td>0.93</td>
<td>1.68</td>
<td>12</td>
<td>0.964</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chl $a$ (ug/L)</td>
<td>8.4</td>
<td>8.7</td>
<td>33.9</td>
<td>62.5</td>
<td>11</td>
<td>0.904</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH3-N (mg/L)</td>
<td>0.029</td>
<td>0.110</td>
<td>0.001</td>
<td>0.001</td>
<td>10</td>
<td>0.000</td>
<td>fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3 (mg/L)</td>
<td>0.063</td>
<td>0.103</td>
<td>0.003</td>
<td>0.002</td>
<td>12</td>
<td>0.075</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ortho. P (mg/L)</td>
<td>0.328</td>
<td>0.274</td>
<td>0.028</td>
<td>0.010</td>
<td>12</td>
<td>0.217</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total P (mg/L)</td>
<td>0.360</td>
<td>0.315</td>
<td>0.031</td>
<td>0.013</td>
<td>12</td>
<td>0.348</td>
<td>pass</td>
</tr>
<tr>
<td>11</td>
<td>HCEPC</td>
<td>DO (mg/L)</td>
<td>7.3</td>
<td>5.3</td>
<td>1.19</td>
<td>2.32</td>
<td>9</td>
<td>0.004</td>
<td>fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BOD5 (mg/L)</td>
<td>1.7</td>
<td>2.0</td>
<td>0.30</td>
<td>1.79</td>
<td>12</td>
<td>0.240</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chl $a$ (ug/L)</td>
<td>5.5</td>
<td>13.0</td>
<td>12.9</td>
<td>170.1</td>
<td>12</td>
<td>0.076</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH3-N (mg/L)</td>
<td>0.158</td>
<td>0.115</td>
<td>0.005</td>
<td>0.001</td>
<td>12</td>
<td>0.024</td>
<td>fail</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3 (mg/L)</td>
<td>0.078</td>
<td>0.098</td>
<td>0.001</td>
<td>0.002</td>
<td>12</td>
<td>0.261</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Org. N (mg/L)</td>
<td>1.385</td>
<td>1.234</td>
<td>0.209</td>
<td>0.113</td>
<td>12</td>
<td>0.086</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total N (mg/L)</td>
<td>1.622</td>
<td>1.519</td>
<td>0.260</td>
<td>0.135</td>
<td>12</td>
<td>0.246</td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total P (mg/L)</td>
<td>0.268</td>
<td>0.289</td>
<td>0.010</td>
<td>0.008</td>
<td>12</td>
<td>0.303</td>
<td>pass</td>
</tr>
</tbody>
</table>
5.3.3 Verification Results

The calibrated EUTRO5 model was applied to the 1983 and 1990 target simulation years with minor adjustment of maximum algal growth rates to reflect likely variations in algaecide application rates to the reservoir. The 1983 and 1990 eutrophication model verification results are presented, in similar fashion to the 1987 simulation, in Figures 5-5 and 5-6, respectively.

General trends and variation in 1983 reservoir water quality conditions are reflected relatively well by the model, including predictions for ammonia. However, no data within the reservoir are available for 1983, so comparisons could only be generated for station HCEPC 105. The consistent difference in predicted segment 11 dissolved oxygen and the HCEPC 105 data is probably the result of the enhanced reaeration of flow exiting the reservoir through the dam. Table 5-6 presents a comparison of the mean and variance of the 1983 model predictions and data. The t-test results suggest a high degree of similarity between the model and data for nearly all water quality parameters. However, the comparison for organic nitrogen suggests that a higher mineralization rate might improve the model fit for 1983 conditions.

The 1990 EUTRO5 verification results, shown in Figure 5-6, also reasonably capture the magnitude, trend, and variation in reservoir water quality conditions. The TBSG data for 1990 is relatively sparse, with only 4 sampling dates compared to 12 for 1987. The results for the paired, two-sample t-tests shown in Table 5-7, suggests that the 1990 verification simulation replicates the general characteristics (mean, and variance) of the data relatively well. As was the case for 1983, the 1990 organic nitrogen results suggest that a higher mineralization rate might improve the model fit for nitrogen species. However, the discrepancy between 1987 TBSG and HCECP ammonia data should be resolved, if possible, before any further adjustments are made to the model calibration parameterization. Other phenomena, such as sediment ammonium release, may also be complicating factors for describing nitrogen kinetics within the reservoir.

Table 5-6. Paired Two Sample t-Test for Means of EUTRO5 Model Predictions vs. Observed Data - 1983 Verification Period.

<table>
<thead>
<tr>
<th>EUTRO5 Segment</th>
<th>Station</th>
<th>Parameter</th>
<th>Mean</th>
<th>Variance</th>
<th>Count</th>
<th>P (T&lt;=t)</th>
<th>a=0.05</th>
<th>P&gt;a ?</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>HCEPC 105</td>
<td>DO (mg/L)</td>
<td>5.6</td>
<td>4.8</td>
<td>4.09</td>
<td>3.97</td>
<td>11</td>
<td>0.371</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BOD5 (mg/L)</td>
<td>1.6</td>
<td>1.7</td>
<td>0.85</td>
<td>3.63</td>
<td>12</td>
<td>0.921</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chl a (ug/L)</td>
<td>8.9</td>
<td>9.5</td>
<td>207.5</td>
<td>329.7</td>
<td>12</td>
<td>0.785</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH3-N (mg/L)</td>
<td>0.104</td>
<td>0.109</td>
<td>0.003</td>
<td>0.001</td>
<td>12</td>
<td>0.788</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3 (mg/L)</td>
<td>0.117</td>
<td>0.154</td>
<td>0.006</td>
<td>0.007</td>
<td>12</td>
<td>0.296</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Org. N (mg/L)</td>
<td>0.946</td>
<td>0.811</td>
<td>0.088</td>
<td>0.064</td>
<td>12</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total N (mg/L)</td>
<td>1.220</td>
<td>1.126</td>
<td>0.110</td>
<td>0.064</td>
<td>12</td>
<td>0.152</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total P (mg/L)</td>
<td>0.284</td>
<td>0.312</td>
<td>0.020</td>
<td>0.012</td>
<td>12</td>
<td>0.372</td>
</tr>
</tbody>
</table>
Figure 5-5. 1983 Hillsborough River Reservoir EUTRO5 Verification Comparison to Data.
Figure 5-6. 1990 Hillsborough River Reservoir EUTRO5 Verification Comparison to Data.
Table 5-7. Paired Two Sample t-Test for Means of EUTRO5 Model Predictions vs. Observed Data - 1990 Verification Period.

<table>
<thead>
<tr>
<th>EUTRO5 Segment</th>
<th>Station</th>
<th>Parameter</th>
<th>Mean Data</th>
<th>Mean Model</th>
<th>Variance Data</th>
<th>Variance Model</th>
<th>Count</th>
<th>P (T&lt;=t)</th>
<th>a=0.05</th>
<th>P&gt;a?</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>TBSG 5</td>
<td>DO (mg/L)</td>
<td>4.3</td>
<td>5.9</td>
<td>5.79</td>
<td>1.30</td>
<td>4</td>
<td>0.134</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chl a (ug/L)</td>
<td>17.0</td>
<td>12.8</td>
<td>15.43</td>
<td>185.0</td>
<td>4</td>
<td>0.252</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH3-N (mg/L)</td>
<td>0.099</td>
<td>0.077</td>
<td>0.001</td>
<td>0.000</td>
<td>4</td>
<td>0.245</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3 (mg/L)</td>
<td>0.053</td>
<td>0.131</td>
<td>0.002</td>
<td>0.013</td>
<td>4</td>
<td>0.329</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ortho. P (mg/L)</td>
<td>0.226</td>
<td>0.214</td>
<td>0.023</td>
<td>0.002</td>
<td>4</td>
<td>0.863</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total P (mg/L)</td>
<td>0.276</td>
<td>0.264</td>
<td>0.015</td>
<td>0.001</td>
<td>4</td>
<td>0.825</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td>11</td>
<td>HCEPC 105</td>
<td>DO (mg/L)</td>
<td>4.2</td>
<td>5.7</td>
<td>6.41</td>
<td>2.00</td>
<td>11</td>
<td>0.121</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BOD5 (mg/L)</td>
<td>2.3</td>
<td>3.7</td>
<td>3.67</td>
<td>9.15</td>
<td>12</td>
<td>0.180</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chl a (ug/L)</td>
<td>26.6</td>
<td>29.4</td>
<td>1370.1</td>
<td>728.5</td>
<td>12</td>
<td>0.823</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NH3-N (mg/L)</td>
<td>0.134</td>
<td>0.091</td>
<td>0.010</td>
<td>0.000</td>
<td>12</td>
<td>0.160</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NO3 (mg/L)</td>
<td>0.092</td>
<td>0.059</td>
<td>0.003</td>
<td>0.003</td>
<td>12</td>
<td>0.135</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Org. N (mg/L)</td>
<td>0.758</td>
<td>0.988</td>
<td>0.194</td>
<td>0.141</td>
<td>12</td>
<td>0.237</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total N (mg/L)</td>
<td>0.984</td>
<td>1.297</td>
<td>0.150</td>
<td>0.230</td>
<td>12</td>
<td>0.112</td>
<td></td>
<td>pass</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total P (mg/L)</td>
<td>0.284</td>
<td>0.296</td>
<td>0.012</td>
<td>0.004</td>
<td>12</td>
<td>0.751</td>
<td></td>
<td>pass</td>
</tr>
</tbody>
</table>

5.3.4 Comparison With Regional Model

To provide a basis for comparing the performance of the EUTRO5 model, annualized models for phosphorus and nitrogen in Florida lakes were applied to the Hillsborough River reservoir for the same three years of interest. These models were based on the EUTROMOD spreadsheet model (Reckhow, 1991). The EUTROMOD phosphorus and nitrogen model equations may be described as follows:

\[
\text{Log}_{10} P = \text{Log}_{10} \left[ \frac{P_{in}}{1 + k \tau} \right]
\]

\[
\text{Log}_{10} N = \text{Log}_{10} \left[ \frac{N_{in}}{1 + k' \tau} \right]
\]

where:
- \(P\) = Average growing season total phosphorus concentration (mg/L)
- \(P_{in}\) = Average total phosphorus concentration in incoming water (mg/L)
- \(N\) = Average growing season total nitrogen concentration (mg/L)
- \(N_{in}\) = Average total nitrogen concentration in incoming water (mg/L)
- \(k\) = Phosphorus trapping parameter (dimensionless)
- \(k'\) = Nitrogen trapping parameter (dimensionless)
- \(\tau\) = Hydraulic detention time (years)

The growing season is defined for EUTROMOD as the period from June through September.
The trapping parameters are calculated as a function of physical characteristics of the lake, as follows:

\[
k = 1.71 \tau^{-0.21} z^{1.01} P_{in}^{0.4}
\]

\[
k' = 0.2 \tau^{-0.89} z^{1.56} N_{in}^{0.33}
\]

where: \( z \) = Average depth (m)

The standard error of the predictions for the phosphorus and nitrogen models are 0.189 mg/L and 0.136 mg/L, respectively.

Table 5-8 presents a comparison of the average growing season concentrations predicted by EUTRO5 and the EUTROMOD equations for the reservoir with average growing season concentrations calculated from monitoring data collected at the 40th Street Bridge (TBSG 5), the City of Tampa Water Treatment Plant intake (WTP), and HCEPC station 105. Unfortunately, TP data were not available for all three years at TBSG #5 and WTP intake, and TN data were not available at all for these two stations.

Table 5-8. Comparison of Average Growing Season TP and TN Predicted by EUTRO5 and EUTROMOD with Observed Concentrations.

<table>
<thead>
<tr>
<th></th>
<th>Total Phosphorus (mg/L)</th>
<th>Total Nitrogen (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUTRO5</td>
<td>0.334</td>
<td>0.361</td>
</tr>
<tr>
<td>EUTROMOD</td>
<td>0.482</td>
<td>0.303</td>
</tr>
<tr>
<td>HCEPC 105</td>
<td>0.405</td>
<td>0.300</td>
</tr>
<tr>
<td>TBSG Station 5</td>
<td>-</td>
<td>0.438</td>
</tr>
<tr>
<td>WTP Intake</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Relative Difference Compared to HCEPC 105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EUTRO5</td>
<td>18%</td>
<td>-20%</td>
</tr>
<tr>
<td>EUTROMOD</td>
<td>-19%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

Of the three monitoring stations, the EUTRO5 and EUTROMOD results compare most favorably with the TP data from HCEPC 105. Comparison of the performance of the two models indicates that EUTROMOD provided better agreement with observed data for 1987, while EUTRO5 provided better estimates for 1983 and 1990. The relative standard error of the TP predictions for EUTRO5 ranged from approximately 21.6 percent in 1987, to 32 percent in 1983. Thus, the observed mean concentrations were within one standard error of the prediction for both models.

The EUTRO5 estimates of mean growing season TN concentrations were significantly closer to the monitoring data than were the EUTROMOD estimates. The relative standard error of the EUTRO5 TN predictions ranged from 12.5 percent in 1987 to 15.7 percent...
for 1990, and the observed concentrations were well within this range. The EUTROMOD estimates for 1983 and 1990 were within one standard error of the prediction.

5.4 CONCLUSIONS

The calibrated EUTRO5 model produces a reasonable picture of Hillsborough River reservoir trophic state conditions across three distinct simulation years, ranging from wet to dry conditions in the watershed. Given the lack of information to describe a complete picture of reservoir hydraulic and nutrient loads, the EUTRO5 model predictions still mimic the general temporal trends for most water quality parameters, across each of the simulation years. An additional uncertainty, beyond external loads, is the role of sediment-water interactions in affecting reservoir water quality. With the present high level of external nutrient loads to the reservoir, the effect of sediments on increasing nutrient levels appears to be minor. However, no information is currently available to assess the possible significance of sediment nutrient fluxes to the water column, so this factor remains a model uncertainty.

The comparisons between EUTRO5 and the regional EUTROMOD statistical model suggest that EUTRO5 model does a reasonable job of predicting the variation in growing season average conditions across each of the simulation years. Although there are many limitations and uncertainties associated with the development of the EUTRO5 model for the reservoir, the calibration and verification results indicate that the EUTRO5 model is suitable for predictive application to examine the possible effects of nutrient load reductions on reservoir water quality conditions.
SECTION 6. WATER QUALITY AND LOADING TARGETS

This section describes the development of water quality targets and associated pollutant loading targets for the Hillsborough River reservoir. The basis for water quality goals is the maintenance of designated beneficial uses of the reservoir, and the focus is on nutrients. The loading targets were calculated using the Hillsborough River reservoir WASP model.

6.1 WATER QUALITY GOALS

Water quality goals were based on the designated uses of the Hillsborough River reservoir. The principal uses may be summarized as follows:

- Potable water supply
- Recreation
- Propagation and maintenance of fish and wildlife

There are various informational resources available describing the water quality requirements associated with these uses. The resources examined in this evaluation included the Florida State water quality criteria, operational action levels used by the City of Tampa water treatment plant, Tampa Bay National Estuary Program nutrient loading targets, and typical water quality values reported for similar systems in Florida. The results of the analysis of information from each of these sources are presented in the following subsections.

6.1.1 State Water Quality Criteria

State water quality standards are issued in both narrative and numerical form, depending on the parameter of interest. For all waters in the state, antidegradation policy (F.A.C Rule 62-302) includes the following specific guidance regarding nutrients:

- It is FDEP policy to limit the introduction of nutrients into waters of the State.
- Particular consideration is given to protection of waters that are already highly enriched and sensitive to additional loadings.
- Particular consideration is given to protection of from enrichment of waters with TN $< 0.3 \text{ mg/L}$ or TP $< 0.04 \text{ mg/L}$.

With regard to numerical standards, The Hillsborough River reservoir is classified as a Class I water by the Florida Department of Environmental Protection (FDEP). The numerical water quality standards for dissolved oxygen and nutrients in Class I waters are as follows:

- Dissolved oxygen: $5.0 \text{ mg/L}$ minimum
- Ammonia (unionized): $0.02 \text{ mg/L}$ maximum
- Nitrate: $10.0 \text{ mg/L}$ maximum (or that concentration that exceeds the nutrient criteria)
6.1.2 Water Treatment Plant Action Levels
The City of Tampa water treatment plant (WTP) has certain operational criteria that are used to evaluate the water quality in the reservoir, and trigger actions to respond to poor intake water quality. The primary criterion relevant to this investigation is that of phytoplankton.

Blooms of phytoplankton, and especially blue-greens, in the reservoir are a major water treatment problem. The WTP controls the occurrence of blooms through the application of copper sulfate-based algaecides on a regular basis. Decisions on application timing and rates are based on monitoring of algal biomass in the reservoir. In general, biomass is measured in terms of cell counts, and not chlorophyll a. The operating practice is to maintain cell counts of *Anabaena sp.* or *Microcystis sp.* in the range of 8,000 - 10,000 cells/100 mL. Unfortunately, the LWWM/WASP water quality model of the Reservoir does not have the capability to represent phytoplankton species or cell counts. Moreover, data are not available to correlate cell counts with chlorophyll a in the Reservoir, which could be predicted by the reservoir model.

There is, however, an indirect means of correlating water treatment plant raw water quality requirements into parameters that the model can represent. This approach is predicated on the assumption that existing chlorophyll a concentrations in the reservoir are maintained at levels that are acceptable to the treatment plant, and nutrient loading that would result in those concentrations without the need for algaecide treatment would represent an appropriate management target. This topic is discussed further in a subsequent subsection.

6.1.3 Tampa Bay National Estuary Program Targets
The Tampa Bay National Estuary Program (TBNEP) developed nutrient loading targets for major tributary basins, including the Hillsborough River Watershed. The target set for the Hillsborough River watershed was no net increase in nitrogen loading over the levels of 1992 - 94, a period that was chosen to represent average precipitation and runoff conditions (Coastal, 1995). For this period, the annual nitrogen loading from the entire Hillsborough River Watershed was estimated to be approximately 309 tons/year (Coastal, 1994).

6.1.4 Typical Water Quality Values
More than 5 million water quality measurements collected at ambient water quality stations throughout Florida were examined by FDEP, and summarized by Friedemann and Hand (1989). The results are presented in terms of parameter distributions by water body type (i.e., lake, stream, estuary). Although there are definite limitations to the results of their analyses (e.g., no consideration of north-south differences or laboratory analytical technique), the data present a good overview of the variations found in Florida waters. It must also be noted that these results lump natural lakes with impoundments and reservoirs. These limitations should be considered in any comparisons with the Hillsborough River Reservoir.
Table 6-1 presents the distributions of values for key water quality parameters of interest to this investigation measured in Florida lakes. Monitoring conducted in the Hillsborough River Reservoir (i.e., at 40th Street) by the City of Tampa’s Bay Study Group show a long-term average TP concentration of 0.317 mg/L for the years 1984-95. The average TP concentration in 1987 was 0.360 mg/L, while the average in 1992-94, the reference period for the Tampa Bay Estuary load evaluations, was 0.312 mg/L. These concentrations place the Reservoir in the top 10 percent of lakes in the state relative to phosphorus enrichment, and suggest that phosphorus loads are elevated relative to other lakes in the state.

Table 6-1. Summary of Percentile Values Reported by Friedemann and Hand (1989) for Total Phosphorus, Total Nitrogen, Chlorophyll a, and Total Suspended Solids in Florida lakes.

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Total Phosphorus (mg/L)</th>
<th>Total Nitrogen (mg/L)</th>
<th>Chlorophyll a (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.01</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>10</td>
<td>0.02</td>
<td>0.5</td>
<td>2.3</td>
</tr>
<tr>
<td>20</td>
<td>0.03</td>
<td>0.7</td>
<td>5.0</td>
</tr>
<tr>
<td>30</td>
<td>0.04</td>
<td>0.9</td>
<td>6.8</td>
</tr>
<tr>
<td>40</td>
<td>0.05</td>
<td>1.2</td>
<td>11.0</td>
</tr>
<tr>
<td>50</td>
<td>0.07</td>
<td>1.4</td>
<td>18.5</td>
</tr>
<tr>
<td>60</td>
<td>0.08</td>
<td>1.5</td>
<td>26.5</td>
</tr>
<tr>
<td>70</td>
<td>0.11</td>
<td>1.7</td>
<td>34.3</td>
</tr>
<tr>
<td>80</td>
<td>0.15</td>
<td>1.9</td>
<td>46.5</td>
</tr>
<tr>
<td>90</td>
<td>0.29</td>
<td>2.7</td>
<td>67.5</td>
</tr>
<tr>
<td>100</td>
<td>0.71</td>
<td>3.8</td>
<td>94.8</td>
</tr>
</tbody>
</table>

It should be noted here that there is evidence of naturally eutrophic conditions occurring in the Hillsborough River watershed. Brenner, et. al. (1996) report that Lake Thonotosassa, the largest water body in the watershed, is naturally eutrophic because, in large part, of the phosphorus-rich geological deposits that exist within its watershed. The implication of this observation is that natural conditions and processes may place surface waters in this watershed, including the Hillsborough River reservoir, on the eutrophic end of a broad collection of Florida lakes.

Total Kjeldahl nitrogen (TKN), nitrate, and nitrite data were collected at the 40th Street station by the City of Tampa’s Bay Study Group between 1984 and 1986. These data allow for calculation of total nitrogen concentrations during this period (i.e., $\text{TN} = \text{TKN} + \text{NO}_2 + \text{NO}_3$). The average TN concentration in the period between 1984 and 1986 was 1.010 mg/L. Unfortunately, TKN was not measured by this program after 1986, so TN concentrations are not available after this date. The available data place the reservoir at around the 30th percentile of all lakes in the state, suggesting that nitrogen loading is probably not excessive relative to other lakes.
Chlorophyll a data collected between 1984 and 1995 show an average concentration of 11.4 µg/L, while the data from 1992-95 show an average concentration of 13.3 µg/L. These values place the reservoir in approximately the 40th percentile relative to other lakes in the state. When considered relative to ambient phosphorus concentrations, the chlorophyll a concentrations clearly reflect application of algaecides to the Reservoir. However, the values also represent conditions that support the use of the reservoir for water supply purposes, and may therefore be a good indication of an appropriate target for chlorophyll a concentrations.

Another approach to defining a chlorophyll a target for the reservoir is to consider the Lake Thonotosassa SWIM Plan target. Based on paleolimnological analyses, and consideration of local geological influences (i.e., high phosphate), a target trophic state index (TSI) of 60 was determined for the lake (SWFWMD, 1996). This TSI value corresponds to a chlorophyll a concentration of 20.0 µg/L. This chlorophyll a target concentration may be a more realistic goal for the reservoir because it reflects the influence of naturally-occurring background conditions that exist in the watershed.

6.1.5 Summary

Based on the information reviewed, Table 6-2 presents preliminary water quality targets for the Hillsborough River Reservoir. These targets are consistent with State water quality standards, as well as the operational requirements of the reservoir to support the designated beneficial uses of the resource.

Table 6-2. Summary of Preliminary Water Quality Targets for the Hillsborough River Reservoir.

<table>
<thead>
<tr>
<th>Water Quality Parameter</th>
<th>Target Concentration</th>
<th>Justification/Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>5.0 mg/L</td>
<td>State water quality standard.</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>1.0 mg/L</td>
<td>Long-term average under existing conditions, consistent with TBNEP recommendations.</td>
</tr>
<tr>
<td>Ammonia (unionized)</td>
<td>0.02 mg/L</td>
<td>State water quality standard.</td>
</tr>
<tr>
<td>Chlorophyll a</td>
<td>13.0 µg/L</td>
<td>Meets the raw water requirements of the water treatment plant without the need for algaecide.</td>
</tr>
<tr>
<td></td>
<td>20.0 µg/L</td>
<td>Corresponds to a TSI value of 60.</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>Varies</td>
<td>Concentration is based on model-predicted requirements to meet chlorophyll a target.</td>
</tr>
</tbody>
</table>
6.2 **POLLUTANT LOADING TARGETS**

The development of pollutant loading targets is based on determining target pollutant loads that will result in meeting water quality targets. This section presents the loading targets that were developed for the Hillsborough River reservoir.

### 6.2.1 Approach

The monitoring data indicate that dissolved oxygen concentrations are routinely below the state water quality standard of 5.0 mg/L (Tables 5-5, 5-6, and 5-7). However, the reservoir WASP water quality model was set up and run with a half-day time-step to support seasonal and annual analyses. Although dissolved oxygen is represented in WASP, using a half-day time-step will not provide adequate predictive capabilities for predicting attainment of the dissolved oxygen target. Adequate evaluation of BOD loading targets will require re-specification of the WASP model to simulate dissolved oxygen concentrations at intervals of less than an hour, an effort that is beyond the scope of this investigation. Thus, target loads for BOD were not developed for this study.

Because the target TN concentrations were set at existing conditions, no modeling was required or conducted for nitrogen species (i.e., TN, unionized ammonia, nitrate).

Target loads for TP were evaluated using the calibrated Hillsborough River reservoir WASP model and the simulations that had been previously developed for 1983, 1987, and 1990, but with maximum algal growth rates adjusted upward (to 2.0 day\(^{-1}\)) to remove the influence of algaecide applications. The purpose of using the three different years was to provide an indication of sensitivity to hydrologic conditions.

### 6.2.2 Loading Targets

Loading targets were investigated for TP and TN, as discussed below.

**Phosphorus**

Figure 6-1 presents plots of model-predicted peak and average annual chlorophyll \(a\) concentrations as a function of annual watershed phosphorus loading for the three years of interest. This analysis examines watershed loads only because watershed management alternatives for phosphorus reduction are practically limited to these sources. These plots also show \(\pm 1\) standard deviation about the predicted annual mean. It can be seen that average annual chlorophyll \(a\) is not especially sensitive to reductions in phosphorus load, with reductions being relatively even across the range. Peak chlorophyll \(a\) is somewhat more sensitive, with apparent break-points around the 30 - 50 percent reduction range. Based on these plots, attainment of the 13 \(\mu g/L\) chlorophyll \(a\) goal appears improbable; only the plot for 1983 shows the average annual mean reaching the goal, and that corresponds to an approximately 92 percent reduction in the total phosphorus loading for that year. However, attainment of the 20.0 \(\mu g/L\) chlorophyll \(a\) goal, corresponding to a TSI of 60, is indicated with a substantial (i.e., 80%) reduction in watershed sources of phosphorus loading.
Figure 6-1. Predicted Peak and Annual Chlorophyll $a$ as a Function of Annual Watershed Phosphorus Loads.
The maintenance of elevated predicted chlorophyll \( a \) levels in the model is the result of both hydrologic conditions and loading from internal sources (i.e., groundwater and pumpage from the Tampa Bypass Canal). For example, in January 1983 the predicted peak chlorophyll \( a \) is associated with more than 30 days of virtually no reported discharge over the reservoir dam, resulting in a much longer residence time in the reservoir. For 1990, the only year with loading data for the Tampa Bypass Canal and Sulphur Springs, loading from those two sources accounted for 11 percent of the total annual phosphorus load. Loading from groundwater contributed an additional 9 percent of the estimated annual load.

The model predictions are also influenced by the conditions under which the model was calibrated. Specifically, the available reservoir monitoring and calibration data reflect a situation where primary productivity was artificially inhibited by algaecide applications. Thus, the calibrated model may not reflect how the reservoir would actually respond in the absence of this artificial influence. Moreover, the calibration was conducted at a much higher range of phosphorus loading than is associated with the relatively low target chlorophyll \( a \) concentration.

An alternative approach to defining a suitable target loading for phosphorus may be provided by looking at the dominance of primary productivity related to nitrogen fixation in the reservoir. The reason that nitrogen fixation is of interest is that it reflects the presence of nitrogen-fixing blue-green phytoplankton, which are commonly the source of taste and odor problems in drinking water supplies. If primary productivity associated with nitrogen fixation is not dominant, then, presumably, smaller amounts of algaeicides may be required to maintain raw water at acceptable quality.

Figure 6-2 presents plots of the predicted percentage of annual primary production due to nitrogen fixation as a function of runoff phosphorus loads for 1983, 1987, and 1990. The 1990 model run showed the highest average annual predictions for percentage of primary productivity associated with nitrogen fixation at approximately 32 percent. Maximum percentages in the other years were in the range of 26 - 29 percent. Unfortunately, there is no standard defining what percentage constitutes dominance. None-the-less, the information in Figure 6-2 may be useful in identifying preliminary load reduction targets. Reductions in the percentage of primary productivity due to nitrogen fixation to reductions in phosphorus loading are relatively level, with the rate of reduction increasing significantly around the 25 percent of current load mark. This level is associated with an average annual percentage of primary productivity due to nitrogen fixation of approximately 20 percent in 1983 and 1987.
Figure 6-2. Predicted Percentage of Annual Primary Production Due to Nitrogen Fixation as a Function of Watershed Phosphorus Loads.
Yet another option for setting target TP loads is to estimate the load required to move the reservoir from its current ranking relative to TP concentrations in all Florida lakes (i.e., 90th percentile) to some other ranking that is in the middle of the population of Florida lakes. Figure 6-3 presents a plot of predicted annual average TP concentrations as a function of percent of current phosphorus load for 1987. The model indicates that a 50 percent reduction in watershed loading of TP would be required to place the reservoir at the 80th percentile ranking.

![Graph.png](attachment:Graph.png)

**Figure 6-3. Predicted Annual Average Total Phosphorus Concentrations in 1987 as a Function of Watershed Phosphorus Loads.**

Finally, application of the Lake Thonotosassa SWIM Plan target TSI of 60 to the Hillsborough River Reservoir yields a target average annual TP concentration of 0.070 mg/L. The model predictions shown in Figure 6-3 suggest that this target could be attained with an approximate 80 percent reduction in watershed sources of phosphorus loading.

The presence of relatively elevated background concentrations of phosphorus in this region may make the attainment of the goal to eliminate the use of algaeicides in the reservoir impractical, or even impossible. Brenner, et al. (1996) state that nutrient management strategies in Lake Thonotosassa should acknowledge the existence of naturally occurring eutrophic conditions, and recognize that efforts to improve trophic state will be limited by these conditions.

The results of this analysis suggest that this same philosophy should be applied to the Hillsborough River reservoir. Using the TSI target of 60 yields an ultimate watershed phosphorus loading target of approximately 34 tons per year, or an 80 percent reduction relative to the reference year.
Nitrogen

The target load for total nitrogen consists of maintaining loads at the same levels as during the period of 1992-94. For the purposes of the present study, there is no evidence to suggest that the sources of nitrogen loading levels in 1992-94 were significantly different than those in 1987 or 1990. The estimates of total loading show that annual nitrogen loads may vary significantly, depending on hydrologic conditions in the watershed, with loads in 1987 (a typical year in terms of precipitation) and 1990 (a dry year) ranging from 857 to 205 tons/year, respectively. The variation in these values reflects hydrologic differences between the two years. The average estimated nitrogen loads for the two years was 531 tons/year, approximately 70 percent higher than the TBNEP estimate (i.e., 309 tons/year). The differences may reflect substantially reduced loadings from two major sources of nitrogen loading in the system between 1990 and 1992-94 (i.e., Plant City WWTP and Florida Sno-Man), the period upon which the TBNEP estimate is based. The nitrogen load of 309 tons/year specified by TBNEP appears to remain a reasonable target.

6.3 LOAD REDUCTION ALLOCATION

The allocation of loads among sources in the watershed to meet targets (e.g., load reductions or load maintenance with changing land uses) is a complex undertaking that involves technical, political, and economic considerations. The technical basis for allocations typically begins with an examination of the relative contributions from various known and quantifiable sources, which is the topic of the remaining discussion in this section. Future analyses must consider the relative controllability of each source to develop a defensible allocation scheme.

6.3.1 Approach to Assessing Relative Contributions

An indication of the relative contributions from the major sources of nutrients to the reservoir may be obtained by comparing the following sources of nutrients in the system against the estimated total loads to the reservoir during the 1987 reference year:

- LWWM/SWMM estimates of annual TP and TN loads in surface runoff
- Reported annual TP and TN loading from NPDES permitted dischargers
- Potential annual TP and TN loadings from onsite wastewater treatments systems
- Potential annual TP and TN loadings from land application of residuals

This approach implicitly assumes that other sources of nutrients, such as livestock operations, citrus farms, and strawberry farms are adequately represented by the 10 land use categories and associated mean event concentrations used by the LWWM/SWMM. Also, contributions from groundwater are not included in this analysis, although it might be argued that the consideration of onsite wastewater treatments systems and land application of residuals explicitly accounts for two major sources of nutrients in surficial groundwaters. The consideration of other potential influences on groundwater loading is
beyond the scope of this investigation. Thus, the analysis should be interpreted as reflecting the relative contribution of quantifiable sources.

6.3.2 Relative Load Contributions

Table 6-3 presents a comparison of the total annual phosphorus and nitrogen load estimates from the identified principal sources in the watershed during 1987 against the estimated total load to the reservoir based on monitoring data at HCEPC 106 plus the SWMM projections for the portion of the watershed below that station. The NPDES dischargers have been subsetted into the Plant City WWTP, which has reduced its discharges significantly since 1987; Florida Sno-Man, which is no longer in operation; and the rest of the permitted dischargers.

Table 6-3. Summary of Load Estimates from Different Watershed Sources for 1987.

<table>
<thead>
<tr>
<th>Load Source</th>
<th>Data Source</th>
<th>P (tons)</th>
<th>N (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runoff</td>
<td>SWMM</td>
<td>73.3</td>
<td>458.1</td>
</tr>
<tr>
<td>OWTS</td>
<td>Ayres, 1995</td>
<td>52.0</td>
<td>85.3</td>
</tr>
<tr>
<td>Land application of residuals</td>
<td>Ayres, 1995</td>
<td>775.6</td>
<td>616.1</td>
</tr>
<tr>
<td>Plant City</td>
<td>TBNEP</td>
<td>14.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Florida Sno-Man</td>
<td>TBNEP</td>
<td>69.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Other NPDES Permits</td>
<td>TBNEP</td>
<td>9.3</td>
<td>24.5</td>
</tr>
<tr>
<td>Total</td>
<td>All sources</td>
<td>994.3</td>
<td>1201</td>
</tr>
<tr>
<td></td>
<td>Less OWTS and land application</td>
<td>166.7</td>
<td>499.6</td>
</tr>
<tr>
<td>Empirical Load Estimate</td>
<td>HCEPC 106 + SWMM</td>
<td>172</td>
<td>854</td>
</tr>
</tbody>
</table>

It can be seen from Table 6-3 that the sum of the individual potential loading sources greatly exceeds the empirical load estimates based on monitoring data plus SWMM. However, if the estimated contributions from OWTS and land application of residuals are eliminated from consideration, there is relatively good agreement (within 5 percent) between the annual phosphorus loading estimates. Nitrogen loading estimates do not compare as well, however, nitrogen is not as of great a concern in the present analysis.

Based on these observations, and the fact that the Ayres (1995) estimates were intended to portray maximum potential (rather than average existing) loadings from OWTS and land application of residuals, it appears likely that the Ayres (1995) estimates are substantially higher than the loadings currently emanating from those sources. It therefore appears reasonable to omit the Ayres (1995) estimates of loadings from OWTS and residuals applications from further consideration in this discussion, which seeks to characterize existing loading conditions in the watershed.
Figure 6-2 illustrates the distribution among watershed sources of phosphorus loading to the Hillsborough River Reservoir. The results in Table 6-3 and Figure 6-2 indicate that Florida Sno-Man was the most significant estimated source of phosphorus in the watershed. The second most significant estimated source of phosphorus was surface runoff. The elimination of the Florida Sno-Man discharge, and reductions that have occurred in the Plant City WWTP discharge represent an approximate 48 percent reduction in phosphorus loads in the watershed to date, and significant progress towards attainment of load reduction goals.

![Pie Chart](image)

**Figure 6-2. Relative Contribution of Potential Sources of Total Phosphorus in the Watershed in 1987.**

With the elimination of the Florida Sno-Man discharge, and the reductions at the Plant City WWTP, stormwater runoff contributes approximately 84 percent of the phosphorus load and more than 90 percent of the nitrogen load in the watershed. Among the permitted point source discharges (Table 2-1), CF Industries facility in Plant City is the primary point source of phosphorus loading, while Crystals International facility in Plant City is the major point source of nitrogen loading. It should be noted that the Crystals International discharge is non-contact cooling water, and the nitrogen apparently originates in groundwater used in the cooling system.

The target of 80 percent reduction in phosphorus loads relative to 1987 corresponds to an approximate 62 percent reduction in current phosphorus loads.
6.3.3 Possible Allocation Schemes

The ultimate allocation of nutrient management efforts, and especially phosphorus load reduction, will require consideration of issues related to magnitude, controllability, uncertainty, and socio-economics. The full range of these considerations is beyond the scope of the current investigation. However, the results provide a basis for an initial focus of management attention upon which future actions can be built. In particular, it appears that once realistic load reduction targets for phosphorus have been defined, management efforts should be focused on stormwater runoff and the major permitted point source discharger. Maintenance of current nitrogen loading will likely require some reductions in existing sources to allow additional loadings from runoff as urban development progresses.

With respect to actual allocation of loads, there are two schemes that might be applied: equal percent removal and equal relative effort. Basic descriptions of each are presented below.

**Equal Percent Removal.** Under this scheme, each load source is required to reduce discharges by the same percentage. With large differences in loads from different sources, this scheme may result in unobtainable allocations for the smaller loading sources.

**Equal Relative Effort.** This strategy might also be called “equal effort relative to contribution.” The idea here is that the relative distribution among loading sources is used to calculate weighting factors to determine percent reduction. Thus, the greater the fraction of total load contributed by a source, the greater the percent reduction required. Weighting factors may be calculated in several different ways, the details of which are beyond the scope of this investigation.

The equal relative effort approach would seem the most reasonable to pursue, given the large differences in relative contribution to loads in the watershed.

6.4 INTERIM LOAD REDUCTION GOALS

Attaining a 62 percent reduction in existing watershed phosphorus loading is an ambitious goal. Moreover, there is invariably some uncertainty in predicting the response of a system to large changes in nutrient loads, and time will invariably bring an improved understanding of loading sources and the system’s response to them. For these reasons, it is advisable to set interim load reduction goals, and provide for periodic reassessment of the progress made and the appropriateness of the goals. Suggested interim phosphorus load reduction goals are provided in Table 6-4. It should be noted that the annual phosphorus loads shown in the table are approximations, based on 1987 as an “average” year. Actual loading on any given year will be strongly influenced by precipitation.
The schedule of interim reductions presented in Table 6-4 is intended as a starting point. Implementation will require consensus among the diverse stakeholders in the watershed, and some revisions are likely to be required to ensure that consensus.

**Table 6-4. Suggested Interim Phosphorus Load Reduction Goals.**

<table>
<thead>
<tr>
<th>Years from Initiation of Load Reduction Program</th>
<th>Phosphorus Load Reduction Relative to Current Conditions</th>
<th>Approximate Annual Phosphorus Load (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>10</td>
<td>81</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>72</td>
</tr>
<tr>
<td>15</td>
<td>30</td>
<td>63</td>
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<tr>
<td>20</td>
<td>40</td>
<td>54</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>34</td>
</tr>
</tbody>
</table>

### 6.5 CONCLUSIONS

The following conclusions are provided based on the examination of water quality targets and pollutant load goals:

- Nitrogen loading targets should be based on the resource requirements of the Tampa Bay estuary. A reasonable estimate of target nitrogen loading is 309 tons/year.

- A target chlorophyll a concentration of 13 µg/L to meet operational requirements at the Tampa Water Treatment Plant and an objective of completely eliminating the use of algaecides by the Plant appears impractical.

- A target chlorophyll a concentration of 20 µg/L, based on achieving a TSI value of 60, appears attainable. With the elimination of the Florida Sno-Man discharge, and reduction in phosphorus loading at the Plant City WWTP, an approximate 62 percent additional reduction in remaining phosphorus loading will be required to achieve this target.

- Nutrient reduction efforts should focus on stormwater runoff, with some attention to ensuring that the major permitted point sources are employing the best available practical technology for phosphorus reduction.

- There is considerable uncertainty surrounding OWTS and land application of residuals as potential sources of nitrogen and phosphorus loading in the watershed. Additional research should be conducted into this issue.

- A schedule of interim load reduction goals should be established and implemented to allow for the attainment of realistic short-term targets, as well as the periodic reassessment of progress and objectives.
SECTION 7. IDENTIFICATION OF PRIORITY SUBBASINS

The scale of this investigation was necessarily broad, and represents the first phase of watershed management efforts. Subsequent management efforts are expected to be more narrowly focused on particular sources and subbasins in the watershed that represent the best opportunities for reductions in excessive nutrient loads. The purpose of this section is to present an identification of priority subbasins where future management scrutiny will be best applied. The emphasis in this discussion is on diffuse nonpoint sources of nutrients because point source discharges are already controlled under the NPDES permitting program, and their contribution to the overall nutrient load is relatively small (Section 6.3.2).

7.1 APPROACH

The strategy used in ranking subbasin priority is based on the idea of disproportionate load contribution relative to surface drainage area. Thus, the basic metric for assessing subbasin priority was expressed in terms of total load generated per unit area. This total estimated load was the sum of contributions from surface runoff. For the purposes of this analysis, all loads were from 1987, the typical precipitation year, and the one best represented by LWWM/SWMM.

The nutrient loading predictive capabilities of SWMM/LWWM were used to estimate total annual nonpoint source loads of nitrogen, phosphorus, and total suspended solids (TSS) in runoff from each subbasin. These individual subbasin loads were then summed and divided by the total area of each of the subbasins. The resulting unit area load generation values were ranked to identify priority subbasins relative to the examined nonpoint sources of each pollutant. Subbasin groups representing the top 70th, 80th, and 90th percentiles were then plotted.

7.2 RESULTS

Figures 7-1 and 7-2 present identified priority ranked subbasins based on runoff unit area loading values for contributions of phosphorus and nitrogen, respectively, from surface runoff. The results indicate that the priority subbasins tend to fall in the more developed areas of Tampa and western Polk County.

7.3 CONCLUSIONS

The results of this analysis indicate that priority subbasins for future efforts to reduce watershed loadings of nitrogen and phosphorus to the Hillsborough River reservoir are located in the more developed areas of Tampa and western Polk County.

The identified priority subbasins are also relevant where trading opportunities might be sought involving reductions in certain existing sources in return for increases in others (e.g., to counteract the influence of urbanization).
Figure 7-1. Estimated Annual Total Phosphorus (TP) Areal Loading from Runoff by Subbasin.
Potential TN loadings

90TH PERCENTILE
≥ 4.27 lb/ac-yr

80TH PERCENTILE
3.69 - 4.17 lb/ac-yr

70TH PERCENTILE
3.41 - 3.65 lb/ac-yr

Drainage subbasin boundary

County boundary

Figure 7-2. Priority Subbasins Based on Total Estimated Unit Area Loads for Nitrogen from Runoff.
SECTION 8. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes conclusions and recommendations drawn from the various elements of this investigation as they apply to future management direction and emphasis.

8.1 WATER QUALITY AND LOADING TARGETS

The following conclusions regarding water quality and loading targets were developed during this investigation:

- Nitrogen loading targets should be based on the resource requirements of the Tampa Bay estuary, which are current loads during the 1992-94 time period (TBNEP, 1997). A reasonable estimate of target nitrogen loading is an average of 309 tons/year.

- A target chlorophyll $a$ concentration of 20 $\mu$g/L will correspond to a TSI of 60, which is consistent with previously developed management targets for Lake Thonotosassa, and naturally occurring eutrophic conditions in this system (SWFWMD, 1996).

- The 20 $\mu$g/L target chlorophyll $a$ concentration will facilitate significant reduction in the Tampa Water Treatment Plant's need to use algaecide. Once significant phosphorus load reductions have been achieved, and additional monitoring data collected, the feasibility of totally eliminating algaecide applications should be revisited.

- Attainment of the chlorophyll $a$ goals will require an approximate 80 percent reduction in annual phosphorus loads from watershed sources, relative to 1987. This corresponds to a target annual phosphorus load of approximately 34 tons per year.

- The changes that have occurred in point source discharges since 1987 have resulted in an approximate 48 percent reduction in annual phosphorus loads from the watershed. An additional 62 percent reduction in existing phosphorus loading will be required to meet the target chlorophyll $a$ goal.

- A schedule of interim load reduction targets is recommended, with incremental reduction milestones over a 30-year period leading to attainment of the final goal. This process should include periodic assessment of the progress made and revisiting of the load reduction goals to ensure that they are still appropriate.

- Future respecification of the EUTRO5 model to a finer time step, as well as use of more complete data that have been collected in recent years, will provide a basis for setting loading targets relative to low dissolved oxygen in the reservoir. This type of analysis should be preceded by a clear definition of data requirements and availability, especially regarding sediment oxygen demand.
8.2 WATERSHED MANAGEMENT FOCUS

The following conclusions regarding future watershed management efforts were developed during this investigation:

- The majority (i.e., approximately 84 percent of phosphorus and 93 percent of nitrogen) of the current watershed nutrient load is from surface runoff. The focus of management efforts to reduce phosphorus loads and maintain nitrogen loads in the future should be on activities that contribute to this category of loading.

- Point source discharges appear to be a relatively minor source of both nitrogen and phosphorus in the watershed.

- The identified priority subbasins are also relevant where trading opportunities are being sought involving reductions in certain existing sources in return for increases in others (e.g., to counteract the influence of urbanization).

- The Tampa Bypass Canal can be a significant source of nutrient loading to the reservoir. During 1990, the only year examined where loading data were available, the Bypass Canal contributed approximately 10 percent of the total annual phosphorus load.

The following recommendations regarding watershed management activities are provided:

- Watershed management efforts should focus on the reduction of phosphorus loading from activities associated with surface runoff, and the maintenance of existing nitrogen loads from this same category of sources.

- Watershed management actions that have the potential to provide phosphorus load reductions consistent with the priority areas identified in this study include the following:
  - Upgrading and retro-fitting of regional stormwater treatment systems in priority areas.
  - Implementing BMPs for existing feedlots and dairies.
  - Implementation of aggressive BMPs and stormwater controls in conjunction with new urban development.
  - Connection of clusters of package treatment plants to central sewer systems.
  - Upgrading phosphorus controls in all surface discharge permits.

- Future research should be directed at obtaining better information on the actual loading from land application and OWTS sources.
8.3 DATA AND MODELING DEVELOPMENT NEEDS

The following recommendations regarding further model development efforts are provided:

- The usefulness of existing water quality data for the Hillsborough River reservoir for supporting water quality modeling is limited by the artificial inhibition of primary productivity by the routine application of algaecides. Further development of the EUTRO5 model should include refinement of the influence of algaecide application in the reservoir. This should be accompanied by collection of quantity and location data on the daily application of algaecides. With this capability, the model could be used to better assess load reductions required to significantly reduce the need for algaecide treatment.

- As an additional test of the EUTRO5 calibration parameterization, the model should be applied to other years where suitable data exists for characterizing loads and reservoir water quality conditions. As part of this effort, historical information on daily reservoir operations, including TBC and Sulphur Spring transfers should be thoroughly researched and located for use in better describing the reservoir hydraulics within the EUTRO5 model. However, it is unlikely that the fundamental conclusions of the present analysis would significantly change.

- Development of a separate hydraulic model to drive the EUTRO5 model water budget should be considered. A hydraulic model of the reservoir would reduce possible model uncertainty related to segment-specific estimated volumes and residence times, but only if all of the sources and losses of water to the reservoir can be adequately characterized.

- Nutrient levels in the reservoir sediments should be measured as an initial step in characterizing this uncertain factor. Additionally, several locations in the reservoir should be measured to assess spatial variability in sediment nutrient levels, because sediments are likely to be accumulating at a faster rate behind the dam. Further consideration of sediment-water interactions should only be undertaken once this information has been collected and analyzed.

The following recommendations are provided regarding data requirements to support future modeling applications:

- A significant factor undermining the efficiency of this study was a general lack of a clear definition of data availability and quality. Many organizations collect data in this watershed, but the format, quality, completeness, etc. of the data vary significantly. Moreover, the criteria for judging data adequacy relative to the needs of a particular organization may bear little relevance to the data requirements for model development, calibration, and application. In the future, the SWFWMD should precede all watershed studies with a separately funded data identification, compilation, and assessment phase that can serve as a confident basis for planning subsequent modeling activities. In the absence of either
adequate data or project resources, simpler models should be used as a matter of course.

- The HCEPC and TBSG monitoring programs should be coordinated to assure that comparable methods of sampling and analysis are used. Greater coordination of these programs is likely to result in a superior database of water quality measurements for the reservoir.

- Additional water quality monitoring stations in the reservoir should added to the ongoing monitoring programs to enhance future modeling efforts.

- An easily accessed central repository and clearinghouse should be established for flow and water quality monitoring data from all organizations (e.g., SWFWMD, HCEPC, City of Tampa, FL DEP, etc.) that collect these data in the watershed. Although much of these data are readily available through the SWFWMD’s database, there is additional water quality and flow data collected by USGS, the City of Tampa Bay Study Program, the City of Tampa Water Treatment Plant, and others that are inconsistently represented, or are only available in hard copy format.
SECTION 9. LITERATURE CITED


Southwest Florida Water Management District, 1996. Surface water improvement and management (SWIM) plan for Lake Thonotosassa (June 1996), Southwest Florida Water Management District, Tampa, Florida.


APPENDIX A. HYDROLOGIC MONITORING STATIONS
### Appendix A. USGS Stream Gaging Stations in the Hillsborough River Watershed

<table>
<thead>
<tr>
<th>Station No.</th>
<th>Station Description</th>
<th>Period of Record (Earthinfo)</th>
<th>Period of Record (SWFWMD)</th>
<th>Latitude (deg,min,sec)</th>
<th>Longitude (deg,min,sec)</th>
<th>County</th>
<th>Drainage Area (sq mi)</th>
<th>Historic Min. (cfs)</th>
<th>Historic Max. (cfs)</th>
<th>Historic Mean (cfs)</th>
<th>On USGS Home Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>02302010</td>
<td>Hillsborough R BL Crystalsprings Nr Zephyrhills, FL</td>
<td>84-84</td>
<td></td>
<td>28 10 43 82 11 21</td>
<td>Pasco</td>
<td>not given</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
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<td>02303000</td>
<td>Hillsborough River Nr Zephyrhills, FL</td>
<td>39-92</td>
<td>1/93-2/96</td>
<td>28 8 59 82 13 57</td>
<td>Hillsborough</td>
<td>220</td>
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<td>New River Nr Zephyrhills, FL</td>
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<td>28 9 55 82 15 55</td>
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<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<td>02303174</td>
<td>Westside Canal At Plant Cty., FL</td>
<td>85-86</td>
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<td></td>
<td></td>
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<td>X</td>
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<td>02303180</td>
<td>Pemberton Ck, at Wallace Branch Rd. Nr Dover, FL</td>
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<td></td>
<td>28 2 25 82 9 16</td>
<td>Hillsborough</td>
<td>not given</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>02303200</td>
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<td></td>
<td>28 1 34 82 14 12</td>
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<td>24</td>
<td></td>
<td></td>
<td></td>
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<td>02303205</td>
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<td>not given</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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<tr>
<td>02303250</td>
<td>T. Gallagher Ditch Nr Dover, FL</td>
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<td>28 0 24 82 14 42</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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<td>Campbell Branch Nr Thonotosassa, FL</td>
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<td></td>
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<td>28 8 20 82 21 50</td>
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<td>23</td>
<td>0 cfs (6/17/91)</td>
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<td>02303351</td>
<td>Morris Bridge Backwash Pond Outflow</td>
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<td>02303500</td>
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<td>02304000</td>
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<td></td>
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<td>02304500</td>
<td>Hillsborough R Nr Tampa, FL</td>
<td>38-92</td>
<td>1/93-9/94</td>
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<td>Hillsborough</td>
<td>650</td>
<td>0 cfs (1945)</td>
<td>13500 cfs (1960)</td>
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<td>02304502</td>
<td>Tampa Water Plant Outflow Nr Tampa</td>
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<td></td>
<td>28 1 23 82 25 43</td>
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<td>not given</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

** SWFWMD shows a period of record for 02301990 beginning in 1969, and for 02303330 beginning in 1970.