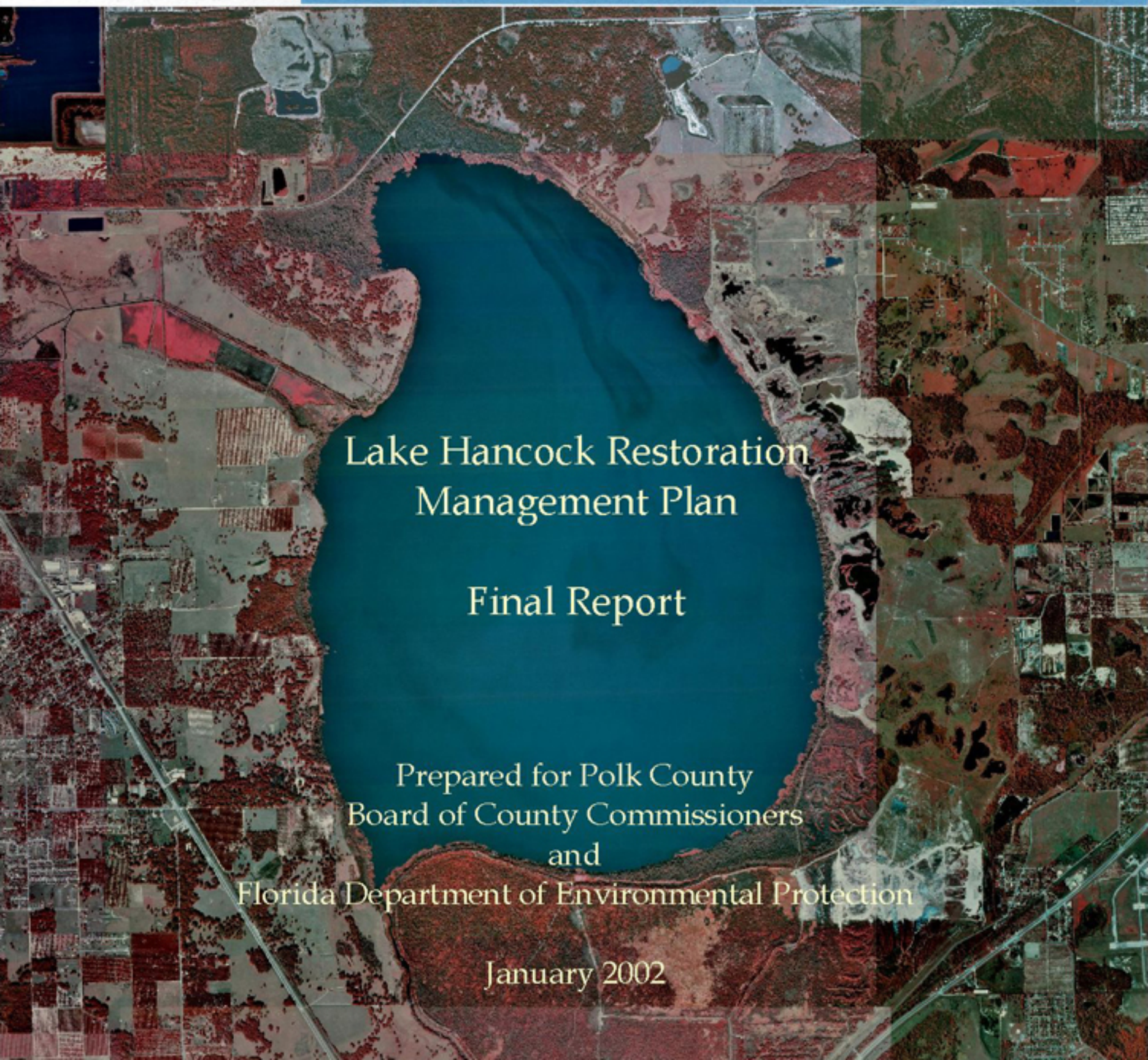
CDM Camp Dresser & McKee



Lake Hancock Restoration Management Plan

Final Report

Prepared for Polk County
Board of County Commissioners
and
Florida Department of Environmental Protection

January 2002

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Acronyms

ACOE	U.S. Army Corps of Engineers
BOD	Biochemcial Oxygen Demand
CDF	Confined Disposal Facility
CDM	Camp Dresser & McKee
CHNEP	Charlotte Harbor National Estuary Program
CWA	Clean Water Act
CY	Cubic Yard
DIP	Dissolved Inorganic Phosphorus
DOP	Dissolved Organic Phosphorus
ENR	Engineering News Record
EPA	Environmental Protection Agency
ERC	Environmental Regulation Commission
ERD	Environmental Research & Design
ERP	Environmental Resource Permit
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FEMA	Federal Emergency Management Agency
FFWCC	Florida Fish and Wildlife Conservation Commission
FGFFC	Florida Game and Freshwater Fish Commission
FS	Florida Statutes
FWS	Free Water Surface
HLR	Hydraulic Loading Rate
HRT	Hydraulic Retention Time
LAC	Liquefied Activated Carbon
LHAG	Lake Hancock Advisory Group
MSSW	Management and Storage of Surface Waters
MT	Metric Ton (1,000 kg)
NGVD	National Geodetic Vertical Datum
O&M	Operations & Maintenance
PCEPD	Polk County Environmental Protection Department

PCNRD	Polk County Natural Resources Division
PLRGs	Pollution Load Reduction Goals
PON	Particulate Organic Nitrogen
POP	Particulate Organic Phosphorus
SWFWMD	Southwest Florida Water Management District
SCS	Soil Conservation Service (Currently Natural Resources Conservation Service)
SRP	Soluble Reactive Phosphorus
SWIM	Surface Water Improvement and Management
SWMM	Stormwater Management Model
TAC	Technical Advisory Committee
TCLP	Toxicity Characteristic Leaching Procedure
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solid
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WMD	Water Management District

Executive Summary

Introduction

Camp Dresser & McKee Inc. (CDM) was retained by the Polk County Board of County Commissioners under the direction of the Polk County Natural Resources Division to develop a restoration management plan for Lake Hancock, and the water discharging to the Peace River from Lake Hancock. The intent of this report is to assist Polk County in the development and implementation of a multiyear/multiphase effort to achieve the following objectives developed by the Lake Hancock Advisory Group:

1. Improve the quality of the water discharged from Lake Hancock by reducing Total Maximum Daily Loads (TMDLs) to the lake.

2. Preserve, and where feasible, enhance the natural greenway/wildlife corridor (Peace River/Green Swamp) through Polk County.

3. Maintain the exceptional wildlife values of Lake Hancock.

4. Enhance the diversity of the fishery of the lake.

5. Provide habitat compatible public access for nature-based recreational activities and commercial fishing.

Past industrial and agricultural activities have extensively affected the lake. These activities include domestic and industrial wastewater discharges, urban development, agricultural activities, loss of wetlands, and phosphate mining. As a result, Lake Hancock is characterized by excessive growth of persistent blue-green algal blooms. The lake contains high nutrient concentrations; has a thick layer of flocculent organic sediments; is dominated by detrital-feeding rough fish; has reduced clarity; and is characterized as having poor water quality. However, Lake Hancock and its shoreline sustain a large, highly diverse fauna. Restoration is needed for this valuable resource as well as for protection of downstream waters that are used as a public drinking water source as well as Charlotte Harbor.

In order to develop the Restoration Management Plan, CDM documented the history of restoration efforts in Lake Hancock and identified available pertinent data for Lake Hancock (including physical, chemical, and biological characteristics of the lake), as well as institutional and regulatory issues, and lake restoration techniques. Then CDM evaluated applied lake restoration techniques and lake restoration options, and selected three lake restoration options. A lake restoration implementation plan was developed for a selected option.

Lake Restoration Techniques

The restoration of eutrophic or hypereutrophic lakes requires the reduction of both external and internal phosphorus loads, as well as the implementation of other management techniques. Therefore, in order to develop the Lake Hancock restoration plan it is important to evaluate available restoration technologies that reduce external and internal loads, as well as other management techniques. Sediment inactivation techniques (dredging, drawdown and mechanical excavation, chemical inactivation, and capping) and recirculating wetlands can remove internal loads. Treatment wetlands and settling ponds can remove external tributary loads. Other in-lake restoration techniques include increasing the lake water level, biological control, and littoral zone habitat restoration. Treatment wetlands, settling ponds and filtration can be used to treat the discharge from the lake.

In order to restore this over-enriched, shallow and turbid lake and to restore a balance to the aquatic flora and fauna, it is necessary to improve the quality of water within the lake. Phosphorus loadings must be reduced from the sediments in the lake as well as from the tributaries. Over half of the annual phosphorus loading comes from the sediments and therefore, techniques that control the phosphorus input from the sediments are critical to restoration of Lake Hancock. A brief description of the restoration techniques follows:

- **Sediment Removal by Hydraulic Dredging** – A barge-mounted pumping system is used to remove submerged sediment from the lake. This technique can provide efficient removal of sediments from the lake.

- **Lake Drawdown and Mechanical Excavation** – Lake water is allowed to drain through the existing P-11 structure at South Saddle Creek, and when sufficiently dry, earth-moving equipment can be used to remove sediments from the lake shoreline.

- **Chemical Inactivation of Sediment with Alum** – Alum is used to immobilize phosphorous within the sediment. The phosphorus and alum bind and settle, becoming unavailable for release back into the water column.

- **Capping of the Sediments with an inert substance** – Clean sand, gravel, geotextiles, or synthetic liner may be used to cover the submerged sediment. This activity would also help bind nutrients within the sediment.

- **Recirculating Treatment Wetland** – This technique removes particulate phosphorous by removing algae and resuspended sediments. This is accomplished by pumping lake water into a filtration wetland, cleaning the water through nutrient uptake and settling.

- **Wetland Treatment of Inflows** – This technique involves the construction of wetlands to treat tributaries entering Lake Hancock. The wetlands capture and transform nutrients from the tributaries before they enter the lake.

- **Lake Level Manipulation** – This technique involves controlling the lake level using the P-11 structure located at the discharge of Lake Hancock. Adjustments to lake level can be used to recreate natural cyclic variations in depth, increase the depth of the lake to facilitate commercial fishing or drawdown the lake for sediment removal.

- **Biological Control/Management** – This technique involves altering biological components in the lake's community. This technique may provide a method of controlling algae growth and promoting increase in fish diversity.

- **Habitat Restoration** – This technique involves restoration of the littoral zone of the lake, which requires improved water transparency and removal of organic sediments to allow growth of submerged rooted plants.

Identification of Suitable Lands for Restoration Activities

An aggressive land acquisition plan has been identified by Lake Hancock Advisory Group as a necessary element of an overall management plan for the lake. Some of those lands will be required for restoration of the lake and an inventory of potential lands for restoration activities was developed. The present evaluation was limited to those areas, which border the lake or it's tributaries where restoration activities are likely to be conducted. Twelve property areas were initially identified and grouped into four general regions, each surrounding the lake and one of the tributaries. The properties contain areas that were formerly wetlands and offer opportunity for wetland restoration. These properties could be incorporated into a trail / greenway / wildlife corridor linking areas north of the lake with the Peace River to the south. Suitable acreage may be available for a demonstration or full-scale project.

Evaluation of Lake Restoration Options for Lake Hancock

Seventeen lake restoration techniques applicable to Lake Hancock were identified and combined into ten options in order to address all five restoration objectives. Each technique was scored for its ability to fulfill the objectives. The sum of the scores for the applied techniques in each option were used to rank the options. The highest ranked restoration options differed primarily in the technology used to address the internal phosphorus loading from the sediments.

Top Three Ranked Options

The top three ranked options included a number of common components and differed primarily in how the sediment phosphorus was controlled. The components common to all three options include:

- **Wetland Treatment of Discharge From South Saddle Creek**. This is in direct response to the need to improve the quality of water discharged from Lake Hancock (Objective 1) and would provide an environmental safeguard to other restoration activities to be conducted in the lake such as hydraulic dredging. This component would also provide a continuation of the greenway, which will enhance the wildlife value of the lake.

- **Chemical Treatment/Settling Pond Treatment of North Saddle Creek Inflow.** The largest external loading of phosphorus is from North Saddle Creek and this component would serve to reduce that loading. This component addresses Objective 1 directly. Improvements to water quality are necessary and complimentary to achieving Objectives 3 (Maintain Exceptional Wildlife) and 4 (Enhance the diversity of the fishery).

- **Wetland Treatment of Banana Creek Inflow.** This common component would improve water quality (Objective 1), increases greenway (Objective 2), improves public access (Objective 5) and enhances the wildlife of the lake (Objective 3) through increased habitat.

- **Passive Drawdown and Mechanical Excavation of the Littoral Zone.** Drawdown and mechanical excavation would be followed by replanting of the shoreline with desirable aquatic plants. This component would provide a significantly improved habitat to diversify the fishery, and provide a perimeter greenway along the lake, leading to the discharge treatment wetland. This component addresses Objectives 2, 3 and 4.

Option 9 - In addition to the common components previously described, the first plan includes a recirculating treatment wetland to address the internal phosphorus loads released from the sediments. This option (**Option 9)** is the most 'balanced' of the top ranked options in terms of equally addressing the five objectives (**Table ES-1)**. The recirculating wetland is patterned after the Lake Apopka restoration effort. Additional public access provided in conjunction with the recirculating wetland accounts for the relatively higher points score for Objective 5 (Provide Public Access for Recreational Activities and Commercial Fishing).

Option 8 - The second option **(Option 8)** utilizes hydraulic dredging to remove the internal loads. This option is slightly less effective at fulfilling Objective 5. While treatment of the decant water will include wetland treatment, the size of the wetland is considerably smaller than the recirculating treatment wetland and public access is expected to be less than with the first option. However, this option does provide the important additional benefit of deepening the lake.

Option 4 - The third option **(Option 4)** includes alum treatment of the lake to control release of phosphorus from the sediments. This option was the least balanced in terms of meeting all of the objectives and provide only a short-term solution since the sediments may be susceptible to resuspension.

Table ES-1
Relationship of Top Ranked Plan to Objectives

Restoration Objective	Option 9	Option 8	Option 4
Improve the Quality of Water Discharged from Lake Hancock by Reducing the Total Maximum Daily Load	16.8	21.6	24.0
Preserve, and Where Feasible Enhance the Natural Greenway / Wildlife Corridor Through Polk County	23.2	18.3	17.8
Maintain the Exceptional Wildlife Values on Lake Hancock	23.8	25.6	24.4
Enhance Diversity of the Lake Hancock Fishery	22.0	25.0	23.0
Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing	15.0	6.8	4.2
Sum of Ranking Points	100.8	97.3	93.4

The estimated initial capital cost of the top ranked option (Option 9) is $57.0M. Of the three, this option results in the least improvement in water quality as shown in **Table ES-2**, but as previously illustrated this option results in greater improvements in the remaining four restoration objectives. The second option (Option 8) included hydraulic dredging, and the estimated initial capital cost is $86.6M. This plan provides a greater improvement to the water quality than the top-ranked option. The third option (Option 4) includes treatment of the whole lake with alum to immobilize the phosphorus and is estimated to cost the least at $49.8M. This option provides the greatest water quality improvement (lowest ISI), and the best cost-effectiveness at removing phosphorus, but is not as effective in addressing some of the remaining objectives.

Table ES-2
Water Quality Results

	Existing Conditions	Option 9 - Recirculating Wetland	Option 8 - Hydraulic Dredging	Option 4 - Alum Treatment
Total P (ug/l)	212	118	63	49
Secchi Disk (m)	0.11	0.26	0.58	0.83
Chlorophyll a (mg/m^3)	172	73	30	0.21
Florida TSI	91	78	66	60
P Removed From Lake (kg/yr)		35,524	52,036	56,955

A summary of the advantages and disadvantages of the three highest scoring lake restoration options based on the preliminary costs and cost effectiveness, technical

feasibility and logistics, environmental effects, and permit requirements is presented below along with a figure illustrating the plan components. Location of the facilities illustrated in the accompanying figures is conceptual only.

Advantages Common To All	***Disadvantages Common to All***
• Improved littoral zone and fish spawning habitat • Increased greenway habitat • Reduction of inflow loading • Improved public access • Improved quality of water discharged to the Upper Peace River	• Uncertainty of the fate of nutrients during drawdown • Negative impact on aquatic life during drawdown • Loss of littoral habitat during drawdown • Loss of commercial fishing revenues during drawdown • May require in-lake berms to protect littoral zone

Option 9 (Including a Recirculating Treatment Wetland)

Advantages

- Least capital cost
- Minimal disruption of wildlife since no dredging or chemical treatment of lake
- Similar technology implemented at Lake Apopka

Disadvantages

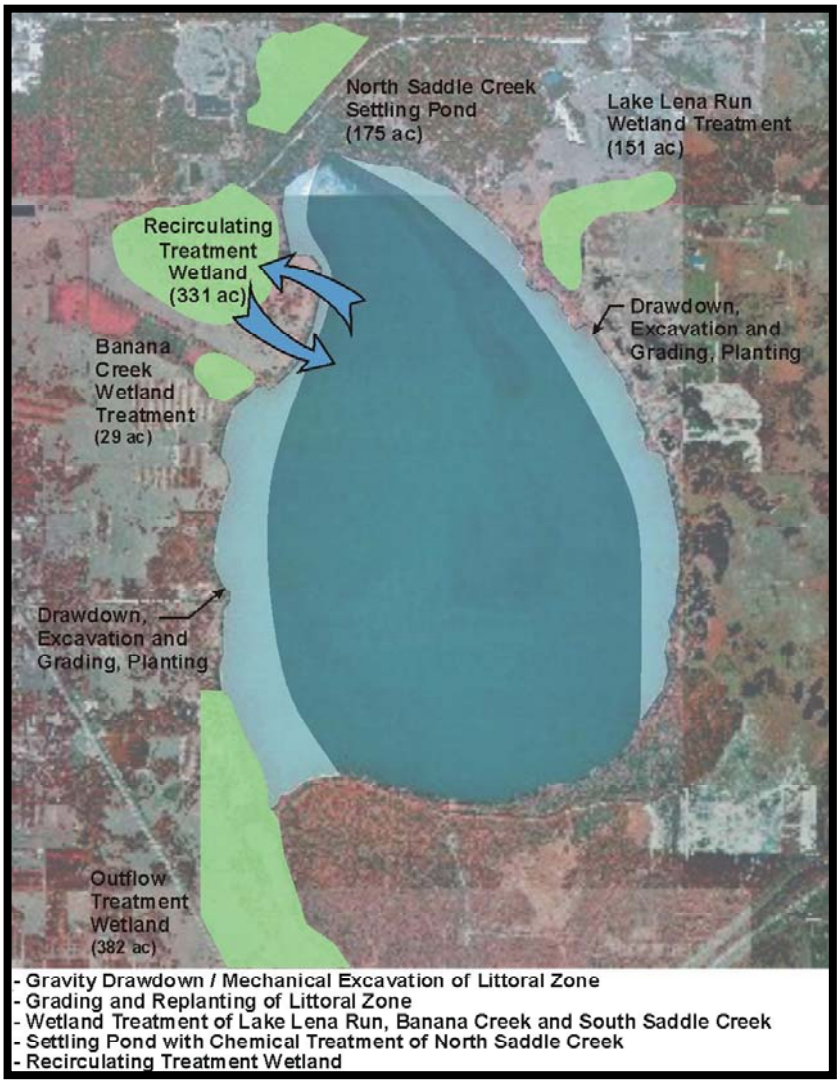
– Long duration to achieve ultimate Trophic State Index (TSI) (35-56 years)

– May require in-lake berms to protect restored littoral zone from wind-driven sediments

– Does not deepen the lake

– Long-term results for recirculating treatment technology not available

– Least improvement in water clarity Trophic State Index (TSI)



Option 9
Recirculating Treatment Wetland

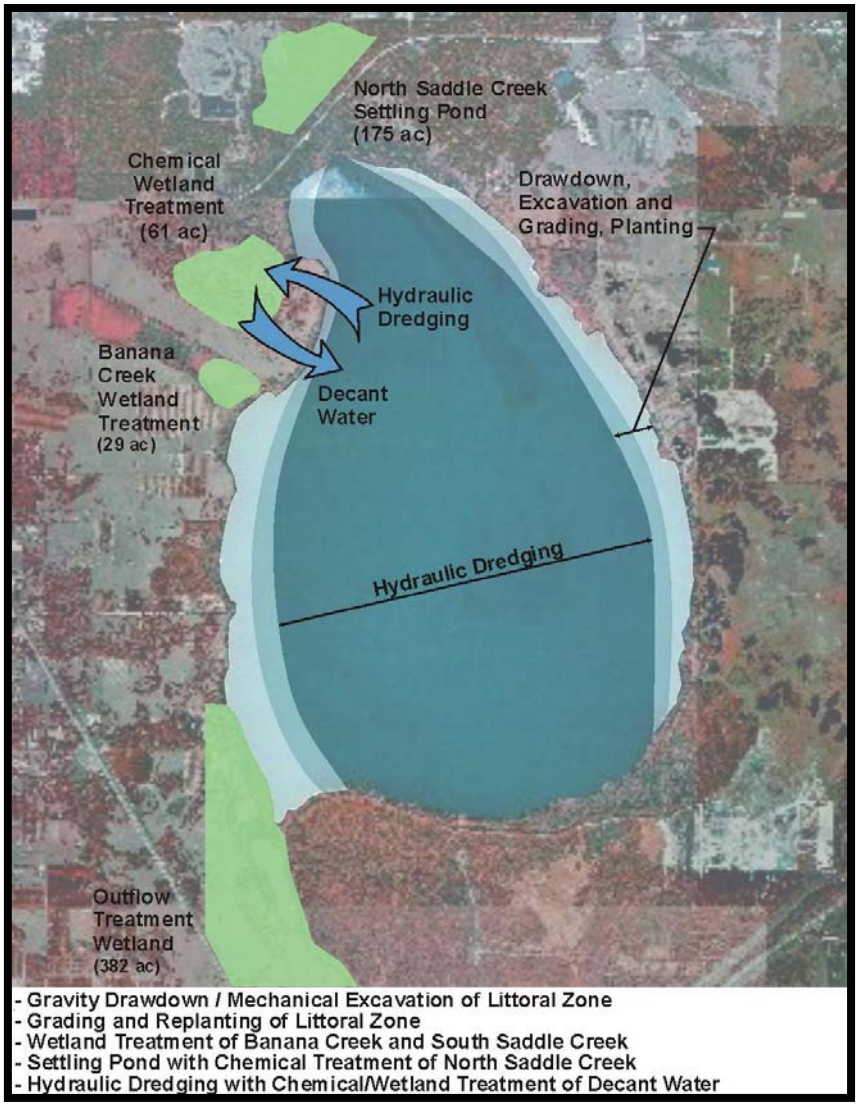
Option 8 (Including Hydraulic Dredging)

Advantages

- Physical removal of sediments
- Deepens lake
- Proven technology

Disadvantages

- Highest capital cost
- Large disposal site required for sediments
- Potential water quality declines during dredging
- Potential negative impacts on aquatic life during dredging



Option 8
Hydraulic Dredging

Option 4 (Including In-Lake Chemical Treatment)

Advantages

- Least capital cost
- Least time consuming
- Greatest improvement in water clarity

Disadvantages

- Stringent permitting requirements due to potential toxicity
- Does not cause deepening of lake
- Least increase in habitat
- Never attempted at this scale in Florida



Option 4
Chemical Treatment

Summary

In the absence of restoration efforts, Lake Hancock will continue to decline in water quality and continued pressure to urbanize will eliminate the possibility to acquire adjacent lands needed for habitat, greenway / wildlife corridors and treatment facilities. Any restoration plan must include control of the phosphorus release from the sediments. Based on the previous discussion of the advantages and disadvantages of the three options, and consensus of the Lake Hancock Advisory Group, it is recommended that the second ranked option (Option 8 hydraulic dredging) be implemented. This restoration plan is based on a technology proven to work at a large-scale. The plan results in a deeper lake, and additional 1,450 acres of wetland, increased public access, improved water quality and protection of downstream receiving waters.

Conclusions and Recommendations

Lake Hancock will continue to degrade if a restoration plan is not implemented. Option 8 was recommended by consensus of the Lake Hancock Advisory Group in October 2001. It is recommended that the Lake Hancock restoration include the following components:

- Construct wetland downstream of P-11
- Construct wetland treatment of Banana Creek inflows
- Construct chemical treatment / settling pond of North Saddle Creek inflows
- Increase water level
- Hydraulic dredging of organic sediments with chemical and wetland treatment of decant water
- Partial lake drawdown using P-11 structure, followed by drying, sediment removal, grading and planting of littoral zone
- Maintain elevated lake level with an annual variation

Advantages of Recommended Option 8

- Proven large-scale technologies
- Protection of downstream water quality
- 1,450 acres of additional wetlands / wildlife corridor
- Deeper lake
- Improved public access
- Improved water quality

- Enhanced fish diversity

Disadvantages of Recommended Option 8

- High cost
- Potential water quality and habitat degradation during dredging
- Duration of dredging
- Disposal of sediments
- Depending on phasing, potential need to construct in-lake berms to protect restored littoral zone from migrating organic sediment

Implementation

Following is a brief description of the recommended, multi-year, phased approach for the restoration of Lake Hancock. The recommended Option 8 includes the following ordered methods for lake restoration:

1. The projects below can be initiated at any time during implementation.

    a. Develop a treatment wetland at the Lake Hancock outfall at South Saddle Creek. Estimated to cost $15,448,046.

    b. Perform the mechanical excavation demonstration project. Estimated to cost $247,275.

    c. Develop a treatment wetland at the Banana Creek. Estimated to cost $1,745,761.

    d. Perform chemical treatment followed by settling for the North Saddle Creek inflow. Estimated to cost $8,407,698.

    e. A hydrologic engineering analysis should be performed to confirm previous established stage-storage relationships and to assess the increased flood potential of raising the lake level. A planning level cost estimate of $410,000 assumes that structure P-11 will be replaced.

2. Drawdown the lake and mechanically remove sediment from the littoral area, and plant wetland plants. Estimated to cost $11,463,420. This should be done before hydraulic dredging only if the demonstration project shows that the sediments do not redeposit in the littoral area.

3. Hydraulically dredge the remaining sediments at an estimated cost of $41,270,877.

Section 1
Lake Hancock Restoration Management Plan

1.1 Introduction

The purpose of this report is to develop a restoration management plan for Lake Hancock through the evaluation of lake restoration techniques and options. This section briefly documents the history of restoration efforts in Lake Hancock and the restoration objectives developed by the Lake Hancock Advisory Group. The Lake Hancock Advisory Group was formed by the Polk County Board of County Commissioners in 1999 to assist with the restoration of Lake Hancock, and consists of representatives from federal, state, county, and local environmental agencies, as well as citizen-based environmental groups, commercial fishermen, and property owners around Lake Hancock.

Subsequent sections of the report describe available pertinent data for Lake Hancock, institutional and regulatory issues, lake restoration techniques, evaluation of applied lake restoration techniques and lake restoration options, evaluation of three selected lake restoration options, and the lake restoration implementation plan.

1.2 Lake Hancock Restoration Objectives

On April 28, 1999 the Lake Hancock Advisory Group (LHAG) participated in a consensus building meeting to develop objectives for the restoration of Lake Hancock and the Upper Peace River. Six areas of complete agreement were recorded in the meeting minutes and include the following precepts:

- *Permanent public access to Lake Hancock should be acquired*
- *The lake should be made deeper*
- *Any restoration actions must take into account the preservation of wildlife*
- *Water quality leaving Lake Hancock is a problem downstream*
- *Any restoration should include a comprehensive/integrated basin management plan, which may include additional regulations and buffer areas. Efforts should be undertaken to reduce and minimize existing and new impacts from upstream pollution sources.*
- *A strategic land acquisition effort needs to be undertaken as part of any restoration.*

This consensus was summarized into five objectives by Polk County in their Surface Water Restoration Grant Application to the State of Florida. These objectives are listed below and serve as the basis for development of the present restoration plan.

1. Improve the quality of the water discharged from Lake Hancock by reducing Total Maximum Daily Loads (TMDLs).

2. Preserve, and where feasible, enhance the natural greenway / wildlife corridor (Peace River / Green Swamp) through Polk County.

3. Maintain the exceptional wildlife values on Lake Hancock.

4. Enhance the diversity of the fishery.

5. Provide habitat compatible public access for nature-based recreational activities and commercial fishing.

1.3 Background

Lake Hancock is an approximately 4,550-acre lake located in the upper portion of the Peace River drainage basin, north of the City of Bartow in Polk County, Florida. See **Figure 1-1**.

Past industrial and agricultural activities have extensively affected the lake. These activities include domestic and industrial wastewater discharges, urban development, agricultural activities, loss of wetlands, and phosphate mining. As a result, Lake Hancock is hypereutrophic (characterized by excessive growth of persistent blue-green algal blooms). The lake contains high nutrient concentrations; has a thick layer of flocculent organic sediments; is dominated by detrital-feeding rough fish; has reduced clarity; and is characterized as having poor water quality. However, Lake Hancock and its shoreline sustain a large, highly diverse fauna including one of Central Florida's largest colonial wading bird rookeries and a large population of American alligators.

Restoration is needed for this valuable resource as well as for protection of the downstream waters that are used as a public drinking water source. There is debate, however, regarding the appropriate restoration techniques for hypereutrophic, shallow, turbid lakes. In general, it appears that restoration of these lakes requires the reduction of both external and internal nutrient loads (phosphorus and nitrogen) as well as the implementation of other management techniques.

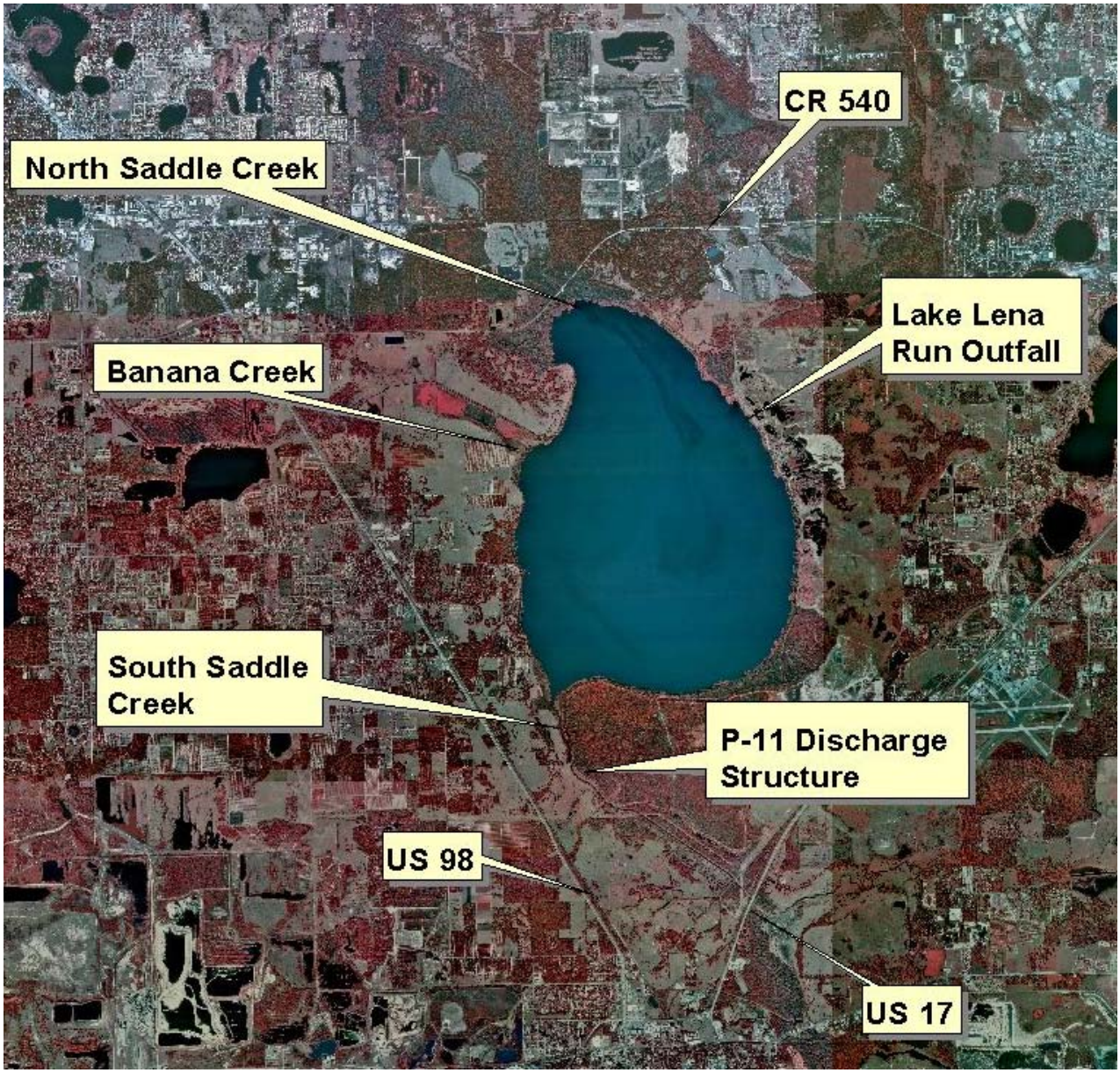


Figure 1-1
Aerial of Lake Hancock

1.4 History of Lake Hancock Restoration Efforts

Concern for the condition of Lake Hancock is not new. The Florida State Board of Health conducted the first comprehensive investigations of water quality in the drainage basin in the early 1950s. In 1962, the Coastal Petroleum Company evaluated the feasibility of dredge mining to recover phosphate mineral underlying the lake. The results of the study indicated that there would be limited economic benefits for this approach. However, a large portion of land surrounding the lake has been strip-mined for phosphate ore and remains in a partially restored condition. In 1969, the Southwest Florida Water Management District (SWFWMD) and the Florida Game and Freshwater Fish Commission (FGFFC) raised concerns regarding the lake and suggested that restoration measures should be implemented.

In 1981, a joint report by the United States Geological Survey (USGS) documented the poor water quality characteristics of Lake Hancock. In 1985, the Polk County Water Resources Division also documented the poor water quality characteristics of Lake Hancock, as well as the high Trophic State Index (TSI).

In 1986, the Florida Legislature enacted a bill recognizing the need for restoration of Lake Hancock and that such restoration might be funded by mining the phosphate mineral which exists beneath the lake. In 1987, the Zellars-Williams Company conducted a feasibility study for lake restoration. The study indicated that there would be significant technical problems associated with in-lake mining making the venture a greater risk than mining dry-land deposits elsewhere in the county. The cost of mining the lake was determined to be greater than the revenues that would be generated. Therefore, Phase I of the study indicated that, in the near-term, a mining operation may not be economically feasible. Non-mining alternatives were investigated in Phase II of the study, including drawdown (decreasing the amount of water in the lake) and sediment desiccation (drying and consolidating of soil), and the removal of sediments by dredging (removing sediment without drawdown). Zellars-Williams also developed a lake water budget with particular attention to the groundwater component, and water quality monitoring to determine nutrient loading to the lake. The study concluded that drawdown was not recommended and that the recommended alternative to restore Lake Hancock was sediment dredging.

By the early 1990s, most of the domestic and industrial discharges into tributaries of Lake Hancock had been totally or partially eliminated, but the lake remained in a highly polluted hypereutrophic condition. In 1991, the FGFFC developed a Lake Hancock restoration plan. The objective of the proposed plan was to enhance aquatic habitat to support a recreational fishery and provide foraging and nesting areas for key wildlife species. The plan included a partial drawdown of the lake to consolidate portions of the organic sediments. The drawdown would expose lake bottom to the air, promoting compaction and consolidation of bottom sediments and their colonization by vascular plants. Nuisance vegetation control would be required. Objectives of the plan included increasing the percentage of sportfish in the littoral zone (portion of the lake occupied by rooted plants); increasing the largemouth bass and panfish fishing success rate; increasing dissolved oxygen levels and Secchi disk transparency; reducing chlorophyll-a levels; and establishing submergent vegetation in the lake. The FGFFC did not proceed with the plan, and has since developed a revised restoration plan.

IMC-Agrico (1998) evaluated a revised mining option but it was rejected due to environmental concerns. Their evaluation concluded:

> "The 'fatal flaw' from a mining standpoint, was the sediment fluidity. During a high volume dewatering phase, large quantities of sediment would flow to the dewatering sump and be transported with the decant water. Therefore, an unacceptable probability for significant

water quality problems in the form of suspended solids would be created."

In 1997, SWFWMD engaged Environmental Research & Design (ERD) to develop updated water and nutrient budgets for Lake Hancock. The goals of the ERD study were to evaluate historical water quality characteristics in Lake Hancock, develop revised water and nutrient budgets; identify present-day nutrient loadings to the lake; and evaluate an affordable water quality improvement project to enhance the water quality of discharges from the lake.

In 1999, the Florida Fish and Wildlife Conservation Commission (FFWCC), formerly the FGFFC, developed a Lake Hancock Habitat Enhancement Plan. The plan involved lake drawdown and mechanical excavation of sediments. The plan involved drawdown to elevation 92 feet NGVD, assisted drying and mechanical excavation of the sediments. The phased plan included development of a comprehensive/ integrated water use and land use basin management component. Each phase of the plan incorporated specific restoration activities that included establishment of project access and staging areas; evaluation of groundwater conditions on the east side of the lake; channel excavation south of the P-11 structure (a weir-dam structure located in Saddle Creek 3,500 feet south of Lake Hancock); construction of a treatment wetland and a new overflow structure south of the P-11 structure; establishment and management of shoreline habitat areas; modification of mine pit areas; channel excavation north of the P-11 structure; construction of additional treatment wetlands; sediment removal and transport; and regrading and planting of littoral areas and treatment wetland areas.

Also in 1999, a local commercial fisherman developed the Thomas Plan for the restoration of Lake Hancock and the Upper Peace River. The objectives of this restoration plan were to manage the lake for wildlife, commercial fisheries, and downstream water quality. It also involved increasing the average water level, as well as the overall fluctuation of the water level in the lake. The plan proposed a series of structures in South Saddle Creek and Peace Creek, beginning with the P-11 structure, that would inundate wetlands in this area. The Thomas Plan concluded that maintaining water levels at elevation 102.5 feet would increase the surface area of the lake approximately 75 percent. Land acquisition of affected properties would be a major component of this plan.

In 2001, Polk County was approached by several firms, which wished to conduct demonstration projects in Lake Hancock using novel restoration techniques. At the request of the County, CDM prepared a list of minimum information **(Appendix A)** needed to further evaluate these technologies. One firm responded with two techniques, which were further evaluated and are described later in this report.

To date, none of the previous plans have been implemented.

Section 2
Integration and Interpretation of Existing Data

Extensive data exists on the physical, chemical, and biological characteristics of Lake Hancock. Existing data were reviewed, integrated and interpreted in order evaluate lake restoration techniques and develop a restoration plan for the lake. A summary of the pertinent physical, chemical, and biological characteristics of the lake is presented below.

2.1 Physical and Chemical Characteristics of Lake Hancock

The stratigraphy beneath Lake Hancock consists of rocks and sediments ranging in age from Paleocene to Holocene (Recent) age (Zellars-Williams, 1987). In general, three groundwater systems are recognized in Polk County, a surficial aquifer system, an intermediate confining layer or intermediate aquifer system, and the Floridan Aquifer. Undifferentiated surficial deposits (Pliocene to Recent) comprise the thin surficial aquifer system in the vicinity of Lake Hancock. The Holocene age deposits are primarily limited to present day stream floodplains, swamps, marshes, and lakes and consist of sand, silt, clay and organic materials (Campbell, 1986). Soils of the marshes, swamps and floodplains adjacent to the lake are mineral and organic, nearly level, poorly drained to very poorly drained, and are subject to flooding and ponding (SCS, 1990).

Lake Hancock is located in a portion of Polk County known as the Polk Upland Area and lies in the relative low area between the Lakeland and Winter Haven Ridges. Lake Hancock is part of the Upper Peace River watershed that constitutes the headwaters of the Peace River. In 1962, the P-11 structure was constructed in South Saddle Creek to control the discharge from the lake. Since construction of the P-11 structure, the water level in the lake has generally been maintained between elevations 97 and 98.5 feet NGVD.

Accumulation of organic sediments in the lake has occurred as a result of the discharge of wastewater effluent leading to hypereutrophic conditions and herbicide application to control water hyacinths (ERD, 1999). IMC-Agrico (1998) performed a detailed sediment characterization of the lake. This study found that the organic material on the bottom of the lake had accumulated to depths as much as 5.5 feet (1.7 meters) thick, which corresponds to an estimated 18 million cubic yards of muck on the bottom of the lake. The approximate total volume of the lake is 16,048 acre-feet with a mean water depth of 3.55 feet (1.08 meters). Kollinger data.

A summary of the mean water quality characteristics in Lake Hancock from 1984 to 1999 is presented in **Table 2-1** (ERD, 1999). The water quality during this period was

extremely poor. The lake was characterized by extremely variable and elevated levels of pH, total nitrogen, total phosphorus, turbidity and chlorophyll-a. The majority of the measured total nitrogen and total phosphorus in the water column is in particulate form.

Table 2-1
Summary of Mean Historical Water Quality Characteristics in Lake Hancock from 1985-1999

Parameter	Units	Mean Value
pH	s.u.	9.18
Diss. Oxygen	mg/l	8.6
Temperature	°C	24.0
Specific Conductivity	µmho/cm	275
Secchi Disk Depth	M	0.2
NH_3-N	mg/l	0.0
NOx-N	mg/l	0.0
Organic N	mg/l	5.95
Total N	mg/l	5.99
Total P	mg/l	0.63
Turbidity	NTU	44.6
Color	Pt-Co	58
Chlorophyll	mg/m^3	170

n = 32 sample

Source: ERD, 1999

Trophic State Index (TSI) values were calculated by ERD (1999) for Lake Hancock based upon the Trophic State Index developed specifically for Florida lakes (Brezonik, 1984). TSI values are based on the amount of total phosphorus and chlorophyll-a in the water column. (Unlike the TSI definitions recently adopted by FDEP, the Brezonik definition also includes Secchi disk depth as an input. For consistency with the prior ERD work, reference to TSI values in the present report refer to the older form of calculation.) TSI values less than 50 indicate oligotrophic conditions (clear water, high oxygen levels), values between 50 and 60 indicate mesotrophic conditions (moderately clear water, less oxygen), values between 61 and 70 indicate eutrophic conditions (plant growth, low oxygen), and values greater than 70 indicate hypereutrophic conditions (dense algae and plants, no oxygen).

Lake Hancock consistently exhibited hypereutrophic conditions from 1984 to 1999 with the overall mean calculated TSI value of 91, well into the hypereutrophic range. No trend of either improving or declining water quality has been apparent, although the water quality characteristics over the past seven to eight years appear less variable than in the 1980s. This may be due to the elimination of domestic wastewater discharges to lake tributaries. A paleolimnological analysis (study of fossil evidence in the lake) is needed to determine the historical trophic status of the lake. The SWFWMD has engaged a firm to collect the necessary data and perform the analysis. The final report is expected to be completed in 2002. Recently, Polk County has

completed the collection and chemical analysis of grab samples of sediments for toxicity characterization (**Appendix B**).

2.2 Biological Characteristics of Lake Hancock

Lake Hancock and its shoreline sustain a large, highly diverse fauna including one of Central Florida's largest colonial wading bird rookeries and a dense American alligator population. Much of the lake open water is bordered by cypress dominated forested swamps. Red maple and black willow dominate the understory and are the dominant woody species when cypress is absent. Very little native herbaceous vegetation extends into the open water. Submerged, floating and emergent nuisance species occur throughout the lake. Historical documentation (soils maps and aerial photographs) indicates that the lake and its associated shoreline wetland formerly occupied a larger area than in its present configuration.

Lake Hancock presently supports a commercial fishery for tilapia and catfish. There is essentially no sport fishery present in the lake, nor has one existed for many years (FGFFC, 1991). This is largely a result of the poor water quality and lack of quality aquatic habitat (Buntz and Chapman, 1971). Some fish species have taken advantage of the hypereutrophic conditions and a few are highly abundant.

Two native species, the gizzard shad (*Dorosoma cepedianum*) and the threadfin shad (*Dorosoma petenense*) often respond favorably to nutrient enriched lakes because of the high levels of algae growth. Many other native species decline in abundance because the food web becomes simplified with prey species not able to feed on the kinds of algae present. Hypereutrophic conditions result in the frequent occurrence of anoxic conditions, which eliminate many fish and invertebrate species that are intolerant of low oxygen concentrations.

In Lake Hancock and other lakes in this region, blue tilapia (*Oreochromis aurea*), a non-native species introduced in 1961, has been able to flourish as a result of the high levels of algae and other plant growth. Commercial harvest began in the early 1970s, initially as part of rough fish removal programs in various lakes, with blue tilapia as the economic incentive for fishing. This fish is sold as a food fish by wholesale and retail fish markets.

Another non-native species, suckermouth catfish (*Hypostomus plecostomus*) has become abundant in Lake Hancock and other lakes in this region. This fish has limited commercial importance as a source of brood stock and egg collection for the aquarium trade. Abundant levels of this fish have begun to interfere with efficient haul seine activity.

Haul seine harvest from Lake Hancock consists of the blue tilapia, catfish and shad. Commercial fishing in Polk County is commonly done from May through September, but may occur in other months. Total annual landings have varied from 152,780 to 763,901 pounds from 1985 through 1999 and averaged 257,753 pounds. About 90 percent of the haul seine catches were from Lake Hancock and the other 10 percent from ten other lakes in the region, according to FFWCC. The shad and suckermouth

catfish are sold for crab bait. Other catfish are sold as food fish by wholesale and retail fish markets. Between 1997 and 1999, blue tilapia made up 80 to 88 percent of the sales value of fish caught from Lake Hancock. The market value of commercial fishing taken by haul seines in Lake Hancock averaged $104,000 (+ / - $30,000 standard deviation) for the five-year period from 1995 to 1999.

2.3 Characteristics of the Lake Hancock Drainage Basin

The drainage basin discharging to Lake Hancock upstream of the P-11 structure is approximately 143 square miles. Lake Hancock occupies approximately 4,550 acres of the 91,550-acre drainage basin (i.e,. watershed area to lake surface area ratio ≅ 20). Surface water inflow to Lake Hancock is generated in four primary subbasin areas, including subbasin areas tributary to Banana Creek, subbasin areas tributary to Lake Lena Run, subbasin areas tributary to Saddle Creek (the largest), and miscellaneous subbasin areas that discharge to Lake Hancock through small conveyance systems or direct overland flow. Information on land use in each of the four primary subbasin areas is based on the 1995 SWFWMD land use coverage and was summarized for each subbasin by ERD (1999). The dominant land use categories in the Banana Creek subbasin are agricultural, residential, open water, lakes and wetlands. The dominant land use categories in the Lake Lena Run subbasin are medium-density residential and un-reclaimed mining. The dominant land use categories in the Saddle Creek subbasin are mining, open water, lakes and wetlands. The dominant land use categories in the miscellaneous subbasin are agriculture, and undeveloped land such as forests and wetlands.

2.4 Hydrologic Inputs to Lake Hancock

The USGS (1981) described the climate of the Lake Hancock area as subtropical with humid, rainy summers and dry, mild winters. About half the annual rainfall occurs during June through September. A water budget for Lake Hancock was developed by ERD (1999). This consisted of estimates of the hydrologic inputs to the lake, including stormwater runoff, dry weather baseflow, direct precipitation, and groundwater seepage. The water budget along with the chemical characteristics of inflows to the lake were used to estimate pollutant loadings to the lake.

ERD used the USEPA Stormwater Management Model (SWMM) to estimate runoff and baseflow into the lake from the three primary tributaries: Banana Creek, Lake Lena Run and North Saddle Creek. These tributaries contributed 4, 9, and 87 percent, respectively, of the total estimated annual tributary inflow to the lake. During the period from 1943 to 1995 the average annual rainfall at the Lakeland monitoring site was 49.72 inches per year. During the period from 1969 to 1998 the estimated annual mean lake evaporation from Lake Hancock was 52.13 inches per year. Detailed field investigations were performed to evaluate the quantity and quality of shallow groundwater seepage entering Lake Hancock under existing conditions. Seepage rates on the eastside of the lake appeared to be the greatest. The average seepage inflow to the lake was estimated to be 11.53 acre-feet per day. The mean annual discharge from the P-11 structure is 59.3 cubic feet per second, based on mean discharge records for the period from 1964 to 1996.

On an annual basis, about 71 percent of the water that enters the lake is contributed by stormwater runoff and baseflow, 24 percent by rainfall, and 5 percent by groundwater seepage. Annually, 54 percent of the inputs to the lake are discharged at the P-11 structure, with 26 percent lost to evaporation and 20 percent lost to deep groundwater, as shown in **Figure 2-1**. The annual average water residence time in Lake Hancock is currently 74 days (ERD, 1999), although the historical residence time was probably lower before the flow diversions and the construction of P-11.

2.5 Nutrient Inputs to Lake Hancock

ERD (1999) performed field investigations to evaluate the chemical characteristics of inflows to the lake to provide a nutrient budget for the lake. Estimates of annual pollutant inflows from stormwater runoff and baseflow were generated for each of the four primary subbasin areas discharging into Lake Hancock. These estimates were based on a combination of field measurements and literature-based loading values.

The most elevated concentrations of nitrogen and phosphorus species were observed in Banana Creek. The dominant nitrogen and phosphorus species observed in Banana Creek were particulate. It appears that much of the measured particulate nitrogen and phosphorus from Banana Creek is comprised of algae transported from Banana Lake. The mean water quality characteristics in Banana Creek are substantially elevated for virtually all of the measured nutrient species, along with total suspended solids (TSS) and biological oxygen demand (BOD). Water quality characteristics of tributary inflow from Lake Lena Run and North Saddle Creek are typical of values commonly observed in runoff and baseflow. The dominant nitrogen species in Lake Lena Run and North Saddle Creek is dissolved organic nitrogen. The dominant phosphorus species in Lake Lena Run and North Saddle Creek is orthophosphorus.

Although nutrient, TSS, and BOD levels in Banana Creek are substantially elevated, the flow from North Saddle Creek to the lake is much greater than from Lake Lena Run and Banana Creek. Therefore, North Saddle Creek is the primary contributor of nutrients from the three primary tributary inflows. The relative loading of the three primary inflows are given in **Table 2-2**.

Table 2-2
Percent of Total Inflow Loading by Tributary

	TN	TP	BOD	TSS
Banana Creek	13%	8%	24%	20%
Lake Lena Run	11%	7%	7%	20%
Saddle Creek	76%	84%	69%	51%

(Adapted from Table 5-11, ERD, 1999)

The nutrient concentration in groundwater is much higher than found in Lake Hancock and provides additional nutrient loading to the lake. This occurs along the

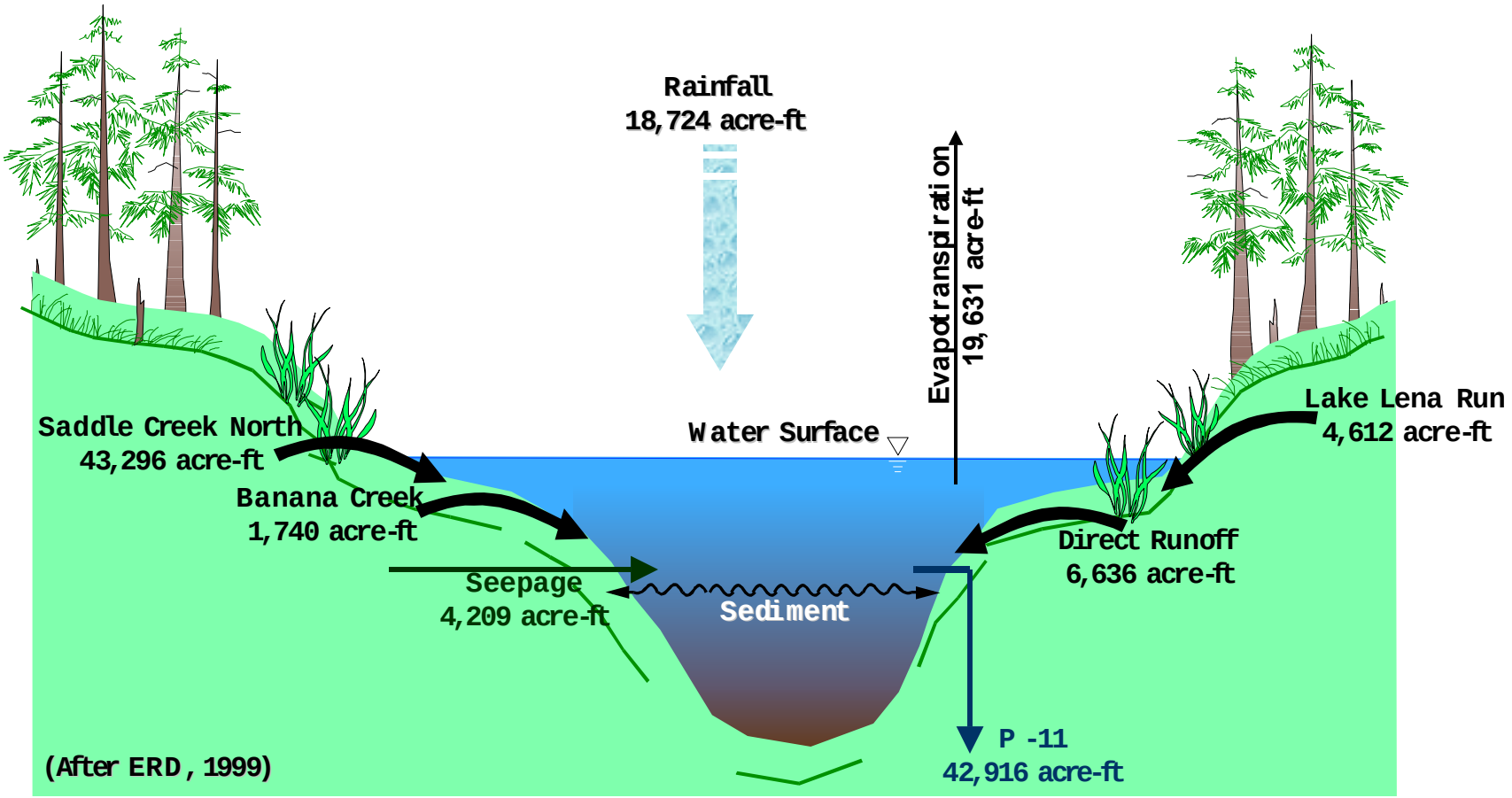


Figure 2-1
Annual Lake Hancock Water Budget

eastern perimeter of the lake adjacent to reclaimed strip-mined areas. These loadings are greater than from bulk precipitation but less than from runoff.

Stormwater runoff and baseflow provide the most significant external nutrient loading to the lake. This does not include internal recycling of phosphorus from the sediments. Groundwater seepage is the second largest contributor to the lake and bulk precipitation provides a relatively minor nutrient contribution to the total nutrient loading.

A summary of the estimated annual nutrient import to the lake is presented in **Table 2-3** (ERD, 1999). Trophic state modeling of Lake Hancock performed by ERD (1999) indicated that internal recycling and resuspension of bottom sediments within the lake, as well as some unknown contribution from excretions by waterfowl and other wildlife, contributed 39,420 kg of phosphorus to the lake. A summary of the estimated annual identified phosphorus loading (external and internal) to the lake is presented in **Table 2-4** (ERD, 1999). These results suggest that internal recycling, sediment resuspension and organic matter decomposition primary sources of phosphorus to the Lake Hancock water column, contributing approximately 53 percent of the estimated annual input. The sediment resuspension and bacterial decomposition of the organic matter produces biologically available inorganic phosphorus. In addition, direct input from animal wastes (alligators, nesting birds etc.) contribute to the recycling, but to a much smaller extent than the resuspension and bacterial decomposition. Stormwater runoff and baseflow inputs contribute approximately 38 percent of the total annual phosphorus input to the lake, with the majority of these inputs contributed by North Saddle Creek.

2.6 Nutrient Exports from Lake Hancock

ERD (1999) derived a phosphorus budget for the lake by adding the inputs (inflow loading, atmospheric deposition and seepage) and applying several lake eutrophication models to predict in-lake concentrations of total phosphorus and chlorophyll-a. ERD then estimated the discharge load as the product of mean lake concentration times flow through the P-11 structure.

Phosphorus export from the lake occurs as a result of sedimentation and surface water discharge. As indicated above, on an annual basis, approximately 54 percent of the hydrologic inputs to the lake are discharged at the P-11 structure. Based on the average flow and phosphorus concentration at this structure, approximately 39,268 kg of phosphorus are discharged from the lake on an annual basis. Therefore, the remaining loss to sediments is approximately 41,236 kg of phosphorus on an annual basis. The estimated loss of phosphorus to sediments is greater than the predicted amount of phosphorus internally recycled to the lake (39,420 kg), resulting in a net annual increase in the estimated phosphorus storage in the lake sediments.

Table 2-3
Estimated Annual Identified External Loading to Lake Hancock

Input Source	Annual Load (kg/yr)				Percent of Total			
	Total N	Total P	BOD	TSS	Total N	Total P	BOD	TSS
Stormwater Runoff/Baseflow	91,157	28,562	180,294	911,945	52	81	77	86
Bulk Precipitation	18,127	1,878	18,473	143,168	10	6	7	14
Groundwater Seepage	66,595	4,646	36,693	0	38	13	16	0
Totals:	175,879	35,086	235,460	1,055,113	100	100	100	100

Does not include additional inputs from internal recycling
Source: ERD, 1999.

Table 2-4
Summary of Annual Identified Phosphorus Loading to Lake Hancock

Source	Estimated Annual Input	
	kg/yr	Percent of Total
Runoff/Baseflow	28,562	38
Groundwater Seepage	4,646	6
Bulk Precipitation	1,878	3
Internal Recycling/Sediment Resuspension	39,420	53
Total:	74,506	100

Source: ERD, 1999.

These estimates suggest that lake restoration must address internal as well as external phosphorus loading to the lake, and treatment of the discharge from the lake is necessary to protect downstream waters that are used as a drinking water source.

2.7 Nutrient Budgets for Lake Hancock

The phosphorus budget for the lake (including inflows, outflows, and storage) is presented in **Figure 2-2** and Table 2-4. The percentage of the inflow for each inflow budget component is indicated in Table 2-4.

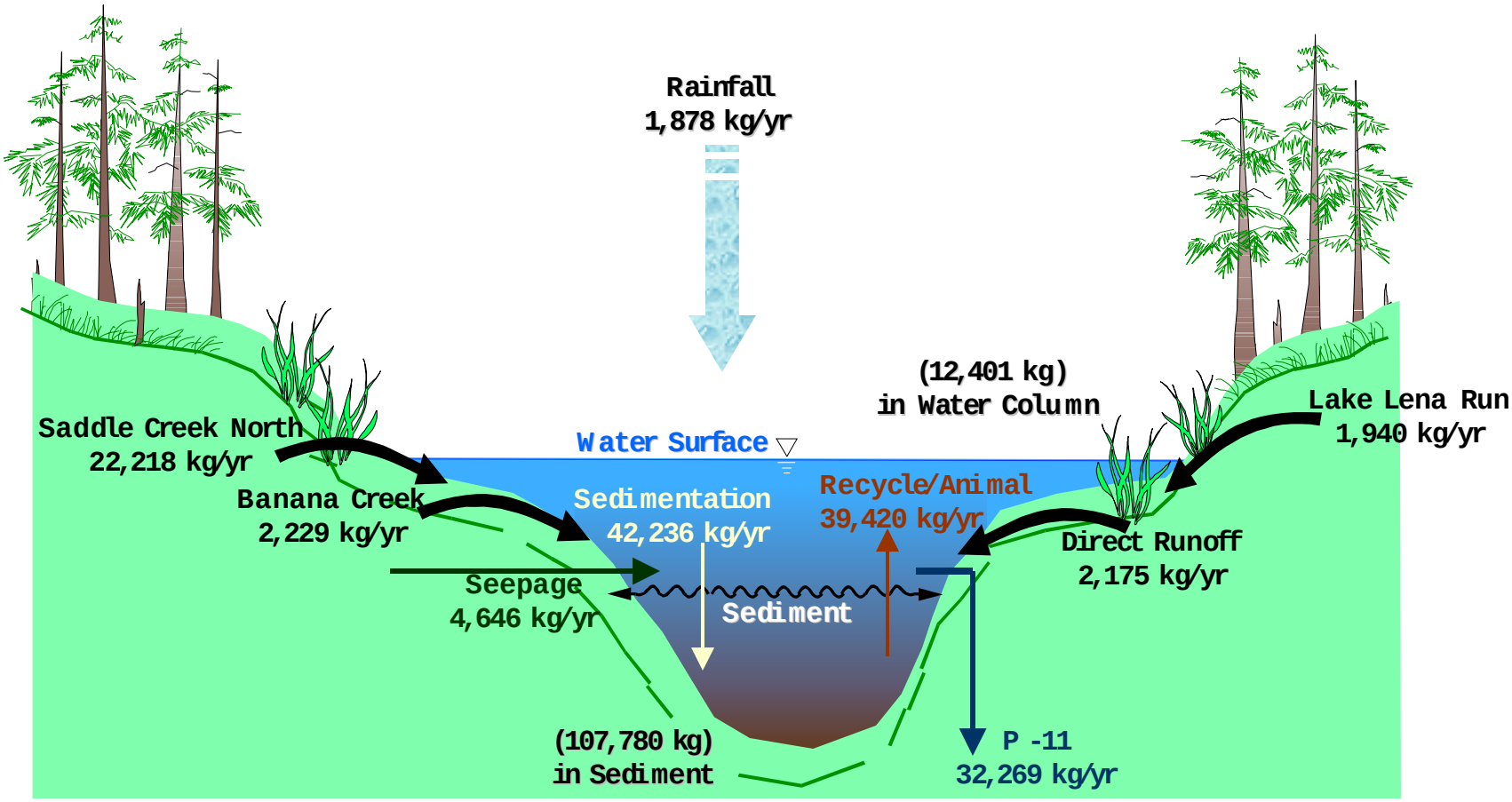


Figure 2-2
Annual Lake Hancock Phosphorus Budget

2.8 Downstream Impacts

Lake Hancock forms the headwaters of the Peace River, which is a major regional potable water supply. Peace River Manasota Regional Water Supply Authority (PRMRWSA) staff have correlated increased counts of noxious taste and odor producing algae with discharges from Lake Hancock. While changes in monitoring and operational procedures at the PRMRWSA limit a full accounting of the problems, there have been years when algae problems have persisted for 5-6 months at a time. If the river is the only source of water available during those times, the cost of treatment increases dramatically, increasing the standard chemical costs by 40 percent from $0.16 to 0.22 / 1,000 gallons (1999 costs). Thus, the quality of discharge from Lake Hancock affects both the ability of the PRMRWSA to withdraw from the river and the cost of producing potable water from that source. In addition to affecting water supply, discharges from the lake affect Charlotte Harbor, which is nitrogen limited. Phosphorus concentrations below Lake Hancock actually increase over the discharge concentration. Concentrations within the Harbor are conservative, suggesting that nitrogen loading from Lake Hancock is of much greater concern to Charlotte Harbor than phosphorus loadings.

Loading estimates developed by Coastal Environmental (1995) and SWFWMD (D. Tomasko, personal communication) indicate that the TN loads discharged from Lake Hancock represent approximately 19 percent of the total Peace River TN loadings. This loading is approximately equivalent to the increased in TN loading expected during the next 10 years as Charlotte Harbor continues to urbanize. Thus, reducing the TN load from Lake Hancock by a similar amount is equivalent to 'holding the line' on nitrogen increases in Charlotte Harbor. For this reason, SWFWMD is investigating the possibility of creating a treatment wetland for the Lake Hancock discharge to reduce the nitrogen loading from this source.

Section 3
Institutional and Regulatory Issues

The clear recognition of institutional issues and the acquisition of environmental permits are key to the success of a lake restoration program. This section identifies state, federal and local government regulations, relevant permitting requirements, as well as private interests, as they relate to potential Lake Hancock restoration activities.

3.1 State - Florida Department of Environmental Protection (FDEP), Southwest Florida Water Management District (SWFWMD) and Florida Fish and Wildlife Conservation Commission (FFWCC)

The Florida Department of Environmental Protection (FDEP) Bureau of Invasive Plant Management coordinates and funds two statewide programs controlling invasive aquatic and upland plants on public conservation lands and waterways. The Bureau reviews and issues aquatic plant management permits for lake restoration projects that eliminate nuisance and undesirable aquatic plants (Chapter 62C-20, Florida Administrative Code [F.A.C.]. More specifically, these permits address the control of nuisance / exotic aquatic plants and under certain conditions, the Aquatic Plant Management Permit also allows for the removal of organic sediments and the reestablishment of aquatic vegetation.

As part of the FDEP review, the FFWCC reviews projects that may potentially affect protected plants and animals. These plants and animals are listed in Section 372.072, Florida Statutes and Chapter 39, F.A.C. Listed wading birds, and the American alligator migrate over and through Lake Hancock. Based on FFWCC data there are seven wading bird nesting sites around the perimeter of the lake. The U.S. Fish and Wildlife Service (USFWS) and the FFWCC would evaluate the project area and provide guidelines and protocols to prevent habitat disturbance to nesting areas. Construction activities required by restoration should be minimized during breeding season to avoid potential nesting and foraging disturbances.

The information that is required for the **Aquatic Plant Control Permit** application includes:

- List of riparian owners (individuals who own land along the edge of the lake) and property boundaries;
- Location map of project site and approximate edge of the lake;
- Plant community identification map;
- Dimensions of property, vegetation proposed for control, and vegetation that will not be controlled (if any);

- Explanation of the purpose and benefit of the management plan;
- Vegetation control methods, equipment list, disposal method, and schedule; and
- Public notification (i.e., posted signs, newspaper, and public hearing).

An **Environmental Resource Permit (ERP)** is required for activities associated with the construction and operation of control structures, repair and replacement of structures, dredge and fill activities, stormwater treatment ponds, and other water quantity related activities pursuant to Chapter 40D-4 F.A.C. The ERP will be evaluated by either FDEP or SWFMWD based on the Operating Agreement concerning Regulation under Part IV, Chapter 373, F.S. The project must avoid and/or minimize dredge and fill activities within and adjacent to the lake. In order to obtain an ERP, Chapter 40D-4, F.A.C. indicates that the following information should be provided:

- Extent of wetlands, proposed wetland impacts, and surface water impacts by proposed activity;
- Type of permit required and fee;
- Location of submerged lands owned by the Board of Trustees of the Internal Improvement Trust Fund (40D-4.041(6));
- Need for an approved site-specific plan and master drainage plan (40D-4.051(a));
- Impacts to listed species, if any (40D-4.101);
- Drawings, calculations, environmental and construction information, and engineering details to define the nature, scope, intent and function of the proposed work (40D-4.101); and
- Application for certification of compliance with state water quality standards, where necessary (Section 401, Public Law 92-500, 33 USC Section 1341) [the net improvement provision of Section 373.414 (1)(b), F.S. would constitute certification of compliance with water quality standards].

No permit is required from the State of Florida for maintenance dredging of existing manmade canals, channels, basins, berths, or intake/discharge structures, where the spoil material is removed and deposited on a self-contained, upland spoil site. A self-contained site will prevent the escape of the spoil material and return water from the spoil site to wetlands or other surface waters. There is an exemption for additional dredging necessary to restore the canal, channels, basins, berths, and intake and discharge structures to original design specifications, and requires control devises at the dredge site to prevent turbidity and toxic or deleterious substances from discharging into adjacent waters. Maintenance dredging is limited to a depth of no more than 5 feet (1.5 meter) below the mean low water level (40D-4.051(12)(d)).

3.2 Federal Programs

3.2.1 U.S. Army Corps of Engineers (ACOE)

Section 404 of the Clean Water Act establishes the permit program to regulate discharges of dredge or fill material into wetlands and other waters of the United States. The ACOE may issue a permit to remove organic material, which improves the condition of a water body. The ACOE issues different types of permits, depending upon the area of impact and type of work proposed. One type of permit is a nationwide permit for discharges with minimal environmental impacts. Individual permits involve a more complex process, including detailed review, public notice, receipt of comments and an opportunity for a public hearing. As part of the review process, federally listed wildlife and plant species that occur or could occur will be reviewed by the U.S. Fish and Wildlife Service (USFWS) to ensure that impacts to habitat and nesting sites are avoided or addressed.

Information required for an **ACOE Section 404 Permit** includes:

- Complete description of the proposed project and purpose, calculations, spoil location, turbidity control, equipment used, area of impact and location;
- Location map and plan and profile view of project site activities;
- Wetlands delineated within the project area and acreage of wetland impact;
- Names and addresses of adjacent property owners; and
- List of authorization required by other agencies.
- A Section 10 approval is also required since Lake Hancock is considered navigable waters.

3.2.2 Charlotte Harbor National Estuary Program (CHNEP)

Charlotte Harbor has been designated an estuary of national significance as defined by section 320 of Clean Water Act. Referred to as the National Estuary Program (NEP), Federal funds are provided to convene a 3-year management “conference” to identify goals and problems and to establish a plan of action for accomplishing those goals. Policy for the management conference is provided by a committee of federal, state and local agencies and municipalities with jurisdiction over the estuarine watershed. The primary inflow to Charlotte Harbor is the Peace River, with its headwaters at Lake Hancock. Thus, not surprising a number of the action plans included in the Comprehensive Conservation and Management Plan (CCMP) for Charlotte Harbor National Estuary Program (CHNEP) address Lake Hancock problems. While the resultant CCMP is not regulatory, if the CCMP is followed FDEP and EPA may accept the management plan in lieu of the regulatory total maximum daily load for the watershed. Elements of the CCMP specific to Lake Hancock include

restoration of water quality and a natural hydrologic regime as indicated by the following quantifiable objectives and action plans.

1. Restore a more natural hydrologic condition for Lake Hancock

    - Evaluate potential alternatives to modification and / or removal of the structure at the southern end of Lake Hancock

2. Restore and maintain Lake Hancock to Class III water quality standards (or better) and improve the Trophic State Index (TSI) value for the water exiting the lake from "poor" to " good" by the year 2010.

    - Establish a buffer zone around Lake Hancock

    - Remove the muck component from the sediments at Lake Hancock

3. Create a public involvement program for Lake Hancock

3.3 Polk County

The Polk County Natural Resources Division (PCNRD) will coordinate the lake restoration activities. The Polk County government coordinates environmental regulations with the FDEP, SWFWMD, and the ACOE concerning dredge and fill activities, stormwater management, and solid waste disposal. No known county permits are required to remove organic material from a lake to an upland site. The county regulates the transport of material on roads (haul roads). Once a haul route is designated, Polk County must be notified.

3.4 Private Interest (Land Owners, Commercial Fishermen, and Environmental Groups)

Public involvement is part of the permit process for the SWFWMD and the ACOE. Private interests of adjacent landowners, lakefront property owners, commercial fishermen, and environmental organizations (i.e., the Audubon Society and the Sierra Club) have participated in a forum for discussion of the restoration of Lake Hancock, called the Lake Hancock Advisory Group. The Lake Hancock Advisory Group developed lake restoration objectives, and will review the options for lake restoration from this study. Discussion of environmental effects and benefits of lake restoration activities took place during meetings with members of the Lake Hancock Advisory Group.

3.5 Total Maximum Daily Loads and Pollution Load Reduction Goals

Total Maximum Daily Loads

The Clean Water Act (1972) requires states to identify waters of the United States that are impaired (i.e., not meeting applicable standards or not achieving their designated uses); the list of impaired waters, known as the "303(d) List" is to be updated every other year. Based upon that list, the states develop Total Maximum Daily Loads (TMDLs). TMDLs are the definition and allocation of the total loading to be discharged to a water body from all sources (natural, point sources and nonpoint sources) that will achieve water quality standards. Florida produced 303(d) lists in 1996, 1998, and is currently working on the 2000 list.

In 1999, Florida adopted the Florida Watershed Restoration Act that deals with TMDLs (the Act is located in Chapter 403.067, Florida Statutes or FS). The Act requires the Florida Department of Environmental Protection (FDEP) to prepare two regulations. The first is to codify procedures to prepare the 303(d) List (i.e., define and identify impaired waters) as well as procedures to de-list waters. These regulations were prepared in conjunction with a Technical Advisory Committee (TAC). The Impaired Waters TAC met from October 1999 to October 2000 during which time the FDEP drafted an Impaired Waters Rule (Rule 62-303, Florida Administrative Codes, or FAC). The Environmental Regulation Commission (ERC) adopted this rule on April 23, 2001. A second TAC formed to address the policy issues related to TMDLs. This TAC produced a report dated February 1, 2001, which outlines the approach for TMDL allocations.

FDEP has developed procedures for the technical preparation of TMDLs in Florida. The procedures identify a five-step program. The steps are:

1. *Initial Basin Assessment*. During this step, stakeholders are identified, an inventory of pertinent information is prepared, existing data are assessed, the watershed is characterized, a detailed description of water resources in the basin is prepared, existing management programs are described, and a field reconnaissance is completed. It is during this step that the impaired waters planning list is prepared.

2. *Coordinated Monitoring*. For the second step, monitoring needed for the technical development of the TMDL is completed through the FDEP and cooperative agreements with stakeholders. After this step, the verified list is created and adopted formally by the FDEP. Water bodies on the verified list will receive a TMDL.

3. *Data Analysis and TMDL Development*. A critical element of the program, the third step assesses the collected data to identify point and nonpoint sources, natural background and seasonal fluctuations. The water body is then modeled for the development of the TMDL.

4. *Basin Management Plan Development*. Once the technical definition of the TMDL has been completed, the allocation and management plan to achieve the allocations is prepared. The preparation will be completed with the support of the stakeholders and subject to a public meeting for review.

5. *Begin Implementation of the Plan*. The last step is the implementation of the Basin Management Plan. The implementation may take a number of years to accomplish; however, the plan itself should define a schedule.

This process is an iterative one that allows for the FDEP to revisit the TMDL analysis periodically to confirm implementation and monitor its success.

For Polk County, the 1998 303(d) List identifies a number of impaired waters. **Table 3-1** provides a summary of the 1998 303(d) listing for Lake Hancock noting that the Lake is defined as impaired due to dissolved oxygen, unionized ammonia, and nutrients. Lake Hancock has been assigned to Group Three and is a high priority. The TMDL for Lake Hancock is scheduled to be completed by 2004.

Pollution Load Reduction Goals

Required by the State Water Policy (Chapter 62-40, Florida Administrative Codes), pollution load reduction goals (PLRGs) are numeric reductions needed to preserve or restore water bodies and achieve their designated use as well as maintain water quality standards. At face value, PLRGs appear to be Florida's counterpart to TMDLs. However, the major focus of the PLRG is stormwater loading; in particular, older stormwater systems built prior to the state's stormwater rule (Chapter 63-25, ca. 1985). Chapter 62-40 requires the FDEP or the water management district (WMD) to set pollution load reduction requirements on a watershed basis for waters in the state. Waters within a Surface Water Improvement and Management (SWIM) plan were to have PLRGs set first following WMD priorities. The PLRG studies were also to define loading targets and potential corrective actions and plans to achieve the targets.

According to the "Florida Nonpoint Source Management Program Update" (FDEP, November 1999), Lake Hancock is not listed as a SWIM water body. However, Banana Lake (which discharges to Banana Creek, a tributary to Lake Hancock) and Charlotte Harbor are listed. This means that while Banana Lake and Charlotte Harbor are subject to PLRGs, Lake Hancock is not. Projects, which benefit only Lake Hancock would not be eligible for SWIM funds, but projects which benefit both Lake Hancock and Charlotte Harbor could be eligible for SWIM funding. One such project is the proposed wetland treatment system for South Saddle Creek that would reduce the nitrogen loading to Charlotte Harbor.

Table 3-1
1998 303(d) List

HUC Name	Water Segment	[2] MAPID	[1] WBID	Parameters of Concern	Comments	Priority	Basin Rotation Group	Projected Year of TMDL Development	*Special TMDL development year	Parameter for special TMDL development
PEACE RIVER	SADDLE CREEK BELOW LAKE HANCOCK	74	1623K	Dissolved Oxygen, Coliforms, Un-ionized Ammonia, Nutrients, Turbidity, Total Suspended Solids		High	Group 3	2004		
PEACE RIVER	LAKE HANCOCK	79	1623L	Dissolved Oxygen, Un-ionized Ammonia, Nutrients		High	Group 3	2004		
PEACE RIVER	WAHNETA FARMS DRAIN CANAL	81	1580	Dissolved Oxygen, Coliforms, Nutrients, Turbidity		High	Group 3	2004		
PEACE RIVER	BANANA LAKE	83	1549B	Dissolved Oxygen, Un-ionized Ammonia, Fluoride, Nutrients	SWIM Waterbody. SWFWMD developed interim PLRG in 1995. Plan on developing final PLRG in 1998.	High	Group 3	2004		
PEACE RIVER	LAKE ELOISE	85	1521B	Nutrients	SWIM Waterbody. Part of Winter Haven Chain of Lakes. SWFWMD performing modeling.	High	Group 3	2004		
PEACE RIVER	LAKE LULU RUN	87	1521C		Listing of the water was based on the NPS Survey.	High	Group 3	2004		
PEACE RIVER	LAKE LULU OUTLET	89	1521	Dissolved Oxygen, Nutrients	SWIM Waterbody. Part of Winter Haven Chain of Lakes. SWFWMD performing modeling.	High	Group 3	2004		
PEACE RIVER	LAKE SHIPP	91	1521D	Dissolved Oxygen, Nutrients	SWIM Waterbody. Part of Winter Haven Chain of Lakes. SWFWMD performing modeling.	High	Group 3	2004		
PEACE RIVER	BANANA LAKE CANAL	92	1549A	Dissolved Oxygen, Coliforms, Nutrients, Turbidity, Total Suspended Solids	SWIM Waterbody. See comments for Banana Lake.	High	Group 3	2004		
PEACE RIVER	LAKE MAY	93	1521E	Nutrients	SWIM Waterbody. Part of Winter Haven Chain of Lakes. SWFWMD performing modeling.	High	Group 3	2004		
PEACE RIVER	CRYSTAL LAKE	95	1497A	Dissolved Oxygen, Un-ionized Ammonia, Nutrients		Low	Group 3	2008		
PEACE RIVER	LAKE LENA RUN	96	1501A	Dissolved Oxygen, Coliforms, Nutrients, Turbidity, Total Suspended Solids		High	Group 3	2004		
PEACE RIVER	PEACE CREEK DRAIN CANAL	97	1539	Dissolved Oxygen, Coliforms, Nutrients, Turbidity, Total Suspended Solids, Biochemical Oxygen Demand, Mercury (Based on Fish Consumption Advisory)		High	Group 3	2004	2011	mercury
PEACE RIVER	LAKE LENA	110	1501	Nutrients		High	Group 3	2004		
PEACE RIVER	LAKE HAINES	113	1488C	Dissolved Oxygen, Coliforms, Nutrients	SWIM Waterbody. Part of Winter Haven Chain of Lakes. SWFWMD performing modeling.	High	Group 3	2004		
PEACE RIVER	LAKE ARIANNA	116	1501B	Nutrients		Low	Group 3	2008		
PEACE RIVER	LAKE TENOROC	117	1497C	Dissolved Oxygen		Low	Group 3	2008		
PEACE RIVER	LAKE ALFRED	118	1488D	Dissolved Oxygen, Nutrients		Low	Group 3	2008		

3.6 Summary

In summary, the following are potential permit requirements for Lake Hancock restoration:

- Aquatic Plant Management Permit, FDEP, Chapter 62C-20, F.A.C. for invasive aquatic plant control and removal of associated organic sediments as stated in F.S. 403.813(2)(r).
- Environmental Resource Permit, SWFWMD, for dredge and fill activities;
- Army Corps of Engineers permit to regulate discharges for dredge or fill materials into wetlands and / or waters of the United States; and

In addition, special attention must be paid to issues identified by the Lake Hancock Advisory Group, as well as the TMDLs for Lake Hancock scheduled for 2004. Also, PLRGs for Banana Creek should be addressed.

Section 4
Lake Restoration Techniques

In order to develop the lake restoration management plan for Lake Hancock, appropriate lake restoration techniques must be identified and evaluated. The evaluation begins with a discussion of the technical approach to the restoration of eutrophic/hypereutrophic, shallow, turbid lakes such as Lake Hancock. A description of available in-lake restoration techniques for Lake Hancock, and their cost, benefits, and environmental effects is then presented.

Sediment inactivation techniques (dredging, drawdown and mechanical excavation, chemical inactivation, and capping) are presented first. Then, other techniques are addressed, including increasing the lake water level (Thomas Plan), biological control, wetland treatment, and habitat restoration. The predicted water quality improvement for the lake for a series of runoff/baseflow inflow treatment options and sediment inactivation is presented, and techniques to treat the discharge from the lake are summarized. The identification of suitable lands for restoration activities is also provided.

4.1 Introduction

In Florida, nutrient loading from urban and agricultural activities has resulted in eutrophication or hypereutrophication of lakes such as Lake Hancock. Lake Hancock is characterized by persistent blue-green algal blooms that produce cloudy water, high nutrient concentrations, and widely fluctuating dissolved oxygen and pH levels. The algae die and sink to the bottom, producing nutrient-rich flocculent bottom sediments that continue to contribute to the eutrophication of the lake.

There is debate regarding the appropriate restoration techniques for eutrophic or hypereutrophic, shallow, turbid lakes. There is a great deal of evidence, beginning with the findings of Vollenweider (1968), that nutrient control, particularly of phosphorus, is the key to lake restoration. Therefore, when a lake is impaired by persistent algal blooms, phosphorus control is often the first step to be taken for lake restoration. However, Canfield et al. (2000) suggest that controls on external loading may not produce noticeable results (clear water and improved recreational fisheries) for decades, if ever, because of the significance of internal phosphorus loading in hypereutrophic lakes.

While ERD (1999) concluded from the TN/TP ratio that Lake Hancock is infrequently phosphorus limited, they also point out that in the presence of nitrogen-fixing blue-green algae the TN/TP ratio may be misleading and phosphorus may actually limit algal productivity. While the debate continues, pragmatically reductions in phosphorus nearly always result in concurrent reductions in nitrogen loading as well.

Phosphorus is one of the key elements affecting ecosystem productivity and perhaps the key nutrient in most freshwater ecosystems (Brezonik and Pollman, 1999). Since some blue-green algae can obtain both carbon and nitrogen from the atmosphere,

phosphorus usually regulates the growth of algal biomass, and ultimately the trophic state of lakes. TN / TP ratios greater than 15 favor green algae and macrophytes. The phosphorus concentration in the water column of a lake is a result of the balance between phosphorus inputs and phosphorus losses through flushing and sedimentation. Many simple mass balance models have been developed to predict lake responses to phosphorus load reductions; however, these simple models have been found to be inadequate for predicting the decline in phosphorus concentrations following phosphorus load reduction because, for a time, the sediments can be a net source of phosphorus to the water column (Battoe et al., 1999).

Canfield et al. (2000) argue that, in shallow productive lakes, recovery is limited in the water column by internal loading from the sediments that maintains the phosphorus concentration in the water column at a higher level than might be predicted from a simple proportion to reduced loading. Phosphorus sedimentation rises in years of high external phosphorus input and decreases in years of low external input. This process maintains the phosphorus concentration in the water column more or less constant in spite of changes in annual phosphorus loading. Therefore, these lakes will be slow to respond to reductions in external phosphorus loading.

In theory, internal loadings decrease with time as phosphorus rich sediments become buried by layers of new sediments with lower phosphorus concentrations. But sediment resuspension is a mechanism that facilitates internal loading of phosphorus in shallow lakes (James et al., 1995). Therefore, Canfield et al. (2000) suggest that external nutrient reductions alone are usually not sufficient in the short-term to switch a lake back from a turbid, algae-dominated stage to a clear-water, macrophyte (larger, rooted aquatic plants) dominated stage. However, Battoe et al. (1999) indicate that over time, a reduction in the external phosphorus load to the lake will lower the phosphorus concentration in the water column, even in lakes with large sedimentary phosphorus stores such as Lake Hancock. The restoration of eutrophic or hypereutrophic shallow lakes requires the reduction of both external and internal phosphorus loads as well as the implementation of other management techniques.

A reduction in phosphorus loading may not always meet a specific restoration goal, such as a shift from eutrophic or hypereutrophic conditions to mesotrophic conditions, because there may be insufficient reduction in overall phosphorus loading or insufficient elapsed time to achieve a new equilibrium (Battoe et al., 1999). Lake restoration is often a long-term process. One theory suggests that restoration of hypereutrophic, shallow, turbid lakes requires reduction in phosphorus loading to lower the stability of algal dominance (especially blue green algae) and increase the stability of macrophyte dominance. Once the phosphorus concentration falls below a threshold for stable algal dominance, other management strategies may hasten the shift from algal to macrophyte dominance. These include biomanipulation (physically adding certain species) of the fish community and planting littoral (on or near shore) vegetation. Prior to 1926 Lake Hancock may have been in a stable, macrophyte-dominated state, and with the impacts of anthropogenic (human influenced) activities

including increased phosphorus loads, the lake entered its existing algal-dominated state. Paleolimnological data are needed to reconstruct the historical pattern of macrophyte and algal dominance in the lake and the historical trophic status of the lake in order to clearly define achievable lake restoration goals.

Lake Apopka, a shallow hypereutrophic lake located in Central Florida near Orlando, is currently undergoing a lake restoration effort. The restoration plan for Lake Apopka consists of four components (Battoe et al., 1999) and many of those components can be incorporated into the Lake Hancock restoration plan.

1. The first component is to significantly reduce the phosphorus loading to the lake to destabilize algal dominance. External phosphorus loads were reduced through purchase of riparian farms and restoration to wetlands to act as nutrient filters.

2. The second component is to reduce internal loads with a lake recirculating treatment wetland. These loads arise primarily from re-suspension and flux from the sediments within the lake.

3. The third component is the physical removal of phosphorus already incorporated into gizzard shad biomass from the lake by commercial fishermen. This harvest of the fish directly removes phosphorus and reduces the amount of sediment re-suspension.

4. The fourth component is replanting of littoral macrophyte beds around the lake. The vegetation will help to stabilize the sediments and provide habitat for spawning game fish.

Results from Lake Apopka, including development of macrophyte beds around the lake and recent improvement in trophic state indicators (TP, TN, TSS, Secchi depth, and Chl-a) indicate that reduction in phosphorus loading, along with the other components of the restoration plan, was the correct lake restoration strategy (Battoe et al., 1999). Similar techniques were incorporated into the Lake Hancock alternatives evaluated.

4.2 Available Restoration Techniques

The restoration of eutrophic or hypereutrophic lakes requires the reduction of both external and internal phosphorus loads, as well as the implementation of other management techniques. Therefore, in order to develop the Lake Hancock restoration plan it is important to evaluate the cost, benefits, and environmental effects of available restoration technologies that reduce external and internal loads, as well as other management techniques.

Sediment inactivation techniques (dredging, drawdown and mechanical excavation, chemical inactivation, and capping) and recirculating wetlands can remove internal loads. Treatment wetlands and settling ponds can remove external tributary loads.

Other in-lake restoration techniques include increasing the lake water level (Thomas Plan), biological control, and littoral zone habitat restoration. Treatment wetlands, settling ponds and filtration can be used treat the discharge from the lake.

4.2.1 Sediment Inactivation

Internal recycling from the lake sediments is a primary source of phosphorus in Lake Hancock, contributing approximately 53 percent of the estimated annual input to the water column. Elevated levels of nitrogen also occur in these sediments. Therefore, inactivation of nutrients in these sediments is a necessary component for lake restoration. Available techniques include sediment removal through mechanical excavation following drawdown and sediment desiccation, hydraulic dredging, in-situ chemical inactivation, and capping or sealing the sediments with an inert and relatively impermeable material.

4.2.1.1 Sediment Removal and Lake Drawdown

In Phase II of the Lake Hancock restoration study (Zellars-Williams, 1987) the removal of sediments by dredging, as well as by mechanical excavation following drawdown and sediment desiccation, were evaluated. More recently, Dames & Moore Inc. (2001) prepared a lake drawdown / hydraulic dredging feasibility study for Lake Jesup, near Orlando, Florida. In addition, mechanical excavation following drawdown and sediment desiccation has been implemented in several other Florida lakes for restoration. A summary of the results from these previous efforts is presented below.

Lake Hancock Restoration Study (Zellars-Williams 1987)

Sediment Characterization

Sediment characterization provided information to guide the evaluation of restoration techniques and options for Lake Hancock. The lake bottom sediments consist of highly fluid organic materials, estimated to be approximately 4 percent solids at the sediment interface, which grade slowly into cohesive muck-like sediments, estimated to be approximately 25 percent solids. There was no evidence of compressed fibrous material or consolidated remnants of sediments. The lake bottom underlying the organic sediment layer is firm and in most cases it is hard and granular. The sediment thickness ranges from 2.6 to 3.5 feet (0.8 to 1.1 meters) (ERD, 1999). The in-place volume was approximately 18 to 19.4 million cubic yards. The moisture content was greater than 80 percent.

Sediment fluidity testing suggests that the effectiveness of sediment removal would be enhanced by drawdown of the lake water level. Sediment drying tests were performed to characterize sediment shrinkage and moisture loss. The results indicate a rapid decrease in weight and a commensurate decrease in volume. All samples lost a minimum of 90 percent of the original weight within three weeks of placement and

underwent an 80 percent decrease in volume. Chemical characterization indicated that the highest phosphorus concentrations in near-surface sediments occur predominantly on the western (deep sediment) side of the lake.

Sediment decant water treatment tests were performed to assess the effectiveness of chemical additives in improving water quality by clarifying waters, removing particulates, and reducing nutrient levels. Alum was found to be most effective for removal of remaining particulates, increasing clarity, and removing phosphorus. Elutriation (decanting or straining) testing revealed that gross disturbance of sediments through pipeline delivery to a disposal area would result in significant nutrient release to the disposal area decant water, and localized lake effects would be expected, as well. Without additional treatment, the total phosphorus and total nitrogen concentrations in the decant water are predicted to be approximately 4 mg/l and 20 mg/l, respectively.

Sediment Removal

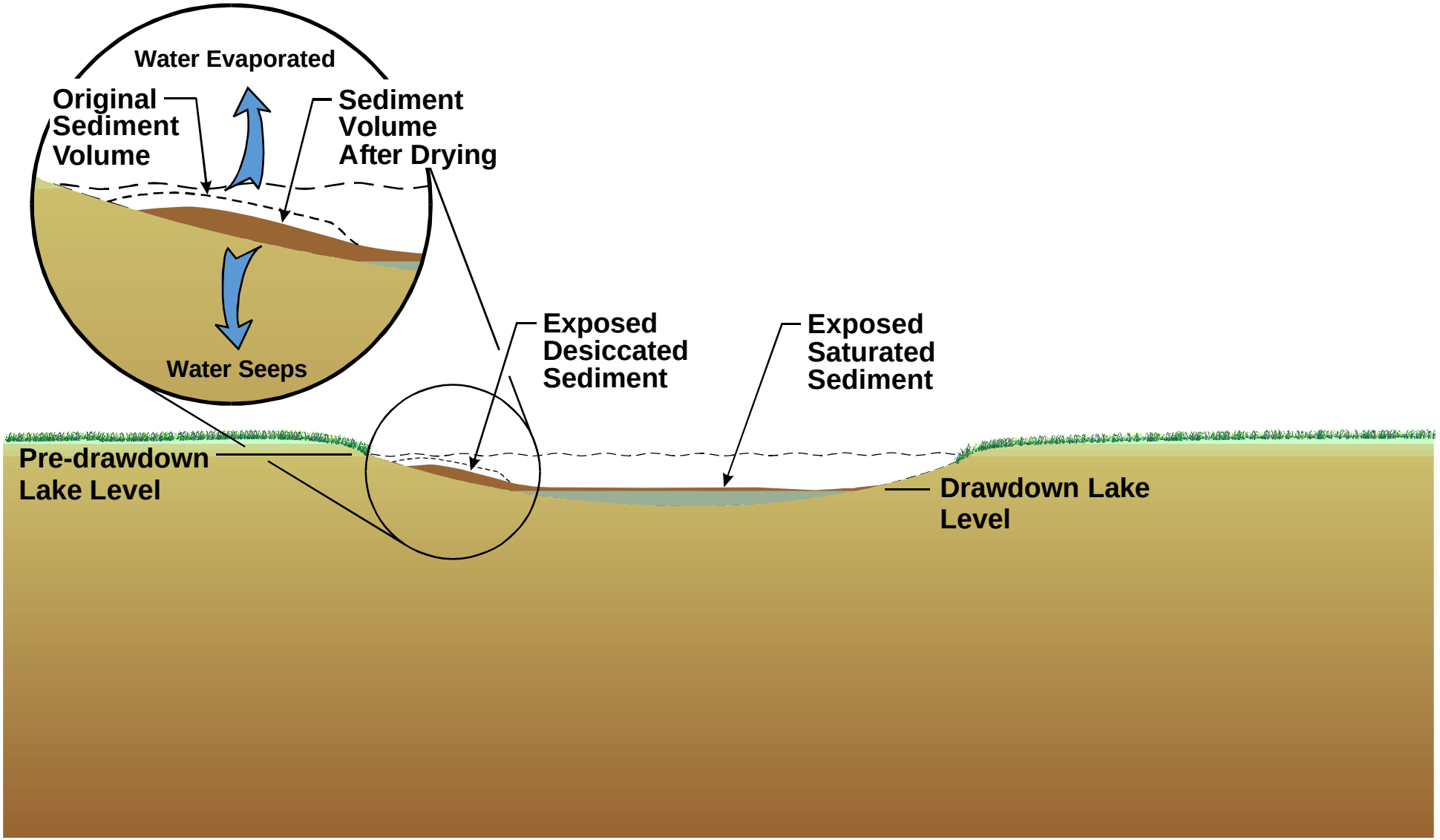
Zellars-Williams (1987) indicated that the most direct way to reduce internal nutrient loading would be to remove the lake-bottom sediments. This could be accomplished by drawdown (**Figure 4-1**) followed by mechanical excavation (**Figure 4-2**) or by hydraulic dredging (**Figure 4-3**). Mechanical excavation and the use of hauling equipment were not considered practical due to the soft sediments, the extremely high moisture content of the sediments even after drying, and the long waste disposal hauling distances. However, these unfavorable factors for mechanical excavation constitute favorable conditions for hydraulic dredging. Lake Hancock has limited water depth (2 to 5 feet), limited sediment thickness (2 to 5 feet) and the opportunity for long straight cut lines that would maximize efficient sediment removal. The operation would require a suction head to move sediments and minimize dilution, with high horsepower for long pumping distances and the large volume of sediment (up to 19 million cubic yards).

Hydraulic Dredging

The lake level should be as high as possible to accommodate the dredge. Zellars-Williams (1987) estimated that 95 percent of the sediments could be accessed by dredging at a removal efficiency of 80 percent. The dredging plan proposed for Lake Hancock by Zellars-Williams includes disposal of sediments in abandoned waste clay settling areas south of the lake, which may eliminate the problems with high nutrient concentrations in the decant water. It would be efficient and economical to perform over-dredging in order to create deeper zones that would trap incoming sediments and these sediment traps could be used to construct emergent areas, islands or peninsulas that would provide new habitat. Submerged and transition vegetation zones could also be developed along the slopes of the sediment traps. The resultant unit cost of $1.02/cubic yard (cy) reported by Zellars-Williams (1987) seemed inordinately low even to the authors, who went on to state:

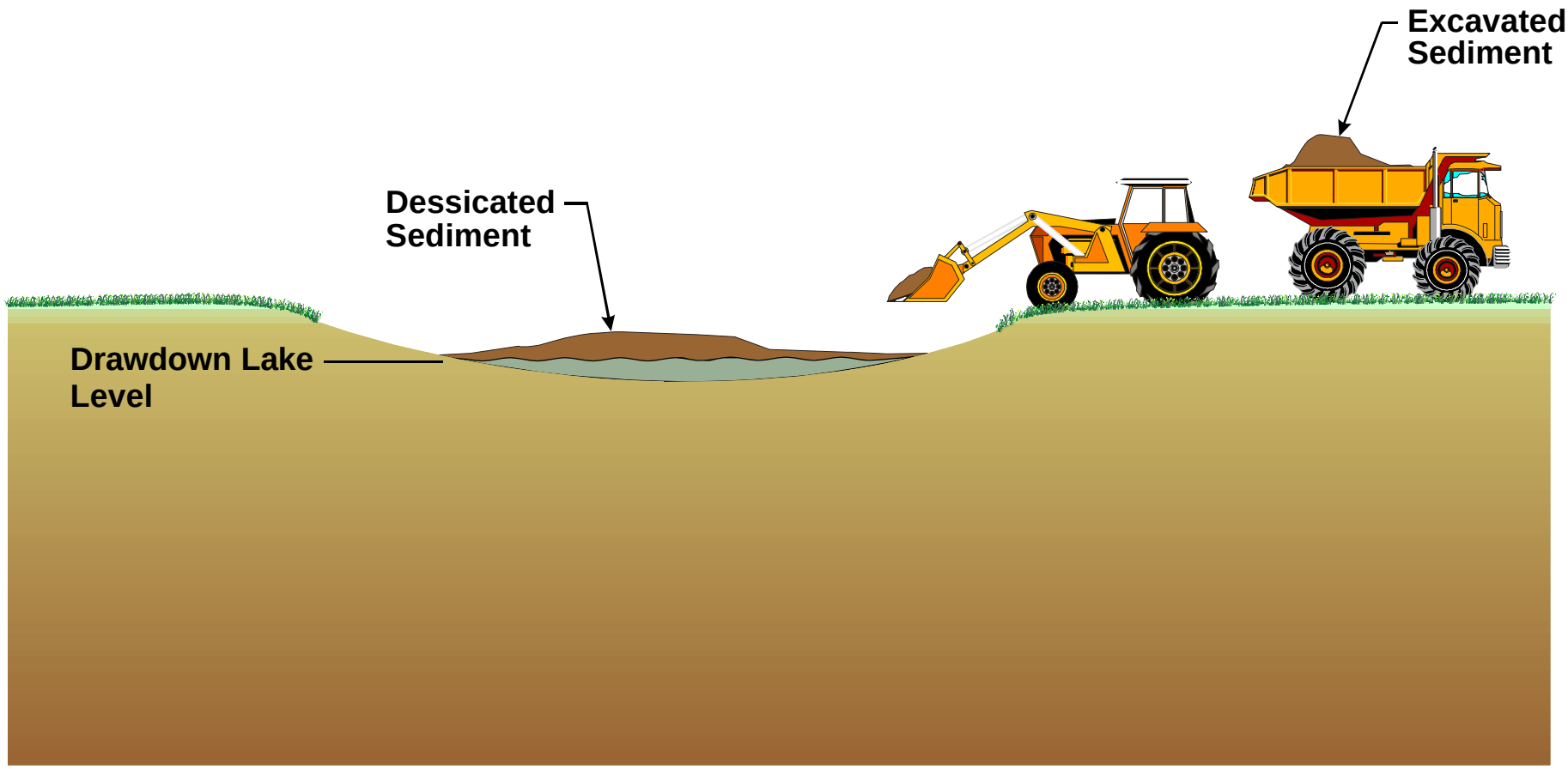
Lake Hancock Restoration Management Plan

Gravity Drawdown — **Figure No. 4-1**



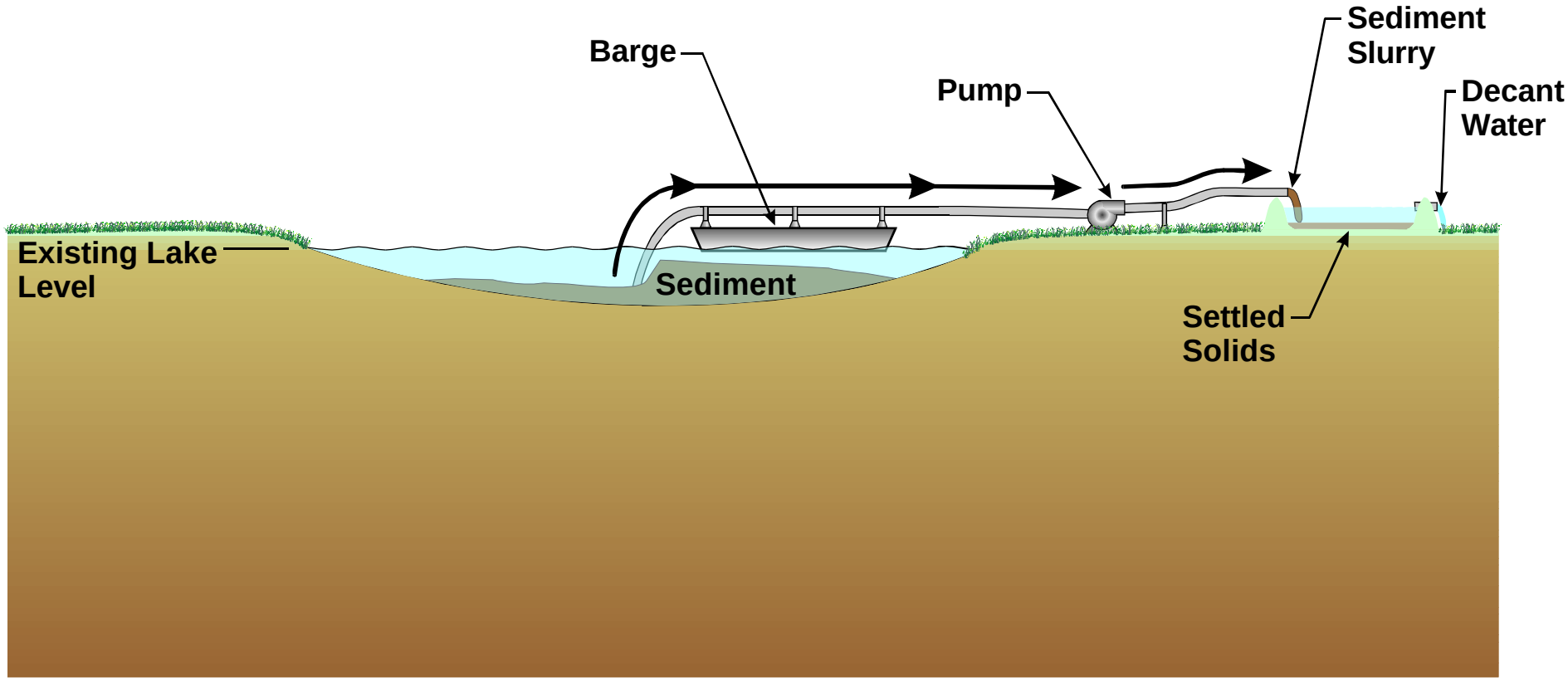
Lake Hancock Restoration Management Plan

Mechanical Excavation — **Figure No. 4-2**



Lake Hancock Restoration Management Plan

Hydraulic Dredging — **Figure No. 4-3**



> *Several factors suggest that the calculated cash costs may be somewhat higher than actual… Countering that idea is the fact that typical bid prices for dredged material removal noted in Florida range from $2 to $5/cy (1987 dollars).*

More recently, dredging of Lake Hollingsworth (G. Medley, personal communication) proceeded at a unit cost of $3.33/cy and the cost of dredging Lake Apopka was estimated at $4.38/cy (Pollman et al., 1986)

The estimated cost in 1987 for removal of 18 million cubic yards of sediment from the lake, earthwork for settling areas, and up to 4.3 million cubic yards of additional sediment removal for sediment traps was $23.5 million. Without additional sediment removal for sediment traps, the estimated cost in 1987 for sediment dredging in Lake Hancock was $18.5 million or $26.8 million in 2001 dollars (ENR Construction Index).

Zellars-Williams (1987) indicated that removal of the sediment from the lake bottom and deposition of this sediment at the south end of the lake is the most attractive alternative from an environmental viewpoint. A large reservoir of nutrient reserves would be removed from the lake and the best possible water quality would be established immediately after dredging of sediment is complete. The majority of the lake would be restored to a depth of 5 to 6 feet (1.5 to 1.8 m), which is ideal for fish. Sediment dredging would result in minimum disturbance to flora and fauna within the lake during lake restoration. However, the deposition of 18 million cubic yards of sediment in settling areas at the south end of the lake would require an area of 1,300 acres and have a profound short-term effect on this area. Zellars-Williams recommended sediment dredging as the preferred method for long-term improvement of Lake Hancock's water quality.

Lake Drawdown, Sediment Desiccation, and Mechanical Excavation

Lowering the lake water level to expose bottom sediments to desiccation has been implemented for lake restoration in Florida. In Lake Hancock, this approach may immobilize nutrients that otherwise are released from the sediments to the water column. In order to develop a plan to drawdown the lake, Zellars-Williams (1987) evaluated the condition of the P-11 structure and associated flow-ways to estimate the discharge rate. The P-11 structure is rated for a flow of 400 cubic feet per second (cfs) and has a controlling (invert) elevation of 91.7 feet NGVD, but Zellars-Williams determined that a downstream sedimentation had created a natural obstruction at elevation 94.0 and that drawdown would be limited to this elevation. At a typical pre-drawdown elevation of 98.5 feet, high inflow conditions, and an initial discharge rate of 400 cfs, it would take two months to drain the lake to an elevation of 94.0 feet. Under inflow conditions typical of the dry season, drawdown would be accomplished in less than a month. (It should be noted that FEMA reported obstructions at elevation 95.4 in 1982, and the Army Corps of Engineers reported an obstruction at 96.4 in 1974.)

Drawdown to the limit of gravity flow (at elevation 94.0 feet) will not promote desiccation of all exposed lake sediments as it would leave nearly 3,000 acres (67 percent of the total) of exposed sediments in a saturated state. Pumping, or construction of weep channels or wormholes would be required to promote desiccation of all exposed sediments, adding to the expense. Therefore, tributary flows would need to be diverted away from the lake and this would require in-lake dikes parallel to the shoreline to promote gravity flow for discharge at the P-11 structure, and an additional month of pumping. Three months of drawdown would be followed by three months of desiccation. With this approach, Zellars-Williams estimated that approximately 3.4 million cubic yards of bottom sediments could be inadvertently entrained in the pumped drawdown water and would be removed from the lake over a six-month period and deposited in settling areas at the south end of the lake.

When the contractor's bidding price for pumpdown was applied to the 3.4 million cubic yards entrained with the pumped water, the resultant unit cost obtained was $1.30 per cubic yard of sediment in 1987. When the earthwork for settling areas, and earthwork for the in-lake dikes for tributary flow diversion were included, the total project cost for drawdown, desiccation and partial sediment removal in Lake Hancock was $5.7 million. Using the ENR construction index, the estimated cost in 2001 dollars is $8.3 million for a pumped drawdown that removes 19 percent of the lake sediments as a by-product of the operation.

Drawdown, desiccation, and partial sediment removal would release nutrients to the lake and have the quickest effect on the water quality of the lake. The effect on aquatic life would be profound during the drawdown and desiccation process but the water quality improvement would be the most rapid of the alternatives considered, with the results being achieved immediately on lake reflooding. However, even if relatively effective desiccation could be brought about by drawdown of the lake, there is no evidence that this approach represents a means of permanently restoring Lake Hancock water quality.

If a low-cost means of exposing large expanses of bottom sediments were available, drawdown might have merit as a means of achieving at least a short-term improvement in the lake. Pumping below elevation 94.0 feet would be expensive, and was not recommended by Zellars-Williams (1987) for the restoration of Lake Hancock. However, gravity drawdown will expose a wide littoral shelf to desiccate (33 percent of the lake area at elevation 94 feet). Thus, a partial drawdown remains a viable sediment removal technique as a precursor to improvements in the littoral zone.

The effects of mechanical sediment removal following drawdown are relatively unknown. Obtaining sufficient desiccation throughout the sediment column following a lowering of the lake previously discussed, may not occur if the surface forms a hardened crust which seals the water in the lower sediments. As indicated above, a passive drawdown to the limit of gravity flow will not promote desiccation

of all of the sediments as it would leave a large percentage of exposed sediments in a saturated state. In order for drawdown and mechanical excavation to be successful, sufficient drying of the sediments to allow for their mechanical removal would be required.

Once the sediments are removed, they must be either hauled off-site, or formed into spoil islands within the Lake. Off-site disposal adds to the cost, but has the advantage of completely removing the nutrients from the system. On-site disposal provides the advantage of decreasing the residence time of water moving through the Lake, but may leach the nutrients back into the Lake as groundwater, stormwater runoff and/or seepage from the perimeter of the islands.

Lake Jesup Drawdown and Hydraulic Dredging Feasibility Study (Dames & Moore, Inc., 2001)

Dames & Moore, Inc. (2001) prepared a lake drawdown/hydraulic dredging feasibility study for Lake Jesup. The study was performed in part to compare the feasibility, potential impacts, and costs of conducting a controlled drawdown to facilitate consolidation of bottom sediments, with the feasibility, potential impacts, and costs of performing hydraulic dredging to remove sediments in particular areas of the lake.

The Dames and Moore Inc. (2001) study provides recent cost data that is useful for comparison purposes. The cost estimate for lake drawdown alternatives with dredging of 1.6 million cubic yards of sediment (without landfill disposal) ranged from $13 to $78 million ($8.13 to $48.76 per cubic yard). The cost estimate for a hydraulic dredging program for removal of 1.6 million cubic yards of sediment was $6.3 million ($3.94 per cubic yard). The cost estimate for a hydraulic dredging program for removal of 102 million cubic yards of sediment was $353 million ($3.46 per cubic yard).

Dames and Moore (2001) indicate that from a cumulative impacts perspective, whole lake dredging would result in the most significant positive long-term impact to the lake but this alternative was determined to be infeasible due to the high costs. Lake drawdown will effect the entire aquatic community due to substantial reduction in both the lake volume and circumference, but as indicated above, a reasonable drawdown and dredging program can be developed to selectively remove limited quantities of dredged material from portions of the lake to enhance lake restoration.

Additional Drawdown Information

A deliberate drawdown, which results in lowering the water table below the base of the organic sediments, would allow the sediments to thoroughly dry. Drying may be enhanced by mechanical discing or tilling the sediments. Moyer et al. (1995) indicated that in Lake Tohopekaliga an extreme drawdown coupled with mechanical removal of organic sediments from the littoral zone provided an immediate positive fish response. An estimated 215,820 cubic yards of sediment were removed with heavy

equipment (bulldozers, front-end loaders, dump trucks) and deposited on adjacent uplands. These authors indicate that drawdowns consolidate and compact organic sediments, release previously bound nutrients, stimulate growth of native aquatic plants, and increase macroinvertebrate and forage fish populations.

Williams et al. (1992) found that in Lake Tohopekaliga water quality deteriorated during drawdown, but flocculent sediments compacted an average of 80 percent. Evaluation of water quality after reflooding was compromised by the continued introduction of point source discharges. Aquatic vegetation and invertebrate populations increased after the drawdown. Similar results were obtained from a 1977 drawdown of Lake Kissimmee. Water quality in the restored littoral zone was significantly improved relative to the limnetic (open-water) portions of the lake. This result implies that desiccation alone does not reduce the sediment nutrient load except possibly in the littoral zone. It is unclear whether the improved littoral water quality was the result of less wind-induced resuspension or biological uptake.

While researchers generally agree that habitat will improve after drawdown, there is not a consensus on the long-term water quality benefits. Zellars-Williams (1987) assumed that nutrient flux from the sediments would be reduced by 75 percent immediately following drawdown and reflooding. However, they questioned whether the reduction would be permanent. The long-term effectiveness of drawdown on water quality has not been determined.

As part of the Lake Apopka restoration effort, a literature review of the effects of extended drawdown was completed by Greening and Doyon, 1990. The study concluded that the primary benefits include sediment compaction, improved shoreline vegetation and macroinvertebrate populations, and increased fish density. However, these benefits were found to be temporary and drawdowns must be repeated every two to seven years. In addition, these authors concluded that drawdowns do not improve water quality and can lead to significant sediment and nutrient loading to downstream waters. In addition, a common problem associated with the drawdown of Florida lakes is the establishment of large number of nuisance macrophytes species after refilling. In some cases, the initial establishment of desirable species was ultimately lost to encroachment by nuisance species.

The 1991 FGFFC plan included a drawdown of Lake Hancock to elevation 95 feet (28.96 meters), exposing 20 percent of the lake bottom. The primary goal of the 1991 FGFFC plan was to enhance habitat and sport fishery, and they recommended maintaining the lake level at elevation 95 feet for eight months. Drawdown would occur during the wet season to provide maximum dilution in the Upper Peace River. Two strategies were proposed to combat nuisance vegetation during the period of drawdown. One approach recommended application of herbicide and the other approach recommended seeding with rye grass, wild rice or other cover crop. Vegetation control was estimated at $290,000 in 1991 (equivalent to $373,000 in 2001 dollars based on the 2001 ENR Construction Cost Index). The 1991 plan did not

include removal of the flocculent sediments prior to planting, and this plan is no longer considered feasible unless the sediments are removed (K. Dutton, personal communication).

There is a concern that, if the exposed lake bottom becomes vegetated during the drying process, the vegetation will float to the surface when the lake is refilled, causing sediment resuspension, nutrient release and navigational hazards due to floating mats. This occurred during the refilling of both Lake Carlton and Fox Lake following drawdown.

Drawdown and Mechanical Excavation Demonstration Project

In order to evaluate the feasibility of mechanical removal, CDM (2001) prepared a technical memorandum to evaluate the removal of sediments from Lake Hancock using conventional excavation equipment in conjunction with a lake drawdown to take advantage of recent drought conditions throughout Florida. A demonstration project was proposed in the technical memorandum that addressed background information regarding historical lake levels, the control of water levels in the lake, a summary of the sediment characteristics in the lake, and a description of the demonstration project sediment removal operations, costs, permitting requirements and monitoring activities.

The demonstration project would consist of the removal of 3,900 cubic yards of sediment and placement of the sediment in an approximately 0.9-acre bermed, non-discharging settling and dewatering cell. The size of the settling area (and therefore the volume of excavated sediment) was selected to meet minimum permitting requirements. The maximum depth of excavation allowed by the aquatic plant management permit is three feet and the dewatered sediment would be removed by a front-end loader or a small dragline. In order to implement the demonstration project, the drawdown capabilities at the P-11 structure need improvement. Vegetation monitoring would be needed to identify establishment of undesirable species. Demonstration project monitoring would include physical and chemical analyses and measurement of the rate of water loss within exposed sediments. The estimated cost of the demonstration project is $332,897. The complete technical memorandum is presented in **Appendix C.**

4.2.1.2 Chemical Inactivation of Sediment

Immobilization of phosphorus through chemical inactivation has been used to successfully restore lakes. Phosphorus inactivation through chemical addition is a technique used to achieve long-term control of phosphorus release from sediments. Iron, calcium and aluminum have salts that can combine (or sorb) inorganic phosphorus or remove phosphorus-containing particulate matter from the water column as part of a flocculant. Aluminum sulfate (alum) has been used most often, and when added to the water produces colloidal aggregates of aluminum hydroxide. The floc forms a precipitate that settles to the sediments with the sorbed phosphorus.

If enough alum is added, a thick layer forms and retards the release of phosphorus to the water column thus reducing the internal load.

ERD provided a preliminary cost estimate for sediment inactivation of phosphorus in Lake Hancock. This cost estimate was based on estimation of several parameters including sediment concentrations of total available phosphorus (mean saloid-bound and iron bound phosphorus in the sediments), the depth from which phosphorus can be recycled from the sediments to the overlying water column, the mean total phosphorus concentration in the water column, and the optimum aluminum to phosphorus ratio for inactivation of phosphorus in the lake. Inactivation of phosphorus in the top 0 to 20 cm (0 to 7.9 inches) of the sediment will require 8.85 million gallons of alum. With mobilization and application, the cost estimate to apply this amount of alum is $5.2 million. Details of this cost estimate are provided in **Appendix D**.

The addition of aluminum salts to a lake with low pH and low alkalinity can cause toxicity problems. However, in the case of Lake Hancock, this is not expected to be a problem as both the pH (9.2 standard units) and alkalinity (50.4 mg/l) are higher than typical for Florida Lakes (7.4 standard units and 31 mg/l respectively). As indicated above, there are significant costs when this technique is applied to large lakes with high phosphorus concentrations in the water column. Baird and Bateman (1987) provided a preliminary assessment of phosphorus precipitation-inactivation as a restoration technique in Lake Apopka. These authors discourage alum use as the sole restoration technique for the lake, but suggest that it could be a potential tool for use in combination with other techniques.

An alternative technique for compacting the sediments and increasing the depth of the Lake was proposed by Madrid Engineering (2000a) in response to a general request for alternative lake restoration techniques issued by Polk County. This technique involves application of liquefied activated carbon (LAC) to the lake to oxidize and thereby reduce the sediment volume by one third. The remaining sediments must still be removed from the lake, and as this is an oxidative process, reduction in the dissolved oxygen in the lake is expected. It is not clear what other chemical reactions will occur with this approach and sediment oxidation may result in the release of organically bound sediment nitrogen and phosphorus which may result in in-lake or downstream water quality impacts.

4.2.1.3 Sediment Capping

This technology consists of sediment inactivation through capping of the sediments in the lake. The sediment cap may be constructed of clean sediments, sand, or gravel or may involve a more complex design using geotextiles, liners and multiple layers. This technology would have limited application in Lake Hancock because the upper sediments are too flocculent.

4.2.2 Alternative Lake Level Control

Manipulation of water levels is a recognized strategy for lake restoration (EPA, 1990a and 1990b). Lowering lake levels through a deliberate drawdown to expose sediments for desiccation and removal was previously described. Increasing the water level in lakes has been used to increase depth and reduce macrophyte growth (EPA, 1990b) and could be used to increase littoral habitat. A plan to increase the water level in Lake Hancock for lake restoration has been proposed by the Lake Hancock commercial fishermen and is described below.

Increased Depth (Thomas Plan)

The owners of Thomas Fish Company, representing the local commercial fishermen, have presented Polk County with justification of, and methods for, optimization of Lake Hancock for commercial fishing while providing for restoration of Lake Hancock and the Upper Peace River. The local commercial fishermen offer practical knowledge of the Lake Hancock / Upper Peace River system. Their plan requires maintaining Lake Hancock at a higher pool water level than at present. The recommendations made by the fishermen are summarized as follows:

- Establish a more natural lake water level fluctuation schedule using a series of structures on the discharge to Saddle Creek and Peace River.
- Modify the P-11 structure to keep the lake water level between 97.5 feet and 102.5 feet NGVD. This is an estimate to be refined upon visual inspection.
- Acquire land along South Saddle Creek (south of the P-11structure) and along Peace Creek. South Saddle Creek and Peace Creek should have an approximate 6-foot water depth to inundate surrounding wetlands.
- Install a weir on Saddle Creek at the old Bartow-Winter Haven Road, as in the FFWCC plan, if necessary to raise the water level sufficiently.
- Place a structure just North of the U.S. Highway 60 bridge to raise the water level along Peace Creek.
- Install two other structures on the Peace River near Ft. Ogden and at the mouth of Horse Creek. One or both of these structures would raise the water level along Horse Creek.
- Acquire land from affected property owners.
- Increase the width of North Saddle Creek as much as possible.
- Acquire the Circle B-Bar Ranch property.
- Manage Lake Hancock to maintain its commercial characteristics. Designate Lake Hancock as a commercial fishing lake and also accommodate sport fishing.

- Construct boat ramps and parking at the mouth of North Saddle Creek and where South Saddle Creek meets Old Highway 17.

- Install nature trails and bank fishing areas around the east side of the lake, along North Saddle Creek, South Saddle Creek, and Peace Creek.

In August 1966, the predecessor to the SWFWMD Governing Board established a desirable operating range of 95.00 to 98.60 feet NGVD. Since August 1966, the average lake level has been 97.80 feet, and has exceeded the proposed minimum level of 97.5 feet, 80 percent of the time. The current overflow level on P-11 is 98.7 feet and the maximum recorded elevation is 101.9 feet when Hurricane Donna inundated the area. Thus, the minimum water level proposed in the Thomas Plan has been exceeded 80 percent of the time, while the higher level proposed has never been exceeded even during a major hurricane. If the normal pool level is maintained at 102.5 feet, flood conditions would extend well beyond the maximum recorded.

Modifying the P-11 structure to maintain the lake level as high as 102.5 feet NGVD would nearly double the surface area of the lake from 4,595 acres at 98.2 feet to 7,120 acres. The volume of the lake at this stage would be approximately 42,700 acre-feet, or an increase of 26,800 acre-feet as illustrated in **Figure 4-4[(1)].** Based on the 10-year flood level reported by SWFWMD for existing conditions, an additional 26,800 acre-feet can be expected during storm conditions, bringing the total lake volume to 69,640 acre-feet. Using a stage-storage curve prepared from the USGS (1981) and ERD (1999) data, if a 10-year flood occurred with a base lake level of 102.5 feet, the estimated flood elevation would extend to 106.7 feet. According to recent survey work by Keith & Schnars, P.A. (M. Phelps, personal communication), the average centerline elevation at North Saddle Creek and State Road 540 is 104.1 feet. During a 10-year flood, this portion of SR-540 would be covered with 2.6 feet and would be impassable.

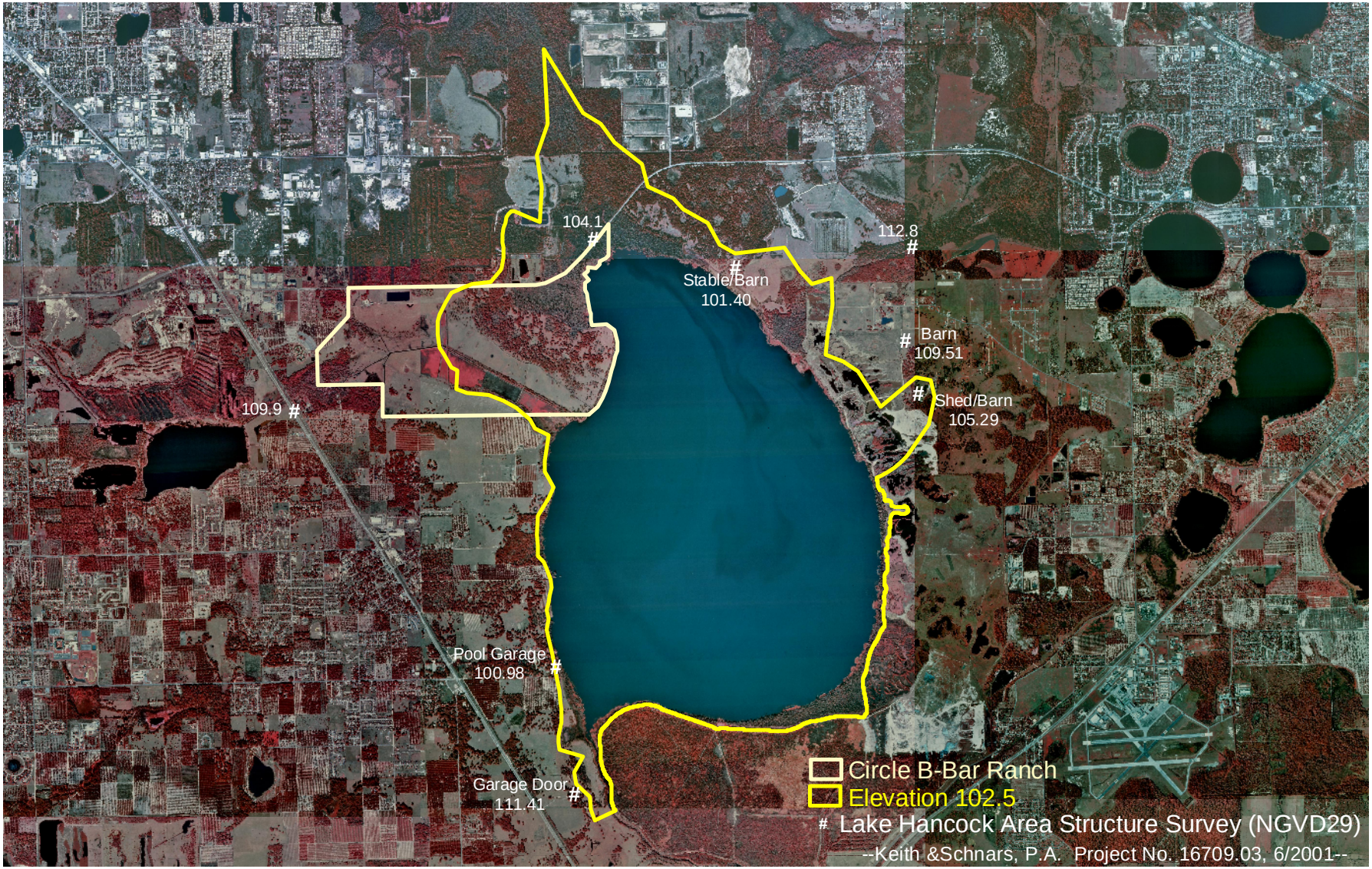
The ACOE and SWFWMD have established an elevation of 102.4 feet as the 10-year flood level for Lake Hancock at structure P-11. At an elevation of 102.5 feet, much of the recently purchased Circle B-Bar Ranch and surrounding properties would be completely submerged. Allowing the lake elevation to rise to 102.5 ft would affect several lakeside homes that use septic systems for waste disposal as illustrated in Figure 4-4.

The proposed six-foot depth in South Saddle Creek downstream of the P-11 structure mimics the 10-year flood level established for the creek by FEMA. For example, the creek bed elevation of Saddle Creek at P-11 is 94 feet and the 10-year flood elevation is 100 feet. At the confluence of Peace Creek and the Peace River Drainage Canal, the streambed elevation is approximately 92 feet and the 10-year flood elevation is 98 feet. At 100 feet, 625 additional acres will be flooded between P-11 and the confluence with Peace Creek. Most of the flooded area is privately owned, currently in pastoral land

(1) Elevations based on current (1987 Photorevised) USGS 7.5 minute Bartow quadrangle and recent survey data provided by Old Florida Plantation.

Lake Hancock Restoration Management Plan

102.5 foot NGVD Contour **Figure No. 4-4**



CDM Camp Dresser & McKee

use and could be converted to additional wetland treatment for discharge to the upper Peace River. Flood frequency information for Peace Creek, Horse Creek, and Peace River in the Fort Ogden area have not been reviewed, but additional areas would be flooded along these streams providing additional treatment.

Maintaining Lake Hancock at an elevation of approximately 101 feet will allow seine fishing to proceed as it has in the past. If the water level in the lake decreases below 97.5 feet or increases above 102.5 feet, seine fishing will be impaired. Maintenance of low water levels in the lake for a long period of time will result in a loss of income for the haul seiners.

If a higher water level is maintained, male blue tilapia compete for space with bream and bass for suitable spawning areas. Increased lake levels will provide more littoral habitat with emergent vegetation that will allow native fish better habitat to spawn and forage even if the lake remains hypereutrophic. Although improved for game fish, these conditions will still not result in game fish populations of lakes with much lower algal levels. Partial lake restoration to a marginally eutrophic level may improve native fish populations, but still leaves the risk of water quality induced fish kills. No measurable changes may occur in the blue tilapia, suckermouth catfish, or shad populations with partial lake restoration.

While primarily developed to serve the needs of the commercial fishing community, the Thomas Plan could result in several other benefits to Lake Hancock. The increased water levels will provide significantly more littoral habitat than now exists. The deeper water may reduce the wind-induced resuspension and movement of flocculent sediments. Finally, the reflooded wetland area south of P-11 will provide a settling / treatment area for discharges to the upper Peace River. However, implementation of the plan would result in massive flooding of public and private property if the normal lake level were raised to 102.5 and even greater flooding would result during superimposed flood events. Furthermore, while the Thomas Plan does indirectly provide for wetland treatment of inflows and outflow, it does not address the reservoir of phosphorus stored in the sediments or potentially catastrophic flooding events.

While the proposed lake level of 102.5 feet may increase the flooding potential too much, maintaining a smaller increase in lake level may be an acceptable risk. Since 1966 when SWFWMD established management levels, the average lake level has been 97.8 feet. Maintaining the lake at approximately 99 feet would provide an extra foot of depth to the lake. Beginning at this level, a 10-year storm would raise the lake pool to approximately 102.7 feet. Beginning at an elevation of 101 feet would result in an estimated 10-year flood level of 104.6 feet.

In addition to maintaining a higher average lake level, it is also desirable to manage the annual fluctuation of the lake. Since 1966, the average annual range has been 2.0 feet. FFWCC recommends (K. Denson, personal communication) an annual variation

of 2.25 feet with the high occurring in late summer and the low occurring in the winter months. Every 5 to 7 years, the water level should be lowered 3 feet below the regulated high for a period of approximately 60 days beginning in late spring.

4.2.3 Biological Control/Management

Biomanipulation (altering the composition of the lake's biological community by eliminating or changing a component of the food web) of zooplankton and fish communities has been used in lakes to control algal populations and improve water clarity. It would be difficult to establish a balanced community through biomanipulation due to the amount of algae present in Lake Hancock. However, it may have application in later stages of the lake restoration program. Fish harvest to remove phosphorus from a lake has been implemented as a component of lake restoration programs. From 1993 to 1997 commercial fishermen harvested 2,220 metric tons (2.22 million kg) of gizzard shad from Lake Apopka, which accounted for removal of 15.6 metric tons (15,600 kg) of phosphorus and 46.6 metric tons (46,600 kg) of nitrogen from the lake. Nuisance aquatic vegetation can be controlled with harvesting, drawdown, herbicides or by using plant-eating organisms such as grass carp or plant pathogenic biocontrol organisms such as insects (EPA, 1990). Nuisance aquatic vegetation is not the major problem in the lake but these techniques may be applicable for later stages of the lake restoration program. Biological control of plants can achieve long-term control without introducing expensive machinery or toxic chemicals.

Stocking of the lake is an immediate and direct biological management strategy. However, in the case of Lake Hancock, it should be done in after habitat improvements. Management of the littoral areas can significantly enhance the diversity of the fisheries by providing habitat suitable for game fish. Stabilizing or removing the flocculent sediments in the littoral zone and planting desirable emergent vegetation will increase the feeding/spawning habitat. Adding physical structures to disrupt wind-induced stress on the plantings and to reduce the transport of flocculent sediments into the restored areas would help to protect the littoral zones.

Natural colonization of the following species from the inflow tributaries is anticipated (K. Denson, personal communication) : largemouth bass, bluegill, redear sunfish, black crappie, warmouth, channel catfish, brown bullhead, golden shiner, taillight shiner, Seminole killifish, sailfin molley, brook silverside and gambusia. These species are found co-existing with talapia and exotic catfish in other eutrophic / hypereutrophic lakes in Polk and Hillsborough County suggesting that a game fish population can be re-established in the presence of exotics.

4.2.4 Wetland Treatment

4.2.4.1 Introduction

Restoration and / or creation of wetlands are relatively new techniques being used in shallow, subtropical lakes in Florida for lake restoration and management, in conjunction with external nutrient load reduction.

A great deal of research has been performed documenting the ability of wetlands, both natural and constructed, to provide consistent and reliable water quality improvement. With proper execution of design and construction elements, constructed wetlands and rehydrated wetlands exhibit characteristics that are similar to natural wetlands, in that they support similar vegetation and microbes to consume pollutants. In addition, these wetlands provide wildlife habitat and environmental benefits that are similar to natural wetlands. Wetlands are effective in the treatment of BOD, TSS, nitrogen, phosphorus, pathogens, metals, sulfates, organics, and other toxic substances. Wetland treatment systems can be designed to treat tributary inflows to the lake, tributary discharges from the lake to downstream waters, and the water in the lake.

Treatment wetlands can be effective for phosphorus treatment. Redistribution of phosphorus to internal sinks is a result of adsorption and precipitation reactions. The magnitude of phosphorus retention capacity varies considerably and is related to the concentration of aluminum and iron in the soil as well as the organic matter content.

Treatment wetlands are effective in nitrogen removal, particularly through a two-step process known as nitrification / denitrification. In the first step, ammonia is converted to nitrate (also a nutrient) consuming oxygen in the process. Later in the treatment wetland, the water enters a cell that has an adequate source of carbon, but no oxygen. Under these conditions, denitrification takes place which converts nitrate to inert nitrogen gas. Treatment wetlands that successfully process nitrogen in this manner have been documented to achieve 75 to 95 percent total nitrogen removal

Wetlands are effective for TSS removal and the efficiency does not decrease at high loading rates. Low water velocities coupled with the presence of vegetation and soils promote sedimentation and filtration of solids. The removal of TSS involves these physical settling processes and therefore minimum detention time is an important design criterion and velocities that cause erosion must be avoided.

Wetland treatment can also be coupled with other techniques to further improve the removal efficiency. Madrid Engineering (2001b) submitted a phosphorus inactivation proposal that combines chemical treatment, wetland treatment and conventional filtration to achieve estimated removal rate of 90 percent. Tributary inflow water is dosed with ferric sulfate and routed through a wetland treatment system. The wetland effluent is routed through a peat soil containing iron humate TM, which is constructed on top of a conventional sand filter.

4.2.4.2 Treatment Wetland Sizing

A specific first-order area-based model developed by Kadlec and Knight (1996) is used to provide a preliminary estimate of wetland treatment area requirements. The model is used to estimate the constructed treatment wetland (**Figure 4-5**) area necessary to reduce the wetland influent concentration of a specific pollutant to a target wetland effluent concentration for that pollutant. The wetland influent concentration, target wetland effluent concentration, and the first-order areal rate constant (k), for specific pollutant are used in the model equation to estimate wetland treatment area requirements.

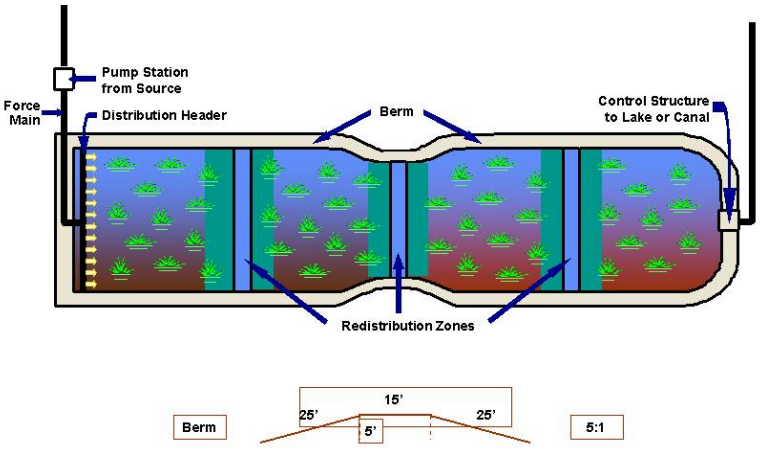


Figure 4-5
Schematic of a Constructed Treatment Wetland

This area-based first-order k-C* model solved for area is as follows.

$$A = \frac{0.0365 \times Q}{k} \times \ln \frac{Ci - C^*}{Ce - C^*}$$

where A = required wetland area in hectares
Q = water flow rate in m3/d
k = first order areal rate constant in m/yr
Ci = wetland influent concentration in mg/l
Ce = target wetland effluent concentration in mg/l
C* = background concentration in mg/l

These first order processes are dependent on wetland area and are limited to non-zero background pollutant levels that naturally occur in wetlands, as specified for each pollutant in the model (C*). Knowledge of areal rate constants (k) for specific pollutants, the wetland influent concentration and the target wetland effluent concentration for specific pollutants, indicate which specific pollutant is critical for estimating wetland treatment area requirements. The pollutant that requires the largest treatment area is the critical pollutant, which for Lake Hancock treatment wetlands is phosphorus.

Coveney et al. (2000) compared the actual removal of phosphorus in the Lake Apopka demonstration marsh flow-way with the removal of phosphorus predicted with the area-based first order k-C* model. Calibration of the model to the demonstration data resulted in a first-order areal rate constant (k) for removal of total phosphorus of 55 m/yr. This value is high in comparison with a set of 92 wetlands where k averaged 10 m/yr. However, as Coveney et al. (2000) indicate, as opposed to most of the systems in the data set, almost all phosphorus in Lake Apopka water was particulate, and particles were removed at a high rate in the demonstration wetland. A k value of 55 m/yr was used to estimate the wetland area necessary to treat the inflows from Banana Creek and the wetland area to treat the outflow at the P-11 structure (South Saddle Creek), as the phosphorus in these flows is predominantly in particulate form. A k value of 10 m/yr was used to estimate the wetland area necessary to treat the inflows from North Saddle Creek and the wetland area necessary to treat the inflows from Lake Lena Run, as the phosphorus in these flows is predominantly in dissolved form. The target wetland effluent concentration used 0.2 mg/l and the wetland background concentration was 0.06 mg/l.

ERD (1999) estimated the size of a treatment wetland for South Saddle Creek based on a flow of 80 cfs, which is greater than the long-term monthly average flow (1964-1996) for all but 2 months of the year, or 76 percent of the total volume of water discharged at the P-11 structure. The mean annual discharge at the P-11 structure for this time period was 59.3 cfs. Similar monthly flow data do not exist for the three inflow tributaries to the lake but the mean tributary inflows were estimated by ERD with a long-term (1960-1998) SWMM simulation as follows; North Saddle Creek 59.8 cfs, Banana Creek 2.4 cfs, and Lake Lena Run 6.37 cfs. The flow used to estimate the size of treatment wetlands for these tributaries was determined based on the ratio of the flow used by ERD to estimate the treatment wetland for South Saddle Creek to the mean annual discharged measured at the P-11 structure (80 cfs: 59.3cfs) which is 1.35. This ratio was multiplied by the estimated mean tributary inflows presented above. Therefore, the flows used to estimate the size of treatment wetlands are as follows; North Saddle Creek 80.7 cfs, Banana Creek 3.24 cfs, and Lake Lena Run 8.59 cfs.

The inflow from North Saddle Creek used in the k-C*model is large (80.7 cfs) and the phosphorus in this inflow is predominantly in dissolved form. The model results indicate that the wetland area necessary to treat this flow is very large (1701 acres) and this much area is not available near the mouth of North Saddle Creek to construct a treatment wetland. Less area intensive techniques can be used to treat the storm flows in North Saddle Creek. The size of the treatment wetlands for Banana Creek, Lake Lena Run and the outflow from the lake (South Saddle Creek) based on the k-C* model are presented below. The total wetland treatment system area requirements will be approximately 10 percent greater than the wetland treatment area requirements to account for containment berms.

The estimate of the size of the wetland to treat the decant water is based on a total decant flow of 3 billion gallons. This is based on 82 percent moisture content for 18

million cubic yards of sediment. Zellars-Williams (1987) estimated that it would take 3.6 years to hydraulically dredge this sediment. An estimate of four years (1460 days) was used to estimate the time for decant water treatment to account for settling time after dredging is completed. Therefore, 2.05 million gallons (3.18 cfs) of decant water would need to be treated each day. The wetland influent phosphorus concentration after chemical treatment was assumed to be 0.8 mg/l (80 percent of 4.0 mg/l) and the target wetland effluent phosphorus concentration was 0.4 mg/l. A k value of 10 m/yr was used to estimate the wetland area necessary to treat the decant water as the phosphorus will predominantly be in dissolved form. The wetland treatment area for the decant water based on the k-C* model is 55 acres and the wetland treatment system area for the decant water is 61 acres. Treatment and total system areas are summarized below.

	Wetland treatment area (ac)	Wetland treatment system area (ac)
Banana Creek	26	29
Lake Lena Run	137	151
South Saddle Creek	347	382
Dredging Decant Water	55	61

4.2.4.3 Lake Recirculating Treatment Wetland

The efficacy of removing particulate phosphorus in Lake Apopka through wetland filtration has been tested (Lowe et al., 1992). A 494-acre marsh flow-way wetland demonstration project was designed and implemented to test and refine this wetland filtration technique. The function of a recirculating treatment wetland (marsh flow-way) is the removal of algae and resuspended sediments and the associated phosphorus from the lake water (Coveney et al., 2000). This technology differs from other wetland treatment systems because the water is recirculated between the wetland and the lake with the purpose of removing particulate phosphorus. Sedimentation of particles from lake water and the accumulation of sediment and plant detritus (debris from decomposed plants) into new wetland soil are the mechanisms whereby phosphorus is removed and sequestered in the wetland (Coveney et al., 2001). This technique may provide a cost-effective program for phosphorus removal from Lake Hancock through the deposition of particulate phosphorus in the wetland.

When considering wetlands for storing phosphorus from eutrophic or hypereutrophic lakes, the relative bioavailability of various forms of phosphorus in the lake sediments and wetland soil must be addressed. The stability of the stored phosphorus and thus, its potential release back into the water column should be evaluated to determine the long-term assimilative capacity of the wetland treatment system and the recovery time for the lake. Long-term stable storage of phosphorus in organic pools in the wetland depends on the quality of detrital material accreted on the soil surface.

A flow-way marsh will remove more particles from the lake than would be expected to be deposited through sedimentation. But, because the fluid muds are subject to continual resuspension in a shallow lake, Canfield et al. (2000) reasoned that as particles were removed through filtration they would be replaced by resuspension of bottom sediments. Consequently, there will be a net (but very slow) movement of particles from the lakebed into the water column and eventually to the marsh flow-way and the outlet.

As Lowe et al. (2001) indicate, a wetland filtration system is not intended to remove all the surface sediments. The primary role of a wetland filtration system is to accelerate achievement of the new equilibrium total phosphorus concentration following phosphorus load reduction by removing sestonic (suspended particulate matter) total phosphorus (Lowe et al., 1992). Coveney et al. (2001) indicate as the mean total phosphorus in the lake water declines through time the total phosphorus concentration in the wetland will limit the wetland for future phosphorus removal. Therefore, these authors indicate that the value of a recirculating treatment wetland lies primarily in phosphorus removal from lake water in the early stages of restoration to accelerate the recovery of the lake.

Nutrient depletion by treatment wetlands may be appropriate for hypereutrophic lakes such as Lake Hancock. In Lake Hancock approximately 91 percent of the phosphorus in the water column is in particulate form and greater than 50 percent of the estimated annual phosphorus input to the water column is from internal recycling (ERD, 1999). Therefore, a recirculating wetland treatment system that removes particulate phosphorus from lake water may be very appropriate for Lake Hancock restoration.

Coveney et al. (2001) indicate that the performance of the Lake Apopka demonstration wetland has substantiated the nutrient removal ability of the larger full-scale wetland. The full-scale Lake Apopka marsh flow-way project is under construction and there are three long-term goals: (1) to establish and maintain a hydrologic regime and vegetation that will maximize phosphorus removal (2), to create a broad and persistent biological connection with the lake; and (3) to establish and maintain a diversity of habitats to support aquatic and wetland wildlife. Similar goals are appropriate for restoration and / or creation of wetlands for Lake Hancock restoration.

The estimate of the size of the recirculating wetland is based on the design of the full-scale Lake Apopka recirculating wetland. Lowe et al. (1989) projected a conservative long-term phosphorus removal efficiency for the Lake Apopka flow-way marsh of at least 30 percent. This projected long-term removal efficiency was based on several factors. Natural wetlands have been shown to remove 60 to 90 percent of suspended solids associated with influent wastewater (Richardson 1989). To determine the estimated removal of particulate phosphorus (42 percent) they multiplied the low end of the range (60 percent) for suspended solids removal by the percentage of

particulate phosphorus in lake water (70 percent). But, they also indicate that phosphorus removal efficiencies for marsh treatment systems are known to decline with continued loading (Nichols 1983). Therefore, a lower phosphorus removal efficiency (30 percent), similar to Nichols (1983) long-term high loading estimate, was selected.

At a flow rate of 14.5 m^3/sec (approximately two Lake Apopka volumes per year) and an inflow phosphorus concentration based on an average lake phosphorus concentration of 0.220 mg/l, the full scale flow-way marsh with 30 percent phosphorus removal efficiency is predicted to remove 30,200 kg P (30.2 MT P) per year from Lake Apopka. The full-scale flow-way marsh has an area of 14 km^2 (3500 acre) and a depth of 0.6 m. For a flow rate of 14.5 m^3/sec the hydraulic loading rate (HLR) is 8.9 cm/day, and the hydraulic retention time (HRT) is 6.7 days.

A flow rate of 1.26 m^3/sec (approximately two Lake Hancock volumes per year) and an inflow phosphorus concentration based on an average lake phosphorus concentration of 0.501 mg/l (ERD 1999) a full-scale flow-way marsh with 30 percent phosphorus removal efficiency is predicted to remove 5950 kg P (5.95 MT P) per year from Lake Hancock. For the same HLR of 8.9 cm/day, HRT of 6.7 days, and depth of 0.6m the treatment area of a Lake Hancock full-scale flow-way marsh would be 301 acres. The total wetland area requirements will be approximately 10 percent greater than the treatment area requirements to account for containment berms, or 331 acres. Greater annual phosphorus load reduction may be achieved with a recirculating treatment wetland as described in **Appendix E**.

Debusk and Dierberg (1999) reviewed techniques for optimizing phosphorus removal in treatment wetlands. They indicated that wetland area requirements for phosphorus removal were high as long-term phosphorus storage processes in wetlands occurred at slow rates. Therefore, there was interest in identifying inexpensive phosphorus control technologies to enhance phosphorus removal capabilities of treatment wetlands. These authors evaluated strategies for chemically enhancing phosphorus removal in wetlands. Chemicals can be added to the wetland inflow, with the inflow region of the wetland serving as a sedimentation basin for the resulting floc. In addition, chemicals can be applied to wetland soils prior to flooding, or during drawdown periods, to either improve adsorption of phosphorus from the water or to reduce the export of native soil phosphorus.

Alum and ferric chloride have received the most scrutiny as coagulation agents and their effectiveness is dependent on target phosphorus levels and other constituents in the water requiring treatment. These compounds have a finite ability to immobilize phosphorus, and cost and dosage are critical in determining feasibility. An understanding of influent and wetland water chemistry and wetland soil chemistry is necessary to determine appropriate dosage requirements.

The review provided by DeBusk and Dierberg (1999) and the ERD (1999) evaluation of settling pond treatment, aided by chemical coagulation, suggest that chemical addition treatment alternatives should be considered in conjunction with a lake recirculating treatment wetland for restoration of Lake Hancock. These could include chemical addition to the wetland inflow with sedimentation in the wetland, direct chemical application to the wetland, and chemical addition and sedimentation prior to wetland application.

4.2.5 Habitat Restoration

An understanding of past conditions is important in establishing specific goals for lake restoration. This sets the limit for what can reasonably be achieved. Historical aerial photographs and maps indicate the previous extent and type of wetlands that surrounded Lake Hancock. These wetlands provided natural treatment of runoff and thereby contributed to the maintenance of the water quality in the lake. The wetlands also provided fish and wildlife habitat. Forested wetlands surround portions of the lake and the vegetation in the lake historically consisted of emergent wetland species and submerged aquatic macrophytes. These diverse plant communities supported a productive sport fishery. Presumably, the shift to an algal dominated lake altered the fisheries habitat and in turn, the fish species composition.

Therefore, an important step in restoration of the lake is to restore wetlands adjacent to the lake and the littoral zone habitat at the edge of the lake. This will require improved water transparency to allow regrowth of submerged, rooted plants (macrophytes). Currently, reestablishment of submerged plants is hindered by shading both from dense algae and from flocculent surficial sediments continuously resuspended by wind action. Successful re-planting of the littoral zone must be preceded by removal of the organic sediments in the littoral zone and removal or stabilization of the remaining organic sediments in the deeper parts of the lake. Lake restoration will require reduction in phosphorus loading to lower the stability of algal dominance and increase macrophyte growth. In addition the littoral zone should be restored through planting. Exposure of the littoral zone by partially draining or pumping the lake would allow for mechanical excavation of the sediment to facilitate planting of emergent and submerged aquatic macrophytes. The establishment of rooted plants in the shallow waters would help to stabilize the shoreline and provide habitat for spawning gamefish. Physical barriers could be constructed to protect the restored littoral zone habitat. Battoe et al. (1999) suggest that once a threshold water quality is achieved in shallow lakes, then growth of submersed macrophytes results in direct and indirect feedback mechanisms to further reduce nutrient levels, algal biomass, and turbidity. They expect that initial establishment of macrophyte beds will, through these feedback mechanisms, further improve local water clarity so that expansion of these submersed macrophytes occurs.

A fisheries management plan must emphasize the establishment of a reasonable submerged aquatic plant coverage. The primary method for restoring submerged macrophytes (and associated fish habitat) in Florida lakes is water level drawdown

(Wegener and Williams 1974, Moyer et al. 1995). Exposure of the littoral zone provides for drying and compaction of organic sediments and reestablishment of rooted aquatic macrophytes through germination of seed reserves and direct planting. These activities stimulated production of both invertebrates and fish in Lake Tohopekaliga (Wegener and Williams 1974). However, a major concern regarding the use of drawdown to reestablish submerged plant coverage in the lake is the stability of the new plant communities. Canfield et al. (2000) caution that care must be taken in establishing submerged macrophytes in the lake, otherwise a massive costly, aquatic weed program will be created.

4.3 Predicted Water Quality Improvement in Lake Hancock

Trophic state modeling of Lake Hancock was performed by ERD (1999) to predict in-lake concentrations of total phosphorus, chlorophyll-a, and Secchi disk depth based on existing estimated loading to the lake. In-lake phosphorus concentrations were predicted based on four parameters: the estimated annual phosphorus input to the lake, a phosphorus retention coefficient which is based upon phosphorus sedimentation dynamics, the mean depth of the lake, and the mean flushing rate for the lake system. After developing the trophic state model, initial runs were performed to examine predicted water quality characteristics in the lake. The initial model runs were found to substantially underestimate measured in-lake concentrations of total phosphorus and chlorophyll-a. Discrepancies between predicted and measured concentrations of total phosphorus and chlorophyll-a suggested the presence of unaccounted-for sources of nutrients such as internal nutrient recycling.

Additional inputs of phosphorus were added to the initial model on an incremental basis until the in-lake concentrations of total phosphorus and chlorophyll-a began to closely approach actual measured water quality characteristics. This occurred with the addition of 108 kg of total phosphorus to the lake on a daily basis or approximately 39,420 kg (39.4 metric tons) of total phosphorus annually. This additional input primarily represents internal recycling and resuspension of bottom sediments within the lake.

The model was then modified to reflect anticipated phosphorus reductions as a result of recommended restoration options for Lake Hancock, and the output results were used to evaluate restoration options. More specifically, the model was used to evaluate anticipated water quality improvements that could be achieved from a series of runoff/baseflow treatment options as well as sediment removal options. North Saddle Creek is the primary contributor of pollutant loading from the three primary tributary inflows. The model results indicate that even with a 75 percent reduction of total phosphorus from North Saddle Creek, the predicted improvements in lake water quality characteristics will be minimal.

Therefore, additional modeling was performed to evaluate potential water quality improvements resulting from sediment removal in Lake Hancock and treatment of inflow loads. Sediment removal was assumed to reduce internal cycling within the lake by approximately 80 percent. The model results indicate that sediment removal in Lake Hancock will result in a significant improvement in water quality characteristics, but the lake will still exist in a hypereutrophic condition. The model results indicate that no combination of sediment removal and treatment options evaluated appear capable of obtaining mesotrophic conditions in Lake Hancock.

4.4 Treatment of the Discharge from the Lake

ERD (1999) evaluated a water quality improvement project to improve the quality of this discharge. The objective of this water quality improvement project was to remove total phosphorus, total nitrogen, and TSS from the water that discharges through the P-11 structure. As the majority of the nutrients that are discharging are in particulate form, primarily algal biomass, treatment alternatives were selected for the removal of algal biomass prior to discharge. Three treatment alternatives were selected: media filtration, wetland treatment, and settling pond treatment aided by chemical coagulation.

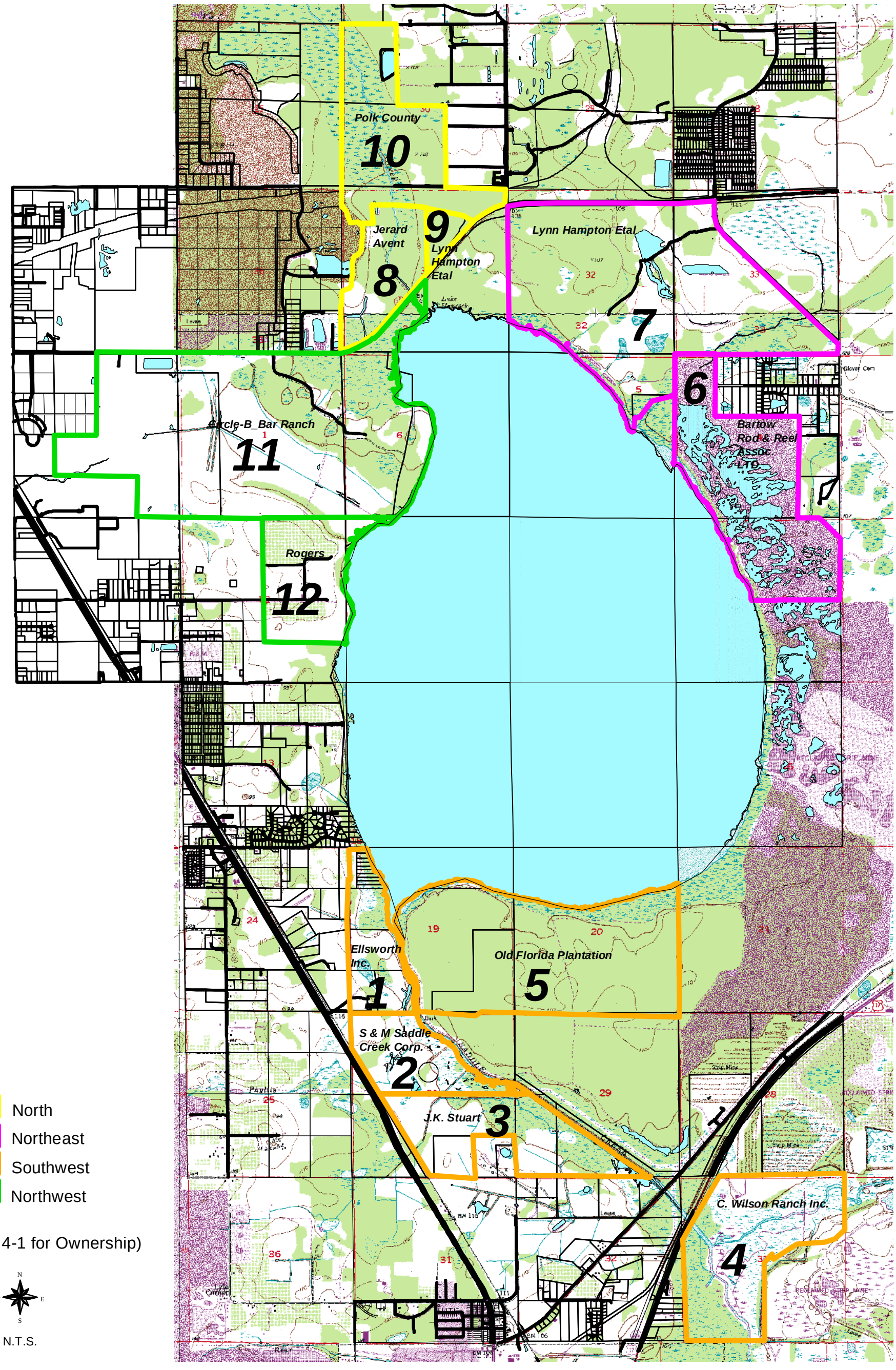
The media filtration alternative would include construction of gravity sand filters in concrete tanks. The wetland treatment alternative would include construction of multiple wetland cells using marsh vegetation to physically filter algae from lake water. The chemical coagulation / settling pond treatment alternative would add a coagulant to the water and pump the treated water into settling ponds for floc settling and drying. The preliminary evaluation indicated that all three alternatives have similar concentration-based, pollutant removal efficiencies for the four parameters of concern (TN, TP, BOD, TSS). Estimated mass removal efficiencies for the three treatment options vary as follows; TN (34 to 46 percent), TP (50 to 61 percent), BOD (38 to 46 percent), and TSS (53 to 69 percent). Conceptual construction costs were developed for these three treatment alternatives. Media filtration had the highest cost, followed by wetland treatment and settling pond treatment. On a present worth cost basis and a present worth cost per mass of pollutant removed basis, however the wetland treatment alternative appeared to be the most cost-effective.

4.5 Identification of Suitable Lands for Restoration Activities

In order to evaluate the implementation of restoration activities, a preliminary inventory of potential lands for restoration activities was developed. The data were provided by the Polk County Natural Resources Division and the results are presented in **Table 4-1**. The table indicates that 12 property areas were initially considered. Three of the property areas (listed in italics) have been eliminated from consideration and the reason is indicated in the table. The 12 property areas have been grouped into four general sites surrounding the lake as presented on **Figure 4-6**, each with a defined flowing water body, as follows.

Lake Hancock Restoration Management Plan

Property Location Map **Figure No. 4-6**



(See Table 4-1 for Ownership)

N.T.S.

CDM Camp Dresser & McKee

Table 4-1
Polk County Environmental Lands
Lake Hancock Sites

SOUTHWEST – S. SADDLE CREEK
1. Ellsworth properties
Ellsworth parcels: **39** acres/ **49** acres/ **36.5** acres/ **21.4** acres
Adjacent to S. Saddle Creek and southern discharge of lake
Great location, low acreage
County and WMD may appraise next year
Could be could be used in conjunction with 2
2. S & M Saddle Creek Corp property
220 acres
Between SR 98 and S. Saddle Creek
Great location, good acreage
Owner may not be interested in selling at this time
County and WMD may appraise next year
Could be used in conjunction with 1
3. Stuart properties
Parcels: **116.6** acres/ **40** acres/ **80** acres/ **114** acres
Two parcels adjacent to drainage canal on south end of S. Saddle Creek
Good location, good acreage
Owner not interested in selling at this time
4. Wilson properties
*Parcels: **82.6** acres/ **328** acres/ **31.4** acres*
South of Bartow Eagle Lake Road adjacent to drainage canal on south end of S. Saddle Creek
Poor location, good acreage
Owner was approached for pipeline mitigation and turned it down
5. Old Fl Plantation properties
*Parcels: **110** acres/ **446** acres/ **110** acres adjacent to lake (south) and adjacent to S. Saddle Creek*
Great location, great acreage, but approved for development
NORTHEAST SITE - LAKE LENA RUN
6. Coscia properties
4 parcels (500± acres)

Adjacent to lake (east) and, south of Lake Lena Run
Great location, good acreage
Owner interested in less-than-fee conservation easement
7. Hampton Hometrack properties
*Parcels: **557.8** acres/ **77.5** acres/ **358.5** acres/ **136.3** acres*
Adjacent to lake (north), adjacent to Lake Lena Run (north)
Great location, great acreage
Owner not interested in selling at this time
NORTH SITE - N. SADDLE CREEK
8. Kent property
191.4 acres
North of SR 540and adjacent to Circle B-Bar Ranch property just north of lake
Bisected by N. Saddle Creek
Great location, low acreage
County and WMD may appraise next year
May be used in conjunction with 9 and 10
9. Lynn Hampton property
136 acres
North of SR 540 adjacent to Kent property
Poor location, low acreage
County and WMD may appraise next year
Could be used in conjunction with 8 and 10
10. Polk County Landfill
303.5 acres
North of Kent property
Bisected by N. Saddle Creek
Good location, good acreage
May be used in conjunction with 8 and 9

NORTHWEST SITE-BANANA CREEK
11. Circle B-Bar Ranch property
Parcels: **297.5** acres/ **140** acres/ **490.3** acres/ **243** acres/ **17.5** acres/ **45** acres
South of SR 540 and adjacent to lake (west) up to N. Saddle Creek
Bisected by Banana Creek
Great location, great acreage
Polk County and the SWFWMD are owners
Evaluate use restrictions
12. Rogers properties
Parcels: **240** acres/ **94** acres/ **12** acres/ **6** acres
4 properties south of Circle B-Bar Ranch property
Smaller properties adjacent to lake (west) but owner unsure about willingness to sell
Good location, good acreage

A. Southwest Site (South Saddle Creek)

The properties in the Southwest Site are located along the western bank of South Saddle Creek. These properties contain areas that were formerly wetlands and offer opportunity for wetland restoration. Wetland restoration in this area could be incorporated into a trail / greenway / wildlife corridor linking areas north of the lake with the Peace River to the south. Suitable acreage may be available for a demonstration or full-scale project. A restored wetland in this area will have the ability to capture the discharge from the lake and directly reduce nutrient transport to downstream waters. As these properties are just south of the lake, return pumping would probably be required to implement a lake recirculating treatment wetland. Some of the properties on this site may provide opportunity for disposal and drying of sediments removed from the lake.

B. Northeast Site (Lake Lena Run)

The properties in the Northeast Site are located south of Lake Lena Run and adjacent to the lake. These properties contain areas that were formerly wetlands and offer opportunity for wetland restoration. Suitable acreage is available for a demonstration or full-scale project. A restored wetland in this area could treat flows from Lake Lena Run and could also be managed as a lake recirculating treatment wetland. These properties also contain abandoned mine pits that may be used for permanent disposal and drying of sediments removed from the lake.

C. North Site (North Saddle Creek)

The properties in the North Site are located north of SR 540 and the Circle B-Bar Ranch property and southwest of the county landfill. These properties are bisected by North Saddle Creek. Because of the relative magnitude of flow, North Saddle Creek is the primary contributor of pollutant loading from the three primary tributary inflows.

For this reason, ERD (1999) suggested that water quality improvement projects should be targeted here first.

The wetland area necessary to treat the flows in North Saddle creek is very large (1,701 acres) and this much area is not available near the mouth of North Saddle Creek to construct a treatment wetland. Less area intensive techniques such as a settling pond with chemical treatment can be used to treat the storm flows in North Saddle Creek. Suitable upland area is available at this site for a settling pond with chemical treatment. The settling pond with chemical treatment on this site could be combined with a treatment wetland or a lake recirculating treatment wetland on the Northwest Site. The settling pond could also potentially be used for chemical addition and sedimentation prior to wetland application.

D. Northwest Site (Banana Creek)

The properties in the Northwest Site are located south of SR 540 and adjacent to the lake. The Circle B-Bar Ranch property is greater than 1,200 acres in size and is owned and managed by Polk County and the SWFWMD. The Circle B-Bar Ranch property is bisected by Banana Creek. These properties contain areas that were formerly wetlands and offer opportunity for wetland restoration. Wetland restoration in this area could be incorporated into a trail / greenway / wildlife corridor linking areas north of the lake with the Peace River to the south. Suitable acreage is available for a demonstration or full-scale project. The site could also be used for disposal and drying of sediments removed from the lake. Some of these activities may be restricted on this property due to the co-ownership with SWFWMD and potential land use restrictions associated with purchase of the property.

A restored wetland in this area could treat flows from Banana Creek and could also be managed as a lake recirculating treatment wetland. The mean water quality characteristics in Banana Creek were substantially elevated for virtually all of the measured nutrient species, along with TSS, and BOD. ERD (1999) indicates that much of this impact appears to be related to discharges of algal biomass from Banana Lake. A lake recirculating treatment wetland on this site could also be combined with a settling pond with chemical treatment on the North Site. As described above the settling pond could also be used for chemical addition and sedimentation prior to wetland application.

4.6 Summary

The available restoration techniques and suitable lands for restoration have been presented previously in this section and restoration objectives were presented in Section 1. In order to develop a successful restoration for Lake Hancock, at a minimum both external and internal phosphorus loads must be managed, and the aquatic habitat must be improved through deepening. Those techniques are summarized below.

Reduce Internal Loads - Sediment Inactivation

- Drawdown and mechanical excavation
  (Removes sediment nutrients and deepens lake)

- Hydraulic dredging
  (Removes sediment nutrients and deepens lake)

- In Situ Chemical inactivation of phosphorus
- (Inactivates nutrients / No impact to depth of the lake)

- Sediment Capping
- (Provides barrier over sediments / Decreases depth of lake)

- Recirculating Treatment Wetland
- (Long-term removal of sediment nutrients / Increases wetland habitat)

Reduce External Loads

- Wetland treatment of inflows
  (Improves water quality / Creates habitat and public access)

- Stormwater attenuation with chemical treatment
  (Improves water quality and prevents flooding)

- Combined wetland and chemical treatment
  (Greatly improves water quality / Creates habitat and public access)

Lake Level Control / Increase Lake Depth

- Increase water level
  (Increase depth and littoral zone / Increase flood risk)

Biological Control/Management

- Fish Harvesting
  (Direct manipulation of food chain and removal of nutrients)

- Fish Stocking
  (Direct intervention / Needs to be done in concert with littoral zone improvements)

Habitat Restoration/Enhancement

- Restore Littoral Zone
- (Remove sediments, plant desirable macrophytes)

- Restore mineralized bottom for spawning
- (Indirect result of dredging or mechanical excavation to remove nutrients)

Combinations of these technologies are presented in the next section and scored according to their achievement of the five restoration objectives presented in Section 1.

Section 5
Development of Lake Restoration Options

5.1 Introduction

This section describes a two-step process used to combine the restoration technologies presented in the previous chapter and to evaluate the effectiveness of achieving the five Lake Hancock Advisory Group restoration objectives. In step 1, seventeen technologies that are complementary and feasible for use in Lake Hancock are defined. These applied techniques are compared to each of the five restoration objectives and assigned up to 10 points for each objective for a possible score of up to 50 points. In the second step, applied technologies are selected and combined into restoration options. Ten options were defined. Combinations reflect the need to address habitat, public access, and fish diversity, and to control internal and external phosphorus loads. Scores of the individual techniques used in the option are combined to provide a ranking for each restoration option evaluated. Evaluation of the three highest-ranked options continues in subsequent sections.

5.2 Lake Restoration Techniques Applied to Lake Hancock

A. Whole lake hydraulic dredging with chemical treatment of decant water

This applied technique consists of inactivating the internal sources of phosphorus, deepening of the lake and improving the sediment habitat through whole lake hydraulic dredging. Additional habitat is created through the use of a wetland to treat the decant water. Zellars-Williams (1987) proposed depositing 18 million cubic yards of sediment in settling areas at the south end of the lake. With appropriate application of organic polymers to the dredge slurry stream, sediment settling times can be up to twenty times faster than under normal conditions, but the use of polymers may cause bio-toxicity problems and must be tested prior to use.

The untreated decant water is expected to contain approximately 20 mg/l TN and 4 mg/l TP, and would require treatment prior to discharge. This would be accomplished with chemicals such as alum. Whole-lake dredging is only feasible in Lake Hancock if sufficient settling area is acquired. Treatment of the decant water is required and chemical treatment alone will not be sufficient to protect downstream receiving waters.

B. Whole lake hydraulic dredging with chemical and wetland treatment of decant water

This applied technique is similar to the previous technology except the treatment of the decant water would be accomplished with chemical treatment followed by a wetland treatment system prior to discharge. The combination of chemical and wetland treatment is expected to produce a treated decant water concentration of 5 mg/l TN and 0.4 mg/l TP. For comparison, the long-term average concentration in the Lake is 6.0 mg/l TN and 0.6 mg/l TP. Whole-lake dredging is only feasible in Lake Hancock if sufficient settling area is acquired. Treatment of the decant water is

required and chemical and wetland treatment may be sufficient to protect downstream receiving waters.

C. Whole lake hydraulic dredging with chemical, wetland, and biomass harvest technologies for treatment of decant water

This technique is similar to the two previous technologies except additional treatment of the decant water is provided to further protect the water quality in the downstream receiving waters. Chemical and wetland treatment would be followed by biomass harvest technologies such as a water hyacinth treatment system or an algal biomass treatment system to further reduce the nitrogen content in the return water. Treated decant water is expected to contain 4 mg/l TN and 0.2 mg/l TP.

D. Mechanical excavation of sediments (80 percent of lake area not associated with the littoral zone)

This applied technique consists of mechanical excavation of all of the sediment in the lake except the sediments in the littoral zone. This technique addresses water quality, depth of lake and quality of sediment habitat. (Improvements to littoral zone are addressed in alternative G.) The sediment would be scraped and transported from the lake, or formed into islands within the lake. In order for mechanical excavation to be successful, sufficient drying of the sediments is required and pumping or weep channels may be required to facilitate drainage.

E. Hydraulic Dredging of sediments (80 percent of lake area not associated with the littoral zone) with chemical and wetland treatment of decant water

This applied technique is identical to technique B, except that the littoral zone (assumed to be 20 percent of the lake area) is not dredged. (Improvements to littoral zone are addressed in alternative G.) Benefits included deepening of the Lake, improved water quality and sediment quality as well as additional wetland habitat and public access. The decant water is expected to contain approximately 20 mg/l TN and 4 mg/l TP, and would require treatment prior to discharge. This would be accomplished with chemical treatment followed by a wetland treatment system prior to discharge. The combination of chemical and wetland treatment is expected to produce a treated decant water concentration of 5 mg/l TN and 0.4 mg/l TP. Hydraulic dredging for this volume of dredged sediment is only feasible in Lake Hancock if sufficient settling area is acquired.

F. Whole lake in situ chemical inactivation of phosphorus

This applied technique involves the use of chemicals to inactivate phosphorus in the lake water. This technique controls the internal nutrient sources and improves water quality. Chemicals such as iron, calcium and aluminum salts are added to the lake and these chemicals combine with the phosphorus and settle to the lake bottom. Inactivation of phosphorus in the top 0 to 20 cm (0 to 7.9 inches) of the sediment will require 1.96 million gallons of alum. The addition of aluminum salts to a lake with low pH and low alkalinity can cause toxicity problems but the pH and alkalinity in

Lake Hancock are high. Chemical inactivation may also have potential for use in combination with other techniques.

G. Lake Drawdown (20 percent of lake area) with in situ drying and mechanical excavation of the littoral zone, and planting and vegetation management of the littoral zone

This applied technique consists of lowering the lake level to expose the lake bottom. A drawdown would consolidate and reduce sediment volume. The dry sediment s would be excavated and the littoral shelf re-graded and then planted with desirable macrophytes. Vegetation monitoring and management may be required to minimize nuisance vegetation. In the event that sediments are not removed from the deeper portions of the lake, it may be necessary to create submerged berms parallel to the littoral zone to reduce the amount of wind-driven sediment that is re-deposited on the vegetated littoral zone.

This technique is expected to result in significant improvements to the habitat, provide habitat for game fish spawning thereby increasing the diversity of fisheries and improve the water quality. Twenty percent of the lake are is approximately 910 acres, or a band averaging 850 feet from shore. The FFWCC has recommended (K. Dutton, personal communication) that alternative G be included as a component of all restoration options evaluated.

The drawdown process may produce poor water quality and in 1991 the FGFWFC recommended that the drawdown occur during the wet season in order to maximize dilution of the drawdown water with higher tributary flows in the Peace River.

H. Recirculating treatment wetland

This applied technique consists of restoring or constructing a wetland adjacent to the lake and recirculating lake water into the wetland for treatment. The function of a recirculating treatment wetland is to remove algae and phosphorus-laden resuspended sediments and the phosphorus in the lake water. Within this capacity, a recirculating wetland can treat both the external and internal loads of phosphorus. This type of treatment wetland differs from other treatment wetlands because water is recirculated between the wetland and the lake and because the primary goal is removal of particulate phosphorus. This technique is appropriate for Lake Hancock because the majority of the phosphorus is particulate. Several locations adjacent to the lake provide the opportunity for a recirculating treatment wetland.

The use of a recirculating wetland for water quality improvement in the lake is a long-term measure. The treatment performance of a recirculating wetland could be enhanced if used in conjunction with chemical treatment of the water discharge to the wetland. Construction of a recirculating wetland will increase wetland habitat adjacent to the lake, improve the water quality and potentially provide for public access.

I. Wetland treatment of Lake Lena Run inflow

This applied technique consists of restoring wetlands near Lake Lena Run to treat the flows from the creek to the lake. Restoring wetlands near Lake Lena Run to treat the flows from the creek will reduce external loading to the lake and enhance wetland habitat adjacent to the lake.

J. Wetland treatment of Banana Creek inflow

This applied technique consists of restoring a wetland, or constructing a wetland near Banana Creek, to treat the flows from the creek to the lake. The most elevated concentrations of nitrogen and phosphorus species were observed in Banana Creek and the dominant species were in particulate form. The source of these particulate forms of nitrogen and phosphorus is the algal biomass discharging from Banana Lake. This treatment wetland would be designed to remove particulate as well as dissolved forms of nitrogen and phosphorus conveyed in this tributary. It will improve water quality and increase wetland habitat adjacent to the lake.

K. Settling pond with chemical treatment of North Saddle Creek inflow

Less area intensive techniques than a wetland treatment system can be used to treat the storm flows in North Saddle Creek. This applied technique consists of treating the North Saddle Creek inflow in a settling pond with the aide of a coagulant, such as alum. The settling pond with chemical treatment could be used to treat the flow from the lake before it is discharged to a recirculating wetland near Banana Creek to maximize the phosphorus removal efficiency of the recirculating wetland. The area of the settling pond is estimated to be 200 acres.

L. Wetland treatment of South Saddle Creek (lake discharge)

This applied technique consists of restoring a wetland, or constructing a wetland, downstream of the P-11 structure to treat the flows discharging from the lake. This treatment wetland would be designed to remove particulate as well as dissolved forms of nitrogen and phosphorus discharging from the lake. Due to magnitude of the flows discharging from the lake a 382-acre treatment wetland system would provide the appropriate level of phosphorus treatment for discharge to downstream receiving waters. Construction of a large treatment wetland will significantly increase habitat adjacent to the lake. This applied technique benefits the Upper Peace River by reducing the discharged load, but it does not improve the water quality in the lake.

M. Wetland treatment upstream of South Saddle Creek (supplemental to L)

This applied technique was derived from the restoration plan proposed by FFWCC in 1999 and consists of restoring a wetland, or constructing a wetland, upstream of the P-11 structure to treat the flows discharging from the lake. This component was not proposed as a stand-alone project and the purpose of this restoration component is to supplement wetland treatment of the P-11 discharge. This treatment wetland would be designed to remove particulate as well as dissolved forms of nitrogen and phosphorus discharging from the lake and id enough area were available the treatment wetland could be operated as a recirculating treatment wetland.

There is limited area upstream of South Saddle Creek to restore or construct a treatment wetland, but if a the wetland were designed as a recirculating wetland it could be used to improve the quality of water discharged to a treatment wetland for the discharge from South Saddle Creek. Construction of a treatment wetland will increase habitat adjacent to the lake.

N. Settling pond treatment with chemical treatment (lake discharge)

This applied technique consists of adding a coagulant, such as alum, to the water discharging from the lake and pumping the treated water into settling ponds for settling and drying. The construction cost and O&M costs for this applied technique are also high and no additional habitat will be restored or created. This applied technique benefits the Upper Peace River by reducing the discharged load, but it does not improve the water quality in the lake.

O. Filtration of South Saddle Creek (lake discharge)

This applied technique consists of filtering the water discharging from the lake and includes construction of gravity sand filters in concrete tanks similar to a traditional drinking water treatment plant. Algae are physically removed as water passes downward through the sand media and an automated backwash system periodically removes filtered algae from the sand filters. The construction cost and O&M costs for this applied technique are high and no additional habitat will be restored or created. This applied technique benefits the Upper Peace River by reducing the discharged load, but it does not improve the water quality in the lake.

P. Increased depth by raising water level

This applied technique consists of increasing the water level in the lake to 102.5 feet NGVD. This technique was proposed by the commercial fishing community as a mechanism to increase the production of commercial fish and to make it easier to fish in Lake Hancock. This approach could increase macrophyte growth and increase littoral habitat in the lake and reduce wind-induced resuspension of sediments. Increasing the water level in the lake may do little to improve the water quality in the lake, and will permanently submerge and thereby eliminate significant existing wetland and upland areas adjacent to the lake. There is also a potential for increasing the flooding of areas not presently flooded.

Q. No Action

One approach is to take no action. This approach was evaluated and scored relative to the lake restoration objectives. If no action is taken, there will be no improvement in the lake water quality or in the discharge from the lake. The existing habitat and wildlife will be maintained.

5.3 Evaluation of Applied Lake Restoration Techniques

In step one of the evaluation, each applied lake restoration technique presented above was evaluated and scored, on a scale from zero to ten, based on how well the applied technique will achieve each lake restoration objective. A score of zero reflects no achievement of the lake restoration objective and a score of ten reflects achievement of

the lake restoration objective in a significant manner. The lake restoration objectives were not weighted and they are presented below.

1. Improve the quality of the water discharged from Lake Hancock by reducing Total Maximum Daily Loads (TMDLs).

2. Preserve, and where feasible, enhance the natural greenway / wildlife corridor (Peace River / Green Swamp) through Polk County.

3. Maintain the exceptional wildlife values on Lake Hancock.

4. Enhance the diversity of the fishery.

5. Provide habitat compatible public access for nature-based recreation activities and commercial fishing.

Evaluation and scoring relative to the first lake restoration objective, was determined quantitatively in terms of the relative phosphorus removal efficiency (relative treatment benefit) of each applied lake restoration technique, as described below. The relative phosphorus removal efficiencies for the applied lake restoration techniques were used because control of phosphorus is generally accepted as The Key to lake restoration. Applied lake restoration techniques that improve in-lake water quality will improve the long-term quality of the water discharging from the lake. Nitrogen reductions will also occur as a direct result of the treatment processes, which will improve water quality in Charlotte Harbor where nitrogen is the limiting nutrient. Additional nitrogen reductions are expected to occur when the effect of in-lake phosphorus reductions cause a shift in the algal assemblage and the abundance of nitrogen-fixing blue-green algae is reduced.

Evaluation and scoring relative to the second lake restoration objective were determined quantitatively in terms of the relative increase in wetland acreage. The basis for establishing the relative increase in wetland acreage for each applied lake restoration technique is presented in **Appendix F.** Evaluation and scoring of the remaining three lake restoration objectives were determined qualitatively in relative terms using experience and professional judgment. The basis for scoring the remaining three lake restoration objectives is presented in **Appendix G**. The sum of the individual lake restoration objective scores provides a total score for each applied lake restoration technique indicating how well the applied technique will achieve the lake restoration objectives. The applied lake restoration techniques, the lake restoration objectives, the individual applied lake restoration objective scores, and the total applied lake restoration objective scores are presented in **Table 5-1** (Objectives Matrix). It should be noted that Table 5-1 presents the restoration component. In step two the restoration options are defined and include one or more of these components. It should also be noted that the component scores are not limited to water quality improvements and are based on the effectiveness of achieving all of the restoration objectives.

Table 5-1
Lake Hancock Restoration/Objective Matrix

	Lake Restoration Technology	Restoration Objectives						
		Improve the Quality of Water Discharged From Lake Hancock by Reducing Total Maximum Daily Load	Preserve and, Where Feasible Enhance the Natural Greenway/Wildlife Corridor Through Polk County	Maintain the Exceptional Wildlife Values on Lake Hancock	Enhance Diversity of the Lake Hancock Fishery	Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing	Sum Ranking Points	
A	*Whole Lake Hydraulic Dredging with Chemical Treatment of Decant Water*	9.1	1.0	6.3	6.0	0.0	22.4	Sediment Inactivation Techniques
B	*Whole Lake Hydraulic Dredging with Chemical and Wetland Treatment of Decant Water*	9.6	1.5	6.3	7.0	2.6	27.0	
C	*Whole Lake Hydraulic Dredging with Chemical, Wetland and Biomass Harvest of Decant Water*	9.8	1.8	7.5	8.0	2.8	29.9	
D	*Whole Lake Mechanical Excavation, Less Littoral Zone (20%)*	8.0	1.0	7.5	8.0	0.0	24.5	
E	*Hydraulic Dredging of Sediments (80% Area) Not Associated with Littoral Zone, plus Chemical and Wetland Treatment of Decant Water*	7.6	1.5	7.5	7.0	2.6	26.2	
F	*Whole Lake In-Situ Chemical Inactivation of Phosphorus*	10.0	1.0	6.3	5.0	0.0	22.3	
G	*Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone*	1.9	10.0	10.0	10.0	2.0	33.9	
H	*Re-Circulating Treatment Wetland (2 Lake Volumes/year)*	2.4	4.0	5.0	3.0	8.0	22.4	
I	*Wetland Treatment - Lake Lena Run Inflow*	0.4	2.4	0.6	1.0	2.8	7.2	Inflow Treatment Technologies
J	*Wetland Treatment - Banana Creek Inflow*	0.4	1.3	0.6	2.0	2.2	6.5	
K	*Settling Pond with Chemical Treatment of North Saddle Creek Inflow*	5.6	1.0	5.0	6.0	0.0	17.6	
L	*Wetland Treatment - South Saddle Creek (Lake Discharge)*	6.1	4.5	2.5	0.0	0.0	13.1	Discharge Treatment Technologies
M	*Wetland Treatment -In Lake, Upstream of South Saddle Creek (Supplemental to L)*	0.0	1.0	0.0	0.0	2.0	3.0	
N	*Settling Pond with Chemical Inactivation (Lake Discharge)*	8.2	1.0	0.0	0.0	0.0	9.2	
O	*Filtration of South Saddle Creek (Lake Discharge)*	6.7	1.0	0.0	0.0	0.0	7.7	
P	*Increased Depth by Raising Water Level*	6.1	7.4	8.8	8.0	10.0	40.3	Other Technologies
Q	*No Action*	0.0	1.0	1.3	0.0	0.0	2.3	

Assumptions :

1) Wetland construction will include public access and management as a greenway/wildlife corridor.

2) Wetland treatment or land acquistion south of P-11 will not provide boating access to Lake Hancock.

3) Improvement in Lake Hancock water quality will result in a more diverse fisheries.

4) "Exceptional Wildlife Values"will be enhanced by improvements to water quality within Lake Hancock.

5) Treatment of inflows and/or inactivation/removal of sediments in Lake Hancock will result in improved water quality.Treatment of discharge from Lake Hancock will have no effect on the quality of the Lake.

6) Littoral shelf drawdown improvements will encompass 20 % of lake (FFWCC)

The phosphorus budget for the lake, as well as the assumed phosphorus removal efficiencies for lake restoration techniques (not the applied techniques), were used to determine the phosphorus removal efficiencies for each applied lake restoration technique. The restoration techniques are individual techniques whereas the applied techniques are individual restoration techniques or combinations of individual restoration techniques for Lake Hancock. For example, wetland treatment is a technique whereas wetland treatment for Banana Creek inflows is an applied technique.

The phosphorus budget for the lake (including inflows, outflows, and storage) is presented on **Figure 2-2** and **Tables 2-3 and 5-2**. The percent of the inflow for each inflow budget component is indicated in Tables 2-3 and 5-2. The assumed phosphorus removal efficiencies for the lake restoration techniques (not the applied techniques) are presented in **Table 5-3.** In contrast, application of this technique to Lake Hancock phosphorous loadings is given in **Table 5-4**.

For example, wetland treatment can reduce phosphorus by 60 percent (Table 5-3). If wetland treatment is applied to Banana Creek inflows that contribute 3 percent of the total input to the Lake, the resultant effective removal rate is 1.8 percent (e.g., 60 percent times 3 percent) for application of that technique to Banana Creek (Table 5-4).

The phosphorus removal efficiencies for each applied lake restoration technique were determined by multiplying the assumed phosphorus removal efficiencies for each technique by the percent of the inflow for each inflow budget component subject to treatment by the particular restoration technique. Sediment phosphorus is an inflow component. The phosphorus removal efficiency for each applied lake restoration technique was used to determine the relative phosphorus removal efficiency (relative treatment benefit) of each applied lake restoration technique. The phosphorus removal efficiencies for each applied lake restoration technique, the relative phosphorus removal efficiency (relative treatment benefit) for each applied lake restoration technique, and the score from zero to ten for each applied lake restoration technique are presented in Table 5-4.

Table 5-2

Total Phosphorus Budget and Percent by Source

	Annual Loading, (kg)	Percent by Source	Ref
Internal Recycling/Sediment Resuspension	39,420	53%	1
Precipitation	1,878	3%	2
Lake Lena Run Inflow	1,940	3%	3
Direct to Lake Drainage	2,175	3%	4
Banana Creek Inflow	2,229	3%	5
Seepage	4,646	6%	6
Saddle Creek Inflow	22,218	30%	7
Sum Inputs	74,506		
Settling Losses	42,236	57%	8
Discharge	32,269	43%	9
Sum Losses	74,505		
Water Column Mass	12,441		

1. Calibration value. ERD page 5-55
2. ERD Table 5-17, page 5-45
3. ERD Table 5-11, page 5-22
4. ERD Table 5-11, page 5-22
5. ERD Table 5-11, page 5-22
6. ERD Table 5-17, page 5-45
7. ERD Table 5-11, page 5-22
8. ERD page 5-57. Sum of inputs minus the discharge through P-11
9. Mean discharge times mean lake concentration. ERD page 5-57 and Table 2-4

Table 5-3
Assumed Removal Efficiencies of Lake Restoration Techniques

Technique	Assumed Removal Efficiency TP	Reference
Mechanical Excavation	80%	1
Dredging removal efficiency	80%	2
Drawdown/Dessication without removal (Short-Term)	75%	3
Chemical Treatment of Decant Water	80%	4
Chemical/Harvest/Wetland Treatment of Decant Water	95%	5
Recircuating Wetland Treatment	30%	6
Sediment P inactivation/ In-Situ P inactivation	80%	7
Wetland Treatment	60%	8
Wetland Followed by Chemical Treatment	90%	9
Media Filtration	65%	10
Chemical Treatment & Settling	80%	11
Flooding - Assume equivalent to wetland treatment of Lake Discharge	60%	12

1. Zellars-Williams page 5-17.
2. Zellars-Williams page 5-19. ERD page 6-31
3. Zellars-Williams page 5-82
4. ERD page 6-21 (Similar to settling pond treatment)
5. Derived Value: 80% removed by chemical treatment. Remaining 20 % is treated with a wetland having a 60 % removal efficiency.
6. Lowe et al. 1989
7. Assumed to be similar to settling efficiencies. See number 4.
8. ERD, page 6-21. Table 6-4
9. Madrid Engineering Proposal
10. ERD, page 6-21, Table 6-4
11. ERD, page 6-21, Table 6-4
12. Wetland treatment assumed because of downstream inundation

Table 5-3
Assumed Removal Efficiencies of Lake Restoration Techniques

Technique	Assumed Removal Efficiency TP	Reference
Mechanical Excavation	80%	1
Dredging removal efficiency	80%	2
Drawdown/Dessication without removal (Short-Term)	75%	3
Chemical Treatment of Decant Water	80%	4
Chemical/Harvest/Wetland Treatment of Decant Water	95%	5
Recircuating Wetland Treatment	30%	6
Sediment P inactivation/ In-Situ P inactivation	80%	7
Wetland Treatment	60%	8
Wetland Followed by Chemical Treatment	90%	9
Media Filtration	65%	10
Chemical Treatment & Settling	80%	11
Flooding - Assume equivalent to wetland treatment of Lake Discharge	60%	12

1. Zellars-Williams page 5-17.
2. Zellars-Williams page 5-19. ERD page 6-31
3. Zellars-Williams page 5-82
4. ERD page 6-21 (Similar to settling pond treatment)
5. Derived Value: 80% removed by chemical treatment. Remaining 20 % is treated with a wetland having a 60 % removal efficiency.
6. Lowe et al. 1989
7. Assumed to be similar to settling efficiencies. See number 4.
8. ERD, page 6-21. Table 6-4
9. Madrid Engineering Proposal
10. ERD, page 6-21, Table 6-4
11. ERD, page 6-21, Table 6-4
12. Wetland treatment assumed because of downstream inundation

Table 5-4
Relative TP Removal Efficiency for Lake Hancock for Application Techniques

		TP Removal Efficiency	Relative Removal Efficiency	Score
A	*Whole Lake Hydraulic Dredging with Chemical Treatment of Decant Water*	39%	91%	9.1
B	*Whole Lake Hydraulic Dredging with Chemical and Wetland Treatment of Decant Water*	40%	96%	9.6
C	*Whole Lake Hydraulic Dredging with Chemical, Wetland and Biomass Harvest of Decant Water*	41%	98%	9.8
D	*Whole Lake Mechanical Excavation, Less Littoral Zone (20%)*	34%	80%	8.0
E	*Hydraulic Dredging of Sediments (80% Area) Not Associated with Littoral Zone, plus Chemical and Wetland Treatment of Decant Water*	32%	76%	7.6
F	*Whole Lake In-Situ Chemical Inactivation of Phosphorus*	42%	100%	10.0
G	*Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone*	7.9%	19%	1.9
H	*Re-Circulating Treatment Wetland (2 Lake Volumes/year)*	10%	24%	2.4
I	*Wetland Treatment - Lake Lena Run Inflow*	2%	4%	0.4
J	*Wetland Treatment - Banana Creek Inflow*	2%	4%	0.4
T	*Settling Pond with Chemical Treatment of North Saddle Creek Inflow*	24%	56%	5.6
L	*Wetland Treatment - South Saddle Creek (Lake Discharge)*	26%	61%	6.1
M	*Wetland Treatment - In Lake, Upstream of South Saddle Creek (Supplemental to L)*	0%	0%	0.0
N	*Settling Pond with Chemical Inactivation (Lake Discharge)*	35%	82%	8.2
O	*Filtration of South Saddle Creek (Lake Discharge)*	28%	67%	6.7
P	*Increased Depth by Raising Water Level*	26%	61%	6.1
Q	*No Action*	0%	0%	0.0

5.4 Results of the Objectives Matrix

The results of the Objectives Matrix are presented in Table 5-1. No Action (Q) does little to meet the lake restoration objectives. Although increasing the water level in the lake (P) is the highest scoring applied restoration technique it cannot be used in conjunction with other applied restoration techniques that remove internal or external loads from the lake (A–K). Increasing the water level could only be implemented after drawdown and mechanical excavation were completed. Increasing the water level would increase the settling and treatment volume for hydraulic dredging. Increasing the water level would flood areas where treatment wetlands could be constructed. Individual applied restoration techniques that remove external loads from the lake (I-K) or treat the discharge from the lake (L-O) do not achieve the lake restoration objectives as well as applied lake restoration techniques that remove or diminish internal loads (A-H). A combination of the applied lake restoration techniques is necessary to meet the lake restoration objectives.

5.5 Selection of Lake Restoration Options

In order to achieve restoration of Lake Hancock, a combination of applied lake restoration techniques will be required. No single technique or component is adequate to achieve all five restoration objectives. Except as noted, various applied lake restoration techniques were combined. By definition, the "No Action" option (Component Q) cannot be combined with other techniques, and increasing the depth of the lake by raising the water level to 102.5 feet NGVD (Component P) was evaluated as a single technology. Raising the water level to 102.5 does provide many benefits and is the highest ranked individual applied technique. However, at the proposed lake level, flooding is a serious concern. Nevertheless, raising the lake level to a lesser level has merit and should be further evaluated as a supplemental technology for the other options. However, many land-use and topographic changes have occurred around the lake and a revised watershed/flooding study should be conducted as part of the evaluation.

Several techniques were common to the remaining 8 options. At the recommendation of FFWCC, restoration of the littoral zone (Component G) was included in all of the remaining options, and wetland treatment of the discharges from the lake (L) was included in seven of the eight remaining options.

The basis for choosing the components to be included in the various options began with consideration of the restoration techniques that remove, or ameliorate the internal loads. The choices included mechanical excavation (Component D), hydraulic dredging with various forms of decant treatment (Components A, B, C), recirculating wetland treatment (Component H) and chemical inactivation of the sediments (Component F). Several of these techniques will require years to implement and may temporarily decrease the water quality during the implementation phase. As a result, treatment of Lake Hancock discharge was included to minimize the physical discharge of noxious algae and to control nitrogen and phosphorus loading to the Upper Peace River. Components L, N and O serve to provide this treatment. Wetland

treatment of South Saddle Creek, and the discharge from the lake (L), is included in six options (3-6 and 7-9). Wetland treatment upstream of South Saddle Creek (M) was only included in option 3.

Hydraulic dredging of 80 percent of the lake sediments (D) [excluding sediment in the littoral zone, Option G] is included in options 7, 8, and 10. Option 3 also includes mechanical excavation of the remaining lake sediments (E). Whole lake chemical inactivation of phosphorus (F) is included in options 4, 5, and 6. Option 9 includes a recirculating treatment wetland (H).

Next, the control of external loads was considered and the choices were either wetland treatment of inflows (Components I and J) or chemical treatment followed by settling (Component K). Wetland treatment of Lake Lena Run inflow (I) is included in options 6 and 9. Wetland treatment of Banana Creek inflow (J) is included in options 4, 6, 8, 9, and 10). A settling pond with chemical treatment (K), which is a less area intensive technique than a wetland treatment system, is included in options 3, 4, and 6-10) for treatment of the North Saddle Creek inflow. The use of a settling pond with chemical treatment (N), and filtration (O), to treat the lake discharge, were not included in the lake restoration options as these applied techniques provide treatment; however, no habitat will be restored or created.

The scores for each applied lake restoration technique included in each lake restoration option were summed to determine the score for each lake restoration option. The selected applied lake restoration techniques, the lake restoration options, and the scores for the lake restoration options are presented in **Table 5-5** (Options Matrix). The lake restoration options are also presented in **Table 5-6**. The Options Matrix can be used to evaluate additional combinations of lake restoration techniques.

Table 5-5
Lake Restoration Options

	Lake Restoration Component	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10
D	***Whole Lake Mechanical Excavation, Less Littoral Zone (20%)***			***24.5***							
E	***Hydraulic Dredging of Sediments (80% Area) Not Associated with Littoral Zone, plus Chemical and Wetland Treatment of Decant Water***							***26.2***	***26.2***		***26.2***
F	***Whole Lake In-Situ Chemical Inactivation of Phosphorus***				***22.3***	***22.3***	***22.3***				
G	***Lake Drawdown (20%) with In Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone***			***33.9***	***33.9***	***33.9***	***33.9***	***33.9***	***33.9***	***33.9***	***33.9***
H	***Re-Circulating Treatment Wetland (2 Lake Volumes/year)***									**22.4**	
I	***Wetland Treatment - Lake Lena Run Inflow***						***7.2***			***7.2***	
J	***Wetland Treatment - Banana Creek Inflow***				***6.5***		***6.5***		***6.5***	***6.5***	***6.5***
K	***Settling Pond with Chemical Treatment of North Saddle Creek Inflow***			***17.6***	***17.6***		***17.6***	***17.6***	***17.6***	***17.6***	***17.6***
L	***Wetland Treatment - South Saddle Creek (Lake Discharge)***			***13.1***	***13.1***	***13.1***		***13.1***	***13.1***	***13.1***	
M	***Wetland Treatment -In Lake, Upstream of South Saddle Creek (Supplemental to L)***			***3.0***							
P	***Increased Depth by Raising Water Level***		***40.3***								
Q	***No Action***	***2.3***									
		2.3	**40.3**	**92.1**	**93.4**	**69.3**	**87.5**	**90.8**	**97.3**	**100.8**	**84.2**

Table 5-6

Components of the Lake Restoration Options

1. No action
2. Increased depth by raising lake level (Thomas Plan)
3. -Drawdown with assisted drainage
   -Mechanical excavation and off site disposal or in-lake storage
   -Littoral zone grading, planting and vegetation management
   -Settling pond with chemical treatment of North Saddle Creek inflow
   -Wetland treatment of South Saddle Creek outflow
4. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -In situ chemical inactivation of phosphorus
   -Wetland treatment of Banana Creek inflow
   -Settling pond with chemical treatment of North Saddle Creek inflow
   -Wetland treatment of South Saddle Creek outflow
5. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -In situ chemical inactivation of phosphorus
   -Wetland treatment of South Saddle Creek outflow
6. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -In situ chemical inactivation of phosphorus
   -Wetland treatment of Banana Creek and Lake Lena Run inflows
   -Settling pond with chemical treatment of North Saddle Creek inflow
7. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -Hydraulic dredging of remaining sediment with chemical and wetland treatment of decant water
   -Settling pond with chemical treatment of North Saddle Creek inflow
   -Wetland treatment of South Saddle Creek outflow
8. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -Hydraulic dredging of remaining sediment with chemical and wetland treatment of decant water
   -Settling pond with chemical treatment of North Saddle Creek inflow
   -Wetland treatment of Banana Creek inflow and South Saddle Creek outflow
9. -Passive drawdown and in situ drying
   -Mechanical excavation of littoral zone (20 percent of lake area)
   -Littoral zone grading, planting and vegetation management
   -Recirculating treatment wetland
   -Settling pond with chemical treatment of North Saddle Creek inflow
   -Wetland treatment of Banana Creek and Lake Lena Run inflows, and South Saddle Creek outflow
10. -Passive drawdown and in situ drying
    -Mechanical excavation of littoral zone (20 percent of lake area)
    -Littoral zone grading, planting and vegetation management
    -Hydraulic dredging of remaining sediment with chemical and wetland treatment of decant water
    -Settling pond with chemical treatment of North Saddle Creek inflow
    -Wetland treatment of Banana Creek inflow

5.6 Results of the Options Matrix

The results of the evaluation are presented in the Options Matrix (Table 5-5). It is clear that a combination of applied lake restoration techniques will be required to meet the lake restoration objectives. The least intensive applied techniques such as the Thomas Plan, or treatment of just lake inflows or the lake outflow score low because they will not meet the lake restoration objectives as well as more complex combinations of applied techniques. Options that reestablish the littoral zone habitat meet more of the lake restoration objectives and therefore score higher.

The highest ranked option is 9 with a score of 100.8 points. **Figure 5-1** illustrates the concept and **Table 5-7** provides a breakdown of how the points relate to the five restoration objectives. Option 9 is the most 'balanced' of the top ranked options in terms of equally addressing the five options and includes a recirculating wetland patterned after the Lake Apopka restoration efforts. Additional public access provided in conjunction with the recirculating wetland accounts for the relatively higher points score for Objective 5 (Provide Public Access for Recreational Activities and Commercial Fishing).

The second ranked option is 8 with a score of 97.3 points and is illustrated conceptually in **Figure 5-2**. **Table 5-8** indicates that this option is slightly less effective at fulfilling Objective 5. This option utilizes hydraulic dredging to remove the internal loads. While treatment of the decant water will include wetland treatment, the size of the wetland is considerably smaller than the recirculating treatment wetland and public access is expected to be less than with Option 9. Option 8, however, does provide the additional benefit of deepening the lake.

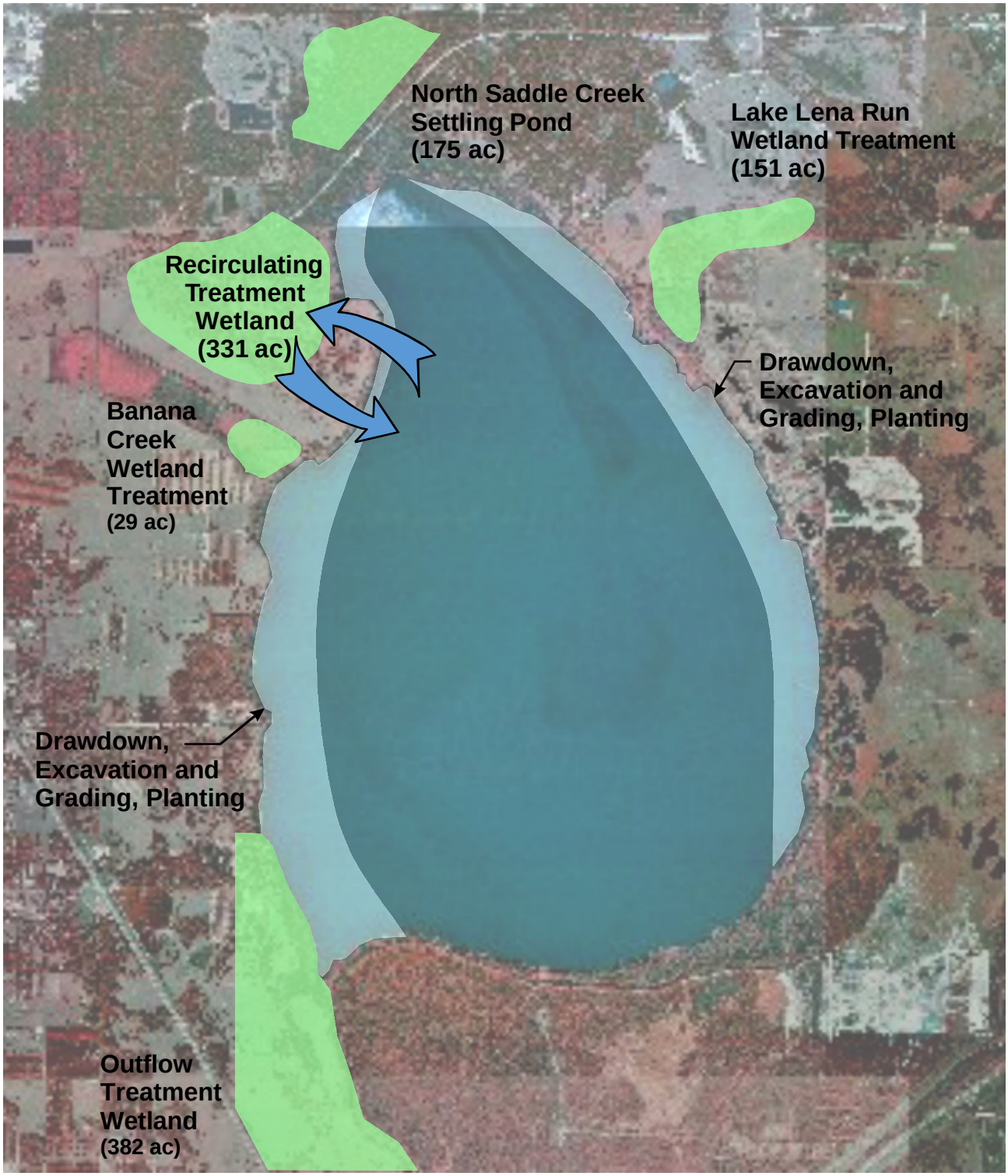
The third ranked option is 4 with a score of 93.4 points. The distribution of points relative to the objectives is given in **Table 5-9** and **Figure 5-3** provides an illustration of this option. This option was the least balanced in terms of meeting all of the objectives and scoring a low of 4 percent of the points for meeting Objective 5 and a high of 26 percent for meeting Objectives 1 (Improve Water Quality) and Objective 3 (Maintain the Exceptional Wildlife Values)

In summary, the three highest scoring options include:

- lake drawdown (20 percent of lake area) with in situ drying
- mechanical excavation of the littoral zone
- planting and vegetation management of the littoral zone
- wetland treatment of Banana Creek inflows
- settling pond with chemical treatment for North Saddle Creek inflows, and
- wetland treatment of the lake discharge.

Lake Hancock Restoration Management Plan

Option 9 **Figure No. 5-1**



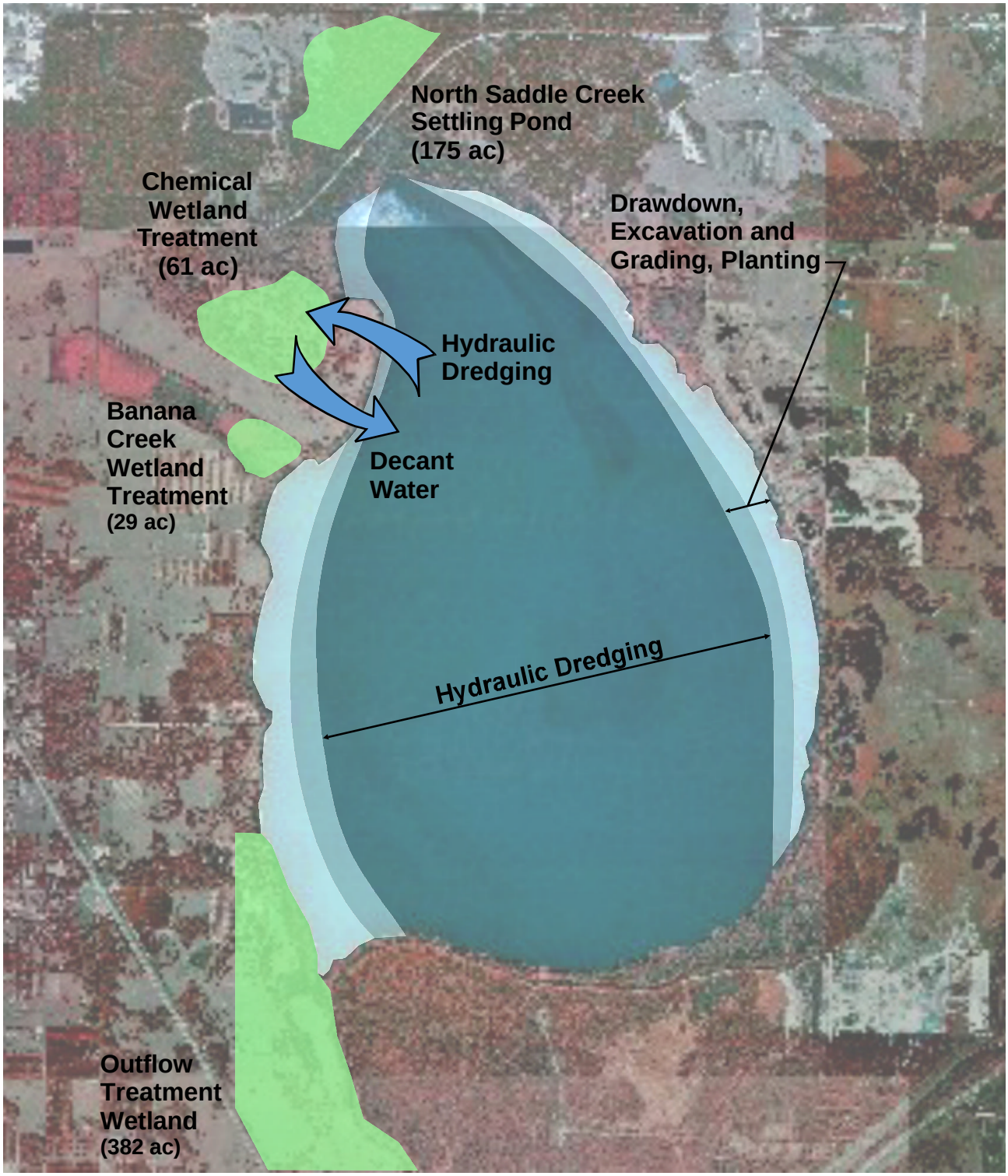
- Gravity Drawdown / Mechanical Excavation of Littoral Zone
- Grading and Replanting of Littoral Zone
- Wetland Treatment of Lake Lena Run, Banana Creek and South Saddle Creek
- Settling Pond with Chemical Treatment of North Saddle Creek
- Recirculating Treatment Wetland

Table 5-7
Relationship of Option 9 to Objectives

Lake Restoration Technology Included		Restoration Objectives					
		Improve the Quality of Water Discharged From Lake Hancock by Reducing Total Maximum Daily Load	Preserve and, Where Feasible Enhance the Natural Greenway/Wildlife Corridor Through Polk County	Maintain the Exceptional Wildlife Values on Lake Hancock	Enhance Diversity of the Lake Hancock Fishery	Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing	Sum Ranking Points
G	*Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone*	1.9	10.0	10.0	10.0	2.0	33.9
H	*Re-Circulating Treatment Wetland (2 Lake Volumes/year)*	2.4	4.0	5.0	3.0	8.0	22.4
I	*Wetland Treatment - Lake Lena Run Inflow*	0.4	2.4	0.6	1.0	2.8	7.2
J	*Wetland Treatment - Banana Creek Inflow*	0.4	1.3	0.6	2.0	2.2	6.5
K	*Settling Pond with Chemical Treatment of North Saddle Creek Inflow*	5.6	1.0	5.0	6.0	0.0	17.6
L	*Wetland Treatment - South Saddle Creek (Lake Discharge)*	6.1	4.5	2.5	0.0	0.0	13.1
Option 9 - Sum of Point By Restoation Objectiv		16.8	23.2	23.8	22.0	15.0	100.8
Option 9 - Percent of Points by Restoration Objective		17%	23%	24%	22%	15%	

Lake Hancock Restoration Management Plan

Option 8 **Figure No. 5-2**



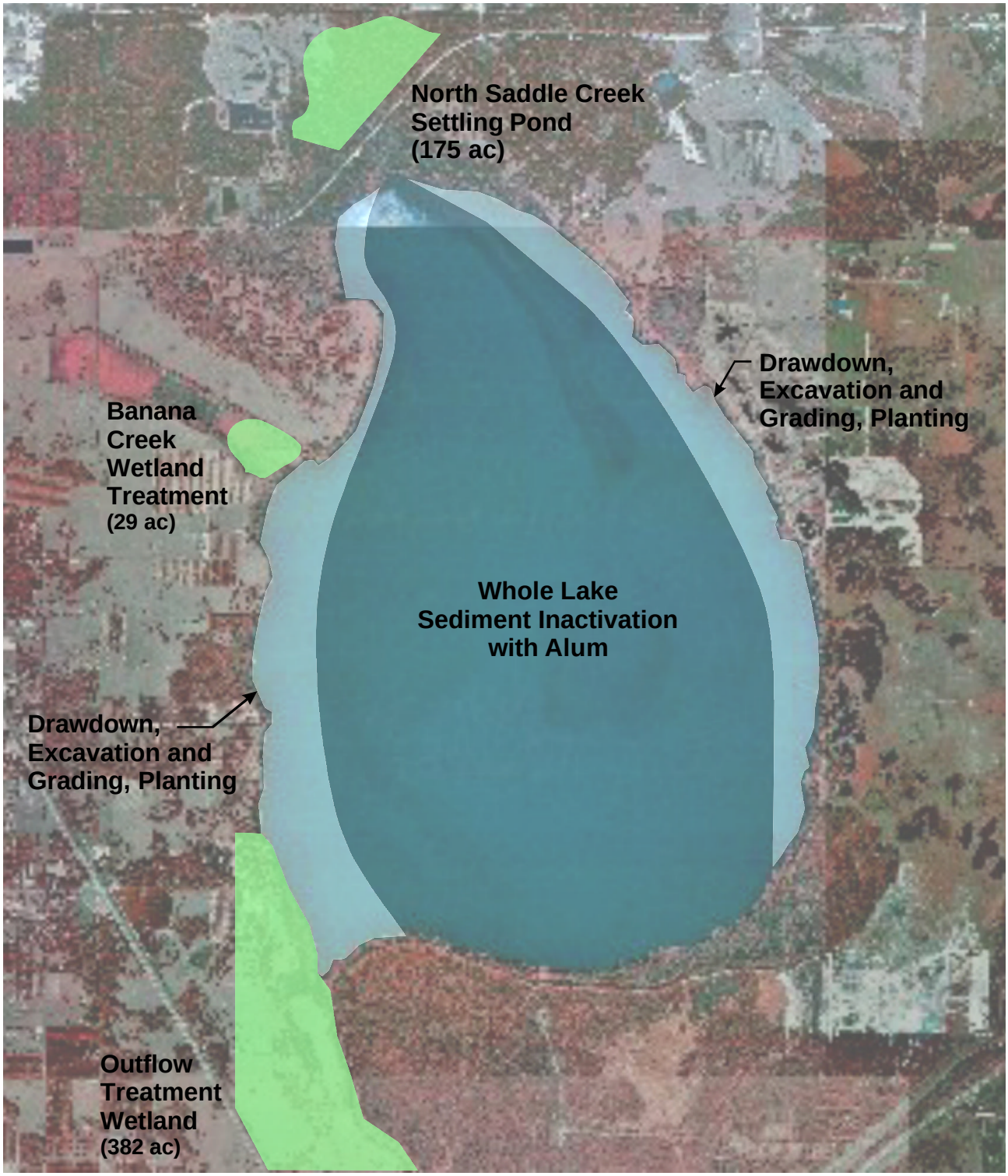
- Gravity Drawdown / Mechanical Excavation of Littoral Zone
- Grading and Replanting of Littoral Zone
- Wetland Treatment of Banana Creek and South Saddle Creek
- Settling Pond with Chemical Treatment of North Saddle Creek
- Hydraulic Dredging with Chemical/Wetland Treatment of Decant Water

Table 5-8
Relationship of Option 8 to Objectives

Lake Restoration Technology Included		Restoration Objectives					
		Improve the Quality of Water Discharged From Lake Hancock by Reducing Total Maximum Daily Load	Preserve and, Where Feasible Enhance the Natural Greenway/Wildlife Corridor Through Polk County	Maintain the Exceptional Wildlife Values on Lake Hancock	Enhance Diversity of the Lake Hancock Fishery	Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing	Sum Ranking Points
E	*Hydraulic Dredging of Sediments (80% Area) Not Associated with Littoral Zone, plus Chemical and Wetland Treatment of Decant Water*	7.6	1.5	7.5	7.0	2.6	26.2
G	*Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone*	1.9	10.0	10.0	10.0	2.0	33.9
J	*Wetland Treatment - Banana Creek Inflow*	0.4	1.3	0.6	2.0	2.2	6.5
K	*Settling Pond with Chemical Treatment of North Saddle Creek Inflow*	5.6	1.0	5.0	6.0	0.0	17.6
L	*Wetland Treatment - South Saddle Creek (Lake Discharge)*	6.1	4.5	2.5	0.0	0.0	13.1
Option 8 - Sum of Point By Restoation Objective		21.6	18.3	25.6	25.0	6.8	97.3
Option 8 - Percent of Points by Restoration Objective		22%	19%	26%	26%	7%	

Lake Hancock Restoration Management Plan

Option 4 **Figure No. 5-3**



- Gravity Drawdown / Mechanical Excavation of Littoral Zone
- Grading and Replanting of Littoral Zone
- Wetland Treatment of Banana Creek and South Saddle Creek
- Settling Pond with Chemical Treatment of North Saddle Creek
- Whole Lake Treatment with Alum

Table 5-9
Relationship of Option 4 to Objectives

Lake Restoration Technology Included		Restoration Objectives					
		Improve the Quality of Water Discharged From Lake Hancock by Reducing Total Maximum Daily Load	Preserve and, Where Feasible Enhance the Natural Greenway/Wildlife Corridor Through Polk County	Maintain the Exceptional Wildlife Values on Lake Hancock	Enhance Diversity of the Lake Hancock Fishery	Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing	Sum Ranking Points
F	*Whole Lake In-Situ Chemical Inactivation of Phosphorus*	10.0	1.0	6.3	5.0	0.0	22.3
G	*Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone*	1.9	10.0	10.0	10.0	2.0	33.9
J	*Wetland Treatment - Banana Creek Inflow*	0.4	1.3	0.6	2.0	2.2	6.5
K	*Settling Pond with Chemical Treatment of North Saddle Creek Inflow*	5.6	1.0	5.0	6.0	0.0	17.6
L	*Wetland Treatment - South Saddle Creek (Lake Discharge)*	6.1	4.5	2.5	0.0	0.0	13.1
Option 4 - Sum of Point By Restoation Objectiv		24.0	17.8	24.4	23.0	4.2	93.4
Option 4 - Percent of Points by Restoration Objective		26%	19%	26%	25%	4%	

The highest scoring option includes a recirculating treatment wetland and wetland treatment of the Lake Lena Run inflow.

The second highest scoring option includes hydraulic dredging of the remaining (80 percent of lake area) sediments not associated with the littoral zone with chemical and wetland treatment of the decant water.

The third highest scoring option includes whole lake in situ chemical inactivation of phosphorus.

There are a number of additional elements that should be included with any restoration plan, but these elements may address only one of the objectives. These include the following:

- Annual Lake level fluctuations.
- If natural colonization is insufficient, the lake should be stocked with gamefish after successful stabilization of the littoral zone
- Removal of unwanted commercial fish by-catch from the lake
- Aggressive land acquisition program to establish a buffer zone around the lake in order to further minimize the pollutant loading resulting from urbanization.

An evaluation of the three highest scoring lake restoration options is presented in **Section 6** in terms of the preliminary costs and cost effectiveness, resultant TSI, technical feasibility and logistics, environmental effects, and permit requirements.

Section 6
Evaluation of the Three Highest Scoring Lake Restoration Options

6.1 Introduction

An evaluation of the three highest scoring lake restoration options is presented in this section in terms of the predicted TSI, preliminary costs and cost effectiveness, technical feasibility and logistics, environmental effects, and permit requirements. A summary table of the advantages and disadvantages of the three highest scoring Lake restoration options is presented. Additional data needs to implement the Lake Hancock Restoration Management Plan are also indicated. The three highest scoring lake restoration options are presented in the Options Matrix (Table 5-5) and in Section 5.6.

6.2 Trophic State Index

Trophic State Index (TSI) values were calculated for Lake Hancock based upon the Florida Trophic State Index developed specifically for Florida lakes by Brezonik in 1984. The TSI values are based on the amount of total phosphorus and chlorophyll-a in the water column as well as the Secchi disk depth. TSI values less than 50 indicate oligotrophic conditions (clear water, high oxygen levels), values between 50 and 60 indicate mesotrophic conditions (moderately clear water, moderate oxygen levels), values between 61 to 70 indicate eutrophic conditions (plant growth, low oxygen levels), and values greater than 70 indicate hypereutrophic conditions (dense algae and plants, very low oxygen levels).

Lake Hancock consistently exhibited hypereutrophic conditions from 1984 to 1999 with the overall mean calculated TSI value of 91, well into the hypereutrophic range. No trend of either improving or declining water quality has been apparent, although the water quality characteristics over the past seven to eight years appear less variable than in the 1980s. This may be due to the elimination of domestic wastewater discharges to lake tributaries. A paleolimnological analysis is needed to determine the historical trophic status of the lake.

Trophic state modeling of Lake Hancock was performed by ERD (1999) to predict in-lake concentrations of total phosphorus, chlorophyll-a, and Secchi disk depth based on existing estimated loading to the lake. The model input was then modified to reflect anticipated phosphorus reductions as a result of recommended restoration options for Lake Hancock, and the output results were used to evaluate restoration options.

The model was used again in the present study to determine the TSI for the three highest scoring lake restoration options based on the annual mass removal of phosphorus for these options. The amount of phosphorus removed for each applied technique included in each option was estimated based on the assumed phosphorus removal efficiencies for the lake restoration techniques (Table 5-3) and the annual

mass loading for each phosphorus source subject to treatment by the particular applied restoration technique (Table 5-2). The amount of phosphorus removed by the three highest scoring options is presented in **Table 6-1**. (It should be noted that the sums in Table 6-1 include the amount of phosphorus removed from the inputs to the lake and the amount removed by treatment downstream of the P-11 structure. The amount (19,361 kg / yr) removed downstream of the P-11 structure will have no affect on the TSI of Lake Hancock). The amount of phosphorus removed from the lake inputs ranges from 35,524 kg / yr (Option 9) to 56,955 kg / yr (Option 4).

Details of the monthly model results are presented in **Appendix H**. A summary of the model results is presented in **Table 6-2** and for comparison purposes includes the existing calculated TSI of 91 for the lake. The results indicate that the TSI range varies considerably. Implementation of Option 9 will result in an imperceptible improvement in clarity and will result in continuation of hypereutrophic conditions. Implementation of Option 4 on the other hand will result in borderline mesotrophic / eutrophic water quality characterization and a significant improvement in the clarity of the water. The results are given in **Figure 6-1**

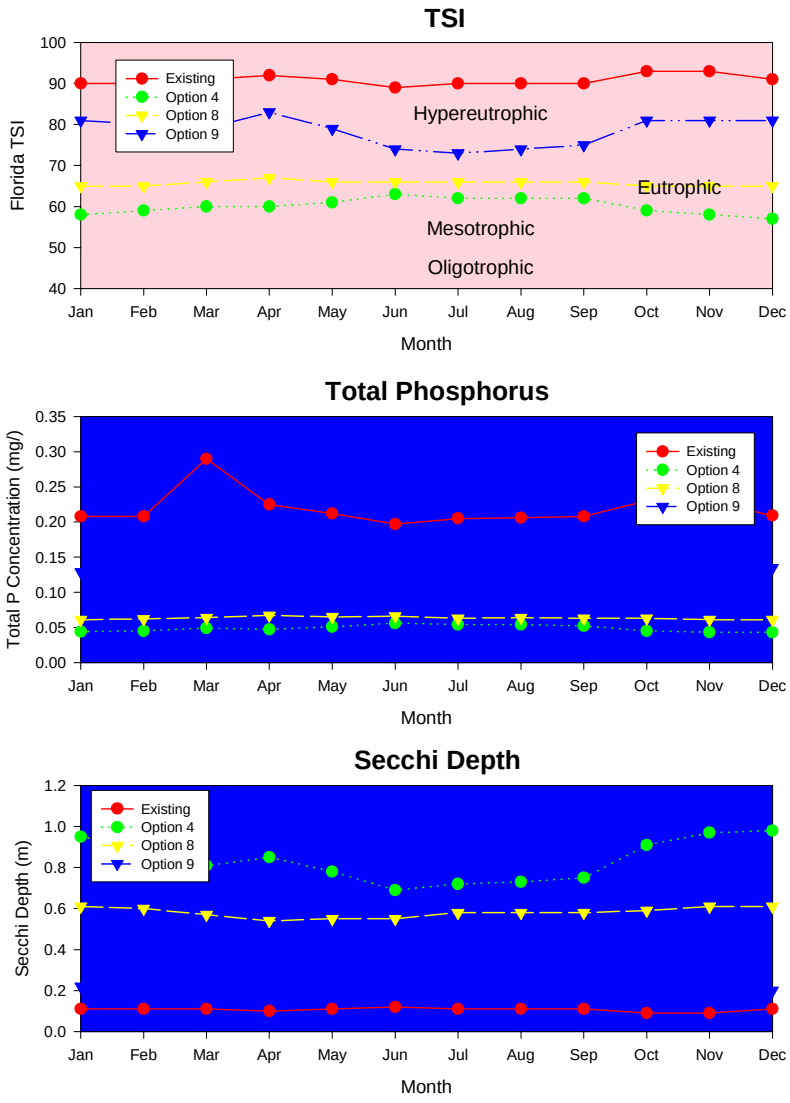


Figure 6-1
Resultant Water Quality

Table 6-1
Amount of Phosphorus Removed by the Three Highest Scoring Options

Unit Removal Percentage by Technology Component	TP Removal
Mechanical Excavation or Hydraulic Dredging	80%
Drawdown + Desiccation // Excavation and Planting of Littoral Zone	16%
Recircuating Wetland Treatment - Fraction of Annual Input Treated	40%
Recirculating Wetland - Treatment Efficiency	30%
Wetland Treatment	60%
Chemical Treatment + Wetland Treatment (of Decant)	90%
Settling Pond with Chemical Treatment	80%
In-Situ Chemical Inactivation of Sediments	80%
Percent of Sediment Load in Pore/Decant Water	44%
Percent of Lake Area Involved in Littoral Shelf Excavation =	20%

	Sediment Recycle / Animal Input	Precipitation	Lake Lena Run Inflow	Direct to Lake Drainage	Banana Creek Inflow	Seepage	N. Saddle Creek Inflow	P-11 Discharge	Sum of P Removed (kg/yr)
Annual Input-->>(kg/yr)	39,420	1,878	1,940	2,175	2,229	4,646	22,218	32,269	
Option 9									-
Lake Drawdown (20%) and Desiccation // Mechanical Excavation of Littoral Zone // Planting	6,307								6,307
Recirculating Wetland Treatment (2/5 of all inputs @ wetland efficiency)	4,730	225	233	261	267	558	2,666		8,941
Wetland Treatment Banana Creek					1,337				1,337
Wetland Treatment of Lake Lena Run			1,164						1,164
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
Settling Pond Treatment of N.Saddle Creek Inflow							17,774		17,774
									-
								Total	**54,885**
Option 8									-
Lake Drawdown (20%) and Desiccation // Mechanical Excavation of Littoral Zone // Planting	6,307								6,307
Hydraulic Dredging of 80 % of lake with Chemical/Wetland Treatment of Decant									-
A) Solids Removal	14,128								14,128
B) Decant Treatment	12,488								12,488
Settling Pond Treatment of N. Saddle Creek Inflow							17,774		17,774
Wetland Treatment of Banana Creek Inflow					1,337				1,337
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
								Total	**71,397**
Option 4									-
Lake Drawdown (20%) and Desiccation // Mechanical Excavation of Littoral Zone // Planting	6,307								6,307
In Situ Chemical Inactivation of Sediments	31,536								31,536
Settling Pond Treatment N. Saddle Creek							17,774		17,774
Wetland Treatment Banana Creek					1,337				1,337
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
								Total	**76,316**

Table 6-2
Trophic State Index Model Results

	Existing Conditions	Option 9 - Recirculating Wetland	Option 8 - Hydraulic Dredging	Option 4 - Alum Treatment
Total P (ug/l)	212	118	63	49
Secchi Disk (m)	0.11	0.26	0.58	0.83
Chlorophyll a (mg/m^3)	172	73	30	0.21
Florida TSI	91	78	66	60
P Removed From Lake (kg/yr)		35,524	52,036	56,955

The TSI results presented in Table 6-2 will not occur immediately. The hydraulic dredging component of Option 8 is expected to take approximately 4 years to complete. The recirculating wetland would not initially reduce the TSI to the values shown in Table 6-2, which are based on removal of annual inputs. Over time, the phosphorus will be further depleted as the phosphorus stored in the sediments migrates to water column and is removed by the recirculating treatment wetland. It is estimated that sediment stores will be depleted over a period of between 35 and 56 years. Inactivation with alum (Option 4) is expected to occur at a faster rate, depending on the method chosen for application. For comparison, a six-month application period was assumed, after which the equilibrium phosphorus concentration should be achieved.

6.3 Preliminary Costs and Cost Effectiveness

The preliminary costs for the three highest scoring lake restoration options are based on several sources. The Zellars-Williams (1987) study provides drawdown costs and some of the hydraulic dredging unit costs. The City of Lakeland's recent dredging and de-watering costs for Lake Hollingsworth provides recent hydraulic dredging unit costs. Costs for the chemical treatment of decant water generated from hydraulic dredging were extrapolated from the cost for whole-lake alum treatment. The Environmental News Record (ENR) Construction Cost Index was used to convert all costs to 2001 dollars. The CDM (2001) technical memorandum (**Appendix C**) provides costs for mechanical excavation. Wetland treatment and littoral planting costs were based on previous CDM cost estimates for these activities in Florida. ERD provided unit costs for in situ chemical inactivation of phosphorus with alum, and for settling pond treatment.

The preliminary cost for drawdown via the P-11 structure, littoral planting, wetland treatment, recirculating wetland treatment, mechanical excavation, hydraulic dredging, and settling pond treatment are presented in **Appendix I**. The preliminary cost estimate for chemical inactivation of phosphorus with alum is presented in **Appendix D**. A summary of the preliminary costs for the three highest scoring lake restoration options is presented in **Table 6-3**.

Table 6-3
Cost Table Summary

*Assuming 3% per year inflation rate for annual costs projection.
*Start-up Costs are assumed to be 5% of the total Capital Cost.

OPTION 4	Capital Construction Costs	25 Percent Constr. Fee	5 Percent Mobilization	Material Construction Costs	Design & Permitting	Constr. & Inspec.	Geotechnical	TOTAL CAPITAL COSTS	Land Purchase Costs	TOTAL CAPITAL PLUS LAND PURCHASE COSTS
Components										
Passive Drawdown, In-Situ Drying										
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$7,885,262	$1,971,316	$394,264	$10,250,843	$410,034	$307,526	$205,017	$11,173,420	$290,000	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$3,185,000	$796,250	$159,250	$4,140,500	$310,538	$207,025	$82,810	$4,740,873		$4,740,873
Chemical Inactivation of Sediment Phosphorus	$5,227,129	$1,306,783	$261,357	$6,795,269	$509,646	$339,764	$135,906	$7,780,585		$7,780,585
Settling Pond Treatment of North Saddle Creek	$4,869,126	$1,217,282	$243,457	$6,329,866	$474,740	$316,494	$126,598	$7,247,698	$1,160,000	$8,407,698
Wetland Treatment:										
Banana Creek	$1,167,732	$291,933	$58,387	$1,518,052	$113,854	$75,903	$37,952	$1,745,761		$1,745,761
South Saddle Creek (Lake Discharge)	$8,986,920	$2,246,730	$449,346	$11,682,996	$876,225	$584,150	$292,075	$13,435,446	$2,012,600	$15,448,046
Access Road	$83,334	$20,834	$4,167	$108,335	$8,126	$5,417	$2,167	$124,045		$124,045
Total	**$31,404,504**	$7,851,128	$1,570,228	$40,825,860	$2,703,163	$1,836,279	$882,525	**$46,247,827**	$3,462,600	**$49,710,428**

OPTION 4	Annual Costs	2011[1]	2021[2]	Average[3]	Annual Cost Present Worth[4]:
Components					
Passive Drawdown, In-Situ Drying	$0	$0	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% Lake Area)	$0	$0	$0	$0	$0
Grading, Vegetation Management and Littoral Shelf Planting	$910,000	$1,222,964	$1,643,562	$1,258,842	$18,728,390
Chemical Inactivation of Sediment Phosphorus	$0	$0	$0	$0	$0
Settling Pond Treatment of North Saddle Creek	$750,468	$1,008,567	$1,355,430	$1,038,155	$15,445,125
Wetland Treatment:			$0		
Banana Creek	$138,588	$186,251	$250,306	$191,715	$2,852,235
South Saddle Creek (Lake Discharge)	$288,488	$387,704	$521,042	$399,078	$5,937,273
Access Road	$0	$0	$0		
Total	**$2,087,544**	$2,805,486	$3,770,340	$2,887,790	**$42,963,023**

OPTION 4	TOTAL CAPITAL COSTS	ANNUAL COSTS PRESENT WORTH	TOTAL 20-YEAR PRESENT WORTH
Components			
Passive Drawdown, In-Situ Drying	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% Lake Area)	$11,463,420	$0	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$4,740,873	$18,728,390	$23,469,263
Chemical Inactivation of Sediment Phosphorus	$7,780,585	$0	$7,780,585
Settling Pond Treatment of North Saddle Creek	$8,407,698	$15,445,125	$23,852,823
Wetland Treatment:			
Banana Creek	$1,745,761	$2,852,235	$4,597,996
South Saddle Creek (Lake Discharge)	$15,448,046	$5,937,273	$21,385,319
Access Road	$124,045	$0	$124,045
TOTAL	**$49,710,428**	**$42,963,023**	**$92,673,451**

Notes
(1) This cost is equal to the annual cost projected to increase at 3 percent per year for 10 years.
(2) This cost is equal to the annual cost projected to increase at 3 percent per year for 20 years.
(3) The average is taken from the present day annual cost, the 10-year projected cost, and the 20-year projected cost.
(4) The annual cost present worth is based on the average annual cost.

Table 6-3
Cost Table Summary

*Assuming 3% per year inflation rate for annual costs projection.
*Start-up Costs are assumed to be 5% of the total Capital Cost.

OPTION 8	Capital Construction Costs	25 Percent Constr. Fee	5 Percent Mobilization	Material Construction Costs	Design & Permitting	Constr. & Inspec.	Geotechnical	TOTAL CAPITAL COSTS	Land Purchase Costs	TOTAL CAPITAL PLUS LAND PURCHASE COSTS
Components										
Passive Drawdown, In-Situ Drying										
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$7,885,262	$1,971,316	$394,264	$10,250,843	$410,034	$307,526	$205,017	$11,173,420	$290,000	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$3,185,000	$796,250	$159,250	$4,140,500	$310,538	$207,025	$103,513	$4,761,576		$4,761,576
Hydraulic Dredging of Remaining Sediment	$24,297,043	$6,074,261	$1,214,853	$31,586,157	$2,368,962	$1,579,308	$789,654	$36,324,081	$968,600	$37,292,681
Chemical Treatment of Decant Water[(a)]	$2,225,523	$556,381	$111,277	$2,893,181	$216,989	$144,660	$72,330	$3,327,160		$3,327,160
Wetland Treatment of Decant Water[(b)]	$2,447,624	$611,906	$122,382	$3,181,912	$238,644	$159,096	$79,548	$3,659,200	$319,000	$3,978,200
Settling Pond Treatment of North Saddle Creek	$4,869,126	$1,217,282	$243,457	$6,329,866	$474,740	$316,494	$126,598	$7,247,698	$1,160,000	$8,407,698
Wetland Treatment:										
Banana Creek	$1,167,732	$291,933	$58,387	$1,518,052	$113,854	$75,903	$37,952	$1,745,761		$1,745,761
South Saddle Creek (Lake Discharge)	$8,986,920	$2,246,730	$449,346	$11,682,996	$876,225	$584,150	$292,075	$13,435,446	$2,012,600	$15,448,046
Access Road	$83,334	$20,834	$4,167	$108,335	$8,126	$5,417	$2,709	$124,587		$124,587
	$55,147,565	$13,786,893	$2,757,383	$71,691,842	$5,018,112	$3,379,579	$1,709,396	**$81,798,929**	$4,750,200	**$86,549,129**

(a) It will take four years to dredge and treat, but this item is treated as a lump sum.
(b) The annual cost will affect the cost of the project for only four years, and is accounted as such in the present worth calculation.

OPTION 8	Annual Costs	2011[(1)]	2021[(2)]	Average[(3)]	Annual Cost esent Worth[(4)]:
Components					
Passive Drawdown, In-Situ Drying	$0	$0	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% Lake Area)	$0	$0	$0	$0	$0
Grading, Vegetation Management and Littoral Shelf Planting	$910,000	$1,222,964	$1,643,562	$1,258,842	$18,728,390
Hydraulic Dredging of Remaining Sediment	$0	$0	$0	$0	$0
Chemical Treatment of Decant Water	$0	$0	$0	$0	$0
Wetland Treatment of Decant Water	$138,588	$186,251	$250,306	$191,715	$2,852,235
Settling Pond Treatment of North Saddle Creek	$750,468	$1,008,567	$1,355,430	$1,038,155	$15,445,125
Wetland Treatment:					
Banana Creek	$138,588	$186,251	$250,306	$191,715	$2,852,235
South Saddle Creek (Lake Discharge)	$288,488	$387,704	$521,042	$399,078	$5,937,273
Access Road	$0	$0	$0	$0	$0
Total	**$2,226,132**	$2,991,737	$4,020,646	$3,079,505	**$45,815,258**

OPTION 8	TOTAL CAPITAL COSTS (w/out Land Purchase Costs)	ANNUAL COSTS PRESENT WORTH	TOTAL 20-YEAR PRESENT WORTH
Components			
Passive Drawdown, In-Situ Drying	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% Lake Area)	$11,463,420	$0	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$4,761,576	$18,728,390	$23,489,966
Hydraulic Dredging of Remaining Sediment	$37,292,681	$0	$37,292,681
Chemical Treatment of Decant Water	$3,327,160	$0	$3,327,160
Wetland Treatment of Decant Water	$3,978,200	$2,852,235	$6,830,435
Settling Pond Treatment of North Saddle Creek	$8,407,698	$15,445,125	$23,852,823
Wetland Treatment:			
Banana Creek	$1,745,761	$2,852,235	$4,597,996
South Saddle Creek (Lake Discharge)	$15,448,046	$5,937,273	$21,385,319
Access Road	$124,587	$0	$124,587
TOTAL	**$86,549,129**	**$45,815,258**	**$132,364,387**

Notes
(1) This cost is equal to the annual cost projected to increase at 3 percent per year for 10 years.
(2) This cost is equal to the annual cost projected to increase at 3 percent per year for 20 years.
(3) The average is taken from the present day annual cost, the 10-year projected cost, and the 20-year projected cost.
(4) The annual cost present worth is based on the average annual cost.

Table 6-3
Cost Table Summary

*Assuming 3% per year inflation rate for annual costs projection.
*Start-up Costs are assumed to be 5% of the total Capital Cost.

OPTION 9	Capital Construction Costs	25 Percent Constr. Fee	5 Percent Mobilization	Material Construction Costs	Design & Permitting	Constr. & Inspec.	Geotechnical	TOTAL CAPITAL COSTS	Land Purchase Costs	TOTAL CAPITAL PLUS LAND PURCHASE COSTS
Components										
Passive Drawdown										
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$7,885,263	$1,971,316	$394,264	$10,250,843	$410,034	$307,526	$205,017	$11,173,420	$290,000	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$3,185,000	$796,250	$159,250	$4,140,500	$310,538	$207,025	$103,513	$4,761,576		$4,761,576
Recirculating Treatment Wetland	$4,545,593	$1,136,399	$227,280	$5,909,272	$443,196	$295,464	$147,732	$6,795,664	$1,745,800	$8,541,464
Settling Pond Treatment of North Saddle Creek	$4,869,126	$1,217,282	$243,457	$6,329,866	$474,740	$316,494	$126,598	$7,247,698	$1,160,000	$8,407,698
Wetland Treatment:										
Banana Creek	$1,167,732	$291,933	$58,387	$1,518,052	$113,854	$75,903	$37,952	$1,745,761		$1,745,761
Lake Lena Run	$3,838,170	$959,543	$191,909	$4,989,622	$374,222	$249,482	$124,741	$5,738,067	$794,600	$6,532,667
South Saddle Creek (Lake Discharge)	$8,986,920	$2,246,730	$449,346	$11,682,996	$876,225	$584,150	$292,075	$13,435,446	$2,012,600	$15,448,046
Access Road	$83,334	$20,834	$4,167	$108,335	$8,126	$5,417	$2,709	$124,587		$124,587
Total	**$34,561,138**	$8,640,287	$1,728,060	$44,929,486	$3,010,935	$2,041,461	$1,040,337	**$51,022,219**	$6,003,000	**$57,025,219**

OPTION 9	Annual Costs	2011[1]	2021[2]	Average[3]	Annual Cost Present Worth[4]:
Components					
Passive Drawdown	$0	$0	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$0	$0	$0	$0	$0
Grading, Vegetation Management and Littoral Shelf Planting	$910,000	$1,222,964	$1,643,561	$1,258,842	$18,728,387
Recirculating Treatment Wetland	$288,488	$387,704	$521,042	$399,078	$5,937,272
Settling Pond Treatment of North Saddle Creek	$750,468	$1,008,566	$1,355,428	$1,038,154	$15,445,110
Wetland Treatment:					
Banana Creek	$138,588	$186,251	$250,306	$191,715	$2,852,234
Lake Lena Run	$167,748	$225,440	$302,973	$232,054	$3,452,370
South Saddle Creek (Lake Discharge)	$288,488	$387,704	$521,042	$399,078	$5,937,272
Access Road					
Total	**$2,543,780**	$3,418,629	$4,594,352	$3,518,921	**$52,352,645**

OPTION 9	TOTAL CAPITAL COSTS	ANNUAL COSTS PRESENT WORTH	TOTAL 20-YEAR PRESENT WORTH
Components			
Passive Drawdown	$0	$0	$0
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$11,463,420	$0	$11,463,420
Grading, Vegetation Management and Littoral Shelf Planting	$4,761,576	$18,728,387	$23,489,963
Recirculating Treatment Wetland	$8,541,464	$5,937,272	$14,478,736
Settling Pond Treatment of North Saddle Creek	$8,407,698	$15,445,110	$23,852,808
Wetland Treatment:			
Banana Creek	$1,745,761	$2,852,234	$4,597,995
Lake Lena Run	$6,532,667	$3,452,370	$9,985,037
South Saddle Creek (Lake Discharge)	$15,448,046	$5,937,272	$21,385,318
Access Road	$124,587	$0	$124,587
TOTAL	**$57,025,219**	**$52,352,645**	**$109,377,864**

Notes
*Detailed cost sheets provided in Appendix G for all option components.
(1) This cost is equal to the annual cost projected to increase at 3 percent per year for 10 years.
(2) This cost is equal to the annual cost projected to increase at 3 percent per year for 20 years.
(3) The average is taken from the present day annual cost, the 10-year projected cost, and the 20-year projected cost.
(4) The annual cost present worth is based on the average annual cost.

In order to compare the cost effectiveness of the three highest scoring lake restoration options, the cost per amount of phosphorus removed ($/kg) for each option was estimated. This was based on the 20-year total present worth cost for each option (Table 6-3) and the amount of phosphorus removed for each option (Table 6-1). It should be noted that this amount differs from the amount used in the TSI calculations. The cost-effectiveness comparison includes both the amount removed from the lake and the amount removed by the wetland treatment downstream of the P-11 structure. In order to incorporate the annual costs, the 20-year present worth cost was divided by the amount of phosphorus that will be removed in 20 years. The results are presented in **Table 6-4**. The most cost-effective option (Option 4) includes whole lake treatment with alum with an average removal cost of $61/kg P over a 20-year period. Of the three options, the least cost effective was Option 9 (recirculating treatment wetland) at an average unit removal cost of $100/kg P. Option 8 has a P removal rate of $93/kg.

6.4 Technical Feasibility and Logistics

All three of the highest scoring options include passive drawdown of the littoral zone via the P-11 structure and in-situ drying followed by mechanical removal of the organic sediments and grading of the littoral zone. Following this, the littoral zone will be planted. The feasibility of a successful drawdown without using pumps is dependent on maintenance dredging of South Saddle Creek below the P-11 structure. Because of siltation, the present controlling elevation is between 95.4 feet (FEMA, 1982) and 96.4 feet NGVD (ACOE, 1974). The controlling elevation (91.7 feet) of the P-11 structure must be restored both upstream and downstream of the structure both for restoration and flood protection. Zellars-Williams (1987) indicate that if the lake can be gravity-drained to an elevation of 94 feet, 1,358 acres of lake (33 percent) will become exposed and will potentially drain. However, obtaining sufficient desiccation may not occur if the surface forms a hardened crust that seals water in the lower sediments. Discing and other mechanical means may be required to promote desiccation to the extent that the material can be physically removed with earth-moving machinery.

It is unclear to what extent wind-driven organic sediments will be driven onto the re-established littoral zone. It is recommended that a pilot restoration be conducted to determine the severity of accumulation and the impact on the littoral flora/fauna. If the accumulation causes problems at the demonstration site, then either protective submerged berms can be created to protect the shoreline for Options 9 and 4, or hydraulic dredging (Option 8) should precede restoration of the littoral zone. As the need for such protection is unknown, the cost of constructing protective berms has not been included in the present cost estimates.

Table 6-4
Cost / kg P Removed Summary

Component	20-Year Present Worth	20-years kg P Removed	Cost per kg P per year
Option 9			
Passive Drawdown			
Mechanical Excavation of Littoral Zone (20% of Lake Area)	$11,463,420		
Grading, Vegetation Management and Littoral Shelf Planting	$23,489,961		
Subtotal	*$34,953,381*	126,140	$277
Recirculating Treatment Wetland	$14,478,730	178,820	$81
Settling Pond Treatment of North Saddle Creek	$23,852,806	355,480	$67
Wetland Treatment:			
Banana Creek	$4,597,991	26,740	$172
Lake Lena Run	$9,985,026	23,280	$429
South Saddle Creek (Lake Discharge)	$21,385,315	387,220	$55
Access Road	$124,583		
Total	**$109,377,832**	**1,097,680**	**$100**
Option 8			
Passive Drawdown, In-Situ Drying			
Mechanical Excavation of Littoral Zone (20% Lake Area)	$11,463,420		
Grading, Vegetation Management and Littoral Shelf Planting	$23,489,961		
Subtotal	*$34,953,381*	126,140	$277
Hydraulic Dredging of Remaining Sediment	$37,292,680	282,560	$132
Chemical Treatment of Decant Water	$3,327,156		
Wetland Treatment of Decant Water	$6,830,427		
Subtotal (treatment of decant water)	*$10,157,584*	249,760	$41
Settling Pond Treatment of North Saddle Creek	$23,852,804	355,480	$67
Wetland Treatment:			
Banana Creek	$4,597,991	26,740	$172
South Saddle Creek (Lake Discharge)	$21,385,315	387,220	$55
Access Road	$124,583		
Total	**$132,364,338**	**1,427,900**	**$93**
Option 4			
Passive Drawdown, In-Situ Drying			
Mechanical Excavation of Littoral Zone (20% Lake Area)	$11,463,420		
Grading, Vegetation Management and Littoral Shelf Planting	$23,489,961		
Subtotal	*$34,953,381*	126,140	$277
Chemical Inactivation of Sediment Phosphorus	$7,814,558	630,720	$12
Settling Pond Treatment of North Saddle Creek	$23,852,806	355,480	$67
Wetland Treatment:			
Banana Creek	$4,597,991	26,740	$172
South Saddle Creek (Lake Discharge)	$21,385,315	387,220	$55
Access Road	$124,583		
Total	**$92,728,634**	**1,526,300**	**$61**

In addition to the restoration of the littoral zone, all three top-ranked options include wetland treatment of Banana Creek inflows, settling pond treatment of North Saddle Creek inflow and wetland treatment of the lake outflow.

The highest scoring option (Option 9) includes wetland treatment of Lake Lena Run inflow and a recirculating treatment wetland (near Banana Creek) to treat the water in the lake with subsequent recirculation to the lake. Construction for these treatment wetlands require clearing and grubbing, grading, berm construction, a pump station and distribution system, and control structures. This option includes a settling pond for treatment of North Saddle Creek inflow. Construction of the settling pond requires clearing and grubbing, excavation and grading, berm construction, control structures, and fencing.

In the second highest scoring option (Option 8), hydraulic dredging is employed to remove the balance of the sediments, followed by chemical and wetland treatment of the decant water. In order to implement hydraulic dredging construction of settling areas will be required, including construction of berms and establishment of flow control structures. Some clearing, grubbing and grading may be required. Treatment of the decant water would be accomplished with chemicals such as alum and a treatment wetland prior to discharge. Hydraulic dredging equipment includes dredges, pipelines, pontoons for pipelines, a booster pump and a barge. This option also includes littoral zone restoration, wetland treatment of Banana Creek inflow and South Saddle Creek discharge. Chemical treatment / settling pond treatment is provided for North Saddle Creek.

The third highest scoring option (Option 4) includes in situ chemical inactivation of phosphorus with alum. Application of alum requires mobilization, chemical storage, lake access for the boat, tanker and application equipment, and pre and post treatment testing. Toxicity testing will be required to demonstrate that there will be no adverse affects to the wildlife. This option also includes wetland treatment of Banana Creek inflow and a chemical treatment / settling pond treatment for North Saddle Creek inflows. South Saddle Creek discharge flows will be subjected to wetland treatment. Construction of the settling pond also requires clearing and grubbing, excavation and grading, berm construction, control structures, and fencing.

6.5 Environmental Effects

The environmental effects of implementing the highest scoring lake restoration options to Lake Hancock, adjacent lands, and downstream waters, are presented in this section. All three of the highest scoring options include drawdown and treatment wetlands. Drawdown, in situ drying, planting and vegetation management of the littoral zone will contribute to the improvement of the water quality and habitat in the lake, but it is unclear whether any nutrient reductions achieved by the drawdown will persist after reflooding. Drawdown and desiccation may immobilize nutrients that otherwise would be released from the sediment to the water column, but these activities may also release nutrients to the lake and downstream waters. The effect on aquatic life may be significant during the drawdown. The restoration or construction of wetlands will add habitat to the lake, which achieves a major goal of this plan.

In the second highest scoring option (Option 8) drawdown and in situ drying are followed by mechanical excavation of the shoreline and hydraulic dredging of the remaining sediments. Decant water will be treated with chemicals and wetland treatment of the decant water. Sediment removal can also release nutrients to the lake and downstream waters. There is concern regarding groundwater seepage from a settling / disposal site for the mechanically excavated sediment, as well as for the treatment of the decant water. Further Geotechnical study of the effects of potential seepage into groundwater should be performed.

Removal of sediment via hydraulic dredging and deposition of this sediment is attractive from an environmental viewpoint. A large reservoir of nutrient reserves would be removed from the lake and the best possible water quality would be established immediately after the dredging of sediment is complete. Determination of a suitable disposal site to settle the dredged material is critical to implementing a dredging program. Dredging is only feasible in Lake Hancock if sufficient settling area is acquired.

The third highest scoring option (Option 4) includes in situ chemical inactivation of phosphorus and the addition of aluminum salts to the lake that has the potential to cause toxicity problems. Toxicity tests using water from Lake Hancock should be conducted. The third highest scoring option could provide the greatest water quality benefit, however the long-term viability of alum is unproven in shallow Florida lakes.

6.6 Permit Requirements

Section 3 of this report addressed regulatory requirements for lake restoration and sediment removal projects. All of the options include some of the same activities, as described above. Therefore, there are similar permit requirements for the three options, as follows.

- FDEP Aquatic Plant Management Permit for littoral excavation, planting and vegetation management,
- SWFWMD Environmental Resource Permit (ERP) for wetland restoration and / or construction and stormwater management,
- ACOE Individual Permit (IP) for wetland restoration or construction,
- FDEP NPDES permit for wetland discharge to surface waters, which may be effected by TMDLs established for these receiving waters.

For the third highest scoring option an additional permit may be required for chemical inactivation of phosphorus. For the second highest scoring option the ERP and the IP will need to address the settling pond. For the third highest scoring option the ERP and IP will need to address mechanical excavation and hydraulic dredging.

6.7 Additional Data Needs

A number of data needs were identified during the course of the present study. Those include

- A paleolimnological analysis is needed to characterize the historical TSI of the lake.
- The species composition of the algal community should be determined because the predominant blue-green algae may not be nitrogen fixers, and this has a bearing on lake restoration activities.
- Continuous flow measuring devices should be installed at the inflow tributaries to quantify treatment design parameters. This activity was undertaken by the SWFWMD in June 2001, and is expected to be completed in early 2002.
- Complete a survey of South Saddle Creek channel from P-11 to the Peace River and remove sediments as needed to restore the drawdown and discharge capabilities of the P-11 structure.
- Conduct additional TCLP tests on sediments around the littoral zone prior to drawdown and mechanical excavation to determine if special disposal requirements are necessary.
- Verify that alum treatment will not cause toxicity problems with Lake Hancock water.

6.8 Summary

A summary of the evaluation of the three highest scoring lake restoration options in terms of preliminary costs and cost effectiveness, technical feasibility and logistics, environmental effects, and permit requirements is presented below.

Advantages Common To All

- Improved littoral / spawning habitat
- Improved quality of water discharged to the Upper Peace River
- Reduction of inflow loading
- Improved public access
- Increased greenway habitat

Disadvantages Common to All

- Uncertainty of the fate of nutrients during drawdown
- Loss of littoral habitat during drawdown
- Negative impact on aquatic life during drawdown
- Loss of commercial fishing revenues during drawdown

Highest Scoring Lake Restoration Option 9 (Recirculating Treatment Wetland)

Advantages

- Least capital cost
- Minimal disruption of wildlife since no dredging or chemical treatment of lake
- Similar to technology implemented at Lake Apopka

Disadvantages

- Long duration to achieve ultimate TSI (35-56 years)
- May require in-lake berms to protect restored littoral zone from wind-driven sediments
- Does not deepen the lake as much as other options.
- May require in-lake berms to protect restored littoral zone from wind-driven sediments

Second Highest Scoring Lake Restoration Option 8 (Hydraulic Dredging)

Advantages

- Physical removal of sediments
- Deepens lake
- Common technology

Disadvantages

- Highest capital cost
- Disposal site required for sediments
- Potential water quality declines during dredging
- Potential negative impacts on aquatic life during dredging
- May require that hydraulic dredging proceed before littoral zone restoration

Third Highest Scoring Lake Restoration Option 4 (Chemical Treatment)

Advantages

- Least capital cost
- Least time consuming

Disadvantages

- Stringent permitting requirements due to potential toxicity
- Does not cause deepening of lake
- Never attempted at this scale in Florida
- May require in-lake berms to protect restored littoral zone from wind-driven sediments.

- Possibly only a short-term solution
- May not be as effective on shallow lakes

6.9 Recommendation

In the absence of restoration efforts, Lake Hancock will continue to decline in water quality and continued pressure to urbanize will eliminate the possibility to acquire adjacent lands needed for habitat, greenway / wildlife corridors and treatment facilities. Any restoration plan must include control of the phosphorus released from the sediments. Based on the previous discussion of the advantages and disadvantages of the three plans, it is recommended that the second ranked plan (Option 8 -hydraulic dredging) be implemented. This plan is based on a technology proven to work at a large-scale. The plan results in a deeper lake, and additional 1,450 acres of wetland, increased public access, improved water quality and protection of downstream receiving waters.

Section 7
Implementation Plan

Restoration of Lake Hancock will require years to complete because of permitting, funding and the time required to obtain property and construct the wetland treatment facilities. Phasing of the individual components provides a convenient framework for restoration and ensures that the sequence of restoration activities is appropriate. The following is a suggested implementation plan for Option 8. Option 8 includes the following components ;

- Wetland treatment of lake discharge in South Saddle Creek below the P-11 structure.
- Littoral zone restoration through lake drawdown and removal of sediments along the littoral zone. Regrading and re-planting of the littoral zone with desirable species. A demonstration project should precede this activity to evaluate the feasibility of mechanical removal and to determine the rate that interior lake sediments are driven onto the shoreline.
- Wetland treatment of Banana Creek inflows
- Chemical treatment followed by settling for North Saddle Creek inflows.
- Hydraulic dredging of remaining sediments.

Overall cost estimates for dredging and the demonstration project may be reduced through direct negotiations with land owners for the disposal of organic sediments. It should be noted that most of the components are common to the three top ranked options and this plan could be easily modified to accommodate any of the three options. It is recommended that completion of the South Saddle Creek wetland treatment facility be complete before the hydraulic dredging of littoral zone restoration commences. Treatment of inflows from Banana Creek or North Saddle Creek may be completed at any time in the overall schedule.

7.1 South Saddle Creek Wetland Treatment

A treatment wetland should be constructed below and/or adjacent to the P-11 structure. During construction the lake level should be lowered to expose the shoreline sediments and begin the drying process required for the excavation demonstration project. Construction of the downstream treatment wetland prior to other activities provides for treatment of poor water quality that may occur during other restoration activities within the lake.

Estimated costs for the South Saddle Creek Wetland project are as follows:

Wetland Treatment – South Saddle Creek (Lake Discharge)

Component	Quantity	Unit	Unit Cost ($)	Cost ($)
PHASE 1 - Land				
Land Purchase	347	acre	5,800	2,012,600
PHASE 2 – Wetland Construction				
Clear and Grub	347	acre	3,000	1,041,000
Grading	1,936,000	sy	2	3,872,000
Berm Construction (onsite soils)	483,840	cy	3.50	1,693,440
Wetland Planting	347	acre	5,000	1,735,000
Berm Stabilization (sodding)	157,853	sy	1.50	236,780
Control Structures	4	ea	25,000	100,000
			Phase 2 Subtotal	8,678,220
PHASE 3 – Distribution System [(1)]				
Pump Station		ea	100,000	100,000
Distribution Piping	2,087	lf	100	208,700
			Phase 3 Subtotal	*308,700*
	Phases 2 and 3 Subtotal			*8,986,920*
Construction Contingency	25%			2,246,730
Mobilization, Bonds, Insurance	5%			449,346
			Construction Cost Subtotal	11,682,996
PHASE 4 - Engineering				
Design, Permitting, Bidding	7.5%			876,225
Construction Services and Inspection	5%			584,150
Geotechnical/Survey	2.5%			292,075
			Total Estimated Cost	**$15,448,046**

(1) Provisional cost. The need for pumping and/or a distribution header will depend upon final site selection and topography of site**.**

7.2 Excavation Demonstration Project

Complete a mechanical excavation demonstration project of the littoral zone concurrent with the drawdown for Item 1. The purpose of the demonstration project is to determine the feasibility of mechanically removing dried sediments from the shoreline, the survivability of littoral vegetation, and to determine the rate that organic sediments from the interior of the lake move and / or are re-deposited in the littoral zone. Excavation, re-grading and replanting of a demonstration area should be divided into two areas. One area should be excavated and replanted on the restored shoreline, and the other area should be protected by a submerged in-lake berms or barrier wall to determine if shielding can protect the shoreline from deep lake sediments carried by shoreward by wind-driven waves.

Vegetative success and deposition rate of organic sediments in the littoral zone should be monitored for a minimum of 4 years. Four years is the length of time it will take to conduct the hydraulic dredging. If during the four-years, the re-deposition of organic

material does not damage the demonstration restoration, then hydraulic dredging may be conducted after restoration of the entire lake littoral zone. Extended monitoring would determine how long of a delay could be tolerated between restoration of the littoral zone and completion of the hydraulic dredging. If the organic sediments deposit at a rate that is damaging to the restored planting, then hydraulic dredging should occur prior to restoration of the littoral zone, or protective in-lake berms must be included in the littoral restoration. Additional TCLP soils testing of the exposed sediments should be conducted prior to excavation.

Estimated costs for the demonstration project are as follows:

Mechanical Excavation Demonstration Project

Component	Quantity	Unit	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Cost	1	acre	5,800	5,800
PHASE 2 – Site Preparation				
Clear and Grub	1	acre	3,000	3,000
Cell excavation	1,600	cy	2.50	4,000
Berm Construction (onsite soil)	2,500	cy	3.50	8,750
Berm Stabilization (sodding)	1,800	sy	1.50	2,700
Cell Liners (if required)	30,000	sf	0.45	13,500
			Phase 2 Subtotal	*31,950*
PHASE 3 – Sediment Removal				
Excavated Volume	3,900	cy	7.50	29,250
Aluminum Barrier Wall	200	lf	*212*	42,400
Wetland Planting	1	acre	5,000	5,000
			Phase 3 Subtotal	*76,650*
			Phases 2 and 3 Subtotal	*108,600*
Construction Contingency	25%			27,150
Mobilization, Bonds, Insurance	L.S.			50,000
			Construction Cost Subtotal	*185,750*
PHASE 4 – Engineering				
Design, Permitting, Bidding	15%	Construction		27,863
Construction Services and Inspection	10%	Construction		18,575
Geotechnical/Survey	5%	Construction		9,287
			Total Estimated Cost	**$247,275**

7.3 Wetland Treatment of Banana Creek

This component can be constructed on existing public lands at any time, including during the littoral zone monitoring period.

Estimated costs for the Banana Creek Wetland project are as follows:

Wetland Treatment - Banana Creek (Inflow)

Component	Quantity	Unit	Unit Cost ($)	Cost ($)
PHASE 1 – Wetland Construction				
Clear and Grub	26	Acre	3,000	78,000
Grading	96,800	Sy	2	193,600
Berm Construction (onsite soil)	132,409	Cy	4	529,636
Berm Stabilization (sodding)	43,198	Sy	1.50	64,797
Wetland Planting	26	Acre	5,000	130,000
Control Structure	2	Ea	25,000	50,000
			Phase 1 Subtotal	*1,046,033*
PHASE 2 – Distribution System [(1)]				
Pump Station		Ea	75,000	75,000
Water Distribution	467	Lf	100	46,700
			Phase 2 Subtotal	*121,700*
			Phases 1 and 2 Subtotal	*1,167,733*
Construction Contingency	25%			291,933
Mobilization, Bonds, Insurance	5%			58,387
			Construction Cost Subtotal	*1,518,053*
PHASE 3 - Engineering				
Design, Permitting, Bidding	7.5%	Construction		113,854
Construction & Inspection	5%	Construction		75,903
Geotechnical/Survey	2.5%	Construction		37,951
			Total Estimated Cost	**$1,745,761**

(1) Provisional cost. The need for pumping and/or a distribution header will depend upon final site selection and topography of site.

7.4 Chemical Treatment/Settling Treatment for North Saddle Creek

Chemical Treatment / Settling Treatment for North Saddle Creek. This component can also be constructed at any time, including during the monitoring period of the littoral zone restoration. Estimated costs for the project are as follows: (Note - Annual operation and maintenance costs may be reduced by treating a smaller percentage of the flows, or by constructing a smaller conventional wetland treatment facility further upstream).

Settling Pond Treatment of North Saddle Creek

Component	Quantity	Unit	Unit Cost ($)	Cost ($)
PHASE 1 - Land				
Land Purchase	200	acre	5,800	1,160,000
PHASE 2 – Pond Construction				
Clear and Grub	175	acre	3,000	525,000
Earthwork	250,000	cy	6	1,500,000
Fencing	13,000	lf	16	208,000
Entrance Road	15,000	sy	32	480,000
			Phase 2 Subtotal	*2,713,000*
PHASE 3 – Distribution System				
Influent Piping				1,054,300
Discharge Piping				263,575
Influent Pump Station				342,648
Chemical Treatment System				316,290
Electrical				158,145
			Phase 3 Subtotal	*2,134,958*
			Phases 2 and 3 Subtotal	*4,847,958*
Construction Contingency	25%			1,211,990
Mobilization, Bonds, Insurance	5%			242,398
			Construction Cost Subtotal	*6,302,346*
PHASE 4 - Engineering				
Design, Permitting, Bidding	7.5%	Construction		472,676
Construction Services and Inspection	5%	Construction		315,117
Geotechnical/Survey	2.5%	Construction		157,559
			Total Estimated Cost	**$8,407,698**

7.5 Littoral Zone Restoration and Hydraulic Dredging

Depending upon the outcome of the demonstration project, either restoration of the littoral zone or hydraulic dredging should proceed next.

7.5.1 Littoral Zone Restoration

Conduct a partial drawdown of the lake and allow the organic sediments in the littoral zone to dry. Construct an upland disposal area, or otherwise arrangement for disposal. Mechanically remove the dried sediments and undesirable emergent vegetation. If required, install protective in-lake barrier walls that will be submerged at normal pool. Re-grade as necessary and plant desirable vegetation. Allow water to return to the lake when complete to the specified elevation.

The units described in the following table were determined using engineering analysis to approximate volume of the sediment that will be removed from the littoral shelf. The calculations included assumptions that a drawdown of the lake would allow the sediment to dewater sufficiently to consolidate to the volume represented in the following table.

Estimated costs for the littoral zone restoration project are as follows:

Mechanical Excavation and Restoration of Littoral Zone
(20 Percent of Lake Sediment)

Component	Unit	Quantity	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Purchase for Disposal Area	50	acre	5,800	290,000
PHASE 2 – Site Preparation				
Clear and Grub	50	acre	3,000	150,000
Cell excavation	106,667	cy	4	426,668
Berm Construction (onsite soil)	72,533	cy	3.50	253,866
Berm Stabilization (sodding)	46,595	sy	1.50	69,892
Cell Liners (if required)	1,525,865	sf	0.45	686,639
			Phase 2 Subtotal	1,587,065
PHASE 3 – Sediment Removal				
Sediment Excavation	293,760	cy	7.50	2,203,200
PHASE 4 – Littoral Shelf Construction				
Planting	910	acre	3,500	3,185,000
Vegetation Maintenance 1st Year	1	ls	910,000	910,000
			Phase 4 Subtotal	4,095,000
			Phases 2, 3, and 4 Subtotal	7,885,266
Construction Contingency	25%			1,971,316
Mobilization, Bonds, Insurance	5%			394,263
			Construction Cost Subtotal	*10,250,844*
PHASE 5 - Engineering				
Design, Permitting, Bidding	4%	Construction		410,034
Construction Services and Inspection	3%	Construction		307,525
Geotechnical/Survey	2%	Construction		205,017
			Total Estimated Cost	**$11,463,420**

7.5.2 Hydraulic Dredging

Construct treatment wetland, settling / decant ponds and disposal areas upland. Raise lake level as high and safe as practical to facilitate dredging. Hydraulically dredge sediments. The disposal area size was developed using information acquired from the City of Lakeland from their Lake Hollingsworth project. Similar methods of multiple cell construction for dewatering the sediment were used for decanting the water to a large treatment wetland.

Estimated costs for the project are as follows:

Hydraulic Dredging
(80 Percent of Lake Sediment)

Component	Quantity	Unit	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Purchase for Disposal Area	167	acre	5,800	968,600
Land Purchase	55	acre	5,800	319,000
			Phase 1 Subtotal	*1,287,600*
PHASE 2 – Site Preparation				
Clear and Grub	167	acre	3,000	501,000
Cell excavation	397,778	Cy	4	1,591,112
Berm Construction (onsite soil)	294,045	Cy	3.50	1,029,158
Berm Stabilization (sodding)	231,834	Sy	1.50	347,751
Cell Liners (if required)	6,284,493	Sf	0.45	2,828,022
			Phase 2 Subtotal	*6,297,043*
PHASE 3 – Decant Treatment Wetland				
Clear and Grub	55	acre	3,000	165,000
Excavation and Grading	120,000	sy	1.50	180,000
Berm Construction (onsite soil)	192,640	cy	3.50	674,240
Berm Stabilization (sodding)	62,849	sy	1.50	94,274
Cell Liners (if required)	2,395,800	sf	0.45	1,078,110
			Phase 3 Subtotal	*2,191,624*
PHASE 4 – Pumping Facility (if required)				
Pump Station	1	each	50,000	50,000
Distribution Piping	1,810	lf	100	181,000
Control Structure	1	each	25,000	25,000
			Phase 4 Subtotal	*256,000*
PHASE 5 – Sediment Removal				
Sediment Dredging	14,400,000	cy	1.25	18,000,000
			Phases 2, 3, 4, and 5 Subtotal	*26,744,667*
Construction Contingency	25%			6,686,167
Mobilization, Bonds, Insurance	5%			1,337,233
			Construction Cost Subtotal	*34,768,067*
PHASE 6 – Engineering				
Design, Permitting, Bidding	7.5%	Construction		2,607,605
Construction Services and Inspection	5%	Construction		1,738,403
Geotechnical Services	2.5%	Construction		869,202
			Total Estimated Cost	**$41,270,877**

The costs presented are for conventional hydraulic dredging followed by settling and decant. Alternative technologies may be developed and proven in the future which will be more cost-effective for drying the sludge and these processes should be considered after the effectiveness has been fully demonstrated.

7.6 Additional Restoration Activities

Depending upon the response of the flora and fauna in the lake, additional restoration steps may be necessary as follows:

- Restock with gamefish.
- Further evaluate the effect of raising the average lake level and increase annual fluctuations to 2.25 feet annually. An in-depth hydrologic evaluation including a long-term water balance should be conducted to confirm earlier stage-storage relationships and to assess the increased flood potential. Planning level cost estimates that follow assume that structure P-11 will need to be replaced.

Hydrologic Analysis to Raise Lake Level

Engineering Report	$ 100,000
Coordination with public agencies	10,000
Permitting	50,000
Construction	200,000
Contingency	50,000
Total	$ 410,000

- Evaluation of nutrient reductions from removal of fish from the lake.
- Continued fee and less-than-fee land purchase to establish a buffer zone around the lake.
- Enhancement of the wetland filter marsh on the outfall from Lena Run.
- Improvement of the public boat access to the lake.

Section 8
Literature Cited

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Appendix A

Alternative Technology - Request for Information

CDM Camp Dresser & McKee Inc.

consulting
engineering
construction
operations

1715 North Westshore Boulevard, Suite 875
Tampa, Florida 33607
Tel: 813 281-2900 Fax: 813 288-8787

March 21, 2001

Mr. Robert J. Kollinger, P.E.
Project Manager/Water Resources Engineer
Polk County Natural Resources Division
4177 Ben Durrance Road
Bartow, Florida 33830

RE: Lake Hancock/Upper Peace River Enhancement Project
Evaluation Requirements Document
6248-31579

Dear Mr. Kollinger:

As we discussed, attached is the information document that Polk County may provide to companies interested in submitting proposals for review. We believe if the submittals contain all the information requested, they will be more easily evaluated, and not as open to interpretation. We trust this document will be helpful in determining if a submitted alternative technique or technology will be viable.

Please call if you should have any questions.

Very truly yours,

CAMP DRESSER & McKEE INC.

Daniel E. Glaser, P.E.
Project Manager

Attachment

cc: Jeff Spence, Polk County
Ken Huntington, FDEP, Tampa
Doug Fredericks, CDM
Mike Heyl, CDM

Information Requirements to Evaluate Alternative Technologies for Lake Hancock Restoration March 21, 2001

The following information will be required by Camp Dresser & McKee Inc. (CDM) in order to evaluate alternative or non-conventional lake restoration technologies. Alternative or non-conventional technologies may include the following:

Techniques or technologies that are not in widespread use for lake restoration. Techniques or technologies that have not been documented in published scientific literature or peer-reviewed journals or that have not been validated under experimental condition.

Minimum Information Required:

1. Describe the technology and its proposed application to Lake Hancock restoration. If proprietary technology is involved, it is not necessary to disclose this information provided an adequate description is given.

2. Describe how the proposed application of the technology will meet the Lake Hancock restoration goals identified in their grant application to Florida Water Advisory Board. A copy of this application may be obtained from Polk County Natural Resources Division.

3. Describe in detail your proposed technical approach to Lake Hancock restoration, including but not limited to the components listed below.

   a. Restoration objectives/performance goals

   b. Expected final results, including anticipated effect on sediments, lake water quality, lake trophic status, lake biota, and waste product disposition. Quantify volume, quality and disposal options for by-products.

   c. Type and volume of materials to be processed/treated, including sediment, water, and other by-products.

   d. Land requirements (area), location, or proposed location. Identify activities that will occur within each location.

   e. Other requirements such as access, easements, roads, and utilities

   f. Schedule

g. Sampling/testing requirements including parameters, frequency, and quality assurance

h. Water quality protection. Quantify potential impacts - including suspended particles, dissolved oxygen, nutrients, toxic metals and organics.

i. Permitting requirements – Identify each requirement and exemption from pertinent federal, state and local agencies. Provide documentation of agency policy for exemptions.

j. Other environmental impacts (e.g., on aquatic biota, riparian vegetation, avian fauna) and controls

k. Cost estimate

l. Liability insurance coverage

m. Ability to meet bonding requirements for work on public or private property.

4. If a technical demonstration project is proposed, describe how the proposed technology/technical approach will be scaled up to provide full-scale lake restoration. Identify and quantify the requirements in detail for performing a demonstration project.

Appendix B

Results of Toxicity Characteristic Leaching Procedure (TCLP) on Lake Hancock Sediments

ENVIRONMENTAL SERVICES
DEPARTMENT

Natural Resources Division

Board of County Commissioners

4177 Ben Durrance Road
Bartow, FL 33830

(863) 534-7377
Fax (863) 534-7374

September 25, 2000

Daniel E. Glaser, P.E.
Camp, Dresser & McKee, Inc.
1715 North Westshore Blvd. - Suite 875
Tampa, FL 33607

Dear Dan:

Enclosed are the results of the sediment sampling we conducted last month. It consisted of grabbing 15 samples from each of the four quadrants of Lake Hancock. Samples sites were selected at approximate equal intervals along the perimeter of the Lake, and GPS coordinates were collected at each location. This information was obtained as an initial screen for metals to determine the total contaminant leaching potential in the event excavation for removal is considered in the future.

Let me know if you need the GPS locations, or any other information.

Sincerely,

Robert J. Kollinger, P.E.
Water Resources Engineer

Enclosure

XC: Joe King, Environmental Specialist, Biologist

PELA

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CERTIFICATE OF ANALYSIS

SAMPLE SUMMARY

SENT TO: POLK COUNTY NATURAL RESOURCES
ATTN: ROBERT KOLLINGER
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

ANALYZED BY: P.E. LaMoreaux Associates, Inc.
4320 OLD HIGHWAY 37
LAKELAND, FLORIDA 33813

PHONE: (863) 646-8526
FAX: (863) 646-1042

PROJECT NO. :
PELA CONTACT :
WORK ORDER NO. : 0008040930

RECEIVED DATE : 8/18/00
REPORTED DATE : 9/7/00

STATE OF FLORIDA CERTIFICATIONS: E84098-ENVIRONMENTAL

LAB ID #	SAMPLE DESCRIPTION	SAMPLE SITE	COLLECTION DATE	COLLECTION TIME
KA1	#1 - NW/LAKE HANCOCK	LAKE HANCOCK	8/17/00	9:30
KA1	#2 - SW/LAKE HANCOCK	LAKE HANCOCK	8/17/00	10:15
KA1	#3 - SE/LAKE HANCOCK	LAKE HANCOCK	8/17/00	11:00
KA1	#4 - NE/LAKE HANCOCK	LAKE HANCOCK	8/17/00	11:30

SENIOR CHEMIST

LABORATORY DIRECTOR

Thank you for giving PELA the opportunity to be of service.
If you need any additional information, please call.

PELA

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT INFORMATION

Client : POLK COUNTY NATURAL RESOURCES
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830
Attention : ATTN: ROBERT KOLLINGER

BILLING INFORMATION

Bill To : POLK COUNTY NATURAL RESOURCES
ATTN: SHARON CLAYTON
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. : WR 90079

SAMPLE INFORMATION

PELA Laboratory No. : KA13889
Sample Identification : #1 - NW/LAKE HANCOCK
Sample Site : LAKE HANCOCK
Sample Type : SOIL
Sample Designators :

SAMPLE COLLECTION INFORMATION

Collection Date : 8/17/00
Collection Time : 9:30
Collected By : CLIENT
Date Received at Lab : 8/18/00
Time Received at Lab : 10:15

FIELD PARAMETERS

SPECIFIC CONDUCTANCE
pH
WATER TEMPERATURE
DISSOLVED OXYGEN
INITIAL WATER LEVEL
WELL ELEVATION
FIELD TURBIDITY
FIELD COLOR
FACILITY GMS #

COMMENTS

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : #1 - NW/LAKE HANCOCK
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KA13889
COLLECTION DATE: 8/17/00
COLLECTION TIME: 9:30

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
INORGANICS							
% SOLID	EPA 160.3	0.01	16.6	%	RLG	16:00 9/6/00	9/7/00
ARSENIC AS AS TCLP	EPA 7060	0.001	0.003	mg/L	SMW	12:01 8/23/00	8/23/00
BARIUM AS BA TCLP	EPA 6010	0.1	BDL	mg/L	SMW	13:13 8/24/00	8/24/00
CADMIUM AS CD TCLP	EAP 6010	0.005	BDL	mg/L	SMW	16:12 8/23/00	8/23/00
CHROMIUM AS CR TCLP	EPA 6010	0.04	BDL	mg/L	SMW	16:12 8/23/00	8/23/00
LEAD AS PB TCLP	EPA 7421	0.001	0.006	mg/L	SMW	15:56 8/22/00	8/22/00
MERCURY AS HG TCLP	EPA 7471	0.0001	BDL	mg/L	SMW	16:27 8/25/00	8/25/00
SELENIUM AS SE TCLP	EPA 7740	0.002	BDL	mg/L	SMW	10:27 8/24/00	8/24/00
SILVER AS AG TCLP	EPA 6010	0.005	BDL	mg/L	SMW	16:12 8/23/00	8/23/00
TOTAL NITROGEN AS N	351.2/353.2	0.10	1350	mg/Kg	DMG	13:00 8/24/00	8/24/00
TOTAL PHOSPHORUS AS P	EAP 365.4	1.0	432	mg/Kg	DMG	16:00 8/24/00	8/24/00

PELA

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT INFORMATION

Client : POLK COUNTY NATURAL RESOURCES
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830
Attention : ATTN: ROBERT KOLLINGER

BILLING INFORMATION

Bill To : POLK COUNTY NATURAL RESOURCES
ATTN: SHARON CLAYTON
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. : WR 90079

SAMPLE INFORMATION

PELA Laboratory No. : KA13890
Sample Identification : #2 - SW/LAKE HANCOCK
Sample Site : LAKE HANCOCK
Sample Type : SOIL
Sample Designators :

SAMPLE COLLECTION INFORMATION

Collection Date : 8/17/00
Collection Time : 10:15
Collected By : CLIENT
Date Received at Lab : 8/18/00
Time Received at Lab : 10:15

FIELD PARAMETERS

SPECIFIC CONDUCTANCE :
pH :
WATER TEMPERATURE :
DISSOLVED OXYGEN :
INITIAL WATER LEVEL :
WELL ELEVATION :
FIELD TURBIDITY :
FIELD COLOR :
FACILITY GMS # :

COMMENTS

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME	POLK COUNTY NATURAL RESOURCES	PELA LAB NUMBER:	KA13890
IDENTIFICATION	#2 - SW/LAKE HANCOCK	COLLECTION DATE:	8/17/00
SITE	LAKE HANCOCK	COLLECTION TIME:	10:15
TYPE	SOIL		

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
% SOLID	EPA 160.3	0.01	33.1	%	RLG	16:00 9/6/00	9/7/00
ARSENIC AS AS TCLP	EPA 7060	0.001	BDL	mg/L	SMW	12:01 8/23/00	8/23/00
BARIUM AS BA TCLP	EPA 6010	0.	BDL	mg/L	SMW	13:13 8/24/00	8/24/00
CADMIUM AS CD TCLP	EAP 6010	0.005	BDL	mg/L	SMW	16:20 8/23/00	8/23/00
CHROMIUM AS CR TCLP	EPA 6010	0.04	BDL	mg/L	SMW	16:20 8/23/00	8/23/00
LEAD AS PB TCLP	EPA 7421	0.001	0.006	mg/L	SMW	16:16 8/22/00	8/22/00
MERCURY AS HG TCLP	EPA 7471	0.0001	BDL	mg/L	SMW	16:27 8/25/00	8/25/00
SELENIUM AS SE TCLP	EPA 7740	0.002	BDL	mg/L	SMW	10:27 8/24/00	8/24/00
SILVER AS AG TCLP	EPA 6010	0.005	BDL	mg/L	SMW	16:20 8/23/00	8/23/00
TOTAL NITROGEN AS N	351.2/3532	0.10	1439	mg/Kg	DMG	13:00 8/24/00	8/24/00
TOTAL PHOSPHORUS AS P	EAP 365.4	.0	167	mg/Kg	DMG	16:00 8/24/00	8/24/00

PELA

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Client : POLK COUNTY NATURAL RESOURCES
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830
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Bill To : POLK COUNTY NATURAL RESOURCES
ATTN: SHARON CLAYTON
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. WR 90079

SAMPLE INFORMATION

PELA Laboratory No.	KA13891
Sample Identification	#3 - SE/LAKE HANCOCK
Sample Site	LAKE HANCOCK
Sample Type	SOIL
Sample Designators	

SAMPLE COLLECTION INFORMATION

Collection Date	: 8/17/00
Collection Time	: 11:00
Collected By	: CLIENT
Date Received at Lab	: 8/18/00
Time Received at Lab	: 10:15

FIELD PARAMETERS

SPECIFIC CONDUCTANCE	:
pH	:
WATER TEMPERATURE	:
DISSOLVED OXYGEN	:
INITIAL WATER LEVEL	:
WELL ELEVATION	:
FIELD TURBIDITY	:
FIELD COLOR	:
FACILITY GMS #	:

COMMENTS

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : #3 - SE/LAKE HANCOCK
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KA13891
COLLECTION DATE: 8/17/00
COLLECTION TIME: 11:00

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
INORGANICS							
% SOLID	EPA 160.3	0.01	16.8	%	RLG	16:00 9/6/00	9/7/00
ARSENIC AS AS TCLP	EPA 7060	0.001	0.002	mg/L	SMW	13:15 8/23/00	8/23/00
BARIUM AS BA TCLP	EPA 6010	0.1	BDL	mg/L	SMW	13:13 8/24/00	8/24/00
CADMIUM AS CD TCLP	EAP 6010	0.005	BDL	mg/L	SMW	16:23 8/23/00	8/23/00
CHROMIUM AS CR TCLP	EPA 6010	0.04	BDL	mg/L	SMW	16:23 8/23/00	8/23/00
LEAD AS PB TCLP	EPA 7421	0.001	0.006	mg/L	SMW	16:20 8/22/00	8/22/00
MERCURY AS HG TCLP	EPA 7471	0.0001	BDL	mg/L	SMW	16:27 8/25/00	8/25/00
SELENIUM AS SE TCLP	EPA 7740	0.002	BDL	mg/L	SMW	16:23 8/23/00	8/23/00
SILVER AS AG TCLP	EPA 6010	0.005	BDL	mg/L	SMW	16:23 8/23/00	8/23/00
TOTAL NITROGEN AS N	351.2/353.2	0.10	1390	mg/Kg	DMG	13:00 8/24/00	8/24/00
TOTAL PHOSPHORUS AS P	EAP 365.4	1.0	164	mg/Kg	DMG	16:00 8/24/00	8/24/00

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Bill To : POLK COUNTY NATURAL RESOURCES
ATTN: SHARON CLAYTON
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. : WR 90079

SAMPLE INFORMATION

PELA Laboratory No. : KA13892
Sample Identification : #4 - NE/LAKE HANCOCK
Sample Site : LAKE HANCOCK
Sample Type : SOIL
Sample Designators :

SAMPLE COLLECTION INFORMATION

Collection Date : 8/17/00
Collection Time : 11:30
Collected By : CLIENT
Date Received at Lab : 8/18/00
Time Received at Lab : 10:15

FIELD PARAMETERS

SPECIFIC CONDUCTANCE
pH
WATER TEMPERATURE
DISSOLVED OXYGEN
INITIAL WATER LEVEL
WELL ELEVATION
FIELD TURBIDITY
FIELD COLOR
FACILITY GMS #

COMMENTS

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CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : #4 - NE/LAKE HANCOCK
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KA13892
COLLECTION DATE: 8/17/00
COLLECTION TIME: 11:30

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
INORGANICS							
% SOLID	EPA 160.3	0.01	46.1	%	RLG	16:00 9/6/00	9/7/00
ARSENIC AS AS TCLP	EPA 7060	0.001	0.001	mg/L	SMW	13:15 8/23/00	8/23/00
BARIUM AS BA TCLP	EPA 6010	0.	BDL	mg/L	SMW	13:13 8/24/00	8/24/00
CADMIUM AS CD TCLP	EAP 6010	0.005	BDL	mg/L	SMW	16:25 8/23/00	8/23/00
CHROMIUM AS CR TCLP	EPA 6010	0.04	BDL	mg/L	SMW	16:25 8/23/00	8/23/00
LEAD AS PB TCLP	EPA 7421	0.001	0.005	mg/L	SMW	16:24 8/22/00	8/22/00
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SELENIUM AS SE TCLP	EPA 7740	0.002	BDL	mg/L	SMW	10:27 8/24/00	8/24/00
SILVER AS AG TCLP	EPA 6010	0.005	BDL	mg/L	SMW	16:25 8/23/00	8/23/00
TOTAL NITROGEN AS N	351.2/353.2	0.10	1162	mg/Kg	DMG	13:00 8/24/00	8/24/00
TOTAL PHOSPHORUS AS P	EAP 365.4	.0	154	mg/Kg	DMG	16:00 8/24/00	8/24/00

N° 40930

REPORTING ADDRESS:
ATTN: Robert Kollinger
CLIENT: Polk Co. Natural Resources
ADDRESS: 4177 Ben Durrance Rd
Bartow 33830

P.E. LaMoreaux & Associates
4320 Old Highway 37
Lakeland, Florida 33813
(941) 646-8526

CHAIN OF CUSTODY

INVOICING ADDRESS:
ATTN: Sharon Clayton
CLIENT: Polk Co Natural Resources
ADDRESS: 4177 Ben Durrance
Bartow 33830

PROJECT NAME	PROJECT LOCATION
Lake Hancock	LK Hancock
PROJECT NO.	PURCHASE ORDER NO.
	WR90079
PROJECT CONTACT	PROJECT TEL. NO.
Bob Kollinger	
SAMPLER NAME(S)	
Joe King/Bob Kollinger	

TYPE: (W)ATER (S)OIL (O)THER

REQUIRED ANALYSIS

TCLP for 8 Heavy Metals
% Solids
Total Nitrogen
Total Phosphorus

NUMBER OF CONTAINERS / CONTAINER SIZE & TYPE / PRESERVATIVE
CONTAINER TYPES: (P)LASTIC (G)LASS (O)THER
PRESERVATIVES: (S)ODIUM HYDROXIDE (Su)LFURIC (N)ITRIC (H)YDROCLORIC (I)CED (O)THER

PAGE | OF

FIELD PARAMETERS

SAMPLING DATE	SAMPLING TIME	SAMPLE IDENTIFICATION			SC (umnos/cm)	pH	TEMP (°C)	D.O.
8/17/00	930	#1 - NW	~~None~~	1 pt-G NONE				
8/17/00	1015	#2 - SW	~~None~~	1 pt-G NONE				
8/17/00	~~1100~~ 1145	#3 - SE	~~None~~	1pt-G NONE				
8/17/00	1130	#4 - NE	~~None~~	1pt-G NONE				

RELINQUISHED BY:	DATE	TIME	RECEIVED BY:	RELINQUISHED BY:	DATE	TIME	RECEIVED BY:
Diane Bonn	8/18/00	935	Jacque McVeigh	Jacque McVeigh	8/18/00	1015	

FOR PELA LABORATORY USE ONLY

RECEIVED FOR LAB	DATE	TIME	WORK ORDER #
	8/18/00	1015	

LABORATORY REMARKS

Imperial
Polk County
BOARD OF COUNTY COMMISSIONERS

Natural Resources Division

4177 Ben Durrance Road
Bartow, FL 33830
(863) 534-7377
FAX (863) 534-7374

Jeffrey F. Spence
Director

FAX COVER PAGE

TO: CDM Tampa

ATTENTION: Dan Glaser, P.E.

FAX NUMBER: (813) 288-8787

FROM: Robert Kollinger, P.E.

DATE: 7 / 2 / 2001

This transmission is 10 Pages (including cover page).

MESSAGE / NOTES:

Lake Hancock TCLP results from composite samples on the eastern shore and southern outfall area of the lake.

PELA

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CERTIFICATE OF ANALYSIS

SAMPLE SUMMARY

SENT TO: POLK COUNTY NATURAL RESOURCES
BOB KOLLINGER
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

ANALYZED BY: P.E. LaMoreaux Associates, Inc.
4320 OLD HIGHWAY 37
LAKELAND, FLORIDA 33813

PHONE: (863) 646-8526
FAX: (863) 646-1042

PROJECT NO. :
PELA CONTACT :
WORK ORDER NO. : 0106043071

RECEIVED DATE : 6/1/01
REPORTED DATE : 7/2/01

STATE OF FLORIDA CERTIFICATIONS: E84098-ENVIRONMENTAL

LAB ID #	SAMPLE DESCRIPTION	SAMPLE SITE	COLLECTION DATE	COLLECTION TIME
KB09697	SOUTH SIDE COMP/LAKE HANCOCK	LAKE HANCOCK	6/1/01	11:00
KB09698	EAST SIDE COMP/LAKE HANCOCK	LAKE HANCOCK	6/1/01	12:30

Joseph M. Stergar
SENIOR CHEMIST

Arnold Martelo
LABORATORY DIRECTOR

Thank you for giving PELA the opportunity to be of service.
If you need any additional information, please call.

PELA

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT INFORMATION

Client : POLK COUNTY NATURAL RESOURCES
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830
Attention : BOB KOLLINGER

BILLING INFORMATION

Bill To : POLK COUNTY NATURAL RESOURCES
BOB KOLLINGER
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. :

SAMPLE INFORMATION

PELA Laboratory No. : KB09697
Sample Identification : SOUTH SIDE COMP/LAKE HANC
Sample Site : LAKE HANCOCK
Sample Type : SOIL
Sample Designators :

SAMPLE COLLECTION INFORMATION

Collection Date : 6/1/01
Collection Time : 11:00
Collected By : CLIENT
Date Received at Lab : 6/1/01
Time Received at Lab : 13:14

FIELD PARAMETERS

SPECIFIC CONDUCTANCE :
pH :
WATER TEMPERATURE :
DISSOLVED OXYGEN :
INITIAL WATER LEVEL :
WELL ELEVATION :
FIELD TURBIDITY :
FIELD COLOR :
FACILITY GMS # :

COMMENTS

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : SOUTH SIDE COMP/LAKE HANC
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KB09697
COLLECTION DATE: 6/1/01
COLLECTION TIME: 11:00

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
INORGANICS							
ARSENIC AS AS TCLP	EPA 7060	0.001	0.005	mg/L	SMW	11:23 6/14/01	6/14/01
BARIUM AS BA TCLP	EPA 6010	0.1	ND	mg/L	SMW	12:22 6/7/01	6/7/01
CADMIUM AS CD TCLP	EAP 6010	0.005	ND	mg/L	SMW	12:22 6/7/01	6/7/01
CHROMIUM AS CR TCLP	EPA 6010	0.04	ND	mg/L	SMW	12:22 6/7/01	6/7/01
LEAD AS PB TCLP	EPA 7421	0.001	0.002	mg/L	SMW	16:18 6/8/01	6/8/01
MERCURY AS HG TCLP	EPA 7471	0.0001	ND	mg/L	SMW	16:58 6/7/01	6/7/01
SELENIUM AS SE TCLP	EPA 7740	0.002	ND	mg/L	SMW	13:18 6/12/01	6/12/01
SILVER AS AG TCLP	EPA 6010	0.005	ND	mg/L	SMW	12:22 6/7/01	6/7/01

ND- NONE DETECTED.

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
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CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : SOUTH SIDE COMP/LAKE HANC
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KB09697
COLLECTION DATE: 6/1/01
COLLECTION TIME: 11:00

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
TCLP CHLORDANE							
CHLORDANE	EPA 8081	0.00002	ND	mg/L	BAM	17:46 6/27/01	6/27/01
TCLP HERBICIDES							
2,4-D	EPA 8151	0.0002	ND	mg/L	BAM	2:55 6/30/01	6/30/01
SILVEX	EPA 8151	0.0001	ND	mg/L	BAM	2:55 6/30/01	6/30/01
TCLP PESTICIDES							
ENDRIN	EPA 8081	0.000006	ND	mg/L	BAM	17:46 6/27/01	6/27/01
G-BHC (LINDANE)	EPA 8081	0.000004	ND	mg/L	BAM	17:46 6/27/01	6/27/01
HEPTACHLOR	EPA 8081	0.000003	ND	mg/L	BAM	17:46 6/27/01	6/27/01
HEPTACHLOR EPOXIDE	EPA 8081	0.000008	ND	mg/L	BAM	17:46 6/27/01	6/27/01
METHOXYCHLOR	EPA 8081	0.00018	ND	mg/L	BAM	17:46 6/27/01	6/27/01
TCLP SEMI-VOLATILES							
2,4,5-TRICHLOROPHENOL	EPA 8270	0.0100	ND	mg/L	JMS	20:27 6/15/01	6/15/01
2,4,6-TRICHLOROPHENOL	EPA 8270	0.0027	ND	mg/L	JMS	20:27 6/15/01	6/15/01
2,4-DINITROTOLUENE	EPA 8270	0.0022	ND	mg/L	JMS	20:27 6/15/01	6/15/01
HEXACHLOROBENZENE	EPA 8270	0.0010	ND	mg/L	JMS	20:27 6/15/01	6/15/01
HEXACHLOROBUTADIENE	EPA 8270	0.0010	ND	mg/L	JMS	20:27 6/15/01	6/15/01
HEXACHLOROETHANE	EPA 8270	0.0016	ND	mg/L	JMS	20:27 6/15/01	6/15/01
M,P-CRESOLS	EPA 8270	0.0100	ND	mg/L	JMS	20:27 6/15/01	6/15/01
NITROBENZENE	EPA 8270	0.0019	ND	mg/L	JMS	20:27 6/15/01	6/15/01
O-CRESOL	EPA 8270	0.0100	ND	mg/L	JMS	20:27 6/15/01	6/15/01
PENTACHLOROPHENOL	EPA 8270	0.0015	ND	mg/L	JMS	20:27 6/15/01	6/15/01
PYRIDINE	EPA 8270	0.0050	ND	mg/L	JMS	20:27 6/15/01	6/15/01
TCLP TOXAPHENE							
TOXAPHENE	EPA 8081	0.00024	ND	mg/L	BAM	17:46 6/27/01	6/27/01

REPORT OF ANALYSIS

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4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : SOUTH SIDE COMP/LAKE HANC
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KB09697
COLLECTION DATE: 6/1/01
COLLECTION TIME: 11:00

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
ORGANICS							
		TCLP VOLATILES					
1,1-DICHLOROETHENE	EPA 8260	0.00012	ND	mg/L	JMS	13:23 6/13/01	6/13/01
1,2-DICHLOROETHANE	EPA 8260	0.00006	ND	mg/L	JMS	13:23 6/13/01	6/13/01
1,4-DICHLOROBENZENE	EPA 8260	0.00003	ND	mg/L	JMS	13:23 6/13/01	6/13/01
BENZENE	EPA 8260	0.00004	ND	mg/L	JMS	13:23 6/13/01	6/13/01
CARBON TETRACHLORIDE	EPA 8260	0.00021	ND	mg/L	JMS	13:23 6/13/01	6/13/01
CHLOROBENZENE	EPA 8260	0.00004	ND	mg/L	JMS	13:23 6/13/01	6/13/01
METHYL ETHYL KETONE	EPA 8260	0.00100	ND	mg/L	JMS	13:23 6/13/01	6/13/01
TETRACHLOROETHENE	EPA 8260	0.00014	ND	mg/L	JMS	13:23 6/13/01	6/13/01
TRICHLOROETHENE	EPA 8260	0.00019	ND	mg/L	JMS	13:23 6/13/01	6/13/01
TRICHLOROMETHANE	EPA 8260	0.00003	ND	mg/L	JMS	13:23 6/13/01	6/13/01
VINYL CHLORIDE	EPA 8260	0.00017	ND	mg/L	JMS	13:23 6/13/01	6/13/01

DETECTION LIMITS REPORTED ARE METHOD DETECTION LIMITS WHICH MAY VARY WITH MATRIX AND CONCENTRATION.
ND- NONE DETECTED.

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT INFORMATION

Client : POLK COUNTY NATURAL RESOURCES
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830
Attention : BOB KOLLINGER

BILLING INFORMATION

Bill To : POLK COUNTY NATURAL RESOURCES
BOB KOLLINGER
4177 BEN DURRANCE ROAD
BARTOW, FLORIDA 33830

Purchase Order No. :

SAMPLE INFORMATION

PELA Laboratory No. : KB09698
Sample Identification : EAST SIDE COMP/LAKE HANCO
Sample Site : LAKE HANCOCK
Sample Type : SOIL
Sample Designators :

SAMPLE COLLECTION INFORMATION

Collection Date : 6/1/01
Collection Time : 12:30
Collected By : CLIENT
Date Received at Lab : 6/1/01
Time Received at Lab : 13:14

FIELD PARAMETERS

SPECIFIC CONDUCTANCE :
pH :
WATER TEMPERATURE :
DISSOLVED OXYGEN :
INITIAL WATER LEVEL :
WELL ELEVATION :
FIELD TURBIDITY :
FIELD COLOR :
FACILITY GMS # :

COMMENTS

7-02-2001 5:00PM FROM POLK CO NATURAL RES 8635347368 P.1

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : EAST SIDE COMP/LAKE HANCO
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KB09698
COLLECTION DATE: 6/1/01
COLLECTION TIME: 12:30

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
INORGANICS							
ARSENIC AS AS TCLP	EPA 7060	0.001	0.005	mg/L	SMW	11:27 6/14/01	6/14/01
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REPORT OF ANALYSIS

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COLLECTION TIME: 12:30

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
TCLP CHLORDANE							
CHLORDANE	EPA 8081	0.00002	ND	mg/L	BAM	18:38 6/27/01	6/27/01
TCLP HERBICIDES							
2,4-D	EPA 8151	0.0002	ND	mg/L	BAM	4:01 6/30/01	6/30/01
SILVEX	EPA 8151	0.0001	ND	mg/L	BAM	4:01 6/30/01	6/30/01
TCLP PESTICIDES							
ENDRIN	EPA 8081	0.000006	ND	mg/L	BAM	18:38 6/27/01	6/27/01
G-BHC (LINDANE)	EPA 8081	0.000004	ND	mg/L	BAM	18:38 6/27/01	6/27/01
HEPTACHLOR	EPA 8081	0.000003	ND	mg/L	BAM	18:38 6/27/01	6/27/01
HEPTACHLOR EPOXIDE	EPA 8081	0.000008	ND	mg/L	BAM	18:38 6/27/01	6/27/01
METHOXYCHLOR	EPA 8081	0.00018	ND	mg/L	BAM	18:38 6/27/01	6/27/01
TCLP SEMI-VOLATILES							
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NITROBENZENE	EPA 8270	0.0019	ND	mg/L	JMS	21:05 6/15/01	6/15/01
O-CRESOL	EPA 8270	0.0100	ND	mg/L	JMS	21:05 6/15/01	6/15/01
PENTACHLOROPHENOL	EPA 8270	0.0015	ND	mg/L	JMS	21:05 6/15/01	6/15/01
PYRIDINE	EPA 8270	0.0050	ND	mg/L	JMS	21:05 6/15/01	6/15/01
TCLP TOXAPHENE							
TOXAPHENE	EPA 8081	0.00024	ND	mg/L	BAM	18:38 6/27/01	6/27/01

REPORT OF ANALYSIS

P.E. LaMoreaux and Associates, Inc.
Geochemistry Laboratory
4320 Old Highway 37, Lakeland, Florida 33813 PHONE 863/646-8526 FAX 863/646-1042

CLIENT NAME : POLK COUNTY NATURAL RESOURCES
IDENTIFICATION : EAST SIDE COMP/LAKE HANCO
SITE : LAKE HANCOCK
TYPE : SOIL

PELA LAB NUMBER: KB09698
COLLECTION DATE: 6/1/01
COLLECTION TIME: 12:30

PARAMETER	METHOD	DETECTION LIMITS	RESULTS	UNIT	ANALYST	TIME/DATE STARTED	DATE FINISHED
ORGANICS							
		TCLP VOLATILES					
1,1-DICHLOROETHENE	EPA 8260	0.00012	ND	mg/L	JMS	14:00 6/13/01	6/13/01
1,2-DICHLOROETHANE	EPA 8260	0.00006	ND	mg/L	JMS	14:00 6/13/01	6/13/01
1,4-DICHLOROBENZENE	EPA 8260	0.00003	ND	mg/L	JMS	14:00 6/13/01	6/13/01
BENZENE	EPA 8260	0.00004	ND	mg/L	JMS	14:00 6/13/01	6/13/01
CARBON TETRACHLORIDE	EPA 8260	0.00021	ND	mg/L	JMS	14:00 6/13/01	6/13/01
CHLOROBENZENE	EPA 8260	0.00004	ND	mg/L	JMS	14:00 6/13/01	6/13/01
METHYL ETHYL KETONE	EPA 8260	0.00100	ND	mg/L	JMS	14:00 6/13/01	6/13/01
TETRACHLOROETHENE	EPA 8260	0.00014	ND	mg/L	JMS	14:00 6/13/01	6/13/01
TRICHLOROETHENE	EPA 8260	0.00019	ND	mg/L	JMS	14:00 6/13/01	6/13/01
TRICHLOROMETHANE	EPA 8260	0.00003	ND	mg/L	JMS	14:00 6/13/01	6/13/01
VINYL CHLORIDE	EPA 8260	0.00017	ND	mg/L	JMS	14:00 6/13/01	6/13/01

DETECTION LIMITS REPORTED ARE METHOD DETECTION LIMITS WHICH MAY VARY WITH MATRIX AND CONCENTRATION.
ND- NONE DETECTED.

Appendix C

Technical Memorandum "Natural Drawdown Action Plan for Assessing Sediment Removal from Lake Hancock, Florida"

CDM

Technical Memorandum
Natural Drawdown Action Plan for Assessing Sediment Removal from Lake Hancock, Florida

Executive Summary

CDM has been contracted by Polk County to develop a Restoration and Management Plan for Lake Hancock and the upper Peace River. The Restoration and Management Plan is to identify up to ten (10) alternatives for restoration of the lake and compare the costs and feasibility of each alternative. One of the ten restoration techniques to be evaluated is a controlled lake drawdown and conventional excavation of the organic sediments that cover the lake bottom.

Florida has been experiencing drought conditions for the past 24 months. These conditions have resulted in extremely low water levels within the lake. These conditions are expected to continue through spring of 2001, which would result in a natural drawdown due to abnormally low levels within Lake Hancock. In order to capitalize on this event, CDM has been directed by the County to initially evaluate the removal of sediment from the lake bottom using conventional equipment and to develop a demonstration action plan to be implemented over the next few months.

Polk County has recently purchased the Circle B-Bar Reserve (Reserve) from the Bellotto family. This site was chosen for the demonstration site to perform a cost analysis of sediment removal using conventional equipment. CDM prepared an analysis of the thickness of sediments adjacent to the property and estimated the acreage that will be exposed in late May 2001. Permitting issues were identified, and a monitoring plan developed to document the physical and environmental changes that occur during extremely low lake levels.

A conceptual plan to remove 3,900 yd^3 was developed along with planning level cost estimates. It is estimated that the total cost for removal of 3,900 yd^3 of sediment, using conventional equipment, is $247,275.

Purpose and Content

The purpose of this technical memorandum is to determine the feasibility of removing sediments from Lake Hancock using conventional earthmoving equipment. CDM was tasked to consider this restoration technique and to design a demonstration project to coincide with an abnormally low lake level in the Spring of 2001 resulting from a record two-year rainfall deficit. The plan is to have Polk County remove a total of 3,900 yd^3 of noxious sediments from the shoreline and place it in a 1.0-acre bermed dewatering cell on the recently acquired Reserve. The sediments removed will dehydrate through draining and evaporation, thus eliminating the potential problems of treating decanted return water.

This technical memorandum (TM) is organized into background information about the historical lake levels, controlling levels and a summary of previous studies

relating to the characteristics of sediments. The background section is followed by a description of the physical operations of sediment removal and associated costs, including a description of the permitting issues associated with the demonstration project. If a demonstration project is to be implemented, a monitoring program is recommended to obtain field verification of previous laboratory measurements and to confirm estimates regarding the rate of in-situ desiccation of sediments. The monitoring program also includes activities to document the recruitment and growth of emergent vegetation on the exposed lake bottom. Finally, construction activities are presented along with estimated costs for completing the demonstration project.

Background

Pertinent Lake Levels

Historical lake levels are given in **Figure 1** and indicate that the recorded extremes range from 101.2 ft to 93.98 ft (all levels expressed as NGVD 1929). The record high of 101.9 ft occurred on September 16, 1960 and was the result of heavy rainfall associated with hurricane Donna. The record low of 93.98 ft occurred on May 23, 1968 and was preceded by the opening of a sinkhole in the lake during March of that year. Annual low levels subsequent to 1968 suggest that large flows to the sinkhole have subsided to more normal rates.

In 1966, the Southwest Florida Water Management District Governing Board defined the maximum desirable lake level as 98.60 and the minimum desirable level as 95.00 ft. Prior to 1963, water levels were controlled by a concrete and timber pile weir approximately 135 yards north of the present P-11 structure in South Saddle Creek. In 1963 a new structure consisting of two 20 ft by 7 ft radial gates were installed with an overflow level of 98.7 ft. The structure has an invert of 91.7 ft, but it is unlikely that this is the controlling elevation for the lake. In 1974 the Army Corps of Engineers reported a controlling channel depth of 96.4 ft and in 1982 the Federal Emergency Management Agency reported a controlling depth of 95.4 ft. In 1987, Zellars-Williams (1987) reported a controlling depth of 93.8, which occurred 200 feet south of P-11. Pertinent lake levels are summarized in the table below.

Pertinent Lake Hancock Lake Levels (NGVD 1919)

Level	Comment
101.9	Highest recorded level (9/16/60)
98.7	P-11 Overflow level
98.5	Maximum desirable lake level
96.4	ACOE reported controlling depth (1974)
95.4	FEMA reported controlling depth (1982)
95.0	Minimum desirable lake level.
93.98	Lowest recorded level (5/23/68)
93.8	Controlling channel depth (1987)
91.7	P-11 invert

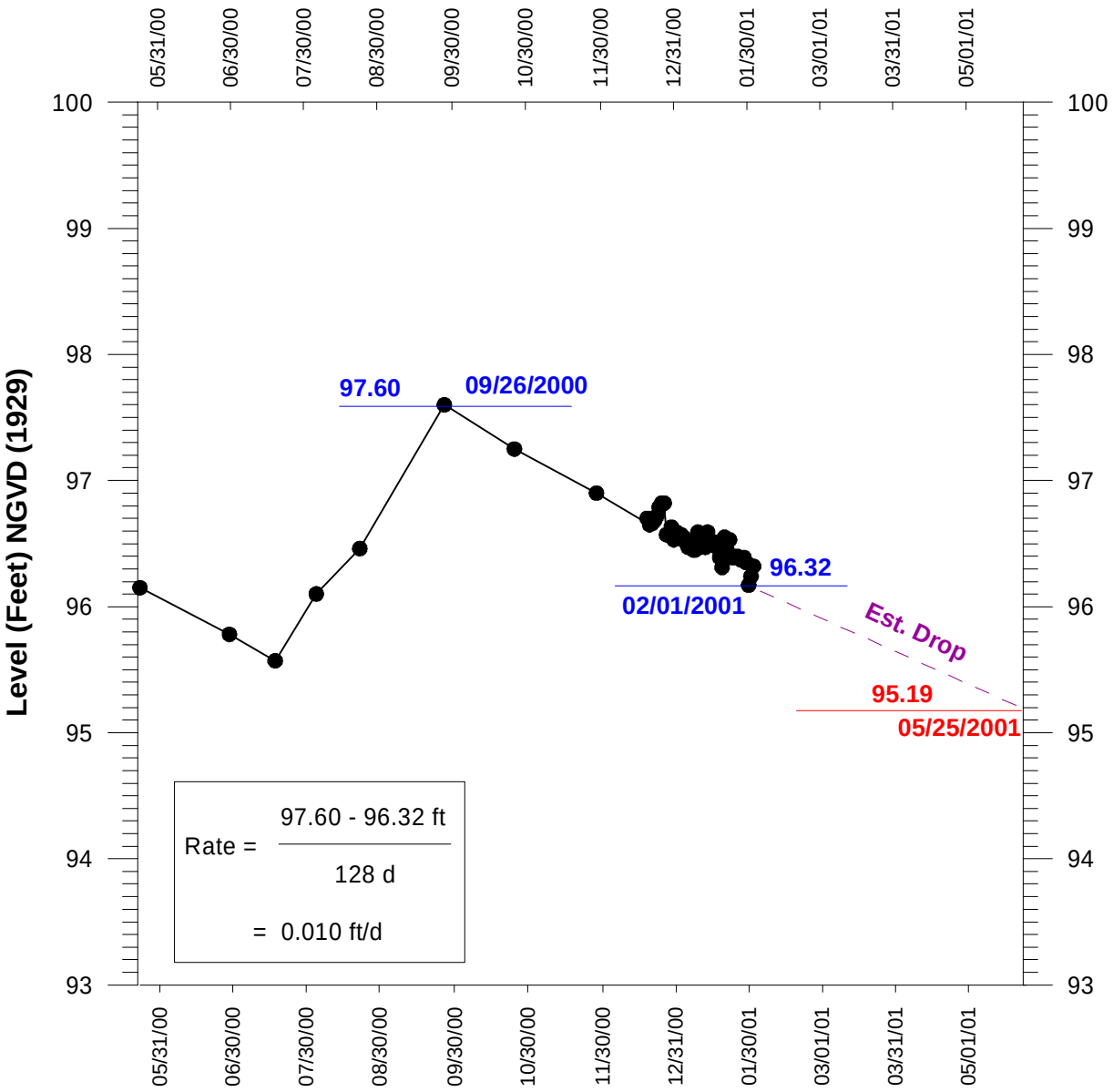


Figure 2
Estimated Decline (2000-2001)

Expected Lake Level - Spring 2001

On February 1, 2001 the water level in Lake Hancock was 96.32 ft. The previous summer seasonal high level occurred on September 26, 2000 at 97.60 ft resulting in an average decrease of 0.010 ft / day for the 128-day period. At the present rate of decline, the lake level in late May is expected to be on the order of 95.19 ft as illustrated in **Figure 2**.

For comparison, during the record low level of 1967-68, the average daily decline was only slightly faster (0.013 ft / day) for the period following a lake level of 96.32 ft as shown in **Figure 3**. However, this level occurred sixty days earlier in 1967 (November 23, 1967) than in 2001 (February 21, 2001) providing additional drying time prior to the onset of the wet season.

It should also be noted that the estimated discharge capacity of P-11 is around 400 cfs when open. In the absence of downstream channel obstructions, the gravity drainage through a fully opened P-11 results in a lake level decrease of approximately 3.7 feet per month under conditions of average rainfall and evaporation.

Extent of Workable Sediments

Zellars-Williams developed an estimate of exposed lake bottom at various stages and coupled these results with estimates of groundwater levels to derive the area of exposed saturated and exposed unsaturated sediments. Only sediment deposits above the predicted groundwater table can drain and dry, and only at lake stages less than 92 ft does the extent of exposed unsaturated sediments exceed that of exposed, but saturated, sediments. The results are given below, and by extrapolation indicate that at a pool elevation of 95.19 ft, 923 acres of unsaturated sediments will be exposed. To adequately expose the sediments and create effective drying conditions, pumping would probably be required to achieve a lake elevation of 90 to 91 ft.

Sediment Exposure as Function of Lake Level

Stage (ft, NGVD)	Area Covered in Water (acres)	Exposed Bottom - Unsaturated Sediment (acres)	Exposed Bottom - Saturated Sediment (acres)
98.5	4553	0	0
97.0	4091	328	134
96.0	3535	683	335
95.0	2087	980	1486
94.0	240	1358	2955
93.0	0	2149	2404
92.0	0	3475	1079
90.0	0	4553	0

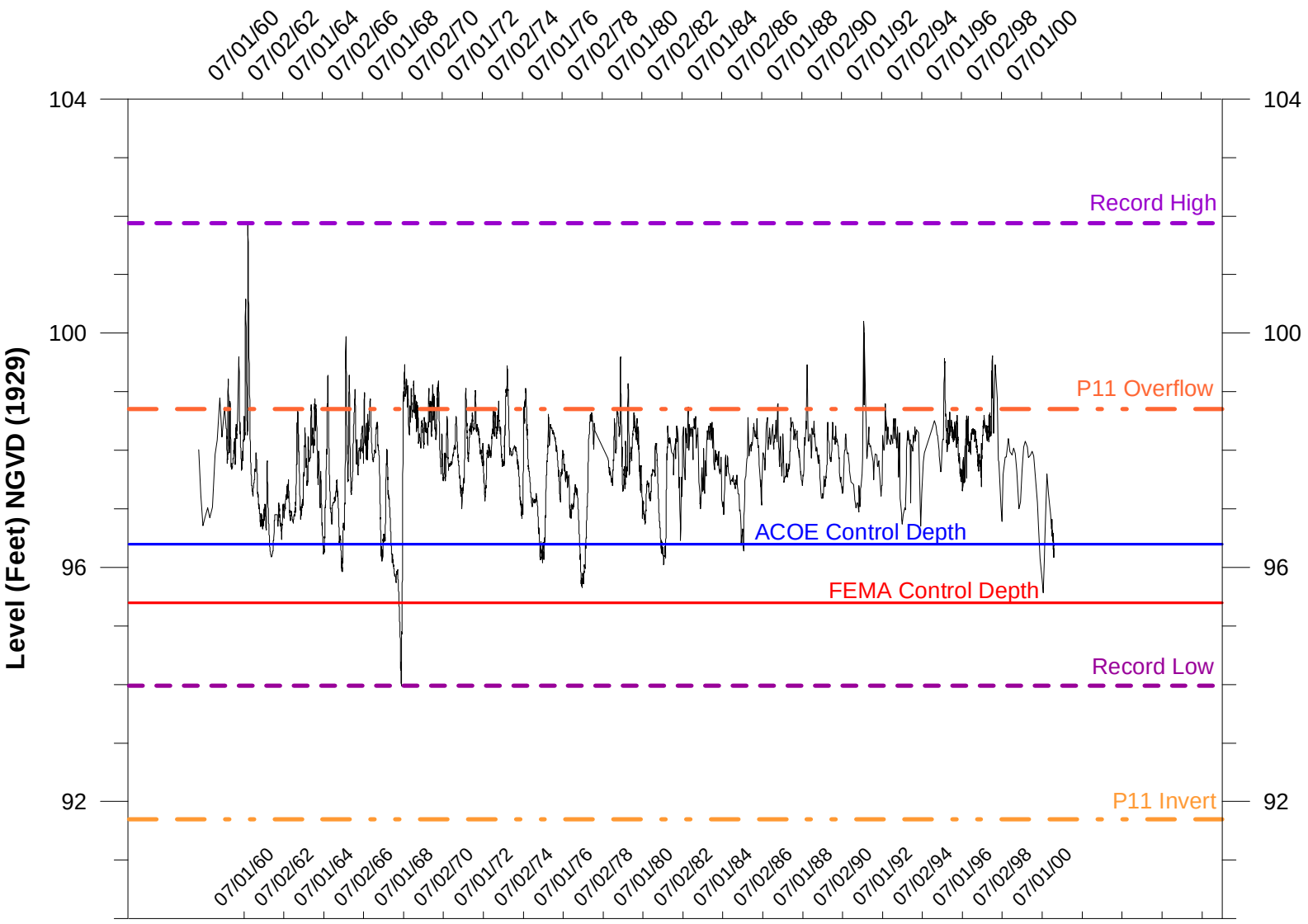


Figure 1
Lake Hancock Lake Levels (1958-2001)

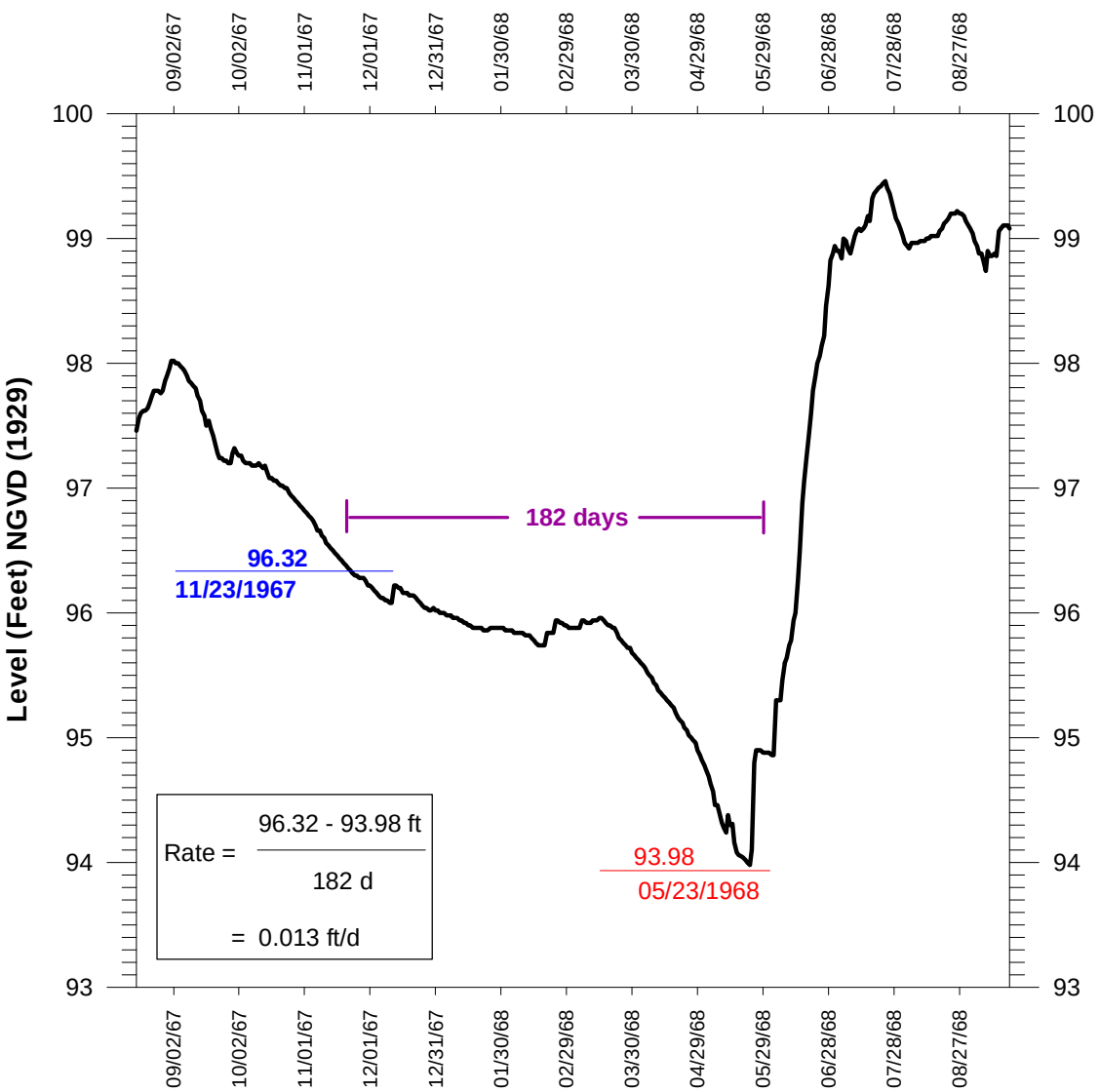


Figure 3
Historical (1967-1968)

Sediment Exposure Adjacent to the Reserve

The proposed excavation demonstration would be conducted using sediments offshore of the Reserve. In order to evaluate the extent of sediment exposure at this location, recent measurements of water depth and sediment thickness were normalized to NGVD and combined using ArcView GIS software. Information was obtained from FDEP (M. Phillips. August 15,2000 survey) and from IMC-Agrico (Correspondence to P. Fricano [FDEP] from M. Hutchens [IMC-Agrico] 12/9/98, surveys from various dates in June/July 1998). Contours were developed from the resulting grid. **Figure 4** illustrates the location of the soundings. **Figure 5** shows the lake bathymetry (to top of sediments). **Figure 6** illustrates the sediment area adjacent to the Reserve, that is expected to become exposed.

Sediment and Pore Water Quality

Several studies (Zellars-Williams, 1987. IMC-Agrico, 1998. Polk County, 2000) have included chemical analysis of sediments recovered from the Lake. **Figure 7** indicates the approximate locations of the Zellars-Williams borings. The analyses varied by study and purpose. In one case, sediments were stirred with distilled water to determine the amount of leachable material. Elutriate water was recovered by vacuum filtration and analyzed. More recent, Polk County evaluated the metals content using an EPA procedure known as Toxicity Characteristic Leaching Procedure (TCLP) in which the sediments were stirred with a solution designed to facilitate removal of metals through chelation. The results can be compared with critical values (**Table 1**) defined by USEPA as 'toxic'. Finally, in all studies some of the cores were dried and the content of certain parameters was determined on the solid material.

These results are given in **Table 2** and provide several important characteristics of the sediments. First, the nutrient content of the pore water (elutriate) is about an order of magnitude higher than in the water column. Therefore, any water decanted from the demonstration project drying beds will probably require treatment prior to return to Lake Hancock. Second, while the nutrient levels are high in the elutriate, the metals content in the elutriate and TCLP extractions were low and none exceeded the EPA thresholds. Based on the data currently available, heavy metal toxicity is not expected. No recent tests for organics have been conducted, but an earlier evaluation of a single composite sediment sample by Zellars-Williams (1987) for 118 priority organic pollutants detected ethyl-benzene, toluene, 1,1,1 trichloroethane and xylene.

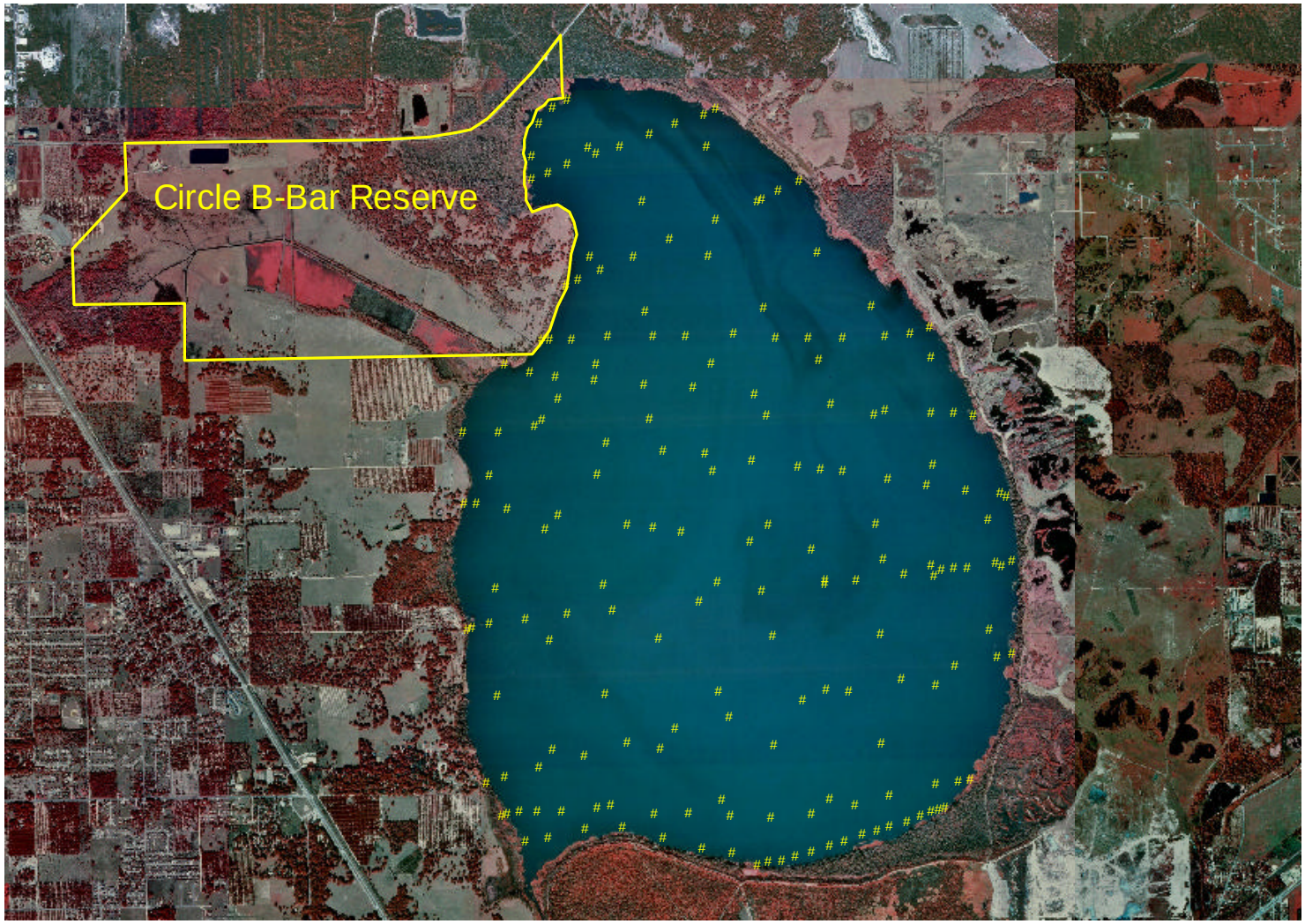


Figure 4
Location of Soundings

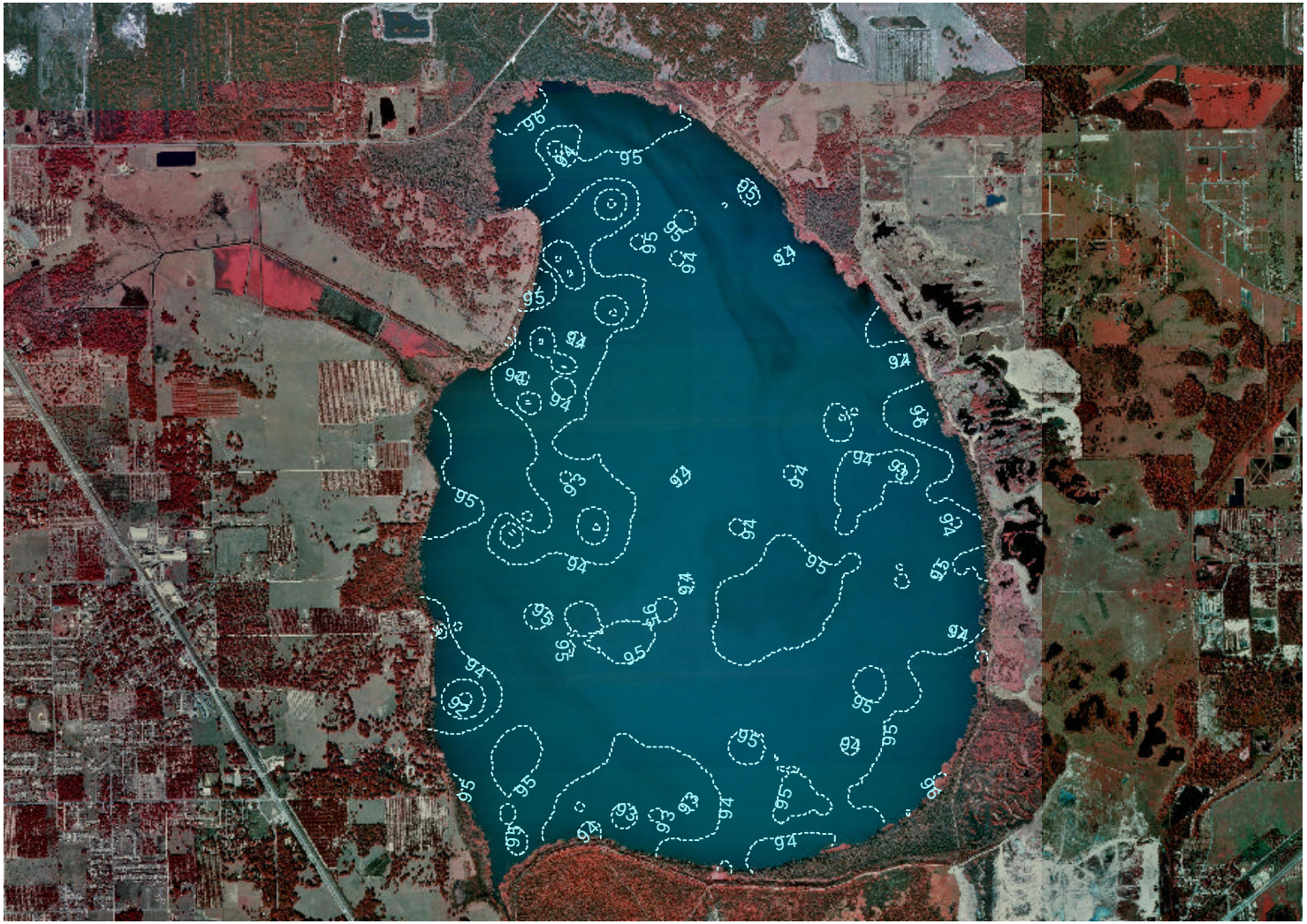


Figure 5
Elevation, Top of Sediment

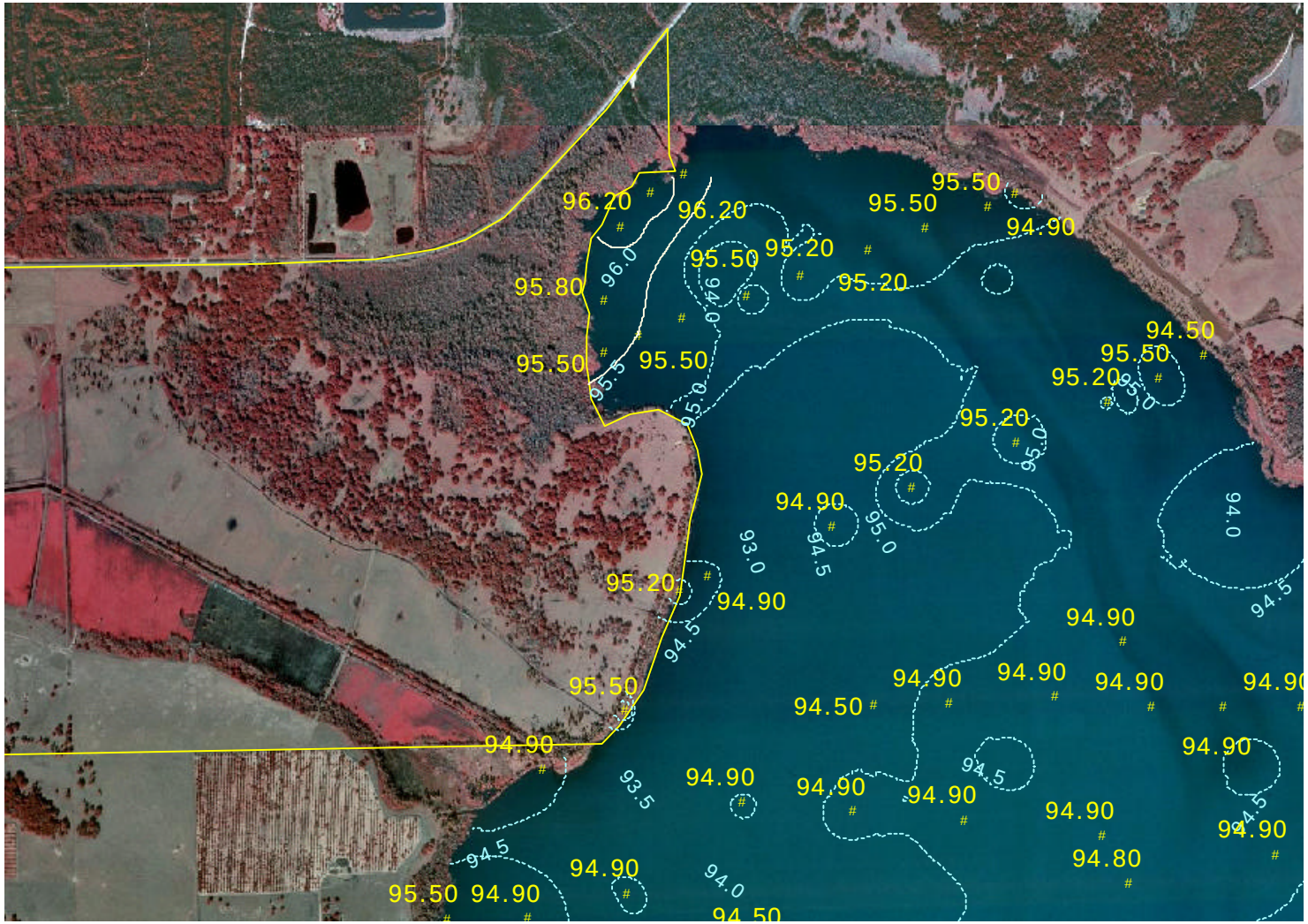


Figure 6
Areas Exposed at Lake Level = 94.5 ft

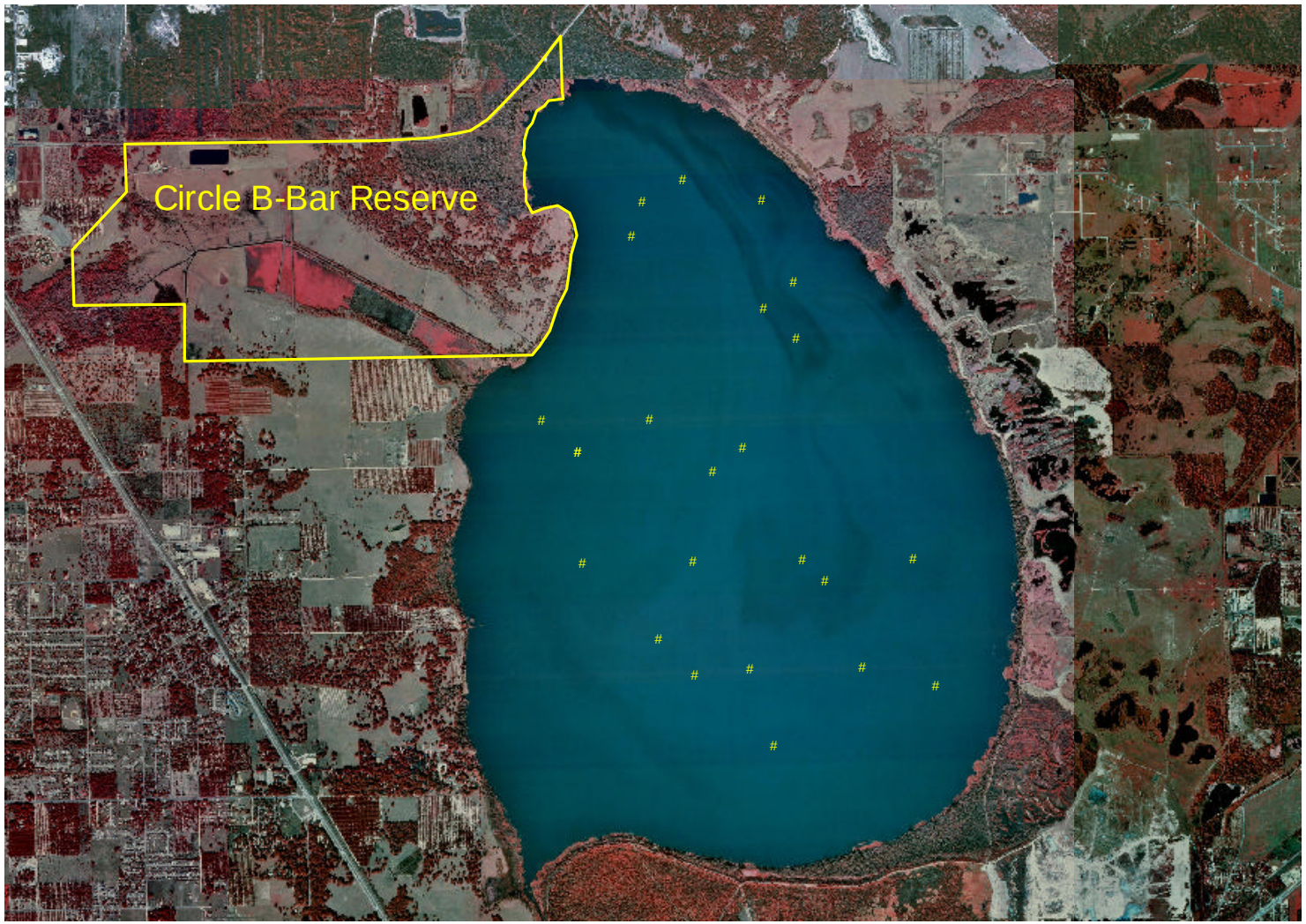


Figure 7
Site of Sediment Borings

Table 1
TCLP Maximum Contaminant Level[(1)]

Contaminant	EPA hazardous waste number	Maximum Concentration (mg/l) in Leachate for Toxicity Chracteristic
Metals		
Arsenic	D004	5.0
Barium	D005	100.0
Cadmium	D006	1.0
Chromium	D007	5.0
Lead	D008	5.0
Mercury	D009	0.2
Selenium	D010	1.0
Silver	D011	5.0
Pesticides		
Chlordane	D020	0.03
Endrin	D012	0.02
Heptachlor and its hydroxide	D031	0.008
Lindane	D013	0.4
Methoxychlor	D014	10.0
Toxaphene	D015	0.5
Herbicides		
2,4-D	D016	10.0
2,4,5-TP (Silvex)	D043	1.0
Volatiles		
Benzene	D018	0.5
Carbon Tetrachloride	D019	0.5
Chlorobenzene	D021	100.0
Chloroform	D022	6.0
1,2-Dichloroethane	D028	0.5
1,1-Dichloroethylene	D029	0.7
Methyl Ethyl Ketone	D035	200.0
Tetrachloroethylene	D039	0.7
Trichloroethylene	D040	0.5
Vinyl Chloride	D043	0.2
Semivolatiles		
o-Cresol	D023	200.0
m-Cresol	D024	200.0
p-Cresol	D025	200.0
Cresol	D026	200.0
1,4-Dichlorobenzene	D027	7.5
2,4-Dinitrotoluene	D030	0.13
Hexachlorobenzene	D032	0.13
Hexachlorobutadiene	D033	0.5
Hexachloroethane	D034	3.0
Nitrobenzene	D036	2.0
Pentachlorophenol	D037	100.0
Pyridine	D038	5.0
2,4,5-Trichlorophenol	D041	400.0
2,4,6-Trichlorophenol	D042	2.0

[(1)] Table 1, 40 CFR 126.24

Table 2
Sediment, TCLP and Elutriate Quality

Sample ID/ Source	Type of Sample	Total organic carbon	Ammonia	TKN	Nitrate-Nitrite	Ortho Phosphorus	Total phosphorus	Moisture content	Bulk specific gravity
		mg/g	ug/g	ug/g	ug/g		ug/g	%	
Zellars-Williams	Dry Sediment, Range	285 / 1.97	2180 / 39.3	20200 / 944	88 / <50		32000 / 303	96 / 26	1.46 / 1.01
NW (Polk County)	Dry Sediment			1350			432		
SW (Polk County)	Dry Sediment			1439			167		
SE (Polk County)	Dry Sediment			1390			164		
NE (Polk County)	Dry Sediment			1162			154		
1254_062925 (IMC-Agrico)	Dry Sediment		325	1027	20.55		0.58		
2854_072925 (IMC-Agrico)	Dry Sediment		368	787.6	21		0.82		
0446_082925 (IMC-Agrico)	Dry Sediment		570	1050	35		0.6		
0446_162925 (IMC-Agrico)	Dry Sediment		126	850	30		0.21		
1238_172925 (IMC-Agrico)	Dry Sediment		382	650	50		0.17		
2062_172925 (IMC-Agrico)	Dry Sediment		269	1350	30		0.22		
2854_182925 (IMC-Agrico)	Dry Sediment		485	6000	15		0.23		
1238_252925 (IMC-Agrico)	Dry Sediment		433	1450	35		0.46		
LH-1 (Zellars-Williams)	Vacuum Elutriate			18.1 mg/l		3.26 mg/l			
LH-2 (Zellars-Williams)	Vacuum Elutriate			17.0 mg/l		3.17 mg/l			
LH-3 (Zellars-Williams)	Vacuum Elutriate			35.6 mg/l		4.58 mg/l			
LH-4 (Zellars-Williams)	Vacuum Elutriate			20.5 mg/l		2.46 mg/l			

Sample ID/ Source	Type of Sample	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
		ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g
Zellars-Williams	Dry Sediment, Range	20 / ---	412 / 12	<16 / ---	166 / <78	<93 / ---	0.06 / ---	<50 / ---	<39 / ---
NW (Polk County)	Dry Sediment								
SW (Polk County)	Dry Sediment								
SE (Polk County)	Dry Sediment								
NE (Polk County)	Dry Sediment								
1254_062925 (IMC-Agrico)	Dry Sediment	6.9		0.58	33.3	22			
2854_072925 (IMC-Agrico)	Dry Sediment	3.9		0.38	33.2	9.7			
0446_082925 (IMC-Agrico)	Dry Sediment	9		BDL	27	10			
0446_162925 (IMC-Agrico)	Dry Sediment	BDL		BDL	48	BDL			
1238_172925 (IMC-Agrico)	Dry Sediment	2		BDL	31	11			
2062_172925 (IMC-Agrico)	Dry Sediment	1		BDL	69	2			
2854_182925 (IMC-Agrico)	Dry Sediment	6		BDL	81	6			
1238_252925 (IMC-Agrico)	Dry Sediment	3		BDL	59	6			
NW (Polk County)	Sediment TCLP	0.003 mg/l	<0.1 mg/l	<0.005 mg/l	<0.04 mg/l	0.006 mg/l	<0.0001 mg/l	<0.002 mg/l	<0.005 mg/l
SW (Polk County)	Sediment TCLP	<0.001 mg/l	<0.1 mg/l	<0.005 mg/l	<0.04 mg/l	0.006 mg/l	<0.0001 mg/l	<0.002 mg/l	<0.005 mg/l
SE (Polk County)	Sediment TCLP	0.002 mg/l	<0.1 mg/l	<0.005 mg/l	<0.04 mg/l	0.006 mg/l	<0.0001 mg/l	<0.002 mg/l	<0.005 mg/l
NE (Polk County)	Sediment TCLP	0.001 mg/l	<0.1 mg/l	<0.005 mg/l	<0.04 mg/l	0.005 mg/l	<0.0001 mg/l	<0.002 mg/l	<0.005 mg/l

Physical Characteristics of Sediments

The physical characteristics of the sediments are key to the effectiveness of any removal program. The behavior of submerged sediments will determine whether they can be effectively dredged, and the rate of in-situ drainage and desiccation will determine if conventional earthmoving will be effective. Settling and drying results reported by Zellars-Williams (1987) are given in **Table 3**. The results indicate that a constant air-dried weight loss of approximately 90 percent was achieved in all cases. Equilibrium weight was achieved in two weeks in all cases and was accompanied by an 85% decrease in volume. These drying results were determined using duplicate 5-kg samples air dried in 10-cm pans.

Table 3
Settling and Drying Characteristics of Sediments

	Settling Test Results				Drying Results		
Sediment ID	Initial Solids Content (%)	Final Solids Content (%)	Settling Duration (hr)	Height @ 80 hrs / Height @ 240 hrs	Air-Dry Weight Loss (%)	Residual Moisture (%)	Volume Change (%)
LH1	3.9	8.7	578*	99%	90	6.29	85
LH2	3.7	7.8	578*	93%	92	6.25	84
LH3	3.7	6.7	578*	93%	94	8.94	86
LH4	2.6	4.2	578*	82%	95	11.80	87
S-1	1.4	12.6	216**	---	---	---	---
S-5	1.4	7.1	48	---	---	---	---
S-10	1.5	8.8	216**	---	---	---	---

* Essentially at equilibrium after about 260 hours.
** Essentially at equilibrium after about 24 hours.

In a full-scale operation it also important to consider the settling rates of saturated sediments. Table 3 also contains the settling rates for sediments slurried with lake water. The results indicate that samples obtained from the southern part of the lake settle less than samples obtained from other locations. This result is attributable to the higher percentage of fine grain material (see **Table 4**). In all cases, the decant water was high in turbidity and nutrients, but low in total suspended solids. Generally, 80-100% of the total settling occurs within the first 80 hours.

Table 4 provides additional information about the sediment characteristics. Sediments average 38 percent solids and 18 percent organic matter. The latter ranges over an order of magnitude (4 - 42 percent) which probably reflects both true spatial differences within the lake as well as differences in coring techniques and / or depths. Grain size determinations are not standardized and different ranges have been employed by various investigators over the years. In both the Zellars-Williams and IMC-Agrico investigations, the distribution strongly favored the fine particles (40 percent less than 0.074mm and 42.4 percent less than 0.0025 mm).

Table 4
Physical Characteristics of Sediments

Sediment ID	Reference	In-situ Solids Contents (%)	% Solids	Organic Content (%)	Grain Size Distribiution (Weight % Retained)					
						>0.589 mm	0.208 - 0.589 mm	0.147 - 0.208 mm	0.074 - 0.147 mm	< 0.074 mm
LH1	Zelllars-Williams	8.7		20.8		9.8	31.6	25.5	21.0	12.1
LH2	Zelllars-Williams	7.2		21.0		1.2	31.3	14.4	32.2	20.9
LH3	Zelllars-Williams	5.5		30.3		6.4	26.0	7.7	17.0	42.9
LH4	Zelllars-Williams	3.5		42.5		1.0	4.1	1.2	9.7	84.0
S-1	Zelllars-Williams									
S-5	Zelllars-Williams			31.7						
S-10	Zelllars-Williams			21.6						
NW	Polk County		16.6							
SW	Polk County		33.1							
SE	Polk County		16.8							
NE	Polk County		46.1							
					>1.68 mm	0.5 - 1.68 mm	0.25 - 0.5 mm	0.125 - 0.25 mm	0.0025 - 0.125 mm	<0.0025 mm
1238_252925	IMC-Agrico				0.5	4.8	22.9	16.8	22.8	32.3
1254_062925	IMC-Agrico		41.86	11.45						
2854_062925	IMC-Agrico				1.5	2.7	8.4	8.8	12.2	66.3
1254_072925	IMC-Agrico				3.3	4.3	11.2	16.9	16.8	47.5
2854_072925	IMC-Agrico		55.41	8.41						
0446_082925	IMC-Agrico		42.9	11	0.7	2	17.2	10.2	16.4	53.5
0446_162925	IMC-Agrico		49.7	4	0.3	2.1	47.6	19.5	20.5	10
1238_172925	IMC-Agrico		49.1	5.74	0.6	1.7	12.2	12.4	22.5	50.6
2062_172925	IMC-Agrico		39.9	16.8	0.4	2.3	27.7	27.9	25.6	16.2
2854_182925	IMC-Agrico		33.4	9.98	0.7	2.2	7.5	8.9	17.6	63.1
1238_252925	IMC-Agrico		34.5	14.5						

(1) Loss on Ignition - Assumed Equivalent to % Organic

The sediment surface is very fluid when exposed and the uppermost sediment is only about 4-9% solids. Laboratory experiments incorporating increasing dilutions indicated that fluidity commences at 6-11 percent solids (Zellars-Williams, 1987). However, submerged sediments are capable of maintaining a 45-degree angle of repose. By contrast, once the sediments became exposed, the unsupported material collapsed and the angle was typically less than 2 degrees (Zellars-Williams, 1987).

The effect of high angle of repose for submerged sediments is that material will not flow readily into a suction dredge, resulting in a loss of solids entrainment. On the other hand, if the area is de-watered in advance of dredging, the exposed material collapses and enters the dewatering stream. IMC-Agrico (1998) summarized the problem as thus:

> *The fatal flaw, from a mining standpoint, was the sediment's fluidity. During a high volume dewatering phase, large quantities of sediments would flow to the dewatering sump and be transported with the decant water. An unacceptable probability for significant water quality problems in the form of suspended solids would be created.*

Thus, for the drawdown / excavation alternative, the primary problem will be to dewater and dry the sediments sufficiently to allow mechanical removal of sediments with high solids content.

Action Items Required

Channel Improvements

The present controlling elevation of Lake Hancock may be as high as 96.4 feet. The top of the sediments adjacent to the Reserve is on the order of 93-95 feet. In order for the sediments in this area to dry sufficiently for conventional excavation, the groundwater level must be lower than the base of the sediments. If the top of the sediments are at 95 ft and are 3 ft thick, then the lake and groundwater must be at 92 ft or less for the sediments to drain. While active drawdown is not a recommended component of this action plan, if such action were contemplated in the future, the controlling depths will need to be near the invert of structure P-11 (91.7 ft). Excavation of sediment build-up in South Saddle Creek to this elevation would be easier when lake level is low. Excavation in this area will also improve conveyance of flood flows should a major storm occur. The County should request that SWFWMD remove the old structure upstream of P-11 and perform maintenance dredging in South Saddle Creek.

Permits

Prior to excavation, the following permits must be acquired:

- Florida Department of Environmental Protection (FDEP) - Bureau of Aquatic Plant Management (Chapter 62C-20)

- U.S. Army Corps of Engineers Clean Water Act Section 404 permit
- NPDES construction permit (Notice of Intent)

In addition, an archeological survey is advisable prior to excavation.

The size of the demonstration project has been selected to simplify permitting. Thirty nine hundred (3,900) cubic yards was chosen to conform to the ACOE NWP27 permitting criteria and to expedite review. Unlike the Individual Permit, the NWP27 requires only agency approvals and eliminates the 30-day pubic notice. The area of earth moving exceeds the 1-acre threshold and a Phase II NPDES construction permit will be required. An Environmental Resource Permit may be required from SWFWMD to perform this work. Prior to excavation, cores will be collected and tested for the TCLP parameters to ensure that disposal is not constrained.

According to Federal law, wildlife included on the threatened and endangered list must be protected. These include alligators, wading birds, and eagles. No terrestrial species listed as threatened or endangered are expected to be affected by this project.

Drought Monitoring

Recently Florida Fish and Wildlife Conservation Commission (FFWCC) expressed a concern that during a lake drawdown dense stands of vegetation will form on the exposed lake bottom. When the water levels return, FFWCC is concerned those vegetated mats will loosen from the bottom and disrupt both bottom habitat and navigation. However, drawdowns are frequently done to control undesirable emergent vegetation (EPA, 1990) and aquatic plant density often increases (Williams et. al.) following re-flooding. Williams et al (ibid.) reviewed 20 lake projects in Florida that included drawdown as a restorative procedure. Floating vegetation mats were not noted for any of these studies. Thus, undesirable vegetation, if controlled during the drawdown, should not be an issue when the area is re-flooded.

Therefore, it is suggested that low level aerial flights be conducted monthly to record (still photography and / or video recordings) the changes from the seasonal high water shoreline out to 50-100 yards into the lake. Flights would begin at the same starting point each month and end at the project, with a particular focus to the Reserve shoreline. A transect should be established perpendicular to the high water shoreline and the type and height of vegetation should be recorded out to the waters edge to gage the rate of growth and extent of coverage that would occur during a deliberate and extended drawdown.

In addition to documenting the changes in vegetation, these over-flights also provide valuable information about the location and exposure duration of sediments. If a deliberate drawdown and excavation were planned for the future, the information gained from the over-flights could be used to develop an excavation schedule. For the present demonstration project, the information can be used to select an appropriate excavation site adjacent to the Reserve.

A similar transect should be established to measure the rate of water loss within the exposed sediments. The coring station(s) should be established in the organic sediment near the seasonal high water shoreline and monitored for percent solids at approximately monthly intervals. As the water level continues to fall, additional coring stations should be added near the new shoreline. Each month, the shoreward stations will be sampled as well as the new shoreline location resulting in a time series at each coring location as the lake continues to decline. To the extent possible, samples should be obtained at approximately one-foot depth intervals in the organic sediments. These values should be compared with groundwater declines obtained from a piezometer established along an upland extension of the sediment transect. The cost of determining percent solids is approximately $10 per sample.

At least two representative depth integrated cores should be recovered for toxicity testing according to USEPA Method 1311 (TCLP) to determine if the recovered material is classified as hazardous waste. The cost of TCLP (metals and organics) is estimated at $750/sample. Grain size analysis should also be performed on these samples (Estimated cost $50-75/sample depending on whether the hydrometer method is required). Monthly sediment sampling will produce an estimated 36 samples (4 locations, 3 depths and 3 sampling episodes). The laboratory costs for percent solids and granulometry for 36 samples and 2 samples for TCLP parameters is estimated at $4,850.

Engineer's Preliminary Opinion of Probable Construction Cost

The demonstration plan proposed includes the following construction activities:

- An excavation of bottom sediment along an area 350 LF of shoreline and 100 LF perpendicular to the shoreline.
- Disposal of sediments in bermed drying cell located on the Reserve.
- Access road from shoreline to disposal site that will later enhance the recreational value of the lake.
- Regrading the road from Highway 540 for construction vehicles and equipment to access the project site.
- Earthen ramps over the lake.
- Additional costs for design, permitting, geotechnical engineering, survey and services during construction, including inspection.
- Additional costs for laboratory testing.

Excavation of Sediment

The maximum depth of excavation is limited to 3 feet by the Aquatic Plant Management permit, which results in the removal of 3,900 y^3 of material. Material will

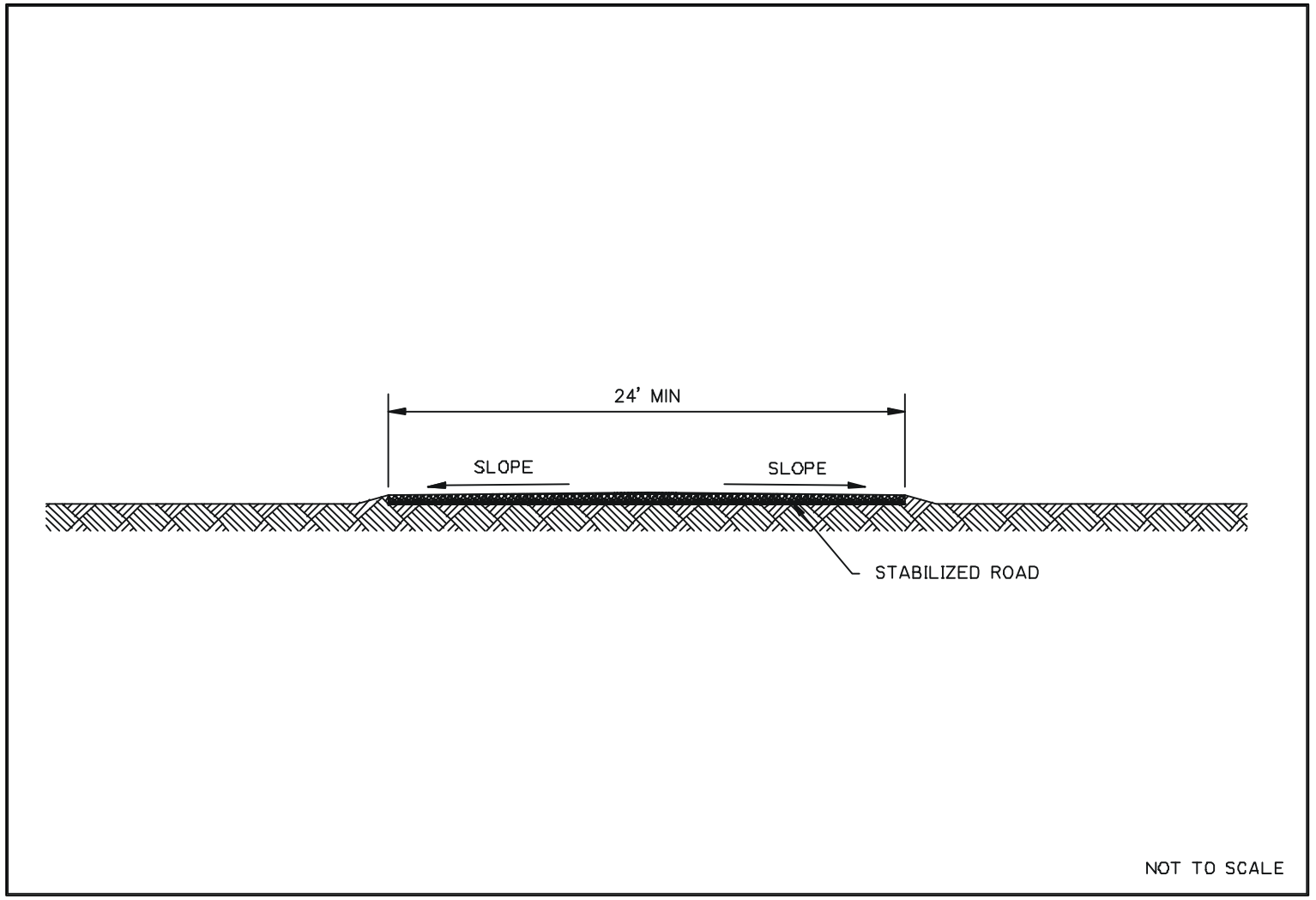


Figure 8
Disposal Area Access Road Cross Section

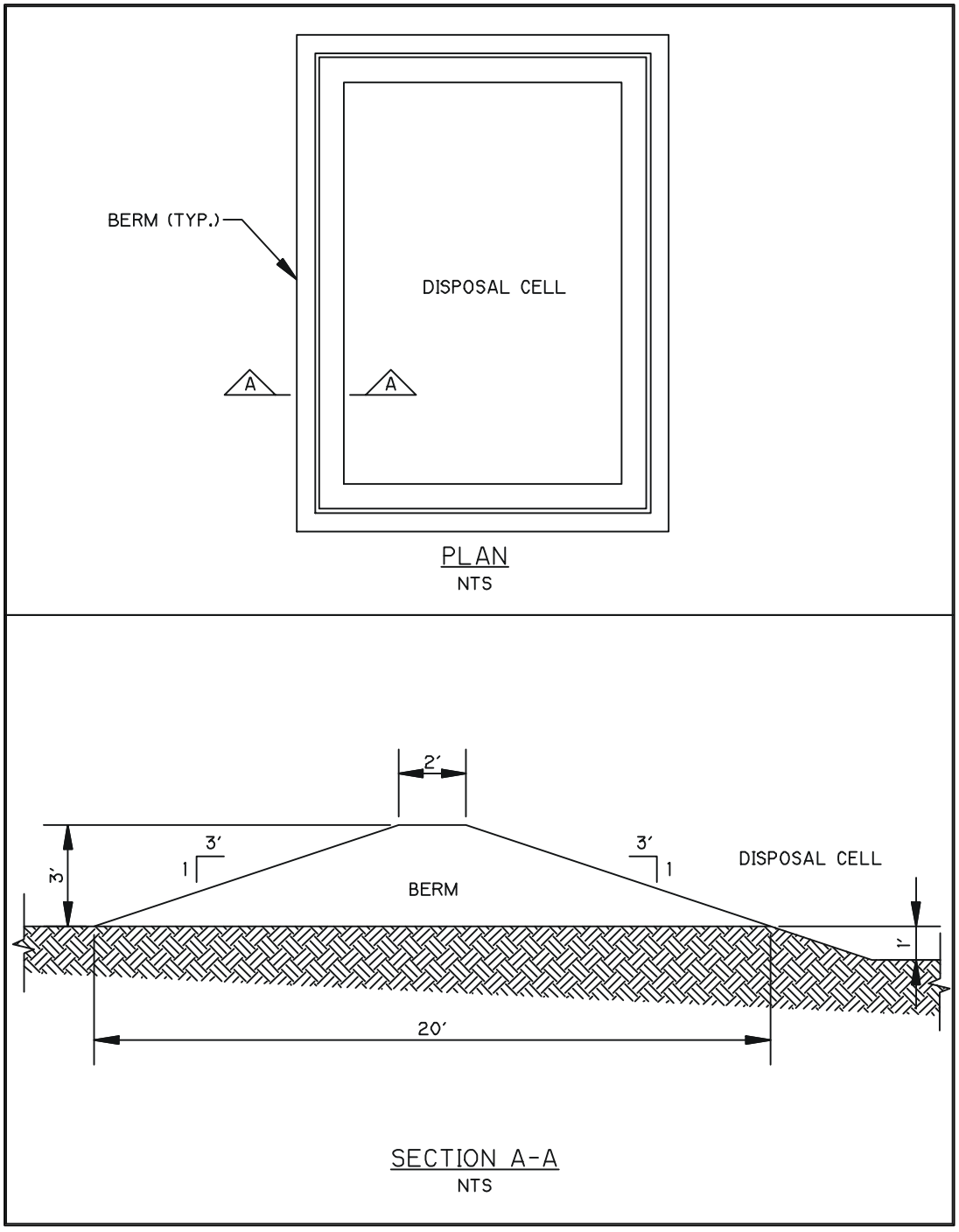


Figure 9
Cell Disposal Area Plan and Cross Section

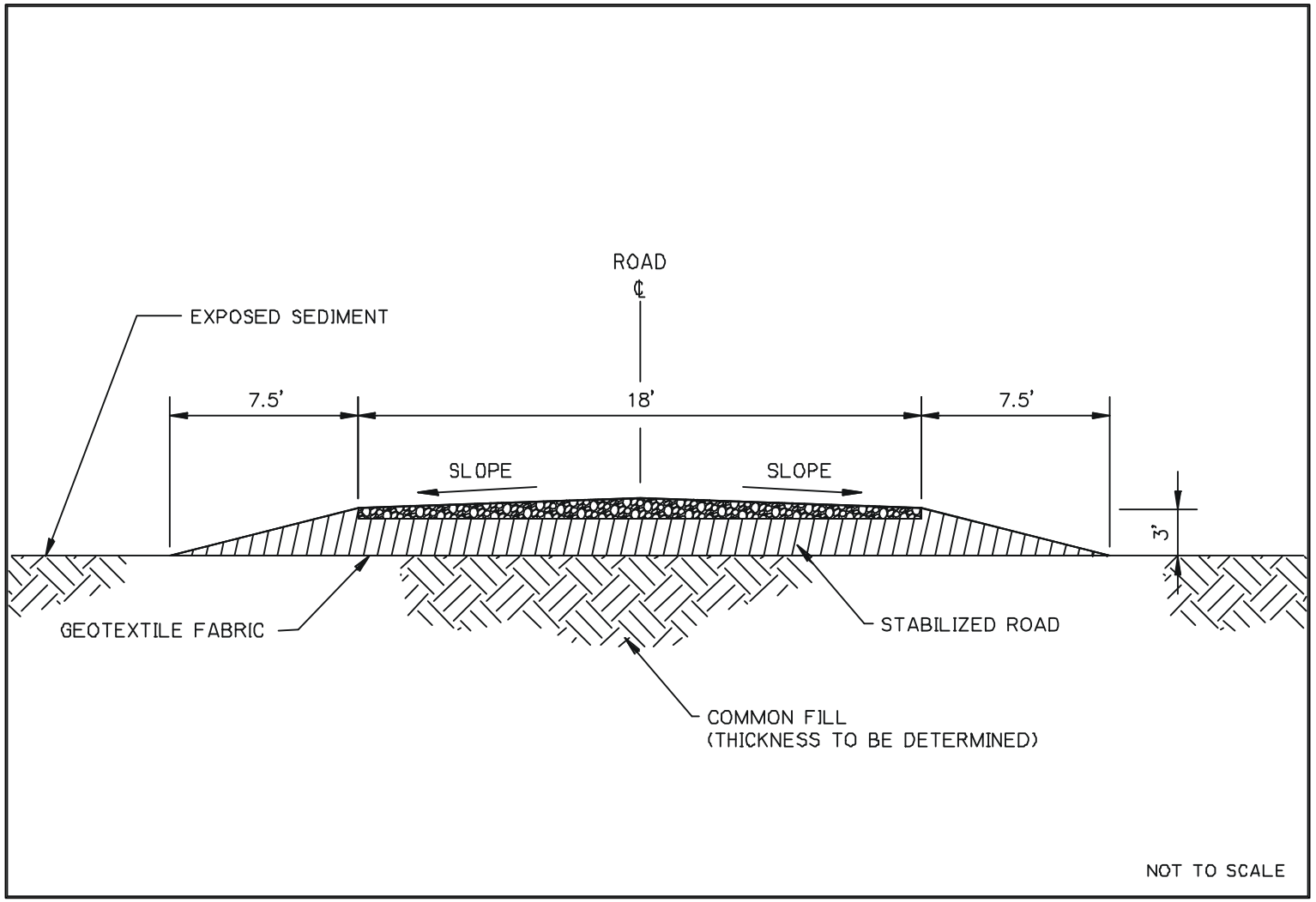


Figure 10
Project Area Excavation Ramp Cross Section

be excavated either by front-end loader or dragline. Excavated material will be stockpiled in a 1.0-acre bermed cell located on-site.

Estimated Excavation Costs

The cost of the excavation demonstration project is given in **Table 5** and totals approximately $247,275. **Figures 8-10** provide the cross sections of the facilities.

Alternatives to Conventional (Mechanical) Sediment Removal

As described above, removal of sediments using conventional earth-moving equipment will be possible only if the sediments have dried sufficiently. Should the natural Spring 2001 drawdown be insufficient to permit conventional excavation methods, i.e. front-end-loaders, track-hoes, backhoes, draglines, it is recommended that dredging be the preferred method for sediment removal. Since the purpose of the present technical memorandum is to capitalize on the on-going drought by investigating conventional sediment removal "in the dry" or at least not under water, the level of effort describing dredging options has not yet been investigated as thoroughly as conventional removal. That option will be explored in greater depth as the Restoration Management Plan is developed. Another aspect of the plan would be to evaluate the success of planting emergent flora as the shoreline recedes and sediment becomes exposed. Because of the FFWCC concerns about vegetation floating when water levels rise, it is recommended that this option be further discussed with FFWCC if implementation is recommended.

Summary of Recommended Activities

In order to prepare for an excavation demonstration project in May, 2001 it is recommended that Polk County commence the following activities as soon as practicable.

- Prepare and submit permits.
- Conduct archeological survey.
- Arrange for aerial surveillance and commence over-flights.
- Establish a piezometer upland of the excavation site.
- Collect and analyze two cores for TCLP parameters.
- Commence monitoring the moisture content of sediments adjacent to the excavation site as the lake recedes.
- Request SWFWMD remove sedimentation and channel obstructions in lower Saddle Creek down to P-11 invert.
- Arrange for excavation equipment for mobilization in May.

Table 5
Lake Hancock Demonstration Project
Engineer's Preliminary Opinion of Probable Construction Cost

Component	Quantity	Unit	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Cost	1	acre	5,800	5,800
PHASE 2 – Site Preparation				
Clear and Grub	1	acre	3,000	3,000
Cell excavation	1,600	cy	2.50	4,000
Berm Construction (onsite soil)	2,500	cy	3.50	8,750
Berm Stabilization (sodding)	1,800	sy	1.50	2,700
Cell Liners (if required)	30,000	sf	0.45	13,500
			Phase 2 Subtotal	*31,950*
PHASE 3 – Sediment Removal				
Excavated Volume	3,900	cy	7.50	29,250
Aluminum Barrier Wall	200	lf	*212*	42,400
Wetland Planting	1	acre	5,000	5,000
			Phase 3 Subtotal	*76,650*
			Phases 2 and 3 Subtotal	*108,600*
Construction Contingency	25%			27,150
Mobilization, Bonds, Insurance	L.S.			50,000
			Construction Cost Subtotal	*185,750*
PHASE 4 – Engineering				
Design, Permitting, Bidding	15%	Construction		27,863
Construction Services and Inspection	10%	Construction		18,575
Geotechnical/Survey	5%	Construction		9,287
			Total Estimated Cost	**$247,275**

References

IMC-Agrico, 1998. Correspondence from Mike Hutchens (IMC-Agrico Superintendent Reserves and Planning) to Pat Fricano (Florida Department of Environmental Protection Environmental Manager) dated December 9, 1998.

Zellars-Williams, 1987. Final Report. Lake Hancock Restoration Study. Prepared for Florida Institute of Phosphate Research. December, 1987.

Polk County, 2000. Correspondence from Robert Kollinger (Polk County Water Resources Engineer) to Daniel Glaser (Camp Dresser & McKee Engineer) dated September 25, 2000.

EPA, 1990. Monitoring Lake and Reservoir Restoration. Technical Supplement to The Lake and Reservoir Restoration Guidance Manual EPA 440/4-90-007.

Williams, V.P., E. J. Moyer and D. Moxley, 1992. Lake Restoration for Aquatic Habitat and Fisheries Improvement in Florida. In Proceedings of the North American Lake Management Society First Annual Southeastern Lakes Management Conference. March 19-21, 1992. Pp. 49-63.

Appendix D

Cost Estimate for Alum Sediment Inactivation for Lake Hancock

ERD ENVIRONMENTAL RESEARCH & DESIGN, INC.

WATER QUALITY ENGINEERING
3419 TRENTWOOD BOULEVARD ■ SUITE 102 ■ ORLANDO, FLORIDA 32812
TELEPHONE: (407) 855-9465 FAX: (407) 826-0419

August 6, 2001

Mr. Daniel E. Glaser, P.E.
Camp Dresser & McKee, Inc. (CDM)
1715 N. Westshore Blvd., Suite 875
Tampa, FL 33607
VIA Fax: 813/288-8787

RE: Cost Estimate for Alum Sediment Inactivation for Lake Hancock

Dear Dan:

As you requested, I have prepared a preliminary cost estimate for sediment inactivation of phosphorus release in Lake Hancock. Preparation of this estimate required estimation of a number of parameters regarding Lake Hancock and the existing sediment characteristics, including sediment concentrations of total available phosphorus (defined as the sum of mean saloid-bound and iron-bound phosphorus in the sediments), estimation concerning the depth from which phosphorus can be recycled from the sediments in Lake Hancock to the overlying water column, mean total phosphorus concentrations in the water column of the lake, as well as the optimum Al:P ratio for inactivation of sediments in the lake. The chemical cost of $0.30/gallon for alum includes chemical costs and transportation.

The analysis indicates that inactivation of sediments in the top 0-20 cm of Lake Hancock will require approximately 1,962,529 gallons of alum at an estimated cost of approximately $2,655,253. Planning and mobilization fees are estimated to be approximately $5000, with an application cost of approximately $900/tanker for application of the alum to the surface of Lake Hancock. The overall estimated fee for the sediment inactivation process is approximately $4.4 million. A series of calculations is attached which summarize the estimated application costs for the alum treatment.

Please feel free to contact me directly if you have any questions concerning the attached analysis or cost estimate.

Sincerely,

Harvey H. Harper, Ph.D., P.E.
President

Job No. 00-027
Enclosure: Sediment Inactivation Calculations

LAKE HANCOCK

EVALUATION OF SEDIMENT INACTIVATION REQUIREMENTS

Sediment inactivation requirements will be based upon the amount of saloid and iron-bound phosphorus in the top 20 cm (8 inches) of the lake sediments. Based on previous analyses performed by ERD on sediments with similar characteristics, the total available phosphorus (equal to the sum of saloid + iron-bound phosphorus) in the surficial sediment layer is estimated to be 135 μg/g on a wet weight basis.

Mean In-Place Sediment Density in the 0-20 cm Layer = 1.5 g/cm^3 wet sediment

1. Estimation of Sediment Volume to be Treated

Typically, sediment inactivation is designed to target the total available phosphorus in the top 10 cm of sediments since this is assumed to be the maximum depth from which phosphorus can migrate by diffusion under anoxic conditions. However, since Lake Hancock is also impacted by wind resuspension of sediments, the depth of sediment phosphorus availability is assumed to extend to 20 cm.

Assuming that the top 20 cm of sediments will be inactivated, the volume of sediments to be treated is calculated as follows (assuming a lake surface area of 4520 acres):

Volume of Sediment to be Treated

$$4520\,ac\ x\ \frac{43{,}560\,ft^2}{}\ x\ \frac{1\,m^2}{(3.28\,ft)^2}\ x\ \frac{(100\,cm)^2}{m^2}\ x\ 20\,cm\ x\ \frac{1\,liter}{1000\,cm^3}$$

$$= 3{,}660{,}232{,}004\ liters\ of\ sediment$$

2. Estimation of Mass of Total Phosphorus to be Treated

The alum treatment must provide sufficient alum to inactivate the bottom sediments and to precipitate existing phosphorus from the water column. Calculations of the amount of total phosphorus in the sediments and water column are given below:

A. Available phosphorus mass in sediments =

$$3{,}660{,}232{,}004\ liters \times \frac{1000\ cm^3}{liter} \times \frac{1.5\ g\ wet\ sediment}{cm^3} \times \frac{135\ \mu g\ P}{g\ wet\ wt} \times \frac{1\ g\ P}{10^6\ \mu g\ P}$$

$$= \underline{741{,}196{,}981\ g\ available\ P}$$

B. Available phosphorus mass in water column (based on a mean water depth of 3.55 ft) is calculated by:

$$Lake\ Volume = 4520\ ac \times 3.55\ ft \times \frac{43{,}560\ ft^2}{acre} \times \frac{7.48\ gal}{ft^3} \times \frac{3.785\ liter}{gal}$$

$$= \underline{1.98 \times 10^{10}\ liters}$$

Assuming a mean total phosphorus concentration in the water column of 500 μg/l (1998-1999 mean), the mass of total phosphorus in the water column is equal to:

$$Phosphorus\ in\ Water\ Column = 1.98 \times 10^{10}\ liters \times \frac{500\ \mu g\ P}{liter} \times \frac{1\ g\ P}{10^6\ \mu g} = \underline{9{,}894{,}461\ g\ P}$$

Based on the requirements for the sediments and the water column, the total phosphorus to be treated =

$$741{,}196{,}981\ g\ P + 9{,}894{,}461\ g\ P = \underline{751{,}091{,}442\ g\ P}$$

Moles of phosphorus to be treated =

$$751{,}091{,}442\ g\ P\ x\ \frac{1\ mole}{31\ g} = \underline{24{,}228{,}756\ moles\ P}$$

3. Estimation of Aluminum Required for Inactivation

Assuming an Al/P ratio of 3:1 is required for inactivation of the sediments and water column:

$$24{,}228{,}756\ moles\ P\ x\ \frac{3\ moles\ Al}{mole\ P}\ x\ \frac{27\ g\ Al}{mole}\ x\ \frac{1\ kg\ Al}{1000\ g\ Al} = \underline{1{,}962{,}529\ kg\ Al}$$

$$1{,}962{,}529\ kg\ Al\ x\ \frac{1000\ g}{kg}\ x\ \frac{1\ lb\ Al}{454\ g\ Al}\ x\ \frac{1\ lb\ alum}{0.044\ lb\ Al}\ x\ \frac{1\ gal\ alum}{11.1\ lb\ alum}$$

$$= \underline{8{,}850{,}843\ gallons\ of\ alum}$$

$$\underline{1967\ Tankers\ of\ Alum}\ (4500\ gallons\ each)$$

4. Average Lake Dose of Alum

Alum Dose = mass of aluminum applied/lake volume =

$$8{,}850{,}843\ gal\ alum\ x\ \frac{11.1\ lb\ alum}{gal\ alum}\ x\ \frac{0.044\ lb\ Al}{lb\ alum}\ x\ \frac{454\ g}{lb}\ x\ \frac{1000\ mg}{g}$$

$$x\ \frac{1}{1.98\ x\ 10^{10}\ liters} = \underline{99\ mg\ Al/liter}$$

5. Estimation of Application Costs

A. Chemical Costs (including transportation):

$$8{,}850{,}843\ gallons\ alum\ x\ \frac{\$0.30}{gallon} = \$2{,}655{,}253$$

B. Planning and Mobilization (Fee includes planning, mobilization, pre- and post-treatment testing = $5,000

C. Application Fee (includes set-up, application, equipment rental, treatment lab testing):

$$1967\ tankers\ x\ \frac{\$900}{tanker} = \$1{,}770{,}300$$

D. Total Cost = $4,430,553

Addendum to Cost Estimate Based on $0.39/gallon of Alum

5. Estimation of Application Costs

A. Chemical Costs (including transportation):

$$8{,}850{,}843 \text{ gallons alum} \times \frac{\$0.39 \quad \cancel{\$0.30}}{gallon} = \cancel{\$2{,}655{,}253} \; 3{,}451{,}829$$

B. Planning and Mobilization (Fee includes planning, mobilization, pre- and post-treatment testing = $5,000

C. Application Fee (includes set-up, application, equipment rental, pre-treatment lab testing):

$$1967 \; tankers \times \frac{\$900}{tanker} = \$1{,}770{,}300$$

D. Total Cost = $~~4,430,553~~ 5,227,129

Appendix E

Optimization of the Recirculation Treatment Wetland

CDM

Appendix E
Optimization of the Recirculation Treatment Wetland

Greater load reduction to Lake Hancock by a recirculating wetland is most likely needed to justify application of this technology for lake restoration. The estimate provided above was based on a conservative long-term phosphorus removal efficiency of 30 percent (the demonstration results indicate total phosphorus removal efficiency as high as 67 percent). The phosphorus removal efficiency of the lake recirculating treatment wetland should be maximized to enhance lake restoration. Therefore, the optimal operational conditions of the system for phosphorus removal should be determined.

Coveney et al. (2000) compared the actual removal of phosphorus in the Lake Apopka demonstration marsh flow-way with model predictions and used modeled performance to examine optimal operational conditions. The first order area-based "k-C*" model (Kadlec and Knight, 1996) was used to estimate the removal of phosphorus in the wetland and to examine performance at phosphorus loading rates (i.e. HLRs) higher than those achieved in the demonstration project. The model describes the decrease in concentration of a constituent in the wetland from the level at the inlet towards a background level C* set by internal processes, rainfall or other factors (Kadlec, 1999).

Results from the demonstration marsh flow-way indicate that the efficiency of total phosphorus removal varied between 30 percent and 67 percent and showed no relationship to phosphorus loading rate. The model predicts a decline in removal efficiency with increases in phosphorus loading (i.e. increased HLRs) but the actual measured rate of phosphorus removal increased with phosphorus loading. The potential rate of phosphorus removal in the wetland is critical to the successful operation of the full-scale project. Therefore, the model was used to project a maximal rate of phosphorus removal of approximately 4 $g/m^2/yr$ at phosphorus loading of 10 to 15 $g/m^2/yr$ (HLR 60 to 90 m/yr or 16.4 to 24.6 cm/day). Results from the demonstration marsh flow-way indicated that the actual rates of phosphorus removal were higher (approximately 8$g/m^2/yr$) than predicted, indicating that higher phosphorus removal rates than those predicted by the model are possible. Therefore, Coveney et al. (2000) indicate that further operation of the wetland at high hydraulic and phosphorus loading is still necessary to determine optimal operational conditions. These results suggest that higher hydraulic loading rates will be appropriate for a lake recirculating treatment wetland to maximize phosphorus removal from Lake Hancock. Kadlec (1999) concluded, based on hydraulic considerations and on phosphorus removal performance, that operation of a wetland at a HLR greater than approximately 100 m/yr (27.4 cm/day) is not feasible.

In order to determine optimal operational conditions for phosphorus removal the design criteria can be evaluated in an operational program. Higher hydraulic and phosphorus loading can be tested by increasing the HLR (i.e. increasing the number

of lake volumes cycled through the wetland). If the flow rate was increased to approximately three lake volumes per year (1.89 m^3/sec) and the same wetland area (301 acres) and depth (0.6 m) were utilized the HLR would increase to 13.4 cm/day and the phosphorus removal rate would increase to 7.3 g/m2/yr (the HRT would decrease to 4.5 days). This HLR is lower than used to simulate maximal phosphorus removal at high phosphorus loading for the demonstration project and the predicted phosphorus removal rate is similar to that achieved at the demonstration project.

With this scenario and an average inflow phosphorus concentration of 0.501 mg/l, the full-scale flow-way marsh with 30 percent phosphorus removal efficiency is predicted to remove 8960 kg P (8.96 MT P) per year from Lake Hancock. This represents 25 percent of the total external load (35.1 MT P) to the lake, and 12 percent of the combined external and internally recycled load (74.5 MT P) to the lake, without sediment removal. If greater than 30 percent phosphorus removal efficiency occurs then an even greater percentage of the load would be removed. In addition, phosphorus removal may be enhanced through implementation of inexpensive phosphorus control technologies, as described above, such as chemical addition to the wetland inflow with sedimentation in the wetland, direct chemical application to the wetland, and chemical addition and sedimentation prior to wetland application. A good understanding of influent and wetland water chemistry and wetland soil chemistry are necessary to determine appropriate dosage requirements.

The Lake Apopka marsh flow-way demonstration project was performed to evaluate the relationships between nutrient removal, flow and loading; the hydraulic behavior of a wetland filter; and the development and management of vegetation (Coveney et al., 2001). The operational results were used for design and operation of the full-scale lake recirculating treatment wetland. In addition to the use of higher HLRs other hydraulic design components were determined. For example, the resistance to flow shown by vegetation and by new flocculent sediments was one reason why multiple cells in parallel were constructed in the full-scale project. The cells have lower aspect ratios than the demonstration wetland and multiple cells allow independent operation and maintenance.

Minimal channelization and short-circuiting were required to meet or exceed target removal efficiencies for TSS and phosphorus. Multiple inlet and outlet flows were distributed evenly at the end of the cells in the full-scale design. Creation of deep areas perpendicular to flow were included in the full-scale project design to alleviate channelization through interception and redistribution of the flow paths (Coveney 2001). These deep water flow redistribution areas provide waterfowl and fish habitat. As indicated above, leaching of soluble phosphorus in the demonstration wetland occurred when the soils were first inundated and again when the new sediments were dried for consolidation. Methods used to deal with the leaching of soluble phosphorus in the full-scale project include application of a soil amendment to bind phosphorus prior to flooding, recycling of initial flood waters through adjacent wetland cells, and minimizing the frequency and duration of drawdowns (Coveney et al., 2001).

A lake recirculating treatment wetland demonstration project could be implemented to evaluate the most cost effective method to maximize the phosphorus removal efficiency of a full-scale Lake Hancock recirculating treatment wetland and to further evaluate wetland treatment technologies for the long-term restoration of Lake Hancock. With an appropriate experimental design the demonstration project can provide design criteria for full-scale implementation. The overall experimental rationale consists of first establishing the appropriate range for wetland treatment and chemical treatment design criteria for the demonstration project. This will provide design criteria at the demonstration scale to determine the most effective combination of chemical and wetland treatment for full-scale design. The treatment wetland design criteria include HLR, HRT, and operating water depth as a function of phosphorus treatment performance. The chemical addition design criteria include method of coagulation / sedimentation, coagulant type and dosing rate, polymer type and dosing rate (if applicable), and mixing and flocculation regime, as a function of phosphorus treatment performance. The lake recirculating treatment wetland demonstration project must be sized to provide useful treatment performance data for extrapolation to larger scale treatment wetlands that will be implemented as part of long-term lake restoration activities.

The first step in evaluating chemical addition technologies is to perform jar tests to determine the specific coagulant and pH adjustment requirements as well as dosage and cost-effectiveness. The selection of the coagulant will be determined in terms of the ability to remove phosphorus and improve floc settleability. Then demonstration scale matrix testing can be performed to determine the most appropriate method of coagulation / sedimentation that optimizes the overall treatment process, including chemical addition to the wetland inflow with sedimentation in the wetland, direct chemical application to the wetland, and chemical addition and sedimentation prior to wetland application. These results can be used to develop design criteria and the related capital and O&M costs necessary for process evaluation for full-scale design. If chemical addition and sedimentation is provided prior to wetland application, then excessive solids carry over from the sedimentation process to the wetlands may need to be prevented. If too many particles of coagulated materials reach the treatment wetland, physical actions, biochemical transformations or chemical reactions could result in excessive release of phosphorus. Chemical conditioning of the coagulated material and the sedimentation process regime can be optimized so that sedimentation of the coagulated materials is as complete as possible.

Although the wetland treatment system will be designed to maximize phosphorus removal, the design will establish a hydroperiod to encourage and maintain valuable wetland communities and wildlife habitat. Understanding of the hydrology and establishment of the hydroperiod (depth and duration) are critical for vegetation development in a wetland treatment system. In order to provide the site-specific design of the wetland treatment system a water balance and wetland hydrologic analyses will be performed.

An annual water budget for the selected site will be determined based on published and calculated data including rainfall, evapotranspiration, runoff, infiltration, and groundwater and surface water flows. The hydrologic analysis will be performed to quantify the surface / groundwater interaction. The water balance analysis will quantify budget components as a function of the meteorological, hydrogeological, and soil conditions on site. These results provide the basis for the hydrologic design model. A simplified groundwater / surface water flow model based on the stratigraphy and associated hydraulic properties will be used to determine the hydrologic design of the wetland treatment system including the appropriate discharge configuration. The hydrologic design model coupled with a water budget analysis and the design criteria will be used to determine the site-specific design parameters to establish the appropriate wetland vegetation communities. A maintenance program may be necessary to address nuisance species and public use can also be incorporated into the design if appropriate.

Appendix F

Basis for Establishing the Relative Increase in Wetland Acreage for Each Applied Lake Restoration Technique

Appendix F
Basis for Establishing the Relative Increase in Wetland Acreage for Restoration Application Techniques

		Estimated Acres	Points	
A	Whole Lake Hydraulic Dredging with Chemical Treatment of Decant Water		1.0	
B	Whole Lake Hydraulic Dredging with Chemical and Wetland Treatment of Decant Water	55	1.5	Section 4.2.4.2. 7.8E3 m3/d, k=10, Ci=0.8, Co=0.4, Ca=0.06
C	Whole Lake Hydraulic Dredging with Chemical, Wetland and Biomass Harvest of Decant Water	83	1.8	Use 1.5 times the wetland size needed to treat dredge decant water.
D	Whole Lake Mechanical Excavation, Less Littoral Zone (20%)		1.0	
E	Hydraulic Dredging of Sediments (80% Area) Not Associated with Littoral Zone, plus Chemical and Wetland Treatment of Decant Water	55	1.5	Similar to 'B'
F	Whole Lake In-Situ Chemical Inactivation of Phosphorus		1.0	
G	Lake Drawdown (20%) with In-Situ Drying. Mechanical Excavation of Littoral Zone. Planting and Vegetation Management of Littoral Zone	904	10.0	20 % of 4,519 acres
H	Re-Circulating Treatment Wetland (2 Lake Volumes/year)	301	4.0	See Section 4.2.4.2. for discussion.
I	Wetland Treatment - Lake Lena Run Inflow	137	2.4	See Section 4.2.4.2. for discussion. 2.1E4 m3/d, k=10, Ci=0.348, Co=0.2, Ca=0.06
J	Wetland Treatment - Banana Creek Inflow	26	1.3	See Section 4.2.4.2. for discussion. 7.9E3m3/d, k=55, Ci=1.059 Co=0.2, Ca=0.06
K	Settling Pond with Chemical Treatment of North Saddle Creek Inflow		1.0	No Significant Habitat Value to Unvegetated Pond
L	Wetland Treatment - South Saddle Creek (Lake Discharge)	347	4.5	See Section 4.2.4.2. for discussion. 1.96E5m3/d, k=55, Ci=0.472, Co=0.2, Ca=0.06
M	Wetland Treatment -In Lake, Upstream of South Saddle Creek (Supplemental to L)		1.0	
N	Settling Pond with Chemical Inactivation (Lake Discharge)		1.0	
O	Filtration of South Saddle Creek (Lake Discharge)		1.0	
P	Increased Depth by Raising Water Level	640	7.4	See Section 4.2.2 . Minimum of 640 wetland acres restored south of P-11.
Q	No Action		1.0	

Appendix G

Basis for Scoring the Remaining Three Lake Restoration Techniques

CDM

Appendix G
Basis for Scoring the Qualitative Lake Hancock Advisory Committee Restoration Objectives

Objective 3. Maintain the Exceptional Wildlife Values on Lake Hancock

Technology	Points	Rational
A.	6.3	Water Quality Improvements and improved sediments for spawning.
B.	6.3	Same comment as A.
C.	7.5	Water Quality Improvements and improved sediments for spawning plus improved treatment of decant water.
D.	7.5	Water quality improvements and improved sediment for spawning.
E.	7.5	Improved habitat and water quality, removal of sediments.
F.	6.3	Improve water quality similar to removing sediments.
G.	10.0	Addition of 960 acres of planted habitat.
H.	5.0	Improved water quality.
I.	0.6	Improved inflow water quality, but only for small inflow.
J.	0.6	Improved inflow water quality, but only for small inflow.
K.	5.0	Improved water quality.
L.	2.5	Additional wetland habitat.
M.	0	Technique is supplemental to L – Only implemented if needed to obtain adequate nutrient removal.
N.	0	No impact on Lake Hancock wildlife.
O.	0	No impact on Lake Hancock wildlife.
P.	8.8	Significant increase in wetland area habitat, but loss of upland.
Q.	1.3	Minimum points for maintenance.

Objective 4. Enhance the Diversity of Lake Hancock Fishery

Technology	Points	Rational
A.	6	Improves WQ
B.	7	Treatment superior to A.
C.	8	Best water quality treatment and deepens lake.
D.	8	Best water quality treatment and deepens lake.
E.	7	Similar to B
F.	5	Equivalent to C & D, but does not deepen lake.
G.	10	Hugh increase in littoral zone (980 acres)
H.	3	Slightly improved WQ, but only 2/5 as effective as wetland treatment of N. Saddle Creek. Does not deepen lake.
I.	1	Marginal WQ improvement; small load
J.	2	Marginal WQ improvement due to small load, but greater than J
K.	6	WQ improvements better than wetland treatment
L.	0	Downstream; does not affect Hancock fishery
M.	0	(ditto)
N.	0	(ditto)
O.	0	Downstream, does not affect Hancock fishery
P.	10	Large increase in littoral zone
Q.	0	Does not enhance

Objective 5. Provide Habitat Compatible Public Access for Nature-Based Recreational Activities and Commercial Fishing

Technology	Points	Rational
A.	0	No change in access or area available for recreation
B.	2.6	Proportional to Wetland Size
C.	2.8	(ditto)
D.	0	(ditto)
E.	2.6	(ditto)
F.	0	No change in access or area available for recreation
G.	2.0	Proportional to Wetland Size
H.	8.0	(ditto)
I.	2.8	(ditto)
J.	2.2	(ditto)
K.	0	No change in access or area available for recreation
L.	0	Public access (if any) will be below the lake
M.	2.0	Minimal in-lake wetland to supplement M; Size unknown
N.	0	No change in access or area available for recreation
O.	0	No change in access or area available for recreation
P.	10.0	Significant increase in wetland area and shoreline access. Provides the most access of all technologies, but causes significant loss of uplands on Circle B-Bar Ranch.
Q.	0	No change in access or area available for recreation

Appendix H

Evaluation of Water Quality Impacts of Selected Treatment Options

E R D ENVIRONMENTAL RESEARCH & DESIGN, INC.

WATER QUALITY ENGINEERING
3419 TRENTWOOD BOULEVARD ■ SUITE 102 ■ ORLANDO, FLORIDA 32812
TELEPHONE: (407) 855-9465 FAX: (407) 826-0419

October 9, 2001

OCT 12
CAMP DRESSER & Mc

Mr. Daniel E. Glaser, P.E.
Camp Dresser & McKee, Inc. (CDM)
1715 N. Westshore Blvd., Suite 875
Tampa, FL 33607

RE: Lake Hancock - Evaluation of Water Quality Impacts of Treatment Options 4, 8 and 9

Dear Dan:

As requested, Environmental Research & Design, Inc. (ERD) performed supplemental water quality modeling for Lake Hancock to evaluate anticipated water quality impacts from three water quality improvement options provided to ERD by Camp Dresser & McKee (CDM), identified as Option 4, Option 8, and Option 9. Option 4 involves a lake drawdown combined with desiccation and mechanical excavation of shoreline areas, littoral zone planting, in-situ chemical treatment of sediments using alum, wetland treatment of Banana Creek inflow, and construction of a settling pond for treatment of North Saddle Creek inflow. Option 8 involves lake drawdown combined with desiccation and mechanical excavation of shoreline sediments, littoral zone planting, hydraulic dredging of 80% of the lake bottom for removal of accumulated sediments, construction of a wetland treatment system for the Banana Creek inflow, and construction of a settling pond for treatment of North Saddle Creek inflow. Option 9 involves a water surface drawdown combined with desiccation and mechanical excavation of shoreline sediments, littoral zone planting, construction of a recirculating wetland treatment system for the lake, construction of a wetland treatment system for Banana Creek, and construction of a wetland treatment system for South Saddle Creek inflow. Information on anticipated phosphorus removal efficiencies and estimated total phosphorus load reductions for each of the evaluated options was provided to ERD by CDM. The estimated total phosphorus load reductions provided by CDM assume that existing hydrologic inputs into the lake will remain unchanged as a result of construction of the evaluated treatment options.

During 1999, ERD developed a modified Vollenweider nutrient limitation model for Lake Hancock as part of a water quality improvement project sponsored by the Southwest Florida Water Management District. The model was developed to provide predictions of water quality characteristics in the lake on a monthly basis. The model includes monthly hydrologic inputs to Lake Hancock from direct precipitation, stormwater runoff, dry weather baseflow, and groundwater seepage. Nutrient inputs to Lake Hancock include estimated loadings from bulk precipitation, stormwater runoff, dry weather baseflow, and groundwater seepage. Hydrologic and mass losses from Lake Hancock are assumed to occur as a result of evaporation, discharges through the outfall structure, and loss to deep groundwater. Net hydrologic inputs into Lake

Hancock are used to provide estimates of mean monthly detention times, as well as flushing rates, which are used in calculation of the phosphorus retention coefficient and corresponding calculations for equilibrium total phosphorus concentrations. Estimates of equilibrium chlorophyll-a concentrations and corresponding Secchi disk depths in the lake are calculated based upon the predicted in-lake phosphorus concentration. The lake model was calibrated based upon historical water quality characteristics for the lake and the results of field monitoring performed in Lake Hancock by ERD during 1998-1999. A detailed discussion of the development of this model is given in Section 5.5 of the December 1999 report titled "Lake Hancock Water and Nutrient Budget and Water Quality Improvement Project", prepared by ERD.

The calibrated model for Lake Hancock was used to predict water quality improvements resulting from construction of the three top ranked options by CDM, referred to as Options 4, 8, and 9. Information on anticipated annual mass reductions of total phosphorus achieved by each of the three treatment options was provided to ERD by CDM. The corresponding nutrient budgets within the model were modified to include the anticipated mass reduction of total phosphorus, as provided by CDM, for each treatment option. The water quality model was then rerun for each of the three treatment options to examine predicted changes in water quality characteristics. A copy of the estimated annual phosphorus load reductions provided by CDM is given in Appendix A and is summarized in Table 1. Copies of the water quality models for the three evaluated treatment options are included in Appendix B.

A summary of anticipated improvements in water quality characteristics in Lake Hancock resulting from the evaluated treatment options is given in Table 2. A graphical comparison of anticipated changes in Florida TSI value and Secchi disk depth in Lake Hancock for existing conditions and the three treatment options is given in Figure 1. In general, the anticipated improvements in water quality characteristics in Lake Hancock vary widely between the three evaluated treatment options. Implementation of Treatment Option 9 will result in only a minimal improvement in water quality characteristics in Lake Hancock. Although water column concentrations of total phosphorus and chlorophyll-a will be reduced by approximately 44% and 58%, respectively, Lake Hancock would continue to exhibit hypereutrophic conditions and poor water column transparency. The anticipated improvement in Secchi disk depth from 0.11 m under existing conditions to 0.26 m following implementation of this option would be barely visible to the naked eye.

Implementation of Treatment Option 8 would result in visible improvements in water quality characteristics within Lake Hancock. Water column concentrations of total phosphorus would be reduced by approximately 70%, with a corresponding 83% decrease in chlorophyll-a. Anticipated water column clarity would increase from 0.11 m under existing conditions to 0.58 m, an increase of more than 400%. The calculated Florida TSI value for Lake Hancock will be reduced from existing hypereutrophic conditions to mid-eutrophic conditions following implementation of this option.

Implementation of Treatment Option 4 would result in the most significant improvements in water quality characteristics within Lake Hancock for the three evaluated treatment options. Water column concentrations of total phosphorus would be reduced by approximately 77%, with a corresponding 88% reduction in chlorophyll-a. Water column clarity would increase from approximately 0.11 m to 0.83 m, an improvement that would be easily noticed by even a casual observer. Under this treatment option, Lake Hancock would be improved from the current hypereutrophic conditions to borderline mesotrophic/eutrophic water quality characteristics.

If you have any questions or comments concerning the previously described modeling efforts, please feel free to contact me directly.

Sincerely,

Harvey H. Harper

Harvey H. Harper, Ph.D., P.E.
President

Job No. 00-027
Enclosures: Tables 1 and 2, Figure 1, Appendices A and B

TABLE 1

SUMMARY OF ESTIMATED TOTAL P LOAD REDUCTIONS FOR EVALUATED TREATMENT OPTIONS

TREATMENT OPTION	SEDIMENT RECYCLING			PRECIPITATION			LAKE LENA RUN		
	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)
4	39,420	37,843	1,577	1,878	0	1,878	1,940	0	1,940
8	39,420	32,923	6,497	1,878	0	1,878	1,940	0	1,940
9	39,420	11,037	28,383	1,878	225	1,653	1,940	233	1,707

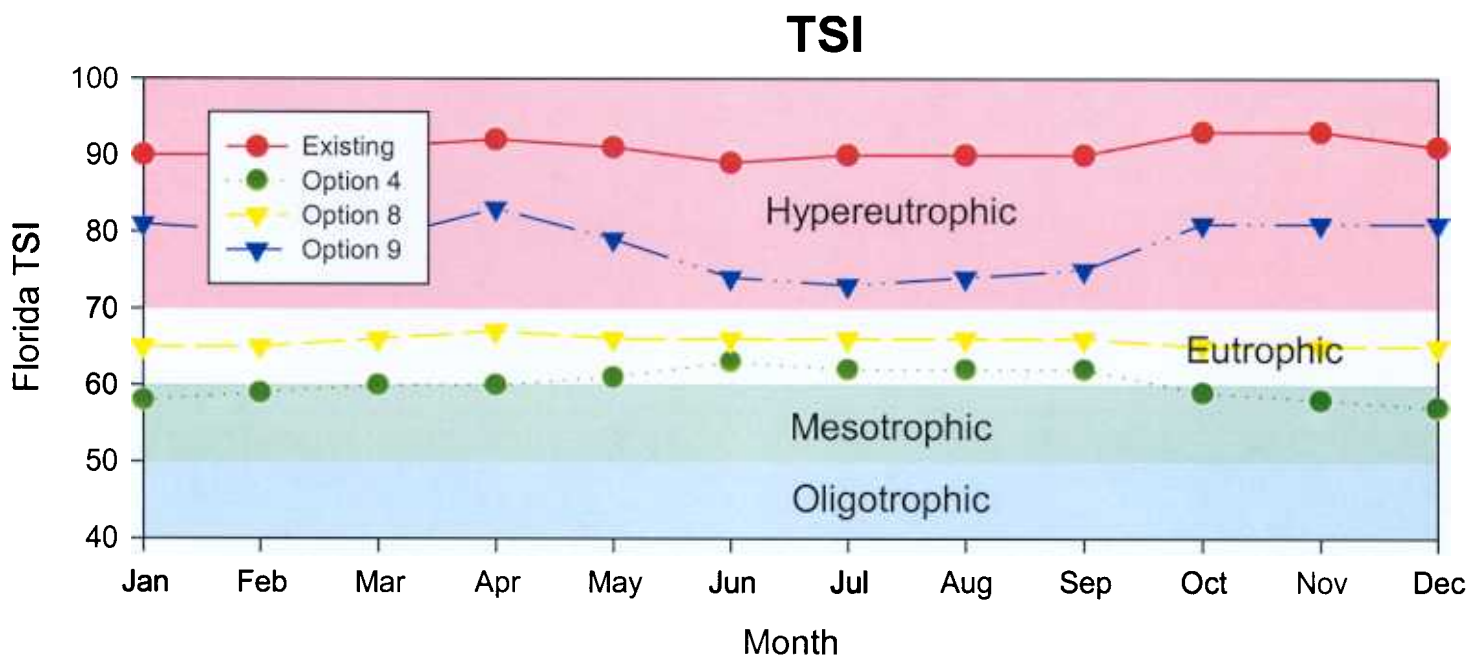
TREATMENT OPTION	DIRECT RUNOFF INPUTS			BANANA CREEK			SADDLE CREEK			SHALLOW SEEPAGE		
	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)	Existing Loading (kg/yr)	Load Removed (kg/yr)	Load Remaining (kg/yr)
4	2,175	0	2,175	2,229	1,337	892	22,218	17,774	4,444	4,646	0	4,646
8	2,175	0	2,175	2,229	1,337	892	22,218	17,774	4,444	4,646	0	4,646
9	2,175	261	1,914	2,229	1,604	625	22,218	20,440	1,778	4,646	558	4,088

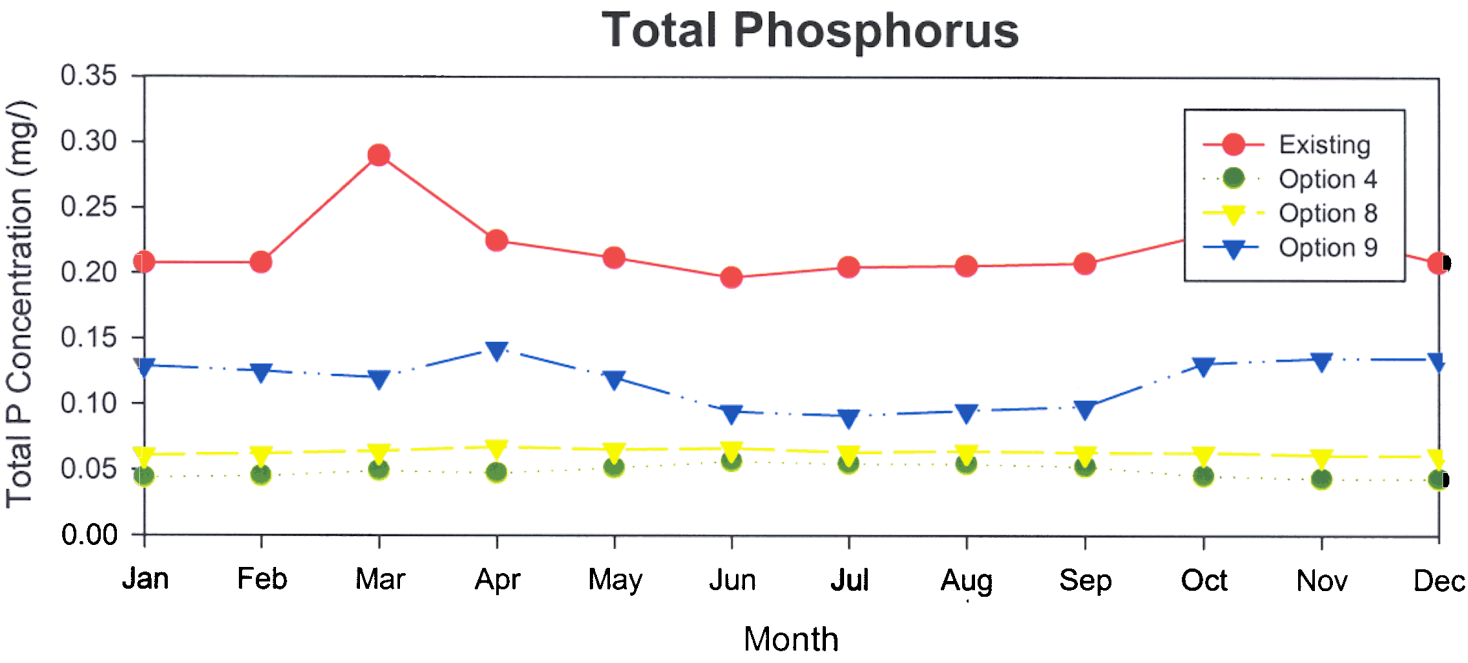
TABLE 2

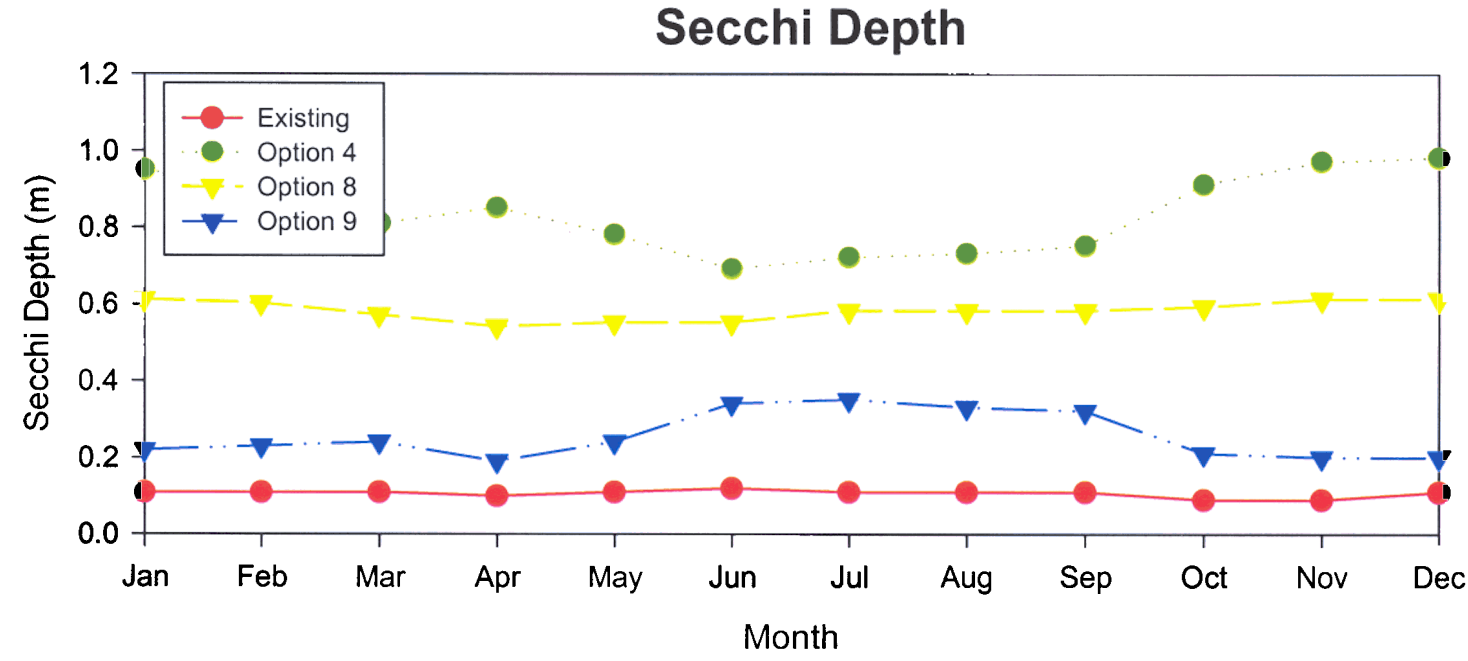
ANTICIPATED IMPROVEMENTS IN WATER QUALITY CHARACTERISTICS IN LAKE HANCOCK FROM EVALUATED TREATMENT OPTIONS[1]

TREATMENT OPTION	TOTAL P (µg/l)	SECCHI DISK (m)	CHLOROPHYLL-A (mg/m^3)	FLORIDA TSI
Existing	212	0.11	172	91
4	49	0.83	21	60
8	63	0.58	30	66
9	118	0.26	73	78

1. Listed values reflect mean annual characteristics.


TSI
Florida TSI
100
90
80
70
60
50
40
Existing
Option 4
Option 8
Option 9
Hypereutrophic
Eutrophic
Mesotrophic
Oligotrophic
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Total Phosphorus
Total P Concentration (mg/)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Existing
Option 4
Option 8
Option 9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


Secchi Depth
Secchi Depth (m)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Existing
Option 4
Option 8
Option 9
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

APPENDICES

APPENDIX A

ESTIMATED TOTAL P LOAD REDUCTIONS FOR EVALUATED TREATMENT OPTIONS

(SOURCE: CDM)

Table 6-1

Amount of Phosphorus Removed by the Three Highest Scoring Options

Unit Removal Percentage by Technology Component	TP Removal
Mechanical Excavation or Hydraulic Dredging	80%
Drawdown + Dessication // Excavation and Planting of Littoral Zone	16%
Recircuating Wetland Treatment - Fraction of Annual Input Treated	40%
Recirculating Wetland - Treatment Efficiency	30%
Wetland Treatment	60%
Chemical Treatment + Wetland Treatment (of Decant)	90%
Settling Pond with Chemical Treatment	80%
In-Situ Chemical Inactivation of Sediments	80%
Percent of Sediment Load in Pore/Decant Water	44%
Percent of Lake Area Involved in Littoral Shelf Excavation =	20%

	Sediment Recycle / Animal Input	Precipitation	Lake Lena Run Inflow	Direct to Lake Drainage	Banana Creek Inflow	Seepage	N. Saddle Creek Inflow	P-11 Discharge	Sum of P Removed (kg/yr)
Annual Input-->>(kg/yr)	39,420	1,878	1,940	2,175	2,229	4,646	22,218	32,269	
Option 9									-
Lake Drawdown (20%) and Desication // Mechanical Excavation of Littoral Zone // Planting	6,307	✓							6,307
Recirculating Wetland Treatment (2/5 of all inputs @ wetland efficiency)	4,730	225	233	261	267	558	2,666		8,941
Wetland Treatment Banana Creek					1,337				1,337
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
Settling Pond Treatment of N.Saddle Creek Inflow							17,774		17,774
									-
								Total	**53,721**
Option 8									-
Lake Drawdown (20%) and Desication // Mechanical Excavation of Littoral Zone // Planting	6,307								6,307
Hydraulic Dredging of 80 % of lake with Chemical/Wetland Treatment of Decant									-
A) Solids Removal	14,128								14,128
B) Decant Treatment	12,488								12,488
Settling Pond Treatment of N. Saddle Creek Inflow							17,774		17,774
Wetland Treatment of Banana Creek Inflow					1,337				1,337
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
								Total	**71,397**
Option 4									-
Lake Drawdown (20%) and Desication // Mechanical Excavation of Littoral Zone // Planting	6,307								6,307
In-Situ Chemical Inactivation of Sediments	31,536								31,536
Settling Pond Treatment N. Saddle Creek							17,774		17,774
Wetland Treatment Banana Creek					1,337				1,337
Wetland Treatment of S. Saddle Creek Discharge (No Reduction in Lake TP)								19,361	19,361
								Total	**76,316**

APPENDIX B

TROPHIC STATE MODELING FOR EVALUATED TREATMENT OPTIONS

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK FOR TREATMENT OPTION 4

Month	Initial P Conc.	Hydrologic and Mass Inputs												Hydrologic and Mass				
		Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	
January	0.043	2.42	911	0.045	50.0	2739	460	196	395	134	3847	1039	0.219	2.53	953	2894	154	
February	0.044	2.65	998	0.045	54.8	3000	504	177	356	121	4175	1036	0.201	3.08	1160	3015	165	
March	0.045	3.65	1375	0.069	116.1	4132	694	196	395	134	5703	1338	0.190	4.57	1721	3982	232	
April	0.049	2.24	844	0.069	71.3	2536	426	190	382	130	3569	1009	0.229	5.55	2090	1479	88	
May	0.047	3.83	1442	0.069	121.8	4336	728	196	395	134	5974	1378	0.187	6.18	2327	3647	220	
June	0.051	6.92	2606	0.094	300.5	7834	1315	190	382	130	10630	2127	0.162	5.59	2105	8524	559	
July	0.056	7.99	3009	0.094	347.0	9045	1519	581	395	134	12634	2394	0.154	5.53	2083	10552	714	
August	0.054	7.31	2753	0.094	317.4	8275	1390	581	395	134	11609	2235	0.156	5.23	1970	9639	639	
September	0.054	6.20	2335	0.092	264.9	7019	1179	562	382	130	9915	1955	0.160	4.58	1725	8191	534	
October	0.052	2.58	972	0.092	110.2	2921	490	581	395	134	4473	1129	0.205	4.02	1514	2959	178	
November	0.045	1.88	708	0.092	80.3	2128	357	562	382	130	3398	949	0.226	2.91	1096	2302	125	
	0.043	2.05	772	0.045	42.4	2321	390	196	395	134	3289	961	0.237	2.36	889	2400	126	
		49.72	18724		1877	56284	9451	4209	4646	1577	79216	17551		52.13	19631	59585	3734	

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 9451

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 2698

Wet Seas

Misc. Total P Inputs (kg/day): 4.3

Inflow Mass Removal (%): 0

Losses				Mean Detention Time	Phosphorus Retention	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI
nt System Losses		Total Losses								
% Removal	(kg)	(ac-ft)	(kg)	(days)	Coeff.	(g/m^2)	(mg/l)	(mg/m^3	(m)	Value
0	0	3847	154	129	0.766	0.048	0.044	17	0.95	58
0	0	4175	165	108	0.732	0.048	0.045	18	0.90	59
0	0	5703	232	87	0.689	0.060	0.049	21	0.81	60
0	0	3569	88	135	0.774	0.050	0.047	20	0.85	60
0	0	5974	220	83	0.679	0.063	0.051	22	0.78	61
0	0	10630	559	45	0.535	0.086	0.056	25	0.69	63
0	0	12634	714	39	0.500	0.092	0.054	24	0.72	62
0	0	11609	639	43	0.521	0.087	0.054	23	0.73	62
0	0	9915	534	49	0.552	0.078	0.052	23	0.75	62
0	0	4473	178	111	0.738	0.052	0.045	18	0.91	59
0	0	3398	125	142	0.782	0.045	0.043	17	0.97	58
0	0	3289	126	151	0.793	0.046	0.043	17	0.98	57
	0	79216	3734	94		0.063	0.049	21	0.83	60

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 1948

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK FOR TREATMENT OPTION 8

Month	Initial P Conc.	Hydrologic and Mass Inputs												Hydrologic and Mass				
		Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	(ac-ft)
January	0.061	2.42	911	0.045	50.0	2739	460	196	395	552	3847	1456	0.307	2.53	953	2894	218	0
February	0.061	2.65	998	0.045	54.8	3000	504	177	356	498	4175	1413	0.274	3.08	1160	3015	228	0
March	0.062	3.65	1375	0.069	116.1	4132	694	196	395	552	5703	1756	0.250	4.57	1721	3982	309	0
April	0.064	2.24	844	0.069	71.3	2536	426	190	382	534	3569	1413	0.321	5.55	2090	1479	119	0
May	0.067	3.83	1442	0.069	121.8	4336	728	196	395	552	5974	1796	0.244	6.18	2327	3647	297	0
June	0.065	6.92	2606	0.094	300.5	7834	1315	190	382	534	10630	2532	0.193	5.59	2105	8524	689	0
July	0.066	7.99	3009	0.094	347.0	9045	1519	581	395	552	12634	2812	0.180	5.53	2083	10552	839	0
August	0.063	7.31	2753	0.094	317.4	8275	1390	581	395	552	11609	2653	0.185	5.23	1970	9639	755	0
September	0.064	6.20	2335	0.092	264.9	7019	1179	562	382	534	9915	2359	0.193	4.58	1725	8191	640	0
October	0.063	2.58	972	0.092	110.2	2921	490	581	395	552	4473	1547	0.280	4.02	1514	2959	229	0
	0.063	1.88	708	0.092	80.3	2128	357	562	382	534	3398	1354	0.323	2.91	1096	2302	176	0
December	0.061	2.05	772	0.045	42.4	2321	390	196	395	552	3289	1378	0.340	2.36	889	2400	181	0
Totals:		49.72	18724		1877	56284	9451	4209	4646	6497	79216	22471		52.13	19631	59585	4681	0

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 9451

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 2698

Wet Seas

Misc. Total P Inputs (kg/day): 17.8

Inflow Mass Removal (%): 0

Losses				Mean Detention Time (days)	Phosphorus Retention Coeff.	Areal P Loading (g/m^2)	Final Lake P Conc. (mg/l)	Chyl-a Conc. (mg/m^3	Secchi Disk Depth (m)	Florida TSI Value
nt System Losses		Total Losses								
	(kg)	(ac-ft)	(kg)							
0	0	3847	218	129	0.766	0.068	0.061	28	0.61	65
0	0	4175	228	108	0.732	0.065	0.062	29	0.60	65
0	0	5703	309	87	0.689	0.079	0.064	30	0.57	66
0	0	3569	119	135	0.774	0.071	0.067	32	0.54	67
0	0	5974	297	83	0.679	0.082	0.065	31	0.55	66
0	0	10630	689	45	0.535	0.101	0.066	31	0.55	66
0	0	12634	839	39	0.500	0.108	0.063	30	0.58	66
0	0	11609	755	43	0.521	0.104	0.064	30	0.58	66
0	0	9915	640	49	0.552	0.094	0.063	30	0.58	66
0	0	4473	229	111	0.738	0.072	0.063	29	0.59	65
0	0	3398	176	142	0.782	0.064	0.061	28	0.61	65
0	0	3289	181	151	0.793	0.065	0.061	28	0.61	65
	0	79216	4681	94		0.081	0.063	30	0.58	66

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 1948

ESTIMATED MASS BALANCE VOLLENWEIDER MODEL FOR LAKE HANCOCK FOR TREATMENT OPTION 9

Month	Initial P Conc.	Hydrologic and Mass Inputs												Hydrologic and Mass				
		Direct Precipitation		P Inputs from Bulk Precipitation		Runoff/Baseflow Inputs		Groundwater Seepage		Misc. Inputs	Total Inputs			Evaporation		Outfall Losses		Treatme
	(mg/l)	(in)	(ac-ft)	(mg/l)	(kg)	(ac-ft)	(kg)	(ac-ft)	(kg)	(kg)	(ac-ft)	(kg)	(mg/l)	(in)	(ac-ft)	(ac-ft)	(kg)	
January	0.135	2.42	911	0.039	44.0	2739	293	196	347	2411	3847	3095	0.652	2.53	953	2894	472	
February	0.129	2.65	998	0.039	48.2	3000	321	177	314	2177	4175	2860	0.555	3.08	1160	3015	472	
March	0.125	3.65	1375	0.060	102.2	4132	442	196	347	2411	5703	3302	0.470	4.57	1721	3982	600	
April	0.120	2.24	844	0.060	62.7	2536	271	190	336	2333	3569	3003	0.682	5.55	2090	1479	239	
May	0.142	3.83	1442	0.060	107.2	4336	464	196	347	2411	5974	3329	0.452	6.18	2327	3647	589	
June	0.120	6.92	2606	0.082	264.5	7834	838	190	336	2333	10630	3772	0.288	5.59	2105	8524	1124	
July	0.094	7.99	3009	0.082	305.4	9045	968	581	347	2411	12634	4031	0.259	5.53	2083	10552	1204	
August	0.091	7.31	2753	0.082	279.4	8275	886	581	347	2411	11609	3923	0.274	5.23	1970	9639	1102	
September	0.095	6.20	2335	0.081	233.2	7019	751	562	336	2333	9915	3653	0.299	4.58	1725	8191	974	
October	0.098	2.58	972	0.081	97.0	2921	313	581	347	2411	4473	3167	0.574	4.02	1514	2959	418	
November	0.131	1.88	708	0.081	70.7	2128	228	562	336	2333	3398	2967	0.708	2.91	1096	2302	377	
	0.135	2.05	772	0.039	37.3	2321	248	196	347	2411	3289	3043	0.750	2.36	889	2400	399	
		49.72	18724		1652	56284	6024	4209	4088	28382	79216	40146		52.13	19631	59585	7969	)

Lake Surface Area (acres): 4519

Runoff/Baseflow Input (ac-ft/yr): 56284

Runoff/Baseflow Total P Input (kg/yr): 6024

Dry Season Seepage Inflow (ac-ft): 1343

Wet Season Seepage Inflow (ac-ft): 2866

Dry Season P Input (kg): 2374

Wet Seas

Misc. Total P Inputs (kg/day): 77.8

Inflow Mass Removal (%): 0

Losses				Mean Detention Time	Phosphorus Retention Coeff.	Areal P Loading	Final Lake P Conc.	Chyl-a Conc.	Secchi Disk Depth	Florida TSI Value
nt System Losses		Total Losses								
% Removal	(kg)	(ac-ft)	(kg)	(days)		(g/m^2)	(mg/l)	(mg/m^3	(m)	
0	0	3847	472	129	0.766	0.143	0.129	84	0.22	81
0	0	4175	472	108	0.732	0.131	0.125	79	0.23	80
0	0	5703	600	87	0.689	0.148	0.120	75	0.24	79
0	0	3569	239	135	0.774	0.151	0.142	96	0.19	83
0	0	5974	589	83	0.679	0.150	0.120	75	0.24	79
0	0	10630	1124	45	0.535	0.145	0.094	53	0.34	74
0	0	12634	1204	39	0.500	0.154	0.091	50	0.35	73
0	0	11609	1102	43	0.521	0.154	0.095	53	0.33	74
0	0	9915	974	49	0.552	0.146	0.098	56	0.32	75
0	0	4473	418	111	0.738	0.150	0.131	85	0.21	81
0	0	3398	377	142	0.782	0.142	0.135	89	0.20	81
0	0	3289	399	151	0.793	0.144	0.135	89	0.20	81
	0	79216	7969	94		0.147	0.118	73	0.26	78

Mean Lake Volume (ac-ft): 16048

on P Input (kg): 1714

Appendix I

Preliminary Costs

Mechanical Excavation and Restoration of Littoral Zone (20 Percent of Lake Sediment)

Component	Unit	Quantity	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Purchase for Disposal Area	50	acre	5,800	290,000
PHASE 2 – Site Preparation				
Clear and Grub	50	acre	3,000	150,000
Cell excavation	106,667	cy	4	426,668
Berm Construction (onsite soil)	72,533	cy	3.50	253,866
Berm Stabilization (sodding)	46,595	sy	1.50	69,892
Cell Liners (if required)	1,525,865	sf	0.45	686,639
			Phase 2 Subtotal	1,587,065
PHASE 3 – Sediment Removal				
Sediment Excavation	293,760	cy	7.50	2,203,200
PHASE 4 – Littoral Shelf Construction				
Planting	910	acre	3,500	3,185,000
Vegetation Maintenance 1st Year	1	ls	910,000	910,000
			Phase 4 Subtotal	4,095,000
			Phases 2, 3, and 4 Subtotal	7,885,266
Construction Contingency	25%			1,971,316
Mobilization, Bonds, Insurance	5%			394,263
			Construction Cost Subtotal	*10,250,844*
PHASE 5 - Engineering				
Design, Permitting, Bidding	4%	Construction		410,034
Construction Services and Inspection	3%	Construction		307,525
Geotechnical/Survey	2%	Construction		205,017
			Total Estimated Cost	**$11,463,420**

Hydraulic Dredging
(80 Percent of Lake Sediment)

Component	Quantity	Unit	Unit Cost ($)	Total Cost ($)
PHASE 1 – Land				
Land Purchase for Disposal Area	167	acre	5,800	968,600
Land Purchase	55	acre	5,800	319,000
			Phase 1 Subtotal	*1,287,600*
PHASE 2 – Site Preparation				
Clear and Grub	167	acre	3,000	501,000
Cell excavation	397,778	Cy	4	1,591,112
Berm Construction (onsite soil)	294,045	Cy	3.50	1,029,158
Berm Stabilization (sodding)	231,834	Sy	1.50	347,751
Cell Liners (if required)	6,284,493	Sf	0.45	2,828,022
			Phase 2 Subtotal	*6,297,043*
PHASE 3 – Decant Treatment Wetland				
Clear and Grub	55	acre	3,000	165,000
Excavation and Grading	120,000	sy	1.50	180,000
Berm Construction (onsite soil)	192,640	cy	3.50	674,240
Berm Stabilization (sodding)	62,849	sy	1.50	94,274
Cell Liners (if required)	2,395,800	sf	0.45	1,078,110
			Phase 3 Subtotal	*2,191,624*
PHASE 4 – Pumping Facility (if required)				
Pump Station	1	each	50,000	50,000
Distribution Piping	1,810	lf	100	181,000
Control Structure	1	each	25,000	25,000
			Phase 4 Subtotal	*256,000*
PHASE 5 – Sediment Removal				
Sediment Dredging	14,400,000	cy	1.25	18,000,000
			Phases 2, 3, 4, and 5 Subtotal	*26,744,667*
Construction Contingency	25%			6,686,167
Mobilization, Bonds, Insurance	5%			1,337,233
			Construction Cost Subtotal	*34,768,067*
PHASE 6 – Engineering				
Design, Permitting, Bidding	7.5%	Construction		2,607,605
Construction Services and Inspection	5%	Construction		1,738,403
Geotechnical Services	2.5%	Construction		869,202
			Total Estimated Cost	**$41,270,877**

Settling Pond Treatment of North Saddle Creek

Component	Quantity	Unit	Unit Cost ($)	Cost ($)
PHASE 1 - Land				
Land Purchase	200	acre	5,800	1,160,000
PHASE 2 – Pond Construction				
Clear and Grub	175	acre	3,000	525,000
Earthwork	250,000	cy	6	1,500,000
Fencing	13,000	lf	16	208,000
Entrance Road	15,000	sy	32	480,000
			Phase 2 Subtotal	*2,713,000*
PHASE 3 – Distribution System				
Influent Piping				1,054,300
Discharge Piping				263,575
Influent Pump Station				342,648
Chemical Treatment System				316,290
Electrical				158,145
			Phase 3 Subtotal	*2,134,958*
			Phases 2 and 3 Subtotal	*4,847,958*
Construction Contingency	25%			1,211,990
Mobilization, Bonds, Insurance	5%			242,398
			Construction Cost Subtotal	*6,302,346*
PHASE 4 - Engineering				
Design, Permitting, Bidding	7.5%	Construction		472,676
Construction Services and Inspection	5%	Construction		315,117
Geotechnical/Survey	2.5%	Construction		157,559
			Total Estimated Cost	**$8,407,698**