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FEASIBILITY OF NATURAL TREATMENT AND RECHARGE OF WASTEWATER AND SURFACE WATERS USING MINED PHOSPHATE LANDS

Prepared by
Schreuder, Inc.

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FIPR
Florida Institute of Phosphate Research

July 2002

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FEASIBILITY OF NATURAL TREATMENT AND RECHARGE OF WASTEWATER AND SURFACE WATERS USING MINED PHOSPHATE LANDS

A CONCEPT TO EXPAND REGIONAL WATER RESOURCE AVAILABILITY

FINAL REPORT

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DISCLAIMER

PERSPECTIVE

Demand for water in central Florida is increasing while the availability of groundwater is dwindling. Because of extensive pumping of fresh water from the Floridan Aquifer, saltwater intrusion is threatening the aquifer in coastal areas, while lowered aquifer levels may affect lake levels and spring flows in more inland areas. The Southwest Florida Water Management District (SWFWMD) has proposed cutting back on the permitted quantities of water pumped from the Floridan Aquifer in the Southern Water Use Caution Area (SWUCA) so as to be closer to sustainable yield levels. This will have a significant impact on current, and especially future, water users. To meet the growing demands of development, alternative sources of water must be sought. Possible sources are reclaimed wastewater, the capture of storm water, the capture of "excess" surface water, development of the surficial aquifer, and desalinization of seawater.

This project is part of an effort to examine the feasibility of storing waste water or excess surface water in reservoirs on mined lands, purifying the water with wetland treatment and sand tailing filtration, and then injecting the treated water into the Floridan Aquifer.

Other FIPR-funded projects on this topic include:

- Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests (FIPR Publication No. 03-113-154). This report addresses the leaching of sand tailings in barrels as a first step in determining the effects of sand tailing filtration on water quality.

- An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters (FIPR Publication No. 03-124-153). This is a laboratory column leaching study to examine microorganism removal by sand tailing filtration.

- Water Quality Investigation of In-Situ Tailing Sand Deposits under Natural Environmental Conditions (FIPR Project 97-03-129). This is a field study of water quality in several sand tailings deposits.

- Pilot Project to Test Natural Water Treatment Capacity of Wetland and Tailing Sand Filtration Concept (FIPR Project 98-03-136). This is a larger field demonstration of wetland treatment and sand tailing filtration on the quality of storm water and wastewater.

Steven G. Richardson
FIPR Reclamation Research Director

ABSTRACT

The project involves the purification of reclaimed and excess surface waters by treatment through natural processes on lands previously mined by phosphate mining companies. As a result of the mining process, the phosphate companies produce open mine pits, clay settling areas (CSA) and tailing sand deposits, which the companies are required to reclaim as land and lakes, wetlands, pasture and agricultural lands. The basis for this project is the premise that the natural systems, in particular, wetlands created on CSAs followed by tailing sand filtration, will remove organic, inorganic and microbiological contaminants from the waters, resulting in water that will meet drinking water standards. The project envisions recharge to the underlying Floridan Aquifer, an extensive confined ground-water system, capable of storing and transmitting large quantities of water. The Florida Institute of Phosphate Research (FIPR) has funded the projects in support of this concept. Studies have been completed on the radiological and microorganism aspects of the percolation of water through tailing sand deposits. This feasibility study has identified five project sites where a total of 84 million gallons per day could be harvested, treated and recharged to the Floridan Aquifer at an average cost of less than $1.20 per 1,000 gallons. This approach fits well in the regional water resources management plan for the Southern Water Use Caution Area, which has projected need by the year 2020 of more than 300 million gallons per day (MGD) to meet agricultural, industrial and public water supply demands.

ACKNOWLEDGMENTS

The initial proposal entitled “Evaluation of the Feasibility of Water Storage Reservoirs on Mined Lands to Meet Future Agricultural, Industrial, and Public Water Supply Demands” was submitted to FIPR with the encouragement of the Executive Director, Richard McFarland, Ph.D., in November of 1994. After the proposal was reviewed under FIPR’s guidelines, the Board approved the contract in the April 1995 meeting and the contract was issued on July 1, 1995.

Since the approval of the initial contract, several other investigations have been undertaken to more fully explore the issues related to the production of drinkable water using mined phosphate lands as the treatment systems. The skillful guidance during the implementation and execution of these projects by the present Executive Director, Dr. Paul R. Clifford, and the Reclamation Research Director, Dr. Steven G. Richardson, were essential in the successful conduct of this research. The members of the Schreuder, Inc. research team that worked on the project were: Peter J. Schreuder, C.P.G., the principal investigator; John M. Dumeyer, P.E., P.G., the project manager; Robert A. Kruppa, the project hydrogeologist; and Amanda Rice, the project engineer. Dr. Lillian M. Stark was the co-principal investigator for the study on the capacity of tailing sand to remove microorganisms.

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EXECUTIVE SUMMARY

The economic development of an area depends on the availability of reasonably priced water of suitable quality to meet the public water supply, industrial, agricultural and mining needs of the region. In the Florida Peninsula, all fresh water is derived from rainfall, and as such the supply is limited. In the past, the water demands were easily met by incoming rainfall. The aquifer system underlying the area is quite large and can store significant quantities of ground water. However, the pumpage of ground water in local areas of the peninsula has exceeded the rate of recharge to the underlying aquifer systems. This has led to significant depletions of the ground water storage in the overlying surficial aquifer, causing lakes and wetlands to go dry.

In 1995 the Board of Directors of FIPR approved a two-year study (Project 94-03-113) to assess the feasibility of the use of mined phosphate lands to store excess surface water and wastewater for later use to help meet the future projected agricultural, industrial and public water supply demands. After the completion of the first year of study, it was determined that significant dependable long-term excess surface water supplies could not be obtained. A change in the scope of the study to concentrate on aquifer recharge was proposed and approved by FIPR. The change involved the use of mined land to naturally treat wastewater and excess surface water so that it would meet drinking water standards to enable the water to be stored in the underlying Floridan Aquifer for later retrieval. In this manner, the large losses and water quality changes incurred by surface water storage facilities would not occur.

The phosphate mining operations result in two key post-mining features of particular interest to this water treatment approach, these are the clay settling areas (CSA) and the production of large quantities of tailing sands. The study investigated temporary storage of excess surface water, wastewater, or storm water in a reservoir; then releasing the water to a manmade wetland area (former CSA) for treatment by biological processes; and then filtration by tailing sands. The sand filtration step should further reduce total suspended solids and improve the water quality to drinking water standards. After filtration, this water can either be stored in the Floridan Aquifer for future use or pumped directly for consumer use. The idea to use sand filtration as a natural means of improving the quality of the water from the Rhine River has been used in the western parts of the Netherlands for over one hundred years. The City of Amsterdam (The Netherlands) has successfully treated up to 40 million gallons per day (gpd) using dune sand deposits as an important step in their treatment process.

This report has identified five project sites where the concept could be implemented. At one site, excess surface water would be captured, treated, filtered and stored. At two sites, reclaimed water would be the source. At two sites, a mixture of surface- and reclaimed water would be the source.

Combining the total rate of flow from the five sites would yield 84 million gpd. The cost to capture, treat and recharge the water ranges from a low of $0.76 to a high of $2.02 per thousand (1000) gallons. The average cost for the 84-million gpd is $1.20 per thousand (1000) gallons (Year 2000 costs).

INTRODUCTION

DESCRIPTION OF THE BASIC CONCEPT

The project involves the purification of wastewater and surface waters by treatment through natural processes on reclaimed lands previously mined for phosphate. As a result of the mining process, mine pits, clay settling areas (CSA) and tailing sand deposits are created. The mining companies are required by law to reclaim the mined areas to include lakes, wetlands, forest, wildlife habitat, pastures and agricultural lands. The basic principle on which this project rests is the assumption that natural processes in wetlands created on reclaimed CSAs, followed by tailing sand filtration, will remove organic, inorganic and microbiological contaminants in the surface waters and wastewaters.

Mined lands can provide a surface water storage area to receive and mix the water prior to a controlled release to a CSA wetland. The release rate of the water from the storage reservoir is controlled by the treatment capacity of the wetland to remove nutrients and organic and inorganic contaminants. From the treatment wetland, the water flows by gravity into filter basins, created from deposits of tailing sands. In the filter basins, the water percolates down to a series of collection pipes. The filtered water is expected to meet drinking water standards. This water can then be recharged into the underlying Floridan Aquifer for storage and later recovery, or it can be piped and pumped to a potable water supply facility. A detailed schematic diagram of the concept of the natural purification of surface waters is presented in Figure 1.

In 1995, FIPR authorized several studies to assess the feasibility of using mined phosphate lands to naturally repurify stormwater, wastewater, and excess surface waters prior to recharge into the underlying Floridan Aquifer for temporary storage and conveyance to existing permitted well withdrawals.

PURPOSE OF THE STUDY

The purpose of the study was to evaluate the technical and economic feasibility of implementing the above-described concept. The study describes preliminary engineering concepts and the approximate costs and five example sites where the concept could be implemented. The costs are expressed as dollars per 1,000 gallons and include capital investment plus operating and maintenance (O & M) costs in Year 2000 dollars.

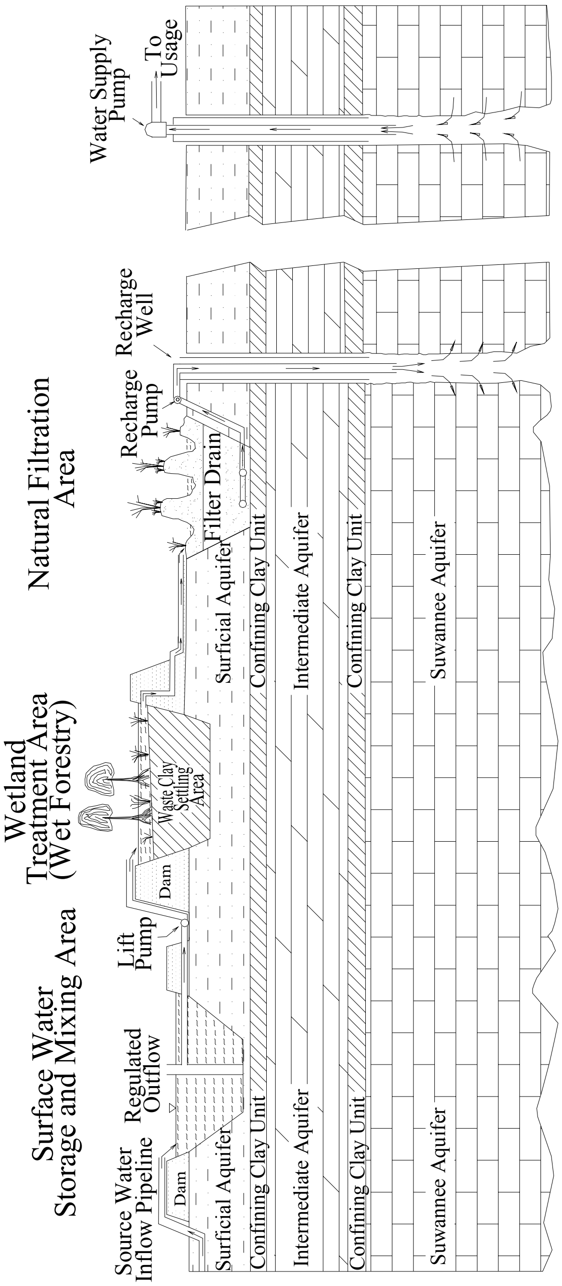

Figure 1. Schematic Diagram of the Natural Purification Concept for Mined Phosphate Lands.

LOCATION OF THE STUDY AREA

The area where the concept could be implemented is within the boundaries of the Bone Valley Phosphate Mining District as shown in Figure 2. Also shown in Figure 2 are the five project sites evaluated in the study. To implement the concept, it is most useful to have CSAs that are essentially full of clay and will no longer be used, but are not yet reclaimed. The other requirement for successful implementation of the concept is the proximity of the CSA to a source of tailing sands and a sustainable source of water with a significant yield.

It was found that major sources of sustainable water supply with significant yields [i.e., Waste Water Treatment Plants (WWTP)] were near large urban counties. These counties were all located to the west of the Bone Valley Phosphate Mining District. It was therefore decided to include the urbanized areas along the I-4 and I-75 corridors into the study area.

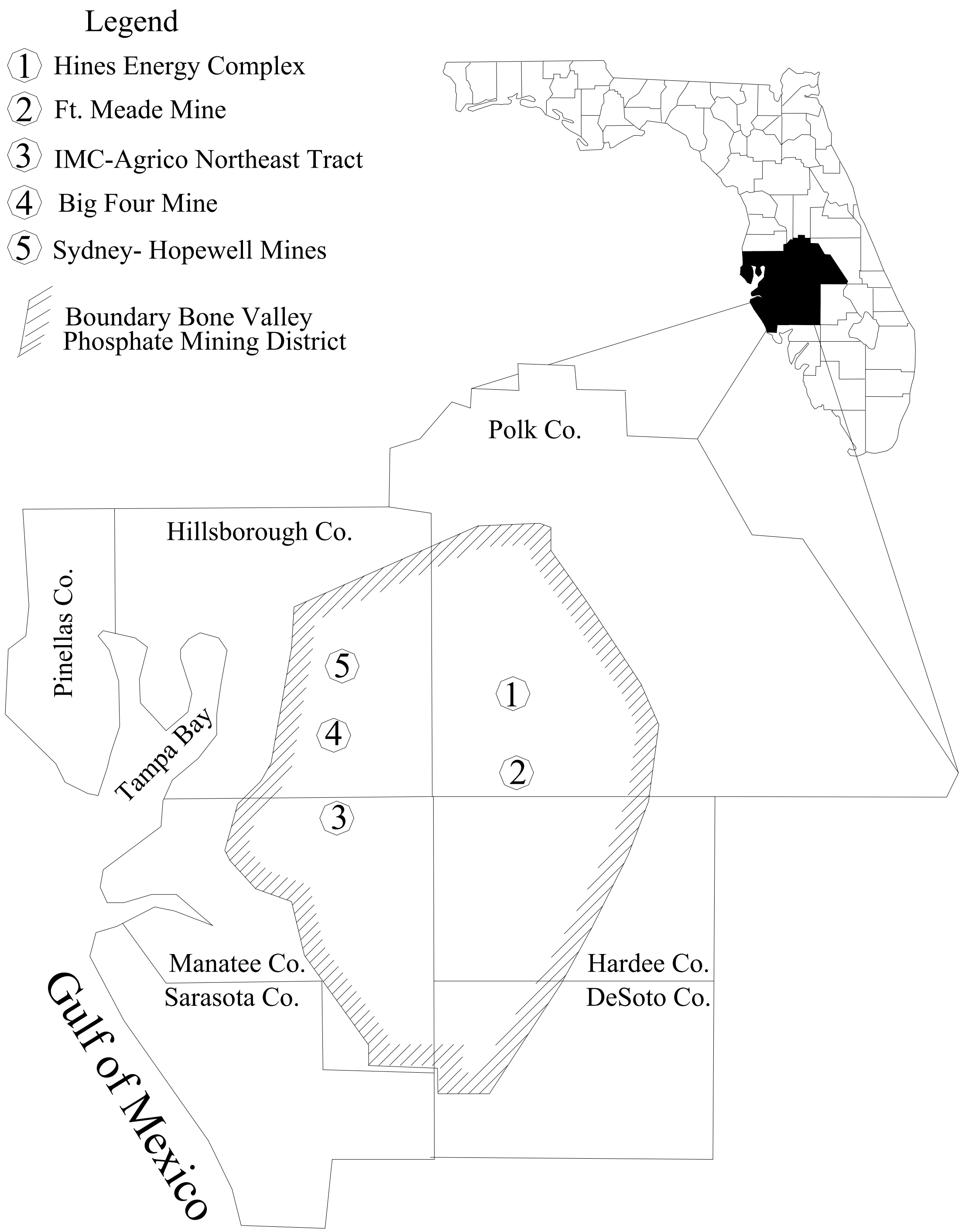

Figure 2. General Location of the Bone Valley Phosphate Mining District and the Project Sites.

DEVELOPMENT OF THE NATURAL TREATMENT AND STORAGE CONCEPT

GOALS OF THE ORIGINAL FEASIBILITY STUDY

The primary goal of the initial study was to evaluate the feasibility of creating water storage reservoirs on mined lands, to assess the operational reliability of such reservoirs to meet the needs of present and future users, and to estimate the anticipated costs. The creation of large water storage reservoirs on lands still to be mined for which reclamation plans have been developed and approved may require a substantial regulatory and permitting effort to modify these plans. The creation of smaller reservoirs on pre-1975 mined-out areas will require technical and engineering modifications, but a lesser regulatory permitting effort.

The second goal was to evaluate natural biological treatment methods that may be used to improve the quality of the wastewater, stormwater and diverted river water collected in the reservoirs. At the time of the preparation of the 1994 proposal, the wastewater from the City of Bartow was co-mingled with IMC Phosphates' waste clay stream flowing into one of their active CSAs. The clarified return water appeared to be of excellent quality.

It is hoped that the treated water will meet primary and secondary drinking water standards and "free-from" requirements (FDEP Rule 62-520). The purpose of this evaluation is to investigate if a permit for recharging the treated water into the Floridan Aquifer can be obtained, thereby increasing the sustainable groundwater development limit to allow more groundwater pumpage or safely maintain withdrawals at the present rate. Distribution costs would be significantly reduced because the Floridan Aquifer is considered to be an efficient and regionally extensive groundwater conveyance system.

The work during the first year focused on determining the availability of surface water, wastewater, and storm water flows, the assessments of water supply deficits, the location of potential surface water reservoirs and their dependable yields, and any water quality issues. The possibility of aquifer storage was also evaluated.

FIRST MODIFICATION OF THE ORIGINAL STUDY

During the first year of the study, several preliminary conclusions became clear. The idea of large surface water reservoirs on mined phosphate lands is, on the face of it, a reasonable concept. Considering, however, the engineering, permitting and water quality constraints, it became clear that this concept was not practically implementable. The first constraint is the availability of excess surface water in the phosphate mining area. The Southwest Florida Water Management District (SWFWMD) generally will not permit any surface water withdrawals of more than ten percent of the average daily flow in a stream, provided that no other users are already withdrawing this quantity. This constraint effectively eliminated consideration of surface water withdrawals from the Hillsborough and Manatee Rivers. Another important reason for the limited success of the surface water reservoir concept is the somewhat unfavorable relationship between surface area and total useable storage volume. To obtain reasonable yields that are dependable ninety-five percent of the time from surface water systems that vary greatly in their rates of flow during the wet and dry seasons, the volume of the reservoir should be large. Because it is quite expensive to build and maintain large (high) dams, the volume issue is quite cost restrictive. A large volume reservoir on the west coast of Florida will require a large surface area with concurrent water losses to evaporation and seepage.

The third and equally important issue is that of possible water quality constraints. In a reservoir, the temperature of the water at the bottom will most likely reflect that of the ambient temperature of the surficial aquifer system surrounding it, assuming that the bottom of the reservoir is the bottom of the mine pit. The mine pit bottoms vary in depth but are generally 40 to 50 feet below land surface. The ambient ground water temperature in the surficial aquifer is about 72 °F. The surface temperature in the reservoir may vary from 50 °F in the winter to more than 90 °F in the summer. Because warmer water generally has a lower dissolved oxygen concentration, the overall dissolved oxygen in relatively quiescent surface water may be rather low. It is conceivable that at the bottom of the reservoir, anaerobic conditions will exist. During periods when, because of the temperature changes, the bottom waters come to the surface, algae blooms have been observed to occur. These algae blooms impact the quality of the surface water, requiring additional treatment to remove taste and odor problems.

Another major engineering constraint was that large surface water reservoirs on mined phosphate lands would be generally located far from urbanized areas and would require long transmission pipelines. While agricultural users are generally closer to the mined lands, the delivery of irrigation water to each individual farm would require an extensive pipeline distribution network. In addition, the water for irrigation needs to be free of suspended solids so it can be used in the modern drip irrigation systems. This would require, as a minimum, that the surface waters be filtered, adding additional costs. On a unit cost basis, this option appeared to be out of reach compared to the cost of the water from a onsite well.

Because of these constraints, the initial focus of the feasibility study was changed by shifting the idea of the storage of waters in reservoirs on the land surface to storage of waters in the Floridan Aquifer. This change in concept required additional modifications, primarily based on the fact that the quality of the water to be stored in the Floridan Aquifer needs to be equal to or better than the quality of the receiving ground water in the aquifer. The water to be recharged and stored in the Floridan Aquifer needs to meet the primary and secondary drinking water standards set by the U.S. Environmental Protection Agency and the State of Florida (FDEP Rule 62-520).

MODIFIED CONCEPT

The basic thought in modifying the initial concept of surface water storage reservoirs was to shift the storage idea from the land surface to the subsurface. This operation is dependent on obtaining a permit for the construction and operation of a Class V recharge well under the Florida Department of Environmental Protection (FDEP) Underground Injection Control program (FDEP Rule 62-528). As stated before, the implementation of the concept would be governed by the feasibility of meeting drinking water standards. These standards not only include the inorganic and organic constituents, but also threshold concentrations of pathogenic microorganisms.

The treatment of waste and storm waters by wetlands has become an accepted technology that is permittable. The one link in the natural treatment process that was missing was the removal of suspended solids and microorganisms. In the Netherlands, the concept of using dune sands along the coast as one of the steps in the treatment of Rhine River water for a potable drinking water supply has been well established for many years. This idea was incorporated into the overall concept for the study. The area of West Central Florida does have old beach sand deposits that were not at the right location to be easily included in the concept. The mining industry, however, produces large quantities of tailing sand, so the investigation focused on the use of tailing sand as a filter in the process to polish the naturally treated water prior to injection. The result of the modification of the initial study objectives resulted in the following concept as summarized and shown schematically in Figure 3.

In the first modified concept, the water would initially be stored in an above ground surface water reservoir, albeit much smaller than in the initial concept. From there, the water would flow by gravity under controlled conditions to a wetland created on mined phosphate lands. The water would flow through the wetland to an area where a tailing sand filter had been built in a mine cut. Drainpipes would be laid at the bottom, and the mine cut would be subsequently filled with tailing sand. The drainpipes would be connected directly to a pump and drop pipe into the recharge well.

Evaluation of the modified concept revealed several important questions. The most important of these was could a tailing sand filter produce water that met drinking water standards, in particular for the radionuclides and microorganisms? To answer these questions, the FIPR Board authorized two additional studies entitled *An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters* (FIPR Project 94-03-113) (Schreuder and others 1998) and *Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests.* (FIPR Project 94-03-124R) (Schreuder and Dumeyer 1998). These studies were intended to be bench-scale tests.

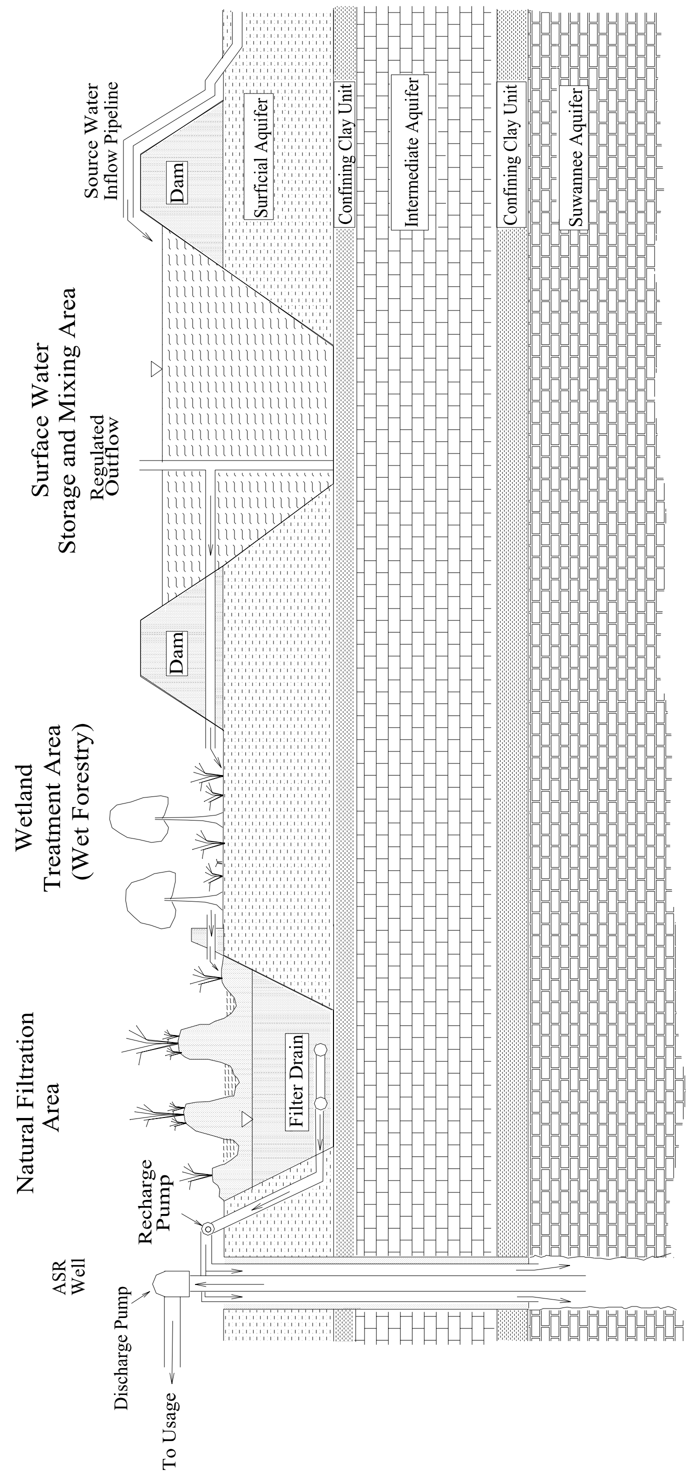

Figure 3. Schematic Diagram of the First Modified Concept.

The bench scale studies provided answers that indicated that a sand tailing filter could indeed provide the natural treatment by removing suspended solids and microorganisms without increasing radionuclide concentrations beyond the drinking water limits for radionuclides and microorganisms.

SECOND MODIFICATION OF THE CONCEPT

In the second modification, the idea of elevating the operating level of the water surface in the receiving reservoir above the surface elevations of the wetland to allow for gravity flow to the wetland was dropped. Instead, the modified concept focused on the use of wetlands that naturally develop on reclaimed CSAs. It was observed that wetland systems on CSAs can develop naturally ideal conditions for the treatment of storm and waste waters.

As an example of the capacity of CSA wetlands to treat wastewater, advanced secondary treated (AST) wastewater from the City of Lakeland's WWTP was analyzed before and after flowing through CSA wetlands near Mulberry, Florida over a two year period. In general, reductions in the concentrations of the water quality parameters listed in Table 1 below were observed from the water flowing out of the wetland. The water quality was improved and the water was discharged to a nearby stream.

Table 1. Average Change in NPDES Parameters in Water Flowing Out of Wetland Compared to Influent Waste Water.

NPDES Parameter	Average Percent Reduction (-) or Increase (+)
Total Nitrogen	-92.0
Total Phosphorus	-22.6
Biochemical Oxygen Demand	-73.4
Dissolved Oxygen	+12.5
Total Suspended Solids	-45.8
Specific Electrical Conductance	-12.8
Total Flow (in MGD)	-27.8

NOTE: Based upon City of Lakeland Monthly NPDES Reports.

The ideal depth of water in a treatment wetland is found to be ranging from 0.5 feet to 3 feet (Kadlec and Knight 1996). This depth of water will ensure small to insignificant losses to seepage through the underlying clay layers. The depositional processes in a CSA guarantee that there will be a sloping topography from one end of the CSA to the other. This aspect will provide a varying depth of water in the treatment wetland that will ensure a better biological function for removal of nutrients and microorganisms. Another very important factor is that the clayey soil conditions will allow for the development of an active biological treatment matrix. Finally, the fact that there are over 100,000 acres of CSA available, makes this idea an attractive modification of the initial concept.

The major constraint on the use of CSAs as treatment wetlands is a regulatory one, in that as long as water is stored in a CSA, the owner or operator of the site is required to comply with FDEP Rule 62-672 on dam monitoring requirements. The authors believe that a modification of this rule, allowing a permanent outflow control that allows for a water depth of only 3 to 4 feet, may be needed to take full advantage of wetlands on CSAs as natural treatment facilities for waste and storm waters.

The use of CSAs as wetland treatment systems eliminates the need for a storage reservoir with high dams to allow gravity drainage to the wetland. In addition, the elevation of the wetland surface will allow for the gravity discharge to the sand tailings basin.

The engineering elements of the second modification of the concept are shown in Figure 4. This modification includes a recharge well. While the recharge well has become standard technology which is easily permittable, conveying the pumped water from storage in the aquifer well by pipeline still added high cost for implementing this part of the concept. To avoid this constraint, a third modification of the concept was introduced.

THIRD MODIFICATION OF THE CONCEPT

The greatest potential limitation to the implementation of the natural treatment and storage concept is the cost of overland conveyance through pipelines from the treatment and storage site to a potential user. The consumers may be municipal utilities or agricultural or industrial users. To overcome this limitation, the element of the conveyance of the recharge water through the highly permeable limestones of the Floridan Aquifer was added as a third modification to the original concept. This would entail injecting the water at one point and pumping it out some distance away.

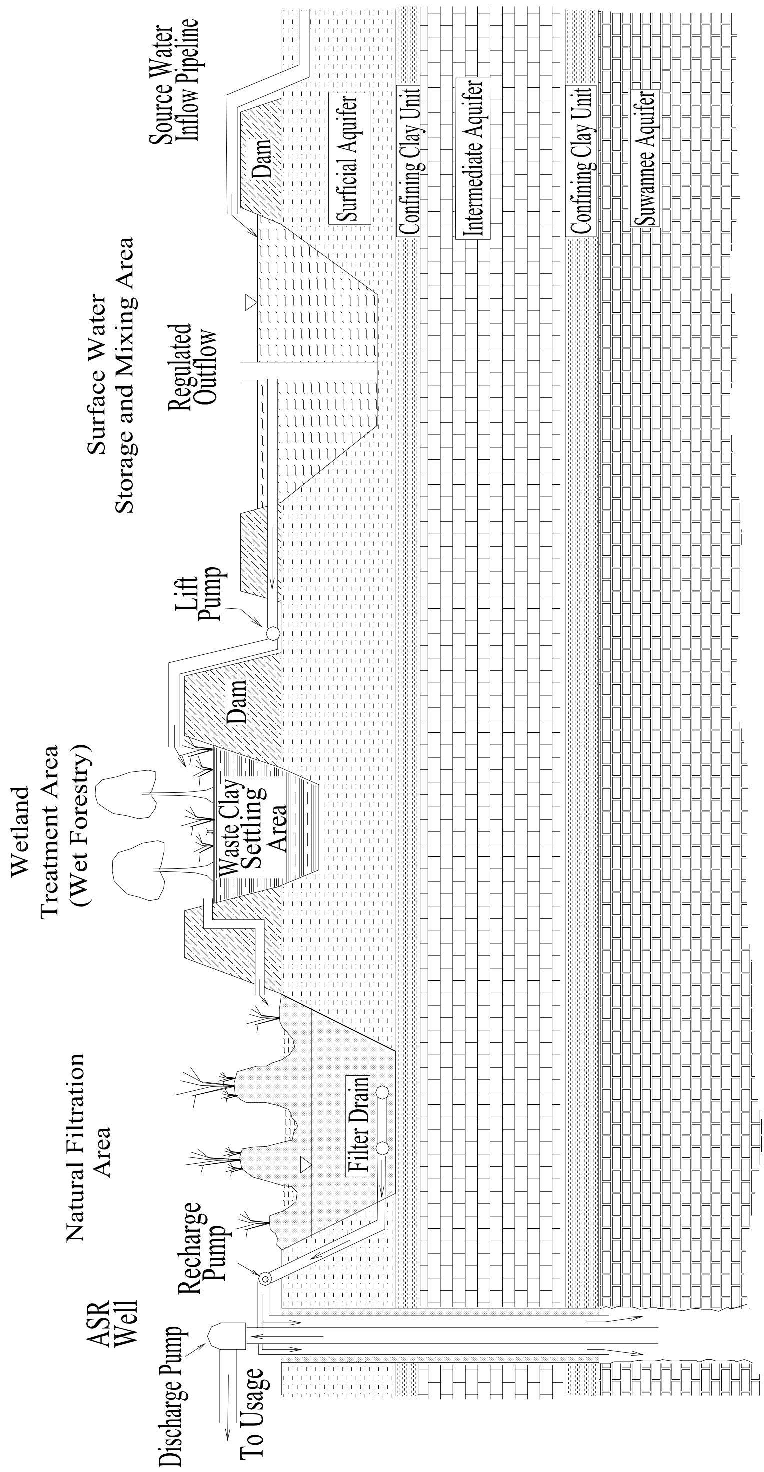

Figure 4. Engineering Elements of the Second Modification of the Concept.

PERMITTING REQUIREMENTS FOR IMPLEMENTATION

The implementation of the natural treatment concept will require the involvement of the SWFWMD, FDEP and several other agencies. To construct such a project will require permits for:

Reservoir	SWFWMD, FDEP and USACOE*
Surface Water Diversions	SWFWMD
Dams	FDEP Bureau of Mine Reclamation
Release of CSA Reclamation	FDEP Bureau of Mine Reclamation
Requirement Wetlands	FDEP-SWFWMD- USACOE Hillsborough Co. Environmental Protection Commission
Recharge Well	FDEP-Underground Injection Control
Water Quality Issues	FDEP
Extraction Well	SWFWMD
Wildlife Corridor Concept	FWCC**

*USACOE---U.S. Army Corps of Engineers
**FWCC-----Florida Fish and Wildlife Conservation Commission

It is quite likely that the permitting of this concept can be done under FDEP's Ecosystem Management guidelines following the team permitting approach. Team permitting involves the multiple agencies and the public in a combined permitting process. The only element of the concept that has no permitting precedent is the aquifer conveyance issue. It is possible that the implementation of the idea to recharge at Point A and withdraw a similar quantity of water at Point B, a certain distance away, may need the development of a specific rule by SWFWMD.

ADDITIONAL TESTING FOR NEW CONCEPT

TAILING SAND WATER FILTRATION STUDY

As described previously, CSAs and tailing sand deposits remaining after phosphate mining can be used for repurification of wastewater and storm water in Central Florida. One aspect of the process entails filtering the water through a tailing sand filter basin. Since the tailing sands can contain small amounts of phosphate minerals, the question was posed regarding the possible leaching of radioactive and other compounds, which would make the filtered water exceed U.S. Environmental Protection Agency and FDEP Drinking Water Standards. The Board of Directors of FIPR funded an additional investigation of the water quality of the leachate water.

The leaching test described in a separate report (Schreuder and Dumeyer 1998) was an amendment to this feasibility project. The key to the successful implementation of the natural surficial water purification concept is the ability of the proposed system to produce water that meets the drinking water standards. Tailing sands contain small quantities of phosphate minerals that naturally contain uranium (Upchurch and others 1991; Oural and others 1986). Uranium occurs in nature as an unstable radionuclide, which decays to a stable state, producing a series of long- and short-lived radionuclides. The drinking water standards place limits on several of these radionuclides. This association between the radionuclides and phosphate minerals in the tailing sands led to this leaching test to determine the possible impact on the quality of water filtered through these sands. To address this water quality concern, Schreuder, Inc. conducted a bench test study to determine the degree that these radionuclides might leach into the filtered water. The report, entitled "Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests," describes methods and results of the testing and chemical/radiological analyses of 126 water samples from three different tailing sands (FIPR Publication 03-113-154).

Ten sources of tailing sands were evaluated and three were selected for the investigation. The three sources were the former Tenoroc Mine on the Florida Fish and Wildlife Conservation Commission's Tenoroc Fish Management Area, Cargill Fertilizer's Ft. Meade Mine and IMC Phosphates' Four Corners Mine.

The tailing sands were transported to the Schreuder, Inc. office in Tampa and placed into 60-gallon polypropylene drums. Each source was used to fill 12 drums. The hydraulic properties of each sand source were determined by sieving and by permeameter flow tests. The hydraulic conductivities were 16.4 feet per day for the Tenoroc sand, 49.4 feet per day for the Ft. Meade sand and 73.2 feet per day for the Four Corners sand.

The leaching test was designed to analyze the results of three water types, low pH (4.0), neutral pH (7.0) and high pH (10.0), to cover the possible ranges of natural water. The source water used was City of Tampa potable water and the low and high pH waters were achieved by adding acid and hydroxide.

The testing was performed in triplicate to produce verifiable data. Therefore, nine barrels were tested of each tailing sand source. The drums were filled with water and samples were drawn from each drum after 1, 5, 15, 50 and 100 days. Measurements were made of temperature, pH and specific conductance at sampling. Laboratory analyses were conducted for total uranium, radium-226, lead-210, polonium-210, gross alpha, sulfate and total phosphorus. Additional sample sets were collected on days 206 and 225.

The analytical results indicated that the leachate from the tailing sand would generally meet the drinking water standards for radioactive elements even under the worst-case conditions of a long contact period in a static environment. The leachate from the Four Corners Mine tailing sand did exceed the drinking water standard of 250 milligrams per liter of sulfate. A subsequent flow-through leaching test of the Four Corners tailing sands indicated that after flushing two pore volumes of water through the sand, the leachate water would not exceed the sulfate limit. Based upon the results indicated by this investigation of tailing sands filtration, the water produced through the sand can meet drinking water standards.

CAPACITY OF TAILING SANDS TO REMOVE MICROORGANISMS

One of the questions raised about tailing sand filtration to purify storm water and, particularly, treated wastewater is the ability to remove microorganisms from the water. In order to address this question, the Board of Directors of FIPR funded an investigation (FIPR Contract No. 96-03-124R) of microorganism removal by tailing sands (Schreuder and others 1998).

The investigation involved placing tailing sands from two sources into polyvinyl chloride (PVC) columns. The sands included a low permeability sand from the Tenoroc State Fish Management Area and a high permeability sand from IMC Phosphates' Four Corners Mine. Three columns were filled with each sand type, and unsaturated depths of 1, 2 or 3 feet were maintained. Each column was seeded with a solution containing *E. Coli* bacteria, coliphage MS2 bacterial virus, human poliovirus and fluorescent microspheres as tracers. The columns were sampled eight times over a period of 38 days. After each sample event, an equal volume of de-ionized water was added to the top of each column to simulate recharge. The collected samples were analyzed at the Florida Department of Health Laboratory in Tampa.

The test results indicated that tailing sand filtration is capable of removing more than 98% (2 log removal) of the applied virus. The lower permeability sand was better able to remove microorganisms than the higher permeability sand. Removal of microorganisms was greater with increasing thickness of the unsaturated zone in the surficial layer.

The use of lower permeability phosphate mine tailings sand in conjunction with an unsaturated zone greater than five feet thick is expected to be effective in removing microorganisms from storm water and treated wastewater. The final report entitled *An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters* has been published by FIPR (FIPR Publication 03-124-153).

EXAMPLE PROJECTS AND COST ESTIMATES

In the following paragraphs, five example projects will be presented along with the estimates of the capital costs, O & M costs and the resulting treatment costs per 1,000 gallons of water. These five projects were chosen based on the availability of surface water and/or wastewater, CSAs, and tailings sand. Significant sources of wastewater and surface water were often somewhat distant from the natural treatment areas and in several cases would have to be brought to the site by pipeline. The cost estimates are based upon Year 2000 costs.

FLORIDA POWER CORPORATION HINES ENERGY COMPLEX

The Concept

Florida Power Corporation (FPC) is building an electric power generating plant called the Hines Energy Complex (HEC) on previously mined land near Homeland. The general location of the project site is shown on Figure 5. The proposed power plant and cooling reservoir will occupy approximately 8,200 acres of previously mined phosphate land adjacent to the headwaters of McCullough Creek and Camp Branch, which are tributaries of the Peace River. The site includes 900 acres of power generating and ancillary facilities and a 722-acre cooling reservoir. Approximately 2,000 acres will be designated as buffer areas along the east and southeast portions of the site, and approximately 520 acres along the west and southwest portions of the site will be left undeveloped to enhance drainage to McCullough Creek. A detailed map of the HEC site is presented in Figure 6.

FPC has negotiated an agreement with the City of Bartow to receive up to 5 MGD of wastewater for the life of the plant. The available wastewater quantities are sufficient for the first two phases of generating capacity. Presently, FPC is operating with a generating capacity of 470 megawatts (MW) (first phase).

Any increase in the number of megawatts produced above 940 MW will require a corresponding increase in groundwater withdrawals. A special condition of the SWFWMD water use permit requires FPC to demonstrate that they will minimize groundwater withdrawals to the greatest extent practicable by implementing all technologically and economically practicable water conservation practices prior to increasing groundwater withdrawals. Further, if total groundwater use in the Southern Water Use Caution Area is restricted, FPC will be required to offset increased groundwater demands above 5 MGD by retiring other actively used permitted quantities or receive alternative water as an offset under Chapter 373, Florida Statutes.

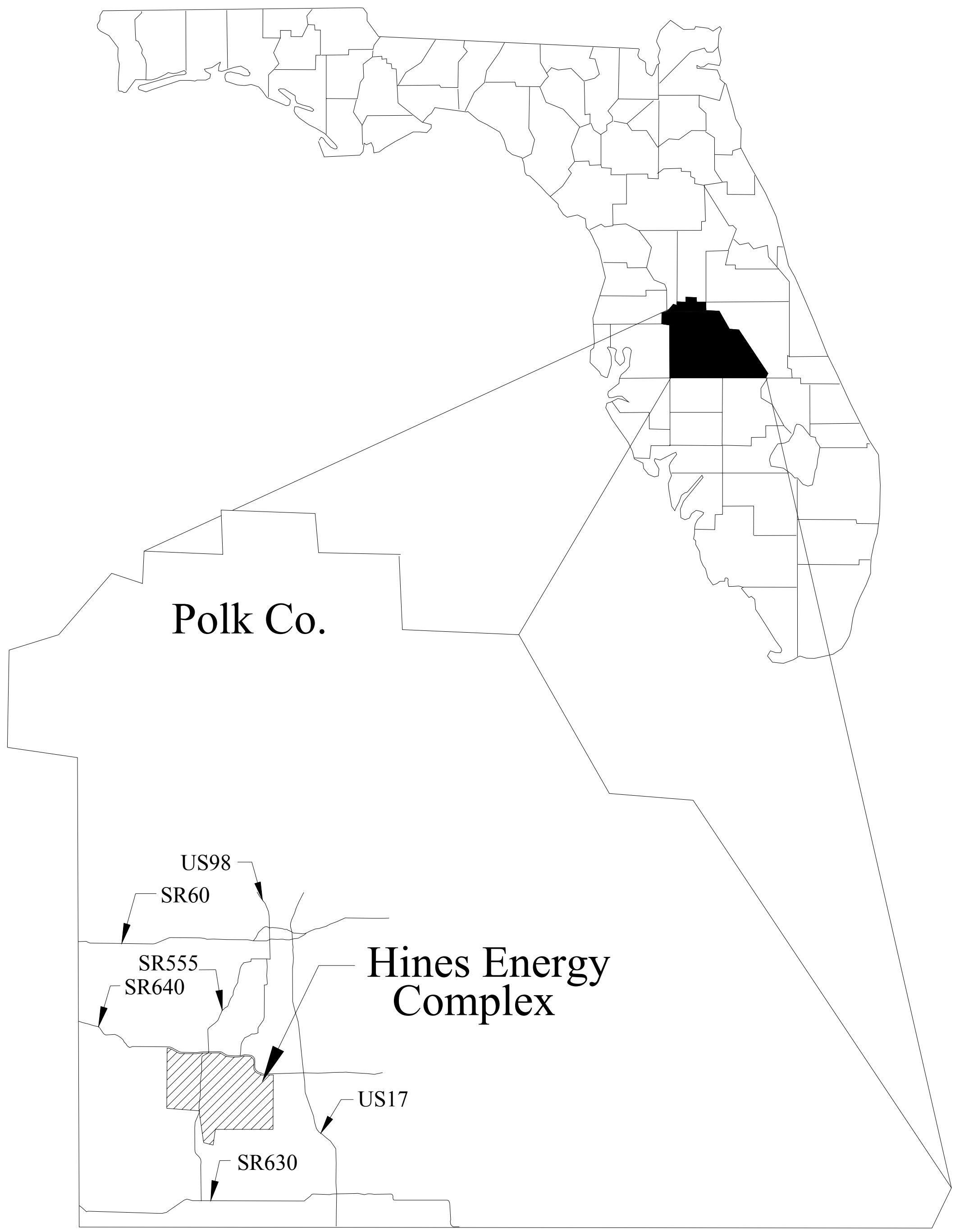

Figure 5. General Location of Hines Energy Complex.

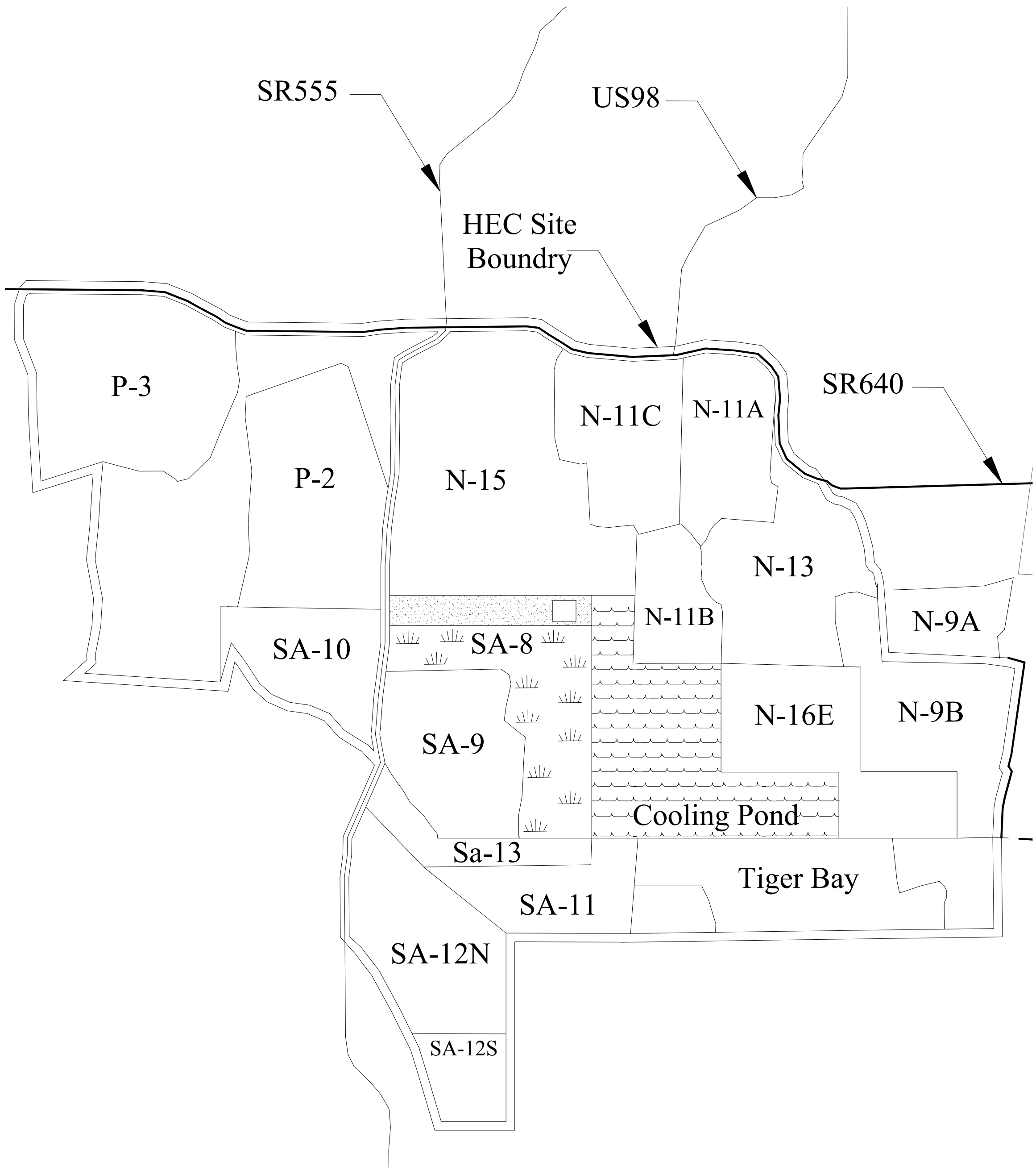

Figure 6. Detailed Map of HEC Power Generating Site.

To respond to this permit condition, FPC has agreed to acquire up to 5 MGD of wastewater from the City of Bartow and to use the capture of rainfall on the plant site. The wastewater is pumped from the wastewater treatment plant in Bartow directly to the cooling water reservoir at the Polk County Site. Use of this source of water has eliminated the need for FPC to withdraw any groundwater from the Upper Floridan Aquifer in support of the first 940 MW (first and second phases) of power generation capacity.

The City of Bartow has a secondary WWTP with a design capacity of 4.0 MGD. Current average flows of 2.6 MGD were reported, with maximum daily flows of 3.6 MGD. The city projects that future flows will reach the 4.5 to 5.0 MGD range by the year 2010 A 24-inch diameter pipeline from the new WWTP to the power plant site southwest of Homeland (approximately nine miles) has been built. FPC began filling the cooling pond in December 1996.

Conceptual Engineering Design

The conveyance capacity of the 24-inch pipeline when full is 12 MGD. At present, the Bartow WWTP has been delivering less than 3 MGD. This leaves an unused pipeline capacity of 9 MGD. The preliminary engineering concept plans the diversion of surface water from the Peace River at the location of the WWTP shown in Figure 7 to utilize the available pipeline capacity.

To estimate how much water could be diverted from the Peace River without a significant impact on downstream users, the following analysis was performed:

1. Review long term flow records near the WWTP site,
2. Determine average daily flows,
3. Subtract a minimum flow, and
4. Take ten percent of the remaining flow as the proposed diversion rate.

In Table 2, the long-term (1940 through 1997) flow records at the Bartow gaging station are presented. In the second column, a minimum flow of 130 cfs is listed and subtracted to yield the resultant flows shown in column 3 that will be used in the diversion calculations. In column 4, the values of ten percent of the resultant ADF are shown. In column 5, the total value of water in acre-feet per month is presented. The average daily diversion capacity is calculated by adding all the total monthly values and dividing by 365 days. This yields an average daily diversion rate of 4.75 MGD.

Table 2. Calculations of Estimated Average Daily Surface Water Flow Diversions from the Peace River at Bartow.

Month	Mean Daily Flow (cfs)	Regulatory Base Level Flow (cfs)	Resultant Mean Daily Flow (cfs)	10% of Resultant Mean Daily Flow (cfs)	Monthly Value (ac-ft)
October	316	130	186	15.8[b]	972
November	142	130	12	1.2	71
December	122	130	a	--	--
January	161	130	31	3.1	191
February	178	130	48	4.8	267
March	215	130	85	8.5	523
April	178	130	48	4.8	286
May	91	130	a	--	--
June	153	130	23	2.3	137
July	287	130	157	15.7	966
August	401	130	271	15.8[b]	972
September	449	130	319	15.8[b]	940
TOTAL ANNUAL VOLUME					5325

NOTE: USGS data.
a: Negative values are not considered.
b: If 10% of the resultant daily flow is greater than the extra conveyance capacity of the pipeline of 15.8 cfs, the latter number is used.

The preliminary engineering concept is shown in Figure 7 and consists of the following elements:

1. Intake structure and pump at the Peace River,
2. Pipeline from the river to the WWTP,
3. Connecting the river segment of the pipeline to the existing pipeline
4. Lift station from cooling pond into SA-8 Treatment Wetland,
5. Tailing sand filtration basin, and
6. Aquifer recharge wells.

After the water is diverted from the Peace River, it will be pumped through the existing 24-inch diameter pipeline to the cooling pond. At the southwest corner of the cooling pond, a pump will lift the water into the SA-8 CSA wetland. The water will then flow northward as sheet flow to a pumping station that will pump the water into the tailing sand filtration basin to be constructed between the SA-8 and N-15 CSAs. The filtered water will be pumped and recharged to the Floridan Aquifer through wells drilled on the east side of the tailing sand filter as shown in Figure 8.

During high rainfall events, additional surface water storage of 4900 acre-feet is available on HEC property on the west side of State Road 555. Preliminary design at the HEC site considers a filtration and aquifer recharge rate of 5 MGD.

Preliminary Cost Estimates

The cost for this preliminary engineering design focuses on the installation of the equipment and pipeline to direct the water from the Peace River to the existing pipeline, which runs from the Bartow WWTP to the cooling pond at the HEC site. The distance from the Peace River to the Bartow WWTP is estimated to be 4000 feet. The existing pipeline is 24 inches in diameter and can easily convey 12 MGD. To size the connecting pipe and the pumping capacity of the diversion structure at the Peace River, a maximum conveyance capacity of 10 MGD was selected.

The cost for a 20-inch diameter pipe from the Peace River to the Bartow WWTP was calculated to be $344,000. The cost of the structure at the Peace River to pump and divert 10 MGD was calculated to be $1,400,000. The cost for the connection of the proposed 20-inch diameter pipe to the existing 24-inch diameter pipe is estimated at $100,000, including the cost for the necessary valves and backflow preventers.

The cost of constructing a lift station to pump the water from the cooling pond to the SA-8 CSA treatment wetland or to one of the storage reservoirs at the HEC property is based on the assumption that a maximum of 12 MGD may need to be pumped. The cost for such a structure is estimated at $1,680,000.

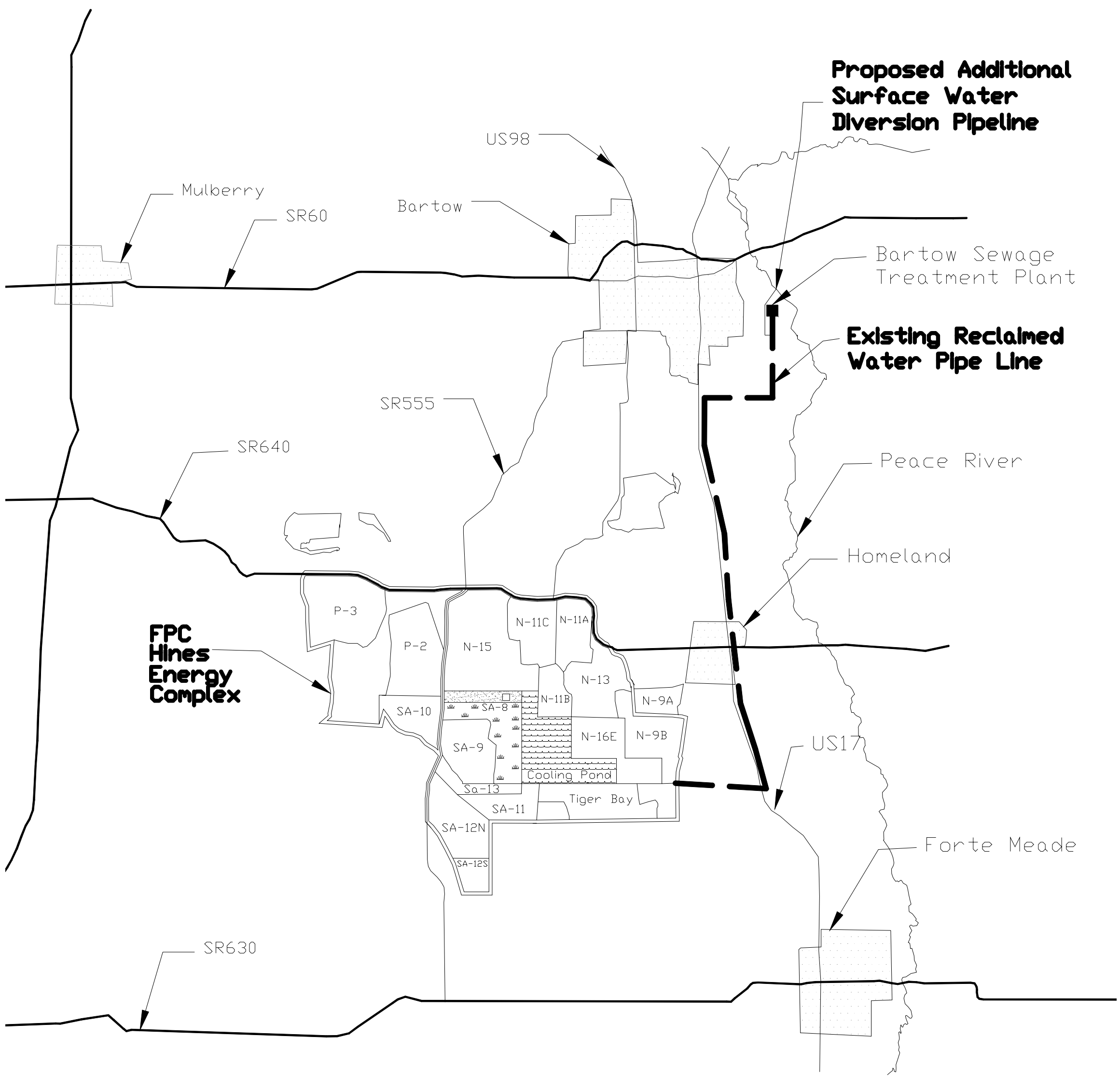

Figure 7. Location and Engineering Elements of the Bartow WWTP.

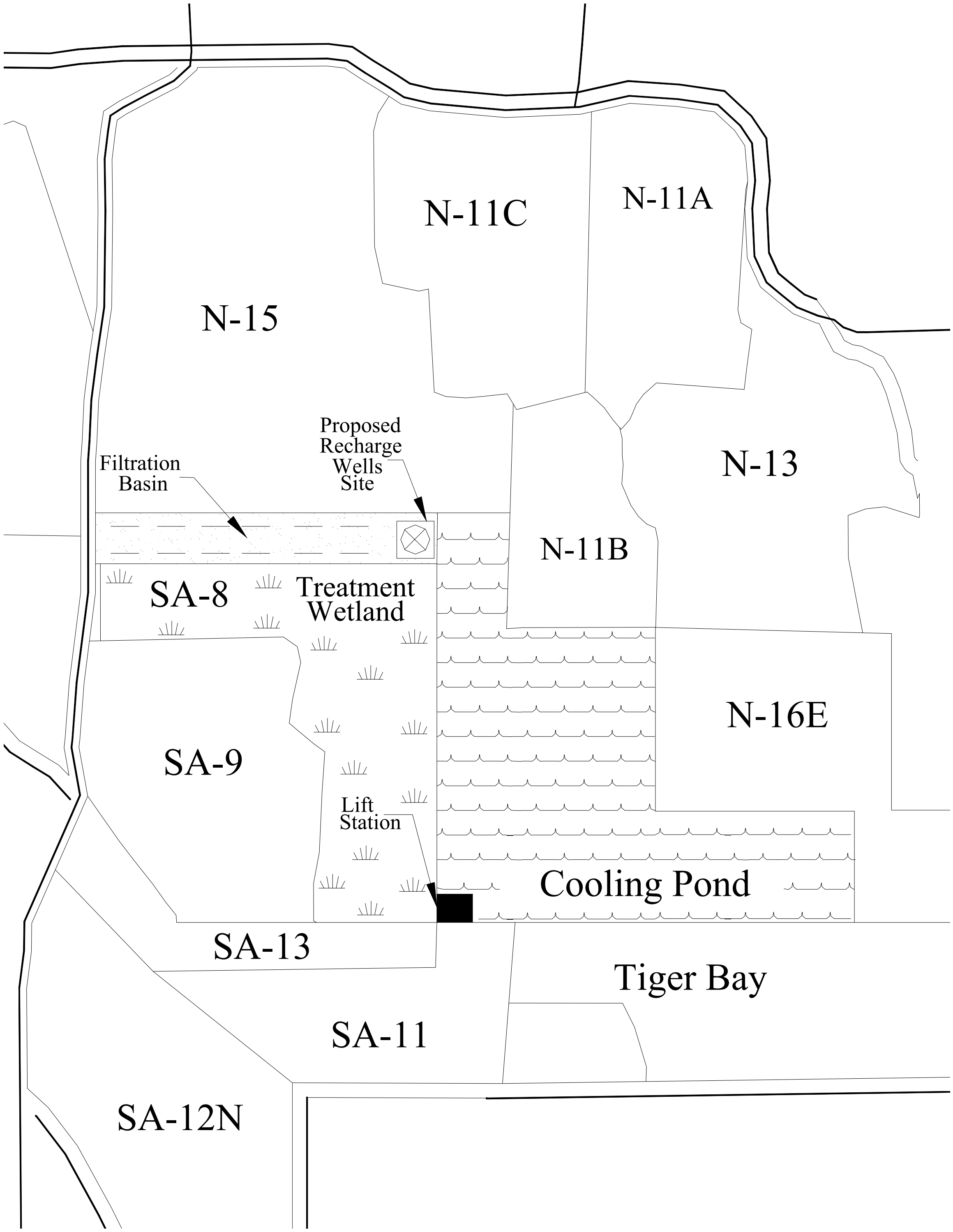

Figure 8. Location of Proposed Floridan Aquifer Recharge Wells.

The cost for the construction of the additional tailing sand filtration capacity is based on the assumption that this project would add an average of 5 MGD to the filtration capacity of FPC's system, which is currently underway. At a rate of 6 inches per day and adding 1/3 more to the area to secure continued effective and efficient recharging operations, a total of 40 acres is contemplated. A total thickness of the tailing sand of 20 feet is needed. At $1.50 per cubic yard, the cost for placing the tailing sand is estimated at $1,936,000. A 6-inch diameter schedule 40 PVC filter screen with a slot size of 0.010 inch, the yield per linear foot of filter pipe is 2.6 gallons per minute. For a capacity of 5 MGD, a total of 1,335 feet of filter pipe is needed. At $65 per foot, the total cost of filter piping is estimated at $86,800. The total cost of the filtration basin is $2,022,000.

To recharge the 5 MGD, two recharge wells will be needed at a cost of $100,000 each, for a total of $200,000. To pump the water from the sand filter system into the recharge wells, two low head pumps at $15,000 each for a total of $30,000 are needed. A total of $75,000 is added for electronic management and control systems. The total cost for the recharge system is $305,000.

Based on the individual cost estimates, the:

Total Construction Costs	$ 5,841,000
Engineering Design/Construction Management Costs @ 15%	$ 876,150
Administrative, Legal, and Contingency Costs @ 20%	$ 1,168,200
Total Capital Costs	**$** 7,885,350

Based on a 30 year and 7% annual amortization, the

Annual Amortization Cost is:	$ 677,025
The total O & M Costs are estimated at	$ 718,300
The estimated Total Annual Cost is	**$** 1,395,325

Based on the total annual cost and the production rate of 5.0 MGD, the unit cost is $0.76/1000 gallons.

CARGILL FERTILIZER, INC., FORT MEADE MINE

The Concept

The general location of the proposed project site is presented in Figure 9. The preliminary concept calls for the diversion of surface water flow from Payne Creek and Little Payne Creek at locations within the Fort Meade Mine of Cargill Fertilizer, Inc. In the conceptual design, the diverted water will be pumped through a pipeline northward to an existing surface water reservoir in the southern half of Section 30 at the Fort Meade Mine. From there, the water will be pumped into the CSA treatment wetland in Sections 19 and 20, from where the water will be released to the sand tailings filtration area in Section 29 by gravity flow. A plan view of the proposed system is presented in Figure 10.

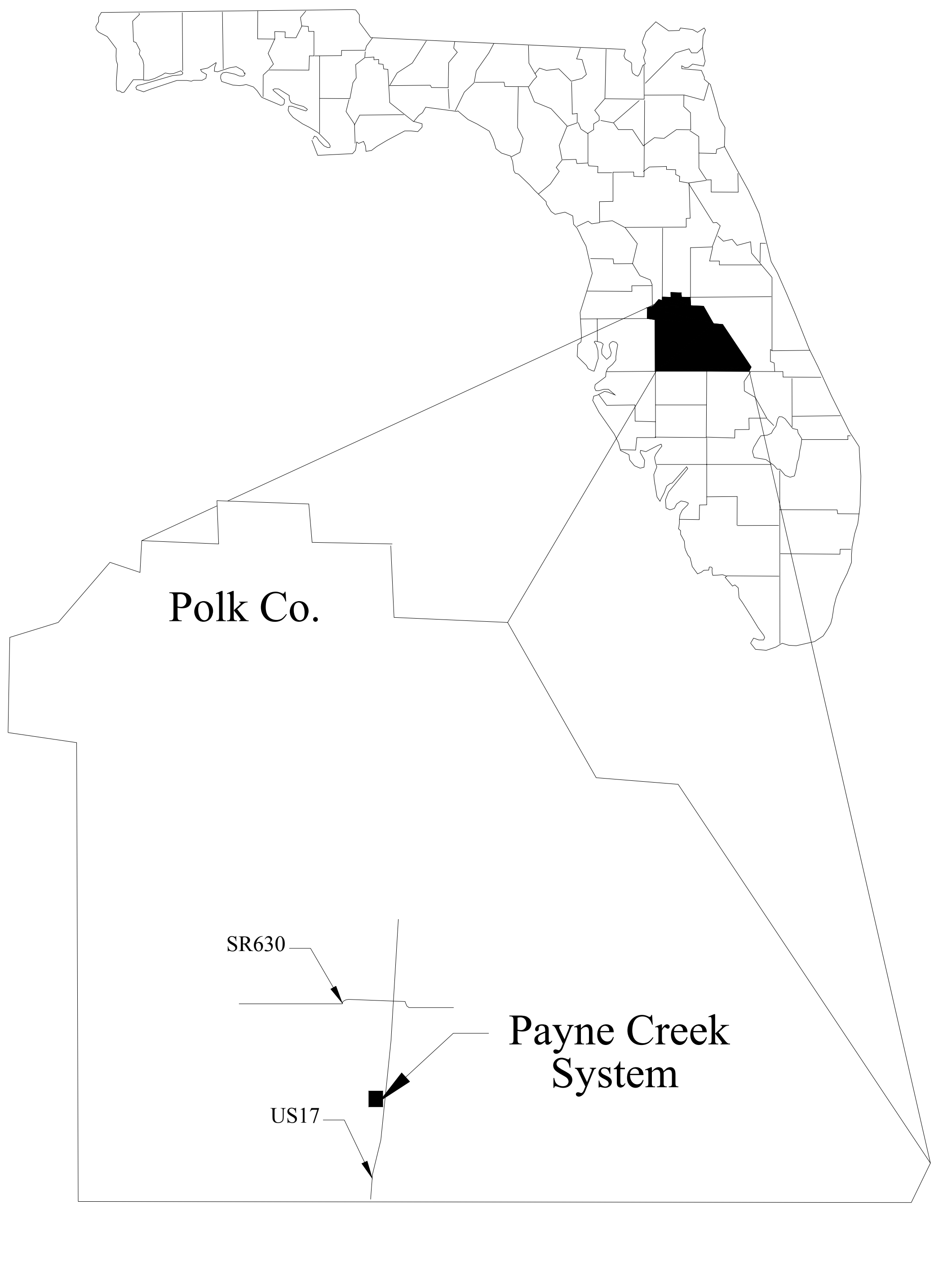

Figure 9. General Location of the Cargill Ft. Meade/Bowling Green Project Site.

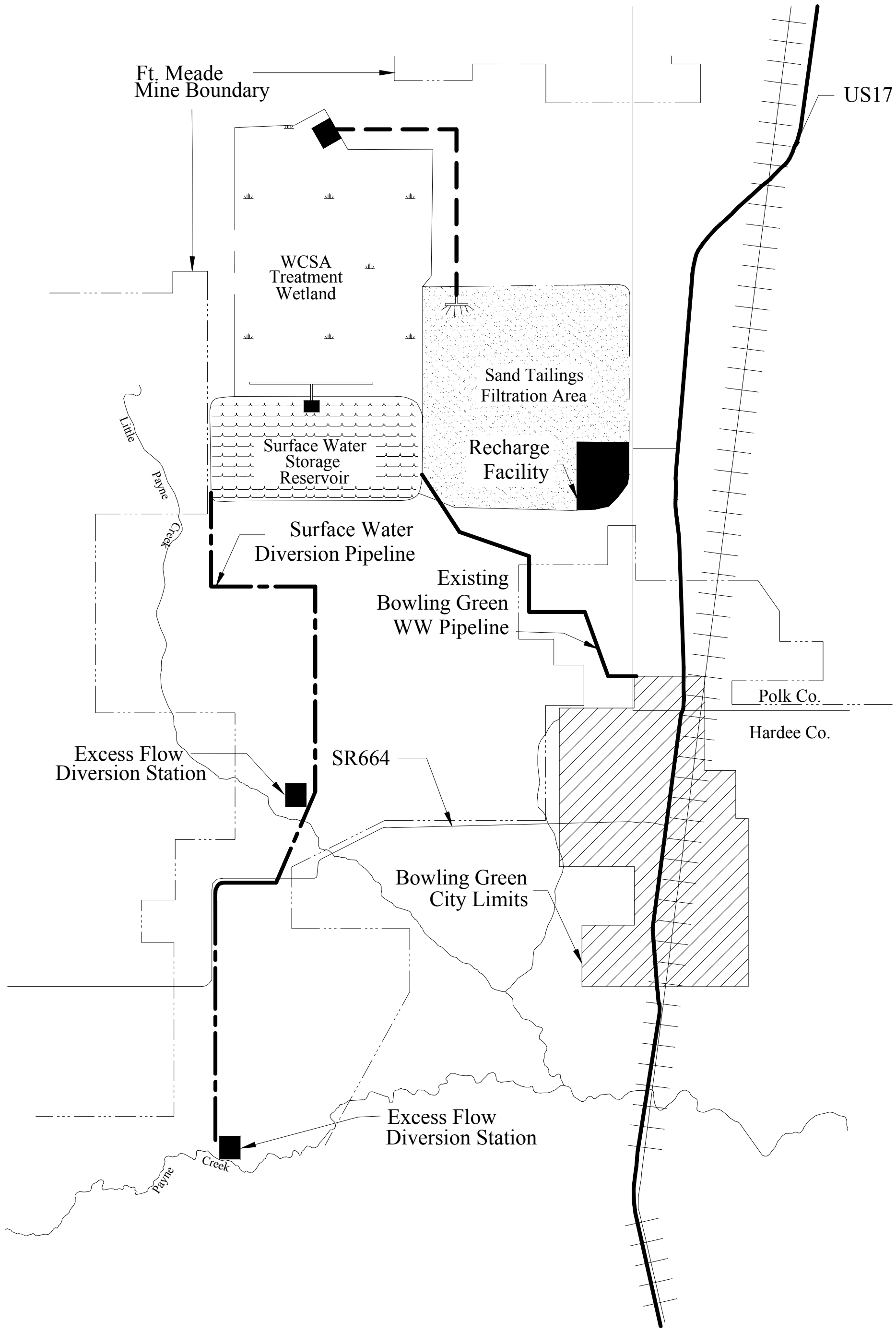

Figure 10. Plan View of the Proposed Cargill Ft. Meade/Bowling Green Project Elements.

Based on the surface water flow records from 1963 through 1997 at the Payne Creek gaging station near Bowling Green, the long-term average daily withdrawals were calculated to be 6.8 MGD. Table 3 presents the calculations. In the first column, the average long-term daily flows for the months indicated are listed. In the second column, the ten percent withdrawals are shown. These volumes are used to calculate the total average monthly volume in acre-feet of surface water that can be diverted. The total annual volume is then divided by 365 days to calculate the average daily withdrawal rate of 6.8 MGD.

Table 3. Estimated Average Daily Surface Water Diversions from Little Payne Creek and Payne Creek.

Month	Mean Daily Flow (cfs)	10% of Mean Daily Flow (cfs)	Monthly Volume (ac-ft)
October	115	11.5	7.7
November	63.0	6.3	375
December	50.3	5.0	308
January	67.3	6.7	412
February	82.7	8.3	461
March	85.3	8.5	523
April	63.5	6.4	381
May	39.6	4.0	246
June	102	10.2	607
July	168	16.8	1033
August	214	21.4	1316
September	216	21.6	1285
TOTAL ANNUAL VOLUME			7,654

NOTE: USGS data.

Conceptual Engineering Design

The conceptual engineering design calls for the construction of two surface water diversion structures on Payne Creek and Little Payne Creek. There are no reliable long-term flow records for the Little Payne Creek to size the diversion structures, however for the preliminary design, we assumed that 2/3 of the total 24-inch diameter pipeline conveyance capacity (9 Mgd) from Payne Creek and the remainder from Little Payne Creek.

The pipeline has been sized to be able to convey the larger monthly flows for August and September shown in Table 3. At a flow rate of 6 ft/sec, the decision was made to select a 24-inch diameter pipeline. This pipe will be installed entirely within the property of Cargill's Ft. Meade Mine. It will cross Little Payne Creek at an existing permitted crossing point. The total length of the pipe is 20,300 ft (3.85 miles).

From the two surface water systems the water will be discharged into an existing surface water storage reservoir that also receives 200,000 gpd of reclaimed water from the Bowling Green WWTP. From the reservoir, the water will be pumped into the southern end of the CSA treatment wetland. The surface area of this treatment wetland is approximately 750 acres. We have estimated that a treatment capacity of 100 acres per 1.0 MGD of surface water effluent is a reasonable and probably conservative volume. Total average flow into the reservoir is estimated to be 6.8 MGD from the creek system and 0.2 MGD from the City of Bowling Green, for a total of 7.0 MGD. Therefore, we believe that the system is well matched.

From the northern end of the CSA Treatment Wetland, the water will be pumped to the sand filtration area in Section 29. Assuming an effective long-term application rate of 6 inches per day, a total filtration area of 36 acres is needed. To ensure effective continuous filtration, an additional area of 36 acres is added for a total of 72 acres.

Tailing sand was deposited in the mined area in Section 29. The creation of a tailing sand filtration system will require the installation of horizontal wells at a depth of 25 feet. Analyses of the tailing sands generally indicates that the selection of a 0.01 to 0.02-inch slotted filter pipe will allow the development of an effective natural gravel pack. The yield for 6-inch diameter Schedule 40 PVC filter pipe range from 2.6 to 4.6 gpm. To filter 7.0 MGD, a total filter pipe length of 2,680 feet is needed.

From the filter pipes, the water will be recharged through two connector wells into the Upper Floridan Aquifer. The rate of recharge is assumed at 2,500 gpm for each well. With an estimated specific capacity of the wells of 300 gpm/ft, the rise in the potentiometric surface at the well head is not expected to exceed 10 to 15 feet, which is less than the 40-foot difference between the water-table elevation in the surficial aquifer and the underlying potentiometric surface in the Upper Floridan Aquifer in September of each year. A third recharge well is added to insure extra capacity during the high flow times and as a stand-by in case any of the other wells need cleaning,.

Preliminary Cost Estimates

The diversion from the Payne Creek system has been sized for the maximum of 14 MGD, shown in Table 3. The total construction cost for both diversion stations is estimated at $1,960,000. The total length of 24-inch diameter pipelines from the diversion structures to the reservoir is estimated at 20,300 feet. At a unit cost of $103 per foot, the total construction cost is estimated at $2,095,000.

To lift and move the water from the reservoir into the adjacent CSA treatment wetland, a pumping station was included in the design. The cost of such a pumping station was estimated at $2,600,000.

To modify the existing CSA into a functioning wetland treatment system, a unit cost of $2,500 per acre was assumed. The total wetland treatment area is estimated at approximately 750 acres and the total construction cost is estimated at $1,875,000.

To allow the water to flow by gravity from the treatment wetland to the tailing sand filtration system, an outfall needs to be constructed with a 24-inch diameter pipeline. The cost of these two facilities is estimated at $500,000 and $743,000 respectively, for a total of $1,243,000.

The construction of the tailing sand filtration basin will involve the installation of horizontal wells at a depth of 25 feet in the existing reclaimed area in Section 29. It will also require the construction of infiltration channels and water distribution systems. Assuming a filter pipe with a 0.010-inch slot size, the total length of the filter pipe is estimated at 2,680 feet. At $65.00/foot, the total cost for the horizontal wells is estimated at $174,000. The modification of the existing area is estimated at a unit cost of $2,500 per acre for a total of $180,000 for 72 acres. Additional costs for the automated control system is estimated at $100,000.

The filtered water will be recharged through three recharge wells at an estimated cost of $100,000 per well, for a total of $300,000. The cost for the pumps is estimated at $15,000 per unit for a total of $45,000.

The total construction cost is estimated by adding all the previous cost estimates:

Total Construction Costs:	$ 10,572,000
Engineering Design/Construction Management Cost at 15%:	$ 1,585,800
Administrative, Legal, and Contingency Costs at 20%:	$ 2,114,400
Total Capital Costs:	$14,272,200

Assuming a 30 year amortization at a 7% annual rate, the

Annual Amortization Cost is:	$ 1,150,140
The Total O & M Cost is estimated at:	$ 975,620
The Total Annual cost is estimated	$ 2,125,760

Based on this total annual cost and a production rate of 7 MGD, the unit cost is $0.83/1,000 gallons.

MANATEE COUNTY/IMC PHOSPHATES NORTHEAST TRACT

The Concept

IMC Phosphates plans future phosphate mining operations in northeastern Manatee county in an area called the Northeast Tract. The location of the project area is presented in Figure 11. With the onset of mining, there will be a unique opportunity to construct a reservoir-wetland treatment-filtration-aquifer recharge facility that may become part of the requested post-mining reclamation plans.

The concept was initially based on the idea that the Manatee County reclaimed water plans called for the delivery of reclaimed water to Lake Parish, which is a man-made impoundment created as a cooling pond for the Manatee County Power Station near Parish owned and operated by Florida Power and Light (FP&L). Surface water diverted from the Little Manatee River fills this impoundment. A plan was developed to bring reclaimed water from Manatee County Utilities to the FP&L power plant. Additional agricultural users would also be served by the reclaimed water line.

This project focused on exploring other additional sources of water for that system, such as the excess flows spilling over the dam at Lake Manatee. SWFWMD provided the record of flow over the dam from 1985 through 1997. A graphical representation of that record is presented in Figure 12. A comprehensive analysis of the record shows that during the period from 1985 through 1997, there were an average 60 days per year when surface water flows greater than 100 MGD (155 cfs) flowed over the Manatee Dam and 48 days when the flow was greater than 148 MGD as shown in Table 4. The flows of 100 MGD and 148 MGD were selected because they are the conveyance capacities of a 72-inch and 84-inch diameter pipeline, respectively.

Assuming that an average of 148 MGD could be withdrawn from the Lake Manatee Reservoir during 48 days per year and 100 MGD for the remaining 12 days per year, a total of 8.3 billion gallons can be diverted to an upland reservoir treatment and recharge facility. The average daily rate would be 23 MGD. A schematic layout of the proposed pipeline systems is shown in Figure 13. According to information provided by Manatee County Utilities and SWFWMD, a 24-inch diameter reclaimed water pipeline is planned to be installed to feed a future reservoir on the IMC Phosphates Northeast Tract as shown in Figure 14. The plans call for the delivery of 8 MGD. In our conceptual engineering design, we included the delivery of 8 MGD of reclaimed water. This will bring the total quantity to 31 MGD. The concept includes that construction of a dual in-ground reservoir system along the south side of the Little Manatee River. From the reservoir, the water would flow by gravity to a large tailing sand filtration area. Both features could be incorporated in the reclamation design for the Northeast Tract.

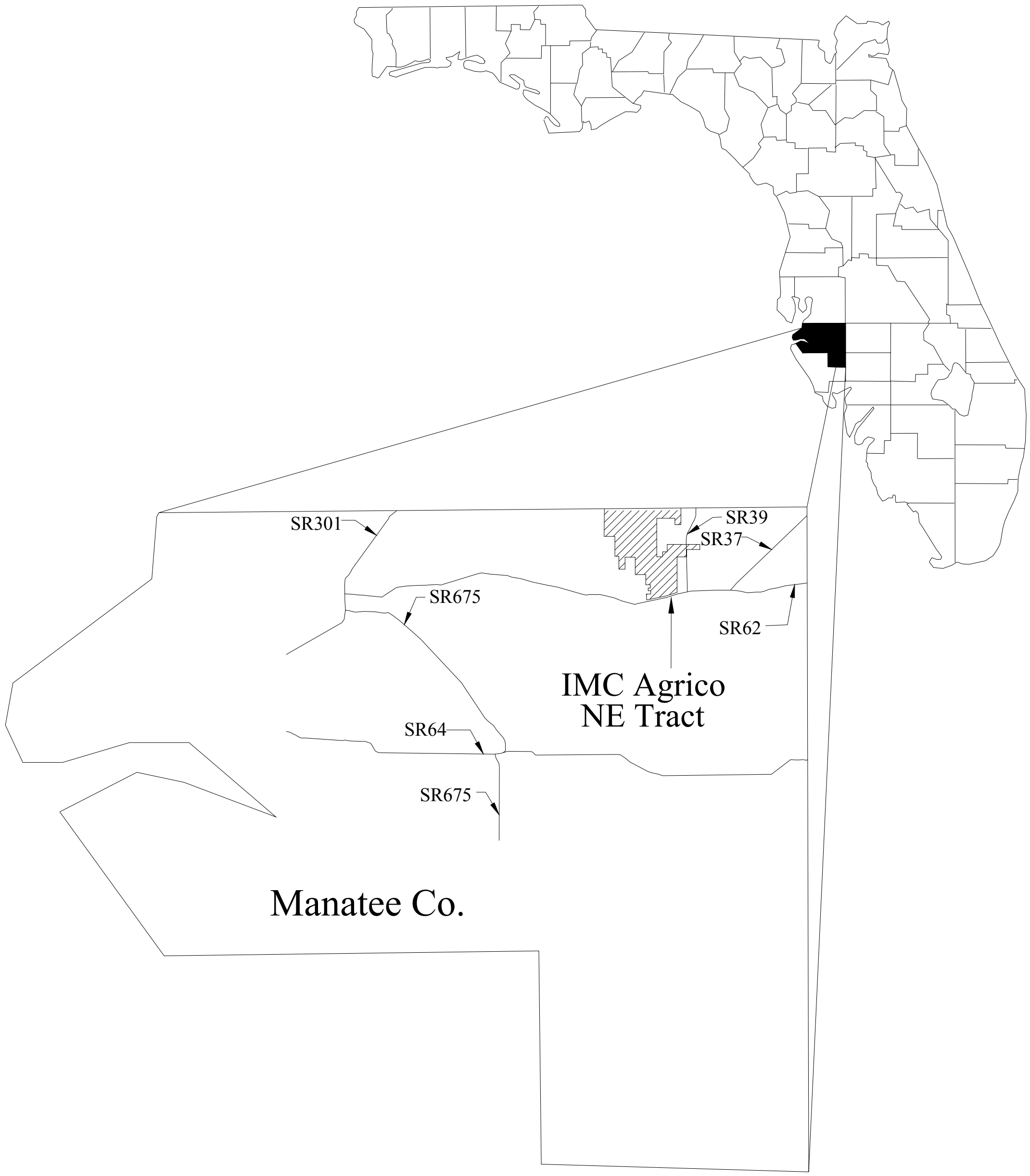

Figure 11. General Location of the Lake Manatee/IMC Phosphates Northeast Tract Project Site.

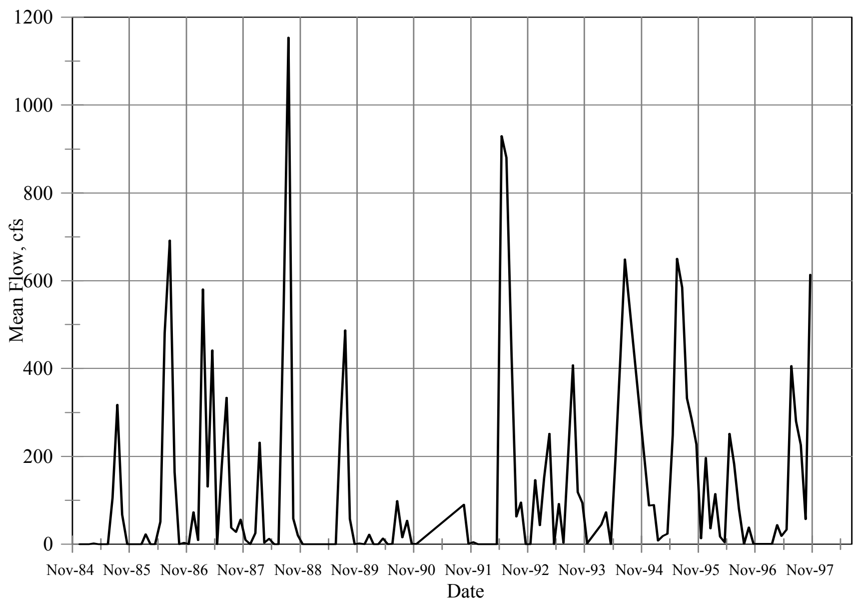

Figure 12. Hydrograph of Long-Term Flow over Lake Manatee Dam.

Table 4. Number of Days in a Year with Flows Greater than 100 and 148 MGD over the Lake Manatee Dam.

Year	Number of Days with Flow Over 100 MGD	Number of Days with Flows Over 148 MGD
1985	19	15
1986	68	65
1987	66	56
1988	61	58
1989	37	34
1990	16	12
1991	4*	3*
1992	62	48
1993	70	58
1994	68*	56*
1995	117	84
1996	63	46
1997	72	41
Total Days	719	573
Average Days/Year	60	48

* Incomplete Record

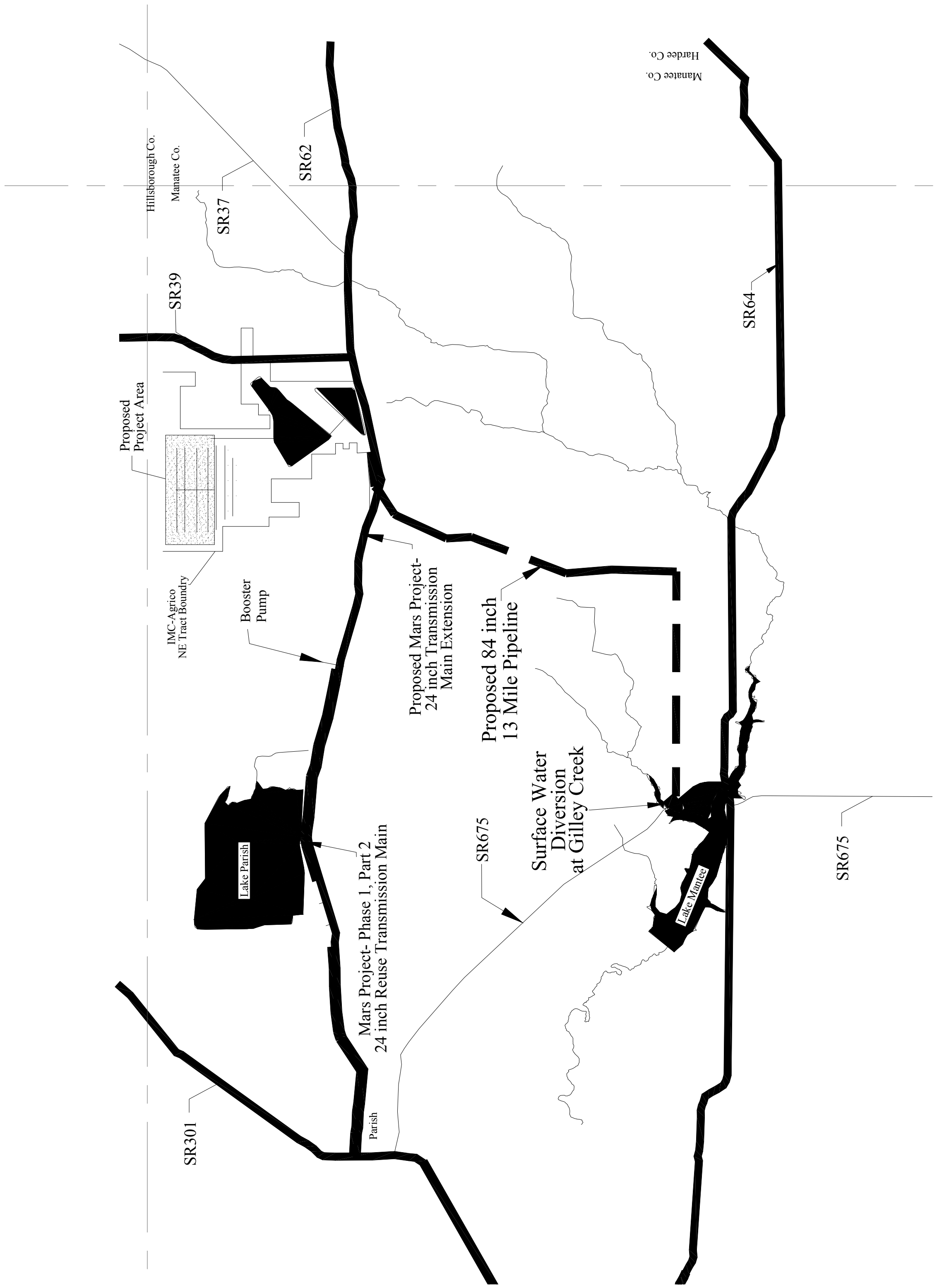

Figure 13. Pipeline and Reservoir Elements of the Proposed Lake Manatee/IMC Phosphates Project Site.

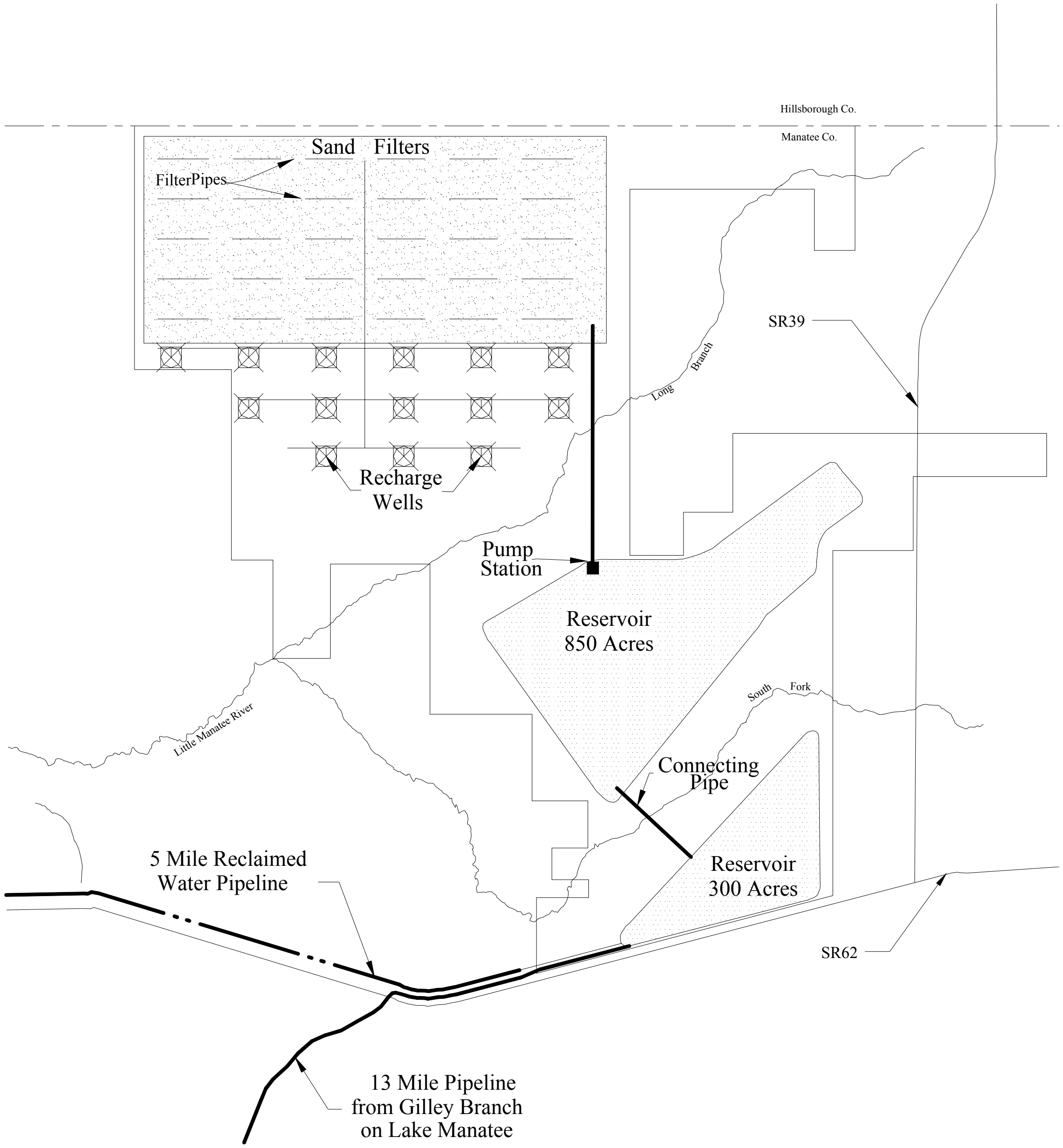

Figure 14. Conceptual Engineering Design for the Manatee County Reclaimed Water-Lake Manatee-IMC Phosphates Northeast Tract.

Conceptual Engineering Design

In Figure 14 the required elements of the conceptual engineering design for the Manatee County Reclaimed Water-Lake Manatee-IMC Phosphates Northeast Tract are presented. The water from the reservoir will be mixed with the reclaimed water in the reservoir. Based on preliminary data from a test at the FPC site, the reservoir and subsequently the filtered water will meet all drinking water standards, except possibly for iron, manganese and color.

There will be an 84-inch diameter pipeline approximately 13 miles long to carry the water from Lake Manatee at Gilley Creek to the Northeast Tract. A pumping station and intake will be needed, capable of pumping 148 MGD through the 84-inch diameter pipeline to the dual reservoir system proposed on the IMC Phosphates Northeast Tract. At the end of the proposed 24-inch diameter Manatee County reclaimed water line, the conceptual design calls for the installation of a booster pump and approximately 5 mile continuation of the 24-inch diameter pipeline to the dual reservoir system. Eight-foot high dams will surround the two reservoirs and the maximum water level will be 3 ft above grade. The water level operating range will be 21 ft. The bottom of the reservoir is at 28 ft below grade and will require flattening the overburden in the excavation.

The two reservoirs will be connected through a 36-inch diameter pipe. The stored water will be pumped from northern reservoir through a 5,700 ft long 36-inch diameter pipeline to the 816-acre tailing sand filtration basin. It is assumed that IMC Phosphates will have created the tailing sand filtration basin as part of their Northeast Tract reclamation plan.

At the 816 acre tailing sand area, the conceptual engineering plan calls for the installation of 14,100 linear feet of 6-inch diameter schedule 40 PVC filter pipe with 0.010-inch slots. The transformation of the 816 acres of tailing sand into a filtration basin has been costed at $2,500 per acre.

Recharge of the filtered water to the underlying Floridan Aquifer will be through 14 recharge wells at a rate of 2,500 gpm. Four additional standby wells are included in the cost estimates. The potentiometric surface of the Floridan Aquifer is generally the highest in the project area in September, when it reaches approximately 10 ft above the National Geodetic Vertical Datum. During the dry month of May, the potentiometric surface often declines to -10 ft below the National Geodetic Vertical Datum. Thus, the downward hydraulic gradient ranges from 75 to 95 ft.

A 30 MGD recharge operation would improve the groundwater conditions in the area, which is highly impacted by pumping, possibly allowing for the development of additional drinking water supply well fields.

Preliminary Cost Estimates

The following cost estimates were prepared for each one of the engineering elements in the conceptual plan described in the previous section:

Intake Structure at Lake Manatee at Gilley Branch	$11,716,000
84-inch Pipeline to Northeast Reservoir	$25,139,520
Extension Reclaimed Water Pipeline	$2,518,000
Booster Pump in Reclaimed Water Pipeline	$1,041,400
Construction of 2 Reservoirs	$5,868,000
Pipe Connection Between Reservoirs	$774,000
Piping and Pumps from Reservoir to Tailing Sand Filtration Basin	$1,900,000
Installation of Filtration Piping	$1,411,500
Preparation of Surface of Tailing Sand Filtration Basin	$2,040,000
Recharge Wells Plus Controls	$2,160,000
Installation of Continuous Monitoring System	$3,500,000
Total Estimated Construction Costs	$58,068,420
Engineering Design/Construction Management	$8,710,263
Administrative, Legal and Contingency Costs	$11,613,684
Total Capital Costs	$78,392,367
The Amortization Cost at 7% for 30 Years:	$6,317,327

The O & M costs were calculated on an daily flow of 30 MGD. The annual O & M costs are estimated to be $3,157,550. The total annual operating cost is $9,474,877. Using a daily average of 30 MGD gives a unit cost of $0.86/1,000 gallons**.**

CITY OF ST. PETERSBURG/IMC PHOSPHATES BIG FOUR MINE

The Concept

The City of St. Petersburg disposes of its wastewater in two ways. First and foremost, the City was the first to develop the concept of redistributing treated wastewater (reclaimed water) to neighborhood yards and parks for garden irrigation. They are considered both nationally and internationally as leaders in this field. However, the City still disposes of approximately 25 MGD of water through deep injection wells during wet weather periods. This practice may have to end in the near future, and therefore other means of disposal are being explored.

One of the disposal options could be the transport of wastewater from the City's Albert Whitted WWTP across Tampa Bay to the IMC Phosphates Big Four and Ft. Lonesome phosphate mines. At the beginning of this project there was interest by the City in the idea of bringing potable water back from the mainland through a parallel pipeline. When the Tampa Bay Water partnership was formed, the City no longer has the responsibility to develop new sources of potable water. While no longer useful to the City, the concept is, however, still included in the project description but not costed.

This specific project would take excess reclaimed water from the Albert Whitted WWTP in St. Petersburg and convey that water by pipeline under Tampa Bay for wetland treatment at the IMC Phosphates Big Four Mine near Ft. Lonesome. Figure 15 shows a location map of the project area. The treated discharge from the wetlands would be filtered through tailing sand deposits and then the potable quality water would be recharged to the Floridan Aquifer through Class V injection wells. An equivalent volume of Floridan Aquifer ground water could then be pumped from an adjacent well field and returned to St. Petersburg in a parallel pipeline under Tampa Bay. This project would provide the City of St. Petersburg with the twin benefits of disposal of excess reclaimed water and allowing the development of an additional ground water supply source. Another option would be to allow the water leaving the treatment wetland to flow into the South Prong of the Alafia River to augment the baseflow of the river.

Conceptual Engineering Design

The conceptual system consists of a series of components linked together to achieve the goals of repurifying reclaimed water, recharging the Floridan Aquifer and providing a potential supply of new ground water for the City of St. Petersburg. To evaluate the size and cost of the proposed system, a nominal system capacity of 12 MGD was selected. This capacity is equal to the treatment capacity of the Albert Whitted WWTP.

A new pumping station would be required at the Albert Whitted WWTP reclaimed water storage basin. The reclaimed water would be carried in a 24-inch buried pipeline across Tampa Bay. The pipeline route is shown on Figure 15 and extends 9.5 miles to the shoreline of Tampa Bay at Simmons Park near Ruskin. The pipeline installation would include two parallel pipes, one to convey reclaimed water and one return pipeline for potable groundwater from a new well field. The onshore pipeline route would extend east from Simmons Park along the southern edge of Township 31S (N 19th Avenue) to Wimauma-Balm Road, then go north to County Road 672 for a distance of 25.5 miles. A booster pumping station for each line would be located west of U.S. Highway 41.

From the 24-inch diameter pipeline, the water would flow and be distributed to existing wetland cells with a total area of 1,210 acres as shown in Figure 16. Average water depth would be about three feet. Rule-of-thumb sizing for treatment wetlands is 100 acres per MGD, so up to 1,200 acres may be required. From the wetlands treatment system, the water would flow to sand filter basins for removal of suspended solids and bacteria. The filter basins could be constructed either in-ground or above ground utilizing existing tailing sand deposits. The proximity to a source of permeable sand is an important consideration in site location.

This project has three options. The first one is the wetland treatment of the reclaimed water followed by discharge to the South Prong of the Alafia River. This mimics the existing City of Lakeland system at Cargill Fertilizer's Bonnie Lake Mine, near Mulberry.

The second option is to filter the water through the tailing sands for recharge to the underlying Floridan Aquifer. The project area is just to the east of SWFWMD's Most Impacted Area and recharging the aquifer with 12 MGD would be beneficial, particularly considering the reduction of the potential for salt water intrusion.

The third option is to install a well field to the west of the ground water recharge point and to extract the same quantity that has been recharged. The water from the well field could be pumped into the existing raw water lines operated by Tampa Bay Water or could be returned to St. Petersburg. This option has not been costed.

In the following section, the costs for each option will be estimated. There is, however, an auxiliary issue which concerns the financial benefit to the City of St. Petersburg if the City does not need to upgrade their WWTP to provide advanced level treatment before the effluent can be discharged to Tampa Bay, instead of being disposed of by deep-well injection.

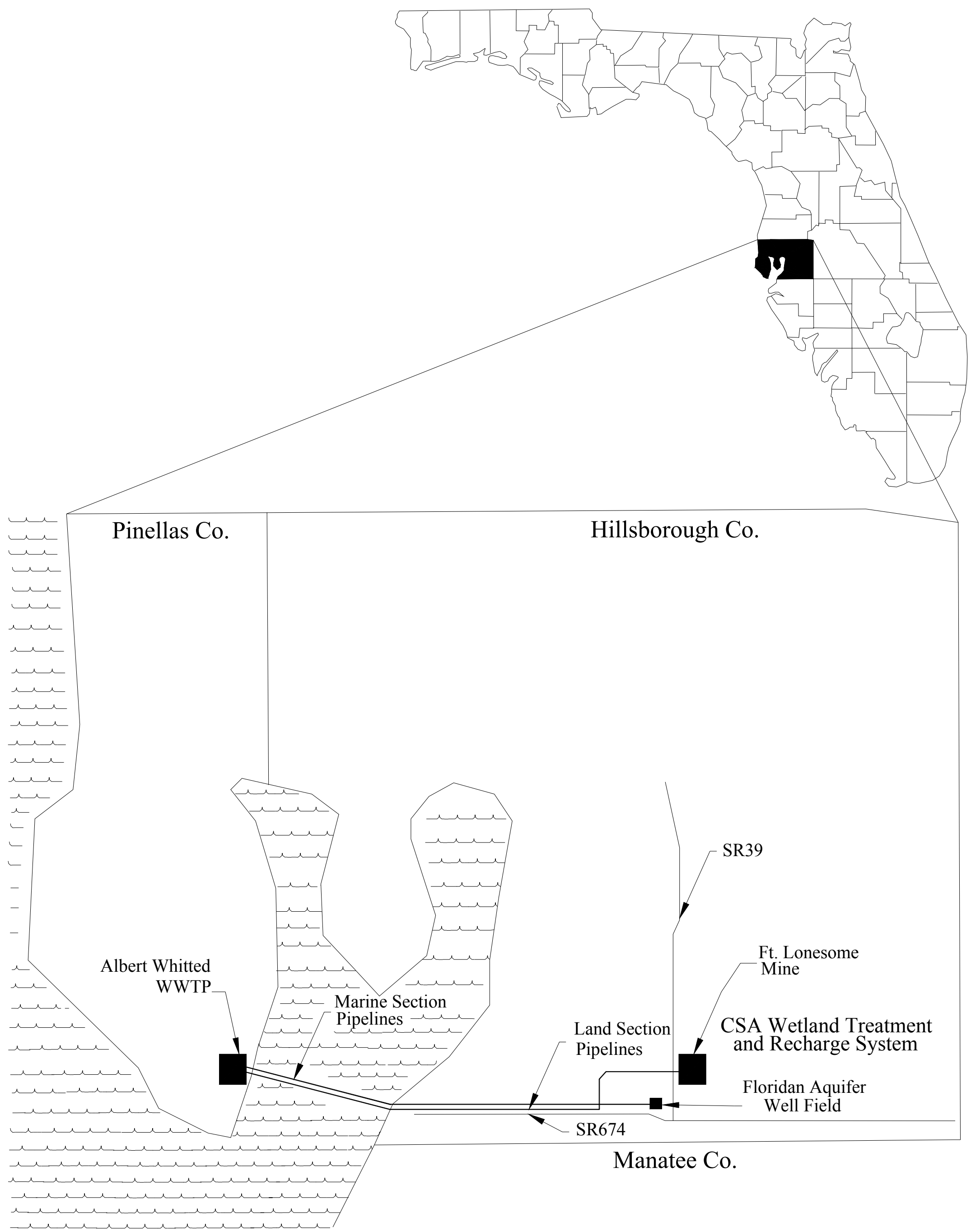

Figure 15. General Location of the St. Petersburg-IMC Phosphates Big Four Mine.

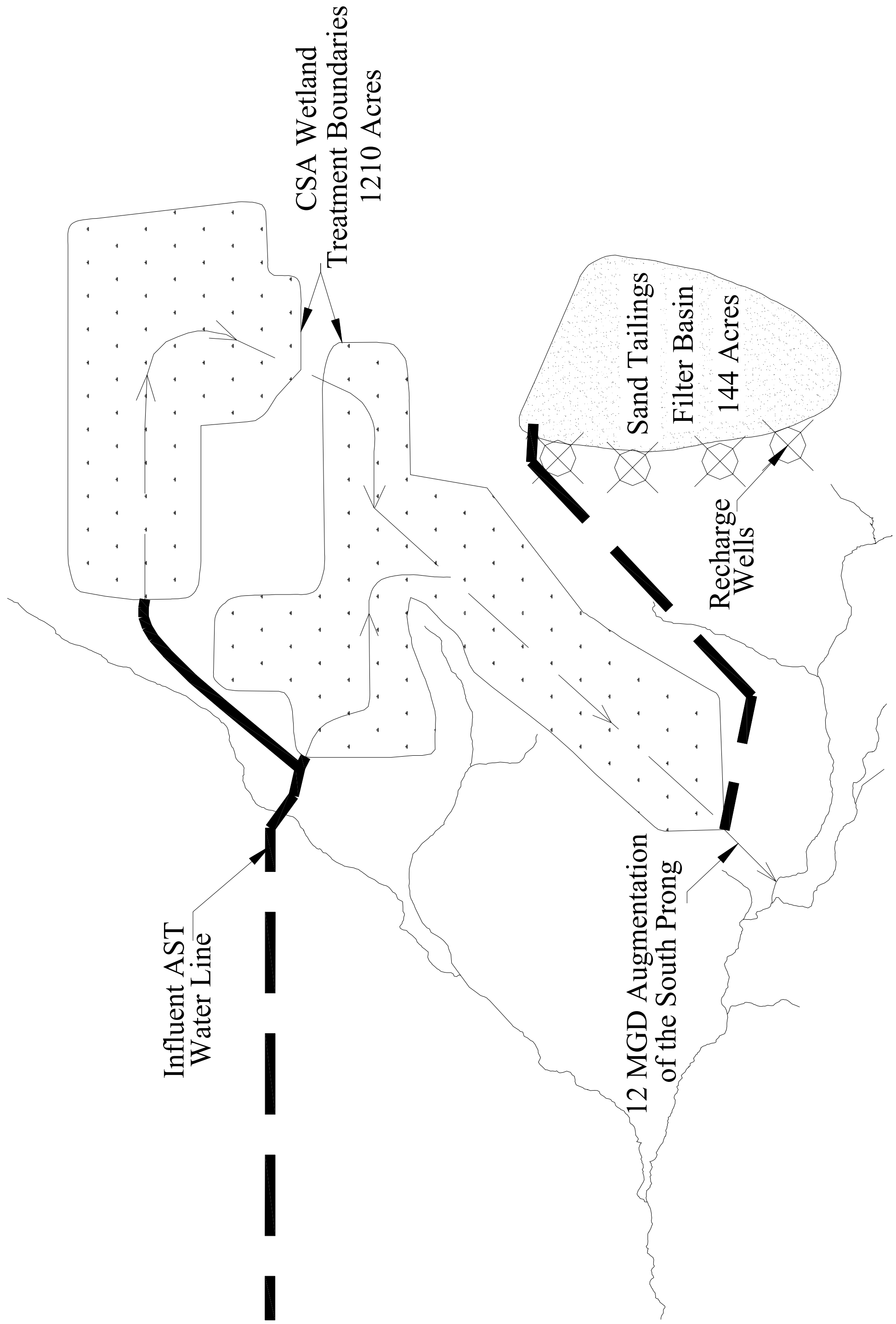

Figure 16. Project Design Elements of the St. Petersburg-IMC Phosphates Big Four Mine.

Preliminary Cost Estimates

Option A: Augmentation of the South Prong of the Alafia River

In this option only the costs for the treatment of 12 MGD from the Albert Whitted WWTP by the wetlands on IMC Phosphates' Big Four Mine, followed by discharge to the South Prong of the Alafia River will be given.

A 9.5 mile long, 24-inch diameter HDPP marine pipeline	$ 27,000,000
A 16.12 mile long 24-inch diameter overland pipeline	$ 13,915,488
Booster Pumps at Albert Whitted WWTP and US 301	$ 2,082,844
Improvements at the existing Big Four CSAs	$ 3,025,000
Construction Outfall Structure	$ 750,000
Control Systems and Continuous Monitoring Stations	$ 3,000,000
Total Estimated Construction Costs	$ 49,773,332
Engineering Design and Construction Management	$ 7,466,000
Administrative, Legal and Contingency	$ 9,954,666
Total Capital Costs	$ 67,193,994

Assuming a 30 year period and an annual interest rate of 7.0%, The annual amortization is:	$ 5,414,896
The annual O & M Costs are estimated at:	$ 2,693,920
The estimated total annual costs are	$ 8,108,816

Based on this cost, the Unit Cost is $1.85/1,000 gallons.

Option B: Recharge to the Floridan Aquifer

The cost of the wetland treatment in this option is the same as in Option A. To this treatment cost the following items are added:

Preparation of 142 acres of existing tailing sand areas	$ 355,000
Construction of the filter piping system	$ 340,000
Installation of recharge wells and pumps	$ 460,000
Control Systems	$ 100,000
Total Additional Construction Costs	$ 1,255,000
Total Construction Cost Option B	$ 51,028,332

Total Capital Cost	$ 70,582,498
Annual Amortized Cost	$ 5,687,961
O & M Costs	$ 3,171,680
Total Annual Cost	$ 8,859,641

Unit Cost to recharge the Floridan Aquifer is $2.02/1,000 gal.

CITY OF TAMPA HOOKERS POINT WWTP/SYDNEY MINE/IMC PHOSPHATES HOPEWELL MINE

The Concept

The City of Tampa operates the Howard F. Curren WWTP at Hookers Point, a peninsula in McKay Bay. This WWTP produces high quality reclaimed water. The concept is based on diversion of 30 MGD of reclaimed water through a 36-inch diameter pipeline to the unreclaimed wetlands on the south side of State Road 60 at the Sydney Mine. A total of 2,542 acres of old CSA have been identified to be converted into treatment wetlands. Bringing water to the site also offers the unique opportunity to create a wildlife habitat and park setting close to an urban area.

From this wetland system, the water could be discharged to the Alafia River to augment baseflow or be pumped to the Hopewell Mine owned and operated by IMC Phosphates for filtration and discharge. The mine produces very clean tailing sands that can be used in the construction of several filtration basins in areas that are presently being mined.

This concept, as shown in Figure 17, offers two opportunities to augment the water resources availability in the area. The first one is the augmentation of the baseflow of the Alafia River. After passing through the wetland system, the wetland treated water can be discharged to Turkey Creek, which flows into the Alafia River. This augmentation would benefit Tampa Bay Water's diversion from the Alafia River.

The second opportunity is the recharge of the Floridan Aquifer which is widely used as a source of ground water to support intensive agriculture and public supply (South Central Hillsborough County Wellfield) and, as such, is being considered as stressed. Augmenting the aquifer would possibly allow the South Central Hillsborough County Wellfield to increase its average daily pumping rate from 24 MGD presently permitted to 40 MGD, which is its maximum pumping capacity. This would significantly improve the delivery capacity of Tampa Bay Water to eastern Hillsborough County.

Conceptual Engineering Design

The plan calls for the construction of a 36-inch diameter 3,000-foot long marine pipeline followed by a 69,000-foot overland pipeline to the Sydney Mine wetlands. A booster pump station is included in the design. At the Sydney Mine, costs have been allocated to modify and prepare the wetlands for their function as a contiguous and hydraulically continuous treatment system. From the wetlands, the water is pumped to the Alafia River via Turkey Creek (Option A) or to the Hopewell Mine (Option B). Option A will require the construction of an outfall structure at Turkey Creek.

For Option B at the Hopewell Mine, two tailing sand filtration basins will be built along with a recharge wellfield of eight wells. A more detailed plan view is provided in Figure 18.

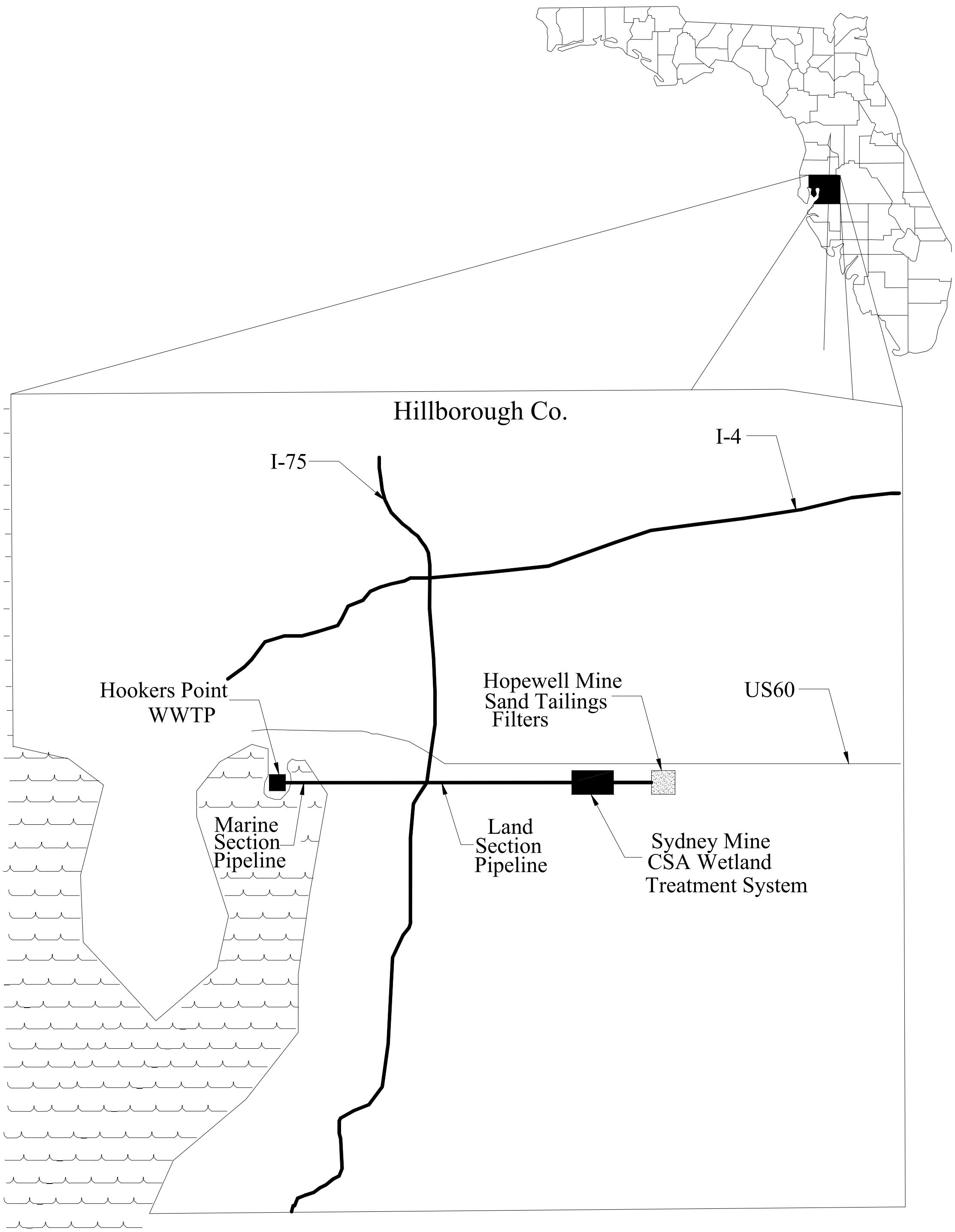

Figure 17. General Location of the City of Tampa/Sydney-Hopewell Mines Concept.

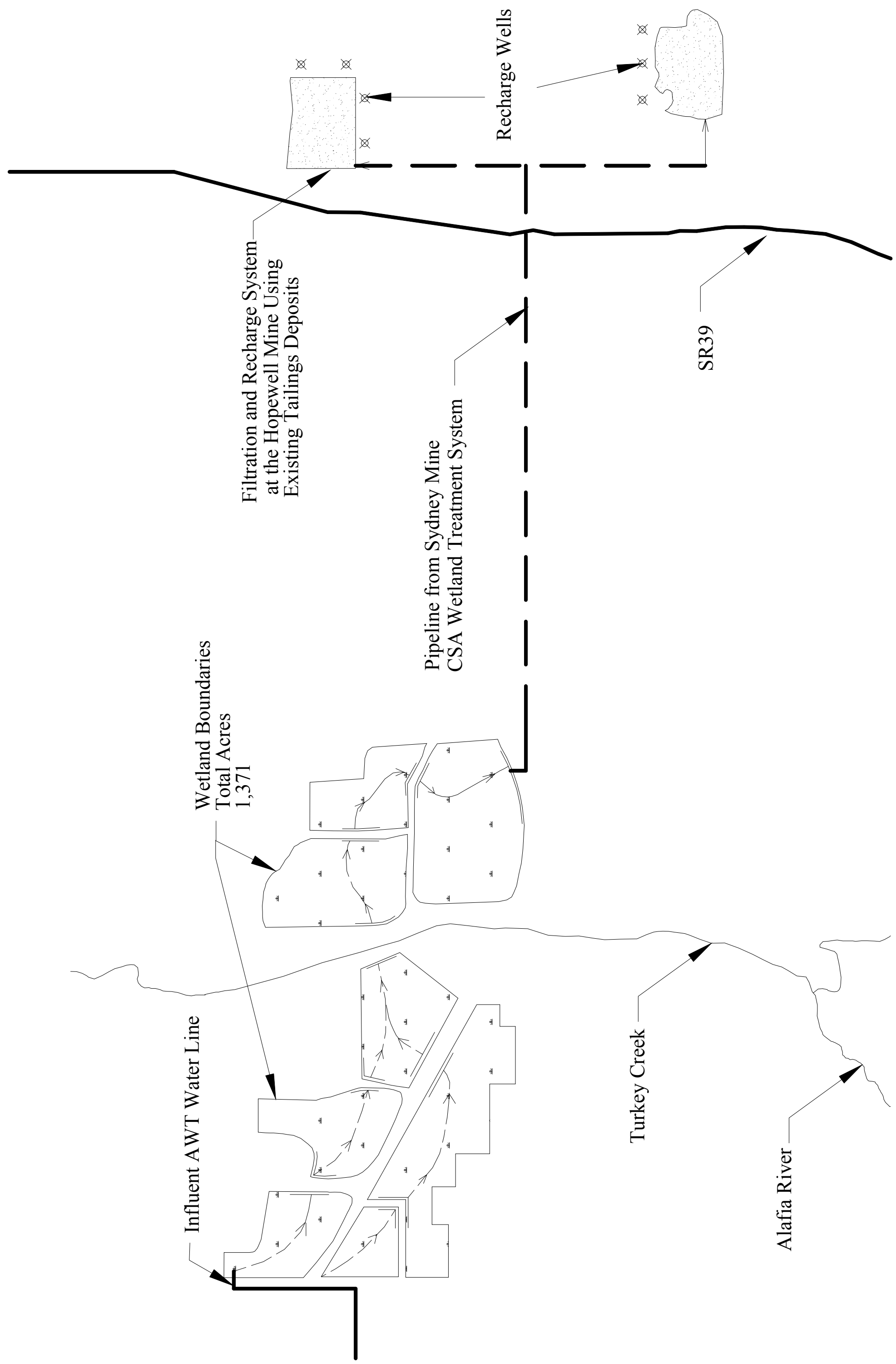

Figure 18. Plan View of the Engineering Elements of the City of Tampa/Sydney-Hopewell Mines Concept.

Preliminary Cost Estimates

A detailed list of the cost elements for each option are presented below.

Option A: Discharge to Alafia River

Pipes:		
	Marine	$ 9,000,000
	Overland	$10,681,000
	Wetland	$ 3,000,000
Pumps:		
	Booster	$ 2,000,000
	Wetland	$ 2,000,000
Wetland Modification: 2,542 acres @ $1,000		$ 2,542,000
Purchase 2,542 acres @ $1,500		$ 3,813,000
Outfall Structure		$ 1,000,000
		$34,036,000
Additional Modifications		$11,912,600
Total Capital Cost		$45,948,600
Annual Amortization at 7%		$ 3,702,814
O & M Costs		$ 3,509,800
Total Annual Cost		$ 7,212,614

Unit Cost is $0.66/1,000 gallons.

Option B: Recharge to Floridan Aquifer

Pipes:		
	Marine	$ 9,000,000
	Overland	$10,681,000
	Wetland	$ 3,000,000
Pumps:		
	Booster	$ 2,000,000
	Wetland	$ 2,000,000
Wetland Modification: 2,542 acres @ $1,000		$ 2,542,000
Purchase 2,542 acres @ $1,500		$ 3,813,000
Outfall Structure		$ 1,000,000
Pipeline to Hopewell		$ 4,365,360
Purchase 245 acres of Tailing Sands @ $2,500/acre		$ 612,500
Modifying Tailing Sand Deposits (245 x $2,500/acre)		$ 612,500

Install filter pipes	$ 846,883
Install 8 recharge wells	$ 800,000
Pumps (and)	$ 160,000
Continuous Monitoring Equipment	$ 1,000,000
Booster pump	$ 1,000,000
	$43,433,243
Additional Costs	$15,201,635
Total Capital Costs	$58,634,878
Annual Amortization at 7%	$ 4,725,150
O & M Costs	$ 4,668,034
Total Annual Cost	$ 9,393,184

Unit Cost is $0.86/1,000 gallons.

CONCLUSIONS

This feasibility study has shown that a mixture of wastewater, storm water and excess surface water can be successfully treated in a natural manner using reclaimed mine lands from the phosphate mining industry. By applying these waters to reclaimed CSAs for wetland treatment, followed by filtration through tailing sand deposits, the water can achieve a water quality to allow it to be recharged into the Floridan Aquifer for later use. This man-controlled process mimics the natural processes on the land surface which provides recharge to the Floridan Aquifer.

The study has shown five example projects that could be implemented to benefit the water resources of Southwest Florida. Total recharge from these projects would add 84 MGD to the Floridan Aquifer at a cost from \$0.76 to \$2.02 per thousand gallons. The average cost is \$1.20 per thousand gallons.

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