

THE USE OF MINED PHOSPHATE LANDS TO EXPAND REGIONAL WATER-RESOURCES AVAILABILITY ON THE WEST COAST OF FLORIDA¹

by

Peter J. Schreuder and Steven G. Richardson²

Abstract. This project involves the purification of reclaimed and excess surface waters by treatment through natural processes on reclaimed lands previously mined by phosphate mining companies. As a result of the mining process, the phosphate companies leave behind open mine pits, clay settling areas (CSA), and tailing sand deposits (TSD). The companies are required to reclaim the mined areas as land and lakes, wetlands, and/or pasture and agricultural lands. The basis for this project is the assumption that the natural systems, in particular, wetlands, created on reclaimed CSA's followed by tailing sand filtration, will remove any organic, inorganic and microbiological contaminants in surface waters and waste waters, resulting in water that will meet drinking water standards. To store the water, the project envisions recharge to the underlying Floridan Aquifer, a regionally extensive limestone confined ground-water system, capable of storing and transmitting large quantities of water. The projects in support of this concept have been funded by the Florida Institute of Phosphate Research. Studies have been completed on the radiological and microorganism aspects of the percolation of water through tailing sand deposits. This paper will present the results of the studies conducted so far and will describe in detail the ongoing pilot project now being constructed at a site owned and operated by Florida Power Corporation. A feasibility study has identified five project sites where a total of 74 million gallons per day could be harvested, treated and recharged to the Floridan Aquifer at an average cost of \$ 1.10 per 1000 gallons. This augmentation fits well in the overall regional water resources management plan for the Southern Water Use Caution Area, in which an increase of 350 MGD in the regional supply to meet agricultural, industrial and public water supply demands is projected for the year 2020.

Additional Keywords: Water supply development, natural treatment, surface water diversion, ground water recharge.

Description of the Basic Concept

The project involves the purification of reclaimed and surface waters by treatment through natural processes on reclaimed lands previously mined by phosphate mining companies.¹ As a result of the mining process, the phosphate companies leave behind open mine pits, clay settling areas (CSA) and tailing sand deposits (TSD). The companies are required to reclaim the mined areas as land and lakes, wetlands, and/or pasture and agricultural lands.

The basic principle on which this project rests was first described in a progress report for the 94-03-113 project to the Florida Institute of Phosphate Research (FIPR) prepared by Schreuder, Inc. (1996). The assumption is that natural systems, in particular, wetlands, created on reclaimed CSA's followed by tailing sand filtration, will remove any organic, inorganic and microbiological contaminants in surface waters and waste waters.

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 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 recharge basins, created on the top of an area containing mine cuts filled with a deposit of tailing sands. From the recharge basins, the water can percolate vertically downward to a series of horizontally placed filter pipes installed in the lower part of the filled-in mine cut. The water exfiltrating from the TSD's is expected to meet drinking water standards. This water can then be recharged into the underlying Floridan

¹ Paper presented at the 17th Annual National Meeting of the American Society for Surface Mining and Reclamation, Tampa, Florida, June 11-15, 2000.

² Peter J. Schreuder, M.Sc., a Certified Professional Geologist and President of Schreuder, Inc., a Water-Resources & Environmental Consulting Firm, 110 West Country Club Drive, Tampa, Florida 33612, and Steven G. Richardson, Ph.D., Reclamation Research Director at the Florida Institute of Phosphate Research, 1855 Main Street, Bartow, Florida 33830-7718.

Aquifer for storage and later recovery, or it can be piped and pumped to a potable water supply facility. Based on the review of the progress report, FIPR authorized a change in the scope of work, allowing further development of the concept. A detailed schematic diagram of the final form of the concept of the natural purification of surface waters is presented in Figure 1. The development of the final form of the concept included several other studies, which are described and referenced in a following section, History of the Studies.

Location of the Study Area

The area in which the concept could be implemented is within the boundaries of the Bone Valley Phosphate Mining District located in the middle of the Florida peninsula along the Gulf Coast (Figure 2). To implement the concept, it is most useful to have CSA's that are essentially full and will no longer be used, but are not yet reclaimed. Because the phosphate mining operations are generally moving in a southerly direction, the oldest unclaimed CSA's are in the northern part of the Bone Valley Phosphate Mining District, not far from the urbanized areas developing along the east-west I-4 Interstate corridor. The other requirement for successful implementation of the concept is the proximity of the CSA to a TSD and a sustainable source of water with a significant yield.

It was found that major sources of sustainable water supply with significant yields were from Waste Water Treatment Plants (WWTP) near large urban centers. These centers were all located at the edge or outside the Bone Valley Phosphate Mining District. It was therefore decided to include the urbanized areas along the I-4 and I-75 corridors in the study area.

History of the Studies

In November 1994, the senior author was encouraged by the Executive Director of the FIPR, Dr. Richard F. McFarlin, to prepare and submit a proposal to evaluate the feasibility of using mined phosphate lands to store surface water to augment industrial, agricultural and public water supply sources in the spring (dry) season. In the spring of 1995, the Board of Directors approved a two year contract. After the first year, the study determined that surface water storage areas were too shallow and had to be quite large in areal extent to hold sufficient volumes of water to provide a significant, rather constant yield that could be relied on 95% of the

time, in particular during the dry spring months. Because of the large evaporative losses due to the large areal extent, the idea was not deemed to be practically feasible. In 1996 the Hydrology Advisory Committee, a group of outside experts assisting the Director of Reclamation Research Dr. Steven G. Richardson in reviewing, approving and/or rejecting potential research projects, approved a change in the direction of the research. Based on prior knowledge and experience in the Netherlands (Amsterdam Water Supply 1994), where sand dune filtration is one of the steps utilized in the process to make Rhine River water potable, the idea was born to apply that concept here using TSD's as the sand dune equivalent. In addition, a large body of knowledge has emerged and is still emerging as to the use of wetlands to treat waste water. Fortunately, there is a practical example in the area in that the WWTP on the south end of the City of Lakeland is discharging advanced secondarily treated waste water to a CSA. Data have been collected on the concentrations of the NPDES parameters at the inflow and outflow stations for several years. Combining the capacity of wetlands to significantly reduce nutrient and BOD concentrations with the capacity of a sand tailing filter to remove suspended solids and microorganisms was believed to provide water that could meet primary and secondary drinking water standards. If this objective could be consistently met, then the water could be recharged to the underlying Floridan (limestone) Aquifer for storage and subsurface conveyance. While evaporative losses were not entirely eliminated, because during the passage through a wetland transpiration losses will occur, they are significantly less than losses from open water ponds during the dry season. Underground storage in the aquifer will eliminate any further evaporative losses.

The tailing sand, however, is the result of an industrial process, and therefore may impart chemicals to the water percolating through it. The project was expanded to include a bench test investigation into the degree of dissolution of radionuclides from the residual phosphatic minerals into the water in contact with the tailing sand during the filtration phase (Schreuder and Dumeyer 1998). Another concern was the capability of the tailing sand filter to remove bacterial and viral microorganisms. A second bench test investigation was conducted to evaluate that capability (Schreuder, Dumeyer and Stark 1998). A third small study was conducted to evaluate how many pore volumes of water was needed to reduce the sulfate concentrations in one of the tailing sand deposits from 700 milligrams per liter

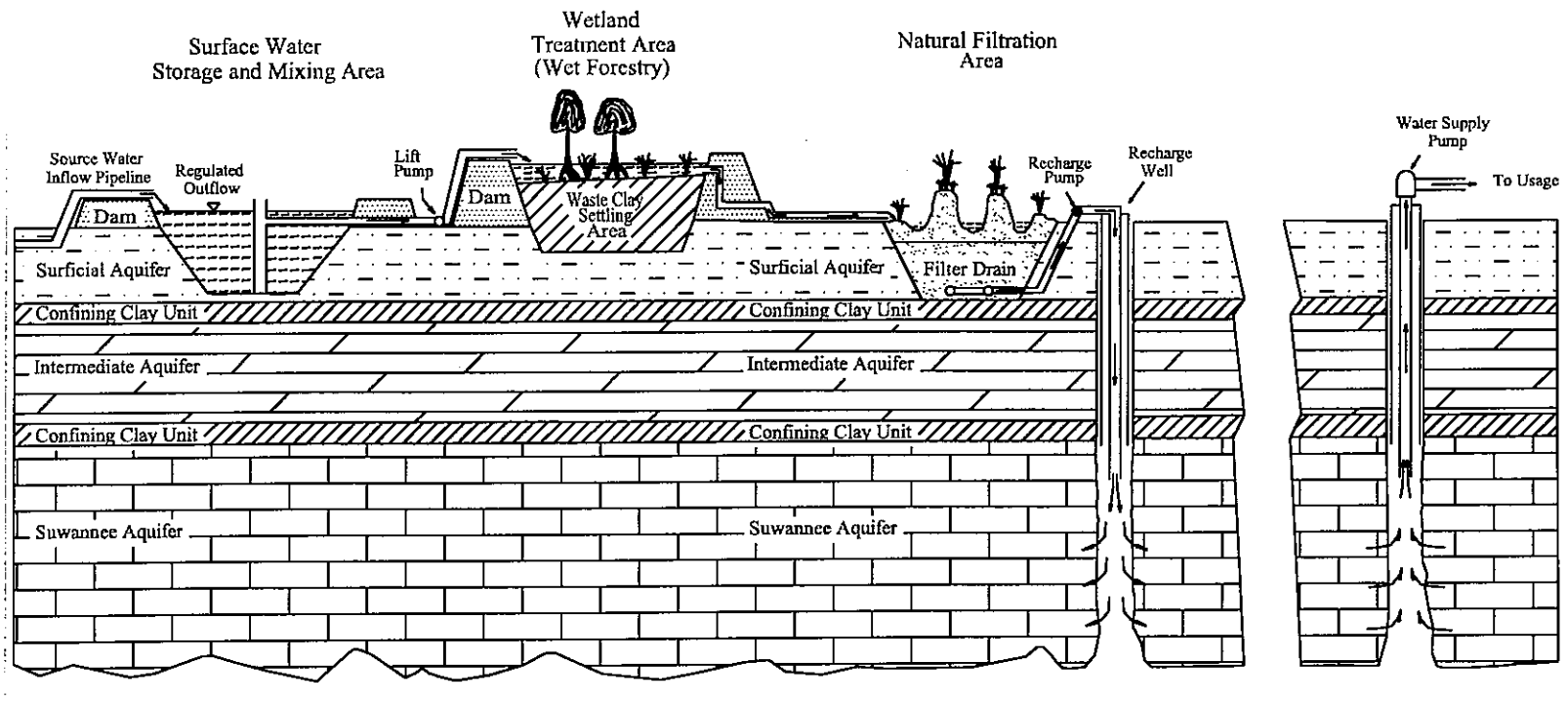


Figure 1: Schematic Diagram of the Integrated Wetland Treatment, Sand Tailing Filtration and Aquifer Recharge Concept

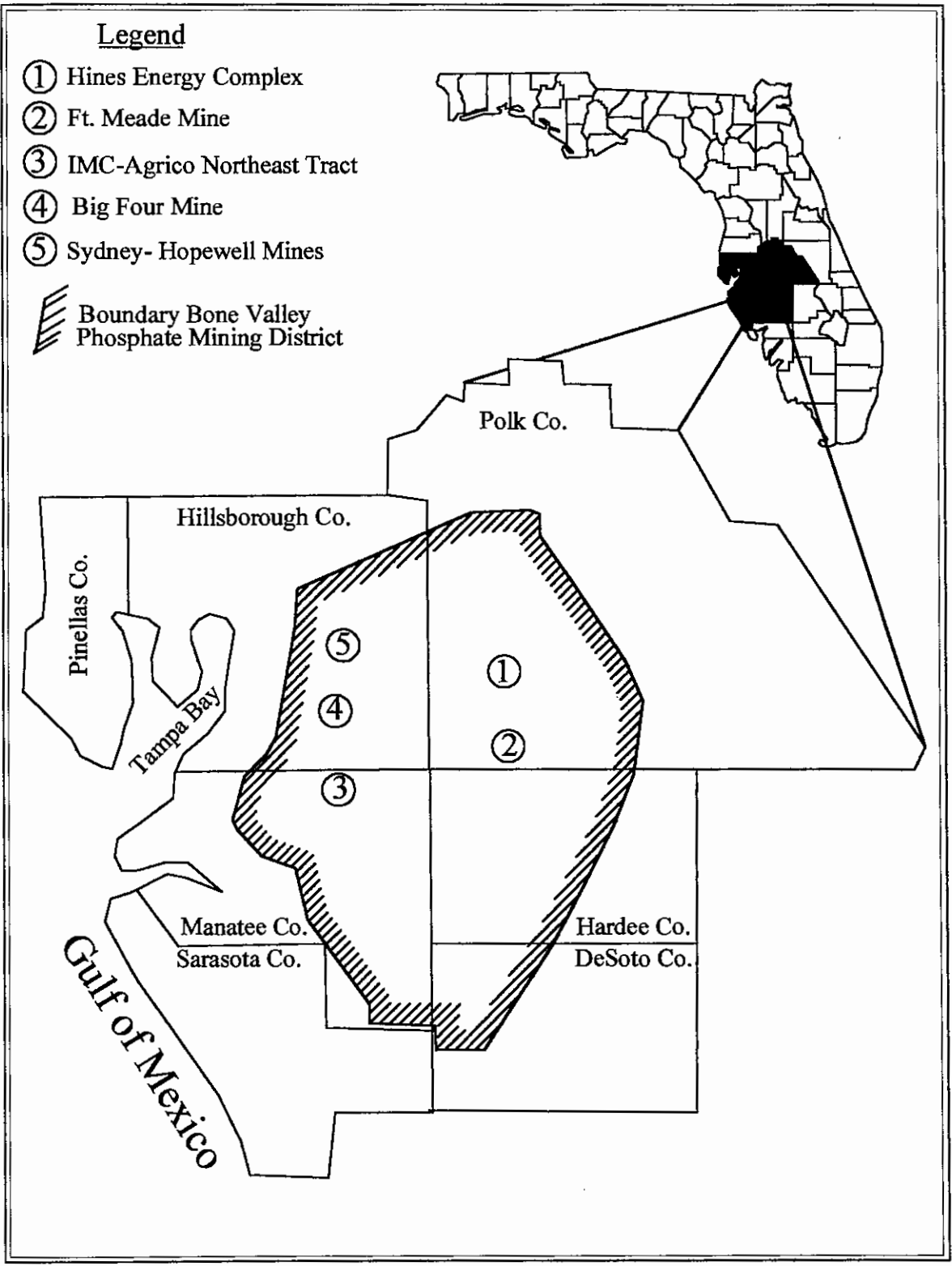


Figure 2: Location of the Project Area, the five proposed Project Sites and the Extent of the Bone Valley Phosphate Deposits

(mg/l) to below the drinking water standard of 250 mg/l. The results are included in the report by Schreuder and Dumeyer (1998).

At present, a pilot study has been jointly funded by the FIPR and the Southwest Florida Water Management District (SWFWMD). In the pilot study, water from three distinctly different sources will be pumped into a wetland on one side, the water will be then pumped from the other side of the wetland onto a tailing sand deposit and the filtered water will be extracted from the tailing sand deposit through a set of horizontal drains or vertical wells. Samples of the water discharging from the tailing sand filter will be collected on a regular basis and analyzed for all recommended primary and secondary water quality constituents as well as for other organic compounds and microorganisms. A summary of the studies that have been sponsored and funded by the FIPR is provided in Table 1.

Results of the Studies to Date

In the following paragraphs a short explanation is given of the results that have been obtained so far.

Feasibility of Natural Treatment and Storage of Waste Waters and Surface Waters Using Mined Phosphate Lands

This project was conducted as an example of the capacity of CSA wetlands to treat advanced secondary treated wastewater from the City of Lakeland's Waste Water Treatment Plant (WWTP). Two years of data from the Bonnie Lake CSA were analyzed and the results are presented below in Table 2. In general, the concentrations of the compounds in the water flowing into the wetland were compared to the concentrations of these same compounds in the water discharging from the wetland into the North Prong of the Alafia River. The reductions and/or increases in the concentrations of the chemical compounds were observed from the water flowing into and out of the wetland.

Information from sand tailing filtration tests is presented in the last item of the list of project descriptions.

The result of the feasibility study is that five (5) potential project sites have been identified as shown on Figure 2. These are presented in Table 3. In that table, a short description of the project is provided, along with

Table 2: Results of the City of Lakeland CSA Waste Water Treatment System

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

the quantity of water that could potentially be recharged to the Floridan Aquifer, and the unit cost per thousand (1000) gallons. This cost was estimated using the preliminary conceptual design and unit costs for certain construction elements (Schreuder and Dumeyer 2000, in press).

Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests

Because the tailing sands can retain phosphate ore, the question was raised if leaching of radioactive compounds associated with the ore could leach into the filtered water to such an extent as to exceed U.S. EPA and FDEP Drinking Water Standards. The Board of Directors of the Florida Institute of Phosphate Research funded an additional investigation of the water quality of the leachate water (Schreuder and Dumeyer 1998).

Tailing sands contain small quantities of phosphate minerals that naturally contain uranium. 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 possible impact on the quality of water filtered through these sands. To address this water quality concern, Schreuder, Inc. (SI) proposed a bench test study to determine the degree that these

Table 1: Summary of Studies conducted in Support of the Integrated Natural Treatment and Aquifer Recharge Concept

<u>Year Proposed</u>	<u>Title of the Study</u>
1994	Feasibility of Natural Treatment and Storage of Waste Waters and Surface Waters Using Mined Phosphate Lands
1996	Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests
1997	An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters
1998	Pilot Project to Test Natural Water Treatment Capacity of Wetland and Tailing Sand Filtration Concept
1998*	Construction and Operation of Two Tailing Sand Test Filters at the Hines Energy Complex
*	This project is funded by the Florida Power Corporation as part of their preliminary investigation to permit a well to recharge the filtered water to the underlying Floridan Aquifer

Table 3: Summary of Project Descriptions, Aquifer Recharge Rates and Unit Costs

<u>Site Number and Project Name</u>	<u>Short Description of the Project</u>	<u>Quantity of Treated Water (MGD)</u>	<u>Unit Cost (\$/1000gal)</u>
1) Peace River/ FPC Hines Site.	Diversion of less than 10% from Peace River flow near Bartow to FPC's Hines Energy Plant site.	5	0.76
2) Payne Creek/ Cargill Ft. Meade Mine.	Diversion from Payne and Little Payne Creek to Cargill's Ft. Meade Mine.	7	0.83
3) Manatee River Reservoir/ IMC-Agrico Northeast Tract.	Diversion from the Manatee River Reservoir during high flow to IMC-Agrico's Northeast Tract (part of Four Corners Mine).	30	0.86
4) City of St. Petersburg Albert Whitted WWTP/ IMC-Agrico's Big Four Mine.	Pumpage of advanced secondary waste water from A. Whitted WWTP through a submarine pipeline across Tampa Bay to IMC-Agrico's Big Four Mine.	12	2.02
5) City of Tampa Hookers Point WWTP/ IMC-Agrico's Sydney Mine.	Pumpage of Advanced Treated Waste Water from the H.F. Curren plant on Hookers Point through a submarine and underground pipeline to the old Sydney Mine and IMC-Agrico's Hopewell Mine.	20	1.07
Total Recharge to Floridan Aquifer (MGD)		74	
Average cost (\$/ 1000 gal.)			1.10

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 (Schreuder and Dumeyer 1998).

Ten sources of tailing sands were initially evaluated and three were selected for the investigation. The three sources were the former Tenoroc Mine on the Florida State Game and Freshwater Fish Commission's Tenoroc Fish Management Area, Cargill Fertilizer's Ft. Meade Mine and IMC-Agrico Company's Four Corners Mine.

The tailing sands were transported to the SI office in Tampa and placed into 60 gallon high density 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 (ft./d) for the Tenoroc sand, 49.4 ft./d for the Ft. Meade sand and 73.2 ft./d for the Four Corners sand.

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

The testing was performed in triplicate to produce verifiable data. Thus, each sand source had three drums of low pH, three drums of neutral pH and three drums of high pH. A spare contingency barrel was included for each water type. Therefore, 12 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, 100 and 225 days. Measurements were made of temperature, pH and specific conductance at the time of 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 day 206.

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 mg/l of sulfate. A subsequent flow-through leaching test of the Four Corners tailing sands indicates that after flushing two pore volumes through the sand, the leachate water would not exceed the sulfate limit. Based upon the results of this investigation of tailing sands filtration, the water produced through the sand can meet drinking water standards for radionuclide concentrations.

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. To address this question, the Board of the FIPR funded the investigation of microorganism removal by tailing sands (FIPR No. 96-03-124R).

The investigation involved placement of tailing sands from two sources into PVC columns. The sands included a low permeability sand from the Tenoroc State Fish Management Area and a high permeability sand from IMC-Agrico's Four Corners Mine. Three columns were filled with each sand type and with a total depth of 3, 4 and 5 feet of sand and filled with water such that a saturated zone of 2 feet was maintained in each column and with unsaturated depths of 1, 2 and 3 feet. Before the experiment began, the sand in each column was sanitized with a chlorine solution and dechlorinated by rinsing with a sodium thiosulphate solution. Each column was then seeded with 143 milliliters of solution containing *E.Coli* bacteria, coliphage MS2 bacterial virus, human poliovirus and fluorescent microspheres as tracers. After seeding, the columns were sampled eight times over a period of 38 days. After each sampling 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. Dr. Lillian Starke of that laboratory was a Co-principal Investigator.

The test results indicate that tailing sand filtration is capable of removing more than 98% (2 log removal) of the applied viral cells. The lower permeability sand was better able to remove microorganisms than the higher permeability sand, and removal of microorganisms was greater with increasing unsaturated depth.

Therefore, the use of low permeability

phosphate mine tailings in conjunction with a deep (> 5 feet) unsaturated zone is expected to be effective in removing microorganisms from storm water and treated wastewater. A report entitled "An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters" has been submitted and is being published by the FIPR (Schreuder, Dumeyer and Stark 1998).

Pilot Project to Test Natural Water Treatment Capacity of Wetland and Tailing Sand Filtration Concept

The Boards of the FIPR and the SWFWMD approved funds to build a pilot project and conduct tests for two years on the effectiveness of the proposed water treatment system. This is a three year study. The project is being built at the Florida Power Corporation's (FPC) Hines Energy Complex (HEC) property. A schematic diagram of the construction is shown in Figure 3. The wetland will be an area along two ditches which are connected on the west side. The northern ditch used to be part of the Noralyn mine recirculation system. The southern ditch is shallower and collects to drain water from the SA-8 CSA. One aspect of the project will involve the removal of nuisance species and the planting of more wetland vegetation. On the east side, a sand tailing filter will be constructed by building a retainer dam on the west side, excavating the soils, installing a liner placing horizontal slotted drainage pipes in the bottom and filling the lined excavation with tailing sand from an onsite source. There will be three (3) sources of water. One source will be treated effluent from the WWTP of the City of Bartow; another source will be storm water collected in the FPC's water cropping areas which are reclaimed CSA's on their property; the third source will be water from FPC's power plant cooling pond.

The project design calls for a continuous rate of flow of 135 gallons per minute. During the first stage of the project, the filtered water will be discharged back to the cooling pond. At a later stage of the project, the filtered water will be used during the testing phase of the installation of an aquifer recharge well at the site. After the construction has been completed, the system will operate for two years during which time water samples will be collected on a quarterly basis and analyzed for all the chemical, physical and microorganism parameters listed in rule number 62-550 [Florida Department of Environmental Protection (FDEP)]. The goal of the study is to assess the practicality of the natural treatment

concept and the feasibility of implementing large scale projects. The SWFWMD is considering including this concept in their long-term water resources management plan, which calls for the diversion, treatment and recharge of surface water during high flow periods for storage in and conveyance through the underlying Floridan (limestone) Aquifer.

Construction and Operation of Two Tailing Sand Test Filters at the Hines Energy Complex

FPC, as part of their effort to obtain a permit for the construction and operation of a recharge well, constructed two sand tailing test filters at the proposed pilot project test site. They consist of the installation of two eight - (8) foot diameter and twelve -(12) foot tall galvanized metal culvert pipes. The bottom end was set in concrete. A visquene liner was placed on top of the concrete. After placing slotted horizontal PVC piping attached to a vertical stand pipe and a piezometer inside the pipe, it was filled with tailing sand from a deposit at the N-11C area. Water from the cooling pond and the "U" shaped wetland was pumped on top of the sand and extracted through the filter pipe at the bottom. Water samples from the water pumped into and from the tailing sand filter were analyzed for a total of 129 parameters. Of this total list, the concentrations of only two parameters (Fe and Mn) in the secondary drinking water standards were exceeded. The investigation into the reason(s) for these exceedances is proceeding.

Conclusions

The studies to date indicate that it may be quite feasible to use mined phosphate lands to "recondition" surface waters and waste waters naturally to meet drinking water standards. The actual proof of this hypothesis will be provided by the results of two pilot studies conducted by SI at the FPC's HEC. These studies are funded by the FIPR, the SWFWMD and FPC. Results are expected to be published in the year 2003.

References

- Schreuder, Inc. 1996. Evaluation of Feasibility of Water Storage Reservoirs on Mined Lands to Meet Future Agricultural, Industrial and Public Water Supply Demands; Progress Report for FIPR Project 94-03-113.
- Amsterdam Water Supply 1994. Drinking Water from

the Dunes, Artificial Recharge and Abstraction in the Amsterdamse Waterleidingduinen; Brochure and map.

Schreuder, Peter J., Dumeyer, John M. and Stark, Lillian M. 1998 An Investigation of the Capacity of Tailing Sand to Remove Microorganisms from Surficial Waters. Final Report prepared for FIPR Project 96-03-124.

Schreuder, Inc. 1998 Potential Use of Phosphate Mining Tailing Sand for Water Filtration: Leaching Tests. Final Report prepared for FIPR Project 94-03-113.

Schreuder, Inc. 2000 Feasibility of Natural Treatment, Aquifer Recharge, Storage and Conveyance of Water-, Storm- and Surface Waters Using Mined Phosphate Lands. Final Report prepared for FIPR Project 94-03-113.

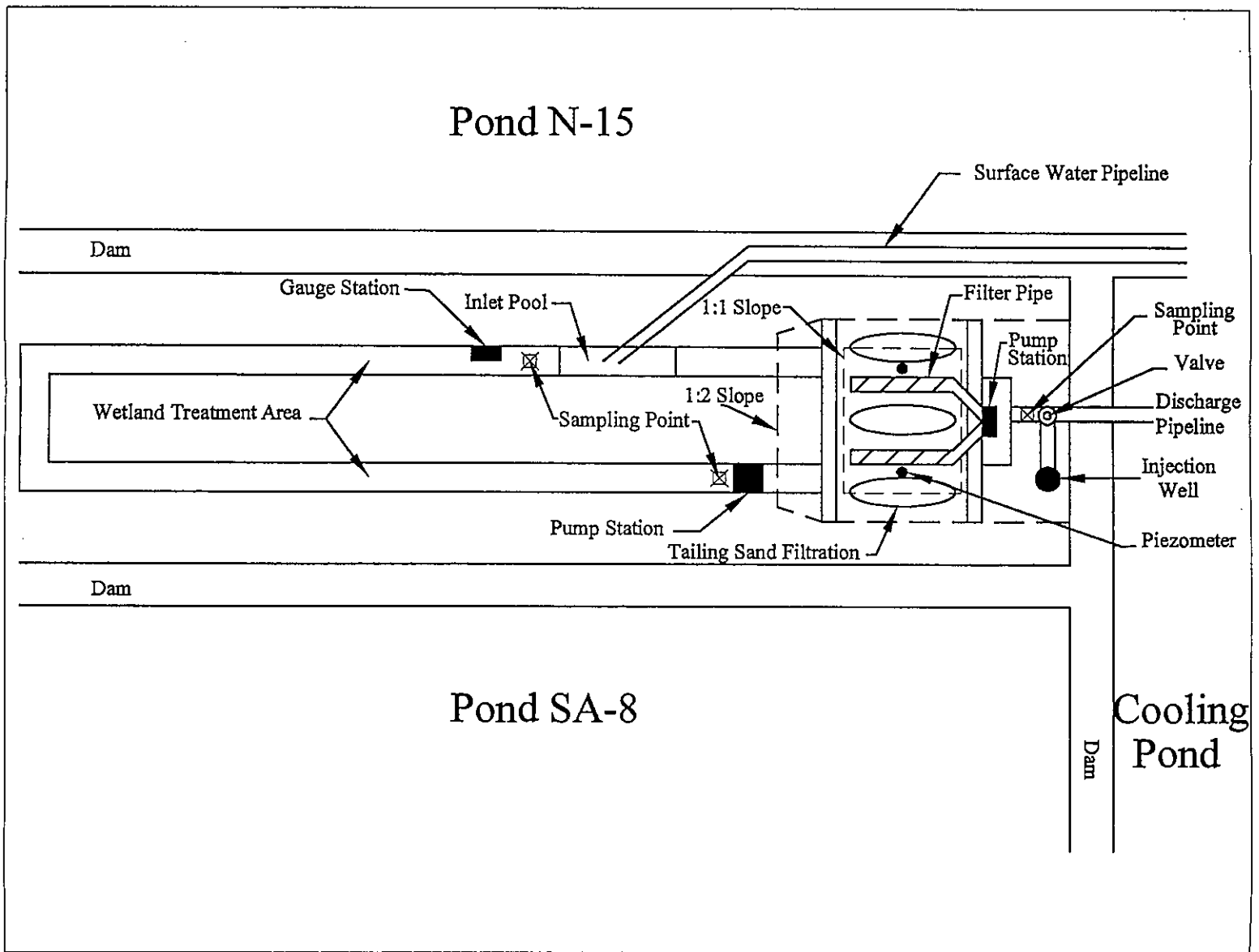


Figure 3: Schematic Diagram of the Wetland Treatment and Tailing Sand Filtration Pilot Project Design