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POTENTIAL TECHNOLOGIES TO REDUCE OR REPLACE GROUNDWATER CONSUMPTION IN THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

FINAL REPORT

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PERSPECTIVE

The need to reduce water consumption is widely recognized in Florida and any reasonable means to accomplish this goal has great merit. This project looks at several ways to reduce water withdrawals from the aquifer. This project evaluated three primary approaches to water conservation, recycling ground water used for cooling back into the aquifer, the possibility of collecting and using surface water instead of ground water, and the practicality of using retired clay settling areas as reservoirs for surface water storage during the rainy season. This project is just a first step in evaluating these and other approaches that may be developed in the course of this study. The water use problem will require ever-increasing attention as the population of Florida continues to grow.

G. Michael Lloyd, Jr.
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ABSTRACT

To explore alternatives to existing groundwater supplies in the Southwest Florida Management District, Ardaman & Associates, Inc., screened potential technologies to reduce or replace groundwater consumption. The following technologies were screened: (1) use of once-through groundwater cooling for power plants or industrial facilities, (2) other cooling options, (3) use of surface water instead of groundwater for industrial makeup water and agricultural irrigation, (4) use of retired clay settling areas as reservoirs for water storage, and (5) use of phosphogypsum process water for process and product cooling. A final feasibility analysis was performed on a combination of technologies (3) and (4).

The feasibility analysis demonstrated that storage provided by long-term settlement of the clay surface could be used to hold water pumped from a nearby stream or river during high flow periods and provide raw water for industrial of agricultural uses for $0.23 to $0.82 per 1000 gallons.

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The primary purpose of this study was to identify technologies to reduce or replace groundwater consumption that are not currently used within the Southwest Florida Water Management District (SWFWMD) but that may be feasible for implementation, with or without an incentive from SWFWMD. Technologies that can reduce or replace groundwater consumption are considered feasible if the cost per 1000 gallons is less than $2.00 to $3.00.

A screening study was performed on the following technologies: (1) use of once-through groundwater cooling using the Floridan aquifer system instead of conventional cooling towers or cooling ponds for power plants or industrial facilities, (2) other cooling options, (3) use of surface water instead of groundwater for industrial makeup water and agricultural irrigation, (4) use of retired clay settling areas as reservoirs for water storage, and (5) use of phosphogypsum process water for process and product cooling.

Based on results of the screening study and discussions with representatives of FIPR, the feasibility of one technology--the use of retired clay settling areas as water supply reservoirs for surface water withdrawn from nearby streams--was selected as the most promising technology that warranted further detailed evaluation and analyses.

The feasibility of a former clay settling area for use as a water supply reservoir depends on: (1) the catchment area of a nearby surface water feature, (2) the available storage after long term settlement of the clay, (3) the condition of the perimeter embankment, (4) the distance to the surface water withdrawal point, (5) the amount of water that can be withdrawn based on hydrologic and regulatory considerations, and (6) the cost of implementation.

Clay settling areas are typically 400 to 800 acres in area and are located from less than a mile to greater than several miles from a major surface water feature. To provide a significant quantity of surface water for agricultural or industrial use, the watershed of the surface water feature should be at least 40 square miles. Streams in the Peace River basin that are close to active clay settling areas and have catchment areas in excess of 40 square miles include, but are not limited to, Payne Creek, Little Payne Creek, Horse Creek, Brushy Creek, and the Peace River.

The feasibility analysis demonstrated that storage provided by long-term settlement of the clay surface in a retired clay settling area could be used to hold water pumped from a nearby stream or river during high flow periods, and provide raw water for industrial or agricultural uses at a cost of $0.23 to $0.82 per 1000 gallons and filtered water for irrigation use at a cost of $0.31 to $0.91 per 1000 gallons.

INTRODUCTION

The primary purpose of this study is to identify technologies to reduce or replace groundwater consumption that are not currently used within the Southwest Florida Water Management District (SWFWMD) but that may be feasible for implementation, with or without an incentive from SWFWMD. Prior to detailed analyses of the different technologies, screening was performed to separate technologies that have merit for further evaluation from those that are deemed not feasible based on technical or economic considerations. Further feasibility analyses will be conducted on promising technologies that are considered viable for implementation.

Our proposal for this study identified the following three technologies:

- Once-through groundwater cooling using the Floridan aquifer system instead of conventional cooling towers or cooling ponds for power plants or industrial facilities;
- Use of surface water instead of groundwater as makeup water for industrial operations (including mining) and agricultural irrigation; and
- Use of retired clay settling areas as reservoirs to provide surface water storage during peak flow periods for later release during low flow periods or for use in industrial operations or agricultural irrigation.

Based on comments by the Florida Institute of Phosphate Research (FIPR) reviewers, we also considered the use of cooling ponds at retired phosphate concentrate plants to temporarily replace cooling towers at nearby power plants or other facilities as another potential groundwater saving technology. This technology was reportedly used at CF Industries concentrate plant near Bartow, Florida, which removed the heat load generated by a 1,000-ton per day sulfuric acid plant using the cooling pond system associated with a retired phosphoric acid plant. We also performed literature and internet research to identify other technologies that might be implemented to reduce or replace groundwater consumption.

WATER USE WITHIN THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

Ardaman & Associates began this project with a review of water use within the SWFWMD. The U.S. Geological Survey (USGS) compiles water withdrawal statistics by county and use category every 5 years. The latest USGS water withdrawal statistics are for the year 2000. Water withdrawal by county, source, and category are summarized in Table 1. The total water withdrawal from SWFWMD counties was 7,892 mgd, of which 1,634 mgd was from groundwater. Of the 1,634 mgd from groundwater, 131 mgd was for commercial, industrial and mining uses and 6.9 mgd was for power generation.

Table 1. Summary of Water Withdrawals (mgd) by County and Category, 2000.

County	Agricultural Irrigation	Commercial/ Industrial/ Mining	Power Generation	Public Supply	Domestic Self-Supplied	Recreational Irrigation	Total Withdrawal
Charlotte	47.19	2.49	0.00	7.28	3.55	3.48	63.99
Citrus	3.35	1.09	395.45	13.97	7.20	4.18	425.24
De Soto	118.87	1.39	0.00	10.59	2.16	0.37	133.38
Hardee	81.73	5.93	0.81	1.78	0.64	0.25	91.14
Hernando	4.29	19.77	0.00	20.27	1.41	4.71	50.45
Highlands	160.31	0.58	0.08	9.14	1.68	2.76	174.55
Hillsborough	87.15	19.67	3188.00	166.39	4.71	13.80	3479.72
Lake	83.58	11.04	0.00	39.92	4.29	8.26	147.09
Levy	22.45	2.02	0.00	2.16	3.95	0.49	31.07
Manatee	105.72	1.00	25.10	49.92	0.17	5.04	186.95
Marion	18.86	2.08	0.00	27.99	16.42	5.46	70.81
Pasco	22.73	5.53	1956.64	102.67	4.50	6.36	2098.43
Pinellas	0.46	0.64	419.11	39.88	0.41	5.39	465.89
Polk	185.51	77.59	19.93	75.49	12.47	11.94	382.93
Sarasota	7.54	0.64	0.00	28.71	0.43	8.96	46.28
Sumter	14.62	17.34	0.00	4.44	4.57	3.52	44.49
SUM	964.36	168.80	6005.12	600.60	68.56	84.97	7892.41
	Groundwater						
Charlotte	28.17	0.15	0.00	3.29	3.55	0.79	35.95
Citrus	2.76	0.80	1.55	13.97	7.20	3.77	30.05
De Soto	116.95	0.06	0.00	4.49	2.16	0.21	123.87
Hardee	81.16	5.93	0.81	1.78	0.64	0.21	90.53
Hernando	4.26	19.70	0.00	20.26	1.41	3.83	49.46
Highlands	143.24	0.55	0.08	9.14	1.68	2.60	157.29
Hillsborough	83.84	14.17	0.00	85.51	4.71	9.21	197.44
Lake	73.40	10.44	0.00	39.92	4.29	4.54	132.59
Levy	21.82	0.06	0.00	2.16	3.95	0.45	28.44
Manatee	104.37	0.47	0.00	13.87	0.17	3.42	122.30
Marion	17.85	2.08	0.00	27.99	16.42	4.26	68.60
Pasco	22.37	4.72	0.14	102.67	4.50	5.29	139.69
Pinellas	0.43	0.09	0.00	39.88	0.41	2.39	43.20
Polk	174.31	71.20	4.27	75.43	12.47	9.65	347.33
Sarasota	6.88	0.31	0.00	27.86	0.43	4.89	40.37
Sumter	14.08	0.36	0.00	4.44	4.57	3.35	26.80
SUM	895.89	131.09	6.85	472.66	68.56	58.86	1633.91
	Surface Water						
Charlotte	19.02	2.34	0.00	3.99	0.00	2.69	28.04
Citrus	0.59	0.29	393.90	0.00	0.00	0.41	395.19
De Soto	1.92	1.33	0.00	6.10	0.00	0.16	9.51
Hardee	0.57	0.00	0.00	0.00	0.00	0.04	0.61
Hernando	0.03	0.07	0.00	0.01	0.00	0.88	0.99
Highlands	17.07	0.03	0.00	0.00	0.00	0.16	17.26
Hillsborough	3.31	5.50	3188.00	80.88	0.00	4.59	3282.28
Lake	10.18	0.60	0.00	0.00	0.00	3.72	14.50
Levy	0.63	1.96	0.00	0.00	0.00	0.04	2.63
Manatee	1.35	0.53	25.10	36.05	0.00	1.62	64.65
Marion	1.01	0.00	0.00	0.00	0.00	1.20	2.21
Pasco	0.36	0.81	1956.50	0.00	0.00	1.07	1958.74
Pinellas	0.03	0.55	419.11	0.00	0.00	3.00	422.69
Polk	11.20	6.39	15.66	0.06	0.00	2.29	35.60
Sarasota	0.66	0.33	0.00	0.85	0.00	4.07	5.91
Sumter	0.54	16.98	0.00	0.00	0.00	0.17	17.69
SUM	68.47	37.71	5998.27	127.94	0.00	26.11	6258.50
SOURCE: USGS (2003). Total water withdrawals in Florida by County, 2000.							

SWFWMD compiles water use statistics and estimates for various purposes using consumptive use permit data and other sources. The latest SWFWMD estimated water use is for the year 2001. Withdrawal by county, source, and category are summarized in Tables 2a and 2b. In 2001, total estimated water withdrawal in the District was 1,340 mgd. Of the 1,340 mgd, 1,149 mgd was from groundwater, including 63 mgd for industrial/ commercial uses and 48 mgd for mining/dewatering. SWFWMD industrial/commercial water use is further broken down in Table 3.

Because of differences in methodology, boundaries and classifications, particularly with regard to power generation and saline water, there are substantial differences in reported water quantities between the SWFWMD reports and the USGS reports. USGS combines commercial/industrial and mining water use and has a separate category for power generation. SWFWMD has a separate category for mining/dewatering but includes power generation as a subcategory of industrial/commercial. The SWFWMD reports do not include surface water withdrawals for once-though cooling or saline water withdrawals. The USGS reports do not separate out water withdrawals within SWFWMD for counties that are only partly within the District.

Neither SWFWMD nor USGS maintains separate statistics on industrial/commercial/institutional (ICI) water use from public water supplies. Based on *ICI Water Conservation in the Tri-County Area of the SWFWMD* (SWFWMD 1997), industrial/commercial water use accounts for 22 percent of the public supply water use in Hillsborough, Pasco and Pinellas counties. USGS Water-Resources Investigations Report 99-4002 (USGS 1999) estimated that of the total public supply water statewide in 1995, 19 percent was attributable to commercial uses and 5 percent to industrial uses.

We also reviewed SWFWMD water demand projections for the year 2020 (Table 4). The June 1998 SWFWMD Districtwide Water Supply Assessment projects a total water demand in 2020 of 1,964 mgd for average conditions and 2,310 for drought conditions. Note that SWFWMD demand projections use some different categories than their water use reports.

EXISTING WATER CONSERVATION TECHNOLOGIES IN USE IN THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

The focus of this study is on technologies that are not currently used in the SWFWMD. Therefore, we briefly reviewed technologies that are currently used or proposed for water conservation initiatives in the District.

Table 2a. Estimated Groundwater Withdrawals (mgd) by County and Category, 2001.

County	Agricultural	Industrial/ Commercial	Mining/ Dewatering	Public Supply (Withdrawal)	Domestic Self-Supply	Recreation/ Aesthetic	Total Withdrawal
Charlotte	14.819	0.017	0.004	2.122	4.072	0.697	21.731
Citrus	1.917	0.781	0.636	12.767	6.439	2.860	25.400
De Soto	87.563	0.048	0.009	4.235	2.113	0.171	94.139
Hardee	69.656	0.213	2.953	1.659	0.681	0.199	75.361
Hernando	2.918	10.242	11.577	19.990	1.857	2.843	49.427
Highlands	47.787	0.182	0.001	8.263	1.584	2.391	60.208
Hillsborough	72.051	10.817	3.761	88.780	6.430	9.530	191.369
Lake	1.400	0.000	0.000	0.000	0.228	0.000	1.628
Levy	8.539	0.029	0.000	0.955	2.615	0.264	12.402
Manatee	93.553	0.242	0.063	13.742	0.484	3.302	111.386
Marion	3.547	0.101	0.000	7.722	6.412	2.486	20.268
Pasco	15.341	2.977	0.167	93.419	5.161	4.493	121.558
Pinellas	0.353	0.054	0.000	33.564	0.922	2.348	37.241
Polk	122.128	36.699	28.407	66.943	4.501	7.438	266.116
Sarasota	6.231	0.175	0.000	25.354	0.662	4.460	36.882
Sumter	10.463	0.231	0.006	6.668	4.565	1.918	23.851
District	558.266	62.808	47.584	386.183	48.726	45.400	1148.967

SOURCE: SWFWMD (2003).

Table 2b. Estimated Surface Water Withdrawals (mgd) by County and Category, 2001.

County	Agricultural	Industrial/ Commercial	Mining/ Dewatering	Public Supply (Withdrawal)	Domestic Self-Supply	Recreation/ Aesthetic	Total Withdrawal
Charlotte	2.827	0.000	0.520	3.969	0.000	2.230	9.546
Citrus	0.102	0.100	0.163	0.000	0.000	0.147	0.512
De Soto	4.395	0.000	0.125	8.583	0.000	0.000	13.103
Hardee	0.182	0.004	0.008	0.000	0.000	0.039	0.233
Hernando	0.027	0.000	0.075	0.012	0.000	0.305	0.419
Highlands	6.555	0.013	0.023	0.000	0.000	0.009	6.600
Hillsborough	2.358	2.607	0.948	78.134	0.000	3.567	87.614
Lake	0.120	0.000	0.000	0.000	0.000	0.000	0.120
Levy	0.288	0.000	0.000	0.000	0.000	0.000	0.288
Manatee	1.301	0.001	0.390	32.798	0.000	1.274	35.764
Marion	0.098	0.000	0.000	0.000	0.000	0.041	0.139
Pasco	0.365	0.315	0.162	0.000	0.000	0.598	1.440
Pinellas	0.033	0.024	0.092	0.000	0.000	2.793	2.942
Polk	3.436	1.768	0.888	0.043	0.000	1.499	7.634
Sarasota	0.260	0.005	0.460	1.220	0.000	3.044	4.989
Sumter	0.406	0.000	18.658	0.000	0.000	0.168	19.232
District	22.753	4.837	22.512	124.759	0.000	15.714	190.575

SOURCE: SWFWMD (2003).

Table 3. Summary of Industrial/Commercial Water Use (mgd) by County and Category, 2001.

County	Product Manufacturing	Food Processing & Packaging	General Commercial	Power Generation	Other Uses	Total Use	Groundwater	Surface Water
Charlotte	0.016	0.000	0.000	0.000	0.001	0.017	0.017	0.000
Citrus	0.097	0.000	0.020	0.629	0.135	0.881	0.781	0.100
De Soto	0.000	0.028	0.000	0.020	0.000	0.048	0.048	0.000
Hardee	0.033	0.032	0.000	0.149	0.003	0.217	0.213	0.004
Hernando	2.455	0.007	0.000	7.780	0.000	10.242	10.242	0.000
Highlands	0.051	0.117	0.024	0.000	0.003	0.195	0.182	0.013
Hillsborough	10.316	1.829	1.236	0.014	0.029	13.424	10.817	2.607
Lake	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Levy	0.024	0.000	0.000	0.000	0.005	0.029	0.029	0.000
Manatee	0.119	0.030	0.019	0.014	0.061	0.243	0.242	0.001
Marion	0.000	0.000	0.095	0.000	0.006	0.101	0.101	0.000
Pasco	0.332	2.062	0.034	0.696	0.168	3.292	2.977	0.315
Pinellas	0.020	0.019	0.039	0.000	0.000	0.078	0.054	0.024
Polk	24.291	4.650	0.844	8.595	0.087	38.467	36.699	1.768
Sarasota	0.004	0.000	0.059	0.112	0.005	0.180	0.175	0.005
Sumter	0.129	0.011	0.066	0.000	0.025	0.231	0.231	0.000
District	37.887	8.785	2.436	18.009	0.528	67.645	62.808	4.837

SOURCE: SWFWMD (2003).

Table 4. Southwest Florida Water Management District Water Demand Projections (mgd).

Water Use Demand Category	Water Use 1995	Average 2020	% Change From 1995	Drought Year 2020	% Change From 1995
Public Supply	428.1	609.5	42%	638.5	49%
Domestic Self-Supply	88.8	141.0	59%	149.6	68%
Industrial/Mining	226.8	196.0	-14%	196.0	-14%
Power Generation	10.2	61.8	506%	61.8	506%
Agricultural	684.7	852.0	24%	1154.5	69%
Recreation	66.5	104.0	56%	109.2	64%
Totals	1505.1	1964.3	31%	2309.6	53%

SOURCE: SWFWMD (2000).

ICI Water Conservation in the Tri-County Area of the SWFWMD recommends the following for reducing water use for hotel and motels, manufacturers, offices, schools and hospitals:

- Reduce excessive blowdown. Many cooling towers operate below the suggested level of total dissolved solids (TDS).
- Consider using ozone as a cooling tower treatment to reduce water use for makeup.
- Shut off water-cooled air conditioning units when not needed or replace with air-cooled systems.
- Capture and reuse steam condensate.
- Connect equipment to a closed-loop system rather than a municipal supply.

The *SWFWMD August 2001 Regional Water Supply Plan* identifies water conservation options and projects including:

- Use of reclaimed water for power plant cooling and agriculture.
- Using existing storage capacity for power plant cooling ponds to facilitate aquifer recharge or distribution to agricultural users.
- Seawater desalination co-located with a power plant.
- Brackish water desalination.
- Audits and efficiency measures for ICI water users.

The Florida Department of Environmental Protection's (FDEP) *Water Conservation Initiative Final Report* (2002) identified six options/recommendations for ICI water users:

ICI-1: Consider establishing a "Conservation Certification" program.
ICI-2: Consider a range of financial incentives and alternative water supply credits.
ICI-3: Consider cooperative funding for the use of alternative technologies to conserve water.
ICI-4: Implement additional water auditing programs.
ICI-5: Promote utilization of reclaimed water.
ICI-6: Investigate methods of assuring that large users from public suppliers have the same conservation requirements as users with individual permits.

The Water Conservation Initiative recommendations are based on programmatic and administrative approaches rather than technological approaches. For example, water auditing programs may lead to changes in technology but they are not themselves a "technology."

Another water conservation technology currently in use in the SWFWMD is aquifer storage and recovery (ASR). ASR is the storage of water in an aquifer during times when water is available and recovery of the water from the aquifer during times when it is needed. The same wells are used for injection and recovery. Large volumes of water are stored underground, reducing or eliminating the need to construct large and expensive surface reservoirs. The source of water for an ASR project can be potable water from a water treatment plant, raw surface water, partially treated surface water, raw groundwater or reclaimed water. ASR projects have been developed in Florida since 1983 with the first project at Lake Manatee in Manatee County. ASR is currently used or proposed (e.g., Tampa ASR) in the District and included in water supply plans.

Aquifer recharge projects, which artificially enhance recharge but do not recover the water at the point of injection, are also used in the District. Artificial recharge refers to the augmentation of natural infiltration into groundwater systems from the activities of humans, such as by means of spreading basins, recharge wells, or induced infiltration of surface water.

Aquifer storage and recovery and aquifer/artificial recharge projects have been adequately studied by others to assess their feasibility in the District. Additional consideration of these technologies is beyond the scope of this project.

REVIEW OF POTENTIAL TECHNOLOGIES

The following technologies were reviewed for groundwater conserving potential in the District, preliminary technical and economic feasibility, and existing applications in the District.

USE OF ONCE-THROUGH GROUNDWATER COOLING FOR POWER PLANTS OR INDUSTRIAL FACILITIES

The use of groundwater and/or the soils or rocks of the aquifer for cooling and heating is known by various names including ground-source heat pumps, earth-source heat pumps, ground-coupled heat pumps, geothermal heat pumps, geoexchange, aquifer thermal energy storage (ATES), and underground thermal energy storage (UTES). There are variations of the technology using open loops, closed loops, surface water and direct exchange with the ground. There are also hybrid systems with supplementary heating or cooling systems. Typical applications have both a cooling cycle and a heating cycle and are limited to residential and commercial buildings.

Groundwater cooling (and heating) is based on the fact that the temperature of groundwater is relatively constant throughout the year. Aquifers are massive thermal energy sinks that can store and release large amounts of energy using water as the transfer medium and the aquifer matrix as the storage medium. The aquifer acts as a heat exchanger with wells used to move water and transfer energy to the aquifer. Once in the aquifer, heat is dissipated by conduction through the overlying soil and rock and by dispersion along the hot-cold interface.

The technology considered here is referred to in this report as once-through groundwater cooling, which is similar to an open-loop groundwater-source heat pump. In a once-through groundwater cooling system, groundwater is withdrawn from the aquifer using production or supply wells. The groundwater is passed through a heat exchanger and heated water is returned to the aquifer through injection wells.

The Florida Water Conservation Initiative Industrial Commercial and Institutional (ICI) Work Group Report, dated October 12, 2001, suggests subsurface (aquifer) cooling systems (pumping water up for once-through cooling then back down into the ground) for industrial/commercial/institutional users while noting that they are more efficient but more expensive than conventional cooling towers. With the possibility of incentives from SWFWMD to offset some of the additional cost, this technology has the potential to significantly reduce groundwater consumption in the district, particularly for industrial operations, such as power generation, and for commercial operations, such as air conditioning.

The use of once-through groundwater cooling would substantially reduce evaporative loss associated with the use of a recirculating cooling tower or cooling pond.

There is an evaporative loss for once-through cooling discharging to surface water because of the elevated temperature of the discharge plume. This loss would be negligible for once–through groundwater cooling because the heat would be lost through conduction through the aquifer/confining layer system.

During operation, a cooling tower may experience an evaporative loss of as much as 2 percent of the circulating water.[1] For a cooling tower with a flow rate of 3,000 gallons per minute (gpm), evaporative loss can exceed 80,000 gallons of water per day. The magnitude of the potential groundwater consumption saving is the amount of evaporation plus drift.

The technical feasibility of a once-through groundwater cooling system will depend on the elevated water temperature and heat transfer or dispersion within the aquifer system and the amount of groundwater that must be withdrawn for cooling relative to the transmissivity of the aquifer. The economic feasibility will depend on the capital cost and operation and maintenance costs for such a system compared to those for a conventional cooling tower or cooling pond. In addition, for an existing facility, where the capital resources have already been committed to a cooling system, these costs would also have to be written off as part of the economic comparison.

In order to realize any reduction in groundwater withdrawals, an existing or proposed power generation or industrial/commercial facility must already use or plan to use groundwater for makeup water in their cooling system. The amount of water withdrawn from groundwater sources to make up for heat load evaporation from power production by both utility companies and industrial facilities in the SWFWMD is estimated to be on the order of 30 mgd.

From our research, the electric power industry in the District has various water conservation and recycling projects in-place at different facilities. The currently favored power generation technologies, including combustion turbines and combined-cycle plants, use significantly less water for cooling than steam-cycle plants. Natural gas- and oil-fired combined-cycle plants derive roughly two-thirds of their net power output from the gas turbine (Brayton cycle) and one-third from the steam turbine (Rankine cycle). Waste heat from the turbine is transferred to a heat recovery steam generator, which supplies steam to the steam turbine. Accordingly, the associated cooling water withdrawal and evaporation rates for a combined-cycle plant are about one-third of those for a steam-cycle plant.

We reviewed the water use for thermoelectric power generation as a function of plant type and capacity (EPRI 2002). Table 5a summarizes typical water withdrawals and consumptive use in gallons/MWh (megawatt-hour) for common power plant and cooling system combinations. Table 5b presents the same information converted to units of mgd/MW. The amount of circulating water that must be withdrawn for once–through cooling for a major power generation facility is quite large in relation to normal

[1]Evaporative loss for a cooling tower is computed as 0.0008 x temperature difference across the condenser in ºF x circulating water flow. Drift loss is approximately 0.0002 x circulating water flow.

groundwater withdrawals. Consequently, most power plants use either surface water for once-through cooling or recirculating cooling systems with towers or ponds.

Table 5a. Cooling Water Withdrawal and Consumption (Evaporation to the Atmosphere) Rates for Common Thermal Power Plant and Cooling System Types.

Plant and Cooling System Type	Water Withdrawal (gal/MWh)	Typical Water Consumption (gal/MWh)	Blowdown (gal/MWh)	
			5 cycles	10 cycles
Fossil/biomass/waste-fueled steam, once-through cooling	20,000 to 50,000[1]	~300	NA	NA
Fossil/biomass/waste-fueled steam, recirculating cooling pond	300 to 600	270 to 500	100	30
Fossil/biomass/waste-fueled steam, recirculating cooling tower	500 to 600	460 to 500	100	40
Nuclear steam, once-through cooling	25,000 to 60,000[1]	~400	NA	NA
Nuclear steam, recirculating cooling pond	500 to 1,100	450 to 900	200	30
Nuclear steam, recirculating cooling tower	800 to 1,100	740 to 900	200	60
Natural gas/oil combined-cycle, once-through cooling	7,500 to 20,000[1]	~100	NA	NA
Natural gas/oil combined-cycle, recirculating cooling tower	~230	~180	50	—
Natural gas/oil combined-cycle, dry cooling	~0	~0	NA	NA
Coal/petroleum residuum-fueled combined-cycle, cooling tower	~380[2]	~200	50	—

SOURCE: EPRI (2002).

[1]Based on temperature increase in water of 12ºF for high flow and 30ºF for low flow.

[2]Includes 130 gal/MWh (0.003 mgd/MW) gasification process water.

Table 5b. Cooling Water Withdrawal and Consumption (Evaporation to the Atmosphere) Rates for Common Thermal Power Plant and Cooling System Types.

Plant and Cooling System Type	Water Withdrawal (mgd/MW)	Typical Water Consumption (mgd/MW)	Blowdown (mgd/MW)	
			5 cycles	10 cycles
Fossil/biomass/waste-fueled steam, once-through cooling	0.48 to 1.20	~0.007	NA	NA
Fossil/biomass/waste-fueled steam, recirculating cooling pond	0.007 to 0.014	0.0065 to 0.012	0.0024	0.0007
Fossil/biomass/waste-fueled steam, recirculating cooling tower	0.012 to 0.014	0.011 to 0.012	0.0024	0.001
Nuclear steam, once-through cooling	0.60 to 1.44	~0.010	NA	NA
Nuclear steam, recirculating cooling pond	0.012 to 0.026	0.011 to 0.022	0.0048	0.0007
Nuclear steam, recirculating cooling tower	0.019 to 0.026	0.018 to 0.022	0.0048	60
Natural gas/oil combined-cycle, once-through cooling	0.18 to 0.48	~0.0024	NA	NA
Natural gas/oil combined-cycle, recirculating cooling tower	~0.0055	~0.0043	0.0012	—
Natural gas/oil combined-cycle, dry cooling	~0	~0	NA	NA
Coal/petroleum residuum-fueled combined-cycle, cooling tower	~0.009[2]	~0.0048	0.0012	—

SOURCE: EPRI (2002).

[1]Based on temperature increase in water of 12ºF for high flow and 30ºF for low flow.

[2]Includes 130 gal/MWh (0.003 mgd/MW) gasification process water.

For recirculating cooling systems with towers or ponds, the total dissolved solids content of the circulating water is increased as a result of evaporation. To prevent the water quality from degrading to an unacceptable level, part of the circulating water (blowdown) is withdrawn periodically and replaced. The number of cycles of concentration depends on the initial water quality, the use of treatment chemicals and the water quality standards for the discharge. This water is not lost but its potential reuse depends on water quality and treatment.

USEPA (2001) discusses the projected water requirements for new electric generating facilities and the costs and energy penalties for various cooling water alternatives including dry cooling. SWFWMD's Power Plant Task Force also addressed cooling water alternatives for power plants.

Based on the documents we reviewed, the required water withdrawals for once-through cooling are 40 to 80 times the withdrawals for recirculating cooling systems (tower or ponds). Even though this water will be returned to groundwater, a consumptive use permit would be necessary for the withdrawal and an injection well permit would be necessary for returning the heated water to the aquifer. Based on a review of existing and proposed aquifer storage and recovery (ASR) projects in Florida, the recovery and injection wells typically have a capacity of 1 to 5 mgd per well. Wells are typically widely spaced to avoid interference between wells.

Aquifer thermal energy storage (ATES) and groundwater cooling projects have been proposed and developed for some time and there are trade associations and interest groups that do research and promote and regulate this technology. However, the typical ATES project is based on cooling and heating a structure or facility. The typical ATES project changes from heating to cooling and uses different processes seasonally. Some examples were available for groundwater use in cooling industrial processes but we were not able to find more than one example of once-through groundwater cooling of a power plant. Groundwater has been used for once-through cooling in Minnesota for industrial facilities such as General Mills (Minnesota Department of Natural Resources 2001) but the groundwater was discharged to surface water rather than returned to the aquifer. Manitoba Hydro (Canada) proposed a groundwater-based cooling system for its Dorsey Converter Station (Wittmeier 2003). The general information for this project is provided in Table 6. According to Mr. Tim Nowitka of Manitoba Hydro, the system is partially completed and is currently serving two converters and cooling about one-quarter of the complex. The system seems to be working well compared to the chillers previously used.

Table 6. Manitoba Hydro Dorsey Converter Station Proposed Groundwater-Based Cooling System.

Facility	Cooling Load (kW)	Estimated Groundwater Requirement		
		(L/s)	(gpm)	(mgd)
Bipole 1 (Pole 1 & 2) Synchronous Condenser Auxiliary Buildings	630	38	602	0.87
Bipole 1 Converter Building Air-conditioning	2100	95	1506	2.17
Bipole 2 Converter Building Air-conditioning	1100	57	903	1.30
Total	3830	190	3012	4.34

SOURCE: Sinclair and Jhinger (2003).
1. The cooling system will include five pumping wells with a capacity of 50 L/s, ten recharge wells with a capacity of 25 L/s and two observation/monitoring wells.
2. Projected annual cooling load is 3×10^6 kWh/year.
3. A winter chilling system is proposed for seasonal thermal balancing.

Based on our review of existing and proposed aquifer thermal energy storage and groundwater cooling projects, a 2 to 4 MW thermal project is considered a large project. The spacing between wells to minimize elevated temperatures in the withdrawal wells would likely become excessive for projects much larger than 4 MW.

For example, the amount of groundwater required for once-through cooling of a 4-MW steam plant with a temperature increase across the condenser of 20 °F is approximately 2.9 mgd. The area encompassed by the 1-foot drawdown contour from a 2.9 mgd withdrawal/injection well system in the Floridan aquifer is estimated to be on the order of 300 acres. The surface area of the groundwater plume needed to dissipate the heat load (20 million BTU/hr) from a 4-MW power plant solely through vertical conduction of the heat through a 200-foot thick confining layer with a thermal conductivity of 1 BTU/hr/°F-ft is estimated at more than 3,000 acres. In an area with a relatively flat groundwater gradient, the distance between the injection and withdrawal wells to minimize elevated temperatures at the withdrawal well could be greater than 2 miles.

USGS (Kipp 1997) has developed a software program for computing the distribution of the increased temperatures within an aquifer system using convection, conduction and dispersion of the heat added to the system. This program could be used to evaluate well spacing and potential areal temperature impacts for this technology during a second phase of this research.

The costs for this technology include water supply and injection wells, pumps and well equipment, piping and control systems. Preliminary cost estimates for new facilities indicate an added cost for this technology, assuming no additional land costs, of less than $0.60/1000 gallons of water saved. Our preliminary cost analysis assumed that heat exchangers would cost the same for whatever cooling system is used. Our estimated net cost includes the avoided cost for a cooling tower including the energy penalty.

Although the area required to dissipate the heat load may limit the feasibility of this technology to projects or facilities with heat loads of less than 10 million BTU/hr, the potential groundwater savings, which would be on the order of 1,000 gpd/million BTU/hr, could be significant if a large number of facilities were to adopt this technology.

Appendix A summarizes the current power generation facilities in SWFWMD counties from the US Department of Energy (DOE) Energy Information Administration database, sorted by prime mover type. As shown in the database, there are only three steam or combined-cycle power plants listed in the District with nameplate power generation capacity of less than 4 MW.

However, the power generator table does not list potential industrial users of cooling water other than for power generation. A portion of the 60 to 80 mgd water use in the industrial/commercial category is also used for cooling. Once-through groundwater cooling could also provide water savings for these users.

OTHER COOLING OPTIONS

Groundwater use for cooling towers could also be decreased by increasing the number of cycles of concentration or concentration ratio (i.e., the ratio of the concentration of total dissolved solids in the blowdown water to the concentration in the makeup water). This conservation practice has been suggested in a number of water conservation strategy reports and presumably has been used in the District. Without performing an audit of cooling towers in the District, we cannot identify the potential for additional water conservation by optimizing cooling tower performance. Table 7 shows the potential water savings from increasing the number of cycles of concentration. For example, increasing the concentration ratio from 1.5 to 3 reduces the amount of makeup water required by 50 percent. Further increasing the concentration ratio from 3 to 6 is less effective, only reducing water consumption by 20 percent. In general, this approach is more beneficial the lower the concentration ratio currently being used. The potential for water savings by this method depends on source water quality and discharge standards.

Table 7. Percent of Makeup Water Saved by Increasing Concentration Ratio.

		New Concentration Ratio (CR_f)										
		2	2.5	3	3.5	4	5	6	7	8	9	10
Initial Concentration Ratio (CR_i)	1.5	33%	44%	50%	53%	56%	58%	60%	61%	62%	63%	63%
	2	—	17%	25%	30%	33%	38%	40%	42%	43%	44%	44%
	2.5	—	—	10%	16%	20%	25%	28%	30%	31%	33%	33%
	3	—	—	—	7%	11%	17%	20%	22%	24%	25%	26%
	3.5	—	—	—	—	5%	11%	14%	17%	18%	20%	21%
	4	—	—	—	—	—	6%	10%	13%	14%	16%	17%
	5	—	—	—	—	—	—	4%	7%	9%	10%	11%
	6	—	—	—	—	—	—	—	3%	5%	6%	7%

SOURCE: North Carolina Department of Environment and Natural Resources (1999)

Dry cooling towers potentially save almost all of the water used for cooling towers and ponds. SWFWMD’s Power Plant Task Force has considered various options for power plant cooling including dry cooling towers. We reviewed four pertinent Power Plant Task Force slide presentations from the SWFWMD website. The March 11, 2003 presentation to the SWFWMD Power Plant Task Force, Alternative Cooling Technologies and Water Conservation for Power Plants, demonstrated (see Figure 1) that dry cooling towers are significantly more expensive than wet cooling towers and have a large energy penalty. The presentation concluded that dry cooling towers are not economically feasible in Florida. This conclusion is supported by other studies including the EPA Technical Development Document for Section 316 (b) of the Clean Water Act. Dry cooling towers may also not be technically feasible for some high capacity power generators in Florida because of high turbine backpressures. The Power Plant Task Force comparison did not consider other objectives such as reducing energy consumption and air emissions. To our knowledge, other variations including hybrid wet/dry and dry helper towers have not been completely explored or dismissed. If the water savings, capital costs and energy penalties are proportional to cooling capacity, we would anticipate that these options would also not be feasible.

For a "standard" 500 MW combined cycle unit

- Wet Cooling Towers
  - 60′ tall
  - 1/2 acre
  - $11.832 million
  - Power penalty= 4.45 MW
  - Low noise
  - Make-up water required (~2.5-3.5 MGD)

- Dry Cooling Towers
  - 110′ tall (183%)
  - 1.1 acres (220%)
  - $28.145 million (238%)
  - Power penalty=21.31MW
  - High noise
  - Very little make-up water required (<1/10th)

Overall Economic Impact of Dry Cooling

- Additional capital cost for dry cooling tower
- Additional O&M costs for dry cooling tower
- Annualized capital carrying costs
- Power replacement costs
- Cost of water saved is $10-14/1,000 gallons

Figure 1. Comparison of Wet and Dry Cooling Towers.

SOURCE: Steve Jenkins Slide Presentation (2003)

USE OF SURFACE WATER INSTEAD OF GROUNDWATER FOR INDUSTRIAL MAKEUP WATER AND AGRICULTURAL IRRIGATION

The use of surface water instead of groundwater as a source of makeup water for industrial uses and for agricultural irrigation needs additional evaluation. According to the SWFWMD 2001 estimated water use (Table 2), approximately 93 percent of self-supplied industrial/commercial water use and 96 percent of agricultural water use in the District was derived from groundwater. Recharge to the Floridan and intermediate aquifers in the District accounts for approximately 10 percent of net rainfall (rainfall minus evapotranspiration). The remaining 90 percent of net rainfall is discharged to surface waters.

Although high quality groundwater is readily available by pumping in most areas within the District, surface water could provide an alternative water source, especially for sites near lakes, rivers, etc, where the cost of pumping would be affordable. Backup wells or storage reservoirs may be required to provide water during low flow periods. The technical feasibility of using surface water as industrial makeup water will depend on the industrial operation or process, and the quality of the surface waters. The surface water quality may not be suitable and, in some cases, cannot be made suitable for industrial use. The economic feasibility will depend on the costs associated with construction and operation of a pipeline and treatment system compared to those associated with operation of groundwater withdrawal wells alone. In a broad sense, this technology is both feasible and already used in the District. The “feasibility” analysis is really identifying opportunities where the substitution of surface water for groundwater is more likely to work.

To explore this alternative further, we would use the SWFWMD, FDEP and USGS geographic information system (GIS) maps and data to identify concentrations of industrial and agricultural water users near surface water bodies with sufficient flow to provide a dependable yield more than 50 percent of the time. Water treatment would be limited to filtration and, possibly, color removal. Sources to be used for surface water quantity include SWFWMD hydrologic conditions reports and minimum flow level reports and USGS Water Resources of Florida surface water reports and online data. Industrial and agricultural users would be identified from consumptive use permits and land use coverages. Distance from the nearest surface water bodies with adequate flow would be determined from hydrologic base maps and analysis of gauging station records. Treatment and delivery costs for this technology are preliminarily estimated to be less than $1.00 per 1000 gallons of groundwater saved.

USE OF RETIRED CLAY SETTLING AREAS AS RESERVOIRS FOR WATER STORAGE

Phosphate mining and processing produces clay wastes, which account for approximately one-quarter to one-third of the material extracted with the phosphate ore. During the beneficiation process, water is used to separate the clays from the phosphate matrix, producing clay slurry with 3 to 6 percent solids. A mine can produce 30,000 to 150,000 gallons of clay slurry per minute. The clay slurry is deposited in large clay settling areas (CSAs) where the suspended clay particles settle and consolidate and the water is clarified for reuse. Clay particles take a considerable amount of time to consolidate. Consequently, several CSAs are used alternately for a period of years until they reach capacity.

Typically, a CSA is an above- and below-grade impoundment, about 500 acres in size, with perimeter embankment dams made of earth. The embankment dams are typically 30 to 50 feet above original grade and surround a 20- to 30-foot deep mine cut. With current technology, a CSA reaches capacity in about 10 years. Drainage, drying and crust development takes about 3 years, after which the area is reclaimed. The CSA is reclaimed by grading and contouring. The crust on the surface of the clay is arable and will support a lightweight truck, but it is not sturdy enough to support heavy farm equipment. Underneath the crust, the clay is very soft, plastic, and relatively impervious to water.

Retired clay settling areas that are located in close proximity to rivers or streams can be used as reservoirs for water storage during periods of high flows. The stored water may be released in a controlled manner later to augment stream flows during periods of low flows or to provide a secondary source of water supply to downstream water authorities or other groundwater users.

In 1996, there were 108,284 acres of clay settling areas within the District, of which 24,066 acres had been reclaimed. The breakdown by county from 1996 is presented in Table 8. Table 9 shows the latest acreage of CSAs based on an ongoing inventory by the Bureau of Mine Reclamation, which is not complete.

Table 8. Acres of Clay Settling Areas (CSAs) in Florida, 1996.

County Location of CSAs	Number of CSAs	CSA Acres Reclaimed	CSA Acres Unreclaimed	Total CSA Acreage
Polk	328	22,566	72,336	94,902
Hillsborough	31	1,080	9,369	10,449
Hardee	7	320	1,553	1,873
Manatee	4	100	960	1,060
Hamilton	10	0	8,724	8,724
Total	380	24,066	92,942	117,008
SWFWMD	370	24,066	92,942	108,284

SOURCE: Bergquist (1996).

Modern clay settling areas are typically 45 to 75 feet deep and at the end of filling contain clay to within 5 feet of the crest road. After clay deposition stops, the clay continues to consolidate and the surface of the clay may settle an additional 15 to 30 feet over the next 10 to 20 years. The void created by the clay settlement is available for storage of water. In the past, the earthen dams surrounding the clay settling area were breached to prevent storage of rainfall and the remaining embankments were flattened with earth moving equipment. Some modern clay settling areas were not filled to capacity at the end of the mine life and may have an even greater potential for water storage. SWFWMD is investigating one such settling area (CS-11) at the former Clear Springs mine. Other existing and proposed CSAs with potential to store in excess of 10 feet of water would be identified during a subsequent phase of this project. The cost of this technology will include the cost to purchase the CSA, the cost of retrofitting the CSA for clear water storage, the cost for inspection and maintenance of the embankments, and the operating cost. The cost avoidance associated with not reclaiming the area will also be included in the cost analysis. The net cost is expected to be less than $2.00 per 1000 gallons of groundwater saved.

Table 9. Acres of Clay Settling Areas (CSAs) in Florida, 2004.

Status	Number of CSAs Ever	CSA Acres Ever	Current Number of CSAs	Current Total CSA Acres[1]
Nonmandatory	243	67,778	227	53,173
Mandatory	158[2]	78,135[2]	114	50,403
Hybrid	33	10,172	33	12,491
Total	[3]	[3]	374	116,067

SOURCE: (FDEP 2004).

[1]Totals do not include acres from CSAs that are missing. The totals will be adjusted when the
data are received.

[2]Including future CSAs

[3]Some CSAs and their respective areas are **not additive**. Because their status changed during their
existence, they are included in more than one status.

Nonmandatory CSA – A clay settling area that is not required to be reclaimed by the landowner/company. The land on which these are located must have been mined prior to the Mandatory Rule of 1975 and clays must have been introduced to the CSA prior to 1984.

Mandatory CSA – A clay settling area that is required by law to be reclaimed by the landowner/company. The land which these CSAs occupy was mined after 1975 or clays were introduced after 1984.

Hybrid CSA – A clay settling area that has a mandatory portion and a nonmandatory portion.

Schreuder, Inc. Study

Schreuder, Inc. (Schreuder and Dumeyer 2002) performed FIPR-sponsored research on the feasibility of natural treatment and storage of wastewater and surface water using mined phosphate lands. The Schreuder study did not consider the use of CSAs as storage reservoirs but rather as wetland treatment facilities. In the original concept, separate storage reservoirs were to be constructed on mined land. Earlier stages of this project investigated surface water storage but the project concept evolved to aquifer recharge rather than surface water reservoirs.

Initially, the primary goals of the study were 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. A secondary 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 for this study, the wastewater from the City of Bartow was commingled with IMC Phosphates' waste clay stream flowing into one of their active CSAs. The clarified return water appeared to be of excellent quality.

The work during the first year of this study focused on determining the availability of surface water, wastewater, and storm water flows, the assessment 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 instead of surface storage was also evaluated.

During the first year of the study, it became clear that use of large surface water reservoirs on mined phosphate lands was not practical because of engineering, permitting and water quality constraints. The first constraint is the availability of excess surface water in the phosphate mining area. SWFWMD generally will not permit any surface water withdrawals of more than 10 to 15 percent of the average daily flow in a stream, provided that no other users are already withdrawing this quantity. Another constraint is that to obtain reasonable yields that are dependable 95 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 needs to be substantial.

Another major engineering constraint was that surface water reservoirs on mined phosphate lands would generally be 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 drip irrigation systems. This would require that the surface waters be filtered, adding additional costs, or that the method of irrigation be changed. On a unit cost basis, this option appeared to be out of reach compared to the cost of the water from an onsite well. Water quality constraints include algal blooms in the reservoir that increase the suspended solids in the water supply.

Because of these constraints, the focus of the feasibility study was changed from storage of waters in reservoirs on the land surface to storage of waters in the Floridan aquifer. This change in concept required water quality requirements for injection wells to be addressed.

The Schreuder report evaluated the feasibility and costs of five case study example projects including the Progress Energy Hines Energy Complex near Bartow, which is located on the site of a former phosphate complex. The initial phase of this project has subsequently been implemented with innovations including the use of treated wastewater from the City of Bartow, a water-cropping system that captures and manages stormwater at the facility and an aquifer recharge and recovery project in partnership with FIPR and SWFWMD that will increase the flow of water into the aquifer.

The conclusion of the Schreuder feasibility study was that new surface water reservoirs on mined land in the District are not economically feasible. The modified concept with treatment of wastewater in former CSAs and aquifer storage rather than reservoir storage into which the project evolved is already being used in the District at the Hines Energy Complex.

SWFWMD Regional Water Supply Plan

The SWFWMD Regional Water Supply Plan (2001) also considered using retired clay settling areas for water storage reservoirs. The project involved withdrawing excess flow from the upper Peace River and storing it in the Upper Floridan aquifer to offset future agricultural or industrial (power plant) groundwater uses in the area. A 1,500-acre partially filled clay setting area, located at the Clear Springs Mine, 4 miles south of Bartow, would be used as an off-stream reservoir with a capacity of 20,000 acre-feet. Water would be diverted from the Peace River during high flow periods. The water would then be pumped into existing created wetlands for treatment to remove solids and allowed to flow into the clay settling basin. A treatment plant constructed adjacent to the reservoir would treat water to potable standards for aquifer recharge. An annual average yield of 10 mgd may be available for diversion from the Peace River with a maximum diversion of 130 mgd. Water would be pumped approximately 3,000 feet from the river into wetlands. Two, 5-mgd Avon Park aquifer recharge wells would be installed to recharge the Upper Floridan aquifer. The projected water supply cost was $2.90 per 1000 gallons. The Regional Water Supply Plan noted that embankments around the clay settling area would require upgrading for surface water storage and the feasibility of using clay settling areas as reservoirs would need to be evaluated.

USE OF GYPSUM POND WATER FOR PROCESS AND PRODUCT COOLING

CF Industries Bartow Phosphate Complex was placed on standby status in June of 1989. Sulfuric Acid Plant 6 (AP-6) at the facility resumed operation in January 1996 and was idled in November 1999. When operating, AP-6 utilized pond water from the phosphogypsum stack system for process cooling throughout the plant. The benefit of using pond water for cooling is that it added heat to the pond water resulting in increased pond water evaporation. Added heat from the sulfuric acid plant evaporated 150 to 210 million gallons of pond water per year depending on the sulfuric acid production rate. There was approximately 1.5 billion gallons in the various process water impoundments on October 25, 1999. The sulfuric acid plant produced approximately 800 tons per day of sulfuric acid and consumed approximately 153 million gallons per year of gypsum pond water (CF Industries 2000).

During operation of a typical fertilizer production complex, the water budget under average rainfall conditions is negative, i.e., water must be added to the system to keep it in balance. However, during periods of excess rainfall, the water inventory increases and water must be treated and discharged from the system to maintain the required freeboard. After the facility closes, the water balance, even in a normal rainfall year, becomes positive and rainwater accumulates in the system. Under both of these scenarios, it would be beneficial to use the water in the phosphogypsum stack system for process water or steam condensate cooling.

Because of the acidity (low pH) of the pond water, a special heat exchanger would be required. The use of phosphogypsum stack pond water in lieu of groundwater from the Floridan aquifer for process water cooling would minimize the discharge of treated pond water to surface waters and reduce the consumption of high quality groundwater. In addition, the net cost of this technology may be relatively low or even negative if the cost of treating the pond water ($10 to $15/1000 gal) is subtracted from the cost of using it for cooling.

This technology would only be feasible where a power plant or other industry with a cooling tower or pond is located near a closed fertilizer production complex. If the circumstances arise, it would be simple enough to calculate the capital and operating costs of pumping pond water to and from the fertilizer facility to a special heat exchanger located at the industrial facility.

RESULTS OF SCREENING EVALUATIONS

Various reports reviewed during the screening evaluation suggested that $2.00 to $3.00 per 1000 gallons should be considered as the unit value of water conserved for screening feasible water conservation projects. The results of our screening analysis and our recommendations for additional research are provided below.

TECHNOLOGY: USE OF ONCE-THROUGH GROUNDWATER COOLING

Although use of this technology is probably limited to heat loads below 10 million BTU/hr, the cost per 1000 gallons of groundwater saved is relatively small compared to other technologies and should be evaluated further.

The next phase of the project could use HST3D: A Computer Code for Simulation of Heat and Solute Transport in Three-Dimensional Ground-Water Flow Systems developed by the USGS or comparable software to project the areal extent of the thermal impacts associated with withdrawal/injection rates varying from 0.025 mgd to 2.9 mgd. The results of the heat transport modeling would also provide a more accurate estimate of the required spacing between the withdrawal and injection wells.

The modeling results would be used to evaluate once-through groundwater cooling for commercial and industrial projects with heat loads in the range of 100,000 to 10 million BTU/hour. The areal extent of the thermal impacts would be provided as a function of aquifer transmissivity, confining layer thickness, regional groundwater gradient, and heat load. Cost per thousand gallons would be provided as a function of heat load.

TECHNOLOGY: OPTIMIZING COOLING TOWER PERFORMANCE

Our understanding is that this has been suggested to ICI water users in the District already and has been implemented at some facilities. The evaluation in the water conservation studies was that this would be a low cost option that would provide immediate return on investment. No further evaluation will be performed as part of this project.

TECHNOLOGY: DRY COOLING TOWERS

Our understanding of the research we reviewed is that dry cooling towers are not economically feasible in Florida and have significant additional environmental impacts. It was not apparent whether these conclusions apply to dry helper towers and wet/dry towers and whether they are also valid for smaller scale projects. No further research is recommended as part of this project.

TECHNOLOGY: USE OF SURFACE WATER INSTEAD OF GROUNDWATER FOR INDUSTRIAL MAKEUP WATER AND AGRICULTURAL IRRIGATION

This technology is feasible but will require incentives or other inducements from SWFWMD if existing permit holders are expected to convert from groundwater to surface water as their primary source of makeup or irrigation water. Surface water, even with minimal treatment, is more expensive than groundwater. Additional research is recommended to identify potential candidate sites and to better estimate the cost of treatment and delivery. Hydrologic analyses would be performed to estimate the amount of water that can be withdrawn at six long-term gauging station sites in the Peace River basin without adversely impacting existing downstream users or resulting in unacceptable cumulative impacts at Charlotte Harbor. Cost per 1000 gallons would be provided as a function of treatment cost and distance from source.

TECHNOLOGY: USE OF RETIRED CLAY SETTLING AREAS AS RESERVOIRS FOR WATER STORAGE

Further research is recommended to identify existing and potential CSAs that will provide in excess of 10,000 acre-ft of water storage after consolidation is complete. The cost of converting a number of these CSAs into surface water reservoirs should be evaluated and the cost per 1000 gallons determined for either augmenting the Peace River during low flow periods or replacing groundwater withdrawals for agricultural irrigation or industrial use.

TECHNOLOGY: USE OF PHOSPHOGYPSUM STACK POND WATER FOR COOLING

This technology has been successfully used at one facility. However, its use is limited to locations where an industrial facility with substantial heat load is available near a closed fertilizer facility. We do not recommend that additional research be performed as part of this project.

TECHNOLOGIES FOR FURTHER EVALUATION

Based on the screening analysis described above and discussions with representatives of FIPR, the feasibility of only one technology--the use of retired clay settling areas as water supply reservoirs for water withdrawn from nearby streams--was selected for evaluation in more detail for this project. The other technologies that Ardaman had proposed for further evaluation were not evaluated further at this time.

CLAY SETTLING AREA RESERVOIR FEASIBILITY STUDY

Ardaman mapped the clay settling areas within the Upper Peace River area using geographic information system (GIS) coverage provided by the FDEP Bureau of Mine Reclamation. The CSAs by category are shown on Figure 2. Already reclaimed CSAs were not considered as useable in this study. The surface water bodies in the Upper Peace River watershed and the existing stream gaging stations are also shown on Figure 2 (in pocket). The GIS coverage is linked to a database, which describes the characteristics of the CSAs shown.

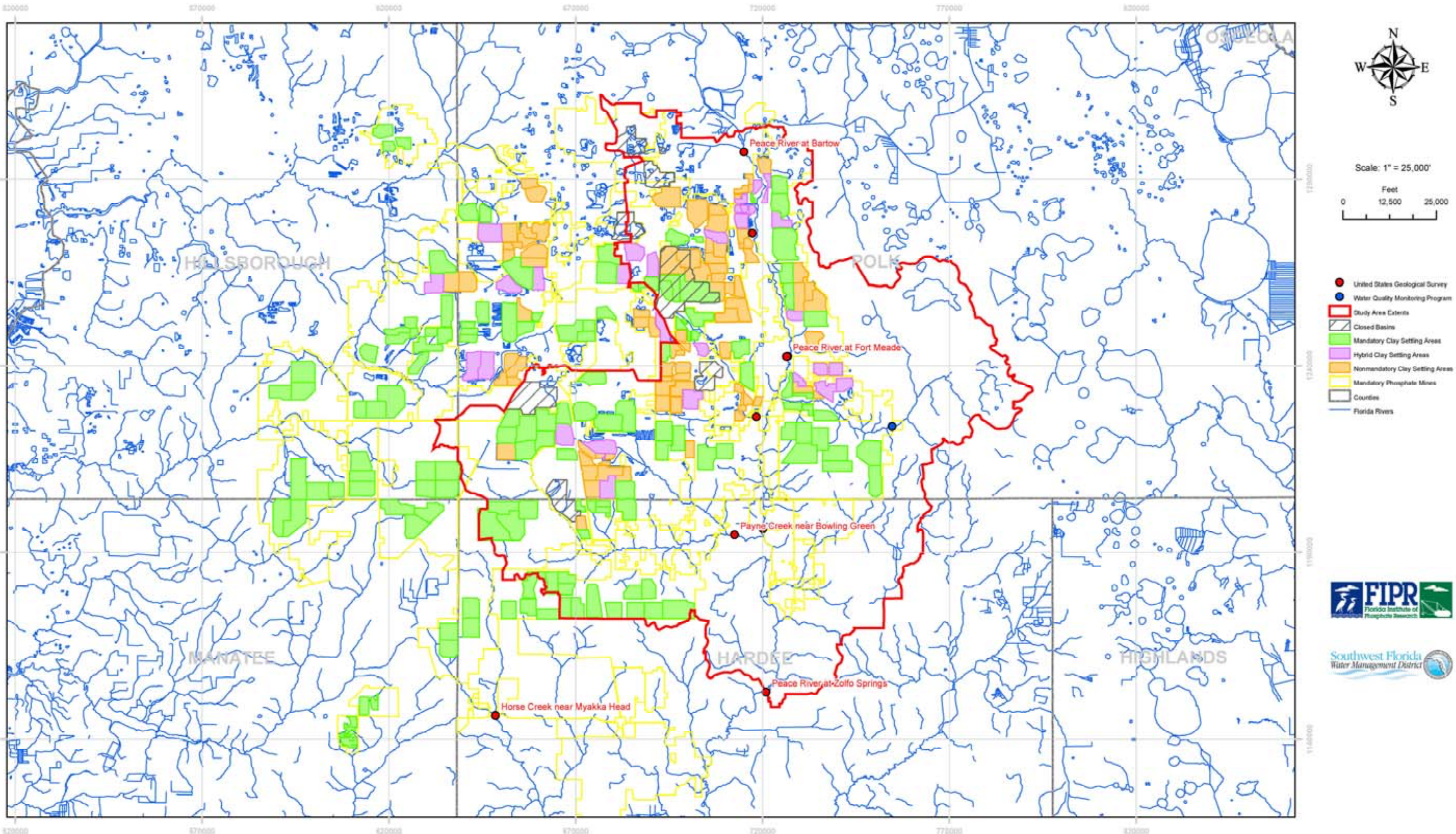
CSAs are typically 400 to 800 acres in area and are located from less than a mile to greater than several miles from major surface water features. As discussed below, to provide a significant quantity of surface water for agricultural or industrial use, the watershed of the surface water feature must be at least 40 square miles. Streams in the Peace River basin that are close to active CSAs and have catchment areas in excess of 40 square miles include, but are not limited to, Payne Creek, Little Payne Creek, Horse Creek, Brushy Creek, and the Peace River.

PREVIOUS RELATED STUDIES

The general feasibility of using CSAs as reservoirs has been considered in several prior projects.

BCI Engineers & Scientists, Inc., prepared the Upper Peace River Minimum Flow Enhancement Feasibility Study for SWFWMD in 2002. The study considered use of clay settling area PR-5 as a reservoir to augment downstream flows in the Peace River. PR-5 has an area of approximately 430 acres. The concept considered was withdrawing 7.2 mgd for 40 to 92 days per year during high flow months and releasing water from the reservoir to the Peace River at an average rate of 12 mgd for 50 to 59 days per year. The proposed reservoir in the CSA had a capacity of 700 million gallons (2,150 acre-feet) with some enhancements to the embankments. No economic analyses were performed for this phase of the study. The yield of the project was less than 2 mgd.

CH2M Hill and others (2001) performed a feasibility analysis of short list water supply development projects for the SWFWMD Regional Water Supply Plan. The



Project: 01-143	Projection: Florida West State Plane (Feet)	
Prepared: 11-11-05	Horizontal Datum: NAD83	Vertical Datum: N/A
Prepared by: T.J.C.	Modified by:	Modified:
File: W:\Projects\2001\01-143\ArcGIS_ArcLayouts\11x17 CSA.mxd		

FIGURE 2. Upper Peace River Area Clay Settling Areas.

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Geotechnical, Environmental and Materials Consultants
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Orlando, Florida 32809

projects evaluated included Project 3 – Upper Peace River Aquifer Recharge and Industrial Supply. The intent of this project is to provide water for aquifer recharge and to supply cooling and make-up water for an electrical generating facility in Polk County. Water would be diverted from the Peace River during high flow periods. The water would be pumped into existing created wetlands for treatment to remove solids and other pollutants, and allowed to flow into partially filled clay settling areas[2] at the Clear Springs Mine site for storage. The water would be treated to potable standards and recharged to the Floridan aquifer using aquifer storage recovery (ASR) wells. (A similar project concept was evaluated for FIPR by Schreuder, Inc., as described above.) The water would be available for any of the region's groundwater users including Progress Energy's power generation facilities about 3 miles to the southwest across the Peace River. Even including a potable water treatment plant, two ASR wells and extensive rehabilitation of 24,000 feet of the CSA embankments, the project had a projected cost of $2.90 per 1000 gallons. The proposed average daily flow was 10 mgd and the storage capacity of the reservoir was 20,000 acre-feet (6,500 Mgal).

Ardaman (McGillivray and Erbland 2004) performed a limited subsurface exploration program and evaluation of the existing dams for former clay settling area CS-11 for SWFWMD. The report's findings were that:

- The earthen dams presently in place around the CS-11 area are safe for use as water retention structures provided that suitable drainage and access modifications are made.
- Upstream improvements such as revetments or liners are required to protect the dams from wave erosion.
- Improvements to the ramps to the crest and upgrading the toe and crest roads to provide all weather access will be required.
- The toe filters and seepage control systems should be upgraded.
- The north and west dams below the toe road should be improved and protected from erosion.
- The existing spillways are not suitable for use in a reservoir system and will have to be abandoned and replaced.
- Piezometric monitoring stations would be required at a section on each dam to evaluate seepage performance of the dam.
- CS-11 has an open water area estimated at 960 acres and a usable storage volume of 9,800 acre-feet.

FEASIBILITY ANALYSES

The feasibility of a water supply reservoir in a former clay settling area depends on:

[2] The report references the clay settling area as CS-11. Based on the conceptual site plan of the proposed reservoir, it encompasses CS-8 and CS-9 and only utilizes part of CS-11.

- The condition of the CSA perimeter embankment.
- The available storage in the former CSA after long-term settlement of the clay.
- The distance to the surface water withdrawal point.
- The catchment area of a nearby surface water feature.
- The amount of water available for withdrawal based on hydrologic and regulatory considerations.
- The cost of the project in comparison to alternatives.

Condition of the CSA Embankments

Clay settling area embankments are designed to contain phosphatic clay. However, most CSAs store clear water above the settled clay. The clay acts as a liner against those portions of the foundation and embankment that are in contact with the clay. Prior to selection for use as a pumped storage reservoir, the CSA will have stored water up to within 5 feet of the crest of the embankment. Because most CSAs are above-grade reservoirs, there is no upstream watershed to create flood levels within the reservoir. A 12-inch rainfall will raise the water level in the pond only slightly more than 12 inches. Overtopping is generally not a concern with CSAs as long as they have a nominal spillway capacity.

The only potential issue associated with long-term use of a CSA as a water reservoir is wave action. Because they are continually being filled with clay, the water level in an active CSA usually does not remain at one level long enough to cause significant erosion. Erosion that does occur is typically repaired as part of routine maintenance. If a CSA is retrofitted to be used as a clear water reservoir for 20 or more years, the upper 14 feet of the inside slope will have to be rip-rapped to prevent wave erosion. An operating freeboard of 10 feet will be required to prevent wave run-up from reaching the dam crest.

In addition, the outlet structures in most CSAs are constructed of steel and have a useful life of about 25 years. These structures will need to be properly abandoned and new concrete structures will need to be constructed to provide an overflow spillway and a pumped or gravity discharge outlet structure. With the addition of slope protection and new outlet structures, a retired CSA should provide a safe and relatively economical pumped storage reservoir.

Storage Capacity

The storage capacity of a CSA must be adequate to store the withdrawals from the surface water body until the water can be used for agricultural or industrial consumption or until it is discharged to augment streamflow during the dry season. The required storage capacity is related to the proposed withdrawal rates and the hydrologic conditions of the water body. The capacity of a retired CSA depends on the extent to which clay has consolidated. In some cases it may take 10 to 20 years after filling is completed to achieve the maximum reservoir capacity. To determine the potential storage capacity of a typical retired CSA, clay disposal plans for three mines were evaluated. The effective area, clay storage height at completion of filling, and clay storage height at ultimate consolidation were obtained and maximum storage capacity was computed. A frequency distribution of maximum storage capacity for the 25 CSAs in the disposal plans reviewed is presented in Figure 3.

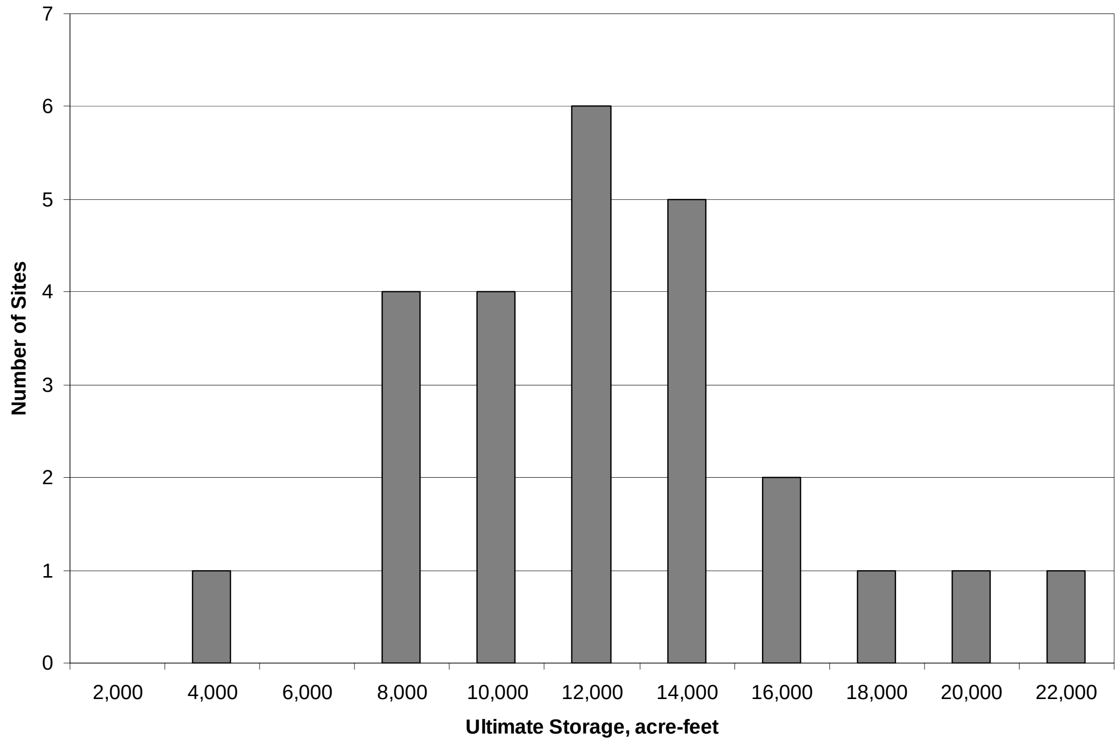

Figure 3. Histogram of Ultimate Storage Capacity for CSA Sites Reviewed.

Surface Water Withdrawal Point

Because there are numerous CSAs along the Peace River, the most likely projects will be close to the Peace River or in the lower reaches of major tributaries with substantial streamflow such as Payne Creek, Little Payne Creek or Horse Creek. As long as there is adequate storage capacity available in CSAs within approximately 1 to 2 miles of the stream, there is no incentive to select a CSA farther from the water body.

Amount of Water Available for Withdrawal

The amount of water available for withdrawal depends on historic streamflows and SWFWMD policies. For analysis purposes, we have assumed that withdrawals above the minimum flow will be limited to a maximum of 10 percent of total mean daily stream flow. We have used the streamflow exceeded 85 percent of the time (P_{85}) as the minimum flow cutoff. The maximum withdrawal was limited by economic considerations. For the smaller tributaries, the optimum pumping capacity was 5,000 gpm. For the Peace River, the optimum pumping capacity was 20,000 gpm.

A statistical analysis of streamflows for five gaging stations on streams with watersheds varying in size from 42 to 1,367 square miles was performed to determine mean daily streamflow, median streamflow (P_{50}) and P_{85} for each stream. The results are summarized in Table 10.

Table 10. Summary of Hydrological Analysis.

Stream Gaging Station Analyzed	Catchment Area (mi^2)	Record Analyzed	P_{50} (cfs)	P_{85} (cfs)	Mean Flow (cfs)
Horse Creek near Myakka Head	42	1977-2003	6.5	0.5	31
Joshua Creek near Nocatee	132	1963-2003	30	7.7	103
Horse Creek near Arcadia	218	1963-2003	41	5.5	181
Peace River at Zolfo Springs	826	1963-2003	265	100	510
Peace River at Arcadia	1,367	1963-2003	395	131	907

Daily streamflows for the time periods shown above were then analyzed to determine the safe yield (sustainable average daily flow) for different pump capacities and storage volumes. The storage volumes used in the analyses were determined by an evaluation of the data presented in Figure 3. The analyses were performed on Microsoft Excel spreadsheets using the following algorithms:

- If mean daily streamflow is greater than P_{85}, withdrawal is limited to the lesser of the pumping capacity, 10 percent of the mean daily flow, or the difference between 10 percent of the mean daily flow and P_{85}.
- If available storage is greater than maximum available storage, storage is increased (or decreased) by withdrawal minus safe yield up to the maximum (or minimum) available storage. Any excess withdrawal is released back to streamflow.
- Safe yield is the highest quantity that can be withdrawn from storage without reducing available storage below zero for the time period used in the analysis.

The results of this analysis are provided in Figures 4 and 5. Table 11 provides our best estimate of the safe yield, storage required and intake capacity for different watershed areas. A comparison of the flow-duration curves for each of the streams with and without the proposed withdrawals is presented in Appendix B. Also provided in Appendix B is a pumping rate-duration curve for each of the analyzed streams.

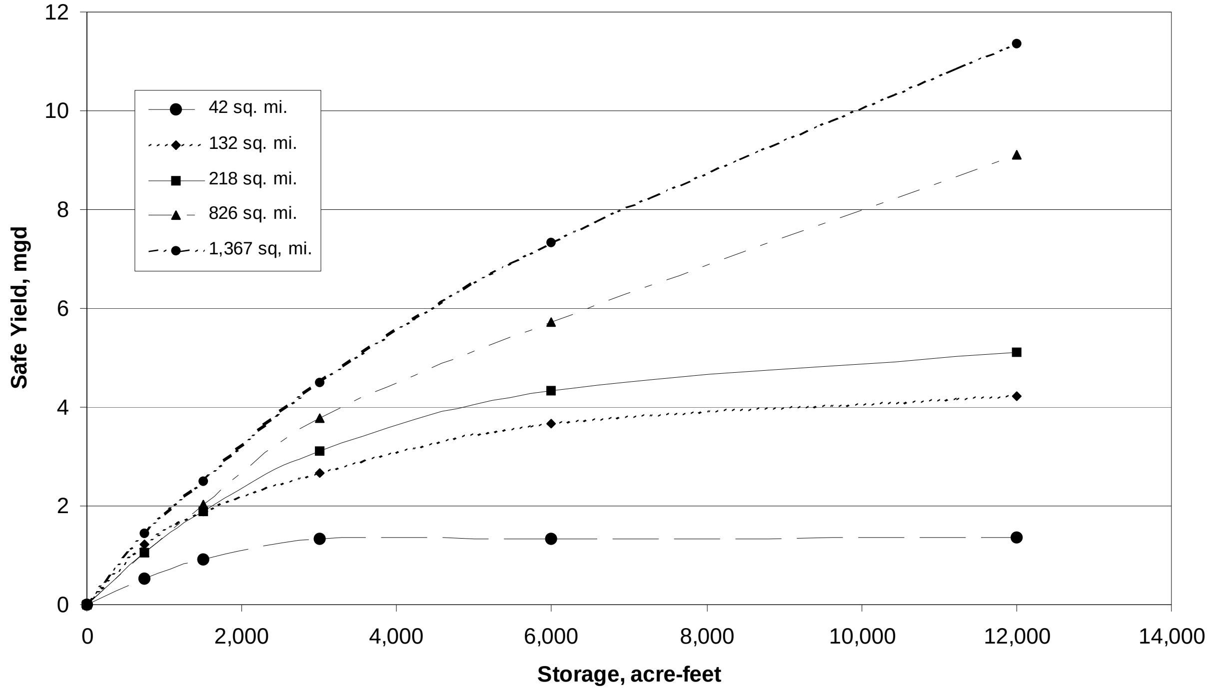

Figure 4. Safe Yield vs. Storage.

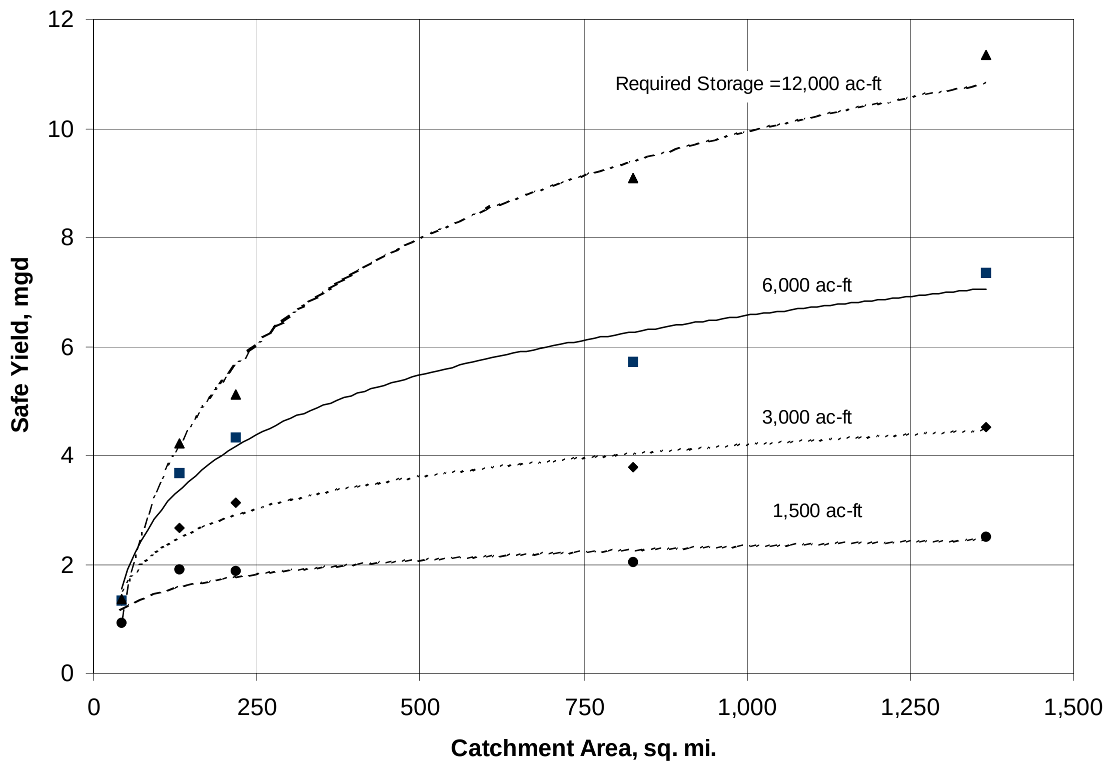

Figure 5. Safe Yield vs. Catchment Area.

Table 11. Summary of Safe Yield Analysis.

Stream Gaging Station Analyzed	Safe Yield (mgd)	Safe Yield (cfs)	Storage Required (acre-feet)	Intake Capacity (mgd)	Intake Capacity (cfs)
Horse Creek near Myakka Head	1.25	1.9	2,500	7.2	11.1
Joshua Creek near Nocatee	3.7	5.7	6,000	21.6	33.4
Horse Creek near Arcadia	4.3	6.7	6,000	14.4	22.3
Peace River at Zolfo Springs	9.1	14.1	12,000	21.6	33.4
Peace River at Arcadia	11.4	17.6	12,000	28.8	44.6

Cost Analysis

A cost analysis was performed to determine the capital cost and operating cost for each of the five scenarios analyzed. The analysis used similar methodology and parameters as other SWFWMD economic comparisons. The following capital costs were included in the cost analysis: intake structure and pump, pipeline, power line, soil cement rip-rap, concrete outlet structure, filtration system, and abandonment of existing outlet structures. Land costs were also included. However, mining companies may be willing to donate retired areas to save reclamation cost and to reduce other potential liabilities. Operating costs included power cost, maintenance, and semi-annual engineering inspections. The computation sheets for each of the five scenarios are included in Appendix C. The capital cost and cost per 1000 gallons are summarized in Table 12. At a cost of $0.23 to $0.82 per 1000 gallons for raw water and $0.31 to $0.91 per 1000 gallons for water filtered for irrigation, the use of retired clay settling areas as pumped storage reservoirs for water withdrawn from nearby streams is feasible and could provide significant quantities of water to agriculture or industry.

Table 12. Summary of Cost Analysis.

Watershed Area (mi^2)	Raw Water		Filtered Water	
	Capital Cost/Capacity ($1000/mgd)	Present Value Project Cost ($/1000 gal)	Capital Cost/Capacity ($1000/mgd)	Present Value Project Cost ($/1000 gal)
42	2,697	0.82	3,098	0.91
132	1,296	0.46	1,777	0.55
218	1,076	0.40	1,567	0.50
826	630	0.26	1,065	0.35
1,367	540	0.23	950	0.31

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Appendix A

DATA FOR POWER GENERATORS IN SWFWMD COUNTIES

DATA FOR POWER GENERATORS IN SWFWMD COUNTIES

Appendix A summarizes the data for current power generation facilities in SWFWMD counties from the U.S. Department of Energy (DOE) Energy Information Administration EIA-860 database (USDOE 2003). The facilities have been sorted by prime mover. The total capacities for each prime mover type are summarized at the end of the table. The field descriptions and codes used in the database are described following the table.

There are only three steam or combined-cycle power generators with nameplate power generation capacity of less than 4 MW listed in the database for District counties:

1. Cutrale Citrus Juices USA, Inc. in Auburndale, Polk County
2. Tampa Electric Company Phillips Station in Highlands County (may not be in the District)
3. Pasco Beverage Company in Pasco County.

Other generating facilities with a nameplate capacity of less than 4 MW are the combustion turbine parts of combined cycle plants, gas turbines, internal combustion engines or biomass generators, which do not require cooling water.

Table A-1. Power Generators in SWFWMD Counties from the Energy Information Administration Database.

County	Company	Plant ID	Plant Name	Primary Purpose Code	Generator ID	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Prime Mover	Energy Source 1	Energy Source 2	Initial Date of Operation
Polk	Calpine Eastern Corp	54658	Auburndale Power Partners LP	22	ST	57.7	49.62	54.24	CA	WH		Apr-94
Polk	Cutrale Citrus Juices USA Inc	10188	Cutrale Citrus Juices USA Inc	311	GEN3	1.5	1.29	1.41	CA	WH		Nov-82
Polk	Florida Power Corp	7302	Hines	22	1ST	199.7	482	529	CA	NG		Apr-94
Polk	Florida Power Corp	7699	Tiger Bay	22	CW1	82.9	207	223	CA	NG		Aug-97
Hardee	Hardee Power Partners Ltd	50949	Hardee	22	GEN3	95.8	78	85	CA	NG	DFO	Jul-92
Lake	Lake Cogen Ltd	54423	Lake Cogen Ltd	22	ST1	31.1	26.5	26.5	CA	NG	DFO	Apr-93
Polk	Lakeland City of	676	C D McIntosh Jr	22	5ST	120	103.2	112.8	CA	NG		Oct-02
Polk	Lakeland City of	675	Larsen Memorial	22	5	25	29	31	CA	WH		Apr-56
Polk	Orange Cogeneration LP	54365	Orange Cogen	22	APC3	28.6	24.6	26.88	CA	WH		Mar-95
Pasco	Pasco Cogen Ltd	54424	Pasco Cogen Ltd	22	ST1	26.5	31.7	31.7	CA	WH		Jul-93
Polk	Polk Power Partners LP	54426	Mulberry Cogen	22	ST1	49.5	42.57	46.53	CA	WH		Jul-94
Hardee	Seminole Electric Coop Inc	7380	Payne Creek	22	ST1	189	162.54	177.66	CA	NG	DFO	Dec-01
Highlands	Tampa Electric Co	748	Phillips	22	CW1	3.6	3	3	CA	WH		Jun-83
Hillsborough	Tampa Electric Co		Bayside Power		1		685.4		CC	NG		May-03
Polk	Tampa Electric Co	7242	Polk	22	1	326.2	250	250	CC	BIT	DFO	Sep-96
Polk	Calpine Eastern Corp	54658	Auburndale Power Partners LP	22	CT	135	116.1	126.9	CT	NG	DFO	Apr-94
Polk	Cutrale Citrus Juices USA Inc	10188	Cutrale Citrus Juices USA Inc	311	GEN1	3.5	3.01	3.29	CT	NG		Dec-87
Polk	Cutrale Citrus Juices USA Inc	10188	Cutrale Citrus Juices USA Inc	311	GEN2	3.5	3.01	3.29	CT	NG		Dec-87
Polk	Florida Power Corp	7302	Hines	22	1GT	173.4	0	0	CT	NG	DFO	Apr-99
Polk	Florida Power Corp	7302	Hines	22	1GT2	173.4	0	0	CT	NG		Apr-99
Polk	Florida Power Corp	7699	Tiger Bay	22	CT1	195.2	0	0	CT	NG		Aug-97
Hardee	Hardee Power Partners Ltd	50949	Hardee	22	GEN1	95.8	70	85	CT	NG	DFO	Jul-92
Hardee	Hardee Power Partners Ltd	50949	Hardee	22	GEN2	95.8	70	85	CT	NG	DFO	Jul-92
Lake	Lake Cogen Ltd	54423	Lake Cogen Ltd	22	GT1	57.4	41.5	41.5	CT	NG	DFO	Apr-93
Lake	Lake Cogen Ltd	54423	Lake Cogen Ltd	22	GT2	69.2	41.5	41.5	CT	NG	DFO	Apr-93
Polk	Lakeland City of	676	C D McIntosh Jr	22	5CT	249	221	268	CT	NG	DFO	May-01
Polk	Lakeland City of	675	Larsen Memorial	22	8	101.5	73	93	CT	NG	DFO	Jul-92
Polk	Orange Cogeneration LP	54365	Orange Cogen	22	APC2	54	46.44	50.76	CT	NG		Feb-95
Polk	Orange Cogeneration LP	54365	Orange Cogen	22	APC1	54	103	103	CT	NG		Mar-95
Pasco	Pasco Cogen Ltd	54424	Pasco Cogen Ltd	22	GT1	48.8	42.5	42.5	CT	NG	DFO	Jul-93
Pasco	Pasco Cogen Ltd	54424	Pasco Cogen Ltd	22	GT2	48.8	42.5	42.5	CT	NG	DFO	Apr-93
Polk	Polk Power Partners LP	54426	Mulberry Cogen	22	GT1	103.5	120	115	CT	NG	DFO	May-94
Hardee	Seminole Electric Coop Inc	7380	Payne Creek	22	CT1A	199	171.14	187.06	CT	NG	DFO	Dec-01
Hardee	Seminole Electric Coop Inc	7380	Payne Creek	22	CT1B	199	171.14	187.06	CT	NG	DFO	Dec-01
Polk	Calpine Eastern Corp	55833	Auburndale	22	CTP	115.5	98.2	113.2	GT	NG	DFO	May-02
Polk	Citrus World Inc	10275	Florida's Natural Growers	311	TA70	7.2	5.7	5.9	GT	NG		Dec-89
Polk	Citrus World Inc	10275	Florida's Natural Growers	311	CE50	3.5	2.1	3.4	GT	NG		Dec-89

Table A-1. Power Generators in SWFWMD Counties from the Energy Information Administration Database.

County	Company	Plant ID	Plant Name	Primary Purpose Code	Generator ID	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Prime Mover	Energy Source 1	Energy Source 2	Initial Date of Operation
Lake	Cutrale Citrus Juices USA Inc	10020	Cutrale Citrus Juices USA Inc	311	GEN1	3.5	2.98	3.43	GT	NG		Dec-87
De Soto	Entergy Power Group	55422	De Soto County Power	22	DES1	182	154.7	178.4	GT	NG		May-02
De Soto	Entergy Power Group	55422	De Soto County Power	22	DES3	182	154.7	178.4	GT	NG		Jun-02
De Soto	Entergy Power Group	55422	De Soto County Power	22	DES2	182	154.7	178.4	GT	NG		May-02
Highlands	Florida Power Corp	624	Avon Park	22	P1	33.7	26	32	GT	NG	DFO	Dec-68
Highlands	Florida Power Corp	624	Avon Park	22	P2	33.7	26	32	GT	DFO		Dec-68
Pinellas	Florida Power Corp	627	Bayboro	22	P4	56.7	46	58	GT	DFO		Apr-73
Pinellas	Florida Power Corp	627	Bayboro	22	P3	56.7	46	58	GT	DFO		Apr-73
Pinellas	Florida Power Corp	627	Bayboro	22	P1	56.7	46	58	GT	DFO		Apr-73
Pinellas	Florida Power Corp	627	Bayboro	22	P2	56.7	46	58	GT	DFO		Apr-73
Pinellas	Florida Power Corp	630	Higgins	22	P1	33.7	27	32	GT	NG	DFO	Mar-69
Pinellas	Florida Power Corp	630	Higgins	22	P4	42.9	34	35	GT	NG	DFO	Jan-71
Pinellas	Florida Power Corp	630	Higgins	22	P3	42.9	34	35	GT	NG	DFO	Dec-70
Pinellas	Florida Power Corp	630	Higgins	22	P2	33.7	27	32	GT	NG	DFO	Apr-69
Pinellas	Florida Power Corp	634	P L Bartow	22	P1	55.7	46	53	GT	DFO		May-72
Pinellas	Florida Power Corp	634	P L Bartow	22	P4	55.7	49	60	GT	NG	DFO	Jun-72
Pinellas	Florida Power Corp	634	P L Bartow	22	P3	55.7	46	53	GT	DFO		Jun-72
Pinellas	Florida Power Corp	634	P L Bartow	22	P2	55.7	46	53	GT	NG	DFO	Jun-72
Hardee	Hardee Power Partners Ltd	50949	Hardee	22	GEN5	86.5	70	85	GT	NG	DFO	May-00
Hardee	Hardee Power Partners Ltd	50949	Hardee	22	GEN4	95.8	70	85	GT	NG	DFO	Jul-92
Polk	Lakeland City of	676	C D McIntosh Jr	22	GT1	26.6	17	20	GT	NG	DFO	May-73
Polk	Lakeland City of	675	Larsen Memorial	22	2	11.2	10	14	GT	NG	DFO	Nov-62
Polk	Lakeland City of	675	Larsen Memorial	22	3	11.2	10	14	GT	NG	DFO	Dec-62
Pasco	Shady Hills Power Co LLC	55414	Shady Hills Generating Station	22	G101	182	154.7	154.7	GT	NG	DFO	Jan-02
Pasco	Shady Hills Power Co LLC	55414	Shady Hills Generating Station	22	G201	182	154.7	178.4	GT	NG	DFO	Jan-02
Pasco	Shady Hills Power Co LLC	55414	Shady Hills Generating Station	22	G301	182	154.7	178.4	GT	NG	DFO	Jan-02
Hillsborough	Tampa Electric Co	645	Big Bend	22	GT1	18	12	17	GT	DFO		Feb-69
Hillsborough	Tampa Electric Co	645	Big Bend	22	GT2	78.7	66	80	GT	DFO		Nov-74
Hillsborough	Tampa Electric Co	645	Big Bend	22	GT3	78.7	66	80	GT	DFO		Nov-74
Polk	Tampa Electric Co	7242	Polk	22	3	195	166	191	GT	NG		Apr-02
Polk	Tampa Electric Co	7242	Polk	22	2	195	150	180	GT	NG	DFO	Jul-00
Hardee	Vandolah Power Co LLC	55415	Hardee	22	G101	182	154.7	178.4	GT	NG		Jun-02
Hardee	Vandolah Power Co LLC	55415	Hardee	22	G401	182	154.7	178.4	GT	NG		Jun-02
Hardee	Vandolah Power Co LLC	55415	Hardee	22	G301	182	154.7	178.4	GT	NG		Jun-02
Hardee	Vandolah Power Co LLC	55415	Hardee	22	G201	182	154.7	178.4	GT	NG		Jun-02
Polk	Lakeland City of	676	C D McIntosh Jr	22	IC2	2.5	3	3	IC	DFO		Jan-70
Polk	Lakeland City of	676	C D McIntosh Jr	22	IC1	2.5	3	3	IC	DFO		Jan-70
Polk	Lakeland City of	7997	Winston	22	WD01	12.5	12.2	12.3	IC	DFO		Apr-02
Polk	Lakeland City of	7997	Winston	22	WD02	12.5	12.2	12.3	IC	DFO		Apr-02

Table A-1. Power Generators in SWFWMD Counties from the Energy Information Administration Database.

County	Company	Plant ID	Plant Name	Primary Purpose Code	Generator ID	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Prime Mover	Energy Source 1	Energy Source 2	Initial Date of Operation
Polk	Lakeland City of	7997	Winston	22	WD03	12.5	12.2	12.3	IC	DFO		Apr-02
Polk	Lakeland City of	7997	Winston	22	WD04	12.5	12.2	12.3	IC	DFO		Apr-02
Pasco	Pasco Cogen Ltd	54424	Pasco Cogen Ltd	22	EDG2	1.2	1.2	1.2	IC	DFO		Jul-93
Pasco	Pasco Cogen Ltd	54424	Pasco Cogen Ltd	22	EDG1	1.2	1.2	1.2	IC	DFO		Jul-93
Hillsborough	St Joseph's Hospital	54534	St Josephs Hospital	622	1	1.7	1.66	1.68	IC	NG		Feb-93
Hillsborough	Tampa Dept of Sanitary Sewers	54347	Howard F Curren AWT	22132	3	0.5	0.5	0.5	IC	OBG		Sep-86
Hillsborough	Tampa Dept of Sanitary Sewers	54347	Howard F Curren AWT	22132	5	0.5	0.5	0.5	IC	OBG		Feb-89
Hillsborough	Tampa Dept of Sanitary Sewers	54347	Howard F Curren AWT	22132	2	0.5	0.5	0.5	IC	OBG		Sep-86
Hillsborough	Tampa Dept of Sanitary Sewers	54347	Howard F Curren AWT	22132	4	0.5	0.5	0.5	IC	OBG		Feb-89
Hillsborough	Tampa Dept of Sanitary Sewers	54347	Howard F Curren AWT	22132	1	0.5	0.5	0.5	IC	OBG		Sep-86
Highlands	Tampa Electric Co	748	Phillips	22	IC1	19.2	17	17	IC	RFO	DFO	Jun-83
Highlands	Tampa Electric Co	748	Phillips	22	IC2	19.2	17	17	IC	RFO	DFO	Jun-83
Highlands	Tampa Electric Co	748	Phillips	22	IC5	0.6	0.6	0.6	IC	DFO		Jan-56
	Tampa Electric Co	55893	Partnership Station	22	1	3	3	3	OT	NG		May-01
	Tampa Electric Co	55893	Partnership Station	22	2	3	3	3	OT	NG		May-01
Hillsborough	Cargill Fertilizer Inc	10204	Cargill Fertilizer Inc	325188	GEN1	35.4	34.4	34.4	ST	WH		Aug-88
Hillsborough	Cargill Fertilizer Inc	10204	Cargill Fertilizer Inc	325188	GEN3	42.5	41.5	41.5	ST	WH		Nov-99
Polk	Cargill Fertilizer Inc	50633	Cargill Fertilizer Inc Bartow	325188	GEN1	36.9	36	36	ST	WH		Dec-85
Polk	Cargill Fertilizer Inc	50633	Cargill Fertilizer Inc Bartow	325188	GEN2	45	44	44	ST	WH		Aug-92
Hernando	Central Power & Lime Inc	10333	Central Power & Lime Inc	22	GEN1	125	139	143	ST	BIT		Jun-88
Hillsborough	CF Industries Inc	50371	CFI Plant City Phosphate Complex	325	MI34	40.5	28.6	27.2	ST	OTH		Nov-88
Lake	Covanta Lake Inc	50629	Lake County	22	GEN1	15.5	12.5	12.5	ST	MSW		Sep-90
Polk	Farmland Hydro Ltd Partner	10205	Farmland Hydro LP	325311	GEN1	38.2	38.2	38.2	ST	OTH		Nov-90
Pasco	Florida Power Corp	8048	Anclote	22	1	556.2	498	522	ST	RFO	NG	Oct-74
Pasco	Florida Power Corp	8048	Anclote	22	2	556.2	495	522	ST	RFO	NG	Oct-78
Citrus	Florida Power Corp	628	Crystal River	22	ST4	739.2	720	735	ST	BIT		Dec-82
Citrus	Florida Power Corp	628	Crystal River	22	5	739.2	717	732	ST	BIT		Oct-84
Citrus	Florida Power Corp	628	Crystal River	22	2	523.8	486	491	ST	BIT		Nov-69
Citrus	Florida Power Corp	628	Crystal River	22	1	440.5	379	383	ST	BIT		Oct-66
Citrus	Florida Power Corp	628	Crystal River	22	3	890.4	842	852	ST	NUC		Mar-77
Pinellas	Florida Power Corp	634	P L Bartow	22	ST1	127.5	121	123	ST	RFO		Sep-58
Pinellas	Florida Power Corp	634	P L Bartow	22	ST2	127.5	119	121	ST	RFO		Aug-61
Pinellas	Florida Power Corp	634	P L Bartow	22	ST3	239.3	204	208	ST	RFO	NG	Jul-63
Hillsborough	Hillsborough County	50858	Hillsborough County Resource Recovery	22	GEN1	29	26	26	ST	MSW		Apr-87
Polk	IMC Phosphates Co	10434	New Wales	325311	TG1	10	8	8	ST	WH		Aug-81
Polk	IMC Phosphates Co	10434	New Wales	325311	TG2	58.5	48	48	ST	WH		Dec-84
Polk	IMC Phosphates Co	10004	South Pierce	325	TG1	7.5	4	4	ST	WH		Jan-78
Polk	IMC Phosphates Co	10004	South Pierce	325	TG2	38	33	33	ST	WH		Jan-92
Polk	Lakeland City of	676	C D McIntosh Jr	22	1	103.5	87	87	ST	NG	RFO	Feb-71
Polk	Lakeland City of	676	C D McIntosh Jr	22	2	126	103	103	ST	NG	RFO	Jun-76

Table A-1. Power Generators in SWFWMD Counties from the Energy Information Administration Database.

County	Company	Plant ID	Plant Name	Primary Purpose Code	Generator ID	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Prime Mover	Energy Source 1	Energy Source 2	Initial Date of Operation
Polk	Lakeland City of	676	C D McIntosh Jr	22	3	363.8	342	342	ST	BIT	NG	Sep-82
Polk	Lakeland City of	675	Larsen Memorial	22	7	44	50	50	ST	NG	RFO	Feb-66
Polk	Lakeland City of	675	Larsen Memorial	22	6	25	24	24	ST	NG	RFO	Dec-59
Hillsborough	Nitram Inc	50958	Nitram Inc	325311	GEN1	6.2	2	2	ST	NG		Jan-85
Pasco	Pasco Beverage Co	50908	Pasco Beverage Co	311	GEN1	1.5	1.4	1.41	ST	NG		May-58
Pasco	Pasco County	50666	Pasco County Solid Waste Resource	22	GEN1	31.2	26	26	ST	MSW		May-91
Pinellas	Pinellas County Solid Waste	50884	Pinellas County Resource Recovery	22	GEN1	50.5	41.1	41.1	ST	MSW		Jan-83
Pinellas	Pinellas County Solid Waste	50884	Pinellas County Resource Recovery	22	GEN2	26	17	17	ST	MSW		Apr-86
Polk	Ridge Generating Station LP	54529	Ridge	22	1	47.1	47.1	47.1	ST	WDS		Mar-94
Hillsborough	Tampa City of	50875	McKay Bay	22	GEN1	22.1	18	18	ST	MSW		Jun-85
Hillsborough	Tampa Electric Co	645	Big Bend	22	ST2	445.5	416	426	ST	BIT		Apr-73
Hillsborough	Tampa Electric Co	645	Big Bend	22	ST4	486	442	447	ST	BIT		Feb-85
Hillsborough	Tampa Electric Co	645	Big Bend	22	1	445.5	416	426	ST	BIT		Oct-70
Hillsborough	Tampa Electric Co	645	Big Bend	22	ST3	445.5	433	443	ST	BIT		May-76
Highlands	Tampa Electric Co	747	Dinner Lake	22	1	12.6	11	11	ST	NG	RFO	Dec-66
Hillsborough	Tampa Electric Co	646	F J Gannon	22	1	125	114	114	ST	BIT		Sep-57
Hillsborough	Tampa Electric Co	646	F J Gannon	22	2	125	98	98	ST	BIT		Nov-58
Hillsborough	Tampa Electric Co	646	F J Gannon	22	3	179.5	145	145	ST	BIT		Oct-60
Hillsborough	Tampa Electric Co	646	F J Gannon	22	6	445.5	372	392	ST	BIT		Oct-67
Hillsborough	Tampa Electric Co	646	F J Gannon	22	4	187.5	159	169	ST	BIT		Nov-63
Hillsborough	Tampa Electric Co	647	Hookers Point	22	1	33	30	32	ST	RFO		Jul-48
Hillsborough	Tampa Electric Co	647	Hookers Point	22	4	49	39	41	ST	RFO		Oct-53
Hillsborough	Tampa Electric Co	647	Hookers Point	22	3	34.5	30	32	ST	RFO		Aug-50
Hillsborough	Tampa Electric Co	647	Hookers Point	22	2	34.5	30	32	ST	RFO		Jun-50
Hillsborough	Tampa Electric Co	647	Hookers Point	22	5	81.6	67	52	ST	RFO		May-55
Polk	US Agri-Chemicals Corp	50291	US Agri-Chemicals Fort Meade	325188	T/G	32	32	32	ST	OTH		Dec-82
						9471	8667	8835	ST			
						911	1241	1349	CA			
						326	935	250	CC			
						2060	1336	1475	CT			
						3417	2838	3301	GT			
						101	96	96	IC			
						6	6	6	OT			
						16291	15119	15313	Total			

Form EIA-860, "Annual Electric Generator Report," - Generator (Existing) File Fields and Codes

FIELD NAME	DEFINITION	DESCRIPTION
Plant ID	Plant Code	Plant Site EIA-assigned Code
Generator ID	Generator Code (ID)	Generator Identification
Prime Mover	Generator Unit Type	See List Below
Energy Source 1	Energy Source 1	Energy Sources listed in order by predominance (BTUs) of Use; Energy Source 1 is greatest; See List Below.
Energy Source 2	Energy Source 2	Second Energy Source in Order of Predominance of Use
Energy Source 3	Energy Source 3	Third Energy Source in Order of Predominance of Use
Energy Source 4	Energy Source 4	Fourth Energy Source in Order of Predominance of Use
Energy Source 5	Energy Source 5	Fifth Energy Source in Order of Predominance of Use
Energy Source 6	Energy Source 6	Sixth Energy Source in Order of Predominance of Use
MultiGenerator code	Multi-Generator Code (Unit Code)	Indicator for Grouped Generators for purpose of reporting aggregate summer and winter capacities

Prime Mover Code	Prime Mover Description
ST	Steam Turbine, including nuclear, geothermal and solar steam (does not include combined cycle)
GT	Combustion (Gas) Turbine (includes jet engine design)
IC	Internal Combustion Engine (diesel, piston)
CA	Combined Cycle Steam Part
CT	Combined Cycle Combustion Turbine Part
CS	Combined Cycle Single Shaft (combustion turbine and steam turbine share a single generator)
CC	Combined Cycle - Total Unit
HY	Hydraulic Turbine (includes turbines associated with delivery of water by pipeline)
PS	Hydraulic Turbine – Reversible (pumped storage)
PV	Photovoltaic
WT	Wind Turbine
CE	Compressed Air Energy Storage
FC	Fuel Cell
OT	Other
NA	Unknown at this time (use only for plants/generators in planning stage)

Energy Source Code	Energy Source Description
BIT	(Anthracite Coal, Bituminous Coal)
LIG	Lignite Coal
SUB	Subbituminous Coal
WC	Waste/Other Coal (Anthracite Culm, Bituminous Gob, Fine Coal, Lignite Waste, Waste Coal)
SC	Coal-based Synfuel and include briquettes, pellets, or extrusions, which are formed by binding materials and processes that recycle material
DFO	Distillate Fuel Oil (includes all Diesel and No. 1, No. 2, and No. 4 Fuel Oils)

Energy Source Code	Energy Source Description
JF	Jet Fuel
KER	Kerosene
RFO	Residual Fuel Oil (includes No. 5 and No. 6 Fuel Oils and Bunker C Fuel Oil)
WO	Oil-Other and Waste Oil, Butane (Liquid), Crude Oil, Liquid Byproducts, Oil Waste, Propane (Liquid), Re-refined
PC	Petroleum Coke
NG	Natural Gas
BFG	Blast Furnace Gas
OG	Other Gas (Butane, Coal Processes, Coke-Oven, Refinery, and other processes)
PG	Propane
NUC	Nuclear (Uranium, Plutonium, Thorium)
AB	Agriculture Crop Byproducts/Straw/Energy Crops
BLQ	Black Liquor
GEO	Geothermal
LFG	Landfill Gas
MSW	Municipal Solid Waste
OBS	Other Biomass Solid (Animal Manure and Waste, Solid Byproducts, and other solid biomass not specified)
OBL	Other Biomass Liquid (Ethanol, Fish Oil, Liquid Acetonitrile Waste, Medical Waste, Tall Oil, Waste Alcohol, and other Biomass not specified)
OBG	Other Biomass Gases (Digester Gas, Methane, and other biomass gases)
OTH	Other (Batteries, Chemicals, Coke Breeze, Hydrogen, Pitch, Sulfur, Tar Coal, and miscellaneous technologies)
PUR	Purchased Steam
SLW	Sludge Waste
SUN	Solar (Photovoltaic, Thermal)
TDF	Tires
WAT	Water (Conventional, Pumped Storage)
WDS	Wood/Wood Waste Solids (Paper Pellets, Railroad Ties, Utility Poles, Wood Chips, and other wood solids)
WDL	Wood Waste Liquids (Red Liquor, Sludge Wood, Spent Sulfite Liquor, and other wood-related liquids)
WND	Wind
NA	Not Available

Appendix B

FLOW-DURATION AND PUMPING-DURATION CURVES

FLOW-DURATION AND PUMPING-DURATION CURVES

Daily streamflows for five United States Geological Survey (USGS) gaging stations on streams in the Peace River watershed were analyzed to determine the frequency of occurrence of different flows and the safe yield (sustainable average daily flow) for different pump capacities and storage volumes. A comparison of the flow-duration curves for each of the streams with and without the proposed withdrawals is presented in this appendix as Figures B-1, B-3, B-5, B-7, and B-9. Also provided is a pumping rate-duration curve for each of the analyzed streams on Figures B-2, B-4, B-6, B-8 and B-10, respectively.

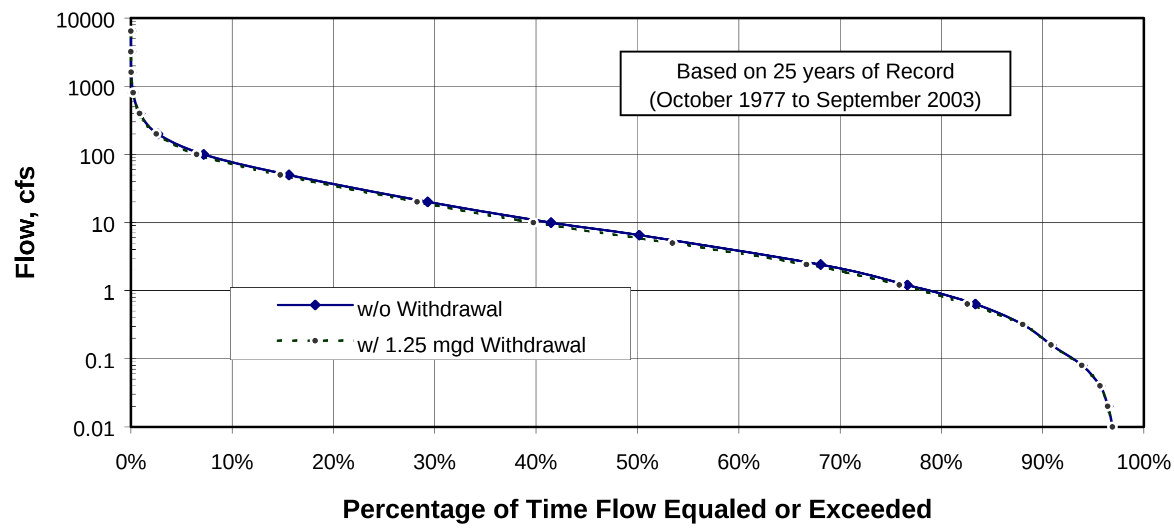

Figure B-1. Flow-Duration Curve for Horse Creek near Myakka Head.

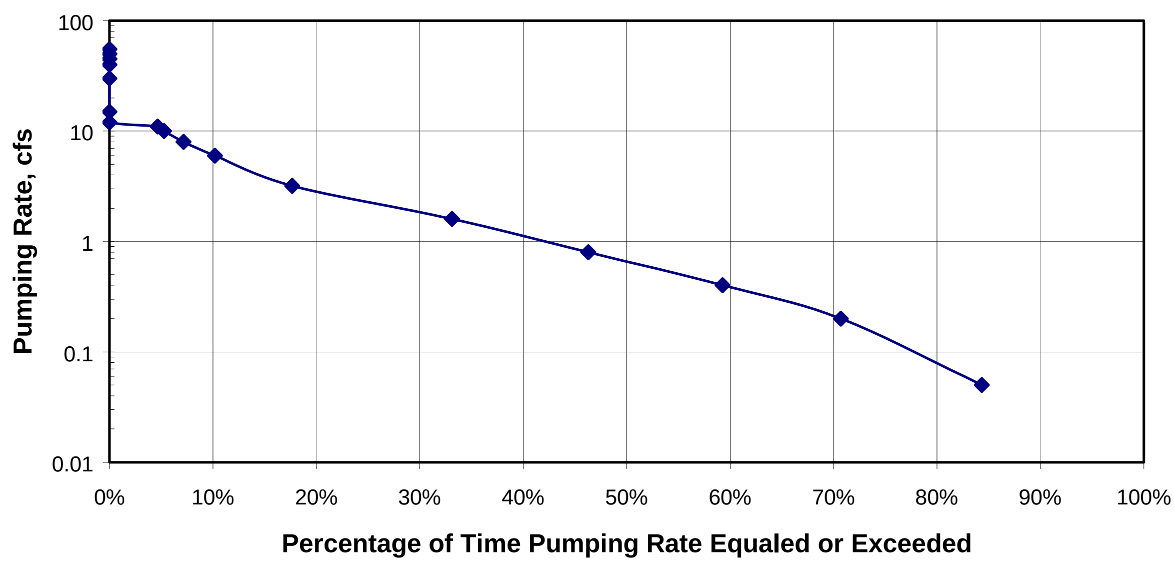

Figure B-2. Pumping-Duration Curve for Horse Creek near Myakka Head.

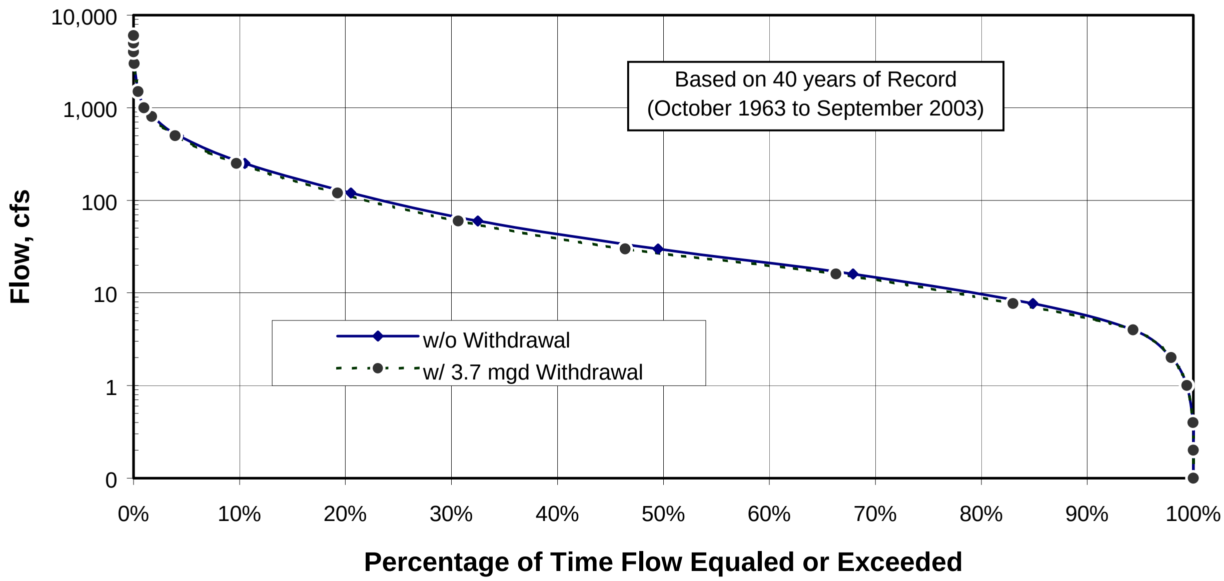

Figure B-3. Flow-Duration Curve for Joshua Creek near Nocatee.

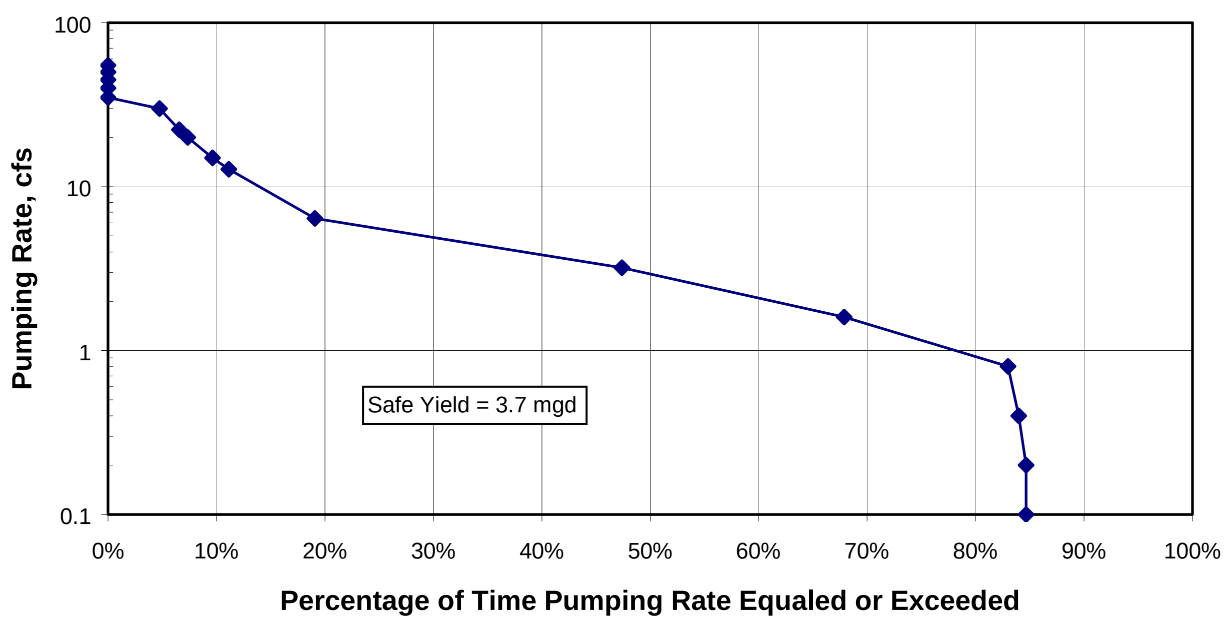

Figure B-4. Pumping-Duration Curve for Joshua Creek near Nocatee.

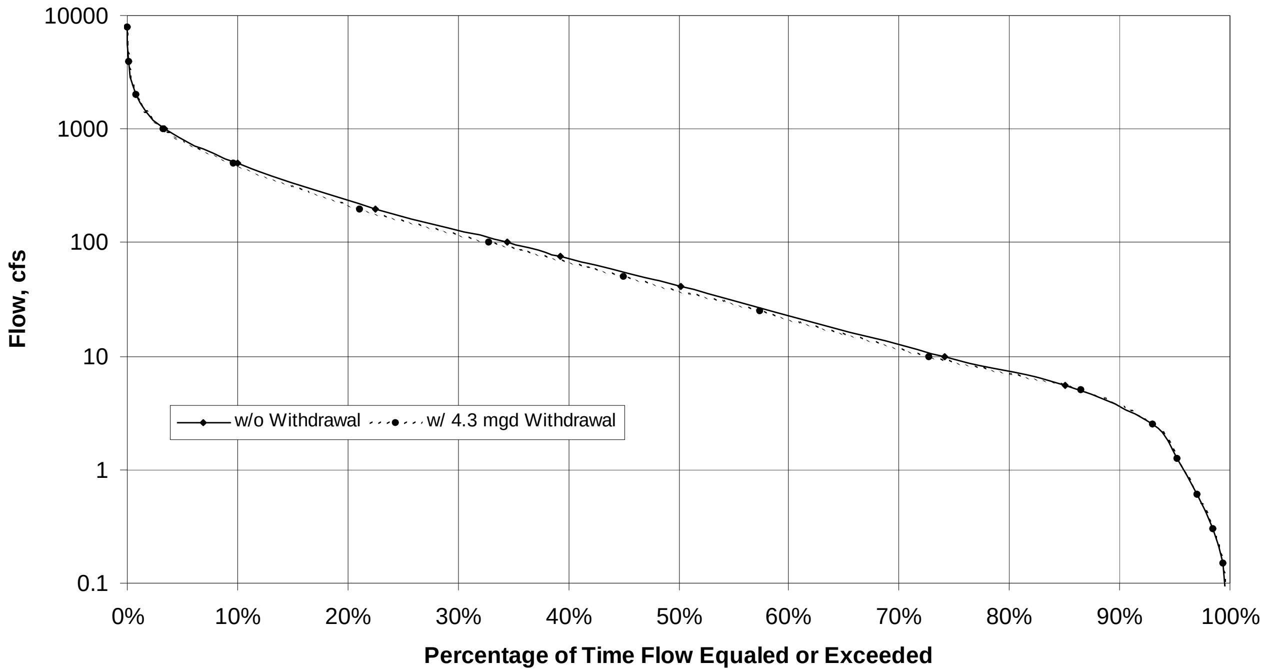

Figure B-5. Flow-Duration Curve for Horse Creek near Arcadia.

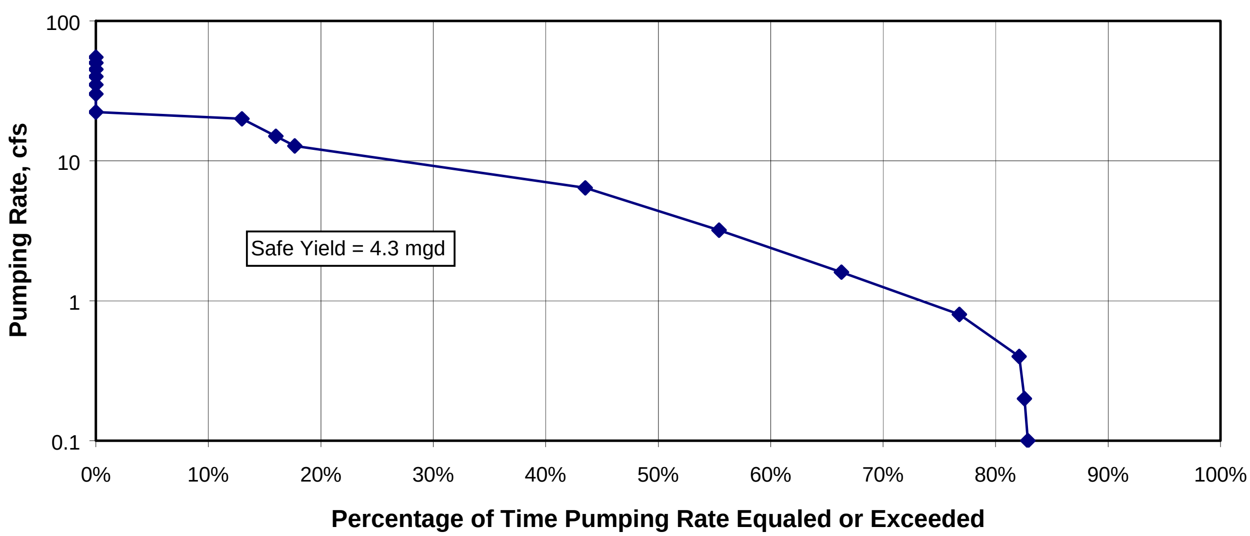

Figure B-6. Pumping-Duration Curve for Horse Creek near Arcadia.

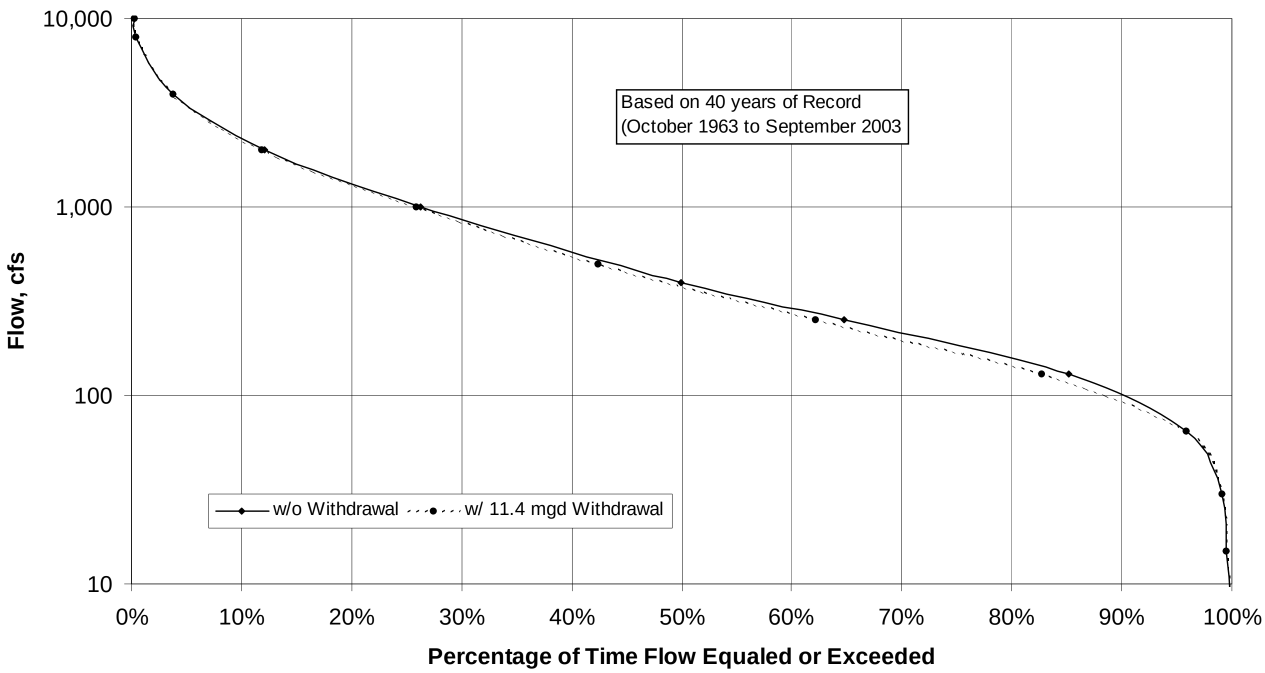

Figure B-7. Flow-Duration Curve for Peace River at Zolfo Springs.

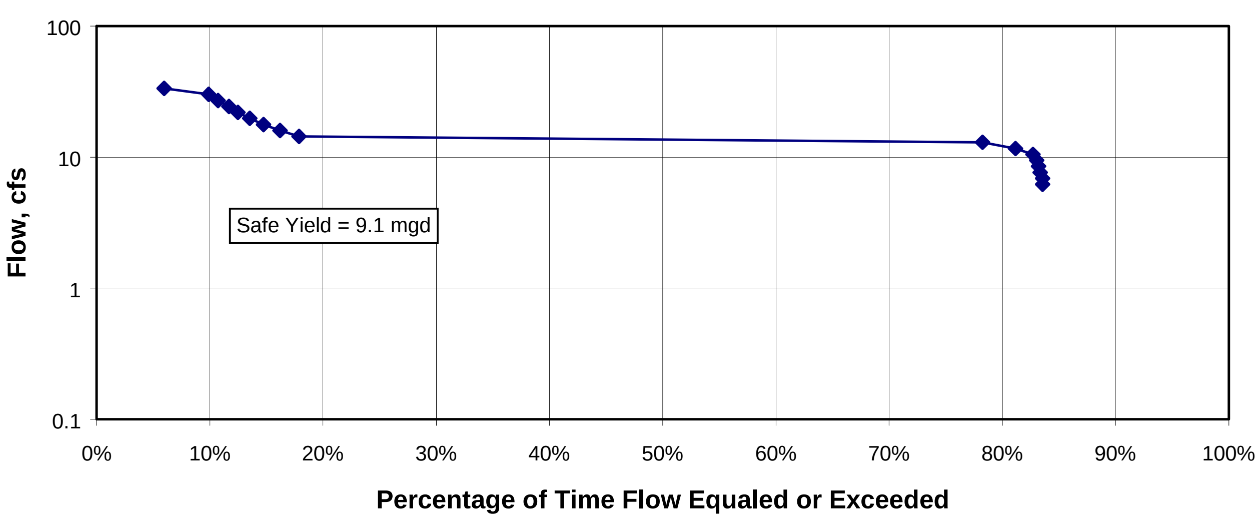

Figure B-8. Pumping-Duration Curve for Peace River at Zolfo Springs.

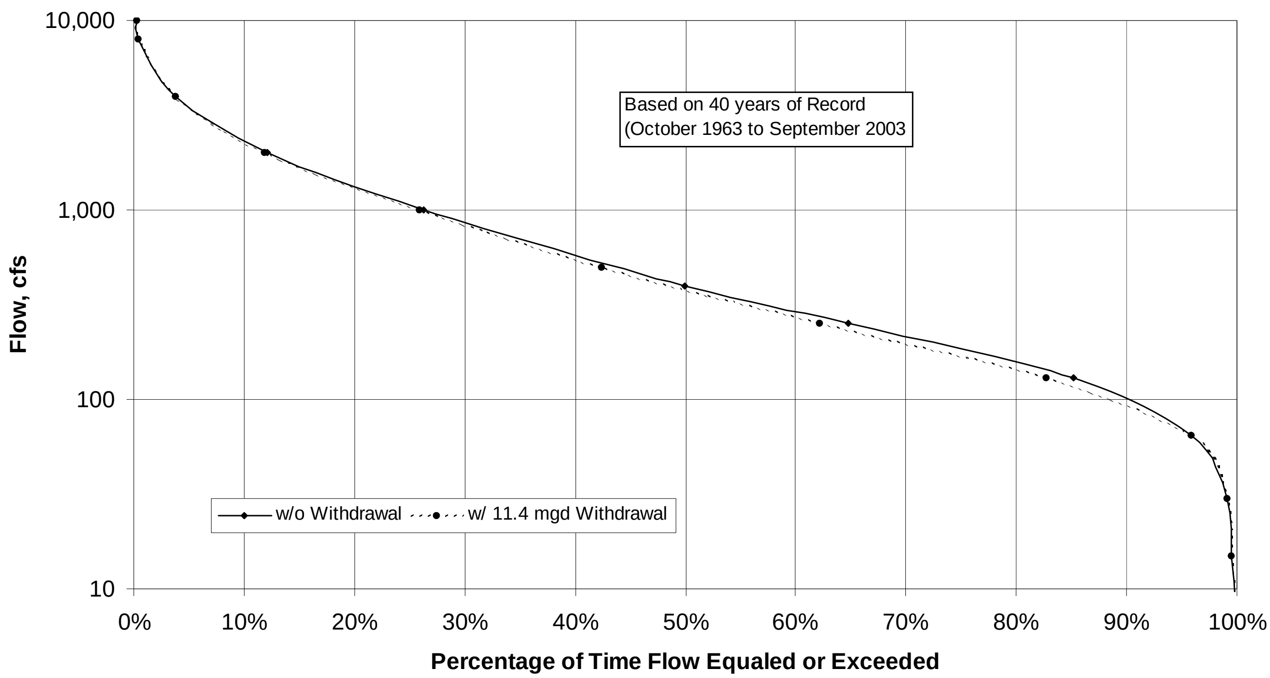

Figure B-9. Flow-Duration Curve for Peace River at Arcadia.

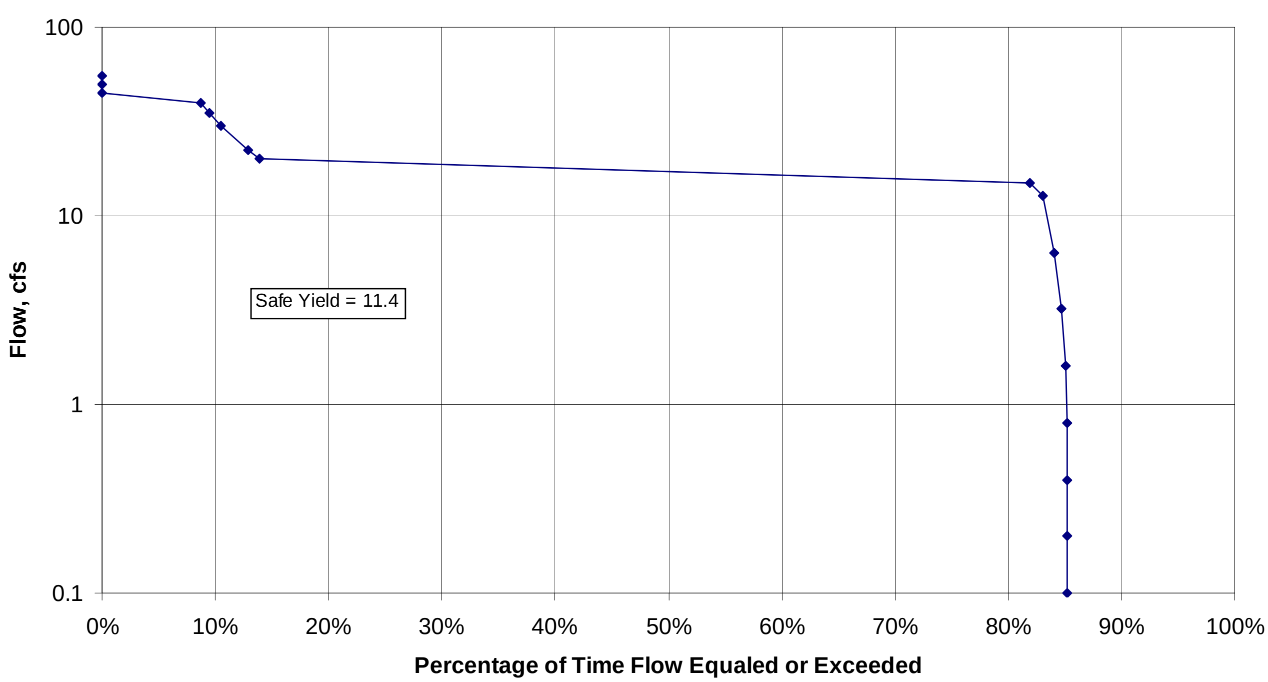

Figure B-10. Pumping-Duration Curve for Peace River at Arcadia.

Appendix C

COST ANALYSES FOR CLAY SETTLING AREA RESERVOIRS

COST ANALYSES FOR CLAY SETTLING AREA RESERVOIRS

Ardaman performed an economic feasibility analysis for five conceptual reservoirs located in retired clay settling areas. Annual daily flows (ADFs), maximum pumping rates and reservoir storage capacity for the analyses were based on the safe yield analysis. Although the flow characteristics were derived from data for specific streams, they are meant to be generic for a certain catchment area within the Peace River, Little Manatee River, and Alafia River watersheds. Reservoirs were assumed to be rectangular with a length to width ratio of two. CSA embankments were assumed to be 50 feet high with a 25-foot wide crest road, 3H:1V exterior slopes and 2H:1V interior slopes. Rip-rap was assumed to extend to a depth of 14 feet below the crest, which would be lowered approximately 2 feet. Interior side slopes would be regarded to 2.75H:1V and clay would be excavated to below the bottom of the rip-rap and placed against the rip-rap after it is constructed.

The cost analyses used a similar methodology to the water supply planning economic analyses performed for SWFWMD (Hazen and Sawyer 1999; CH2M Hill and others 2001). Cost factors, interest rates, project life and some capital and O&M costs were derived from SWFWMD reports. Other costs were derived from R.S. Means Heavy Construction Cost Data, personal communications with contractors, vendors and representatives of the phosphate, citrus and construction industries, and the experience of Ardaman engineers familiar with similar construction.

Costs were derived for raw water and filtered water options at the reservoir site. Filtration is considered for removal of suspended solids for some types of irrigation. Costs of transportation and distribution and water treatment beyond filtration are not included. Costs are presented per 1000 gallons of water yield.

The analyses are presented in the Tables C-1 through C-5, which follow.

Table C-1. Cost Analysis for 42-Square Mile Catchment Area.

ADF:	1.25	mgd
Intake Capacity:	7.2	mgd
Pipeline	16	inch
Reservoir Capacity:	815	Mgal
	2,500	acre-feet
Reservoir Area:	300	acres
Embankment Length:	15,337	feet

TOTAL CAPITAL COST					
I. Construction Costs					
	Item	Unit	Unit Cost	No. of Units	Total Cost
	Surface Water Intake and Pump	L.S.	–	–	125,000
	Pipeline	L.F.	$50	5,000	250,000
	Electric Power	mile	$30,000	1	30,000
	Rip-rap CSA Embankments	L.F.	$100	15,337	1,533,700
	Abandon Existing Outlet Structures	each	$40,000	2	80,000
	New Discharge Structures	each	$125,000	1	125,000
	Pumping Station	L.S.	–	–	78,000
	Filtration System	L.S.	–	–	345,600
	Avoided Closure Cost	acre	reflected in lower land price		
	TOTAL CONSTRUCTION COST				$2,567,300
II. Non-Construction Capital Costs					
	(Construction Cost x 0.45)				1,155,300
	includes engineering, permitting				
	administration and contingency				
	TOTAL NON-CONSTRUCTION CAPITAL COSTS				$1,155,300
III. Land Costs					
	Purchase from Owner	acre	$300	500	150,000
	TOTAL LAND COST				150,000
	TOTAL CAPITAL COST				$3,872,600
OPERATING AND MAINTENANCE COST (ANNUAL)					
	Pipes and Pump Stations	–	–	–	15,000
	Power (from River to Reservoir)	KWH	$0.06	210,000	12,600
	Filtration System (includes power)	–	–	–	6,000
	Embankment Maintenance	acre	$100	68	6,800
	Embankment Inspection	each	$2,500	2	5,000
	TOTAL ANNUAL O&M COST				$45,400
	TOTAL ANNUAL O&M COST without Filtration System				$39,400
ANNUAL PROJECT COST					
Capital cost annualized over 20 years at 7.1% interest rate plus annual O&M cost					$413,800
PRESENT VALUE PROJECT COST ($/1000 gallons)					0.91
PRESENT VALUE PROJECT COST ($/1000 gallons) without Filtration System					0.82
CAPITAL COST/ CAPACITY ($/mgd)					$3,098,000
CAPITAL COST/ CAPACITY ($/mgd) without Filtration					$2,697,000

Table C-2. Cost Analysis for 132-Square Mile Catchment Area.

ADF:	3.7	mgd
Intake Capacity:	21.6	mgd
Pipeline	20	inch
Reservoir Capacity:	1,955	Mgal
	6,000	acre-feet
Reservoir Area:	400	acres
Embankment Length:	17,710	feet

TOTAL CAPITAL COST					
I. Construction Costs					
	Item	Unit	Unit Cost	No. of Units	Total Cost
	Surface Water Intake and Pump	L.S.	–	–	375,000
	Pipeline	L.F.	$64	10,000	640,000
	Electric Power	mile	$30,000	2	60,000
	Rip-rap CSA Embankments	L.F.	$100	17,710	1,771,000
	Abandon Existing Outlet Structures	each	$40,000	2	80,000
	New Discharge Structures	each	$150,000	1	150,000
	Pumping Station	L.S.	–	–	107,000
	Filtration System	L.S.	–	–	1,226,800
	Avoided Closure Cost	acre	reflected in lower land price		
	TOTAL CONSTRUCTION COST				$4,409,800
II. Non-Construction Capital Costs					
	(Construction Cost x 0.45) includes engineering, permitting administration and contingency				1,984,400
	TOTAL NON-CONSTRUCTION CAPITAL COSTS				$1,984,400
III. Land Costs					
	Purchase from Owner	acre	$300	600	180,000
	TOTAL LAND COST				180,000
	TOTAL CAPITAL COST				$6,574,200
OPERATING AND MAINTENANCE COST (ANNUAL)					
	Pipes and Pump Stations	–	–	–	30,000
	Power (from River to Reservoir)	KWH	$0.06	1,120,000	67,200
	Filtration System (includes power)	–	–	–	7,700
	Embankment Maintenance	acre	$100	78	7,800
	Embankment Inspection	each	$2,500	2	5,000
	TOTAL ANNUAL O&M COST				$117,700
	TOTAL ANNUAL O&M COST without Filtration System				$110,000
ANNUAL PROJECT COST					
Capital cost annualized over 20 years at 7.1% interest rate plus annual O&M cost					$743,100
PRESENT VALUE PROJECT COST ($/1000 gallons)					0.55
PRESENT VALUE PROJECT COST ($/1000 gallons) without Filtration System					0.46
CAPITAL COST/ CAPACITY ($/mgd)					$1,777,000
CAPITAL COST/ CAPACITY ($/mgd) without Filtration					$1,296,000

Table C-3. Cost Analysis for 218-Square Mile Catchment Area.

ADF:	4.3	mgd
Intake Capacity:	14.4	mgd
Pipeline	20	inch
Reservoir Capacity:	1,955	Mgal
	6,000	acre-feet
Reservoir Area:	400	acres
Embankment Length:	17,710	feet

TOTAL CAPITAL COST					
I. Construction Costs					
	Item	Unit	Unit Cost	No. of Units	Total Cost
	Surface Water Intake and Pump	L.S.	–	–	250,000
	Pipeline	L.F.	$64	10,000	640,000
	Electric Power	mile	$30,000	2	60,000
	Rip-rap CSA Embankments	L.F.	$100	17,710	1,771,000
	Abandon Existing Outlet Structures	each	$40,000	2	80,000
	New Discharge Structures	each	$150,000	1	150,000
	Pumping Station	L.S.	–	–	115,000
	Filtration System	L.S.	–	–	1,457,600
	Avoided Closure Cost	acre	reflected in lower land price		
	TOTAL CONSTRUCTION COST				$4,523,600
II. Non-Construction Capital Costs					
	(Construction Cost x 0.45)				2,035,600
	includes engineering, permitting				
	administration and contingency				
	TOTAL NON-CONSTRUCTION CAPITAL COSTS				$2,035,600
III. Land Costs					
	Purchase from Owner	acre	$300	600	180,000
	TOTAL LAND COST				180,000
	TOTAL CAPITAL COST				$6,739,200
OPERATING AND MAINTENANCE COST (ANNUAL)					
	Pipes and Pump Stations	–	–	–	30,000
	Power (from River to Reservoir)	KWH	$0.06	1,450,000	87,000
	Filtration System (includes power)	–	–	–	8,800
	Embankment Maintenance	acre	$100	78	7,800
	Embankment Inspection	each	$2,500	2	5,000
	TOTAL ANNUAL O&M COST				$138,600
	TOTAL ANNUAL O&M COST without Filtration System				$129,800
ANNUAL PROJECT COST					
Capital cost annualized over 20 years at 7.1% interest rate plus annual O&M cost					$779,700
PRESENT VALUE PROJECT COST ($/1000 gallons)					0.50
PRESENT VALUE PROJECT COST ($/1000 gallons) without Filtration System					0.40
CAPITAL COST/ CAPACITY ($/mgd)					$1,567,000
CAPITAL COST/ CAPACITY ($/mgd) without Filtration					$1,076,000

Table C-4. Cost Analysis for 826-Square Mile Catchment Area.

ADF:	9.1	mgd
Intake Capacity:	21.6	mgd
Pipeline	24	inch
Reservoir Capacity:	3,910	Mgal
	12,000	acre-feet
Reservoir Area:	600	acres
Embankment Length:	21,690	feet

TOTAL CAPITAL COST					
I. Construction Costs					
	Item	Unit	Unit Cost	No. of Units	Total Cost
	Surface Water Intake and Pump	L.S.	–	–	375,000
	Pipeline	L.F.	$78	10,000	780,000
	Electric Power	mile	$30,000	2	60,000
	Rip-rap CSA Embankments	L.F.	$100	21,690	2,169,000
	Abandon Existing Outlet Structures	each	$40,000	2	80,000
	New Discharge Structures	each	$150,000	1	150,000
	Pumping Station	L.S.	–	–	172,000
	Filtration System	L.S.	–	–	2,732,500
	Avoided Closure Cost	acre	reflected in lower land price		
	TOTAL CONSTRUCTION COST				$6,518,500
II. Non-Construction Capital Costs					
	(Construction Cost x 0.45)				2,933,300
	includes engineering, permitting				
	administration and contingency				
	TOTAL NON-CONSTRUCTION CAPITAL COSTS				$2,933,300
III. Land Costs					
	Purchase from Owner	acre	$300	800	240,000
	TOTAL LAND COST				240,000
	TOTAL CAPITAL COST				$9,691,800
OPERATING AND MAINTENANCE COST (ANNUAL)					
	Pipes and Pump Stations	–	–	–	30,000
	Power (from River to Reservoir)	KWH	$0.06	2,750,000	165,000
	Filtration System (includes power)	–	–	–	17,400
	Embankment Maintenance	acre	$100	94	9,400
	Embankment Inspection	each	$2,500	2	5,000
	TOTAL ANNUAL O&M COST				$226,800
	TOTAL ANNUAL O&M COST without Filtration System				$209,400
ANNUAL PROJECT COST					
Capital cost annualized over 20 years at 7.1% interest rate plus annual O&M cost					$1,148,800
PRESENT VALUE PROJECT COST ($/1000 gallons)					0.35
PRESENT VALUE PROJECT COST ($/1000 gallons) without Filtration System					0.26
CAPITAL COST/ CAPACITY ($/mgd)					$1,065,000
CAPITAL COST/ CAPACITY ($/mgd) without Filtration					$630,000

Table C-5. Cost Analysis for 1,367-Square Mile Catchment Area.

ADF:	11.4	mgd
Intake Capacity:	28.8	mgd
Pipeline	28	inch
Reservoir Capacity:	3,910	Mgal
	12,000	acre-feet
Reservoir Area:	600	acres
Embankment Length:	21,690	feet

TOTAL CAPITAL COST					
I. Construction Costs					
	Item	Unit	Unit Cost	No. of Units	Total Cost
	Surface Water Intake and Pump	L.S.	–	–	500,000
	Pipeline	L.F.	$92	10,000	920,000
	Electric Power	mile	$30,000	2	60,000
	Rip-rap CSA Embankments	L.F.	$100	21,690	2,169,000
	Abandon Existing Outlet Structures	each	$40,000	2	80,000
	New Discharge Structures	each	$150,000	1	150,000
	Pumping Station	L.S.	–	–	200,000
	Filtration System	L.S.	–	–	3,222,500
	Avoided Closure Cost	acre	reflected in lower land price		
	TOTAL CONSTRUCTION COST				$7,301,500
II. Non-Construction Capital Costs					
	(Construction Cost x 0.45) includes engineering, permitting administration and contingency				3,285,700
	TOTAL NON-CONSTRUCTION CAPITAL COSTS				$3,285,700
III. Land Costs					
	Purchase from Owner	acre	$300	800	240,000
	TOTAL LAND COST				240,000
	TOTAL CAPITAL COST				$10,827,200
OPERATING AND MAINTENANCE COST (ANNUAL)					
	Pipes and Pump Stations	–	–	–	35,000
	Power (from River to Reservoir)	KWH	$0.06	2,890,000	173,400
	Filtration System (includes power)	–	–	–	21,100
	Embankment Maintenance	acre	$100	94	9,400
	Embankment Inspection	each	$2,500	2	5,000
	TOTAL ANNUAL O&M COST				$243,900
	TOTAL ANNUAL O&M COST without Filtration System				$222,800
ANNUAL PROJECT COST					
Capital cost annualized over 20 years at 7.1% interest rate plus annual O&M cost					$1,273,900
PRESENT VALUE PROJECT COST ($/1000 gallons)					0.31
PRESENT VALUE PROJECT COST ($/1000 gallons) without Filtration System					0.23
CAPITAL COST/ CAPACITY ($/mgd)					$950,000
CAPITAL COST/ CAPACITY ($/mgd) without Filtration					$540,000